1.2.5 GASIFICATION - UNIT 21

The Texaco Coal Gasification Process (TCGP), characterized as an entrained slagging downflow gasifier, is utilized in the design of the Gasoline Plant. The utilization of this technology was specified in the Cooperative Agreement Statement of Work with engineering design information obtained through Texaco Development Corporation.

A. Basis of Design

The quantity of synthesis gas generation capacity required by the size of the Gasoline Plant necessitated the incorporation of 20 operating coal gasifier trains and two spares into the design. The total of 22 trains are arranged in four modules with two modules containing six trains (five operating plus one spare) and the remaining two modules contain five each. The feed and product streams shown on the following two pages depict the design basis utilized in the design of this unit.

B. Process Selection Rationale

The design of the Gasoline Plant centers around the TCGP for combustion of Kentucky No. 9 high-sulfur, agglomerating coal specified in the Cooperative Agreement. This commercially available technology has been demonstrated as capable of efficiently gasifying high-sulfur content, high swelling index coals; operating at high-pressure and affording an excellent heat recovery scheme to reduce operating cost; and producing an environmentally acceptable syngas and nonhazardous slag.

In the ensuing years, a commercially sized demonstration plant has been built and is operating at the Ruhrchemie Chemical Complex in Oberhausen-Holten, West Germany. The Ruhrchemie gasifier has been running successfully since early 1978. For these reasons, Texaco has licensed this process for other commercial installations and considers this process to be commercial.

Gasifier Feed Streams

Component	Total Coal Slurry to Gasification (lb mol/hr)	Total Oxygen to Gasification (lb mol/hr)
H_2		-
CH_2		-
CO		-
CO_2		-
O_2		54,968.76
N_2		-
Ar		276.28
H_2S		-
COS		-
Total Dry, lb mol/hr	Proprietary	55,245.04
H_2O		-
Total Wet, lb mol/hr		55,245.04
Coal, lb/hr		-
Ash, lb/hr		-
Carbon		-
Total, lb/hr	Proprietary	1,770,040
Pressure, psia	1,200	1,015
Temperature, °F	200	200

Product Streams

Component	Total Raw Syngas (lb mol/hr)	(mol%)
H_2	62,580.97	36.19
CH_4	343.44	0.20
CO	75,760.77	43.81
CO_2	30,788.72	17.81
O_2	-	-
N_2	823.02	0.48
Ar	276.24	0.16
H_2S	2,201.17	1.27
COS	135.71	0.08
Total Dry, lb mol/hr	172,910.04	100.00
H_2O	123,170.76	
Total Wet, lb mol/hr	296,080.80	
Total, lb/hr	5,945,560.00	
Pressure, psia	874	
Temperature, °F	435	

C. Process Description

The equipment arrangement and material balance for this unit are shown on Process Flow and Control Diagram D-21-MP-1NP.

The coal-water slurry is pumped at high pressure through the slurry preheater into the gasifier. In the gasifier, the slurry is partially oxidized with oxygen at 900 psig and at high temperature. The hot synthesis gas and molten slag generated flows downward from the gasifier into the radiant boiler, where much of the heat of reaction is recovered by generating high-pressure saturated steam. The slag falls into the water sump and solidifies and shatters to glass-like granules. The synthesis gas is withdrawn from the radiant boiler for further processing.

The gas exiting the radiant waste heat boiler undergoes a succession of scrubbing stages to remove particulate material. At the final step, the gas is washed with condensate before it flows to the CO Shift Unit.

A substantial portion of the ash and recycle slag in the gasifier feed agglomerates into coarse molten slag droplets. The slag is solidified and quenched in the radiant boiler. This slag settles through the water bath and is collected in a lock hopper. The contents of the lock hopper are discharged periodically.

The coarse slag is sent to slag disposal while water and slag fines passing through a screen are pumped to the clarification system.

Water streams from the radiant boiler, slag discharge, and the scrubber system contain suspended ash and char particles, which are routed to a clarification system. The fine slag and unconverted coal are formed in a concentrated underflow that is returned to the Coal Grinding and Slurry Preparation Unit. The clarified water overflows into a water holding tank for reuse in the gasification system.

D. Risk Assessment

The commercially available Texaco Coal Gasification Process offered through Texaco Development Corporation (TDC) is an expansion of the well-proven Texaco Synthesis Gas Generation Process. TDC, a wholly owned subsidiary of Texaco Inc., has been engaged in the development and licensing of the Texaco Synthesis Gas Generation Process since 1945. The synthesis gas generated by this technology is a mixture predominantly of hydrogen and carbon monoxide, which is used as a feedstock for the production of ammonia, methanol, hydrogen, oxo products, reducing gas, fuel gas, and Fischer-Tropsch liquid hydrocarbons.

Over 80 Texaco synthesis gas generation plants have been licensed since the early 1950s involving some 150 gasifiers. Early units were natural gas-fired. Later, liquid fuels such as naphtha and heavy fuel oil were introduced. The majority of plants now in operation utilize heavy residual oils.

Generator size has increased steadily, with present units producing 20 times the output of the early commercial units. Operating pressure has risen from 350 psig in initial plants to 1,200 psig in one plant in operation since 1968. Commercial operation as low as 30 psig has also been demonstrated. Pilot unit commercial operation on residual fuels has been conducted at 2,500 psig. Syngas coolers have been used in 20 commercial plants, while the remainder have used direct quench.

The Texaco Coal Gasification Process is a modification of the Texaco Synthesis Gas Generation Process, producing generally the same type of synthesis gas for the same commercial applications. Development work on coal gasification, started in 1948, has involved large-scale pilot unit operation on many solid fuels including lignites, bituminous coals, anthracites, coal-liquefaction residues, and petroleum cokes.

A demonstration plant was erected at the Morgantown Ordnance Works in West Virginia in 1956. This unit charged 100 tons per day of an eastern bituminous coal in water slurry and was in operation for 2 years. This plant confirmed gasifier scale-up criteria and demonstrated the ash-handling system.

At the Montebello Research Laboratory, extensive facilities are available for the gasification of solid fuels. These include three 15- to 20-tpd coal gasification pilot units including one stand-alone pilot plant. Testing has included gas cooling, sulfur removal, and wastewater treatment. These pilot units have been operating on a wide range of coals at pressures ranging from 300 to 1,200 psi. Detailed environment data have been accumulated on both eastern and western U.S. coal.

Ruhrchemie AG (RCH) and Ruhrkohle AG (RAG) completed a demonstration plant utilizing the Texaco Coal Gasification Process in 1977 at Oberhausen-Holten, Germany. The demonstration plant has been in operation more than 4 years. Over 10,000 hours of operation, with a total throughput of more than 50,000 tons of coal, have been achieved. Eleven different types of coal have been tested. Three of the coal grades used were supplied from the United States.

A number of variables that may affect the coal gasification process in the Gasoline Plant are:

(1) Gasifier thermal performance

(2) Effectiveness of ash removal and carbon recycle systems.

(3) Pumpability range of high solids content slurries.

(4) Assessment of unexpected corrosion, erosion, and refractory life.

The temperatures and pressures involved in the Gasoline Plant are within the range for which equipment has been supplied for petrochemical and process plants. Some key items in this process area are slurry charge pumps, slurry preheating, gasifier burner, and gasifier/waste heat boiler system.

The removal and handling of slag from the gasifier are particularly arduous applications for valving. Special attention was applied to the details of valve design. Safety interlocks on valves and instrumentation for sequencing prevent maloperation of the lock hopper system for slag collecting and dumping. The gasification units are provided with alarms to warn of abnormal conditions. The purpose of the alarm system is to allow operators to take corrective action before an automatic shutdown is initiated.

The efficiency of the process can be affected by three significant variables including slurry concentration, ash content of the coal, and melting point of the ash. The gasification facilities were designed for a range of coal analyses centered on the design coal used in the normal operating condition. An increase in ash content, a decrease in slurry concentration, or an increase in combustion zone temperature requires more coal and oxygen feed per Btu of heating value of gas produced. This results in higher operating costs than provided in the Operating Cost Summary.

Technical risk is related mainly to equipment life and maintenance requirements, which includes the rate of wear of the refractory. Life of at least a year is expected. Two spare gasifier trains were included in the design so that replacement of refractory can be scheduled sequentially. The spare gasifier trains also allow an aggressive program of recognizing and solving problems to be carried out by periodic rotation of units for inspection, preventive maintenance, and maintenance.

The slurry charge pumps provided are commercially available proven equipment, and require no scale-up or extrapolation of design. The pumps are discussed in the section covering Coal Grinding and Slurry Preparation.

The gasifier design pressure of 900 psi and design basis (slurry concentration coal types, gasifier temperatures, etc.) are considered well within commercial use and conservatively set. Burner replacement is a simple matter and adequate spares are stocked. Gasifier lock hopper valves are critical items, but operating units have confirmed technical adequacy.

Reactions with high-purity oxygen produce large quantities of heat and require careful monitoring and control. As described herein, the gasifier system is highly instrumented to provide operators with information on the operating conditions. This information is integrated into a trip system that shuts down a train automatically if unsafe conditions arise.

The waste heat boiler system is a very critical item sir it represents simultaneous gas cooling and recovery of a major portion of the heat (steam) utilized in plant drivers. The design is based on the successful operating experience in the Ruhrchemie demonstration plant at Oberhausen. Special soot blowing equipment is utilized in maintaining heat transfer surface coefficients and that source of technology is used for material selection.

The means by which slag is discharged from the gasifier requires special attention during operation to minimize the risk associated with the scale-up from existing units.

A significant risk results from the uncertainty relating to corrosion rates in the circulating water system, although information available at present suggests that this corrosion may not be unusually high.

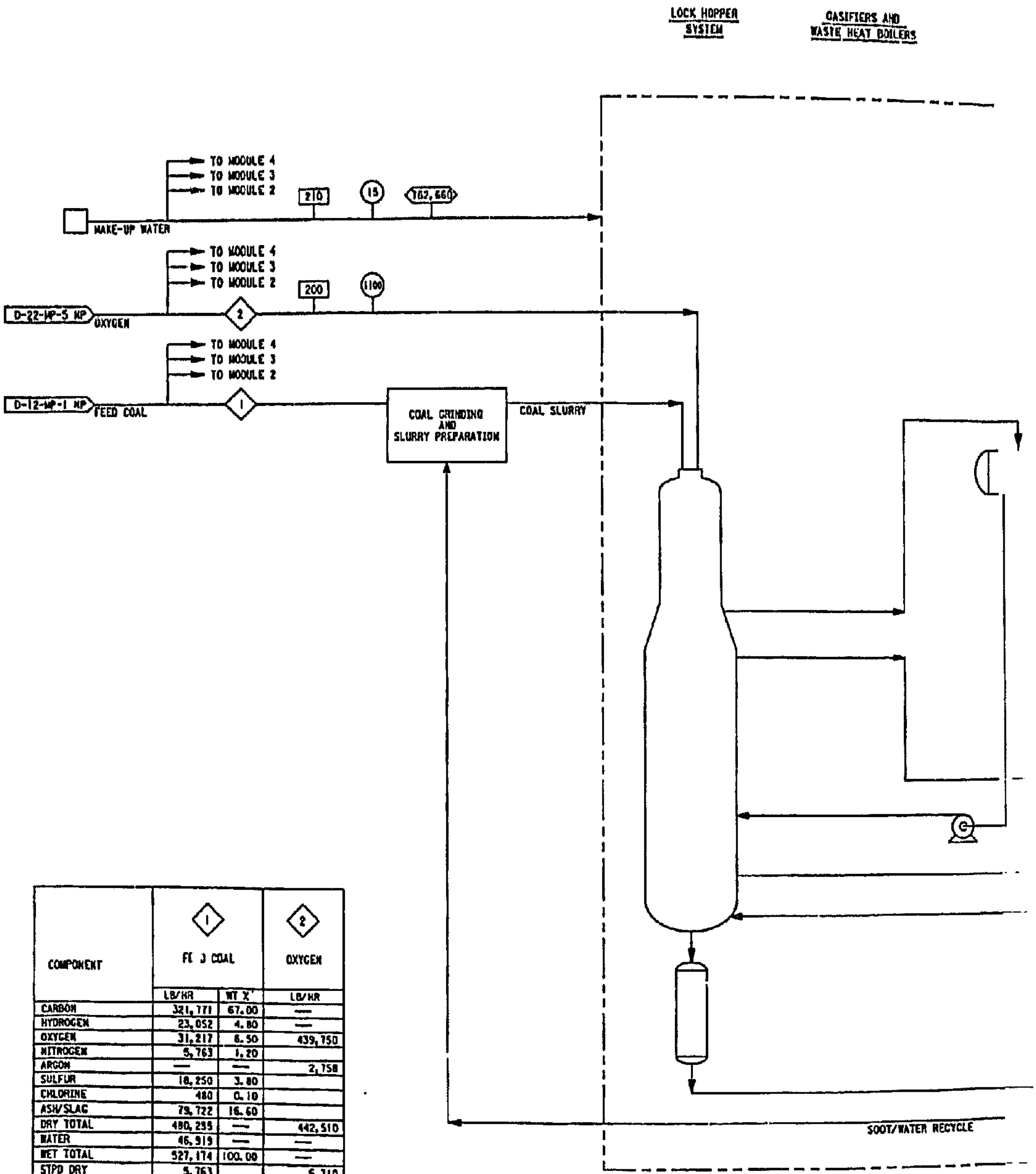
Uncertainties associated with the design and operation of coal slurry heaters do not pose serious risks as the plant can be operated satisfactorily without them.

In general, the gasification section contains certain equipment mentioned above that has relatively severe operating conditions; however, commercial operation has proven the adequacy of the process. In conjunction with conservative designs and adequate sparing, the technical risk is considered minimal.

E. Process Flow and Control Diagram (Including Material Balance)

The Process Flow and Control Diagram for Gasification Unit 21 is as follows:

Drawing No.	Title
D-21-MP-1NP	PFCD Gasification - Unit 21

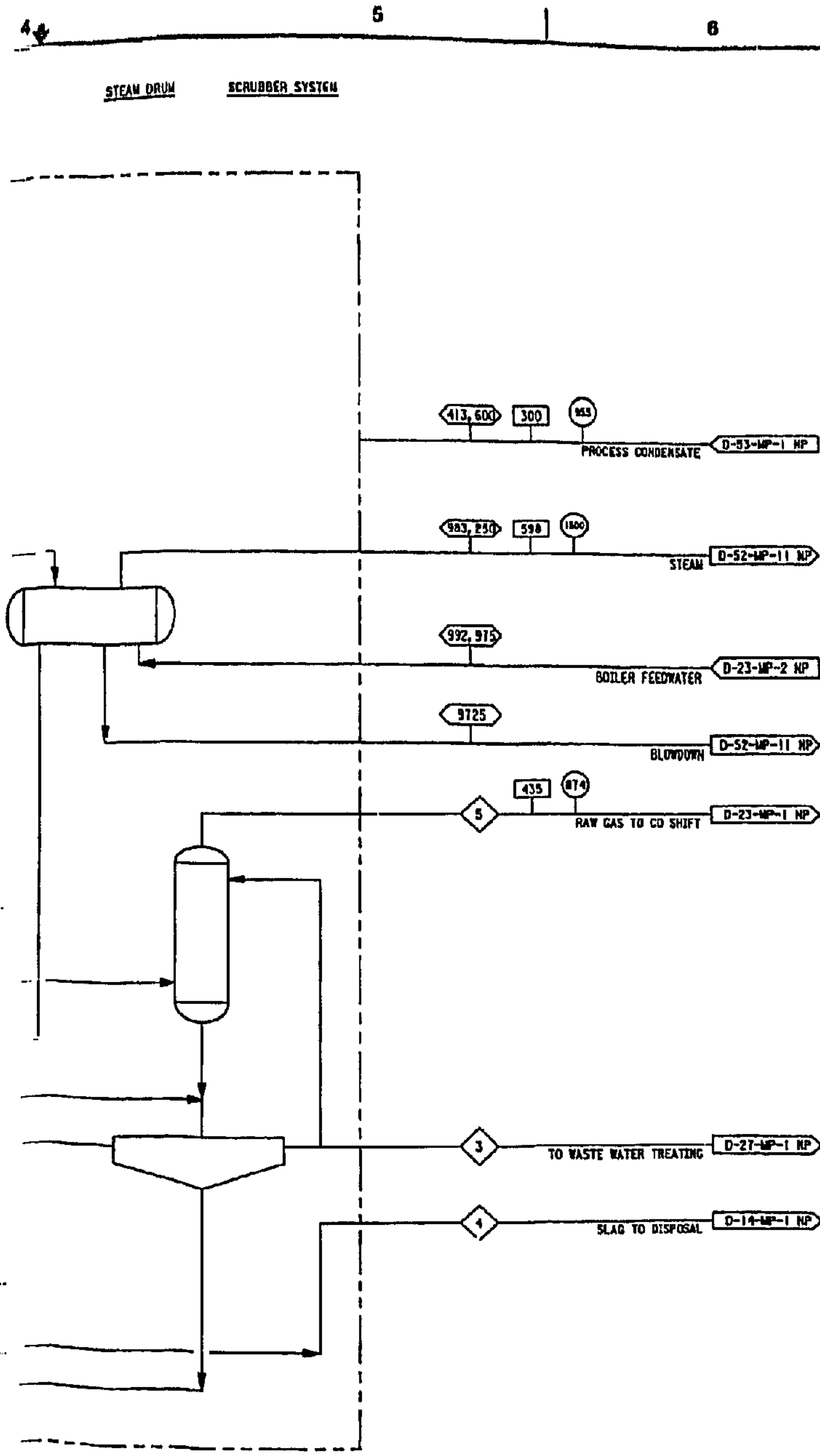


COMPONENT	⟨1⟩ FE J COAL		⟨2⟩ OXYGEN
	LB/HR	WT %	LB/HR
CARBON	321,771	67.00	—
HYDROGEN	23,052	4.80	—
OXYGEN	31,217	6.50	439,750
NITROGEN	5,763	1.20	
ARGON	—	—	2,758
SULFUR	18,250	3.80	
CHLORINE	480	0.10	
ASH/SLAG	79,722	16.60	
DRY TOTAL	480,255	—	442,510
WATER	46,919	—	—
WET TOTAL	527,174	100.00	—
STPD DRY	5,763		5,310
STPD WET	6,326		—
BTU/LB HHV DRY	12,362		—

NO.	DATE	BY	CHKD	SEC	PROJ	CLIENT
D	6-16-82					
C	3/25/82	PCH	JCY	RAW	CS	
B	4/16/	PCH	JCI		CS	
A	4/1/82		JCI	RAW	CS	

REFERENCES — DRAWING NO. — DESCRIPTION

REVISIONS — NO. — DATE — BY — CHKD — SEC — PROJ — CLIENT — DESCRIPTION



NOTES:

1. THE GASIFICATION UNIT CONSISTS OF TWENTY-TWO TRAINS (22), 20 OPERATING AND 2 SPARES, IN FOUR (4) MODULES:
   MODULE 1 CONSISTS OF TRAINS 1 THRU 6-(5 OPERATING, 1 SPARE)
   MODULE 2 CONSISTS OF TRAINS 7 THRU 11-(5 OPERATING)
   MODULE 3 CONSISTS OF TRAINS 12 THRU 17-(5 OPERATING, 1 SPARE)
   MODULE 4 CONSISTS OF TRAIN 18 THRU 22-(5 OPERATING)
2. MATERIAL BALANCE STREAMS AND STEAM RATE ARE SHOWN AT NORMAL OPERATING CONDITIONS FOR ONE MODULE OF 5 GASIFIER TRAINS OF A NOMINAL 50,000 BPD GASOLINE PLANT.

COMPONENT		⟨5⟩ RAW GAS FROM GASIFICATION	
	MOL. WT.	LB MOL/HR	MOL %
H_2	2.02	15,645.27	36.19
CH_4	16.04	85.86	0.20
CO	28.01	18,940.21	43.81
CO_2	44.01	7,697.10	17.81
N_2	28.02	205.75	0.48
Ar	39.94	69.07	0.16
H_2S	34.08	550.29	1.27
COS	60.07	33.93	0.08
TOTAL DRY		43,227.48	100.00
H_2O		30,792.69	
TOTAL WET		74,020.17	
LBS/HR		1,486,240	
MOLECULAR WT.		20.08	
MMSCFD		674.1	
PSIA		874	
°F		435	

COMPONENT	⟨3⟩ EFFLUENT WATER	⟨4⟩ SLAG TO DISPOSAL
	LB/HR	LB/HR
CARBON	—	395
HYDROGEN	—	—
OXYGEN	—	—
NITROGEN	—	—
ARGON	—	—
SULFUR	—	—
CHLORINE	—	—
ASH/SLAG	1149	78574
DRY TOTAL	1149	78969
WATER	572871	31771
WET TOTAL	574020	110740

D21MP1NP.DGA

U.S. DEPARTMENT OF ENERGY

BASKETT — W.R. GRACE & CO. — KENTUCKY

50,000 B.P.D.

COAL - TO - METHANOL - TO - GASOLINE PLANT

TITLE: PROCESS FLOW & CONTROL DIAGRAM GASIFICATION - UNIT 21

SCALE	ACCOUNT NUMBER	JOB NUMBER	REVISION
NONE	2800	6182	D

DOCUMENT NUMBER: D-21-MP-1 NP

DESCRIPTION		
REPORT	FOR	
FOR CLIENT APPROVAL	DRAWN	MEY
FOR LICENSOR APPROVAL	CHECKED	
FOR CLIENT 50% REVIEW	APVD DEPT HD	
	APVD PROJ MGR	
	APVD CLIENT	

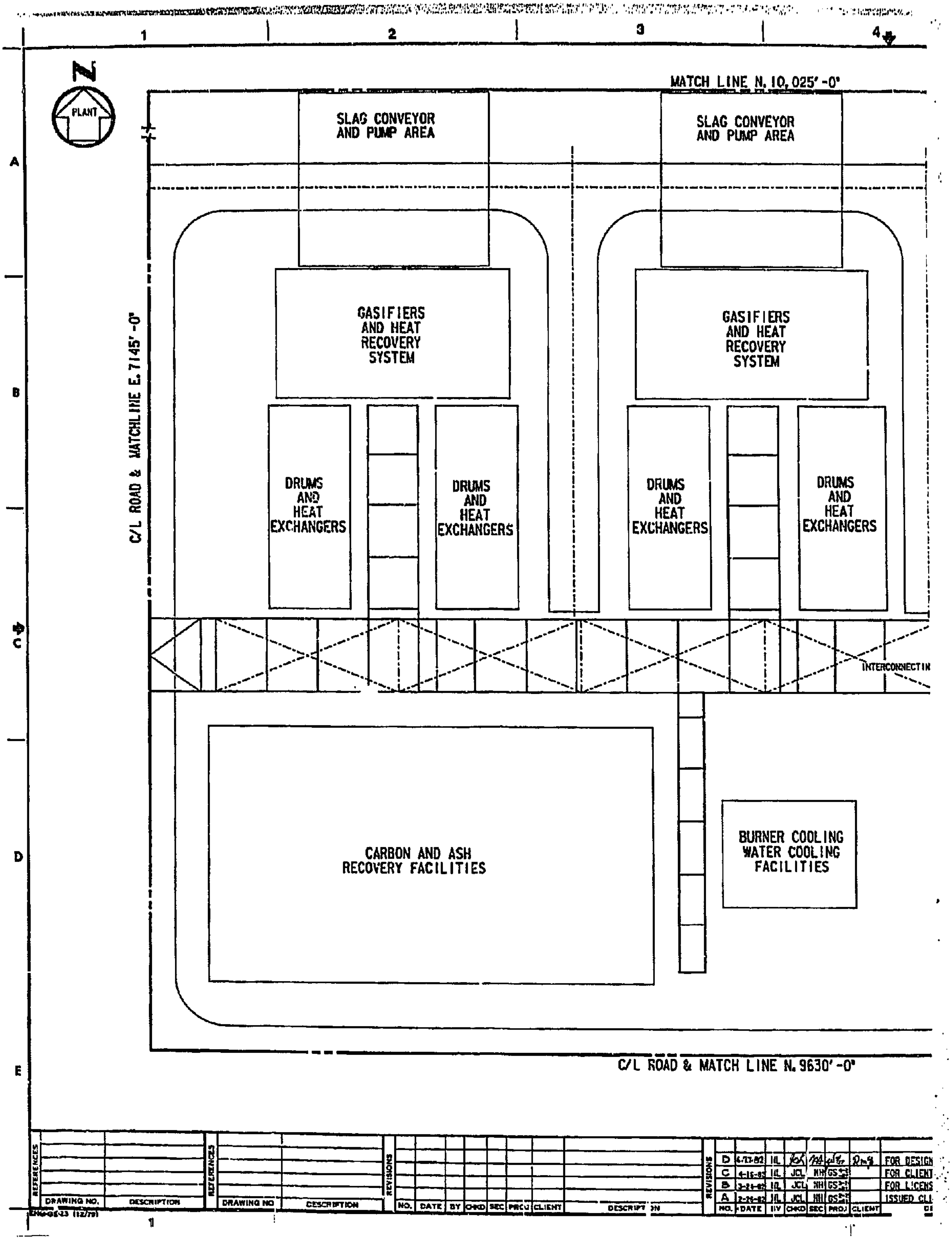
RMP

THE RALPH M. PARSONS COMPANY
PASADENA, CALIFORNIA

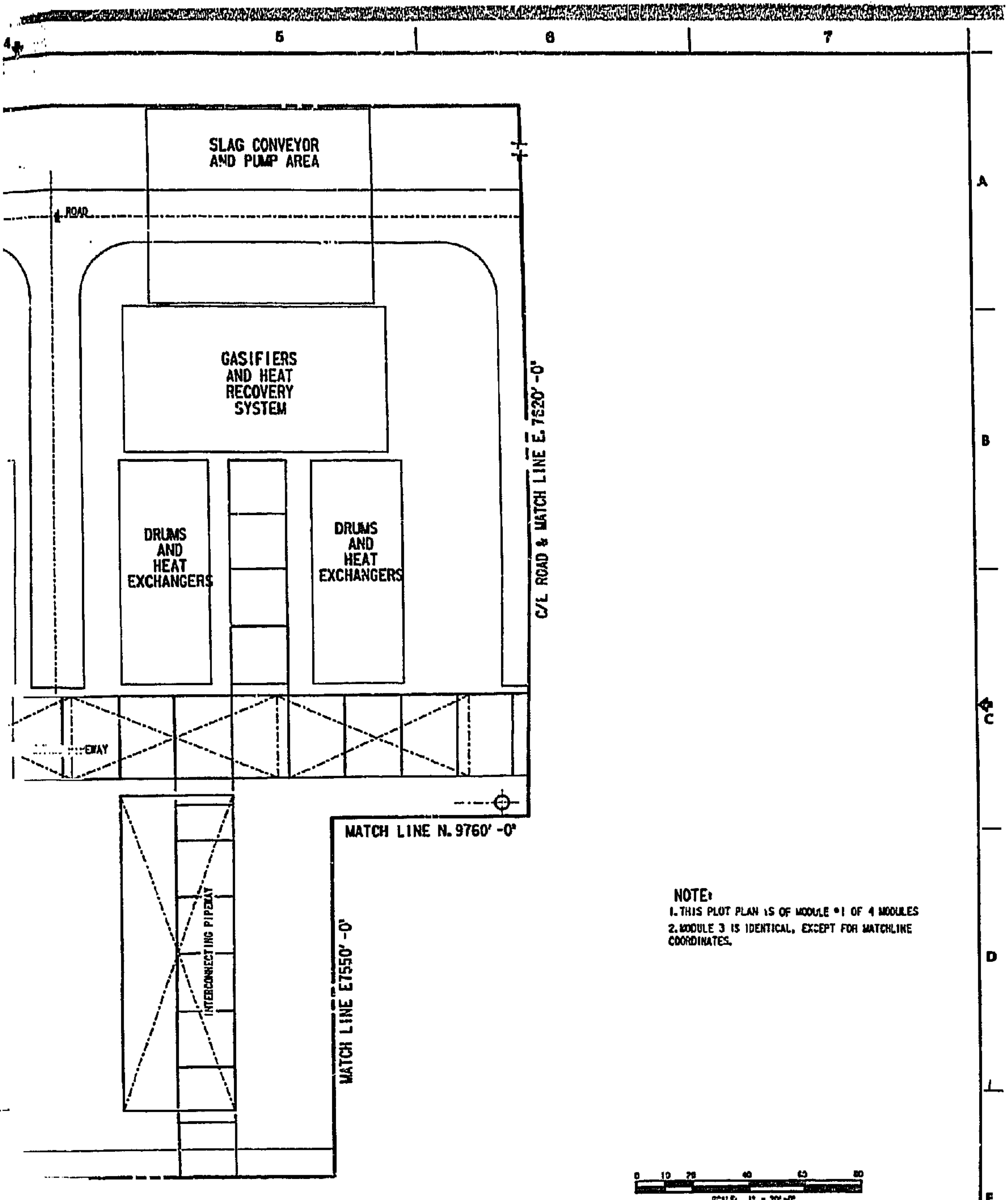
F. Plot Plan/General Arrangement Drawings

Plot Plan/General Arrangement Drawings for Gasification Unit 21 are as follows:

Drawing No.	Title
D-21-PD-1NP	Plot Plan - Unit 21 Gasification
D-21-PD-2NP	Plot Plan - Unit 21 Gasification
D-21-MH-1NP	General Arrangement - Gasification - Unit 21 Gasifier Area - Plan and Elevation



PLANT
MATCH LINE N. 10,025'-0"
SLAG CONVEYOR AND PUMP AREA
SLAG CONVEYOR AND PUMP AREA
GASIFIERS AND HEAT RECOVERY SYSTEM
GASIFIERS AND HEAT RECOVERY SYSTEM
C/L ROAD & MATCHLINE E. 7145'-0"
DRUMS AND HEAT EXCHANGERS
DRUMS AND HEAT EXCHANGERS
DRUMS AND HEAT EXCHANGERS
DRUMS AND HEAT EXCHANGERS
INTERCONNECTIN
CARBON AND ASH RECOVERY FACILITIES
BURNER COOLING WATER COOLING FACILITIES
C/L ROAD & MATCH LINE N. 9630'-0"
REFERENCES
DRAWING NO.
DESCRIPTION
REVISIONS
NO.
DATE
BY
CHKD
SEC
PROJ
CLIENT
DESCRIPTION
FOR DESIGN
FOR CLIENT
FOR LICENS
ISSUED CLI



NOTE:
1. THIS PLOT PLAN IS OF MODULE #1 OF 4 MODULES
2. MODULE 3 IS IDENTICAL, EXCEPT FOR MATCHLINE COORDINATES.

U.S. DEPARTMENT OF ENERGY

BASKETT — W.R. GRACE & CO. — KENTUCKY

50,000 B.P.D.

COAL - TO - METHANOL - TO - GASOLINE PLANT

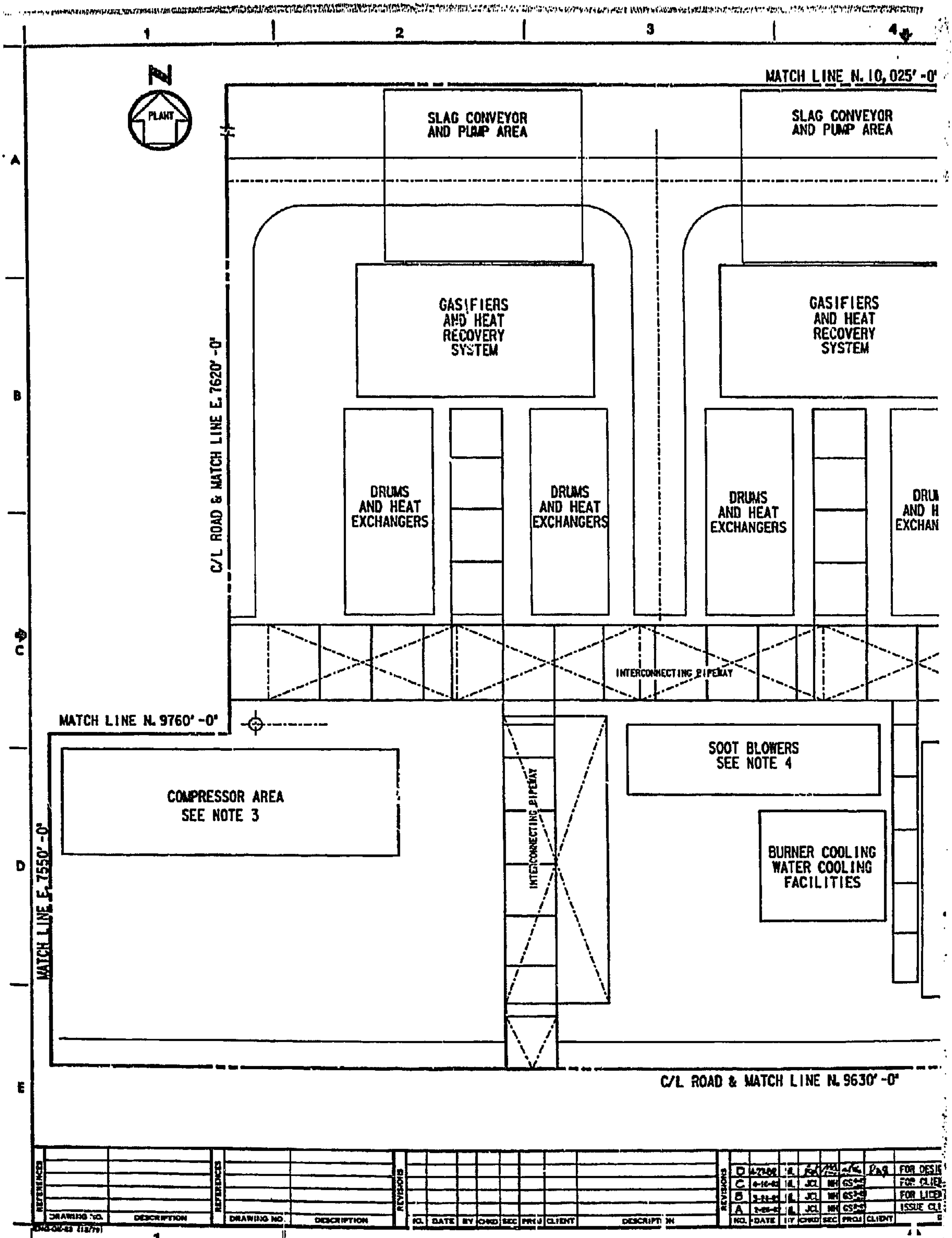
DRAWN	ML	
CHECKED		
APVD DEPT MGR	NH	2-25-82
APVD PROJ MGR	CS	2-25-82
APVD CLIENT		

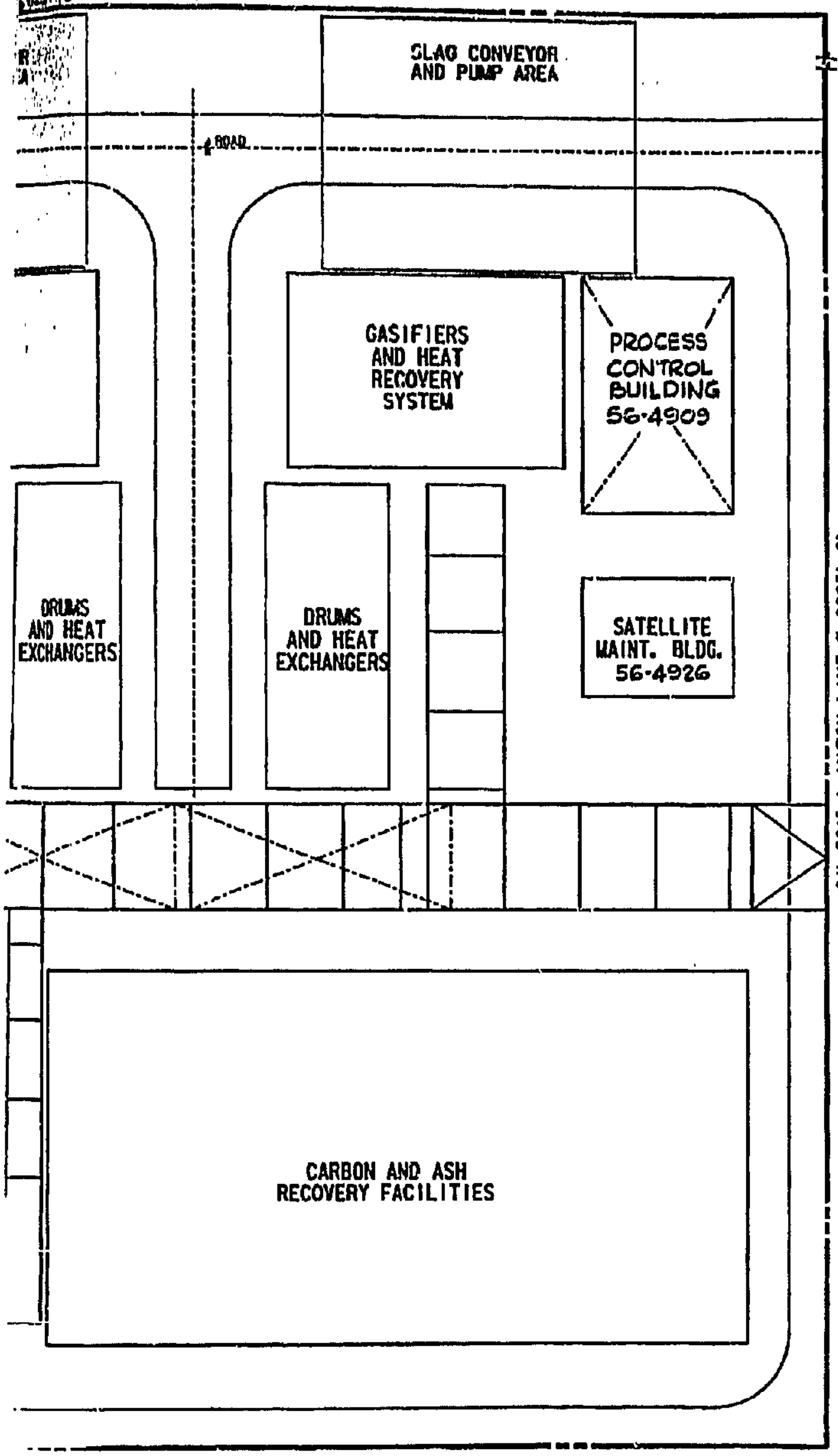
RMP — THE RALPH M. PARSONS COMPANY, PASADENA, CALIFORNIA

TITLE: PLOT PLAN UNIT 21 GASIFICATION

SCALE: 1"=20'-0" — ACCOUNT NUMBER: T243 — JOB NUMBER: 6182

DOCUMENT NUMBER: D-21-PD-INP — REVISION: D


PLANT
MATCH LINE N. 10,025' -0"
SLAG CONVEYOR AND PUMP AREA
SLAG CONVEYOR AND PUMP AREA
GASIFIERS AND HEAT RECOVERY SYSTEM
GASIFIERS AND HEAT RECOVERY SYSTEM
C/L ROAD & MATCH LINE E. 7620' -0"
DRUMS AND HEAT EXCHANGERS
DRUMS AND HEAT EXCHANGERS
DRUMS AND HEAT EXCHANGERS
INTERCONNECTING PIPEWAY
MATCH LINE N. 9760' -0"
SOOT BLOWERS SEE NOTE 4
COMPRESSOR AREA SEE NOTE 3
INTERCONNECTING PIPEWAY
BURNER COOLING WATER COOLING FACILITIES
MATCH LINE E. 7550' -0"
C/L ROAD & MATCH LINE N. 9630' -0"
REFERENCES
DRAWING NO.
DESCRIPTION
REVISIONS
NO.
DATE
BY
CHKD
SEC
PROJ
CLIENT
DESCRIPTION
D
C
B
A
JCL
FOR DESIG
FOR CLIE
FOR LICE
ISSUE CL



NOTE:

1. THIS PLOT PLAN IS OF MODULE #2 OF 4 MODULES.
2. MODULE 4 IS IDENTICAL, EXCEPT FOR MATCHLINE COORDINATES AND OTHERWISE NOTED. PROCESS CONTROL BLDG. 56-4908 AND SATELLITE MAINT. BLDG. 56-4925
3. COMPRESSOR AREA LOCATED IN MODULE #2 (SERVES MODULES #1 AND #2) AND MODULE #4 (SERVES MODULES #3 AND #4), ONLY.
4. SOOT BLOWERS LOCATED IN MODULE #2 ONLY, SERVES ALL MODULES.

