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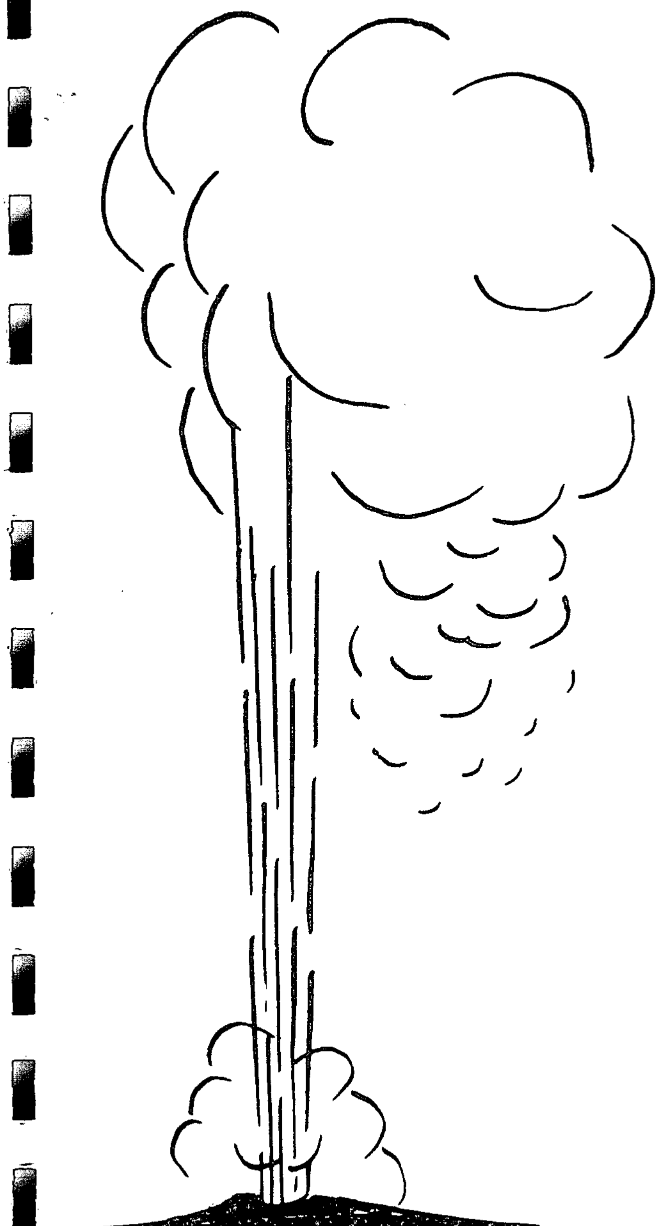

Engineering & Economic Studies
for Direct Application of Geothermal Energy

ETHANOL PRODUCTION FOR AUTOMOTIVE FUEL USAGE

Quarterly Report, 1 October - 31 December, 1979

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San Francisco, California

U. S. DEPARTMENT OF ENERGY
Geothermal Energy

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ABSTRACT

The conceptual design of the 20 million gallon per year anhydrous ethanol facility at Raft River has been completed. The corresponding geothermal gathering, extraction and reinjection systems to supply the process heating requirement were also completed. The ethanol facility operating on sugar beets, potatoes and wheat will share common fermentation and product recovery equipment.

The geothermal fluid requirement will be approximately 6,000 gpm. It is anticipated that this flow will be supplied by 9 supply wells spaced at no closer than 1/4 mile in order to prevent mutual interferences. The geothermal fluid will be flashed in three stages to supply process steam at 250° F, 225° F and 205° F for various process needs. Steam condensate plus liquid remaining after the third flash will all be reinjected through 9 reinjection wells.

The capital cost estimated for this ethanol plant employing all three feedstocks is $64 million. If only a single feedstock were used (for the same 20 mm gal/yr plant) the capital costs are estimated at $51.6 million, $43.1 million and $40.5 million for sugar beets, potatoes and wheat respectively. The estimated capital cost for the geothermal system is $18 million.

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Section 1

INTRODUCTION

Efforts related to this study during this reporting period have concentrated on the completion of the conceptual design of the 20 million gallon per year ethanol plant. This conceptual design forms the focal point for the rest of the study tasks. These other tasks include 1) definition of the geothermal resource requirements, 2) design of the geothermal system to supply the necessary process needs, 3) estimation of the capital and operating costs of the plant to produce the ethanol and provide an economic evaluation, 4) addressing the site institutional factors relating to the construction of such a facility at the Raft River area of Idaho, and 5) preparing a preliminary implementation plan to proceed with an ethanol production facility.