U.S. DEPARTMENT OF ENERGY

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50,000 B.P.D.

COAL - TO - METHANOL - TO - GASOLINE PLANT

REPORT	DRAWN	ML
APPROVAL	CHECKED	
R APPROVAL	APVD SECT MG	RH 2-25-81
T REVIEW 50%	APVD PROJ MGR	GS 2-25-81
DESCRIPTION	APVD CLIENT	RJ 4/21/81

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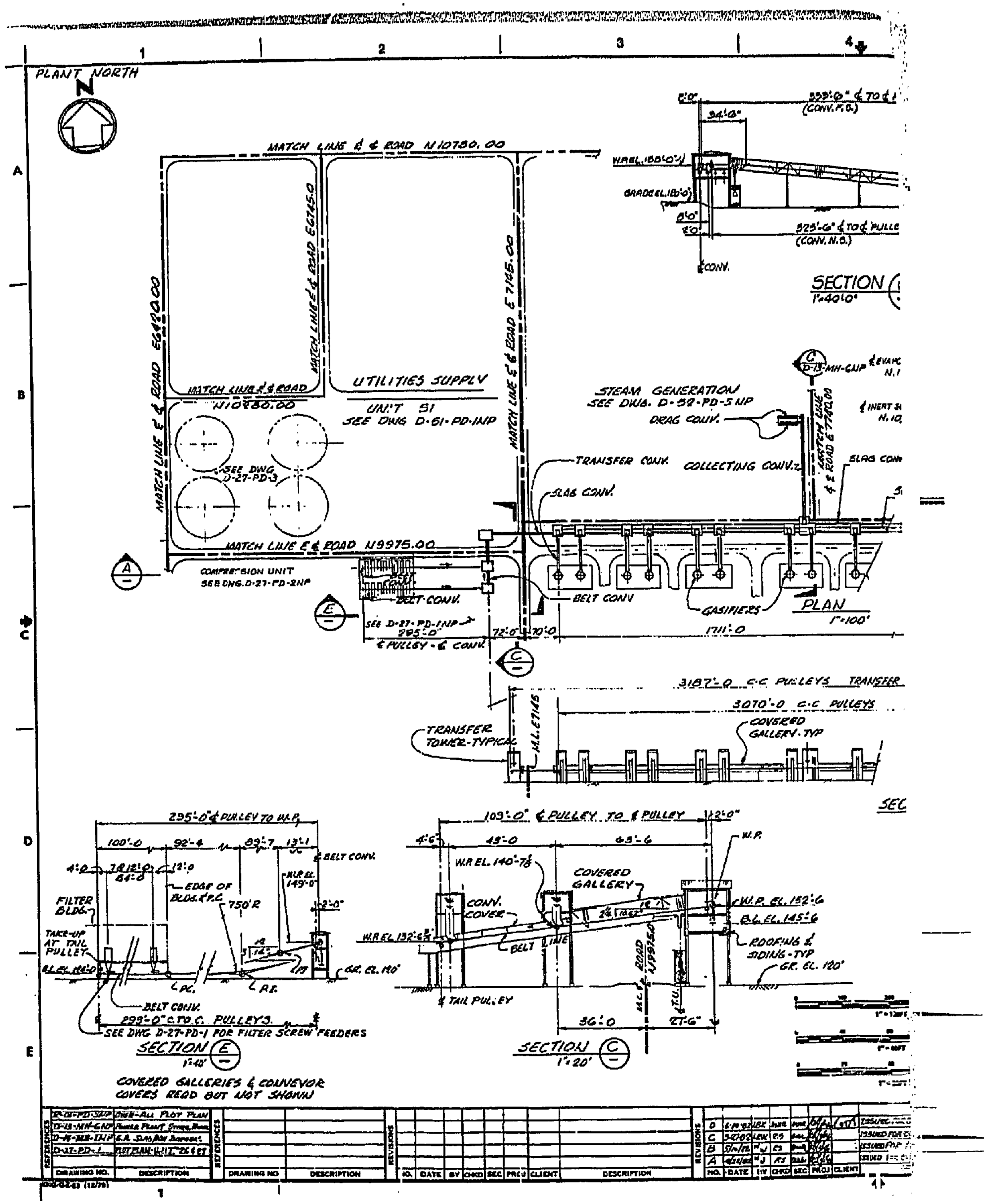
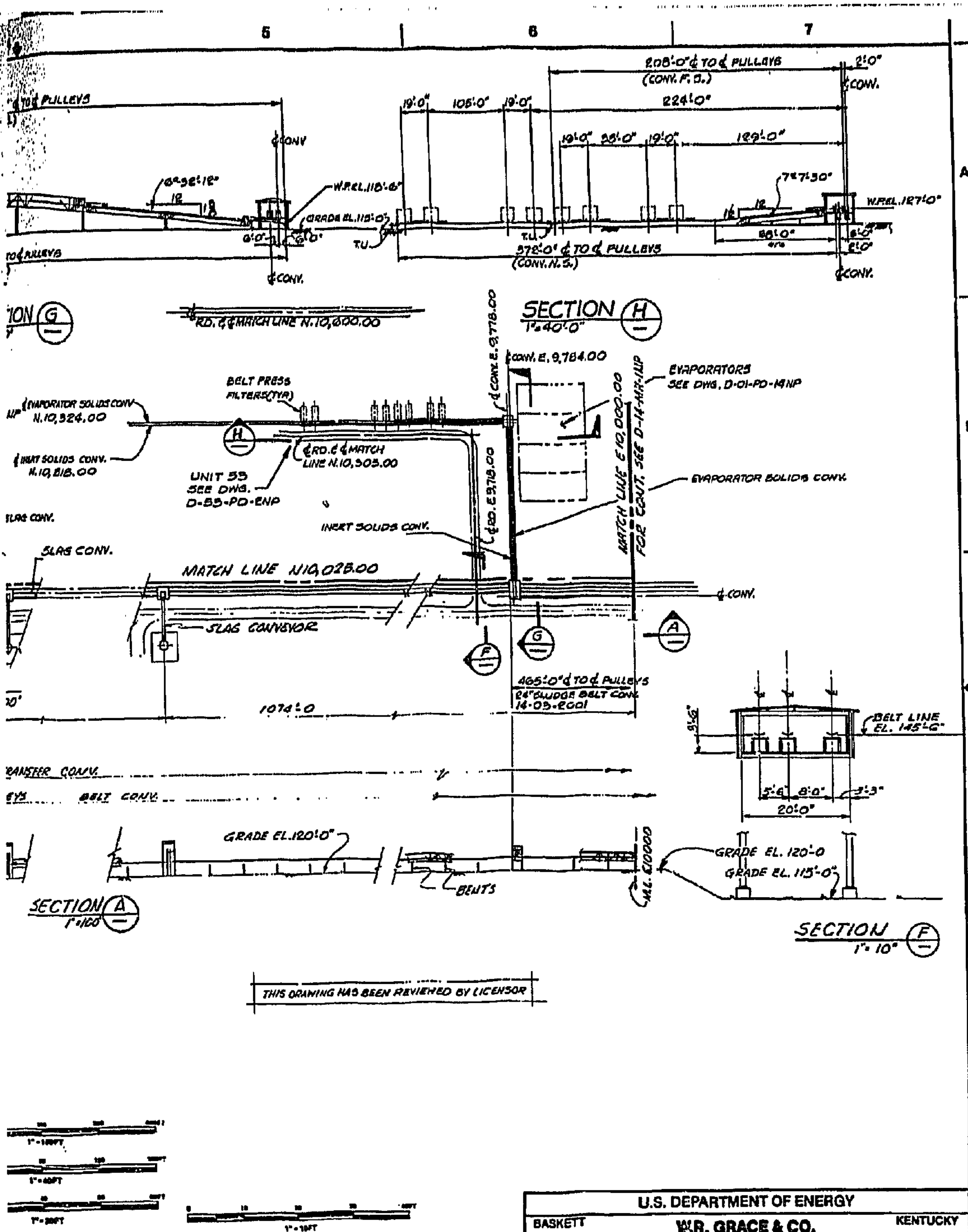
PASADENA, CALIFORNIA

TITLE	SCALE			REVISION
PLOT PLAN UNIT 21 GASIFICATION	1"=20'-0"	7243	6182	0
	D-21-PD-2NP			



PLANT NORTH
N
MATCH LINE ℄ ℄ ROAD N10780.00
MATCH LINE ℄ ℄ ROAD E6745.0
MATCH LINE ℄ ℄ ROAD E6420.00
MATCH LINE ℄ ℄ ROAD E7145.00
MATCH LINE ℄ ℄ ROAD N10280.00
UTILITIES SUPPLY
UNIT 51
SEE DWG D-51-PD-1NP
SEE DWG D-27-PD-3
MATCH LINE ℄ ℄ ROAD N9975.00
COMPRESSION UNIT
SEE DWG. D-27-PD-2NP
BELT CONV.
SEE D-27-PD-1NP
295'-0
℄ PULLEY - ℄ CONV.
72'-0
70'-0
1711'-0
STEAM GENERATION
SEE DWG. D-52-PD-5NP
DRAG CONV.
TRANSFER CONV.
COLLECTING CONV.
SLAG CONV.
BELT CONV
GASIFIERS
PLAN
1"=100'
D-13-MH-GNP
MATCH LINE ℄ ℄ ROAD E7740.00
SECTION
1"=40'-0"
WP EL. 188'-0"
GRADE EL. 120'-0"
34'-0"
525'-6" ℄ TO ℄ PULLE
(CONV. N.O.)
(CONV. F.O.)
℄ CONV.
3187'-0 C-C PULLEYS TRANSFER
3070'-0 C-C PULLEYS
COVERED GALLERY-TYP
TRANSFER TOWER-TYPICAL
M.L. E7145
295'-0" ℄ PULLEY TO W.P.
100'-0
92'-4
89'-7
13'-1
84'-0
12'-0
℄ BELT CONV.
W.P. EL. 149'-0"
FILTER BLDG.
EDGE OF BLDG. & P.C.
750'R
TAKE-UP AT TAIL PULLEY
B.L. EL. 146'-0
GR. EL. 120'
P.C.
P.T.
BELT CONV.
295'-0" C. TO C. PULLEYS
SEE DWG D-27-PD-1 FOR FILTER SCREW FEEDERS
SECTION E
1"=40'
103'-0" ℄ PULLEY TO ℄ PULLEY
12'-0"
4'-6"
45'-0
63'-6
W.P.
W.P. EL. 140'-7⅞
COVERED GALLERY
CONV. COVER
W.P. EL. 132'-6⅞
BELT LINE
W.P. EL. 152'-6
B.L. EL. 145'-6
ROOFING & SIDING-TYP
GR. EL. 120'
℄ TAIL PULLEY
M.L. ℄ ROAD N9975.0
T.U.
36'-0
27'-6"
SECTION C
1"=20'
COVERED GALLERIES & CONVEYOR COVERS REQD BUT NOT SHOWN
REFERENCES
OVER-ALL PLOT PLAN
D-27-PD-1
PLOT PLAN - UNIT 26 & 27
DRAWING NO.
DESCRIPTION
REVISIONS
NO. DATE BY CHKD SEC PROJ CLIENT
ISSUED FOR



REV	DESCRIPTION
	ISSUED FOR DESIGN REPORT
	ISSUED FOR CLIENT APPROVAL
	ISSUED FOR LICENSEE APPROVAL
	ISSUED FOR CLIENT DOE REVIEW

DRAWN	G.A.T.	4-20-81
CHECKED	W W	4-29-81
APPD SECT MGR		4-21-81
APPD PROJ MGR		
APPD CLIENT		

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U.S. DEPARTMENT OF ENERGY

BASKETT — W.R. GRACE & CO. — KENTUCKY

60,000 B.P.D.

COAL - TO - METHANOL - TO - GASOLINE PLANT

TITLE: GENERAL ARRANGEMENT
GASIFICATION - UNIT 21
GASIFIER AREA - PLAN & ELEVATIONS

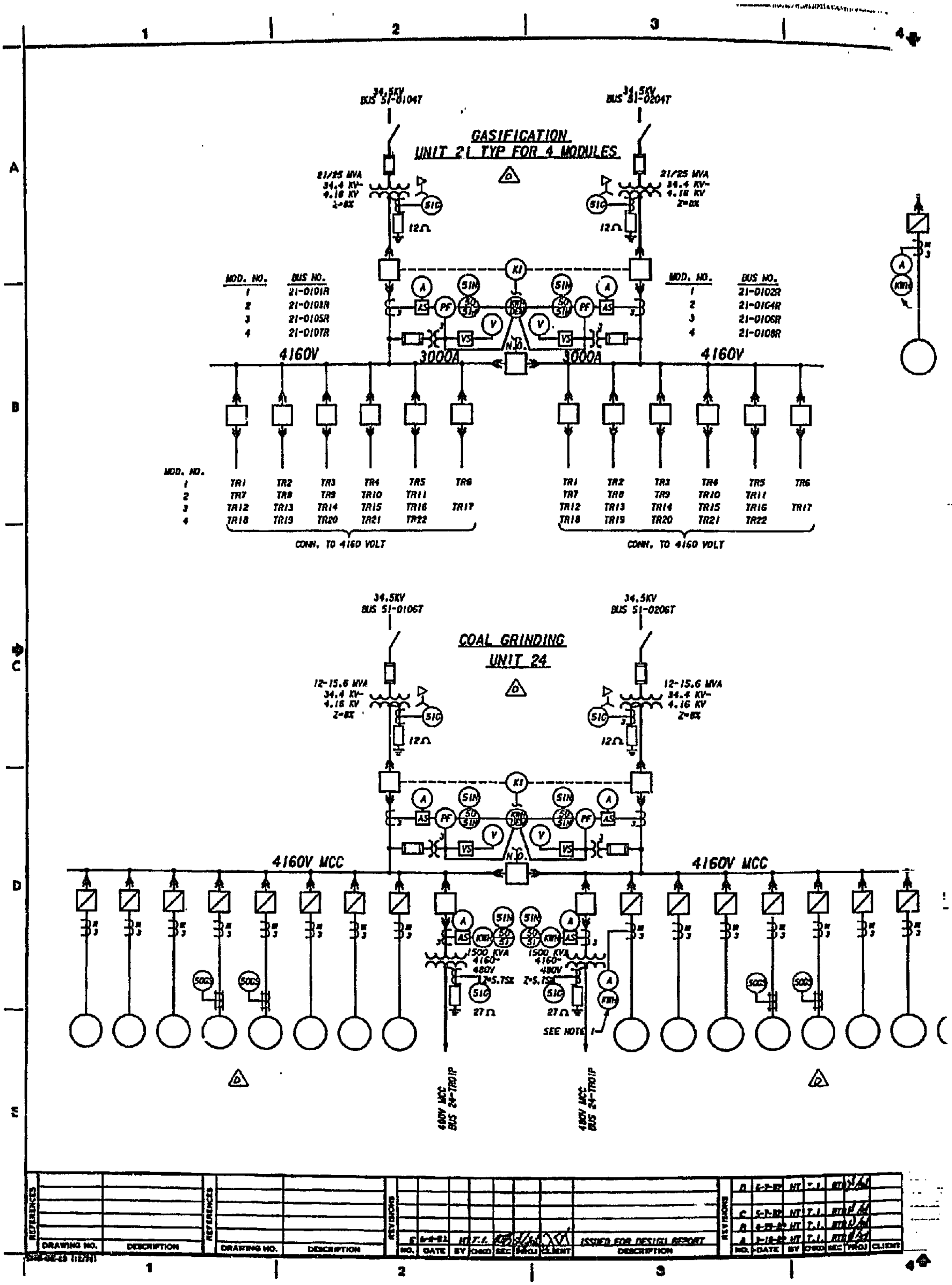
SCALE	ACCOUNT NUMBER	JOB NUMBER	REVISION
AS NOTED	2000	6182	D

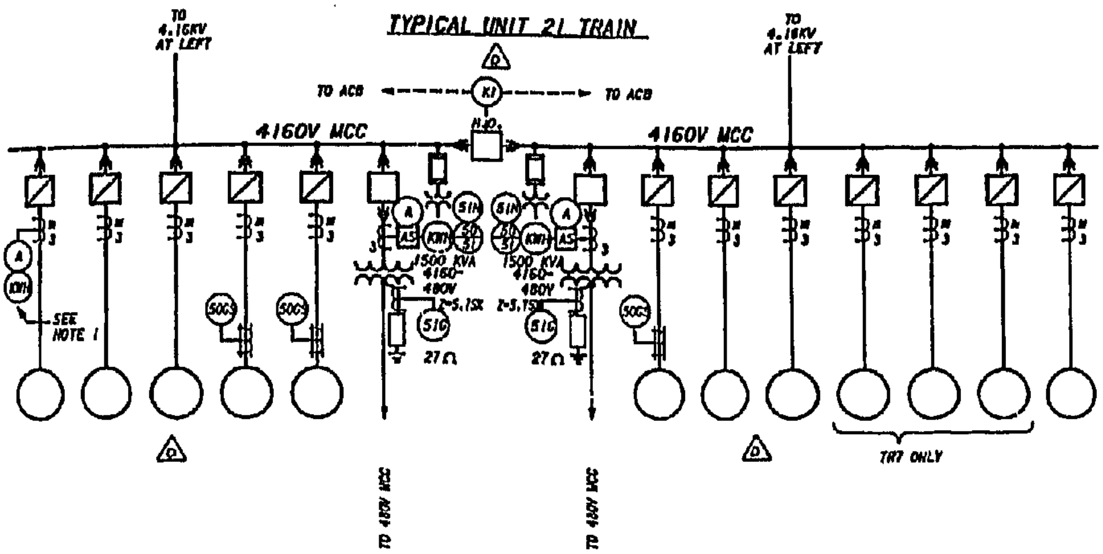
DOCUMENT NUMBER: D-21-MH-1NP

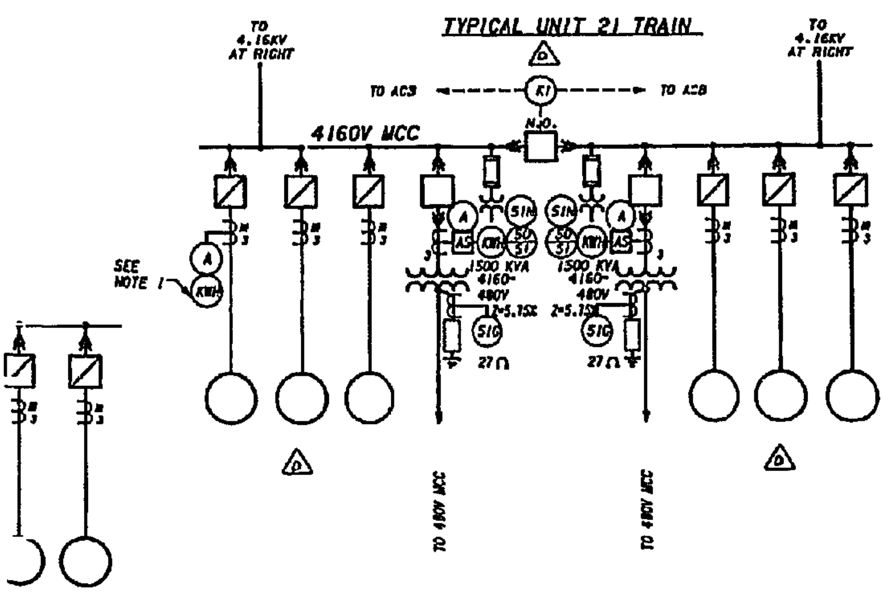
G. **Single-Line Diagram**

Single-Line Diagram for Gasification Unit 21 is as follows:

Drawing No.	Title
D-51-EE-3NP	One-Line Diagram - Units 21 and 24


GASIFICATION
UNIT 21 TYP FOR 4 MODULES
34.5KV BUS 51-0104T
34.5KV BUS 51-0204T
21/25 MVA 34.4 KV-4.16 KV Z=8%
12Ω
MOD. NO.
BUS NO.
21-0101R
21-0103R
21-0105R
21-0107R
21-0102R
21-0104R
21-0106R
21-0108R
4160V
3000A
N.O.
TR1 TR2 TR3 TR4 TR5 TR6
TR7 TR8 TR9 TR10 TR11
TR12 TR13 TR14 TR15 TR16 TR17
TR18 TR19 TR20 TR21 TR22
CONN. TO 4160 VOLT
COAL GRINDING
UNIT 24
34.5KV BUS 51-0106T
34.5KV BUS 51-0206T
12-15.6 MVA 34.4 KV-4.16 KV Z=8%
4160V MCC
1500 KVA 4160-480V Z=5.75%
27Ω
SEE NOTE 1
480V MCC BUS 24-TR01P
ISSUED FOR DESIGN REPORT
DRAWING NO.
DESCRIPTION
REFERENCES
REVISIONS
NO. DATE BY CHKD SEC PROJ CLIENT





NOTES:

1. PROVIDE AM, KWH, METERS AT ALL LOCATIONS MARKED *

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50,000 B.P.D.

COAL - TO - METHANOL - TO - GASOLINE PLANT

ONE LINE DIAGRAM
TEXACO COAL GASIFICATION U-21
COAL GRINDING & SLURRY PREP. U-24

SCALE		
NONE	4600	6182

D-51-EE-3NP

THE RALPH M. PARSONS COMPANY
PASADENA, CALIFORNIA

ISSUED FOR CLIENT APPROVAL
ISSUED FOR LICENSOR
ISSUED FOR CLIENT APPROVAL
ISSUED FOR CLIENT SITE REVIEW
DESCRIPTION

1.2.6 OXYGEN - UNIT 22

The partial oxidation process associated with the Texaco Gasification Process (TCGP) requires an oxidizer to sustain the partial combustion of the coal feedstock. This oxidizer in the form of high-purity gaseous oxygen is supplied from an air separation plant which cryogenically separates air into its major components oxygen and nitrogen. All of the oxygen is required for the gasification process while the nitrogen produced is used for process, purge, catalyst regeneration, and blanketing requirements in the process and offsite units.

A. Basis of Design

The design of the air separation (oxygen) plant is based upon the utility supply of 25,000 stpd of oxygen at 99.5% purity. The oxygen is compressed to 1,100 psig to feed the TCGP. Due to the large requirement of oxygen, ten parallel 2,500-stpd air separation plants (trains), which are based on the largest commercially available, are included in the design. Total nitrogen produced from these plants is about 8,500 stpd and available at 7 psig with a maximum 10 ppmv oxygen content. The feed and product streams for this unit are shown on the next page.

B. Process Selection Rationale

A summary of the process selection rationale discussed below is based upon the engineering trade-off study performed for this unit.

1. Oxygen Plant Vendor Comparison. Investigations were made of the principal air separation plant suppliers in order to establish a source of information for the preliminary design. These investigations included Air Liquide, Lotepro, Union Carbide, Airco, and Air Products. The approach dictated for this unit was that the air separation plant is a process utility which is required to supply the specific amount of purity oxygen noted above for process requirements. Therefore, the selection of an air separation plant vendor was not necessary and was not made.

Based primarily on the extensive experience by Air Liquide in its supply of large-scale oxygen plants for the SASOL facility and lower capital cost, it was determined that data for the preliminary design would be obtained from Air Liquide.

2. Gaseous Oxygen Compression vs Liquid Oxygen Pumping. Two alternative oxygen pressurization process schemes were considered: gaseous oxygen compression and liquid oxygen pumping. Of the five oxygen plant vendors contacted, none had considerable experience in liquid oxygen pumping. Airco, Air Products, Lotepro, and Union Carbide favored gaseous oxygen compession. Air Liquide was open, however; its very extensive experience recently in the SASOL plants is with centrifugal compression to 500 psig.

From the oxygen plant vendors' comments, it was concluded that the current industry consensus is that gaseous oxygen compression is preferred to liquid oxygen pumping, and gaseous oxygen compression was researched further.

3. Gaseous Oxygen Compression. Based on current commercial experience, the selected scheme was centrifugal compression to 610 psig followed by reciprocating compression to 1,100 psig. Sulzer and Demag confirmed that in 1982 there were centrifugal oxygen compressors operating at 1,500 psig and that commercial experience is being developed for all-centrifugal oxygen compressors.

C. Process Description

The equipment arrangement and material balance for this unit are shown on Process Flow and Control Diagrams D-22-MP-1NP, -2NP, -3NP, -4NP, -5NP, and -6NP.

Feed Streams

Component	Air to Cold Box (lb mol/hr)	(mol%)
N_2	210,733	78.11
Ar	2,509	0.93
O_2	56,548	20.96
Total dry, lb mol/hr	269,790	100.00
H_2O	-	
Total wet, lb mol/hr	269,790	
Total, lb/hr	7,813,640	
Pressure, psia	84	
Temperature, °F	95	

Product Streams

Component	Oxygen to Gasification (lb mol/hr)	(mol%)	Nitrogen (lb mol/hr)	(mol%)
N_2	-	-	23,470.6	100.00
O_2	54,968.8	99.50	0.2	Max. 10 ppmv
Ar	276.2	0.50	1.2	50 ppmv
Total dry, lb mol/hr	55,245.0	100.00	23,472.0	100.00
H_2O	-			
Total wet, lb mol/hr	55,245.0		23,472.0	
Total, lb/hr	1,770,030		657,600	
Pressure, psia	1,115		22	
Temperature, °F	201		90	

Atmospheric air, after passing through an inlet air filter, is compressed in the air compressor. Following compression, the air is cooled in direct-contact Water Wash Tower 22-01-1203. The cooled compressed air then enters the cold box, an enclosed steel structure containing cryogenic equipment filled with insulating material. The air enters through a set of automatic switching valves that controls the flow to Reversing Exchanger 22-01-1306. The reversing exchanger is an assembly of brazed aluminum, extended surface heat exchangers that have the dual function of cooling the air and removing water and carbon dioxide from it at the same time. The air is cooled by heat exchange with outflowing gaseous products and waste nitrogen. The passages are arranged so that at predetermined intervals the air and waste nitrogen streams are switched by operation of the valves at the warm end, with the check valves controlling the flows at the cold end. When the air is cooled, the contained moisture is condensed as water and ice, and the carbon dioxide is deposited as a solid at lower temperatures. When the air and waste nitrogen passages are switched over, the deposits are evaporated into the vent stream in one set of passages and carried out of the system while the impurities from the air are deposited in the other set. Since all the passages are in thermal contact with each other and with the products, there is continuous heat exchange.

The cooled air, now at about -280°F and close to its dew point, is sent to the bottom of High-Pressure Column 22-01-1202 as feed. The principal function of this column is to provide pure nitrogen at the top as product, impure liquid nitrogen as reflux for Low-Pressure Column 22-01-1201, and a liquid rich in oxygen at the bottom as feed for the low-pressure column. Reflux for the high-pressure column is provided by Main Vaporizer 22-01-1310, which by vaporizing liquid oxygen in the sump of the low-pressure column, condenses nitrogen rising from below.

Rich liquid from the sump of the high-pressure column is withdrawn and passed through either Rich Liquid Filter 22-01-2203 or 22-01-2204. These filters, filled with adsorbent, serve to remove the bulk of any hydrocarbons that enter with the air and are not deposited in the reversing exchanger. Following the filters, the rich liquid is subcooled in

Auxiliary Vaporizer 22-01-1308 by vaporizing liquid oxygen and then expanded into the low-pressure column as feed. The low-pressure column operates at about 19 psia, with boil-up from the main vaporizer and rich liquid feed and impure liquid nitrogen reflux from the high-pressure column.

Pure oxygen is produced at the bottom of the low-pressure column. As a safety precaution, part of the liquid is circulated via thermosiphon action in the auxiliary vaporizer through Liquid Oxygen Filter 22-01-2202, which is similar to the rich liquid filters. Another part of the liquid oxygen will be withdrawn to Oxygen Vaporizer 22-01-1311, where it is partially evaporated to give a gaseous oxygen product. The gaseous product is withdrawn overhead from Separator 22-01-1204, while excess liquid is returned to the sump of the low-pressure column by either Oxygen Pump 22-01-1503 or 22-01-1504. In order to evaporate the liquid oxygen, a stream of gas having essentially the same composition as air is taken from the high-pressure column, condensed, and then fed back to the column. Part of this condensed air is withdrawn again from the column and used as additional reflux in the low-pressure column.

Gaseous waste nitrogen is produced at the top of the low-pressure column. This is used in Subcooler 22-01-1309 to subcool the liquid nitrogen product and reflux streams and the liquid air reflux. The waste is be warmed further by condensing a small airstream and by the pure gaseous nitrogen product before it passes out through the reversing exchanger, removing the deposited water and carbon dioxide as it is finally warmed to ambient temperature and exhausted through a silencer. The gaseous oxygen and nitrogen products also flow out through the reversing exchanger, leaving at ambient temperature, ready for compression.

In order to maintain the correct temperatures throughout the cold box, it is necessary to produce refrigeration at a low-temperature level. This is achieved by taking some pure gaseous nitrogen from the top of the high-pressure column, reheating it partially in the cold-reversing exchanger and then expanding it in Turbine 22-01-1803. The turbine is coupled to an electric generator, and the gas temperature will be lowered by about 70°F while producing power. It is be sent back through the subcooler and the reveising exchanger as gaseous nitrogen product.

The plant is provided with the means to dispose of purged liquids by evaporation, using warm compressed air in Purge Stack 22-01-1401. For deriming and reactivation of filters, Derime System 22-01-2803 with Regeneration Heater 22-01-1321 is provided, and the dry air heated in Defrosting Heater 22-01-1312.

D. Risk Assessment

The gasification unit requires a maximum of 24,600 stpd of oxygen at 1,100 psig. Ten oxygen plants provide this. High-pressure oxygen gas is provided by compressing the gaseous oxygen from the cold box in two stages. The centrifugal compressor compresses oxygen to about 610 psig and the reciprocating compressor to 1,100 psig. The nitrogen gas required by the process units is provided by compressing the low-pressure nitrogen produced in the cold box Using this approach, most of the equipment remains within the limits of commercially proven technology. The recently commissioned 3 x 1,000 stpd oxygen facility near Houston employs this combination to compress the oxygen output to 1,250 psig, the only difference being the capacity of the oxygen compressors: 2,500 stpd vs 1,000 stpd.

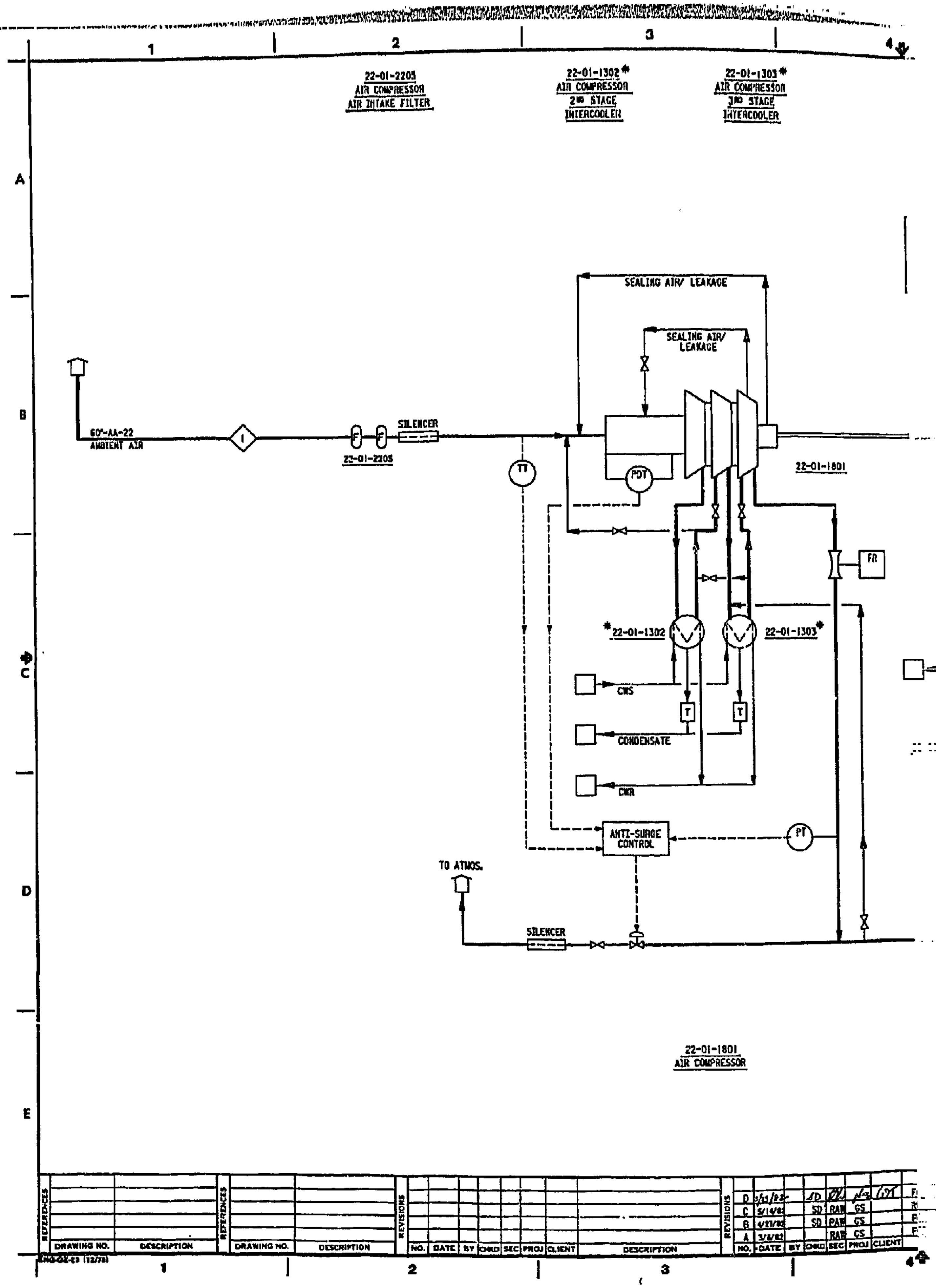
The oxygen supply is of critical importance to the gasifiers to maintain plant output. Fortunately, in recent years there has been excellent experience with large oxygen plants. The design selected is similar to the system operated successfully at SASOL. Air compressor and oxygen compressor selections have been influenced strongly by commercial experience. The oxygen plants at SASOL and this plant produce 2,500 stpd of oxygen at 500 psig and 1,100 psig, respectively. The oxygen compression facilities are now designed and operated with a very high level of safety and reliability.

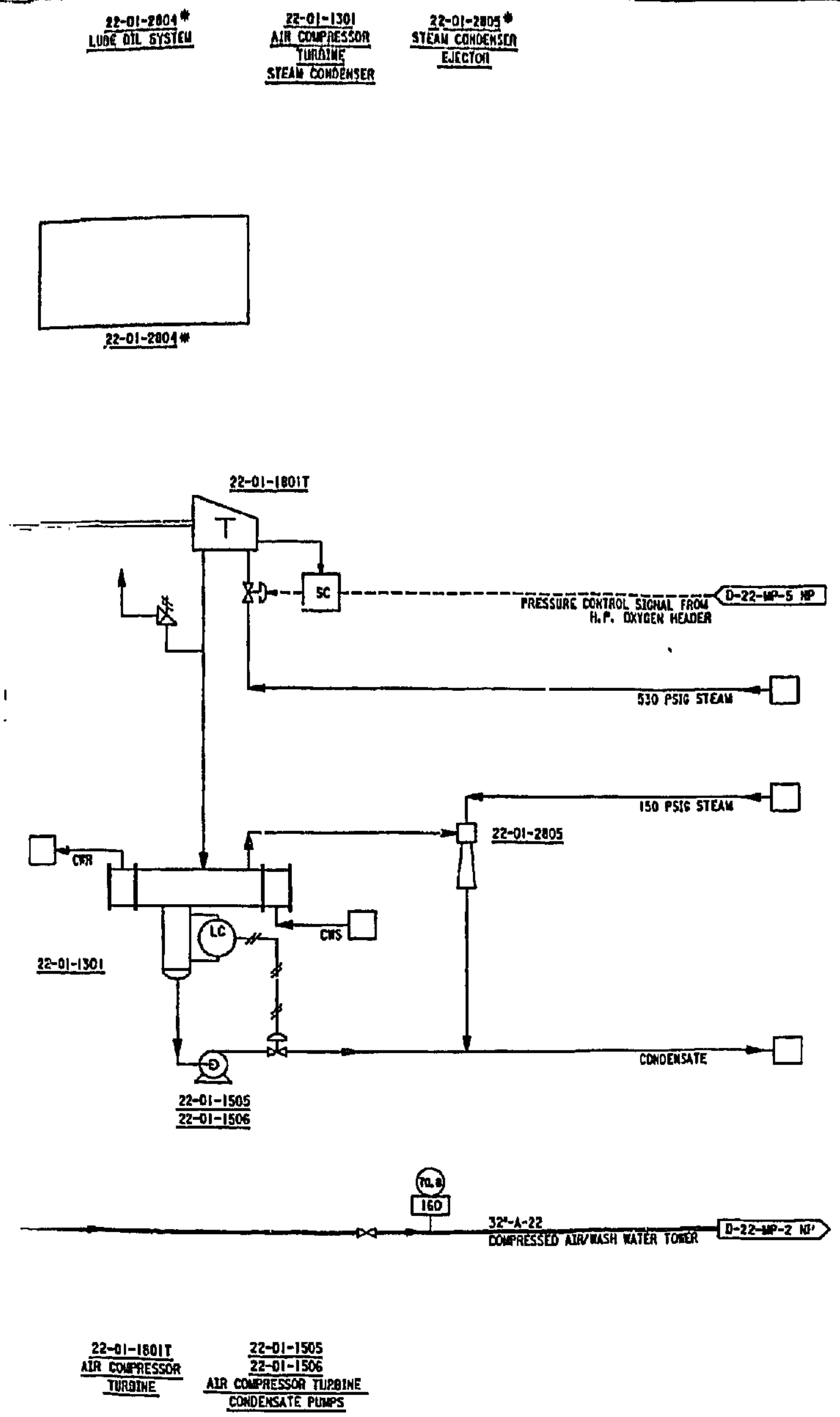
The cold box, with few moving parts and 100% installed spares, contributes very little to shutdown time of the plant. With normal air quality, there are no problems of corrosion using the specified standard materials of construction. Adequate oxygen capacity is included to allow for flexible operation of the gasifiers and maintenance, deriming, etc.

E. <u>Process Flow and Control Diagrams</u> (Including Material Balance)

Process Flow and Control Diagrams for Oxygen Plant Unit 22 are as follows:

Drawing No.	Title
D-22-MP-1NP	PFCD Oxygen Plant - Unit 22 Air Compression
D-22-MP-2NP	PFCD Oxygen Plant - Unit 22 Cold Box
D-22-MP-3NP	PFCD Oxygen Plant - Unit 22 Cold Box
D-22-MP-4NP	PFCD Oxygen Plant - Unit 22 Oxygen Compression
D-22-MP-5NP	PFCD Oxygen Plant - Unit 22 Common Equipment
D-22-MP-6NP	PFCD Oxygen Plant - Unit 22 Material Balance


22-01-2205
AIR COMPRESSOR
AIR INTAKE FILTER
22-01-1302 *
AIR COMPRESSOR
2ND STAGE
INTERCOOLER
22-01-1303 *
AIR COMPRESSOR
3RD STAGE
INTERCOOLER
SEALING AIR/ LEAKAGE
SEALING AIR/
LEAKAGE
60"-AA-22
AMBIENT AIR
I
F
F
SILENCER
22-01-2205
TT
PDT
22-01-1801
FR
* 22-01-1302
22-01-1303 *
CWS
T
T
CONDENSATE
CWR
ANTI-SURGE
CONTROL
PT
TO ATMOS.
SILENCER
22-01-1801
AIR COMPRESSOR
REFERENCES
DRAWING NO.
DESCRIPTION
REVISIONS
NO.
DATE
BY
CHKD
SEC
PROJ
CLIENT
DESCRIPTION
D
C
B
A
SD
RAW
GS
1
2
3
4
A
B
C
D
E



NOTES:
1. THE EQUIPMENT SHOWN ON THIS DRAWING IS FOR ONE TRAIN. THERE ARE TEN IDENTICAL TRAINS IN THIS UNIT.

EQUIPMENT SHOWN ON THIS DRAWING:

22-01-1301	22-01-1801
22-01-1302	22-01-1801T
22-01-1303	22-01-2205
22-01-1505	22-01-2804
22-01-1506	22-01-2805

D22MP1NP.DGA

U.S. DEPARTMENT OF ENERGY

BASKETT — W.R. GRACE & CO. 50,000 B.P.D. — KENTUCKY

COAL - TO - METHANOL - TO - GASOLINE PLANT

PROCESS FLOW & CONTROL DIAGRAM
OXYGEN PLANT - UNIT 22
AIR COMPRESSION

SCALE	ACCOUNT NUMBER	JOB NUMBER	REVISION
NONE	2500	6182	0

DOCUMENT NUMBER: D-22-MP-1 NP

THE RALPH M. PARSONS COMPANY
PASADENA, CALIFORNIA

DESCRIPTION		
FOR DESIGN REPORT	DRAWN	REV
REVISED/RECEIVED FOR APPROVAL	CHECKED	
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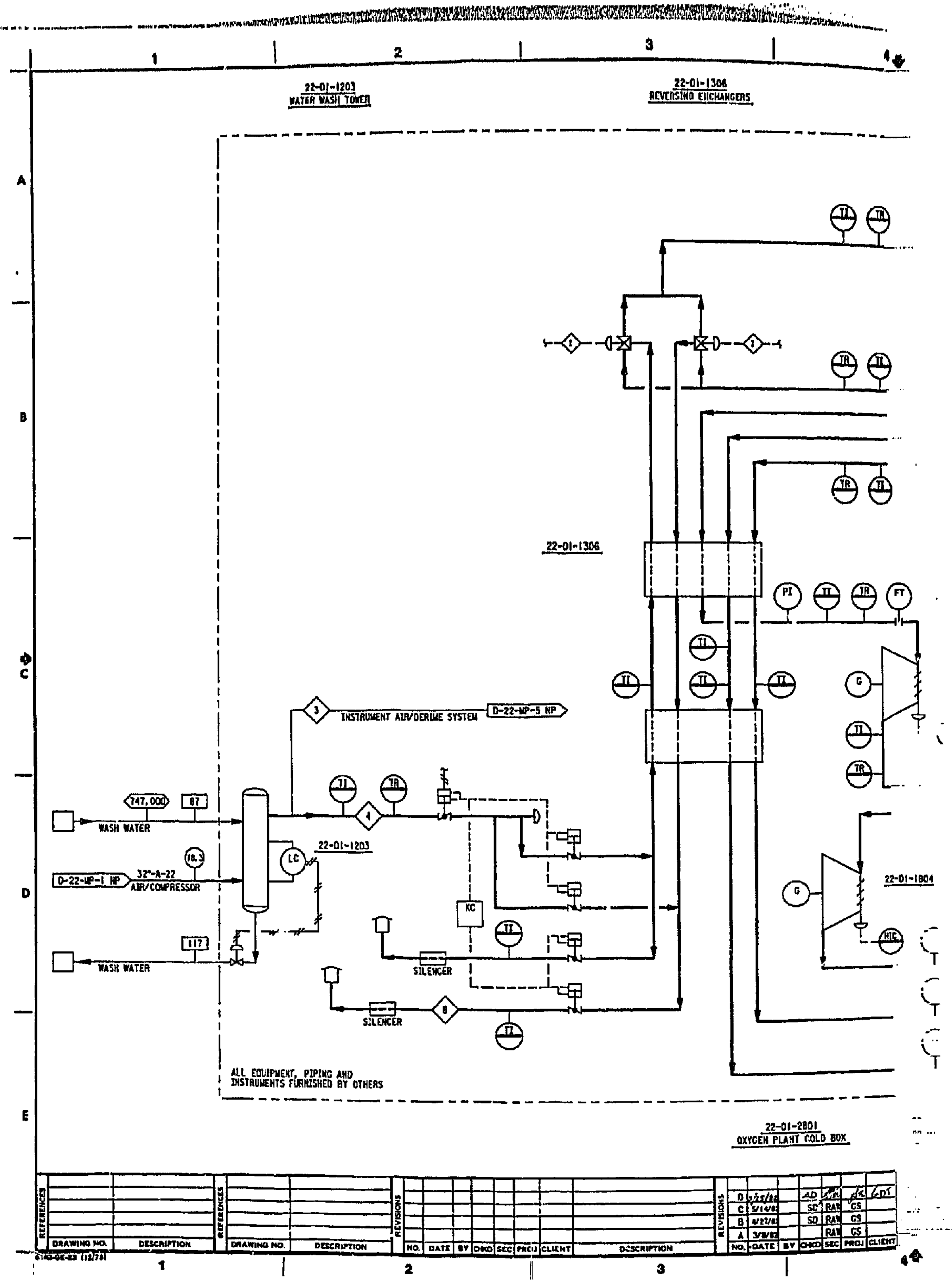
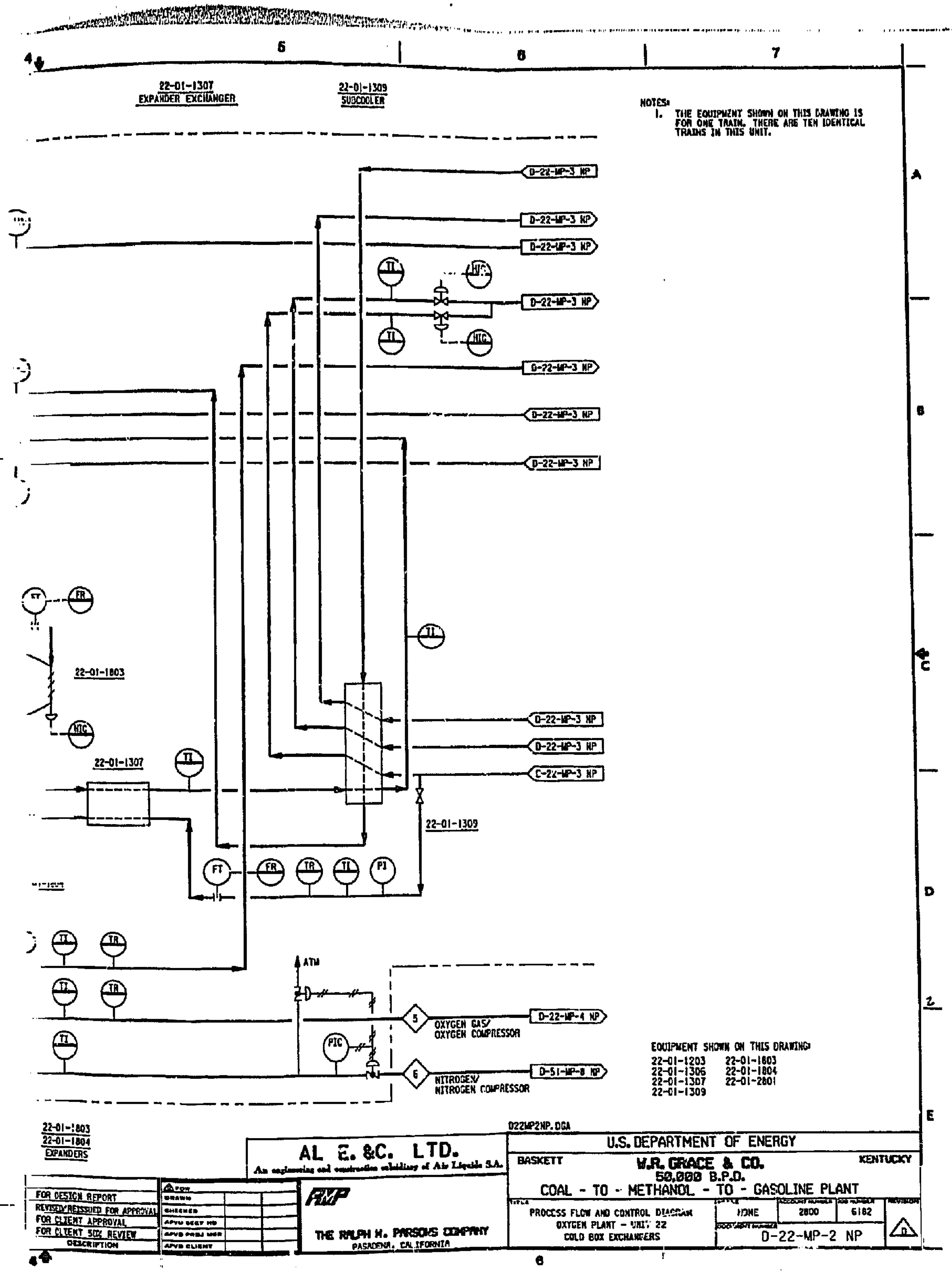
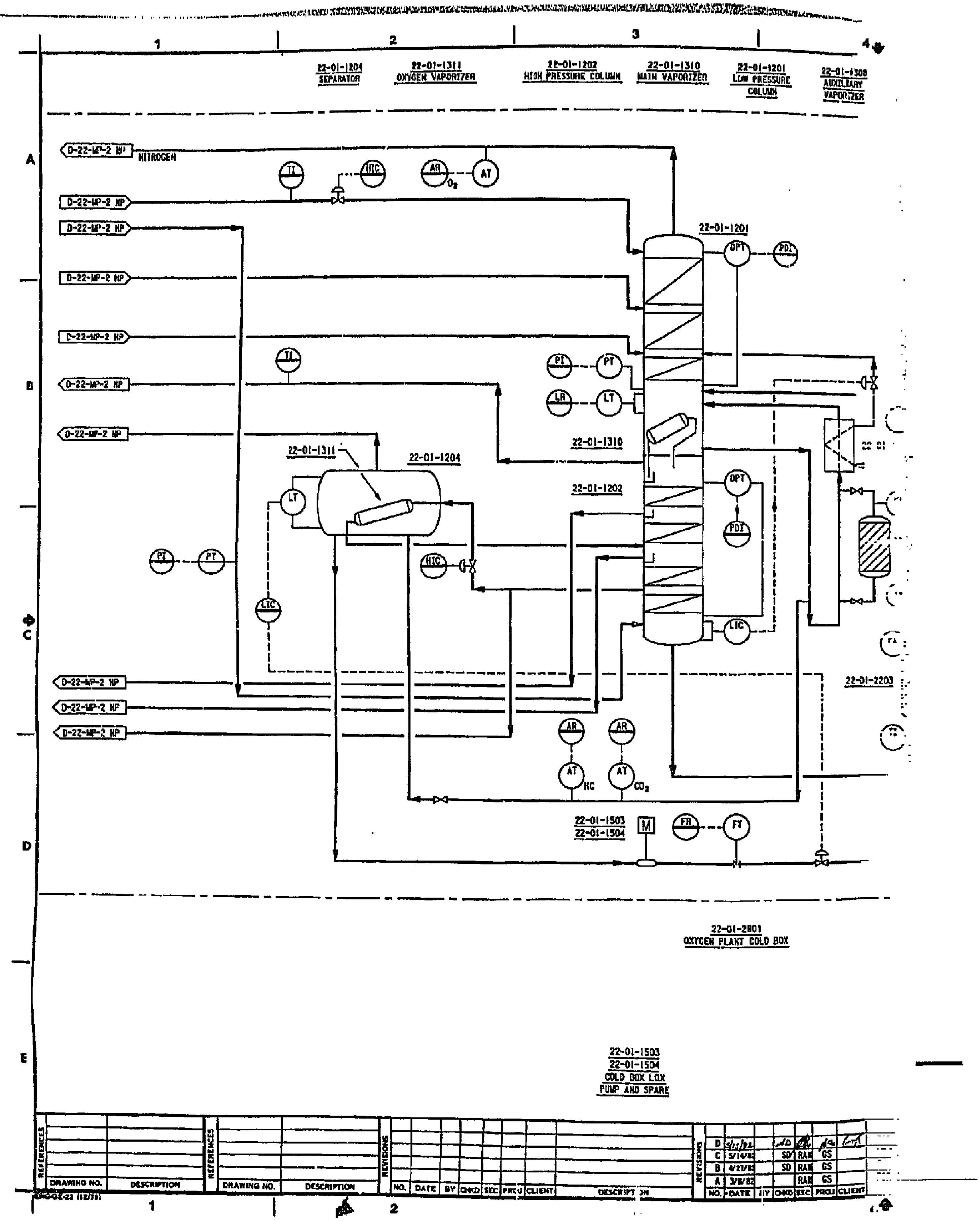
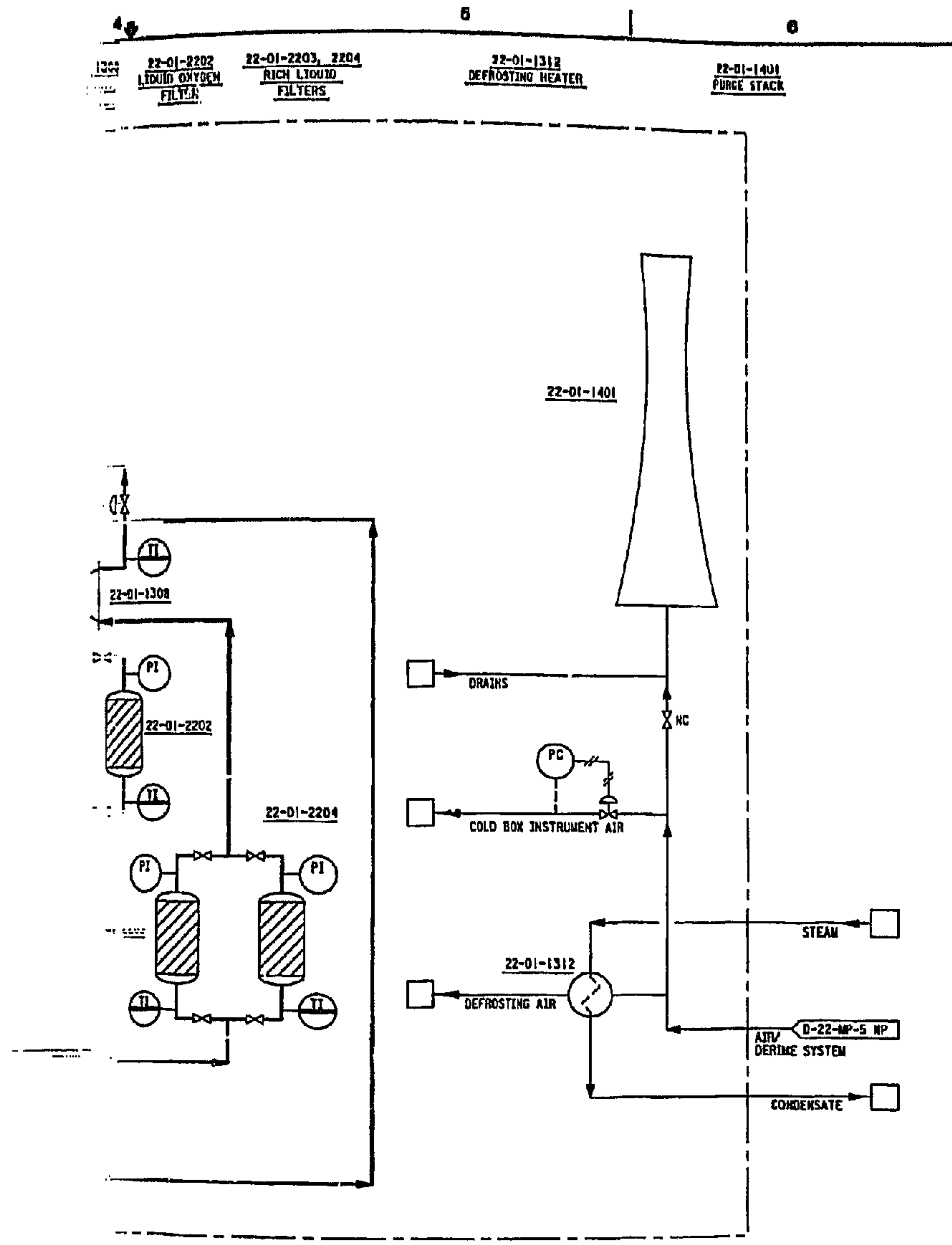
FOR CLIENT 50% REVIEW	APVD PROJ MGR	
	APVD CLIENT	


22-01-1203
WATER WASH TOWER
22-01-1306
REVERSING EXCHANGERS
22-01-1306
INSTRUMENT AIR/DERIME SYSTEM
D-22-MP-5 NP
747,000
87
WASH WATER
D-22-MP-1 NP
32"-A-22
AIR/COMPRESSOR
LC
22-01-1203
KC
117
WASH WATER
SILENCER
SILENCER
22-01-1804
ALL EQUIPMENT, PIPING AND
INSTRUMENTS FURNISHED BY OTHERS
22-01-2801
OXYGEN PLANT COLD BOX
REFERENCES
DRAWING NO.
DESCRIPTION
REVISIONS
NO.
DATE
BY
CHKD
SEC
PROJ
CLIENT
D
C
5/14/82
SD
RAW
GS
B
SD
RAW
GS
A
3/8/82
RAW
GS


22-01-1307
EXPANDER EXCHANGER
22-01-1309
SUBCOOLER
NOTES:
1. THE EQUIPMENT SHOWN ON THIS DRAWING IS FOR ONE TRAIN. THERE ARE TEN IDENTICAL TRAINS IN THIS UNIT.
D-22-MP-3 NP
TI
HIC
FT
FR
TR
PI
PIC
22-01-1803
22-01-1307
22-01-1309
ATM
OXYGEN GAS/
OXYGEN COMPRESSOR
D-22-MP-4 NP
NITROGEN/
NITROGEN COMPRESSOR
D-51-MP-8 NP
EQUIPMENT SHOWN ON THIS DRAWING:
22-01-1203 22-01-1803
22-01-1306 22-01-1804
22-01-1307 22-01-2801
22-01-1309
22-01-1803
22-01-1804
EXPANDERS
D22MP2NP.DGA
U.S. DEPARTMENT OF ENERGY
BASKETT
W.R. GRACE & CO.
50,000 B.P.D.
KENTUCKY
COAL - TO - METHANOL - TO - GASOLINE PLANT
AL E. &C. LTD.
An engineering and construction subsidiary of Air Liquide S.A.
FOR DESIGN REPORT
REVISED/REISSUED FOR APPROVAL
FOR CLIENT APPROVAL
FOR CLIENT 50% REVIEW
DESCRIPTION
RMP
THE RALPH M. PARSONS COMPANY
PASADENA, CALIFORNIA
PROCESS FLOW AND CONTROL DIAGRAM
OXYGEN PLANT - UNIT 22
COLD BOX EXCHANGERS
NONE
2800
6182
D-22-MP-2 NP



22-01-1204
SEPARATOR
22-01-1311
OXYGEN VAPORIZER
22-01-1202
HIGH PRESSURE COLUMN
22-01-1310
MAIN VAPORIZER
22-01-1201
LOW PRESSURE COLUMN
22-01-1308
AUXILIARY VAPORIZER
NITROGEN
22-01-1201
22-01-1310
22-01-1311
22-01-1204
22-01-1202
22-01-2203
22-01-1503
22-01-1504
22-01-2801
OXYGEN PLANT COLD BOX
22-01-1503
22-01-1504
COLD BOX LOX
PUMP AND SPARE
REFERENCES
DRAWING NO.
DESCRIPTION
REVISIONS
NO.
DATE
BY
CHKD
SEC
PROJ
CLIENT
DESCRIPTION
D
C 5/14/82 SD RAW GS
B 4/21/82 SD RAW GS
A 3/8/82 RAW GS



NOTES:
1. THE EQUIPMENT SHOWN ON THIS DRAWING IS FOR ONE TRAIN. THERE ARE TEN IDENTICAL TRAINS IN THIS UNIT.

EQUIPMENT SHOWN ON THIS DRAWING:

22-01-1201
22-01-1202
22-01-1204
22-01-1308
22-01-1310
22-01-1311
22-01-1312
22-01-1401
22-01-1503
22-01-1504
22-01-2202
22-01-2203
22-01-2204
22-01-2801

D22MP3NP.DGA

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COAL - TO - METHANOL - TO - GASOLINE PLANT

AL E. &C. LTD.
An engineering and construction subsidiary of Air Liquide S.A.

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THE RALPH M. PARSONS COMPANY
PASADENA, CALIFORNIA

DESCRIPTION
FOR DESIGN REPORT
REVISED/REISSUED FOR APPROVAL
FOR CLIENT APPROVAL
FOR CLIENT 50% REVIEW

FOR	
DRAWN	
CHECKED	
APVD SECT HD	
APVD PROJ MGR	
APVD CLIENT	

TITLE: PROCESS FLOW AND CONTROL DIAGRAM
OXYGEN PLANT - UNIT 22
COLD BOX

SCALE	ACCOUNT NUMBER	JOB NUMBER	REVISION
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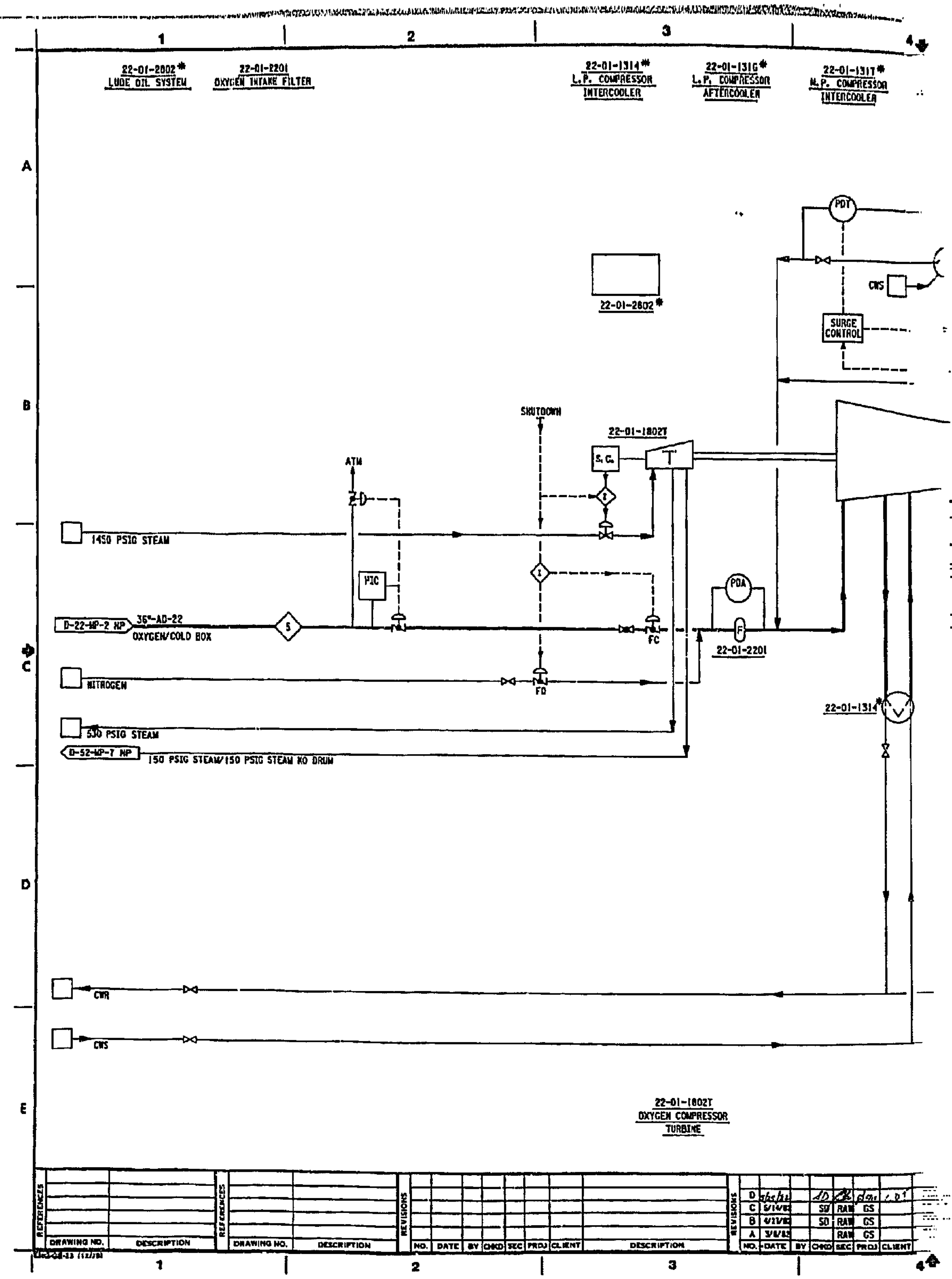
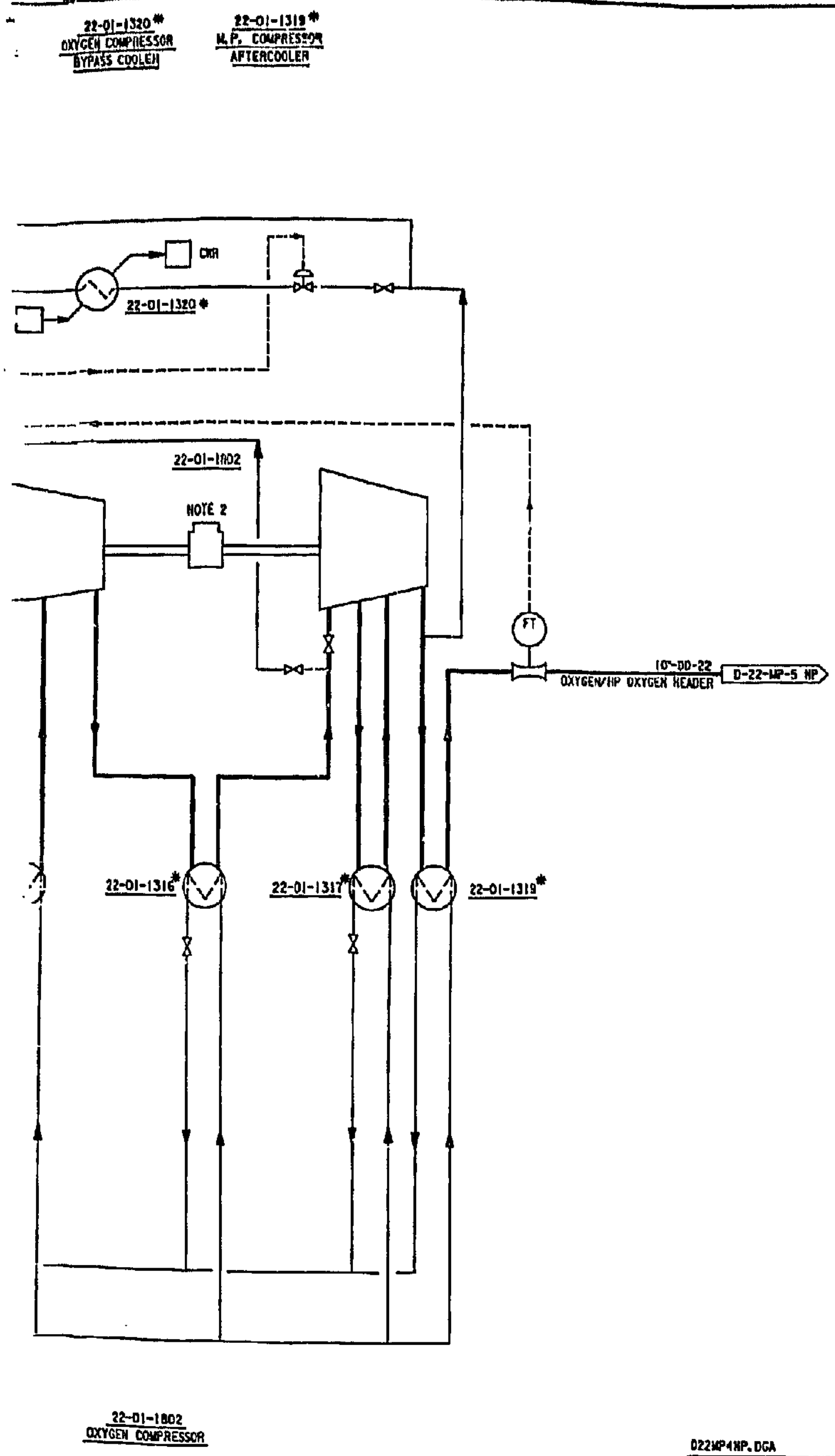
DOCUMENT NUMBER: D-22-MP-3 NP



1
2
3
4
A
B
C
D
E
22-01-2802*
LUBE OIL SYSTEM
22-01-2201
OXYGEN INTAKE FILTER
22-01-1314*
L.P. COMPRESSOR
INTERCOOLER
22-01-1316*
L.P. COMPRESSOR
AFTERCOOLER
22-01-1317*
H.P. COMPRESSOR
INTERCOOLER
PDT
CWS
22-01-2802*
SURGE
CONTROL
SHUTDOWN
22-01-1802T
S.C.
T
ATM
1450 PSIG STEAM
PIC
PDA
D-22-WP-2 NP
36"-AD-22
OXYGEN/COLD BOX
S
FC
22-01-2201
NITROGEN
FO
22-01-1314*
530 PSIG STEAM
D-52-WP-7 NP
150 PSIG STEAM/150 PSIG STEAM KO DRUM
CWR
CWS
22-01-1802T
OXYGEN COMPRESSOR
TURBINE
REFERENCES
DRAWING NO.
DESCRIPTION
REVISIONS
NO.
DATE
BY
CHKD
SEC
PROJ
CLIENT
D
C
B
A
5/14/82
4/21/82
3/4/82
SD
RAW
GS



NOTES:

1. THE EQUIPMENT SHOWN ON THIS DRAWING IS FOR ONE TRAIN. THERE ARE TEN IDENTICAL TRAINS IN THIS UNIT.
2. SPEED INCREASING GEAR BOX.

EQUIPMENT SHOWN ON THIS DRAWING:

22-01-1205	22-01-1802
22-01-1314	22-01-1802T
22-01-1316	22-01-1805
22-01-1317	22-01-2201
22-01-1319	22-01-2802
22-01-1320	

D22MP4NP.DGA

DESCRIPTION		
FOR DESIGN REPORT	FOR DRAWN	
REVISED/REISSUED FOR APPROVAL	CHECKED	
FOR CLIENT APPROVAL	APVD SECT HD	
FOR CLIENT 50% REVIEW	APVD PROJ MGR	
	APVD CLIENT	

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THE RALPH M. PARSONS COMPANY
PASADENA, CALIFORNIA

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BASKETT — W.R. GRACE & CO. — KENTUCKY

50,000 B.P.D.

COAL - TO - METHANOL - TO - GASOLINE PLANT

TITLE: PROCESS FLOW & CONTROL DIAGRAM
OXYGEN PLANT - UNIT 22
OXYGEN COMPRESSION

SCALE	ACCOUNT NUMBER	JOB NUMBER	REVISION
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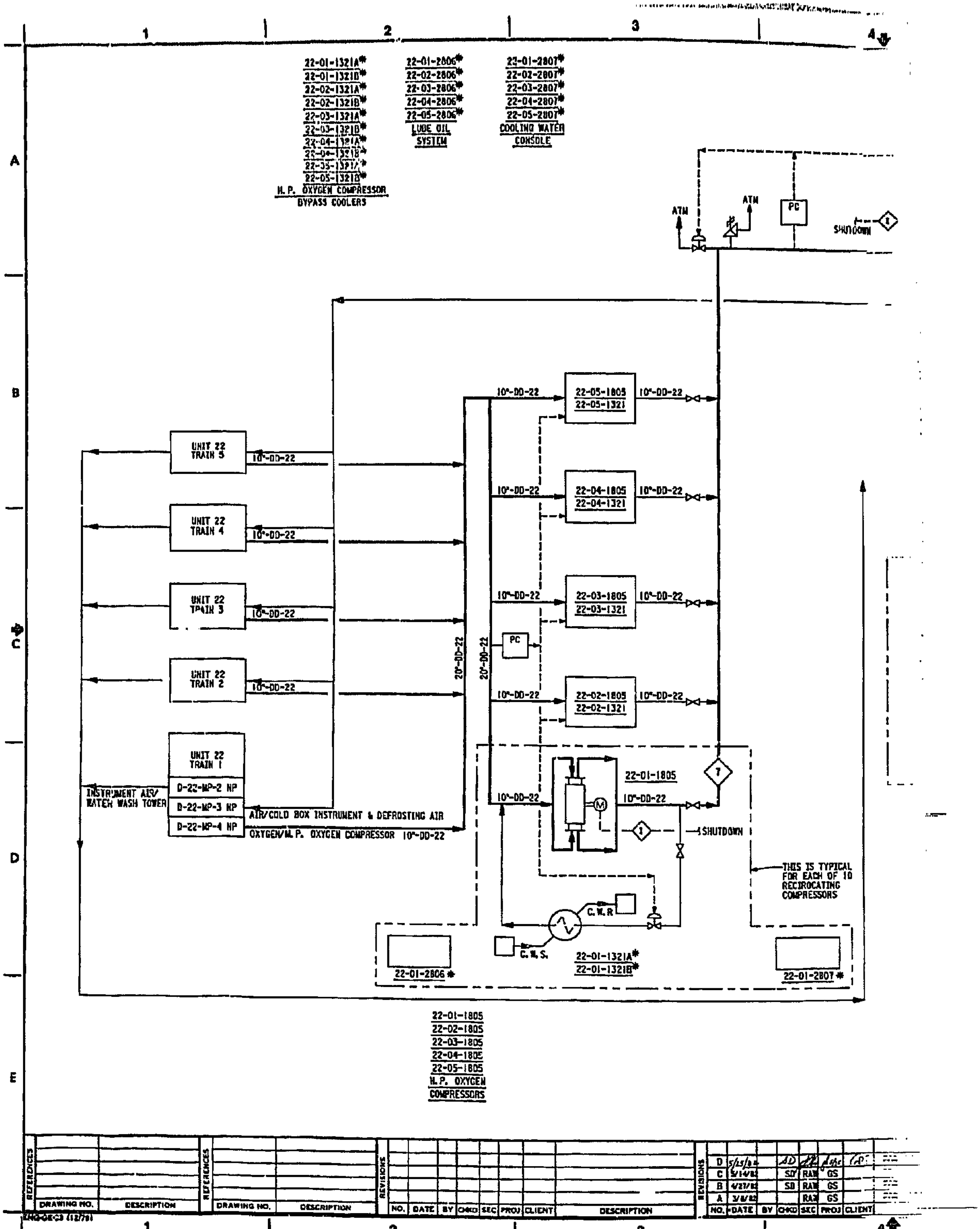
DOCUMENT NUMBER: D-22-MP-4 NP


22-01-1321A*
22-01-1321B*
22-02-1321A*
22-02-1321B*
22-03-1321A*
22-03-1321B*
22-04-1321A*
22-04-1321B*
22-05-1321A*
22-05-1321B*
H. P. OXYGEN COMPRESSOR
BYPASS COOLERS
22-01-2806*
22-02-2806*
22-03-2806*
22-04-2806*
22-05-2806*
LUBE OIL
SYSTEM
22-01-2807*
22-02-2807*
22-03-2807*
22-04-2807*
22-05-2807*
COOLING WATER
CONSOLE
ATM
ATM
PC
SHUTDOWN
UNIT 22
TRAIN 5
10"-DD-22
UNIT 22
TRAIN 4
10"-DD-22
UNIT 22
TRAIN 3
10"-DD-22
UNIT 22
TRAIN 2
10"-DD-22
UNIT 22
TRAIN 1
D-22-MP-2 HP
D-22-MP-3 HP
D-22-MP-4 HP
INSTRUMENT AIR/
WATER WASH TOWER
AIR/COLD BOX INSTRUMENT & DEFROSTING AIR
OXYGEN/H.P. OXYGEN COMPRESSOR 10"-DD-22
20"-DD-22
20"-DD-22
PC
22-05-1805
22-05-1321
22-04-1805
22-04-1321
22-03-1805
22-03-1321
22-02-1805
22-02-1321
22-01-1805
10"-DD-22
M
SHUTDOWN
C.W.R
C.W.S.
22-01-1321A*
22-01-1321B*
22-01-2806*
22-01-2807*
THIS IS TYPICAL
FOR EACH OF 10
RECIPROCATING
COMPRESSORS
22-01-1805
22-02-1805
22-03-1805
22-04-1805
22-05-1805
H.P. OXYGEN
COMPRESSORS
A
B
C
D
E
1
2
3
4
REFERENCES
DRAWING NO.
DESCRIPTION
REVISIONS
NO.
DATE
BY
CHKD
SEC
PROJ
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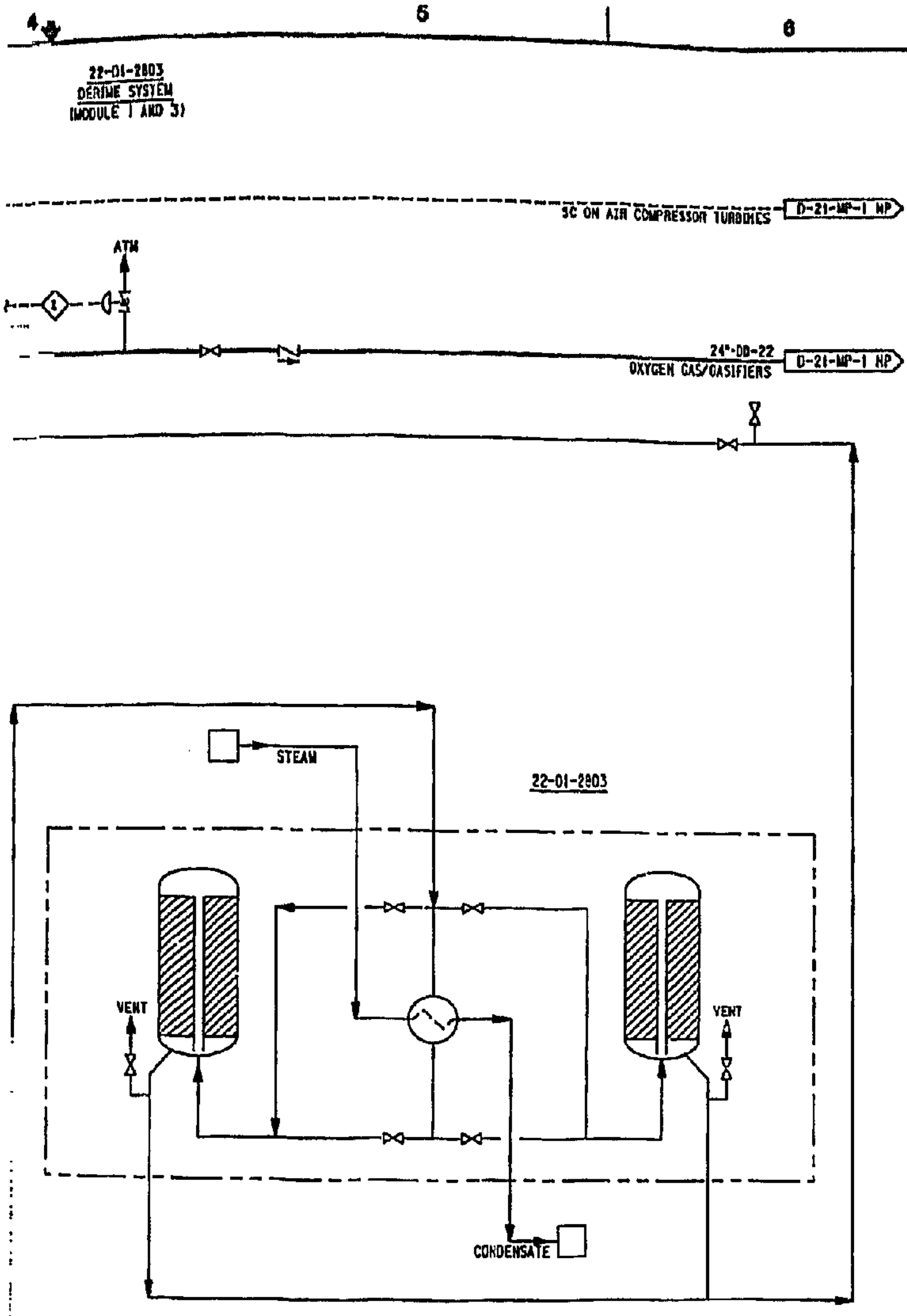
B 4/27/82 SD RAW GS
A 3/8/82 RAW GS



NOTES:

1. THE EQUIPMENT SHOWN ON THIS DRAWING IS FOR FIVE TRAINS. THERE ARE 10 RECIPROCATING COMPRESSORS IN 10 TRAINS IN OXYGEN PLANT UNIT 22.
2. THERE ARE TWO DERIME SYSTEMS, ONE IN MODULE #1 (SERVING MODULES #1 & #2) AND ONE LOCATED IN MODULE #3 (SERVING MODULES #3 & #4).