During the first quarter, part of the conceptual design relating to sugar beet and potatoes was completed. The remaining process design, including wheat processing, was completed during this quarter and is reported in Section 2 of this report.

Based on the conceptual design, the geothermal resource requirement was defined and the design of a geothermal gathering, extraction and reinjection systems were prepared. The design and equipment specifications are reported in Sections 2, 3 and 4 of this report.

The capital cost estimate for the ethanol plant along with geothermal gathering, extraction and reinjection systems, were prepared. These are reported in Section 5 of this report.

Section 2

ALCOHOL FACILITY CONCEPTUAL DESIGN

2.1 PROCESS FLOW DIAGRAMS

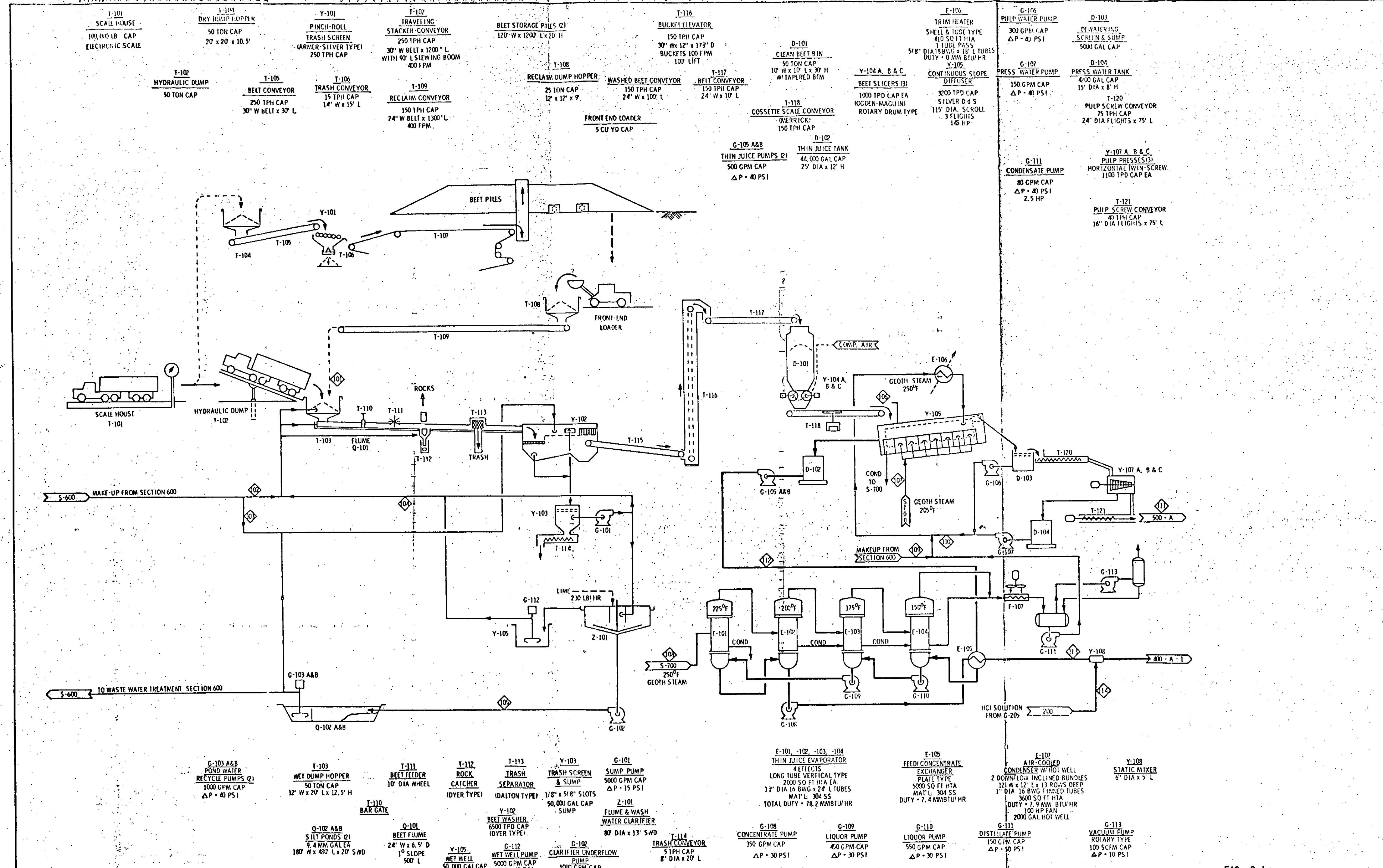
The conceptual design of the 20 million gallon per year ethanol plant is complete. The process flow diagrams including material balances and equipment specifications are presented as Figures 2.1 through 2.13. The facility is divided into 6 sections corresponding to the 100 through 600 section drawings. Because three different feedstocks will be used during each year of operation, three separate sets of material balances and equipment specifications are presented. Portions of the plant are common to all three feedstocks. Where common usage is anticipated, equipment is not duplicated.

Sections 100, 400-A and 500-A represent the plant operation when sugar beet is used as feedstock. Sections 200, 400-B and 500-B represents potatoes operation and Sections 300, 400-C and 500-C represents wheat operation. Section 600, the offsites including the geothermal system, is common to all three feedstocks operations.

The design bases and descriptions of the sugar beet and potatoes operations were reported in the first quarterly report[1]. The description and design basis for the wheat case is reported in the next section.

2.2 PROCESS DESCRIPTION (WHEAT CASE) -- Summary

Soft white winter wheat is processed in the alcohol facility three months per year, normally in August, September and October. Wheat is purchased on the open market and delivered by truck to the plant during the processing period. The wheat is cleaned and ground whole. The whole ground wheat is processed much like potatoes to liberate the starch molecules. Design throughput is 891.5 bushels per hour. Net alcohol production is 2555 gallons per hour for a net yield of 2.87 gal/per bushel.



	101 BEET FEED		102 FLUME MAKE-UP		103 WASH WTR MAKE-UP		104 FLUME RECYCLE		105 BLOWDOWN WATER	
COMPONENT			LB/HR	% WT	LB/HR	% WT	LB/HR	% WT	LB/HR	% WT
SUGAR BEETS	(219,876)	(93.46)								
WATER	167,392	71.16	73,220	99.97	36,888	99.97	1,759,280	99.77	439,820	97.31
SUCROSE	35,180	14.95					1,556	0.09	389	0.09
SOLIDS - SOLUBLE	6,310	2.68					1,556	0.09	389	0.09
MARC/INSOLUBLES	10,994	4.67							230	0.05
SILT & TRASH	15,391	6.34					352	0.02	10,994	2.43
YEAST										
ETHANOL			25	0.03	13	0.03	608	0.03	152	0.03
CARBON DIOXIDE										
FUSEL OIL										
ALDEHYDE										
NUTRIENTS										
HCl										
TOTAL	235,267	100.0	73,245	100.0	37,201	100.0	1,763,352	100.0	451,974	100.0

	106 SLICED BEETS		107 STEAM TO DIFFUSER		108 STEAM TO EVAPORATOR		109 DIFFUSION WTR. MAKE-UP		110 PULP WTR RETURN	
COMPONENT	LB/HR	% WT	LB/HR	% WT	LB/HR	% WT	LB/HR	% WT	LB/HR	% WT
SUGAR BEETS	(219,876)	(100.00)								
WATER	167,612	76.23	15,400	100.00	22,352	100.00	22,267	99.6	197,959	97.00
SUCROSE	35,070	15.95							3,059	1.5
SOLIDS - SOLUBLE	6,200	2.82							3,059	1.5
MARC/INSOLUBLES	10,994	5.00								
SILT & TRASH										
YEAST										
ETHANOL							8	0.04	12	TR
CARBON DIOXIDE										
FUSEL OIL										
ALDEHYDE										
NUTRIENTS										
HCl										
TOTAL	219,876	100.0	15,400	100.0	22,352	100.0	22,275	100.0	204,089	100.0