EQUIPMENT SHOWN ON THIS DRAWING:

22-01-1321A	22-01-2803
22-01-1321B	22-01-2806
22-02-1321A	22-02-2806
22-02-1321B	22-03-2806
22-03-1321A	22-04-2806
22-03-1321B	22-05-2806
22-04-1321A	22-01-2807
22-04-1321B	22-02-2807
22-05-1321A	22-03-2807
22-05-1321B	22-04-2807
22-01-1805	22-05-2807
22-02-1805	
22-03-1805	
22-04-1805	
22-05-1205	

D22MP5NP.DGA

DESIGN REPORT	DRAWN
REVISED/REISSUED FOR APPROVAL	CHECKED
FOR CLIENT APPROVAL	APVD ASST MD
FOR CLIENT 50% REVIEW	APVD PROJ MGR
DESCRIPTION	APVD CLIENT

RMP

THE RALPH M. PARSONS COMPANY
PASADENA, CALIFORNIA

U.S. DEPARTMENT OF ENERGY

BASKETT — W.R. GRACE & CO. — KENTUCKY

50,000 B.P.D.

COAL - TO - METHANOL - TO - GASOLINE PLANT

TITLE	SCALE	ACCOUNT NUMBER	JOB NUMBER	REVISION
PROCESS FLOW AND CONTROL DIAGRAM OXYGEN PLANT - UNIT 22 COMMON EQUIPMENT	NONE	2800	6182	D
	DOCUMENT NUMBER D-22-MP-5 NP			

COMPONENT	1 AMBIENT AIR INTAKE		2 AIR LOSSES		3 INSTRUMENT AIR		4 PROCESS AIR		5 OXYGEN GAS TO OXYGEN COMPRESSOR		6 GASEOUS NITROGEN	
MOL WEIGHT	LB MOL/HR	MOL %	LB MOL/HR	MOL %	LB MOL/HR	MOL %	LB MOL/HR	MOL %	LB MOL/HR	MOL %	LB MOL/HR	MOL %
N_2 28.02	21,925.87	78.11	828.20	78.11	24.37	78.11	21,073.30	78.11	0.0	0.0	2,347.[illegible]	[illegible]
Ar 39.94	261.05	0.93	9.86	0.93	0.29	0.93	250.90	0.93	27.62	0.50	0.12	[illegible]
O_2 32.00	5,883.58	20.96	222.24	20.96	6.54	20.96	5,654.80	20.96	5,496.88	99.50	0.02	10 PPM
TOTAL FLOW	28,070.50	100.00	1,060.30	100.00	31.20	100.00	26,979	100.00	5,524.50	100.00	2,347.20	100.00
MOL WEIGHT	28.96		28.96		28.96		28.96		32.04		28.02	
LB/HR	812,978		30,708		904		781,368		177,004		65,761	
MMSCFD	255.66		9.66		0.28		245.72		50.32		21.38	
PRESSURE PSIA	14.3		-		80		84		22		22	
TEMPERATURE °F	80		-		90		95		90		90	

REFERENCES DRAWING NO.	DESCRIPTION	REFERENCES DRAWING NO.	DESCRIPTION

NO.	DATE	BY	CHKD	SEC	PROJ	CLIENT	DESCRIPTION
B	[illegible]		SD	[illegible]	[illegible]	[illegible]	
A	5/1/82		SD	RAW	GS		

EAG-02-33 (12/79)

6	7		8	
	OXYGEN TO GASIFIERS		WASTE NITROGEN	
%	LB MOL/HR	MOL %	LB MOL/HR	MOL %
00	0.0	0.0	18,725.15	98.00
PPM	27.62	0.50	223.56	1.17
10 PPM	5,496.88	99.50	158.59	0.83
100.00	5,524.50	100.00	19,107.30	100.00
	32.04		28.19	
	177,004		538,601	
	50.32		174.02	
22	1.115		14.7	
90	201		90	

NOTES:

1. THE MATERIAL BALANCE SHOWN ON THIS DRAWING IS FOR ONE OF TEN TRAINS AND FOR NORMAL OPERATION.
2. THERE ARE THREE TRAINS IN MODULES #1 AND #3, AND TWO TRAINS IN MODULES #2 AND #4.
3. AIR LOSSES, ⟨2⟩, OCCUR BETWEEN AIR INTAKE AND COLD BOX. (STREAM ⟨2⟩ IS NOT INDICATED ON THE PFCD'S).

D22MP6NP.DGA

U.S. DEPARTMENT OF ENERGY

BASKETT | W.R. GRACE & CO. 50,000 B.P.D. COAL - TO - METHANOL - TO - GASOLINE PLANT | KENTUCKY

TITLE: PROCESS FLOW & CONTROL DIAGRAM
OXYGEN PLANT - UNIT 22
MATERIAL BALANCE

SCALE	ACCOUNT NUMBER	JOB NUMBER	REVISION
NONE	2800	6182	8

D-22-MP-6 NP

DESCRIPTION	
FOR DESIGN REPORT	
FOR CLIENT SOX REVIEW	

FOR / DRAWN / CHECKED / APVD SECT HD / APVD PROJ MGR / APVD CLIENT

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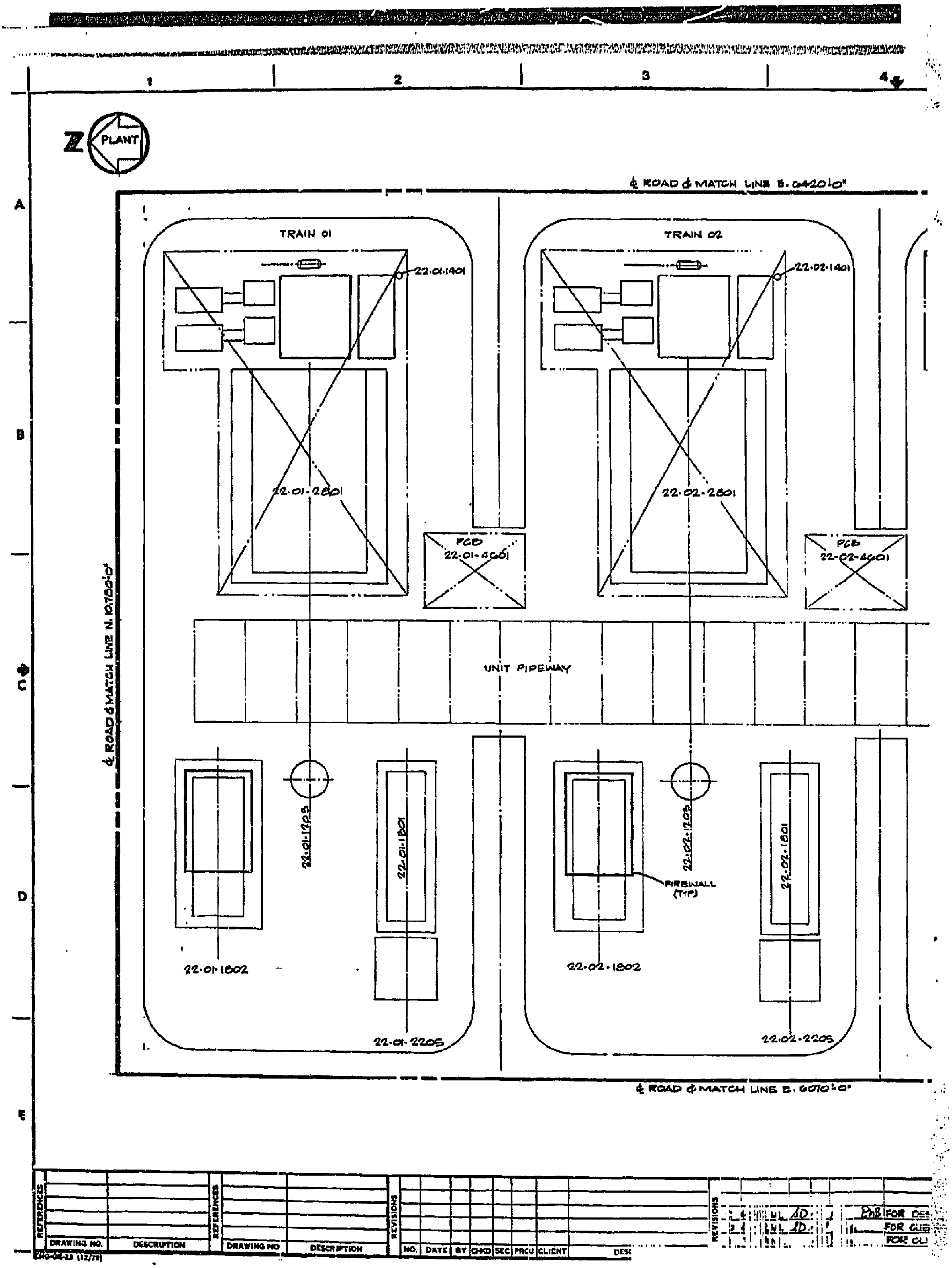
THE RALPH M. PARSONS COMPANY
PASADENA, CALIFORNIA

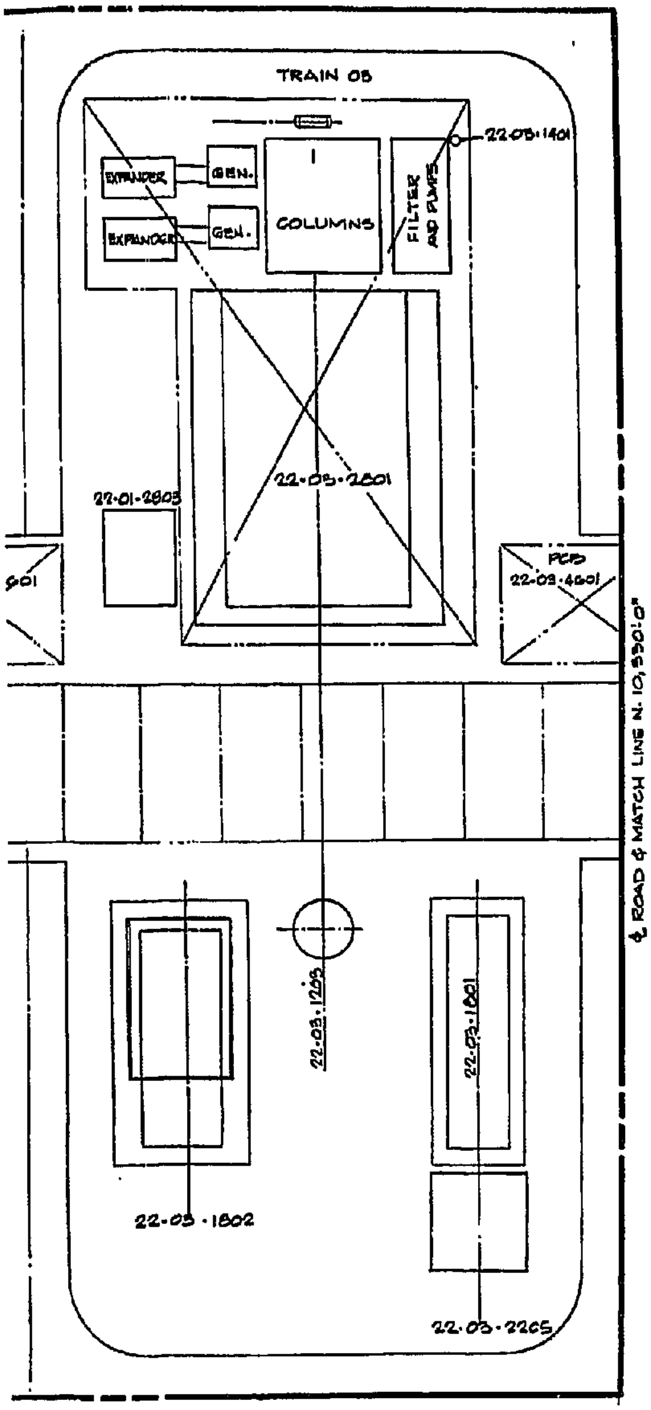
F. Plot Plan/General Arrangement Drawings

Plot Plan/General Arrangement Drawings for Oxygen Plant Unit 22 are as follows:

Drawing No.	Title
D-22-PD-1NP	Plot Plan - Unit 22 Oxygen Plant
D-22-PD-2NP	Plot Plan - Unit 22 Oxygen Plant
D-22-PD-3NP	Plot Plan - Units 22 and 51 Oxygen and Nitrogen Compression
D-22-PD-4NP	ation - Unit 22 Oxygen Plant



PLANT
TRAIN 01
TRAIN 02
℄ ROAD & MATCH LINE E. 6420'-0"
℄ ROAD & MATCH LINE N. 10,780'-0"
℄ ROAD & MATCH LINE E. 6070'-0"
22.01.1401
22.02.1401
22.01.2801
22.02.2801
PGB
22.01.4601
22.02.4601
UNIT PIPEWAY
22.01.1205
22.02.1205
22.01.1801
22.02.1801
22.01.1802
22.02.1802
22.01.2205
22.02.2205
FIREWALL (TYP)
REFERENCES
DRAWING NO.
DESCRIPTION
REVISIONS
NO.
DATE
BY
CHKD
SEC
PRCU
CLIENT
FOR CLIENT



EQUIPMENT LIST

22-01-1801 AIR COMPRESSOR W/ACCESSORIES
- * 22-01-1502 AIR COMPRESSOR 2ND STAGE INTERCOOLER
- * 22-01-1503 AIR COMPRESSOR 3RD STAGE INTERCOOLER
- * 22-01-2804 LUBE OIL SYSTEM

*22-01-1801T AIR COMPRESSOR TURBINE
*22-01-1501 AIR COMPRESSOR TURBINE STEAM CONDENSER
*22-01-2805 AIR COMPRESSOR TURBINE CONDENSER EJECTOR
*22-01-1505 CONDENSATE PUMP
*22-01-1506 CONDENSATE PUMP SPARE
*22-01-2205 AIR INTAKE FILTER

22-01-1802 OXYGEN COMPRESSOR W/ACCESSORIES
- * 22-01-1514 L.P. COMPRESSOR INTERCOOLER
- * 22-01-1516 L.P. COMPRESSOR AFTERCOOLER
- * 22-01-1517 M.P. COMPRESSOR INTERCOOLER
- * 22-01-1519 M.P. COMPRESSOR AFTERCOOLER
- * 22-01-1520 OXYGEN COMPRESSOR BYPASS COOLER
- * 22-01-2802 LUBE OIL SYSTEM

*22-01-1802T OXYGEN COMPRESSOR TURBINE
*22-01-2201 OXYGEN INTAKE FILTER

22-01-2801 COLD BOX W/ACCESSORIES
- * 22-01-1201 LOW PRESSURE COLUMN
- * 22-01-1202 HIGH PRESSURE COLUMN
- * 22-01-1204 OXYGEN SEPARATOR
- * 22-01-1506 REVERSING EXCHANGER
- * 22-01-1507 EXPANDER EXCHANGER
- * 22-01-1508 AUXILIARY VAPORIZER
- * 22-01-1509 SUB COOLER
- * 22-01-1510 MAIN VAPORIZER
- * 22-01-1511 OXYGEN VAPORIZER
- * 22-01-1512 DEFROSTING HEATER
- * 22-01-1401 PURGE STACK
- * 22-01-1503 COLD BOX LOX PUMP
- * 22-01-1504 COLD BOX LOX PUMP SPARE
- * 22-01-1803 EXPANDER
- * 22-01-1804 EXPANDER
- * 22-01-2202 LIQUID OXYGEN FILTER
- * 22-01-2203 RICH LIQUID FILTER
- * 22-01-2204 RICH LIQUID FILTER

22-01-2803 DERIME SYSTEM W/ACCESSORIES
22-01-1203 WATER WASH TOWER

NOTES:
1. THIS PLOT PLAN IS MODULE 1 OF 4 MODULES
2. THIS MODULE IS IDENTICAL TO MODULE B
3. * INDICATES EQUIPMENT NOT SHOWN OR INCLUDED WITH MAJOR EQUIPMENT.
4. ALL COMPRESSORS SHALL BE UNDER SHELTERS
5. SEE DWG. D-22-PD-BNP FOR EQUIPMENT LIST AND PLOT PLAN FOR H.P. OXYGEN COMPRESSORS AND NITROGEN COMPRESSORS.

1" = 20FT

		FOR		
		DRAWN	ML	
	FOR DESIGN REPORT	CHECKED		
	FOR CLIENT APPROVAL	APVD SECT HD	[illegible]	
	FOR CLIENT 50% REVIEW	APVD PROJ MGR		
NT	DESCRIPTION	APVD CLIENT	[illegible]	[illegible]

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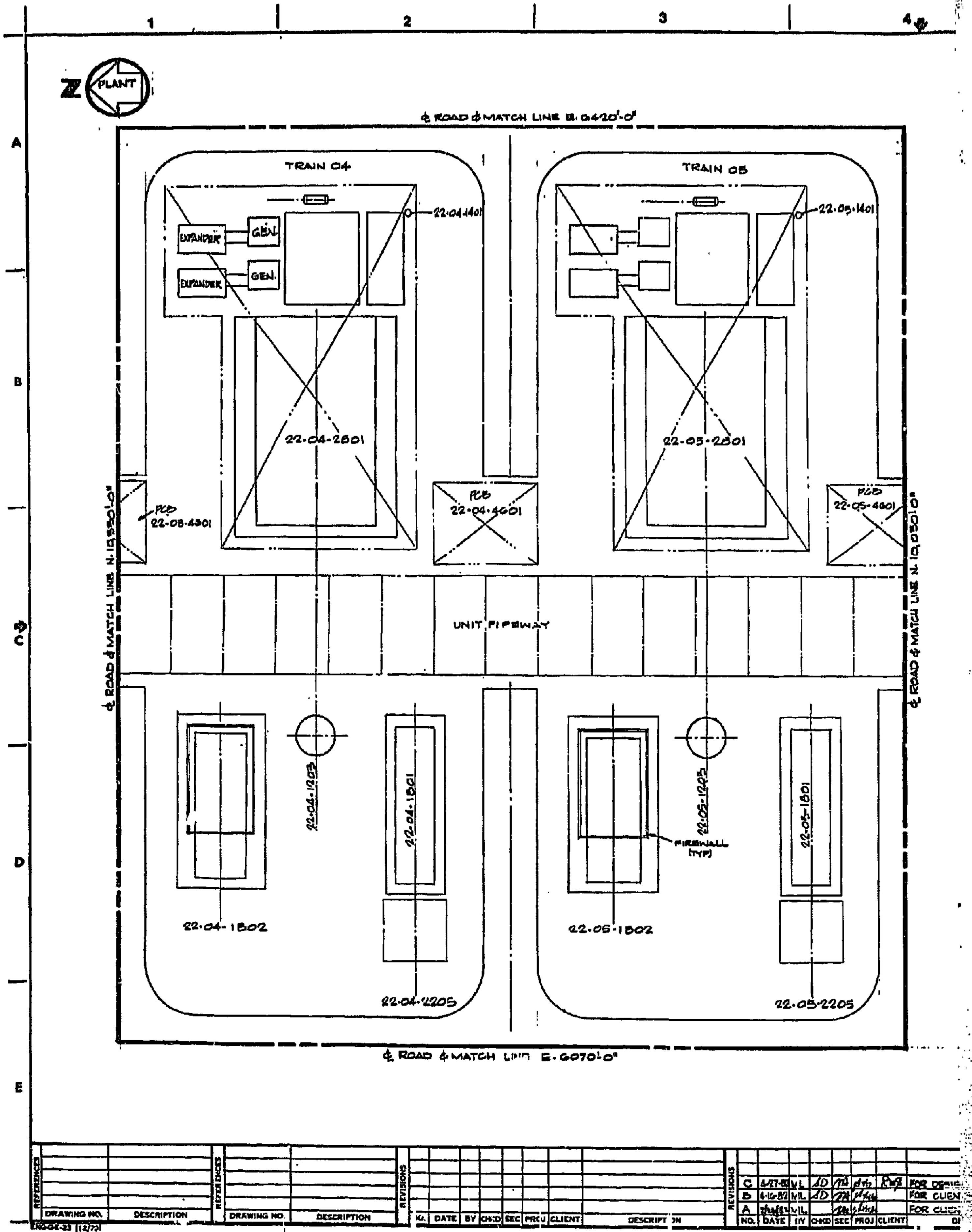
THE RALPH M. PARSONS COMPANY
PASADENA, CALIFORNIA

U.S. DEPARTMENT OF ENERGY
BASKETT — W.R. GRACE & CO. — KENTUCKY
60,000 B.P.D.
COAL-TO-METHANOL-TO-GASOLINE PLANT

TITLE: PLOT PLAN UNIT 22 OXYGEN PLANT
SCALE: 1" = 20'-0"
ACCOUNT NUMBER: 7645
JOB NUMBER: 0182
DOCUMENT NUMBER: D-22-PD-INP
REVISION: C



PLANT
℄ ROAD ℄ MATCH LINE E.6420'-0"
TRAIN 04
TRAIN 05
EXPANDER
GEN.
EXPANDER
GEN.
22-04-1401
22-05-1401
22-04-2801
22-05-2801
PCB
22-08-4801
PCB
22-04-4601
PCB
22-05-4801
℄ ROAD ℄ MATCH LINE N. 12,850'-0"
℄ ROAD ℄ MATCH LINE N. 10,050'-0"
UNIT PIPEWAY
22-04-1203
22-04-1801
22-05-1203
22-05-1801
FIREWALL (TYP)
22-04-1802
22-05-1802
22-04-2205
22-05-2205
℄ ROAD ℄ MATCH LINE E. 6070'-0"
REFERENCES
DRAWING NO.
DESCRIPTION
REVISIONS
NO.
DATE
BY
CHKD
SEC
PROJ
CLIENT
DESCRIPTION
C
4-27-82
B
4-16-82
A
FOR CLIENT

℄ ROAD & MATCH LINE N. 10,050'0"

NOTES:

1. SEE D-22-PD-1NP FOR EQUIPMENT LIST
2. THIS PLOT PLAN IS MODULE 2 OF 4 MODULES
3. THIS MODULE IS IDENTICAL TO MODULE 4 EXCEPT PCS-22-05-4601

1" = 20FT

		FOR		
		DRAWN	ML	
	FOR DESIGN REPORT	CHECKED		
	FOR CLIENT APPROVAL	APVD SECT HD		
	FOR CLIENT 50% REVIEW	APVD PROJ MGR		
	DESCRIPTION	APVD CLIENT		

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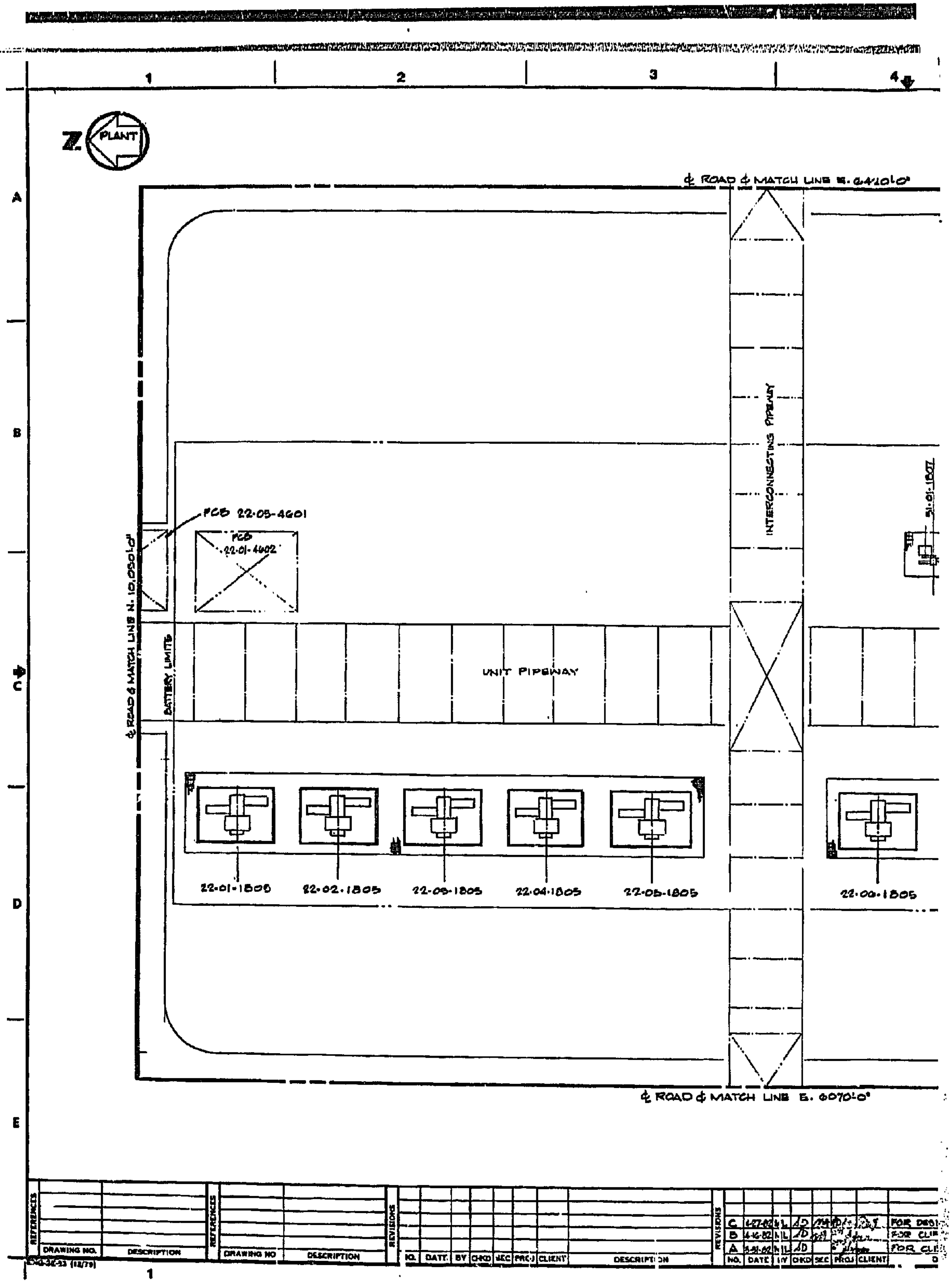
U.S. DEPARTMENT OF ENERGY

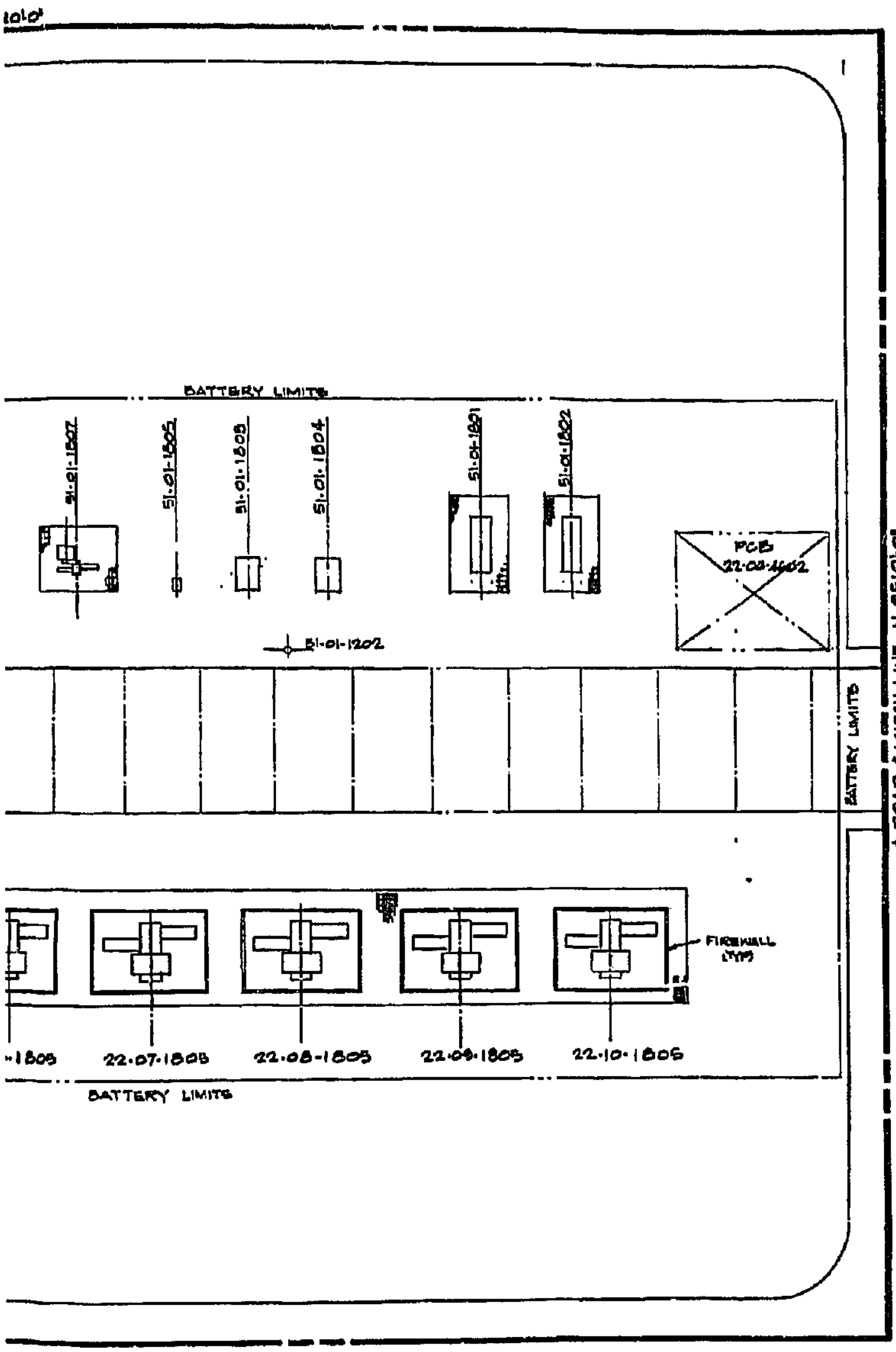
BASKETT — W.R. GRACE & CO. — KENTUCKY
50,000 B.P.D.
COAL - TO - METHANOL - TO - GASOLINE PLANT

TITLE	SCALE	ACCOUNT NUMBER	JOB NUMBER	REVISION
PLOT PLAN UNIT 22 OXYGEN PLANT	1" = 20'0"	7243	0162	C
	DOCUMENT NUMBER: D-22-PD-2NP			

p



1
2
3
4
A
B
C
D
E
PLANT
℄ ROAD ℄ MATCH LINE E. 6410'-0"
INTERCONNECTING PIPEWAY
FCB 22-05-4601
FCB 22-01-4602
℄ ROAD ℄ MATCH LINE N. 10,050'-0"
BATTERY LIMITS
UNIT PIPEWAY
22-01-1805
22-02-1805
22-03-1805
22-04-1805
22-05-1805
22-06-1805
51-01-1807
℄ ROAD ℄ MATCH LINE E. 6070'-0"
REFERENCES
DRAWING NO.
DESCRIPTION
REVISIONS
NO.
DATE
BY
CHKD
SEC
PROJ
CLIENT
DESCRIPTION
C
B
A
FOR DESI
FOR CLI
FOR CLI



EQUIPMENT LIST

51-01-1202	GASIFIER PYROMETER PURGE NITROGEN SURGE VESSEL
51-01-1801	LOW PRESSURE NITROGEN COMP W/AFTER COOLER 51-01-1519-
51-01-1802	LOW PRESSURE NITROGEN COMP SPARE W/AFTERCOOLER 51-01-1520 -
51-01-1803	GASIFIER PYROMETER PURGE NITROGEN COMP W/ 1ST STAGE INTERCOOLER, 2ND STAGE INTERCOOLER AND AFTERCOOLER 51-01-1521, 51-01-1525, 51-01-1523-
51-01-1804	GASIFIER PYROMETER PURGE NITROGEN COMP SPARE W/ 1ST STAGE INTERCOOLER, 2ND STAGE INTERCOOLER AND AFTERCOOLER 51-01-1522, 51-01-1524, 51-01-1526-
51-01-1805	HF ACID UNLOADING NITROGEN COMP W/AFTERCOOLER 51-01-1527 - INCLUDED WITH COMPRESSOR
51-01-1807	REGENERATION NITROGEN COMP. W/AFTERCOOLER 51-01-1528 -
22-01/10-1805	H.P. OXYGEN COMPRESSORS W/ 22-01-2806 LUBE OIL SYSTEM, 22-01-2807 COOLING WATER CONSOLE - INCLUDED WITH COMPRESSOR
22-01/10-1521 A&B	H.P. OXYGEN COMPRESSOR BY-PASS COOLER (NOT SHOWN)

NOTES:
1. ALL COMPRESSORS SHALL BE UNDER SHELTERS.

1" = 20FT

U.S. DEPARTMENT OF ENERGY

BASKETT — W.R. GRACE & CO. — KENTUCKY

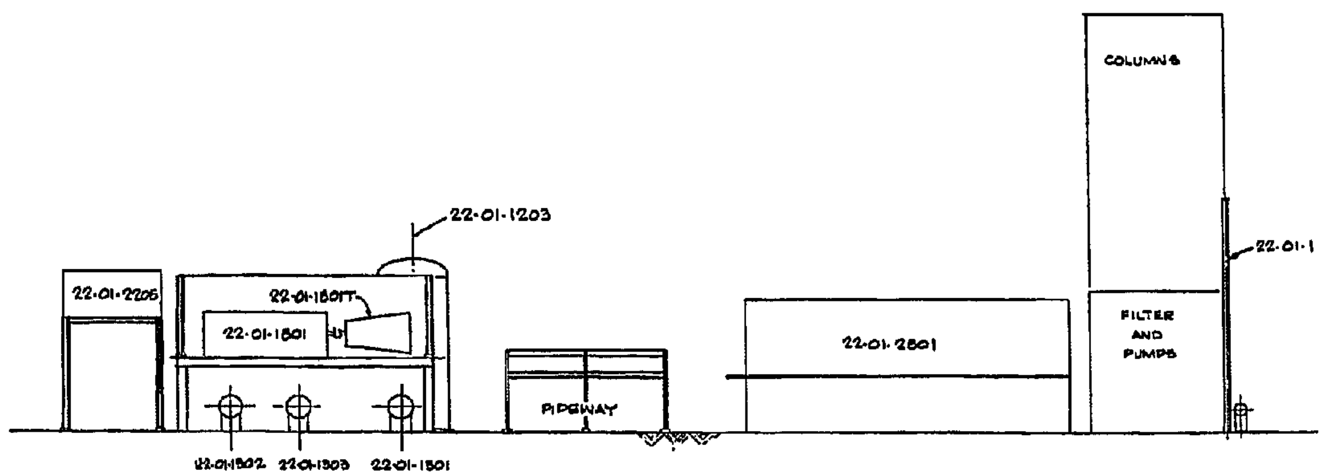
50,000 B.P.D.