	111 PRESSED PULP		112 THIN JUICE FEED		113 FERMENTER FEED		114 5% HCl SOLUTION	
COMPONENT	LB/HR	% WT	LB/HR	% WT	LB/HR	% WT	LB/HR	% WT
SUGAR BEETS								
WATER	50,183	79.997	211,222	84.17	139,696	77.86	456	95
SUCROSE	776	1.237	34,294	13.67	34,294	19.11		
SOLIDS - SOLUBLE	776	1.237	5,424	2.16	5,424	3.03		
MARC/INSOLUBLES	10,994	17.525						
SILT & TRASH								
YEAST								
ETHANOL	2	0.004	12	TR	6	TR		
CARBON DIOXIDE								
FUSEL OIL								
ALDEHYDE								
NUTRIENTS								
HCl							24	5.
TOTAL	62,731	100.0	250,952	100.0	179,420	100.0	480	100

FIG. 2.1

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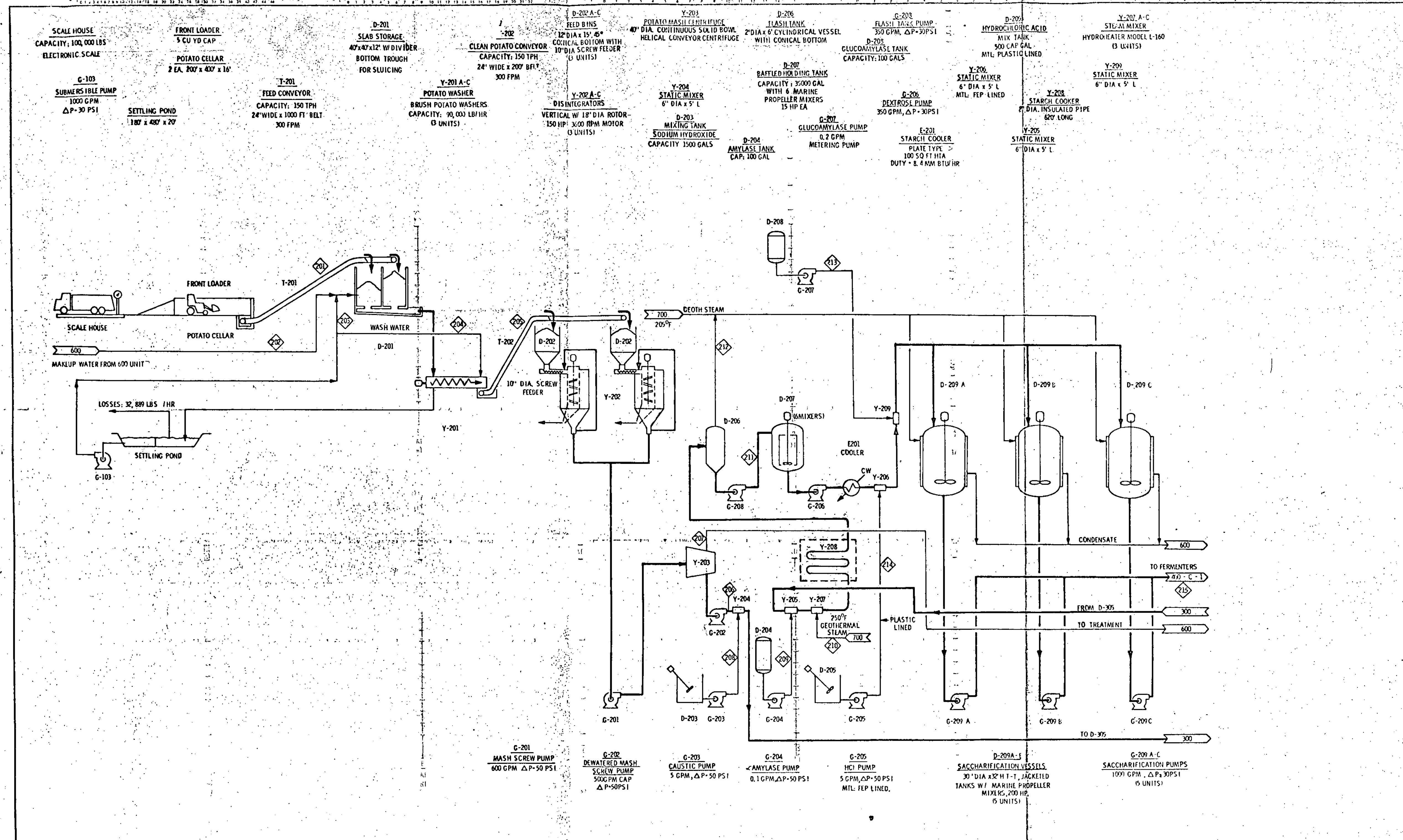
FLOW DIAGRAM
20 MM GAL/YR NOMINAL ETHANOL FACILITY
SUGAR BEET PROCESSING