COAL - TO - METHANOL - TO - GASOLINE PLANT

FOR DESIGN REPORT	DRAWN: ML
FOR CLIENT APPROVAL	CHECKED
FOR CLIENT 50% REVIEW	APVD SECT HD
DESCRIPTION	APVD PROJ MGR
	APVD CLIENT: RAS 4/81

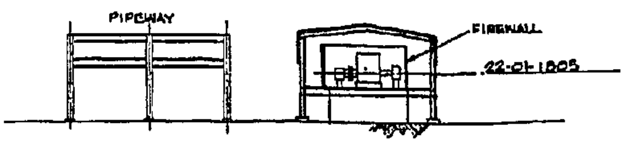
THE RALPH M. PARSONS COMPANY
PASADENA, CALIFORNIA

TITLE	SCALE	ACCOUNT NUMBER	JOB NUMBER	REVISION
PLOT PLAN UNIT 22 & UNIT 51 OXYGEN & NITROGEN COMPRESSION	1"=20'0"	7343	0182	C
	DOCUMENT NUMBER: 1-22-PD-5			



ELEVATION AT OXYGEN UNIT

-22-01-1401



ELEVATION AT H.P. OXYGEN COMPRESSORS

1" = 20FT

	FOR		
	DRAWN	ML	
FOR DESIGN REPORT	CHECKED		
FOR CLIENT APPROVAL	APVD DEPT MGR		
FOR CLIENT 50% REVIEW	APVD PROJ MGR		
DESCRIPTION	APVD CLIENT		

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PASADENA, CALIFORNIA

U.S. DEPARTMENT OF ENERGY

BASKETT — W.R. GRACE & CO. — KENTUCKY
50,000 B.P.D.
COAL - TO - METHANOL - TO - GASOLINE PLANT

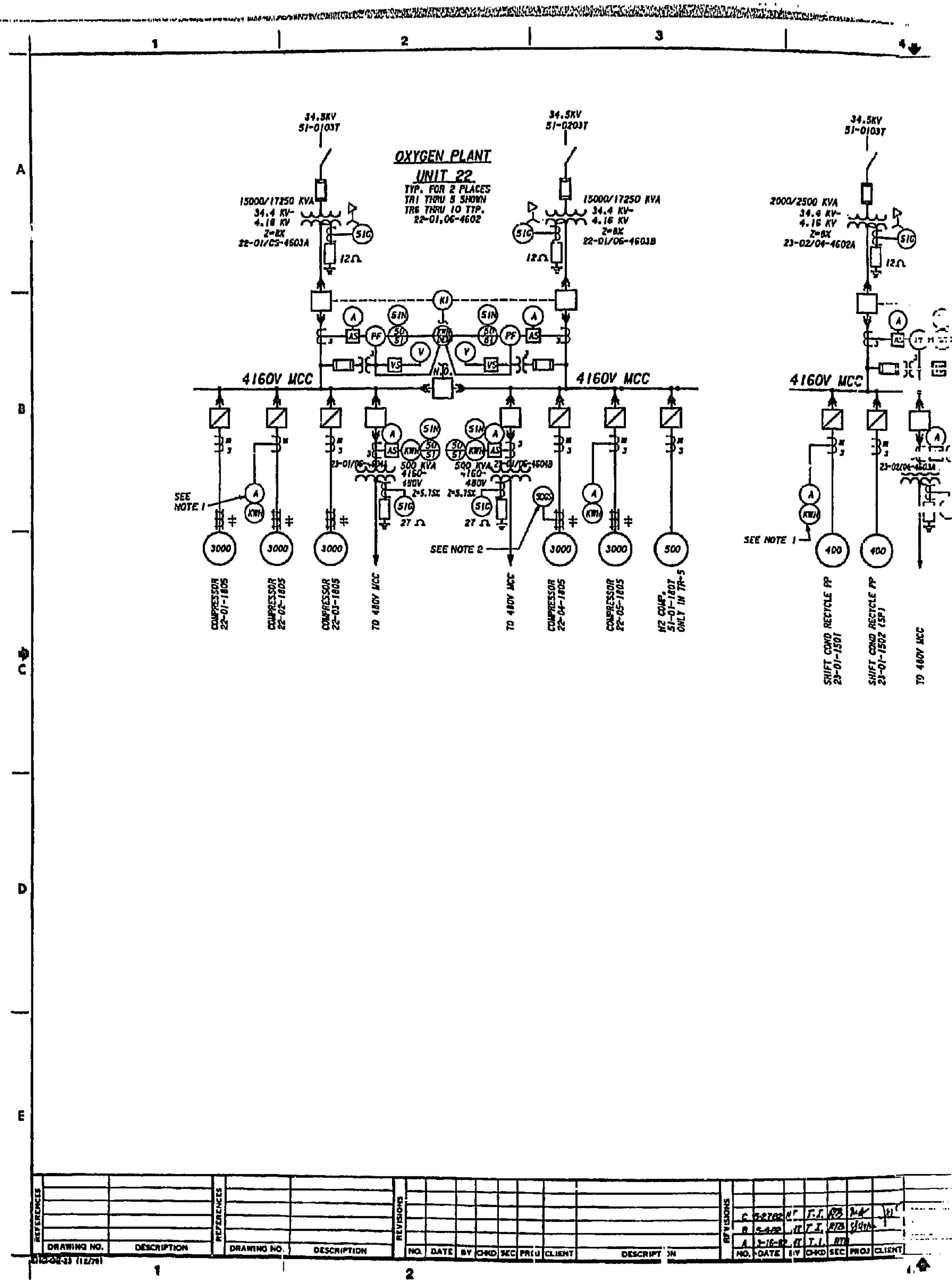
TITLE: ELEVATIONS
UNIT 22
OXYGEN PLANT

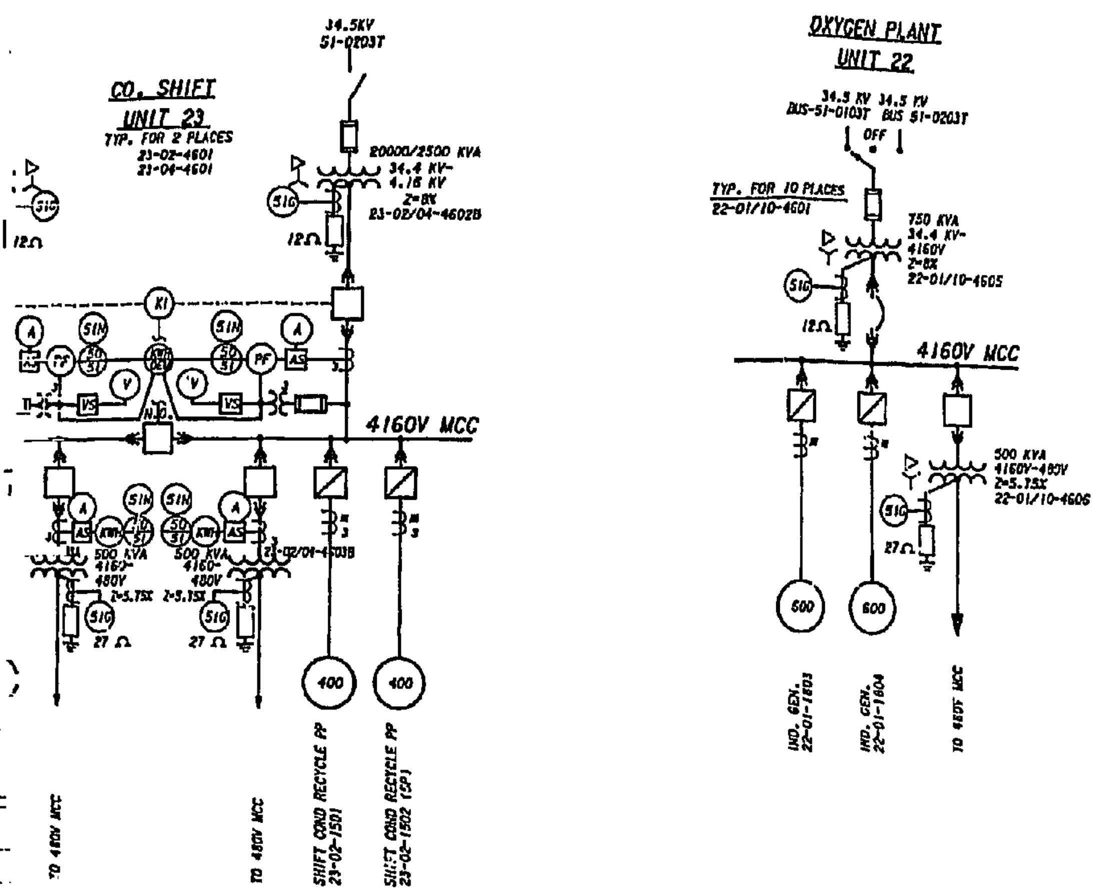
SCALE: 1" = 20'-0" | ACCOUNT NUMBER: 7245 | JOB NUMBER: 6182
DOCUMENT NUMBER: D-22-PD-4NP | REVISION: C

G. Single-Line Diagram

Single-Line Diagram for Oxygen Plant Unit 22 is as follows:

Drawing No.	Title
D-51-EE-4NP	One-Line Diagram - Units 22 and 23


OXYGEN PLANT
UNIT 22
TYP. FOR 2 PLACES
TR1 THRU 5 SHOWN
TR6 THRU 10 TYP.
22-01,06-4602
34.5KV
51-0103T
34.5KV
51-0203T
15000/17250 KVA
34.4 KV-
4.16 KV
Z=8%
22-01/05-4603A
22-01/06-4603B
2000/2500 KVA
23-02/04-4602A
12Ω
4160V MCC
N.O.
500 KVA
4160-
480V
Z=5.75%
27 Ω
23-01/06-4604A
23-01/06-4604B
SEE NOTE 1
SEE NOTE 2
3000
500
400
COMPRESSOR 22-01-1805
COMPRESSOR 22-02-1805
COMPRESSOR 22-03-1805
TO 480V MCC
COMPRESSOR 22-04-1805
COMPRESSOR 22-05-1805
H2 COMP. 51-01-1801 ONLY IN TR-5
SHIFT COND RECYCLE PP 23-01-1501
SHIFT COND RECYCLE PP 23-01-1502 (SP)
REFERENCES
DRAWING NO.
DESCRIPTION
REVISIONS
NO.
DATE
BY
CHKD
SEC
PROJ
CLIENT



NOTES:

1. PROVIDE AM, KWH METERS AT ALL LOCATIONS MARKED #
2. PROVIDE 50GS RELAY TO ALL MOTORS MARKD ‡

ISSUED FOR DESIGN REPORT	DRAWN HT
ISSUED FOR CLIENT APPROVAL	CHECKED
ISSUED FOR CLIENT 50% REVIEW	APVD SECT HD
DESCRIPTION	APVD PROJ MGR / APVD CLIENT

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PASADENA, CALIFORNIA

U.S. DEPARTMENT OF ENERGY
BASKETT — KENTUCKY
W.R. GRACE & CO.
50,000 B.P.D.
COAL - TO - METHANOL - TO - GASOLINE PLANT

TITLE: ONE LINE DIAGRAM
OXYGEN PLANT U-22
CO SHIFT UNIT U-23

SCALE	ACCOUNT NUMBER	JOB NUMBER	REVISION
NONE	4600	6182	C

DOCUMENT NUMBER: D-51-EE-4NP

1.2.7 CO SHIFT - UNIT 23

The CO Shift Unit processes about 62% of the raw synthesis gas from the coal gasification unit over a cobalt-molybdenum catalyst bed to obtain the required H_2:CO ratio for the methanol synthesis unit and recovers heat as the gas if cooled for further downstream processing. The balance of the raw gas is diverted to a separate gas cooling system, which recovers heat to produce steam.

A large amount of heat is available from cooling shift reactor effluent and unshifted gas. An integrated heat recovery scheme is designed to recover useful energy for heating shift feed gas, high-pressure boiler feedwater, process condensate, and vacuum condensate. Process condensate from cooled shift effluent and unshifted gas are reheated and returned to the gasification unit.

A. Basis of Design

The large quantity of syngas from the gasification unit requires that four parallel modules, each containing one shifted train and one unshifted train, be installed. The split of syngas into shifted and unshifted train results in lower capital and operating costs for the downstream Acid Gas Removal Unit. The Basis of Design includes Feed Streams and Product Streams (shown on the following two pages).

B. Process Selection Rationale

The raw syngas received from the gasification unit consists mainly of CO, H_2, and CO_2, with sulfur present as H_2S and COS. The water/gas shift reaction converts CO and H_2O to CO_2 and H_2 so that the desired H_2:CO ratio is obtained to feed the downstream Methanol Synthesis Unit.

Feed Streams

Component	Raw Shift Feed Gas (lb mol/hr)	Raw Shift Feed Gas (mol%)	Makeup Steam (lb mol/hr)	Unshifted Gas (lb mol/hr)	Unshifted Gas (mol%)
H_2	39,069.34	36.19	-	23,511.64	36.19
CH_4	214.41	0.20	-	129.03	0.20
CO	47,297.49	43.81	-	28,463.28	43.81
CO_2	19,221.42	17.81	-	11,567.31	17.81
N_2	513.81	0.48	-	309.21	0.48
Ar	172.46	0.16	-	103.78	0.16
H_2S	1,374.19	1.27	-	826.98	1.27
COS	84.72	0.08	-	50.99	0.08
Total Dry, lb mol/hr	107,947.84	100.00	-	64,962.21	100.00
H_2O	76,895.59		31,073.04	46,275.17	
Total Wet, lb mol/hr	184,843.43		31,073.04	111,237.38	
Total, lb/hr	3,711,910.00		559,800.00	2,233,650.00	
Pressure, psia	850		900	850	
Temperature, °F	435		640	435	

Product Streams

Component	Shifted Effluent to AGR (lb mol/hr)	Shifted Effluent to AGR (mol%)	Unshifted Gas to AGR (lb mol/hr)	Unshifted Gas to AGR (mol%)	Combined Condensate (lb mol/hr)
H_2	73,546.72	51.61	23,511.64	36.19	-
CH_4	214.41	0.15	129.03	0.20	-
CO	12,820.12	9.00	28,463.28	43.81	-
CO_2	53,771.42	37.73	11,567.31	17.81	-
N_2	513.81	0.36	309.21	0.48	-
Ar	172.46	0.12	103.78	0.16	-
H_2S	1,446.82	1.02	826.98	1.27	-
COS	12.10	0.01	50.99	0.08	-
Total Dry, lb mol/hr	142,497.86	100.00	64,962.22	100.00	-
H_2O	171.42		75.28		119,416.08
Total Wet, lb mol/hr	142,669.28		65,037.48		119,416.08
Total, lb/hr	2,951,690.00		1,401,320.00		2,151,400.00
Pressure, psia	795		820		790
Temperature, °F	100		100		223

The water/gas shift reaction has been used in many chemical process plants; however, in most applications, a nonsulfur-tolerant catalyst is used to treat a sulfur-free gas. The sulfur content of the raw syngas requires a sulfur-tolerant shift catalyst (e.g., a cobalt-molybdenum type). The catalyst manufacturer with the most experience in sour gas shift is BASF with its K8-11 catalyst. The reactor is sized according to the BASF catalyst requirement. The resulting shift section is capable of operating with catalyst from any of the other three vendors solicited for recommendations.

The system is designed for maximum useful recovery of waste heat from the shifted train and unshifted train. The use of waste heat for generating steam and heating condensate and boiler feedwater reduces the cost of providing gasoline.

The feed gas is split into shifted and unshifted streams to individual acid gas absorbers to give the most economical design. The H_2:CO ratio in the feed to the Methanol Synthesis Unit is adjusted by varying the flow of syngas to the shifted train.

Direct sour shift following gasification is selected over a scheme using sulfur removal, conventional hot shift followed by CO_2 removal. Positioning the conventional hot shift between sulfur removal and CO_2 removal involves cooling and reheating the raw gas from gasification and thus will reduce the overall thermal efficiency of the Gasoline Plant.

C. Process Description

The equipment arrangement and material balance for the CO Shift - Unit 23 is presented on Process Flow and Control Diagrams D-23-MP-1NP, -2NP, and -3NP.

The purpose of the CO Shift Unit is to shift carbon monoxide and steam to carbon dioxide and hydrogen in order to obtain the ratio required for methanol synthesis. Approximately 62% of the raw syngas from gasification passes through the shift section while the remainder of the raw syngas is routed through the gas cooling section of the CO Shift Unit.

The portion of the raw syngas going to the shift section is mixed with superheated makeup steam to obtain a steam to dry gas ratio of 1:1. The shift feed gas is heated to 600°F in Shift Effluent/ Feed Heat Exchanger 23-01-1301 and then flows to Shift Reactor 23-01-2501. Approximately 73% of the CO entering the reactor is shifted with H_2O to CO_2 and H_2. The shift reaction is exothermic and the gas temperature rises from 600°F at the reactor inlet to 879°F at the outlet.

The shift reactor effluent is cooled by exchange with reactor feed in Shift Effluent/Feed Heat Exchanger 23-01-1301. The shift effluent gas is cooled to 250°F in a series of four exchangers: Shift Effluent Boiler Feedwater Heater 23-01-1302, Shift Effluent 50-psig Steam Generator 23-01-1303, HP Boiler Feedwater Preheater 23-01-1304, and HP Turbine Condensate Exchanger 23-01-1305. The heat removed from the shift effluent is used to heat HP boiler feedwater from 250°F to 500°F and turbine condensate from 126°F to 220°F and to generate 50-psig steam. The condensate in the shift effluent is removed in Shift Effluent 1st Knockout Pot 23-01-1202.

The Shift Effluent 1st Knockout Pot overhead is finally cooled by flowing through a series of two exchangers, Shift Effluent Air Cooler 23-01-1306 and Shift Effluent Water Cooler 23-01-1307. These exchangers cool the gas to 100°F. The condensate formed in the air cooler and water cooler is separated from the gas in Shift Effluent 2nd Knockout Pot 23-01-1204. The overhead from the Shift Effluent 2nd Knockout Pot flows to the Acid Gas Removal Unit.

The raw syngas from gasification not destined for the shifted section is sent to the unshifted gas cooling section. The diverted raw gas is cooled by a series of six exchangers. Approximately 94% of the heat removed from the raw gas in the unshifted section is recovered by generating steam and heating condensate, while the remaining 6% of the waste heat is lost to air and water cooling.

The raw diverted gas from the gasification section is cooled in Shift Bypass 150-psig Steam Generator 23-01-1308 and then flows to Shift Bypass 50-psig Steam Generator 23-01-1309. The partially condensed bypass stream from the 50-psig Steam Generator flows to Shift Condensate Heater 23-01-1311, where heat is recovered by heating condensate from 223°F to 300°F. The bypass stream is cooled further in HP Turbine Condensate Heater 23-01-1312, where heat removed from the bypass stream is used to heat turbine condensate from 126°F to 220°F. The bypass stream flows from HP Turbine Condensate Heater 23-01-1311 to Shift Bypass 1st Knockout Pot 23-01-1203, where the condensate is separated from the gas.

The overhead from Shift Bypass 1st Knockout Pot 23-01-1203 is cooled to 100°F by two exchangers in series: Shift Bypass Air Cooler 23-01-1312 and Shift Bypass Water Cooler 23-01-1313. The condensate formed in the two coolers is separated from the gas in Shift Bypass 2nd Knockout Pot 23-01-1207. The unshifted gas leaving Shift Bypass 2nd Knockout Pot 23-01-1207 is sent to the Acid Gas Removal Unit.

The condensate from each knockout pot in the shifted section and unshifted section is sent to Knockout Pots Bottoms Collecting Drum 23-01-1205. Part of the condensate from the collecting drum is reheated to 300°F in Shift Condensate Heater 23-01-1310, then returned to the gasification unit. The remainder of the condensate is sent to the gasification unit as makeup water.

D. Risk Assessment

The CO Shift Unit uses conventional cobalt-molybdenum (CoMo) sour-shift catalysts backed by several years of commercial experience. The catalyst is available from several reputable suppliers such as BASF and United Catalyst Inc. However, the shift unit designed for this project is capable of using catalysts from other suppliers as well. The process configuration of the CO Shift system is simple and process conditions do not pose any fabrication problems.

The BASF sulfur-tolerant shift conversion catalyst, with more than 10 years of successful operation, was selected for this project. Presently this catalyst is in operation in several plants. BASF shift catalysts meet the following requirements:

(1) High activity in the presence of sulfur compounds in the synthesis gas.

(2) High mechanical strength.

(3) Resistance to high stream partial pressure.

BASF catalyst K8-11 is used in a temperature range of approximately 450°F to 950°F. It is resistant to temperatures of up to 1,000°F. Successful pilot tests have been made at pressures of up to 1,500 psia, and there is a plant in operation at 1,100 psia.

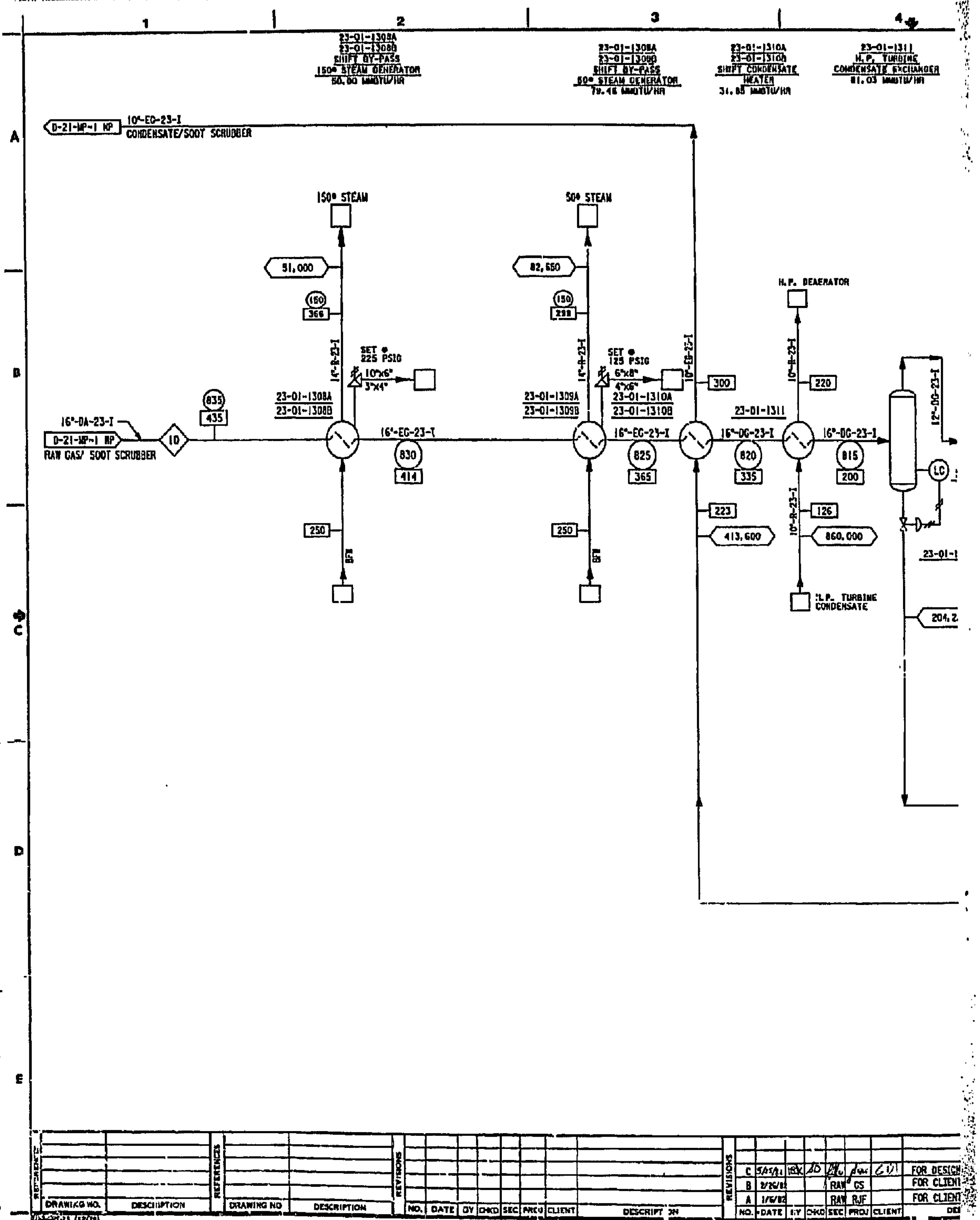
Shift catalyst has a lifetime of about 2 years or more when it is directly exposed to raw gas from the gasifiers, such as in this case where there is only one shift reactor per train.

Technical risk in this section is minimal.

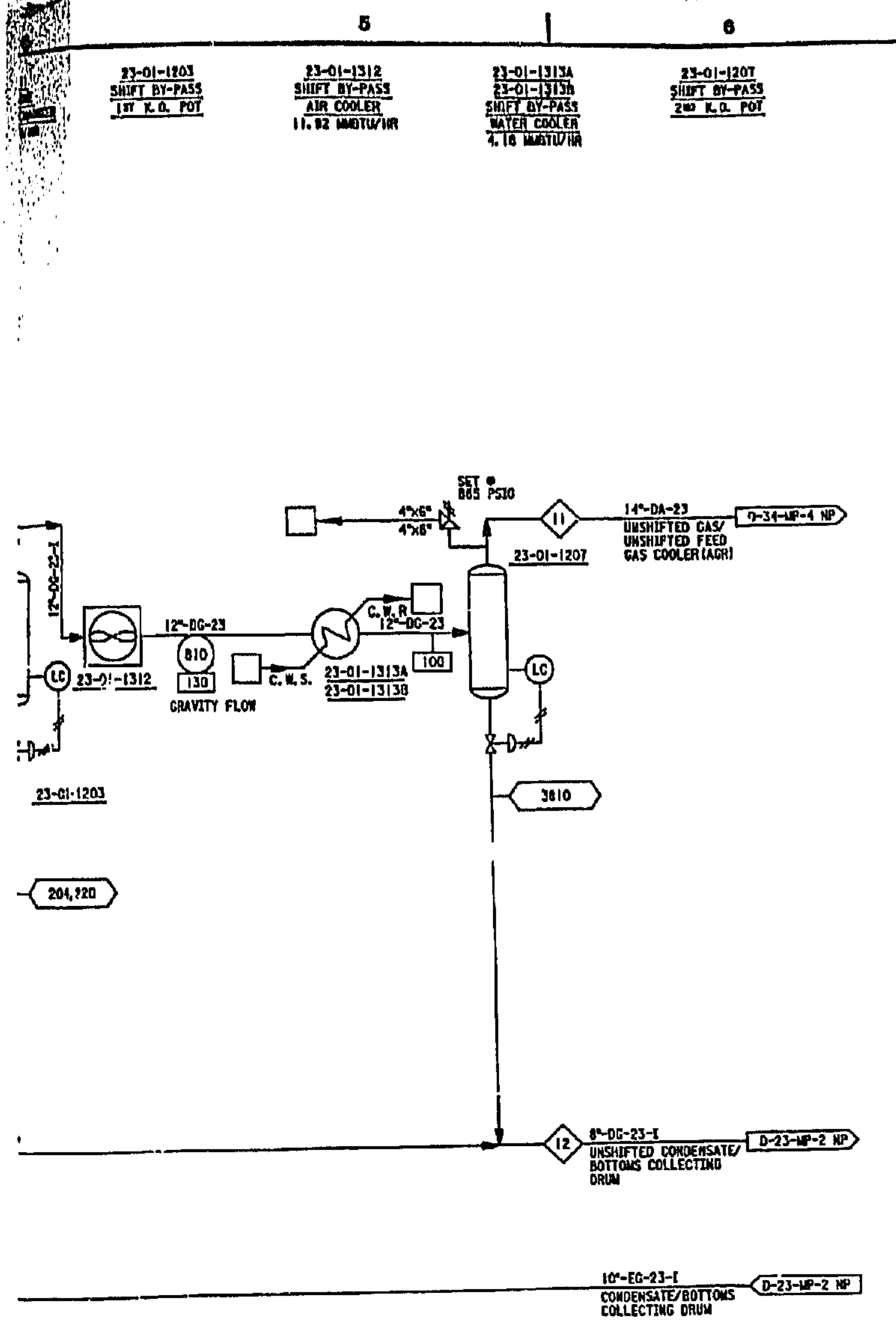
E. Process Flow and Control Diagrams (Including Material Balance)

Process Flow and Control Diagrams for CO Shift Unit 23 are as follows:

Drawing No.	Title
D-23-MP-1NP	PFCD CO Shift - Unit 23 Gas Cooling
D-23-MP-2NP	PFCD CO Shift - Unit 23 Shift Section
D-23-MP-3NP	Material Balance CO Shift - Unit 23



23-01-1308A
23-01-1308B
SHIFT BY-PASS
150# STEAM GENERATOR
50.00 MMBTU/HR
23-01-1309A
23-01-1309B
SHIFT BY-PASS
50# STEAM GENERATOR
79.46 MMBTU/HR
23-01-1310A
23-01-1310B
SHIFT CONDENSATE HEATER
31.85 MMBTU/HR
23-01-1311
H.P. TURBINE
CONDENSATE EXCHANGER
81.03 MMBTU/HR
D-21-MP-1 MP
10"-EG-23-I
CONDENSATE/SOOT SCRUBBER
150# STEAM
50# STEAM
51,000
82,650
H.P. DEAERATOR
SET @ 225 PSIG
10"x6"
3"x4"
SET @ 125 PSIG
6"x8"
4"x6"
16"-DA-23-I
D-21-MP-1 MP
RAW GAS/ SOOT SCRUBBER
16"-EG-23-I
16"-DG-23-I
12"-DG-23-I
413,600
860,000
H.P. TURBINE CONDENSATE
LC
DRAWING NO.
DESCRIPTION
REFERENCES
REVISIONS
NO. DATE BY CHKD SEC PROJ CLIENT
FOR DESIGN
FOR CLIENT



NOTES:

1. THERE ARE A TOTAL OF FOUR MODULES IDENTICAL TO THIS MODULE.
2. HEAT AND MATERIAL BALANCES SHOWN ARE FOR ONE MODULE AT THE NORMAL OPERATING CONDITIONS.
3. LINE SIZING IS BASED ON THE DATA OF DESIGN OPERATING CONDITIONS.

EQUIPMENT SHOWN ON THIS DRAWING:

23-01-1203	23-01-1310B
23-01-1207	23-01-1311
23-01-1308A	23-01-1312
23-01-1308B	23-01-1313A
23-01-1309A	23-01-1313B
23-01-1310A	

D23MP1NP.DGA

U.S. DEPARTMENT OF ENERGY

BASKETT — KENTUCKY

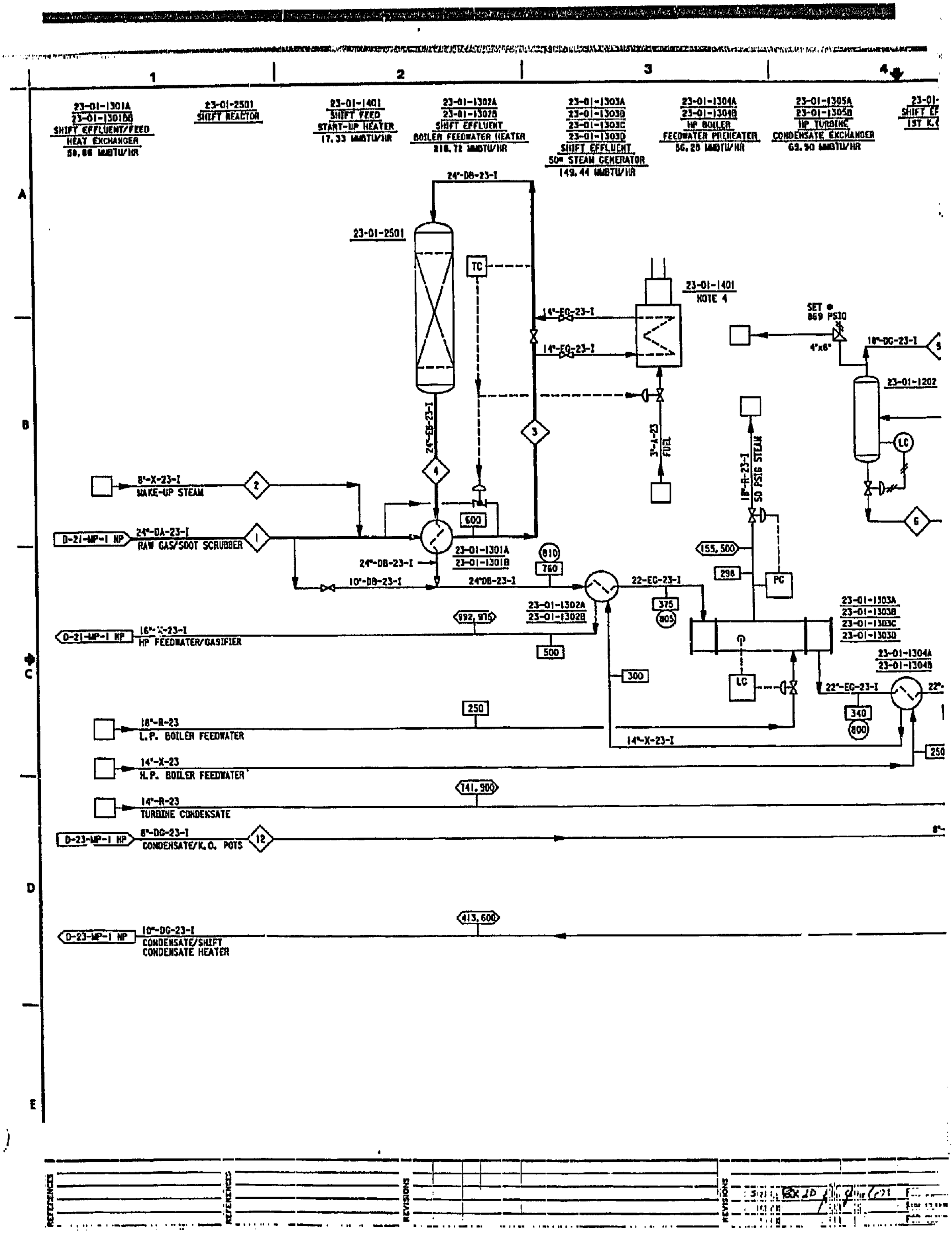
W.R. GRACE & CO.
50,000 B.P.D.
COAL - TO - METHANOL - TO - GASOLINE PLANT

TITLE: PROCESS FLOW AND CONTROL DIAGRAM
CO SHIFT - UNIT 23
GAS COOLING

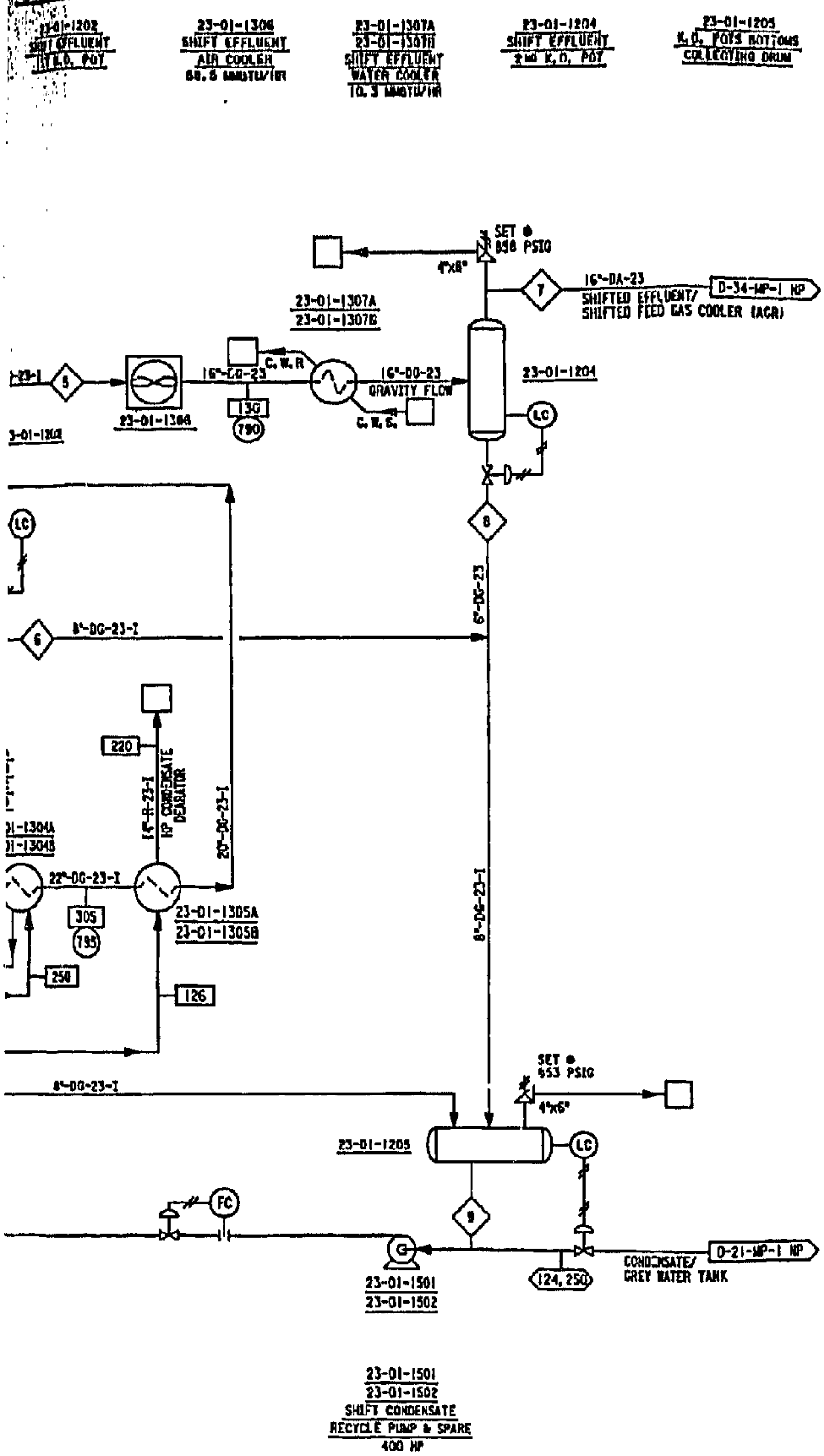
SCALE: NONE | ACCOUNT NUMBER: 2800 | JOB NUMBER: 6182 | REVISION: C
DOCUMENT NUMBER: D-23-MP-1 NP

DESCRIPTION			
FOR DESIGN REPORT	APVD SECT MGR	JCL	1/5/82
FOR CLIENT APPROVAL	APVD PROJ MGR	RF	1/5/82
FOR CLIENT 50% REVIEW	CLIENT		

RMP
THE RALPH M. PARSONS COMPANY
PASADENA, CALIFORNIA



1
2
3
4
23-01-1301A
23-01-1301B
SHIFT EFFLUENT/FEED
HEAT EXCHANGER
58.86 MMBTU/HR
23-01-2501
SHIFT REACTOR
23-01-1401
SHIFT FEED
START-UP HEATER
17.33 MMBTU/HR
23-01-1302A
23-01-1302B
SHIFT EFFLUENT
BOILER FEEDWATER HEATER
218.72 MMBTU/HR
23-01-1303A
23-01-1303B
23-01-1303C
23-01-1303D
SHIFT EFFLUENT
50# STEAM GENERATOR
149.44 MMBTU/HR
23-01-1304A
23-01-1304B
HP BOILER
FEEDWATER PREHEATER
56.28 MMBTU/HR
23-01-1305A
23-01-1305B
HP TURBINE
CONDENSATE EXCHANGER
69.90 MMBTU/HR
A
24"-DB-23-I
23-01-2501
TC
23-01-1401
NOTE 4
14"-EG-23-I
14"-EG-23-I
SET @
869 PSIG
4"x6"
18"-DG-23-I
23-01-1202
B
24"-EB-23-I
3"-A-23
FUEL
18"-R-23-I
50 PSIG STEAM
LC
8"-X-23-I
MAKE-UP STEAM
600
D-21-MP-1 HP
24"-DA-23-I
RAW GAS/SOOT SCRUBBER
23-01-1301A
23-01-1301B
810
760
24"-DB-23-I
10"-DB-23-I
24"DB-23-I
22-EG-23-I
155,500
298
PC
375
805
23-01-1302A
23-01-1302B
892,975
D-21-MP-1 HP
16"-X-23-I
HP FEEDWATER/GASIFIER
500
23-01-1303A
23-01-1303B
23-01-1303C
23-01-1303D
23-01-1304A
23-01-1304B
C
300
LC
22"-EG-23-I
340
800
250
18"-R-23
L.P. BOILER FEEDWATER
14"-X-23-I
14"-X-23
H.P. BOILER FEEDWATER
250
741,900
14"-R-23
TURBINE CONDENSATE
D-23-MP-1 HP
8"-DG-23-I
CONDENSATE/K.O. POTS
D
413,600
D-23-MP-1 HP
10"-DG-23-I
CONDENSATE/SHIFT
CONDENSATE HEATER
E
REFERENCES
REFERENCES
REVISIONS
REVISIONS



NOTES:

1. THERE ARE A TOTAL OF FOUR MODULES IDENTICAL TO THIS MODULE.
2. HEAT AND MATERIAL BALANCES SHOWN ARE FOR ONE MODULE AT THE NORMAL OPERATING CONDITIONS.
3. LINE SIZING IS BASED ON THE DATA OF DESIGN OPERATING CONDITIONS.
4. START-UP HEATER 23-01-1401 IS IN MODULE ONE BUT SERVES MODULES ONE AND TWO. ALSO START-UP HEATER 23-03-1401 IS IN MODULE THREE BUT SERVES MODULES THREE AND FOUR.

EQUIPMENT SHOWN ON THIS DRAWING:

23-01-1202	23-01-1304A
23-01-1204	23-01-1304B
23-01-1205	23-01-1305A
23-01-1301A	23-01-1305B
23-01-1301B	23-01-1306
23-01-1302A	23-01-1307A
23-01-1302B	23-01-1307B
23-01-1303A	23-01-1401
23-01-1303B	23-01-1501
23-01-1303C	23-01-1502
23-01-1303D	23-01-2501

D23MP2NP.DGA

U.S. DEPARTMENT OF ENERGY

BASKETT — W.R. GRACE & CO. — KENTUCKY

50,000 B.P.D.

COAL - TO - METHANOL - TO - GASOLINE PLANT

PROCESS FLOW CONTROL DIAGRAM
CO SHIFT - UNIT 23
SHIFT SECTION

SCALE		
NONE	2800	6182

D-23-MP-2 NP — Revision C

DESCRIPTION			
FOR DESIGN REPORT	CHECKED		
FOR CLIENT APPROVAL	APVD SECT HD	JCL	1/5/82
FOR CLIENT 50% REVIEW	APVD PROJ MGR	RF	1/5/82

RMP — THE RALPH M. PARSONS COMPANY, PASADENA, CALIFORNIA

COMPONENT	MOL. WT.	1 RAW GAS TO SHIFT TRAIN	2 MAKE-UP STEAM	3 SHIFT FEED GAS	4 SHIFT REACTOR EFFLUENT	5 1ST K.O. POT OVERHEAD	6 1ST K.O. POT CONDENSATE	7 SHIFTED EFFLUENT TO ACR	8 2ND K.O. POT CONDENSATE
		MOLES/HR	MOLES/HR	MOLES/HR	MOLES/HR	MOLES/HR	MOLES/HR	MOLES/HR	MOLES/HR
H_2	2.02	9,767.34		9,767.34	18,386.68	18,386.66		18,386.66	
CH_4	16.04	53.60		53.60	53.60	53.60		53.60	
CO	28.01	11,824.37		11,824.37	3,205.03	3,205.03		3,205.03	
CO_2	44.01	4,805.36		4,805.36	13,442.86	13,442.86		13,442.86	
N_2	28.02	128.45		128.45	128.45	128.45		128.45	
Ar	39.94	43.12		43.12	43.12	43.12		43.12	
H_2S	34.08	343.59		343.59	361.71	361.71		361.71	
COS	60.07	21.18		21.18	3.03	3.03		3.03	
TOTAL DRY		26,986.95		26,986.95	35,624.46	35,624.46		35,624.48	
H_2O		19,218.69	7,768.26	26,986.95	18,349.46	1,370.66	16,978.80	42.59	1,328.07
TOTAL WET		46,205.64	7,768.26	53,973.92	53,973.92	36,995.12	16,978.80	35,667.09	1,328.07
POUNDS/HR		927,780	139,950	1,067,730	1,067,730	761,840	305,890	737,910	23,930
MOLECULAR WT.		20.08	18.02	19.78	19.78	20.59	18.02	20.69	18.02
MMSCFD		420.84	70.75	491.59	491.59	336.95		324.85	
PRESS, PSIA		850	900	840	830	805	805	795	795
TEMP °F		435	640	600	879	250	250	100	100

REFERENCES

DRAWING NO. | DESCRIPTION

REFERENCES

DRAWING NO. | DESCRIPTION

REVISIONS

REVISIONS

FOR DES

FOR CL

FOR CL

NOTES:
1. HEAT AND MATERIAL BALANCES ARE GIVEN AT NORMAL OPERATING CONDITIONS FOR ONE MODULE OF A TOTAL FOUR MODULE PLANT.

8 ...O. POT ...NSATE	9 COMBINED CONDENSATE	10 RAW GAS TO UNSHIFTED TRAIN	11 UNSHIFTED GAS TO AGR	12 UNSHIFTED CONDENSATE
...S/HR	MOLES/HR	MOLES/HR	MOLES/HR	MOLES/HR
		5,877.91	5,877.91	
		32.26	32.26	
		7,115.82	7,115.82	
		2,891.83	2,891.83	
		77.30	77.30	
		25.95	25.95	
		206.74	206.74	
		12.75	12.75	
		16,240.56	16,240.56	
328.07	29,853.90	11,565.85	18.82	11,547.03
328.07	29,853.90	27,806.41	16,259.38	11,547.03
23,930	537,850	558,360	350,330	208,030
18.02	18.02	20.08	21.55	18.02
		253.26	148.09	
795	790	850	820	820
100	233	435	100	199

D23MP3NP.DGA

U.S. DEPARTMENT OF ENERGY

BASKETT — W.R. GRACE & CO. — KENTUCKY

50,000 B.P.D.

COAL - TO - METHANOL - TO - GASOLINE PLANT

TITLE: MATERIAL BALANCE CO SHIFT - UNIT 23

SCALE: NONE | 2800 | 6182

D-23-MP-3 NP

REVISION: C

DESCRIPTION			
FOR DESIGN REPORT	CHECKED		
FOR CLIENT APPROVAL	APVD DEPT HD	JCL	1/5/82
FOR CLIENT 50% REVIEW	APVD PROJ MGR	RF	1/5/82

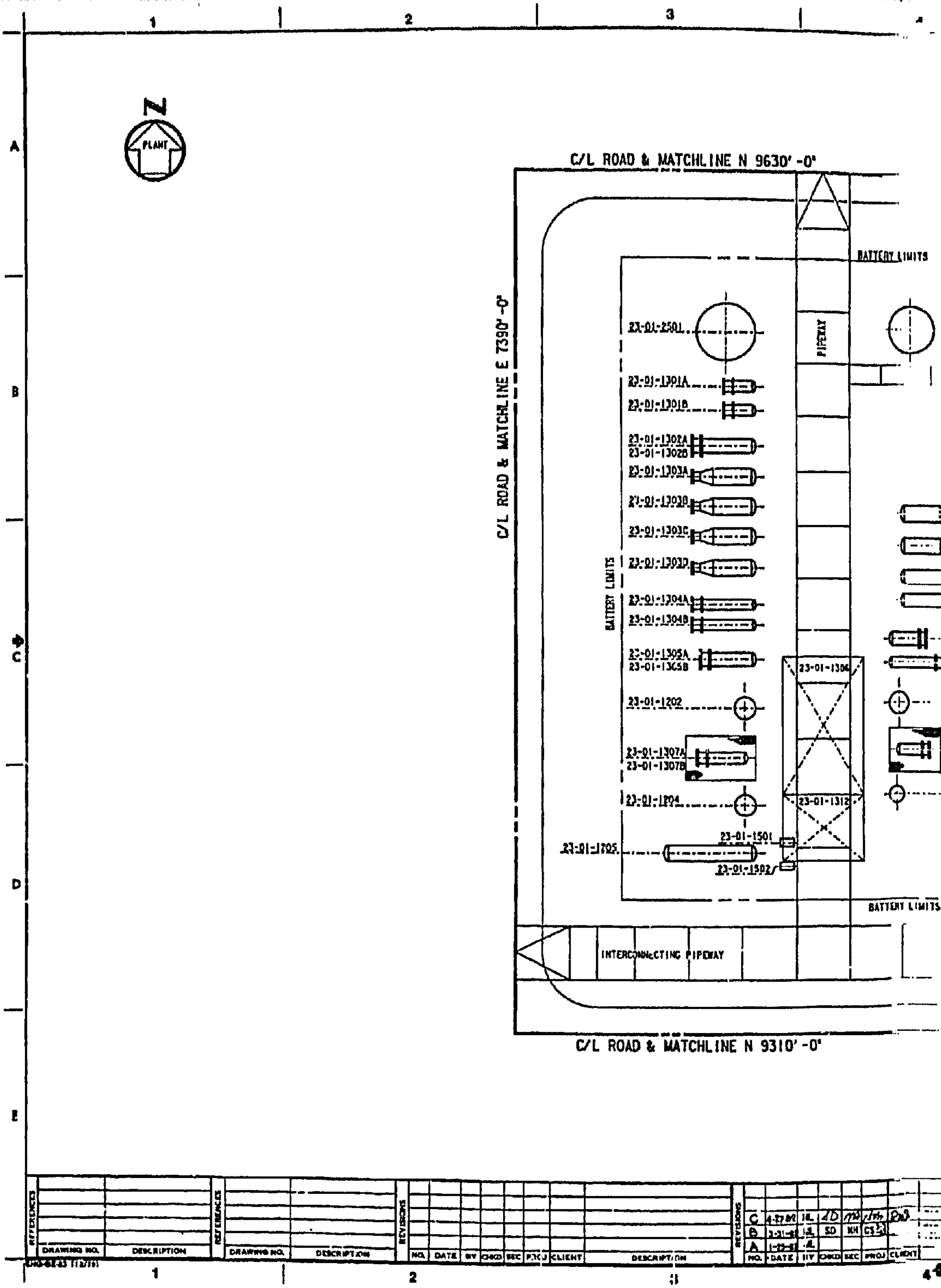
RMP

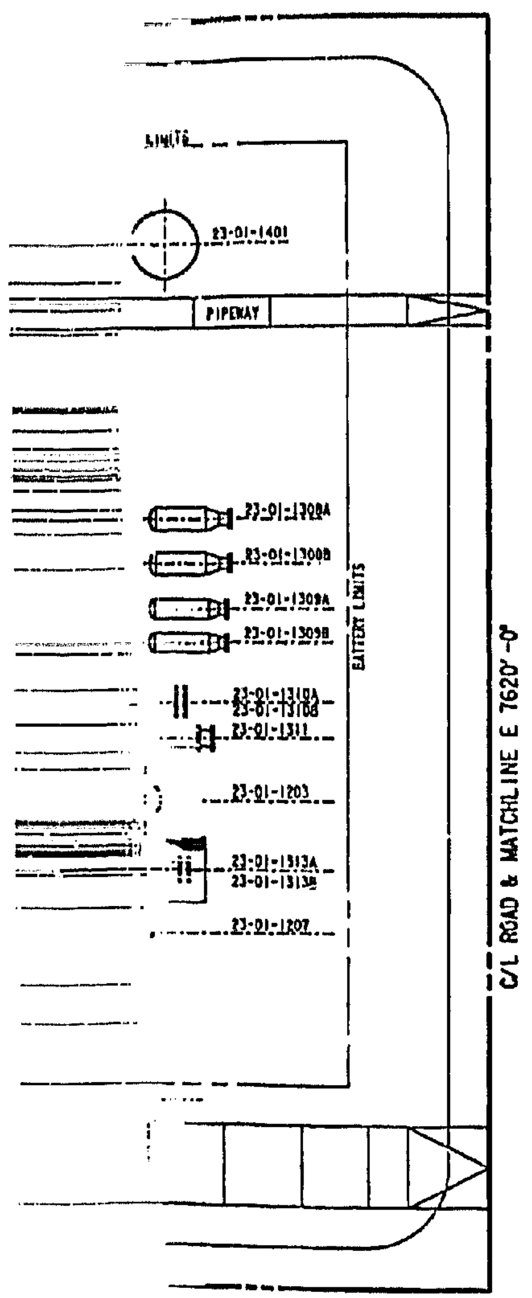
THE RALPH M. PARSONS COMPANY
PASADENA, CALIFORNIA

F. Plot Plan/General Arrangement Drawings

Plot Plan/General Arrangement Drawings for CO Shift Unit 23 are as follows:

Drawing No.	Title
D-23-PD-1NP	Plot Plan - Unit 23 CO Shift
D-23-PD-2NP	Plot Plan - Unit 23 CO Shift
D-23-PD-3NP	Plot Plan - Unit 23 CO Shift
D-23-PD-4NP	Plot Plan - Unit 23 CO Shift
D-23-PD-5NP	Elevation - Unit 23 CO Shift


N
PLANT
C/L ROAD & MATCHLINE N 9630'-0"
C/L ROAD & MATCHLINE E 7390'-0"
C/L ROAD & MATCHLINE N 9310'-0"
BATTERY LIMITS
PIPEWAY
INTERCONNECTING PIPEWAY
23-01-2501
23-01-1301A
23-01-1301B
23-01-1302A
23-01-1302B
23-01-1303A
23-01-1303B
23-01-1303C
23-01-1303D
23-01-1304A
23-01-1304B
23-01-1305A
23-01-1305B
23-01-1202
23-01-1307A
23-01-1307B
23-01-1204
23-01-1205
23-01-1501
23-01-1502
23-01-1306
23-01-1312
REFERENCES
DRAWING NO.
DESCRIPTION
REVISIONS
NO.
DATE
BY
CHKD
SEC
PROJ
CLIENT
C
B
A



EQUIPMENT LIST

23-01-1202	SHIFT EFFLUENT 1ST K.O. POT
23-01-1203	SHIFT BY-PASS 1ST K.O. POT
23-01-1204	SHIFT EFFLUENT 2ND K.O. POT
23-01-1205	K.O. POTS BOTTOMS COLLECTING DRUM
23-01-1207	SHIFT BY-PASS 2ND K.O. POT
23-01-1301A&B	SHIFT EFFLUENT/FEED HEAT EXCHANGER
23-01-1302A&B	SHIFT EFFLUENT BOILER FEEDWATER HEATER
23-01-1303A, B, C&D	SHIFT EFFLUENT/50# STEAM GENERATOR
23-01-1304A&B	HP BOILER FEEDWATER PREHEATER
23-01-1305A&B	HP TURBINE CONDENSATE EXCHANGER
23-01-1306	SHIFT EFFLUENT AIR COOLER
23-01-1307A&B	SHIFT EFFLUENT WATER COOLER
23-01-1308A&B	SHIFT BY-PASS 150# STEAM GENERATOR
23-01-1309A&B	SHIFT BY-PASS 50# STEAM GENERATOR
23-01-1310A&B	SHIFT CONDENSATE HEATER
23-01-1311	MP TURBINE CONDENSATE EXCHANGER
23-01-1312	SHIFT BY-PASS AIR COOLER
23-01-1313A&B	SHIFT BY-PASS WATER COOLER
23-01-1401	SHIFT FEED START-UP HEATER
23-01-1501	SHIFT CONDENSATE RECYCLE PUMP
23-01-1502	SHIFT CONDENSATE RECYCLE PUMP (SPARE)
23-01-2501	SHIFT REACTOR

NOTE:
1. THIS PLOT PLAN IS MODULE #1 OF 4 MODULES

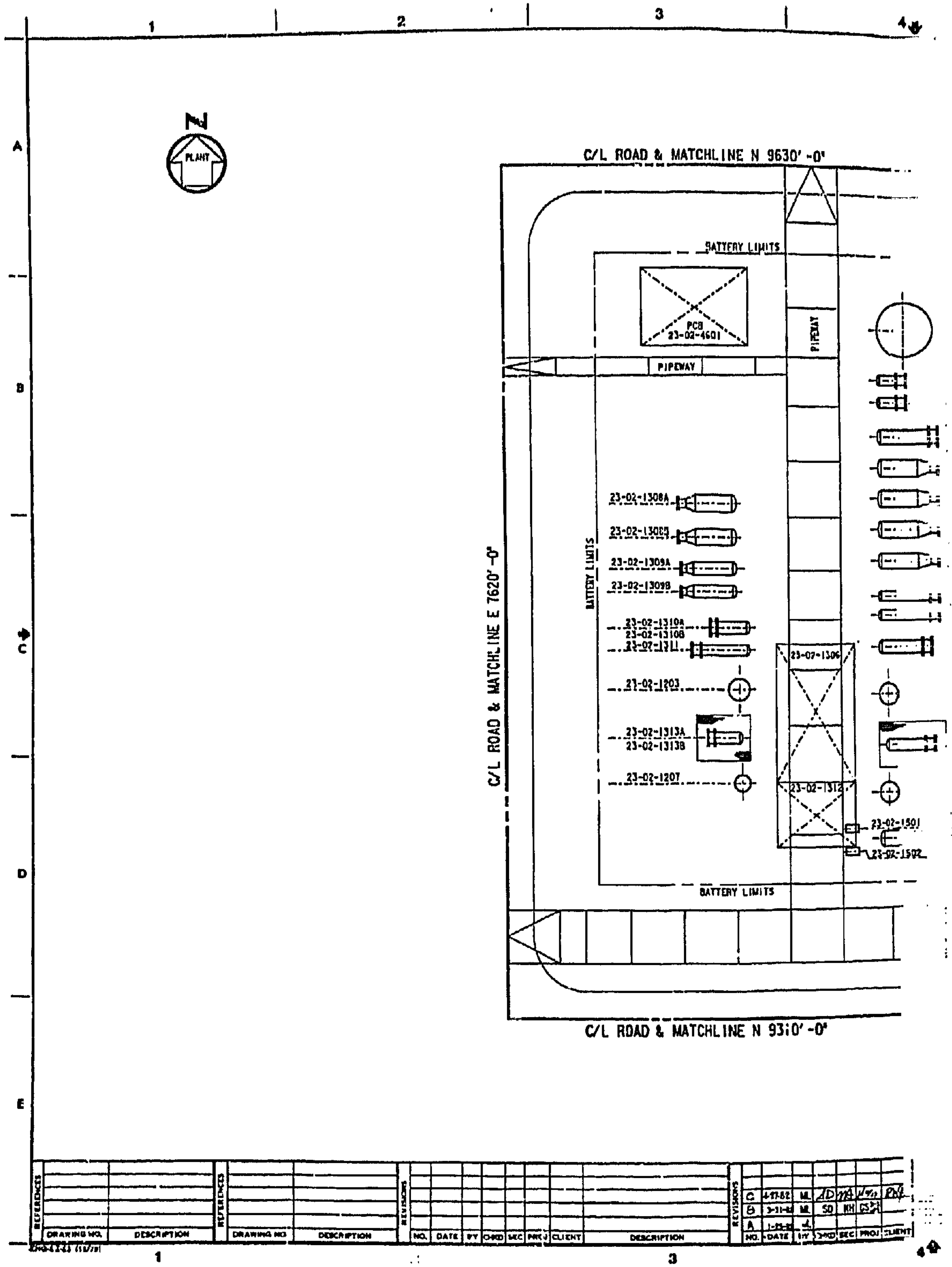
SCALE: 1" = 20'-0"

FOR DESIGN REPORT	FOR CLIENT REVIEW
FOR CLIENT APPROVAL	DRAWN MY/CAD
ISSUE CLIENT REVIEW 50% COMP.	CHECKED
DESCRIPTION	APVD SECT HD
	APVD PROJ MGR RF 1-23-1
	APVD CLIENT

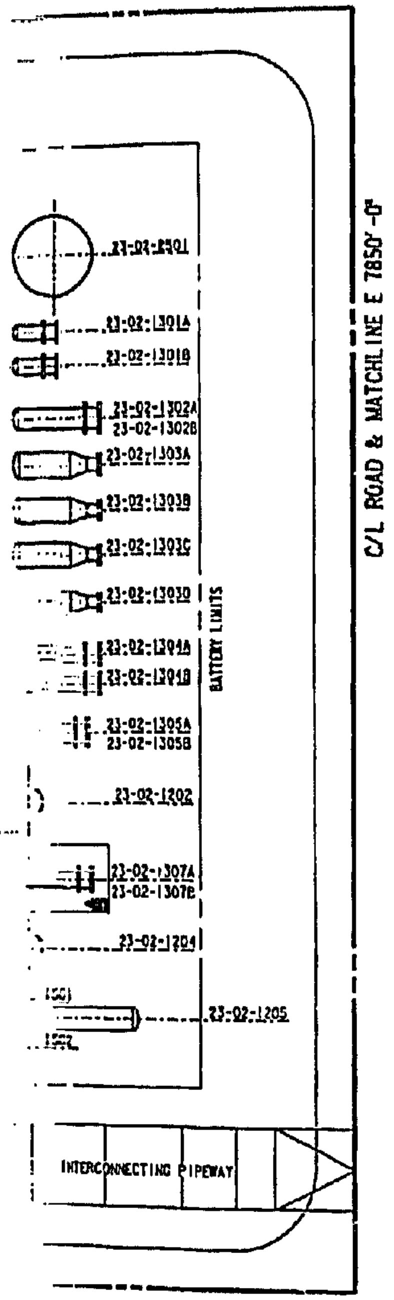
RMP
THE RALPH M. PARSONS COMPANY
PASADENA, CALIFORNIA

U.S. DEPARTMENT OF ENERGY
BASKETT — W.R. GRACE & CO. — KENTUCKY
50,000 B.P.D.
COAL - TO - METHANOL - TO - GASOLINE PLANT

TITLE	SCALE	CONTRACT NUMBER	JOB NUMBER	REVISION
PLOT PLAN UNIT 23 CO SHIFT	1"=20'-0"	7243	6182	C
	DOCUMENT NUMBER D-23-PD-1NP			



1
2
3
4
A
B
C
D
E
N
PLANT
C/L ROAD & MATCHLINE N 9630'-0"
BATTERY LIMITS
PCB
23-02-4601
PIPEWAY
PIPEWAY
C/L ROAD & MATCHLINE E 7620'-0"
BATTERY LIMITS
23-02-1308A
23-02-1308B
23-02-1309A
23-02-1309B
23-02-1310A
23-02-1310B
23-02-1311
23-02-1203
23-02-1313A
23-02-1313B
23-02-1207
23-02-1306
23-02-1312
23-02-1501
23-02-1502
BATTERY LIMITS
C/L ROAD & MATCHLINE N 9310'-0"
REFERENCES
DRAWING NO.
DESCRIPTION
REFERENCES
DRAWING NO.
DESCRIPTION
REVISIONS
NO.
DATE
BY
CHKD
SEC
PROJ
CLIENT
DESCRIPTION
REVISIONS
NO.
DATE
BY
CHKD
SEC
PROJ
CLIENT
1
3



EQUIPMENT LIST

23-02-1202	SHIFT EFFLUENT 1ST K.O. POT
23-02-1203	SHIFT BY-PASS 1ST K.O. POT
23-02-1204	SHIFT EFFLUENT 2ND K.O. POT
23-02-1205	K.O. POTS BOTTOMS COLLECTING DRUM
23-02-1207	SHIFT BY-PASS 2ND K.O. POT
23-02-1301A&B	SHIFT EFFLUENT/FEED HEAT EXCHANGER
23-02-1302A&B	SHIFT EFFLUENT BOILER FEEDWATER HEATER
23-02-1303A, B, C&D	SHIFT EFFLUENT/50# STEAM GENERATOR
23-02-1304A&B	HP BOILER FEEDWATER PREHEATER
23-02-1305A&B	HP TURBINE CONDENSATE EXCHANGER
23-02-1306	SHIFT EFFLUENT AIR COOLER
23-02-1307A&B	SHIFT EFFLUENT WATER COOLER
23-02-1308A&B	SHIFT BY-PASS 150# STEAM GENERATOR
23-02-1309A&B	SHIFT BY-PASS 50# STEAM GENERATOR
23-02-1310A&B	SHIFT CONDENSATE HEATER
23-02-1311	MP TURBINE CONDENSATE EXCHANGER
23-02-1312	SHIFT BY-PASS AIR COOLER
23-02-1313A&B	SHIFT BY-PASS WATER COOLER
23-02-1501	SHIFT CONDENSATE RECYCLE PUMP
23-02-1502	SHIFT CONDENSATE RECYCLE PUMP (SPARE)
23-02-2501	SHIFT REACTOR

NOTE:
1. THIS PLOT PLAN IS MODULE #2 OF 4 MODULES.

SCALE: 1" = 20'-0"

FOR DESIGN REPORT	
FOR CLIENT APPROVAL	
ISSUE CLIENT REVIEW 50% COMP.	
DESCRIPTION	

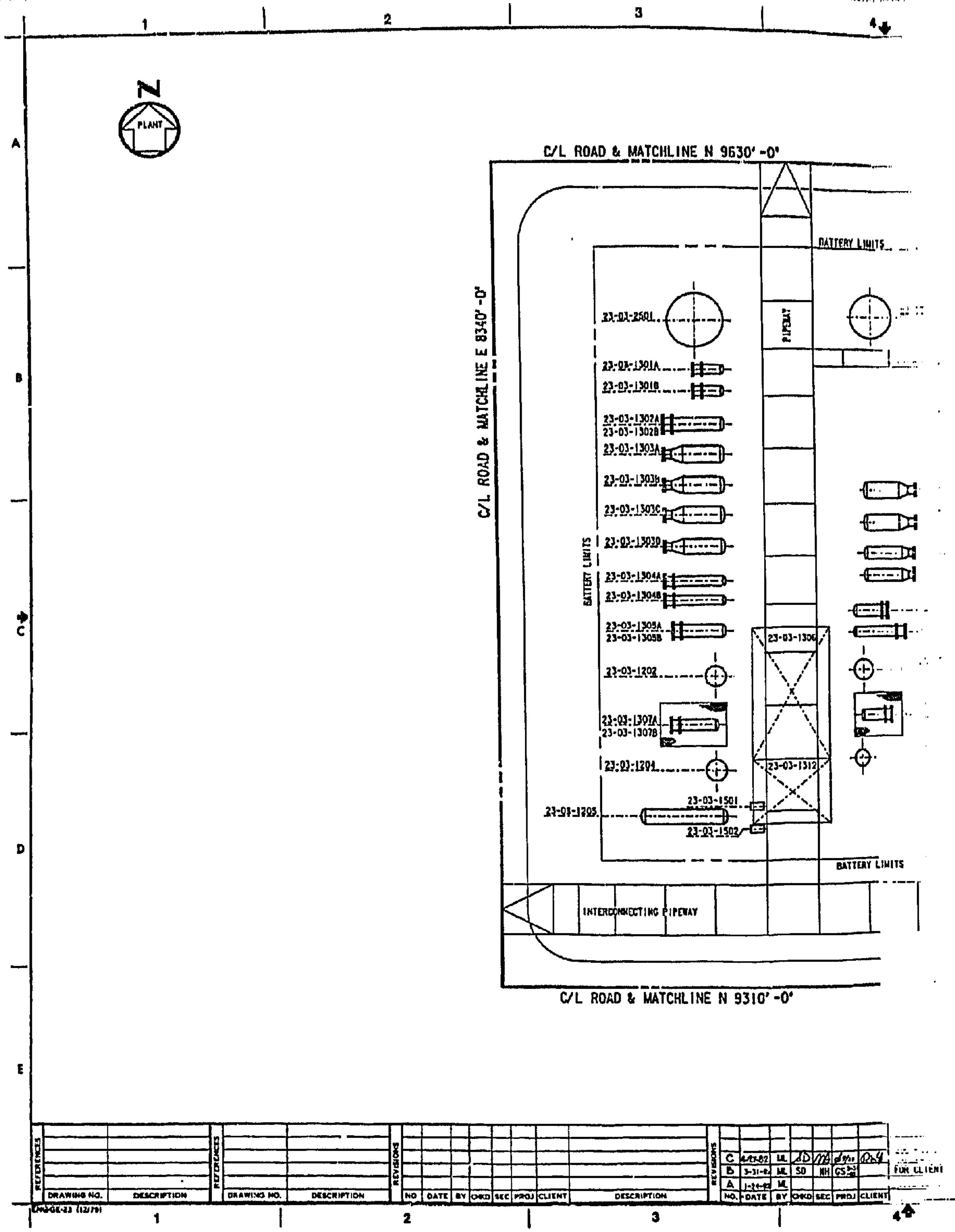
FOR CLIENT REVIEW		
DRAWN MY/CAD		
CHECKED		
APVD SECT HD		
APVD PROJECT	RF	1-25-81
APVD CLIENT	[illegible]	[illegible]

RMP
THE RR[illegible] P[illegible] COMPANY

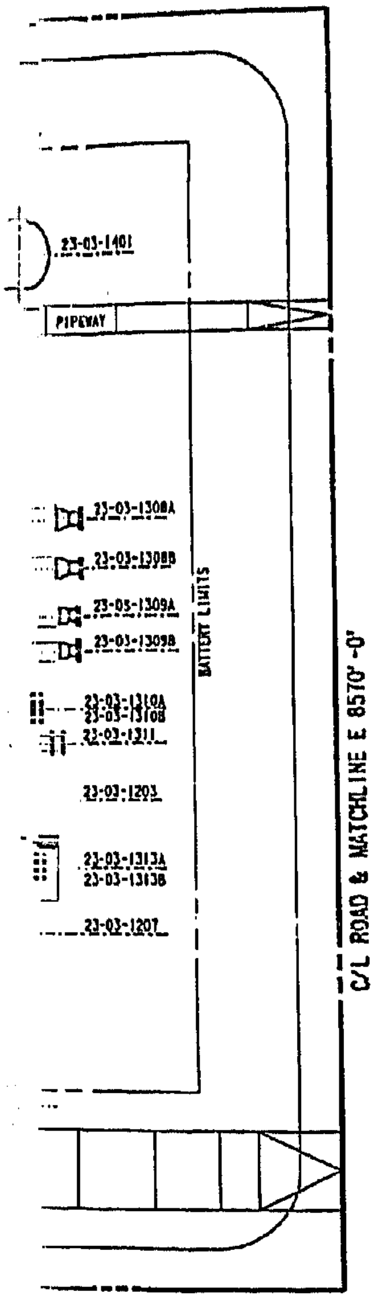
U.S. DEPARTMENT OF ENERGY
BASKETT — W.R. GRACE & CO. — KENTUCKY
50,000 B.P.D.
COAL - TO - METHANOL - TO - GASOLINE PLANT

TITLE	SCALE	ACCOUNT NUMBER	JOB NUMBER	REVISION
PLOT PLAN UNIT 23	1"=20'-0"	7243	6182	C

DOCUMENT NUMBER [illegible]



PLANT
C/L ROAD & MATCHLINE N 9630'-0'
C/L ROAD & MATCHLINE E 8340'-0'
C/L ROAD & MATCHLINE N 9310'-0'
BATTERY LIMITS
PIPEWAY
INTERCONNECTING PIPEWAY
23-03-2501
23-03-1301A
23-03-1301B
23-03-1302A
23-03-1302B
23-03-1303A
23-03-1303B
23-03-1303C
23-03-1303D
23-03-1304A
23-03-1304B
23-03-1305A
23-03-1305B
23-03-1202
23-03-1307A
23-03-1307B
23-03-1204
23-03-1205
23-03-1501
23-03-1502
23-03-1306
23-03-1312
REFERENCES
DRAWING NO.
DESCRIPTION
REVISIONS
NO
DATE
BY
CHKD
SEC
PROJ
CLIENT
FOR CLIENT



EQUIPMENT LIST

23-03-1202	SHIFT EFFLUENT 1ST K.O.POT
23-03-1203	SHIFT BY-PASS 1ST K.O.POT
23-03-1204	SHIFT EFFLUENT 2ND K.O.POT
23-03-1205	K.O.POTS BOTTOMS COLLECTING DRUM
23-03-1207	SHIFT BY-PASS 2ND K.O.POT
23-03-1301A&B	SHIFT EFFLUENT/FEED HEAT EXCHANGER
23-03-1302A&B	SHIFT EFFLUENT BOILER FEEDWATER HEATER
23-03-1303A,B,C&D	SHIFT EFFLUENT/50# STEAM GENERATOR
23-03-1304A&B	HP BOILER FEEDWATER PREHEATER
23-03-1305A&B	HP TURBINE CONDENSATE EXCHANGER
23-03-1306	SHIFT EFFLUENT AIR COOLER
23-03-1307A&B	SHIFT EFFLUENT WATER COOLER
23-03-1308A&B	SHIFT BY-PASS 150# STEAM GENERATOR
23-03-1309A&B	SHIFT BY-PASS 50# STEAM GENERATOR
23-03-1310A&B	SHIFT CONDENSATE HEATER
23-03-1311	MP TURBINE CONDENSATE EXCHANGER
23-03-1312	SHIFT BY-PASS AIR COOLER
23-03-1313A&B	SHIFT BY-PASS WATER COOLER
23-03-1401	SHIFT FEED START-UP HEATER
23-03-1501	SHIFT CONDENSATE RECYCLE PUMP
23-03-1502	SHIFT CONDENSATE RECYCLE PUMP (SPARE)
23-03-2501	SHIFT REACTOR

NOTE:
1. THIS PLOT PLAN IS MODULE #3 OF 4 MODULES.

SCALE: 1" = 20'-0"

DESCRIPTION			
ICN REPORT	DRAWN: MY/CAD		
FOR CLIENT APPROVAL	CHECKED		
ISSUE CLIENT REVIEW FOR COMP.	APVD SECT HD		
	APVD PROJ MGR	RF	1-25-8?
	APVD CLIENT	RmR	2/1/82

CLIENT REVIEW

THE RALPH M. PARSONS COMPANY
PASADENA, CALIFORNIA

U.S. DEPARTMENT OF ENERGY

BASKETT — W.R. GRACE & CO. — KENTUCKY

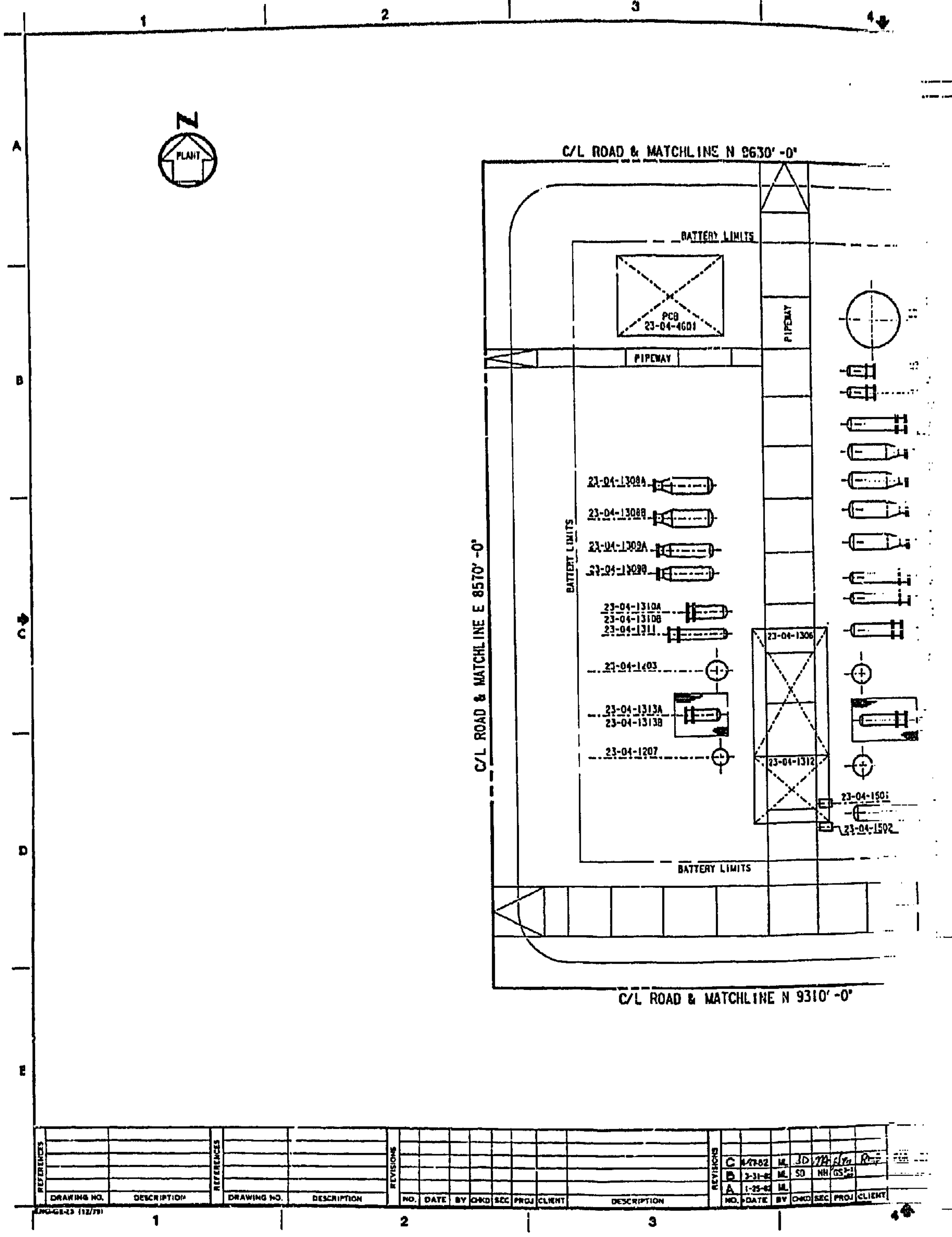
50,000 B.P.D.

COAL - TO - METHANOL - TO - GASOLINE PLANT

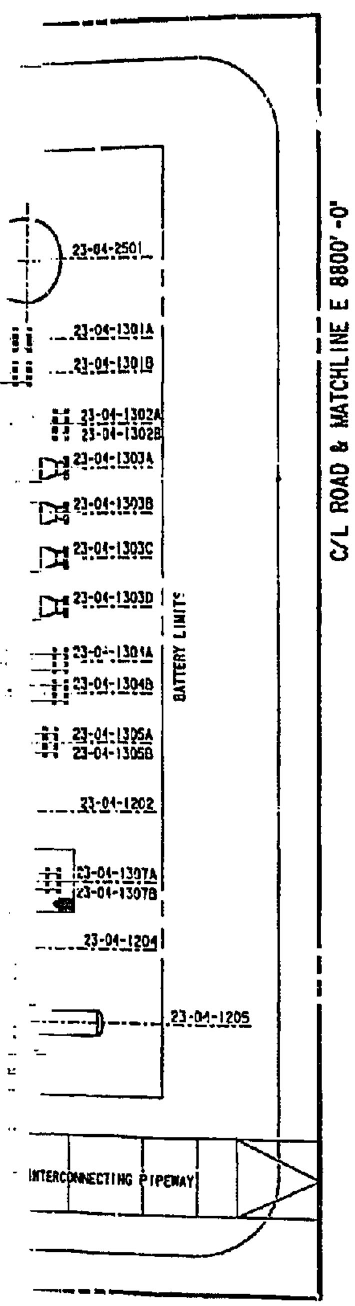
TITLE: PLOT PLAN UNIT 23 CO SHIFT

SCALE: 1"=20'-0" | 7243 | 6182 | REVISION: C

DOCUMENT NUMBER: D-23-PD-3NP



N
PLANT
C/L ROAD & MATCHLINE N 8630'-0"
BATTERY LIMITS
PCB
23-04-4601
PIPEWAY
PIPEWAY
23-04-1308A
23-04-1308B
23-04-1309A
23-04-1309B
BATTERY LIMITS
23-04-1310A
23-04-1310B
23-04-1311
23-04-1203
23-04-1313A
23-04-1313B
23-04-1207
23-04-1306
23-04-1312
23-04-1501
23-04-1502
BATTERY LIMITS
C/L ROAD & MATCHLINE E 8570'-0"
C/L ROAD & MATCHLINE N 9310'-0"
REFERENCES
DRAWING NO.
DESCRIPTION
REVISIONS
NO. DATE BY CHKD SEC PROJ CLIENT DESCRIPTION
C
B 3-31-82 ML SD NH
A 1-25-82 ML
ENG-GE-23 (12/79)



EQUIPMENT LIST

23-04-1202	SHIFT EFFLUENT 1ST K.O. POT
23-04-1203	SHIFT BY-PASS 1ST K.O. POT
23-04-1204	SHIFT EFFLUENT 2ND K.O. POT
23-04-1205	K.O. POTS BOTTOMS COLLECTING DRUM
23-04-1207	SHIFT BY-PASS 2ND K.O. POT
23-04-1301A&B	SHIFT EFFLUENT/FEED HEAT EXCHANGER
23-04-1302A&B	SHIFT EFFLUENT BOILER FEEDWATER HEATER
23-04-1303A,B,C&D	SHIFT EFFLUENT/50# STEAM GENERATOR
23-04-1304A&B	HP BOILER FEEDWATER PREHEATER
23-04-1305A&B	HP TURBINE CONDENSATE EXCHANGER
23-04-1306	SHIFT EFFLUENT AIR COOLER
23-04-1307A&B	SHIFT EFFLUENT WATER COOLER
23-04-1308A&B	SHIFT BY-PASS 150# STEAM GENERATOR
23-04-1309A&B	SHIFT BY-PASS 50# STEAM GENERATOR
23-04-1310A&B	SHIFT CONDENSATE HEATER
23-04-1311	HP TURBINE CONDENSATE EXCHANGER
23-04-1312	SHIFT BY-PASS AIR COOLER
23-04-1313A&B	SHIFT BY-PASS WATER COOLER
23-04-1501	SHIFT CONDENSATE RECYCLE PUMP
23-04-1502	SHIFT CONDENSATE RECYCLE PUMP (SPARE)
23-C1-2501	SHIFT REACTOR

NOTE:
1. THIS PLOT PLAN IS MODULE #4 OF 4 MODULES.