JOB No.	DRAWING No.	REV.
13412	100	0



*COMPONENTS OF FEED POTATOES

COMPONENTS	201 POTATO FEED		202 FLUME WATER MAKE-UP		203 FLUME WATER RECYCLE		204 WASH WATER		205 CLEAN POTATOES		206 DEWATERED POTATO MASH		207 CENTRATE	
	LB / HR	% WT	LB / HR	% WT	LB / HR	% WT	LB / HR	% WT	LB / HR	% WT	LB / HR	% WT	LB / HR	% WT
POTATO	217,270	100.0							217,270	99.1				
WATER	168,384*		20,032	100	1,703,397	100.0	112,455	100.0	1,874	0.9	99,572	67.8	70,686	97.7
STARCH	32,590*										32,427	22.1	163	0.3
FIBERS	11,733*										11,674	7.9	59	0.1
PROTEINS & FAT	4,563*										3,194	2.2	1,369	1.9
GLUCOSE														
YEAST														
ETHANOL														
HCl														
NaOH														
CO_2														
α-AMYLASE														
GLUCOAMYLASE														
SOLUBLE SOLIDS														
TOTAL	217,270	100.0	20,032	100	1,703,397	100.0	112,455	100.0	219,144	100.0	146,867	100.0	72,277	100.0

COMPONENTS	208 2% NaOH SOLUTION		209 α-AMYLASE		210 COOKING STEAM		211 COOKED POTATO MASH		212 FLASHED STEAM		213 GLUCOAMYLASE		214 5% HCl SOLUTION		215 FERMENTER FEED	
	LB / HR	% WT	LB / HR	% WT	LB / HR	% WT	LB / HR	% WT	LB / HR	% WT	LB / HR	% WT	LB / HR	% WT	LB / HR	% WT
POTATO																
WATER	1470	98.0			18,326	100.0	119,179	71.6	189	100.0			513	95.0	116,089	69.4
STARCH							32,427	19.5								7.0
FIBERS							11,674	7.0							11,674	1.9
PROTEINS & FAT							3,194	1.9							3,194	21.6
GLUCOSE															36,030	
YEAST																
ETHANOL																
HCl													27	5.0		
NaOH	30	2.0														
CO_2																
α-AMYLASE			49	100.0												
GLUCOAMYLASE											73	100.0				
SOLUBLE SOLIDS							79	0.05							179	0.1
TOTAL	1500	100.0	49	100.0	18,326	100.0	166,553	100.0	189	100	73	100	540	100.0	167,166	100.0