SCALE: 1" = 20'-0"

CLIENT REVIEW	DRAWN MY/CAD	
...ION REPORT	CHECKED	
...CLIENT APPROVAL	APVD SECT HD	
...CLIENT REVIEW 50% COMP.	APVD PROJ MGR	RF 1-25-1[illegible]
DESCRIPTION	APVD CLIENT	[illegible]

RMP
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PASADENA, CALIFORNIA

U.S. DEPARTMENT OF ENERGY
BASKETT — KENTUCKY
W.R. GRACE & CO.
50,000 B.P.D.
COAL - TO - METHANOL - TO - GASOLINE PLANT

TITLE: PLOT PLAN UNIT 23 CO SHIFT

SCALE	ACCOUNT NUMBER	JOB NUMBER	REVISION
1"=20'-0"	7243	6182	C

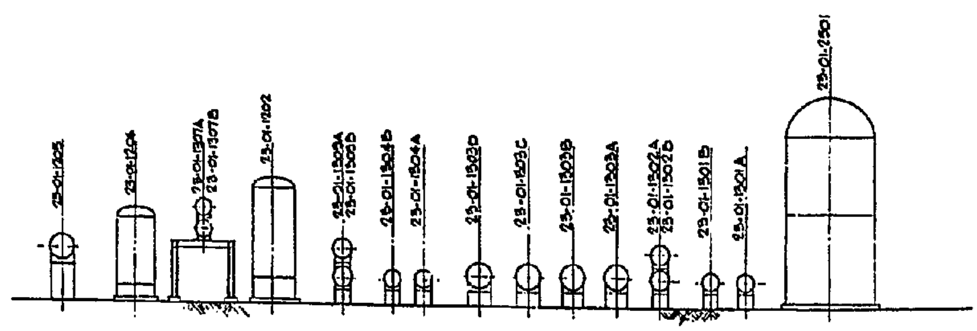
DOCUMENT NUMBER: D-23-PD-4NP

1	2	3	4

A

B

C



D

E

REFERENCES: DRAWING NO.	DESCRIPTION	REFERENCES: DRAWING NO.	DESCRIPTION

REVISIONS: NO.	DATE	BY	CHKD	SEC	PROJ	CLIENT	DESCRIPTION

REVISIONS: NO.	DATE	BY	CHKD	SEC	PROJ	CLIENT
C	5-12-82	ML	JD	[illegible]	[illegible]	[illegible]
B	4-20-82	ML	JD	[illegible]	[illegible]	
A	4-16-82	ML	JD	[illegible]	[illegible]	

FOR

ENG-GE-23 (12/78)

1	2	3

1" = 20FT

U.S. DEPARTMENT OF ENERGY

BASKETT | W.R. GRACE & CO. | KENTUCKY

50,000 B.P.D.

COAL - TO - METHANOL - TO - GASOLINE PLANT

TITLE: ELEVATIONS UNIT 23 C.O. SHIFT

SCALE	1" = 20'0"	
ACCOUNT NUMBER	7245	
JOB NUMBER	6182	
DOCUMENT NUMBER	D-23-PD-5 NP	
REVISION	C	

DRAWN	ML	
CHECKED		
APVD SECT HD	[illegible]	
APVD PROJ MGR		
APVD CLIENT	[illegible]	[illegible]

DESCRIPTION
FOR DESIGN REPORT
FOR CLIENT APPROVAL
FOR CLIENT 50% REVIEW

THE RALPH M. PARSONS COMPANY
PASADENA, CALIFORNIA

G. <u>Single-Line Diagram</u>

See Volume II, 1.2.6(G) for CO Shift Unit 23 Single-Line Diagram.

1.2.8 COAL GRINDING AND SLURRY PREPARATION - UNIT 24

A. Basis of Design

The Texaco slurry preparation technique utilizes wet grinding technology which does not require drying of the coal prior to slurrying. Design of the coal slurry unit was based on a summary of the criteria listed below:

(1) Top size of coal particles controlled for compatibility of downstream equipment.

(2) Provide a coal particle size distribution as specified for gasifier feed.

(3) Concentration of solids controlled close to the slurry concentration specified for the gasifier feed.

The selection of equipment provides a high degree of control on particle size and water balance in the slurry. These were important design features required to produce a pumpable slurry of the desired concentration.

The Coal Grinding and Slurry Preparation Unit has parallel grinding trains and is arranged in modules compatible with those of the TCGP.

Feed Stream

Component	Total Coal Feed (lb/hr)
Coal	1,921,021
Water	187,674
Total	2,108,695
Average Solids Density	1.444
Particle Size	2" x 0
Temperature °F	Ambient

B. Process Selection Rationale

The process selection of the Texaco Coal Gasification Process (TCGP) was specified by W.R. Grace & Co. prior to the initial phase of the preliminary design of the Coal-to-Methanol-to-Gasoline Plant. The slurry preparation system is considered to be an integral part of the Texaco Coal Gasification Process and contains proprietary data; specifically, the coal grind distribution and slurry concentration. This confidentiality extends to equipment associated with producing this size distribution.

The Demonstration Plant (SGDPP contract between W.R. Grace & Co. and DOE) design incorporated wet grinding. However, at this stage of the program in 1979, the impact of oversize material on the performance of the Texaco gasifier had not been demonstrated, particularly the impact of a slurry on a steady flow through the high-pressure positive displacement pumps. Therefore, until this problem could be investigated in more detail, the Demonstration Plant design included the necessary facilities to provide a positive system for removal of oversize material from the product grind. Similar coal grinding for slurry transportation is a proven technology, largely developed in the United States.

Experience with Texaco gasifiers at Montebello and at Oberhausen-Holten continued during the time period that elapsed between the SGDPP work and the Gasoline Plant Project. Design of the coal slurry unit for the Gasoline Plant was based on criteria established by Texaco.

C. Process Description

The arrangement of equipment and material balance for this unit is shown on Process Flow and Control Diagrams D-24-MP-1NP, -2NP, and -3NP.

The design of the coal slurry unit is based on criteria set out by Texaco as indicated above in the Basis of Design.

The Coal Grinding and Slurry Preparation Unit has parallel grinding trains. The grinding trains are arranged into modules for purposes of construction sequence. Each group of grinding trains has a common header, linking the trains to the slurry holding tanks.

A 29,000-ton covered live day storage in silos is the source of feed to the coal grinding trains. Raw coal 2 inches and under is reclaimed from a silo by a discharge feeder and transferred to a belt conveyor for feeding to a grinding train. An individually controlled variable flow of coal is used for each of the grinding trains. Provisions were made in the coal surge storage for downtime of mill trains caused by maintenance.

Each train was designed to handle 2-inch coal containing 8.9% moisture at normal operating rates ranging from 118 to 151 tons per hour, 24 hours per day, 7 days per week. Design coal feed rate was set at 200 tph. This rate permits normal production of slurry from each group of grinding trains for the normal operating condition with design coal, even if the spare grinding trains are out of service.

The 2-inch and under coal conveyed from each live storage silo is fed to a first-stage reduction mill for reduction. Feed to the impact type crusher discharges from a 30-inch belt conveyor operating at about 260 fpm. The coal discharges from the head pulley through a chute and drops vertically to the first-stage reduction mill. Crushed material is removed by a belt conveyor to a revolving mill. Coal is weighed during transport to the mill on a belt scale.

This digital weigher records the coal flow and provides a signal to control water addition to the mill and also to the feeding arrangement in the coal day storage in Unit 12 to ensure a uniform flow rate that can be varied from 70 to 200 tph. The coal is sampled automatically as it is discharged from the conveyor head pulley by gravity to a cone for feeding to the revolving mill.

Fresh coal feed is mixed with a recycle slurry from Unit 21 plus makeup water and a viscosity additive. Water is added in proportion to the weight of coal feed determined by the belt scales. The desired coal-ash-water proportion in the mill discharge varies by weight according to coal type.

Slurry overflow from the mill passes through a trommel screen and is discharged to a surge sump. The trommel screen has openings to remove tramp material. The reject on the screen is discarded. A meter in the sump monitors slurry viscosity and transmits this information to the plant control system, where it is tied in with the mill water feed controls.

The slurry is pumped from the mill sump to a safety screen for scalping of tramp material from the slurry product, thereby ensuring adequate protection to downstream equipment from oversize material. The oversized material removed by the screen deck is sluiced back to the feed cone of the mill using a portion of the makeup water. The slurry passing through the screen deck flows by gravity to a screen sump and is pumped to agitated slurry holding tanks.

The slurry tanks are positioned adjacent to each other with a tie-between. If one of the tanks is out of service, the flow to the others is increased. These tanks are designed for working volume storage of 4 hours at a normal operating level that permits over another hour's storage up to a maximum liquid level, leaving adequate freeboard allowance.

Working volume calculations are predicated on maintaining a minimum operating level to provide proper submergence of bottom propeller. A tank may be emptied below that level, but the agitator is turned off to prevent damage to the shaft. A slurry feeding pump circulates slurry from the slurry tanks to the suction side of the gasifier charge pumps.

The preceding description covers the operation of the slurry preparation subsystem when producing the Texaco grind specification for normal operating conditions. The Operating Costs summary is based on the standard grind specification which is used over 85% of the time.

Texaco uses additives in coal slurries to improve slurry viscosity and increase solids concentration. Consequently, a slurry additive system was incorporated in the slurry preparation unit. Storage capacity provides for a maximum of 30 days' storage. One unloading pump handles the unloading stations.

One area sump and pump per slurry preparation module is provided. Spills and floor cleanup in the slurry preparation building are sent to the gasification unit and is pumped back along with the gasifier recycle.

For some coals, it may be necessary to add basic material to the slurry to prevent corrosion because of low pH. Provision was made to add ammonia, if needed, to the water line to the mill at plant startup. Such addition ceases after the operating system reaches steady state pH of about 8.0.

D. Risk Assessment

This system includes impact crushers, wet grinding mills, wet vibrating screens, slurry tanks, slurry pumps, and belt conveyors. All equipment selected for coal grinding and slurry preparation is conventional, commercially available, and has a history of successful operation with coal or in other applications. All pumps are spared. Lines and equipment have appropriate corrosion-erosion allowances, along with wear plates according to accepted slurry handling practice.

Built-in slurry holding capacity in process sumps provides a buffer against slurry surge from mills and screens in case of power failure. Slurry pH is held slightly basic by automatic monitoring and controlling the pH of the recycle streams.

The Coal Grinding and Slurry Preparation Unit is comprised of parallel grinding trains. The grinding trains are arranged into modules for purposes of construction sequence. Each group of trains has a common header, linking the trains to the slurry holding tanks.

The unit was designed in a particularly conservative manner; that is, to provide a range of potential grind analyses. This provides the possibility of varying the grind size to suit slurry concentration, carbon conversion, and gasifier performance for a wide range of coal analyses.

Based on experience with other coals, the equipment is not expected to encounter undue clogging or plugging problems. The vibrating screen for each train is a safety or scalping screen to remove tramp or oversized product, thereby furnishing protection against oversize material that might interfere with operation in downstream equipment. The screen has a built-in feed splitter to produce three feedstreams. Each of these streams is sent to one of three separate screening sections of the multifeed screen. Each screen is spared as further insurance against screen blinding.

The areas of uncertainty include the ability to produce on a continuous basis the coal slurry required for the normal operating condition case without containing oversize solids and the ability to handle these coal slurries. A system is incorporated to provide an additive ahead of the grinding mill for modifying slurry viscosity. Screens are subject to blinding at higher solids concentration and are spared. The handling of coal slurries and suspension of solids particles in water are arduous applications for valving. Special attention was applied to the detail of valve design to ensure long-term continuous operation without undue maintenance.

The coal grinding and slurry preparation system must deliver coal, ground to the proper grind size specification, while still achieving the design slurry concentration. Failure to meet either of these desired conditions results in difficulties in the process units downstream of the unit, principally in gasification. To a considerable extent, downstream facilities were designed to compensate for deviation in slurry concentration.

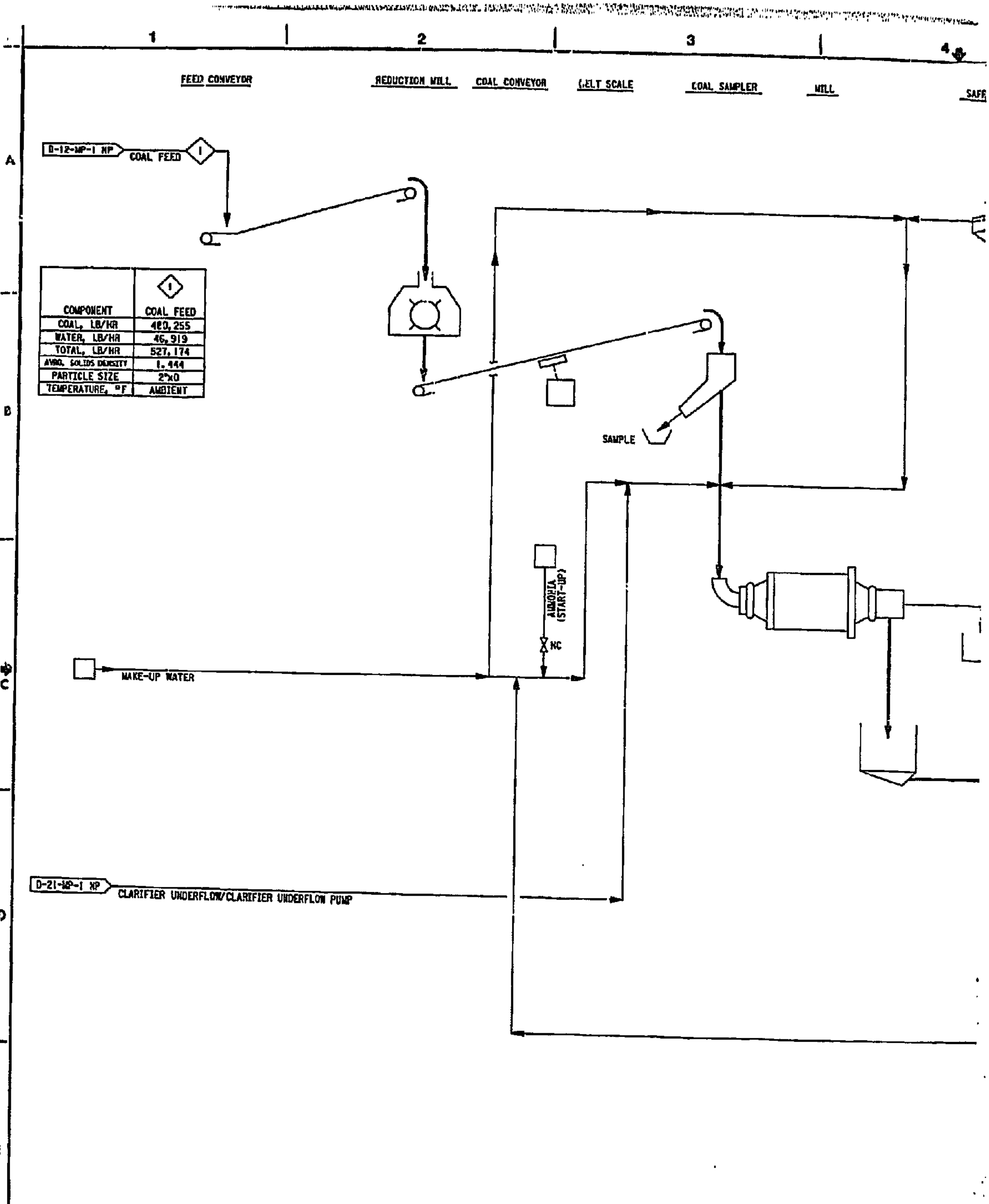
A flexible coal grinding system was designed to produce the required grind size distribution and slurry concentration, while at the same time protecting against oversize particles. This permits the capability of producing a divergence of coal grind size distributions. This approach gives the plant the capability of tailoring the grinding system to optimize the overall gasification system performance.

The coal slurry presents special problems for high-pressure charge pumps. Some experience was obtained in the Texaco pilot plant where equivalent coal slurries were pumped to the gasification pressure of 1,200 psig. It is preferable to use pumps with no water dilution. A number of suppliers are available for selection on this basis.

E. Process Flow and Control Digrams (Including Material Balance)

Process Flow and Control Diagrams for Coal Grinding and Slurry Preparation Unit 24 are as follows:

Drawing No.	Title
D-24-MP-1NP	PFCD Coal Grinding and Slurry Preparation Unit 24 - Coal Grinding
D-24-MP-2NP	PFCD Coal Grinding and Slurry Preparation Unit 24 - Slurry Preparation
D-24-MP-3NP	PFCD Coal Grinding and Slurry Preparation Unit 24 - Viscosity Additive System



COMPONENT	◇1 COAL FEED
COAL, LB/HR	480,255
WATER, LB/HR	46,919
TOTAL, LB/HR	527,174
AVRG. SOLIDS DENSITY	1.444
PARTICLE SIZE	2"x0
TEMPERATURE, °F	AMBIENT

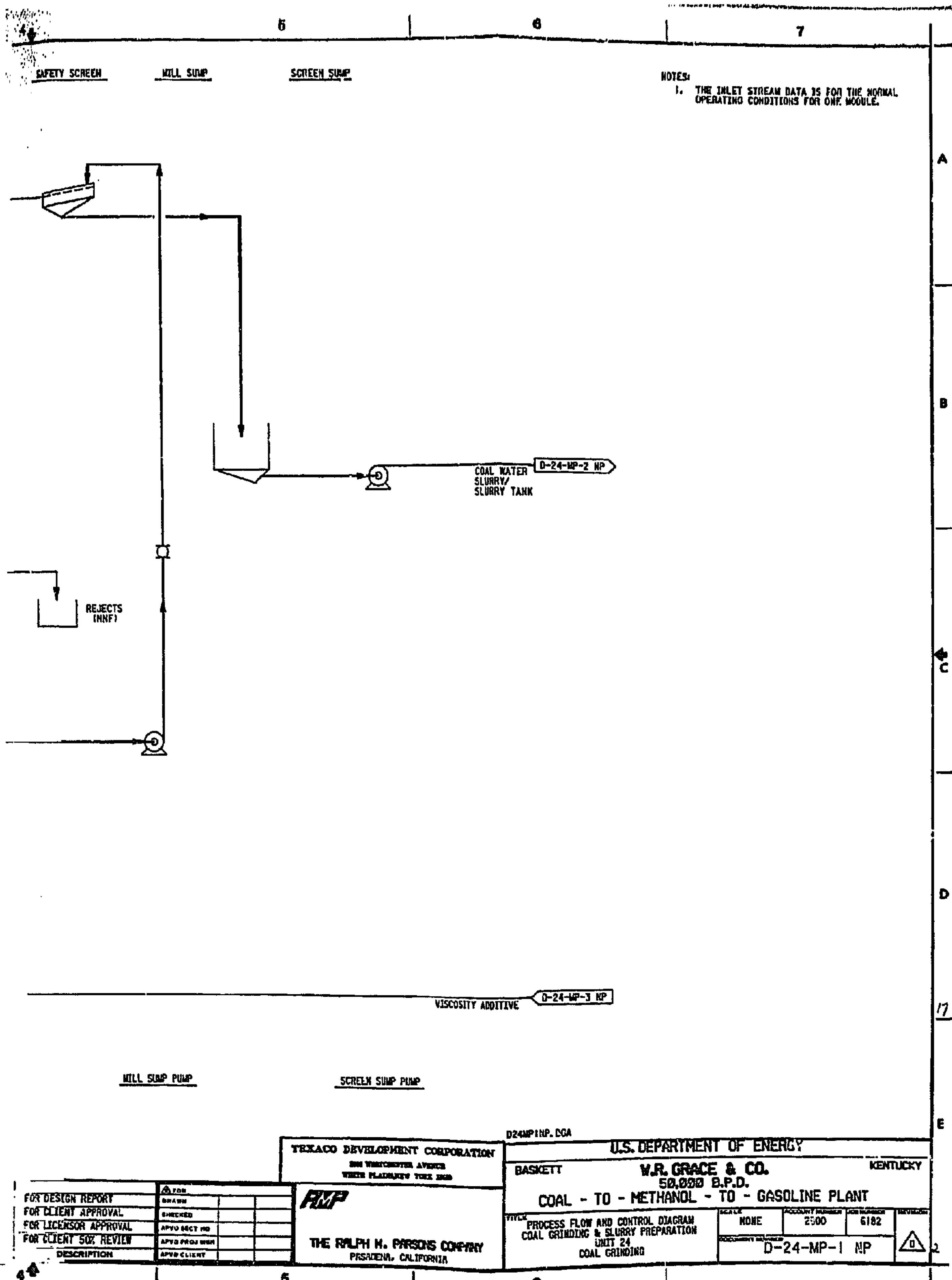
REFERENCES	
DRAWING NO.	DESCRIPTION

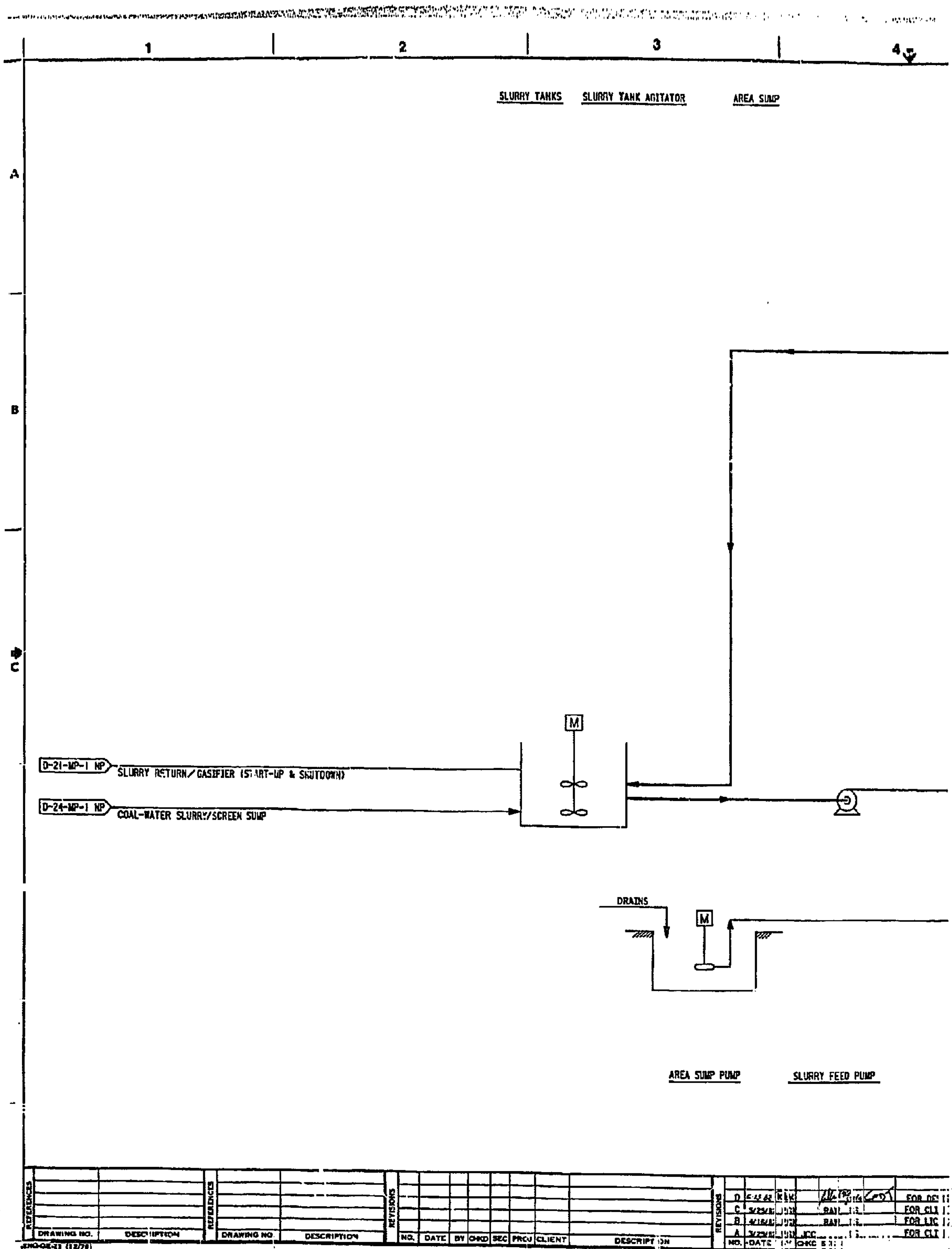
REFERENCES	
DRAWING NO.	DESCRIPTION

NO.	DATE	BY	CHKD	SEC	PROJ	CLIENT	DESCRIPTION

NO.	DATE	BY	CHKD	SEC	PROJ	CLIENT	REVISIONS
D	5-13-82	FGK					FOR DE
C	8/25/82	FGK		RAW	GS		FOR CL
B	3/23/82	FGK		RAW	GS		FOR LI
A	4/16/82	FGK	JCC		GS		FOR CL

ENG-OE-23 (12/79)
1


SAFETY SCREEN
MILL SUMP
SCREEN SUMP
NOTES:
1. THE INLET STREAM DATA IS FOR THE NORMAL OPERATING CONDITIONS FOR ONE MODULE.
COAL WATER SLURRY/ SLURRY TANK
D-24-MP-2 NP
REJECTS (NNF)
VISCOSITY ADDITIVE
D-24-MP-3 NP
MILL SUMP PUMP
SCREEN SUMP PUMP
D24MP1NP.DGA
TEXACO DEVELOPMENT CORPORATION
THE RALPH M. PARSONS COMPANY
PASADENA, CALIFORNIA
FOR DESIGN REPORT
FOR CLIENT APPROVAL
FOR LICENSOR APPROVAL
FOR CLIENT 50% REVIEW
DESCRIPTION
U.S. DEPARTMENT OF ENERGY
BASKETT
W.R. GRACE & CO.
50,000 B.P.D.
KENTUCKY
COAL - TO - METHANOL - TO - GASOLINE PLANT
PROCESS FLOW AND CONTROL DIAGRAM
COAL GRINDING & SLURRY PREPARATION
UNIT 24
COAL GRINDING
NONE
2500
6182
D-24-MP-1 NP


1
2
3
4
A
B
C
SLURRY TANKS
SLURRY TANK AGITATOR
AREA SUMP
D-21-MP-1 NP
SLURRY RETURN/GASIFIER (START-UP & SHUTDOWN)
D-24-MP-1 NP
COAL-WATER SLURRY/SCREEN SUMP
M
DRAINS
M
AREA SUMP PUMP
SLURRY FEED PUMP
REFERENCES
DRAWING NO.
DESCRIPTION
REFERENCES
DRAWING NO
DESCRIPTION
REVISIONS
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DATE
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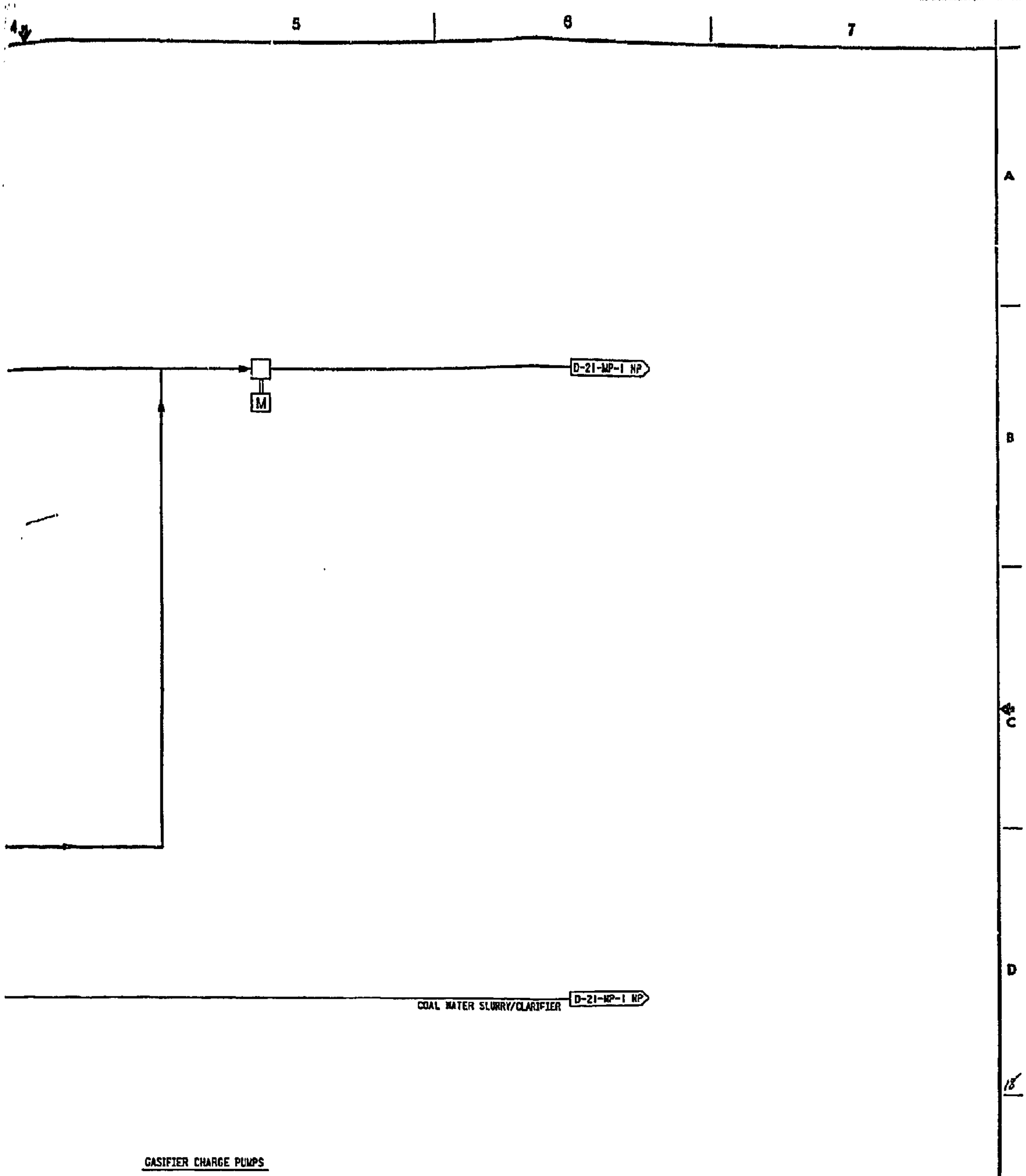

D24MP2NP.DGA

TEXACO DEVELOPMENT CORPORATION
[illegible]

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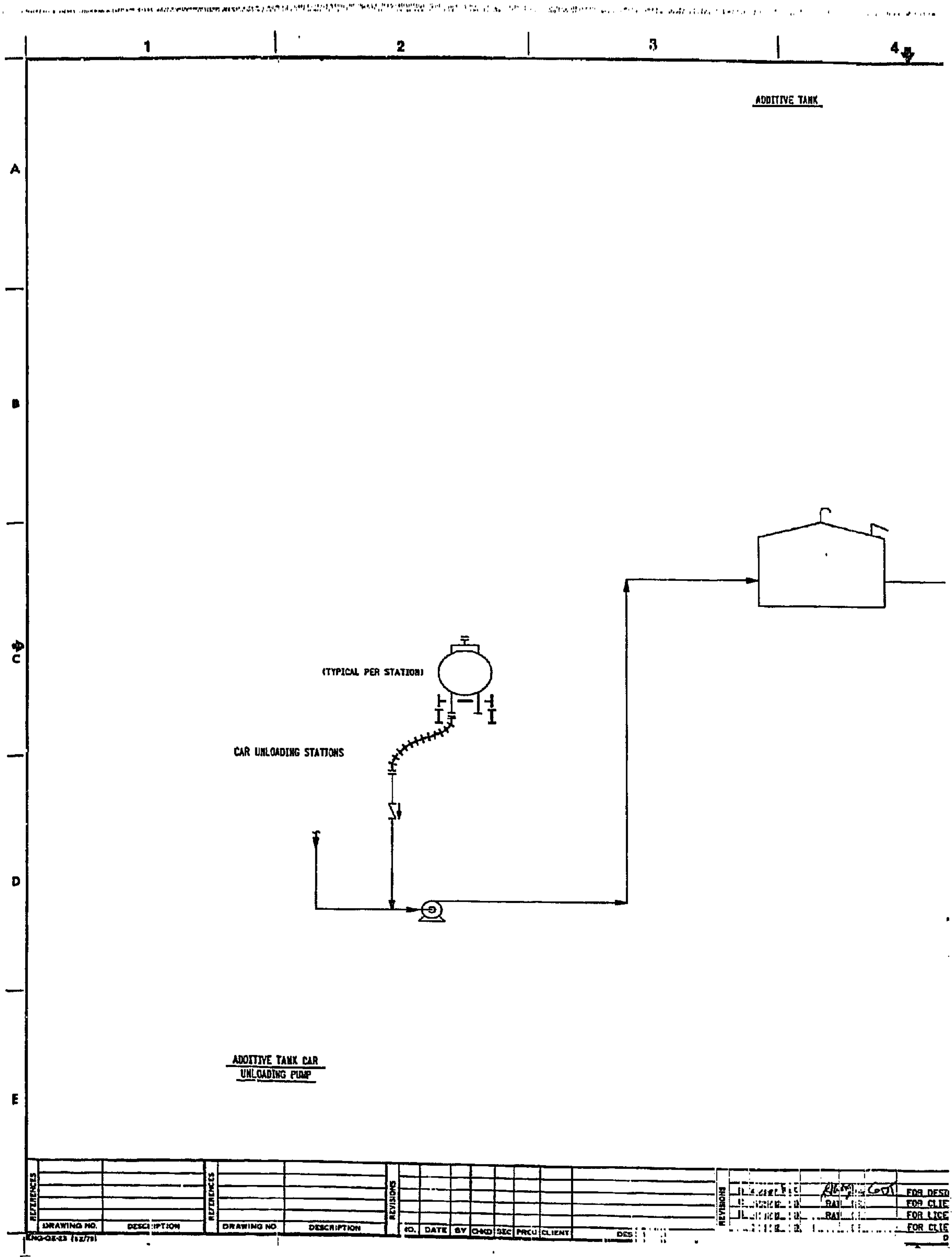
BASKETT — W.R. GRACE & CO. — KENTUCKY
50,000 B.P.D.
COAL - TO - METHANOL - TO - GASOLINE PLANT

TITLE: COAL GRINDING AND SLURRY PREPARATION
UNIT 24
SLURRY PREPARATION

SCALE	ACCOUNT NUMBER	JOB NUMBER	REVISION
NONE	2800	6182	D

DOCUMENT NUMBER: D-24-MP-2 NP

DESCRIPTION	FOR		
FOR DESIGN REPORT	DRAWN		
FOR CLIENT APPROVAL	CHECKED		
FOR LICENSOR APPROVAL	APVD SECT MGR		
FOR CLIENT 5/27 REVIEW	APVD PROJ MGR		
	APVD CLIENT		



1
2
3
4
A
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E
ADDITIVE TANK
(TYPICAL PER STATION)
CAR UNLOADING STATIONS
ADDITIVE TANK CAR
UNLOADING PUMP
REFERENCES
DRAWING NO.
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FOR CLIE
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FOR CLIE

ADDITIVE FEED PUMP

D24MP3NP.DGA

U.S. DEPARTMENT OF ENERGY

BASKETT — W.R. GRACE & CO. — KENTUCKY

50,000 B.P.D.

COAL - TO - METHANOL - TO - GASOLINE PLANT

FOR DESIGN REPORT	DRAWN	MFV	
FOR CLIENT APPROVAL	CHECKED		
FOR LICENSOR APPROVAL	APVD SECT HD		
FOR CLIENT 50% REVIEW	APVD PROJ MGR		
DESCRIPTION	APVD CLIENT		

RMP

THE RALPH M. PARSONS COMPANY
PASADENA, CALIFORNIA

TITLE: PROCESS FLOW AND CONTROL DIAGRAM
COAL GRINDING & SLURRY PREPARATION-
UNIT 24
VISCOSITY ADDITIVE SYSTEM

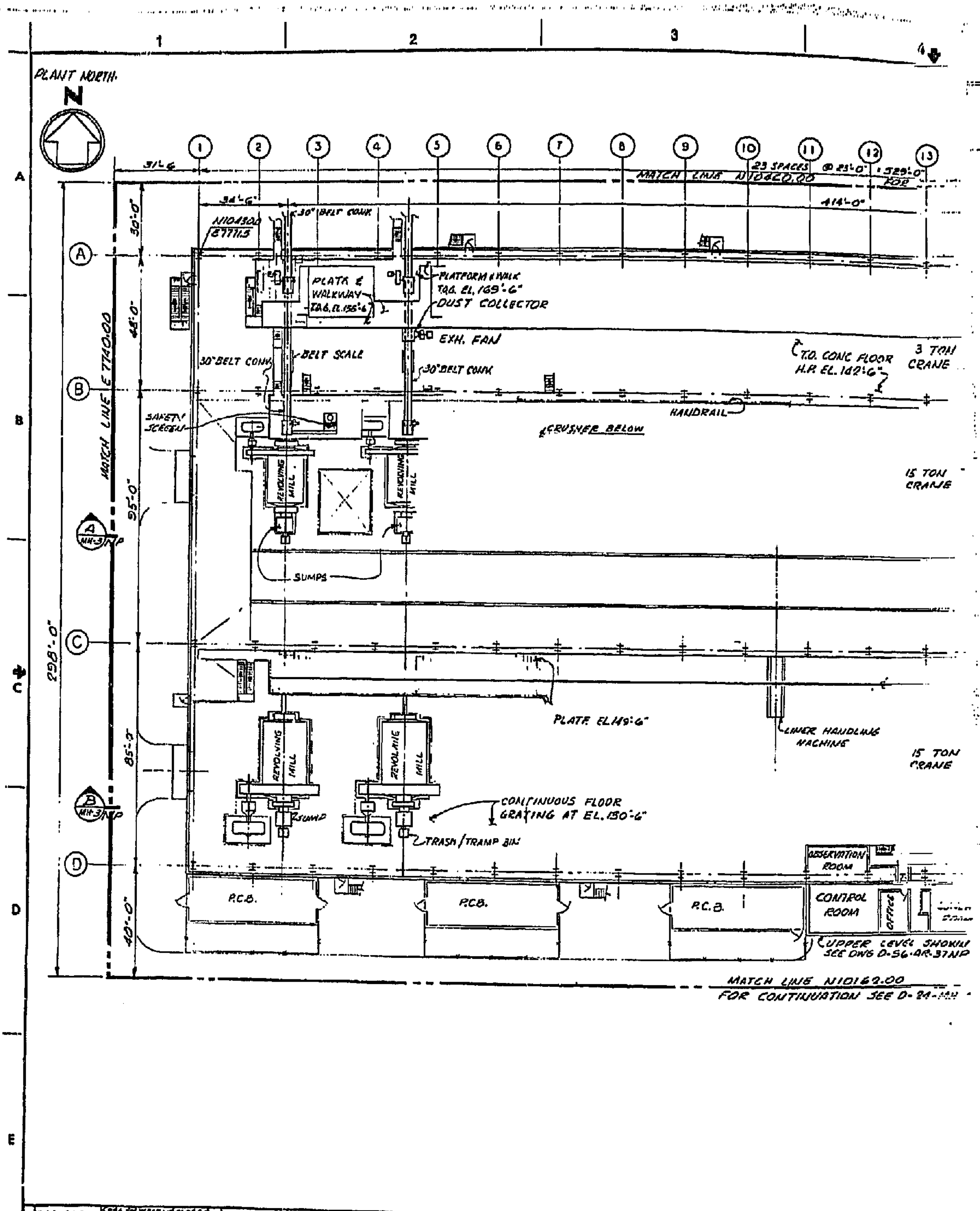
SCALE	ACCOUNT NUMBER	JOB NUMBER	REVISION
NONE	2800	6182	0

DOCUMENT NUMBER: D-24-MP-3 NP

F. Plot Plan/General Arrangement Drawings

Plot Plan/General Arrangement Drawings for Coal Grinding and Slurry Preparation Unit 24 are as follows:

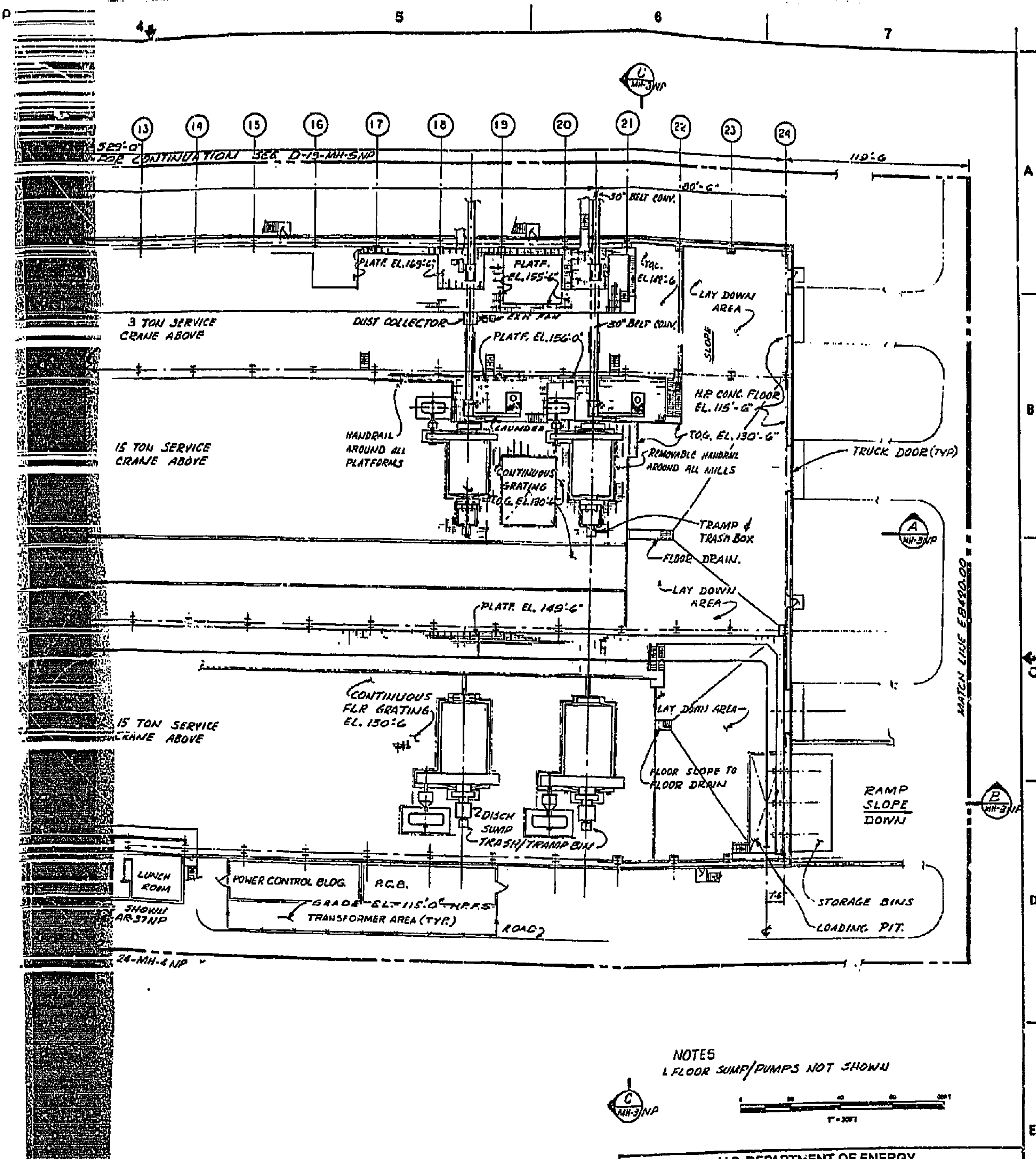
Drawing No.	Title
D-24-MH-2NP	General Arrangement Coal Slurry and Grinding - Unit 24 Slurry Preparation Building - Plan
D-24-MH-3NP	General Arrangemont Coal Slurry and Grinding - Unit 24 Slurry Preparation Building - Sections
D-24-MH-4NP	General Arrangement Coal Slurry and Grinding - Unit 24 Slurry Tanks and Pump Building - Plan and Section



REFERENCES DRAWING NO.	DESCRIPTION
D-M-MH-3NP	Coal Grinding Area Floor Sections
D-M-MH-4NP	Secondary Primary Grinding Areas

NO.	DATE	BY	CHKD	SEC	PROJ	CLIENT
D	5-11-81	G.T.	E.S.			
C	3-4-81	G.T.	E.S.			
B	4-3-80	G.T.	R.S.			

ANGGE-23 (12/79)



U.S. DEPARTMENT OF ENERGY

BASKETT — W.R. GRACE & CO. — KENTUCKY

50,000 B.P.D.

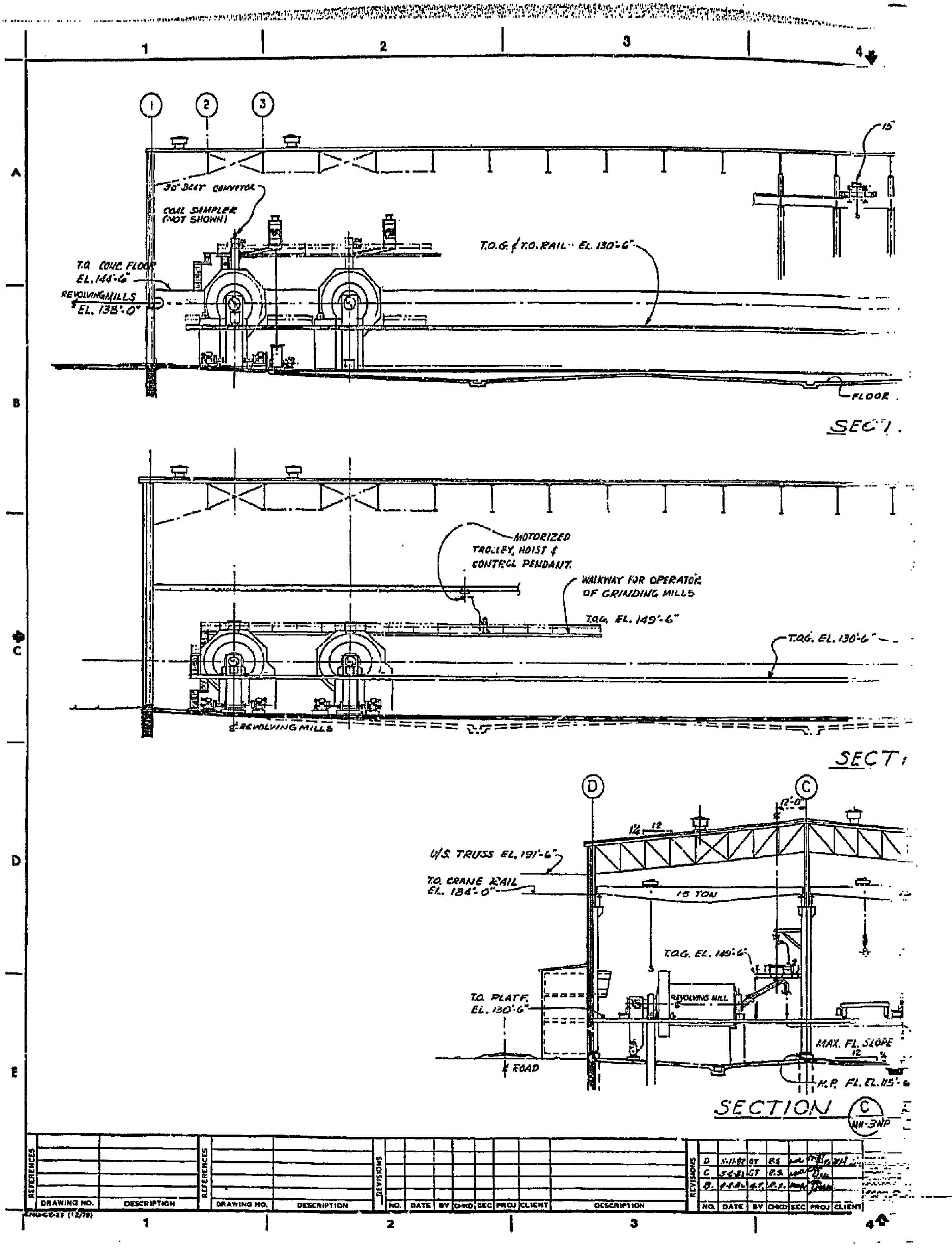
COAL - TO - METHANOL - TO - GASOLINE PLANT

TITLE: GENERAL ARRANGEMENT COAL SLURRY & GRINDING - UNIT 24 SLURRY PREPARATION BUILDING PLAN

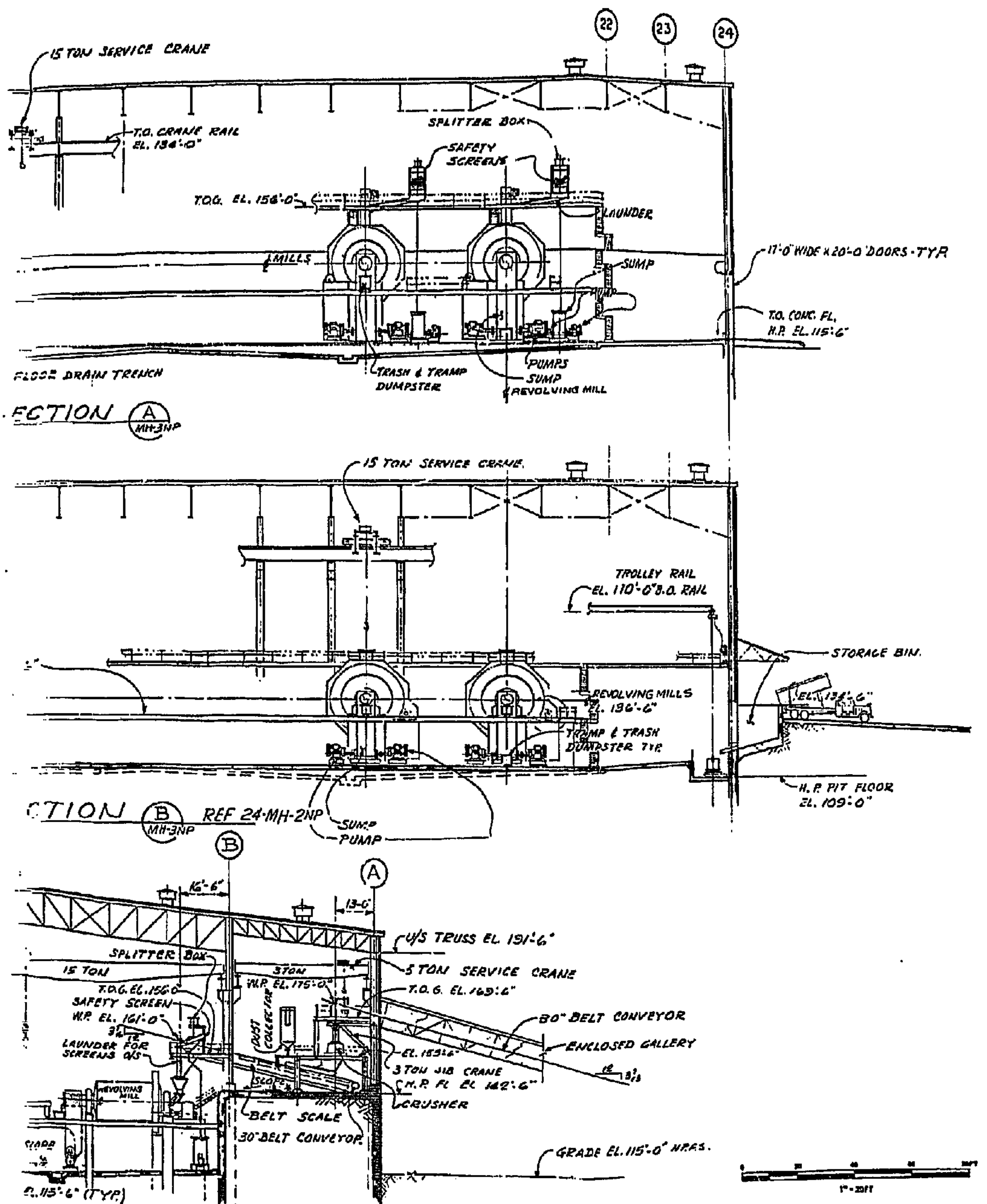
SCALE: 1" = 20'-0" | 2000 | 6182

D-24-MH-2NP

THE RALPH M. PARSONS COMPANY
PASADENA, CALIFORNIA



1
2
3
4
A
B
C
D
E
30" BELT CONVEYOR
COAL SAMPLER (NOT SHOWN)
T.O. CONC. FLOOR EL. 144'-6"
REVOLVING MILLS ℄ EL. 138'-0"
T.O.G. & T.O. RAIL EL. 130'-6"
FLOOR
SECT
MOTORIZED TROLLEY, HOIST & CONTROL PENDANT.
WALKWAY FOR OPERATOR OF GRINDING MILLS
T.O.G. EL. 149'-6"
T.O.G. EL. 130'-6"
℄ REVOLVING MILLS
SECT
U/S TRUSS EL. 191'-6"
T.O. CRANE RAIL EL. 184'-0"
15 TON
T.O.G. EL. 149'-6"
REVOLVING MILL
T.O. PLATF. EL. 130'-6"
℄ ROAD
MAX. FL. SLOPE
H.P. FL. EL. 115'-6
SECTION C
REFERENCES
DRAWING NO.
DESCRIPTION
REVISIONS
NO.
DATE
BY
CHKD
SEC
PROJ
CLIENT



U.S. DEPARTMENT OF ENERGY

BASKETT — KENTUCKY

W.R. GRACE & CO.
50,000 B.P.D.
COAL-TO-METHANOL-TO-GASOLINE PLANT

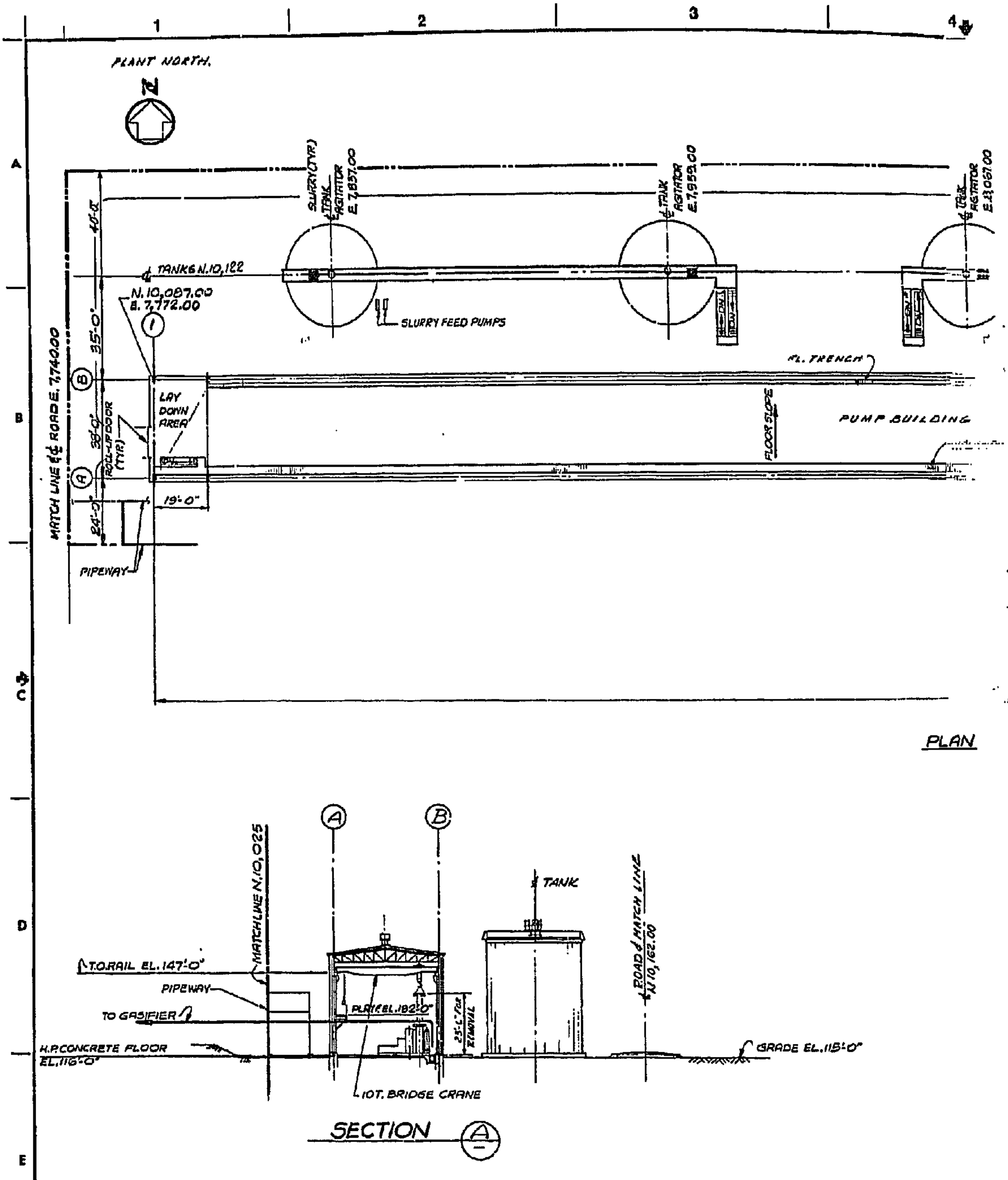
TITLE: GENERAL ARRANGEMENT
COAL SLURRY & GRINDING - UNIT 24
SLURRY PREPARATION BUILDING
SECTIONS

SCALE	ACCOUNT NUMBER	JOB NUMBER	REVISION
1" = 20'-0"	2000	6182	D

DOCUMENT NUMBER: D-24-MH-3NP

RMP
THE RALPH M. PARSONS COMPANY
PASADENA, CALIFORNIA

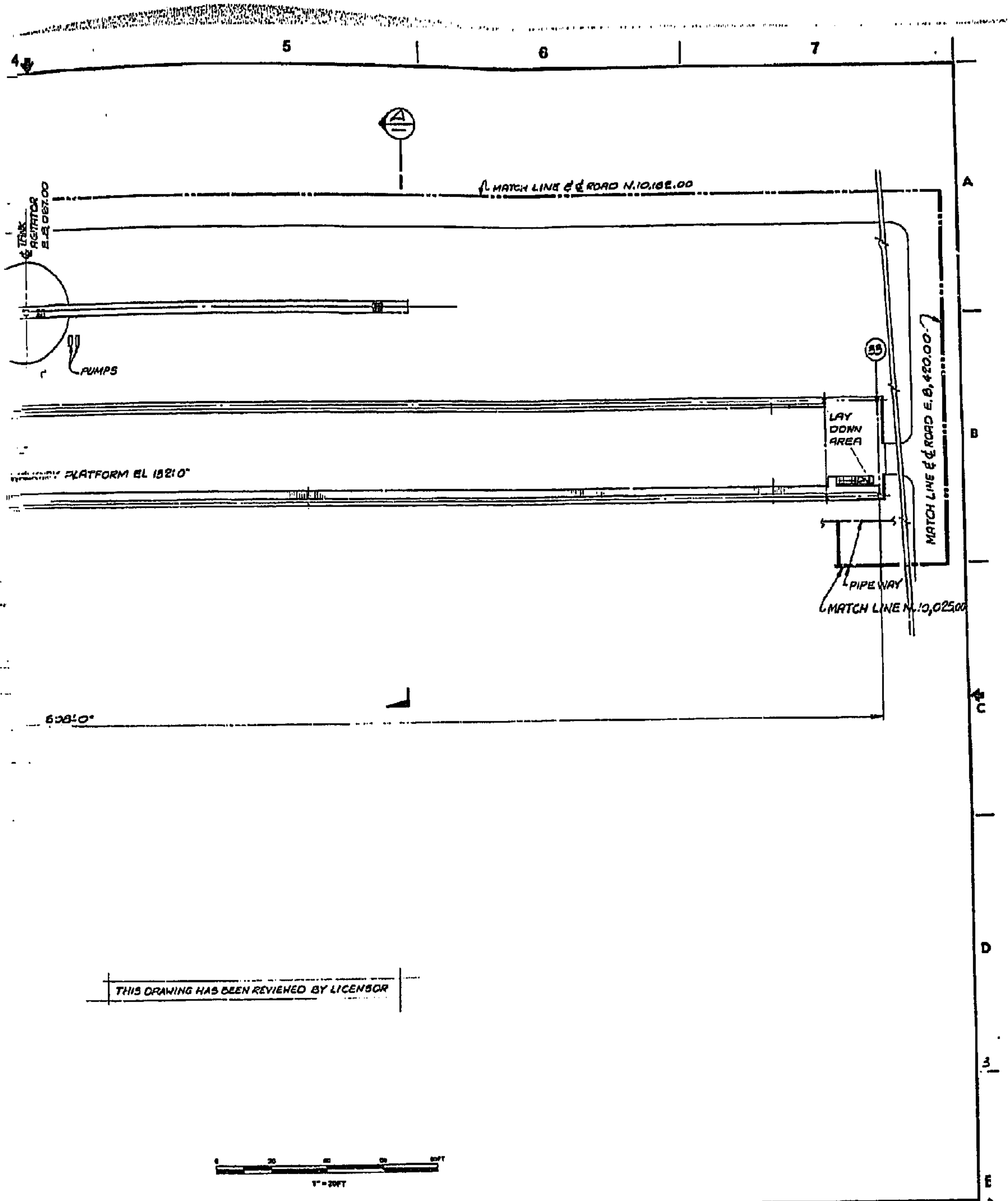
D FOR CLIENT REVIEW			
ISSUED FOR CLIENT APPROVAL	DRAWN	Wiggill	12-15-81
	CHECKED	R.S.	12-??-81
	APVD DEPT HD		
	APVD PROJ MGR		
DESCRIPTION	APVD CLIENT		



REFERENCES: DRAWING NO.	DESCRIPTION
D-24-MH-2NP	SLURRY PREP BLDG PLAN

REVISIONS: NO.	DATE	BY	CHKD	SEC	PROJ	CLIENT
D	5-27-81	LK	RS	[illegible]	[illegible]	[illegible]
C	5-13-81	LK	RS	[illegible]	[illegible]	
B	4-16-81	LK	RS	[illegible]	[illegible]	
A	4-3-81	LK	RS	[illegible]	[illegible]	

ENG-GE-23 (12/79)



DESCRIPTION			
DESIGN REPORT	DRAWN	LBK	4-2-82
ISSUED FOR CLIENT APPROVAL	CHECKED	R.S.	4-2-82
LICENSOR APPROVAL	APVD SECT HD		4-2-82
30% REVIEW	APVD PROJ MGR		
	APVD CLIENT		

RMP

THE RALPH M. PARSONS COMPANY
PASADENA, CALIFORNIA

U.S. DEPARTMENT OF ENERGY

BASKETT — KENTUCKY

W.R. GRACE & CO.
50,000 B.P.D.
COAL - TO - METHANOL - TO - GASOLINE PLANT

TITLE: GENERAL ARRANGEMENT
COAL SLURRY & GRINDING - UNIT 24
SLURRY TANKS & PUMP BUILDING
PLAN & SECTION

SCALE	ACCOUNT NO.	JOB NUMBER	REVISION
1" = 20'-0	2000	6182	D

DOCUMENT NUMBER: D-24-MH-4NP

G. Single-Line Diagram

See Volume II, 1.2.5(G), for Coal Grinding and Slurry Preparation Unit 24 single-line diagram.

1.2.9 METHANOL SYNTHESIS - UNIT 25

A Lurgi methanol synthesis unit has been selected to convert synthesis gas, after partial CO shift and acid gas removal, to methanol. Approximately 17,000 stpd of methanol are required to produce the nominal 50,000 bpd of gasoline. Because of the large amount of synthesis gas, four parallel trains are provided. Because of physical constraints on equipment size, each methanol synthesis unit has two reactors in parallel.

Also included is a single-train Pressure Swing Adsorption (PSA) module to serve all of the methanol synthesis modules. The PSA design is based on Union Carbide's HYSIV process.

A. Basis of Design

The large amount of synthesis gas to be converted to obtain the required methanol volume necessitates several parallel trains. Based on the current status of reactor and catalyst development, four trains have been used in the design to convert synthesis gas to methanol. Each train has two reactors operating in parallel.

Feed, product, and fuel/purge gas by-product stream compositions are given in the following tables.

Feed Streams

Component	Makeup Gas lb mol/hr	mol%
H_2	96,813.76	67.54
CH_4	322.59	0.22
CO	40,826.39	28.48
CO_2	4,300.52	3.00
N_2	814.21	0.57
Ar	273.28	0.19
Total Dry, lb mol/hr	143,350.75	100.00
H_2O	-	
Total Wet, lb mol/hr	143,350.75	
Total, lb/hr	1,566,940	
Pressure, psia	750	
Temperature, °F	82	

Product Streams

Component	"Wild" Methanol (lb mol/hr)	"Wild" Methanol (mol%)	Crude Methanol[a] (lb mol/hr)	Crude Methanol[a] (mol%)
H_2	119.31	0.24	0.57	12 ppmv
CH_4	58.20	0.12	1.23	26 ppmv
CO	21.94	0.05	0.26	5 ppmv
CO_2	290.90	0.60	29.12	0.06
N_2	48.88	0.10	0.42	9 ppmv
Ar	30.64	0.06	0.42	9 ppmv
CH_3OH	44,092.78	90.59	43,694.08	91.55
Hydrocarbons	0.70	16 ppmv	0.52	11 ppmv
High Boilers	53.06	0.11	52.80	0.11
Low Boilers	37.10	0.08	31.97	0.07
H_2O	3,920.48	8.05	3,913.51	8.20
Total, lb mol/hr	48,673.99	100.00	47,724.90	100.0
Total, lb hr	1,505,720		1,476,610	
Pressure, psia	415		10	
Temperature, °F	100		94	

[a]Composition of methanol produced when the MTG unit is down and "wild" methanol is let down to 10 psia prior to storing in crude methanol tanks.

<u>By-products</u>

Component	Flash Gas From "Wild" Methanol (lb mol/hr)	(mol%)	Flash Gas From Crude Methanol[a] (lb mol/hr)	(mol%)
H_2	270.77	61.56	118.74	12.60
CH_4	29.98	6.82	56.97	6.05
CO	19.95	4.53	21.68	2.30
CO_2	28.77	6.54	261.78	27.79
N_2	61.35	13.95	48.46	5.14
Ar	24.47	5.56	30.22	3.21
CH_3OH	4.46	1.01	398.70	42.32
Hydrocarbons	-	-	0.17	0.02
High Boilers	-	-	0.26	0.03
Low Boilers	0.11	0.03	5.13	0.54
Total Dry, lb mol/hr	439.86	100.00	942.11	100.00
H_2O	0.03		6.97	
Total Wet, lb mol/hr	439.89		949.08	
Total, lb/hr	5,700		29,070	
Pressure, psia	45		10	
Temperature, °F	100		94	

[a]Flash gas from crude methanol is produced when methanol is sent to storage.

Component	Purge Gas (lb mol/hr)	(mol%)	Leakage Gas (lb mol/hr)	(mol%)
H_2	3,483.28	71.43	502.60	69.98
CH_4	216.08	4.43	18.32	2.55
CO	174.16	3.57	98.20	13.67
CO_2	136.68	2.80	21.36	2.97
N_2	645.96	13.25	58.04	8.08
Ar	200.64	4.11	17.56	2.44
CH_3OH	19.84	0.41	2.20	0.31
Total Dry, lb mol/hr	4,876.64	100.00	718.28	100.00
H_2O	0.04		-	
Total Wet, lb mol/hr	4,876.68		718.28	
Total, lb/hr	48,130		7,390	
Pressure, psia	994		750	
Temperature, °F	100		127	

B. Process Selection Rationale

Data were requested from ICI, Lurgi, and Topsoe for a 17,000-stpd methanol plant for this project. Such data, together with meetings with each of the potential licensors and information available from other sources, formed the bases of a process selection study. Based on an evaluation against predetermined criteria, the Lurgi process was selected for incorporation in the gasoline plant. Key attributes of the Lurgi process contributing to its selection are as follows:

(1) Lurgi's methanol plant experience based on synthesis gas from heavy oil gasification as well as from natural gas reforming. At the present time, there are four operating plants using vacuum or heavy residue and four others are under construction. Also one plant using coal as feedstock is under construction in the United States. This is supported by Lurgi's extensive experience with coal and coal gasification through its own process - and Lurgi's experience in Rectisol acid gas removal plants prior to methanol synthesis.

(2) The Lurgi process, because of its special reactor design, recovers heat at a higher temperature level.

(3) The Lurgi process utilizes an isothermal reactor which enables optimization of catalyst and recycle gas requirements.

C. Process Description

Refer to Process Flow and Control Diagrams D-25-MP-1NP, -2NP, -3NP, and -4NP for equipment arrangement and material balance.

The synthesis gas coming from the Acid Gas Removal Unit is compressed in Makeup Gas Compressor 25-01-1801 from 750 psia to 998 psia. The gas is added to the recirculating gas, and the two gases are compressed to synthesis pressure in Recycle Gas Compressor 25-01-1802.

The gas is heated to 437°F in Feed/Effluent Exchangers 25-01-1301 and -1302 by a portion of the hot reactor effluent gas in countercurrent flow.

Conversion of H_2 with CO and CO_2 to methanol takes place in Synthesis Reactors 25-01-2501 and -2502, which are equipped with parallel vertical tubes holding the catalyst. The heat released during the exothermic conversion reaction is transferred in situ to boiling water, which ensures exact temperature control and eliminates damage to the catalyst caused by overheating. The reactor outlet temperature is regulated easily and closely by controlling the pressure in Steam Drums 25-01-1201 and -1202.

As already mentioned, a portion of the hot reactor effluent gas heats the reactor inlet gas. Boiler Feedwater Preheater 25-01-1303 is installed in parallel with the interchangers to preheat the boiler feedwater in countercurrent flow to the remaining reactor effluent gas. Further cooling of the gas and condensation of methanol and water occur in Air Coolers 25-01-1304 and -1305 and Water Coolers 25-01-1306 and -1307. To avoid an accumulation of inerts in the synthesis loop, the system is purged continuously, with the purge gas being routed to either PSA Unit 25-01-2801 or the plant fuel gas system. The condensate is separated in Methanol Separator 25-01-1203 and supplied by level control to Flash Drum 25-01-1204, where raw methanol is expanded to 415 psia. Flash gases released by this expansion are routed to the fuel gas header and, under normal operating conditions, the resultant "wild" methanol flows to Methanol-to-Gasoline Unit 31.

When the MTG unit is down, "wild" methanol is expanded further to 10 psia in Low-Pressure Flash Drum 25-01-1205. Low-Pressure Flash Drum Pump 25-01-1503 supplies crude methanol to the crude methanol tanks in Intermediate Tankage - Unit 63. Low-Pressure Flash Drum Eductor 25-01-2802 uses purge gas to produce a vacuum in the low-pressure flash drum. Flash gases from the low-pressure letdown flow to the fuel gas system.

D. Risk Assessment

Compressed synthesis gas from the Acid Gas Removal Unit is mixed with the recycle gas from the product separator and compressed to synthesis pressure. Synthesis gas is charged to the reactor after heat exchange with the reactor effluent. The design of the isothermal methanol synthesis reactor is based on experience in the construction of Fischer-Tropsch plants. The exothermic conversion of hydrogen with carbon monoxide and carbon dioxide to methanol takes place in the tubes filled with copper-based catalyst. The reaction heat is used to generate steam from the boiler water surrounding the tubes. The reaction mixture exchanges the major portion of its sensible heat with the reactor feed in a heat exchanger. It is cooled to ambient temperature with air and cooling water and sent to the product separator. "Wild" methanol is produced after the product separator bottoms is flashed at medium pressure and sent to the MTG plant.

Lurgi's methanol synthesis process is a highly commercialized, efficient, and reliable process. Makeup gas and recycle gas compressors are key items, but operating pressures and flows are not extreme. Service is clean and nonfouling.

The outstanding features of the methanol synthesis catalyst are high-conversion efficiency, long life, and almost complete suppression of side reactions. The methanol reactor may be compared to a shell-and-tube heat exchanger with no mechanically moved part in the overall reactor system.

The catalyst temperature in the synthesis reactor is controlled by the vapor pressure of the evaporating boiler water around the tubes, which ensures that the copper catalyst is not exposed to extreme temperatures. This would result in premature aging of the catalyst caused by recrystallization of the copper. The reactor design and the reactor control of the catalyst temperature by steam pressure offers the following major advantages:

- Constant catalyst temperatures even at upset operating conditions by maloperation.

- Gentle catalyst treatment by avoiding excessive temperatures and sudden temperature changes.

- Almost complete utilization of the reaction heat for high-pressure steam generation.

- Excellent turndown ratio.

- High flexibility regarding variations of CO and CO_2 content in the synthesis gas.

Although the catalyst is sensitive to sulfur, commercial operation of this type of reactor design in conjunction with Rectisol units has shown that sulfur poisoning is not a problem.

The technical risk of methanol synthesis by the Lurgi process is judged to be very low.

1.2.9-1 PRESSURE SWING ADSORPTION (PSA) UNIT

The Heavy Gasoline Treating (HGT) unit used to reduce durene in the finished gasoline to about 2 wt% durene requires a small flow of high-purity hydrogen. A PSA unit produces this hydrogen stream from the methanol synthesis purge stream.

A. Basis of Design

Feed to the PSA unit is the purge gas stream from the methanol synthesis unit. Product hydrogen is fed to the HGT unit to catalytically hydrotreat a heavy gasoline stream. The PSA purge or tail gas is sent to the plant fuel gas system. Feed, product, and tail gas compositions are shown below.

Feed and Product Streams

Component	PSA Feed (lb mol/hr)	Hydrogen Product (lb mol/hr)	PSA Tail Gas (lb mol/hr)
H_2	566.03	329.06	236.97
CH_4	35.13	Trace	35.13
CO	28.32	Trace	28.32
CO_2	22.12	-	22.12
N_2	104.98	0.25	104.73
Ar	32.62	0.08	32.54
CH_3OH	3.23	-	3.23
Total dry, lb mol/hr	792.43	329.39	463.04
H_2O	8 ppm	-	13 ppm
Total wet, lb mol/hr	792.43	329.39	463.04
Total, lb/hr	7,821.0	673.6	7,147.1
Pressure, psia	994	650	60
Temperature, °F	100	110	100

B. Process Selection Rationale

The process selection of PSA was made to meet the requirement by Mobil for a 99.9 purity hydrogen for hydrotreating use in the HGT unit. The principal supplier of technology meeting this requirement is Union Carbide.

C. Process Description

The basic PSA process is one in which impurities are absorbed from the feed gas at high pressure and then are desorbed at low pressure. The process operates on a repeated cycle having two basic steps - adsorption and regeneration. There is no change in temperature except for that caused by the heat of adsorption and desorption.

The Union Carbide HYSIV PSA unit employs a patented PSA process to purify a crude hydrogen feedstream and produce a high-purity hydrogen product stream. The process uses four adsorbent beds to provide a continuous and constant hydrogen product flow. One adsorber is always on adsorption while the other three are in various stages of regeneration. During the adsorption step, feed gas enters the bottom of the adsorber and all impurities are adsorbed. High-purity hydrogen product is available at the top of the adsorber at 2 to 3 psi less than the feed pressure. Following the adsorption step, an adsorber is regenerated in four basic steps:

(1) The adsorber is depressurized in a direction cocurrent with the feed flow to a low-pressure level. This cocurrent flow is used to repressurize and purge other adsorbers.

(2) The adsorber is depressurized in a countercurrent direction to waste pressure and remove impurities from the system.

(3) The adsorber is purged at low pressure with pure hydrogen (from another adsorber) to complete the removal of impurities from the adsorbent.

(4) The pressure of the adsorber is raised to adsorption pressure with pure hydrogen in preparation for another adsorption step.

Operation of the PSA unit is completely automatic with all control valves being actuated by an electric/pneumatic control system. Controls are provided to regulate internal system pressures and flows. The capacity of the unit can be varied from 100% of design to zero by varying the hydrogen withdrawal rate.

The hydrogen product is available at constant flow, pressure, and temperature. Hydrogen recoveries can be maintained at a flow rate as low as 30% of rated design flow. At the lower withdrawal rates, the hydrogen recovery decreases unless the cycle time is increased.

D. Risk Assessment

Over 190 PSA hydrogen units have been constructed worldwide during the past 15 years or are currently under construction. Seven units have been designed to process a methanol purge stream.

The PSA unit can be operated with any production rate desired, from 100% of design down to zero flow, while maintaining product hydrogen purity. It is the feature of operating at zero hydrogen flow that allows the PSA unit to recover rapidly from upsets caused by changes in the feed condition. The PSA unit can be started up or shut down instantaneously. For longer shutdown periods, a short purging procedure may be necessary. A weekend shutdown with immediate restart without purging is common practice with some PSA units.

The operation of the PSA unit is automatic and requires no direct operator attention. The adsorbers switch automatically through the various cycle steps. These steps are controlled by time delay relays and pressure switches. If the feed rate is increased or decreased, the cycle time may be adjusted to obtain maximum performance. This adjustment may be made at the PSA control panel or from a remote location.

The PSA unit shuts down automatically on cycle advance failure, loss of instrument air, or loss of adsorption pressure. Each adsorber is isolated at the pressure corresponding to its particular step in the cycle sequence at the time of shutdown. Thus, all adsorbers are ready for subsequent startup.

The only moving parts in the PSA unit are control components and automatic valves. Considerable care has gone into selection of the various controls and valves. The proposed design is the result of over 15 years of continual updating based on field-operating experience. Union Carbide's most recent survey of operating units showed that the average onstream availability of the units between scheduled shutdowns exceeded 99.8%.

Units built in the last several years have shown even better reliability and experience periods well in excess of 1 year between unscheduled shutdowns. No physical deterioration or reduction in adsorbent capacity of the adsorbent has been observed in any of the existing units. This covers a period of over 15 years. Union Carbide concludes from this that the life of the adsorbent is good for the life of the equipment.

E. Process Flow and Control Diagrams (Including Material Balance)

Process Flow and Control Diagrams for Methanol Synthesis Unit 25 are as follows:

Drawing No.	Title
D-25-MP-1NP	PFCD Methanol Synthesis - Unit 25 Gas Compression
D-25-MP-2NP	PFCD Methanol Synthesis - Unit 25 Gas Reaction
D-25-MP-3NP	PFCD Methanol Synthesis - Unit 25 Pressure Swing Adsorption
D-25-MP-4NP	Material Balance Methanol Synthesis - Unit 25