FIG. 2.2

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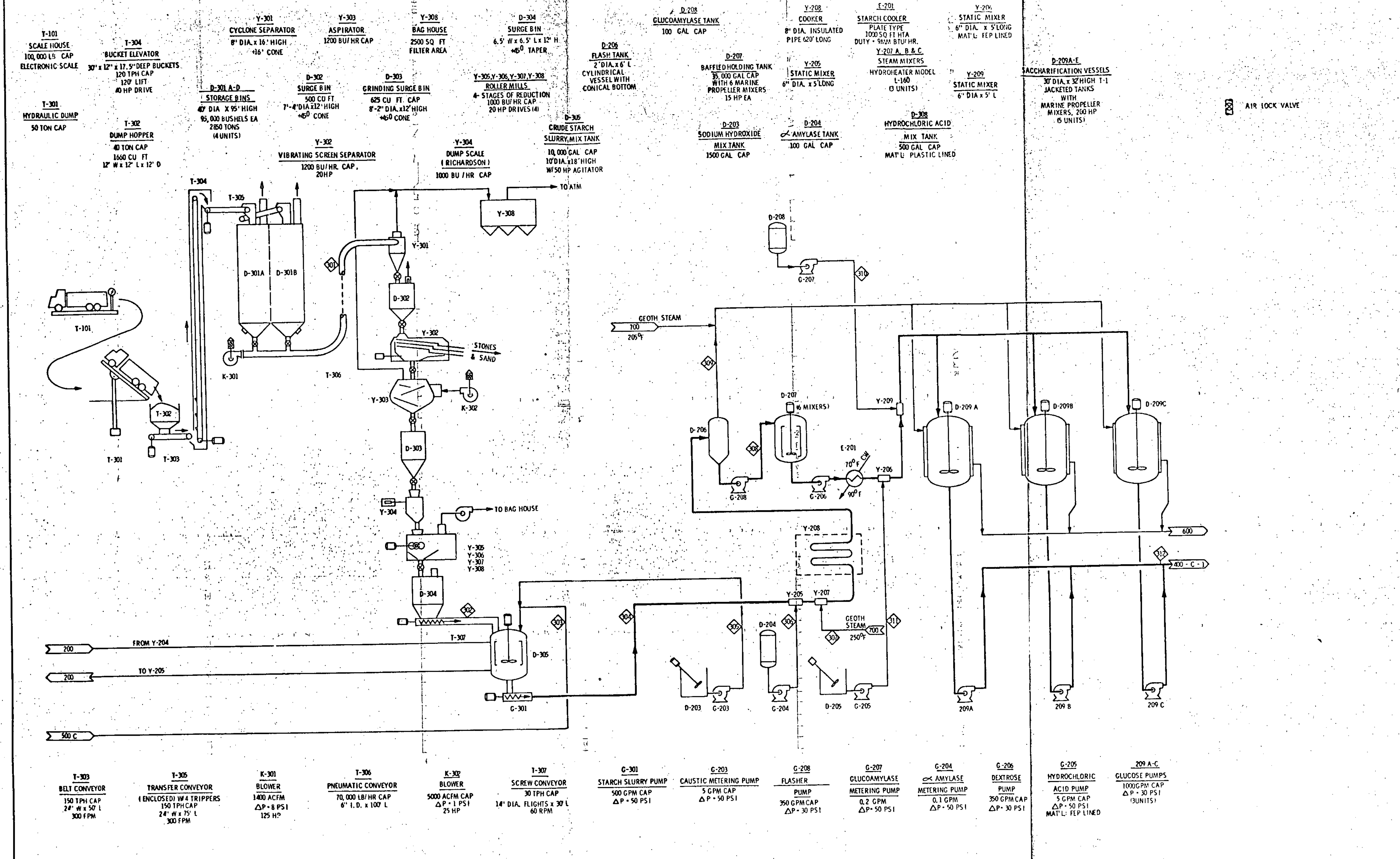
FLOW DIAGRAM
20 MM GAL/YR NOMINAL ETHANOL FACILITY
POTATO PROCESSING

JOB No. 13412 | DRAWING No. 200 | REV. 0



NOTE: (1) FOREIGN MATTER - SAND, DIRT, STONES, STICKS

	301 FIELD RUN WHEAT		302 CLEAN GROUND WHEAT		303 SLURRY WATER MAKE UP		304 CRUDE STARCH SLURRY		305 2% NaOH		306 α AMYLASE	
COMPONENTS	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT
WHEAT	(53,487)	(80.0)	53,487	100.0								
WATER	4,785	7.16	4,785	8.95	108,853	99.96	115,108	70.24	1470	98.0		
STARCH	30,949	46.30	30,949	57.87			30,949	18.88				
FIBERS	4,815	7.20	4,815	9.00			4,815	2.94				
PROTEINS & FATS	6,190	9.26	6,190	11.57			6,190	3.77				
SUGAR	1,687	2.52	1,687	3.15			1,687	1.03				
ETHANOL					42	0.04	42	0.03				
HCl												
NaOH									30	2.0		
AMYLASE											49	100.0
GLUCOAMYLASE												
FOREIGN MATTER	13,372 (1)	20.0										
SOLUBLE SOLIDS	5,061	7.56	5,061	9.46			5,091	3.11				
TOTAL	66,859	100.0	53,487	100.00	108,895	100.00	163,882	100.00	1500	100.00	49	100.0

	307 COOKING STEAM		308 COOKED WHEAT MASH		309 FLASHED STEAM		310 GLUCOAMYLASE		311 5% HCl SOLUTION		312 FERMENTER FEED	
COMPONENTS	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT
WHEAT												
WATER	11,072	100.0	123,526	71.67	2,654	99.93			513	95.0	120,599	69.73
STARCH			30,949	17.96								9
FIBERS			4,815	2.79							4,815	2.78
PROTEINS & FATS			6,190	3.59							6,190	3.58
SUGAR			1,687	0.98							36,074	20.86
ETHANOL			40	0.02	2	0.07					40	0.02
HCl									27	5.0		
NaOH												
AMYLASE												
GLUCOAMYLASE							70	100.0				
FOREIGN MATTER												
SOLUBLE SOLIDS			5,140	2.99							5,237	3.03
TOTAL	11,072	100.0	172,347	100.00	2,656	100.00	70	100.0	540	100.0	172,955	100.00

FIG. 2.3

No.	DATE	REVISIONS	BY	CHKD
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SCALE NONE | DESIGNED RIASAN MASON | DRAWN W. MASON

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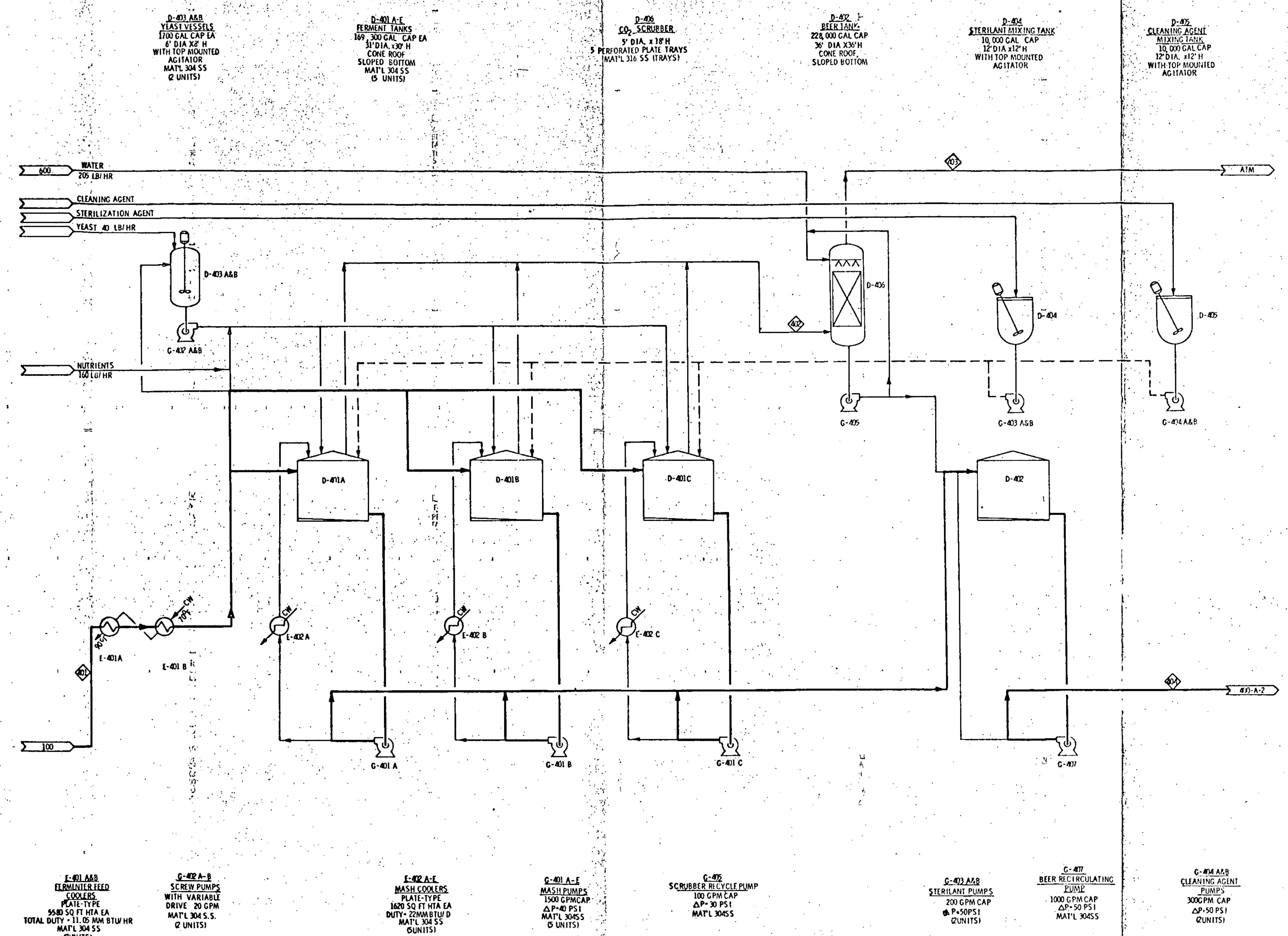
DEPARTMENT OF ENERGY

FLOW DIAGRAM
20 MM GAL/YR NOMINAL ETHANOL FACILITY
WHEAT PROCESSING

JOB No.	DRAWING No.	REV.
13412	30.0	0

34 x 44 "E" SIZE



STREAM	401 FERMENTER FEED		402 FERMENTER GAS		403 SCRUBBER OFF-GAS		404 BEER STILL FEED	
COMPONENTS	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT
WATER	139,696	77.86	335	1.91	205	1.18	139,187	85.25
SOLIDS - SOLUBLE	5,424	3.03					5,448	3.34
YEAST,PROTEIN&FIBER							859	0.53
ETHANOL			102	0.58	64	0.37	16,900	10.35
CARBON DIOXIDE	6	tr	17,111	97.31	17,110	98.25	107	0.06
FUSEL OIL			0.2	tr	tr		321	0.20
ALDEHYDE			35	0.20	34	0.20	447	0.27
SUCROSE	34,294	19.11						
TOTAL	179,420	100.00	17,583.2	100.00	17,413	100.00	163,269	100.00

FIG. 2.4

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SCALE NONE DESIGNED RIASAN/W.M. DRAWN W. MASON

BECHTEL
SAN FRANCISCO

DEPARTMENT OF ENERGY

FLOW DIAGRAM
20 MM GAL/YR NOMINAL ETHANOL FACILITY
SUGAR BEET FERMENTATION

JOB No.	DRAWING No.	REV.
13412	400-A-1	0

34 x 44 "E" SIZE

E-403
FEED/BOTTOMS INTERCHANGER
PLATE-TYPE
5825 SQ FT HTA
DUTY -6.5MM BTU/HR

C-401
BEER STILL
8' DIA. x 172' T-T
83 SIEVE TRAYS @ 24" TRAY SPACING
REFLUX - TRAY 1
SIDE DRAW - TRAY 9
FEED TRAYS 42
MAT'L: 304 SS TRAYS 42 - 83

D-409
B. S. OVERHEAD ACCUMULATOR
5500 GAL CAP
8'-0" DIA X 15' T-T

E-409
AZEO COLUMN REBOILER
THERMOSIPHON - TYPE
8700 SQ FT HTA
1" DIA 16 BWG TUBES X16'L
DUTY = 33.5 MM BTU/HR
STEAM - 200°F - SAT'D

C-402
AZEOTROPIC DISTILLATION COLUMN
9'-6" DIA x 112' T-T
53 VALVE TRAYS @ 24" SPACING
REFLUX - TRAY 1
FEED - TRAY 5

D-410
FUSEL OIL WASHER
845 GAL CAP
3'-0" DIA. x 16' T-T WITH 4'-0" DIA. X 3' T-T SETTLING DRUM

C-403
HYDROCARBON STRIPPER
3'-6" DIA X 60' T-T
27 VALVE TRAYS
@ 24" SPACING
REFLUX - TRAY 1
FEED - TRAY 11

E-404 A&B
REBOILERS
FORCED CIRCULATION PLATE-TYPE
6291 SQ FT HTA EA.
DUTY = 44.4 MM BTU/HR
STEAM -250°F SAT'D
(2 UNITS)

E-405
B. S. OVERHEAD CONDENSER (PARTIAL)/FEED PREHEATER
HORIZONTAL IN-SHELL TYPE
2450 SQ FT HTA
6 TUBE PASSES
1" DIA X 16 BWG X 24'L
DUTY = 5.3 MM BTU/HR

E-416
AZEO/STRIPPER FEED INTERCHANGER
SHELL & TUBE TYPE
85 SQ. FT. HTA.
2 TUBE PASSES,
5/8" DIA., 18 BWG. X 18'L
DUTY 0.34 MM BTU/HR

E-417
AZEO-FEED SUBCOOLER
SHELL & TUBE TYPE
60 SQ FT HTA
2 TUBE PASSES
5/8" DIA BWG X8'L
DUTY 0.44 MM BTU/HR

E-410
AZEO-COL. OVERHEAD CONDENSER (PARTIAL)
HORIZONTAL IN-SHELL TYPE
2600 SQ. FT. HTA.
6 TUBE PASSES
1" DIA. 16 BWG X 24' L
DUTY = 10 MM BTU/HR

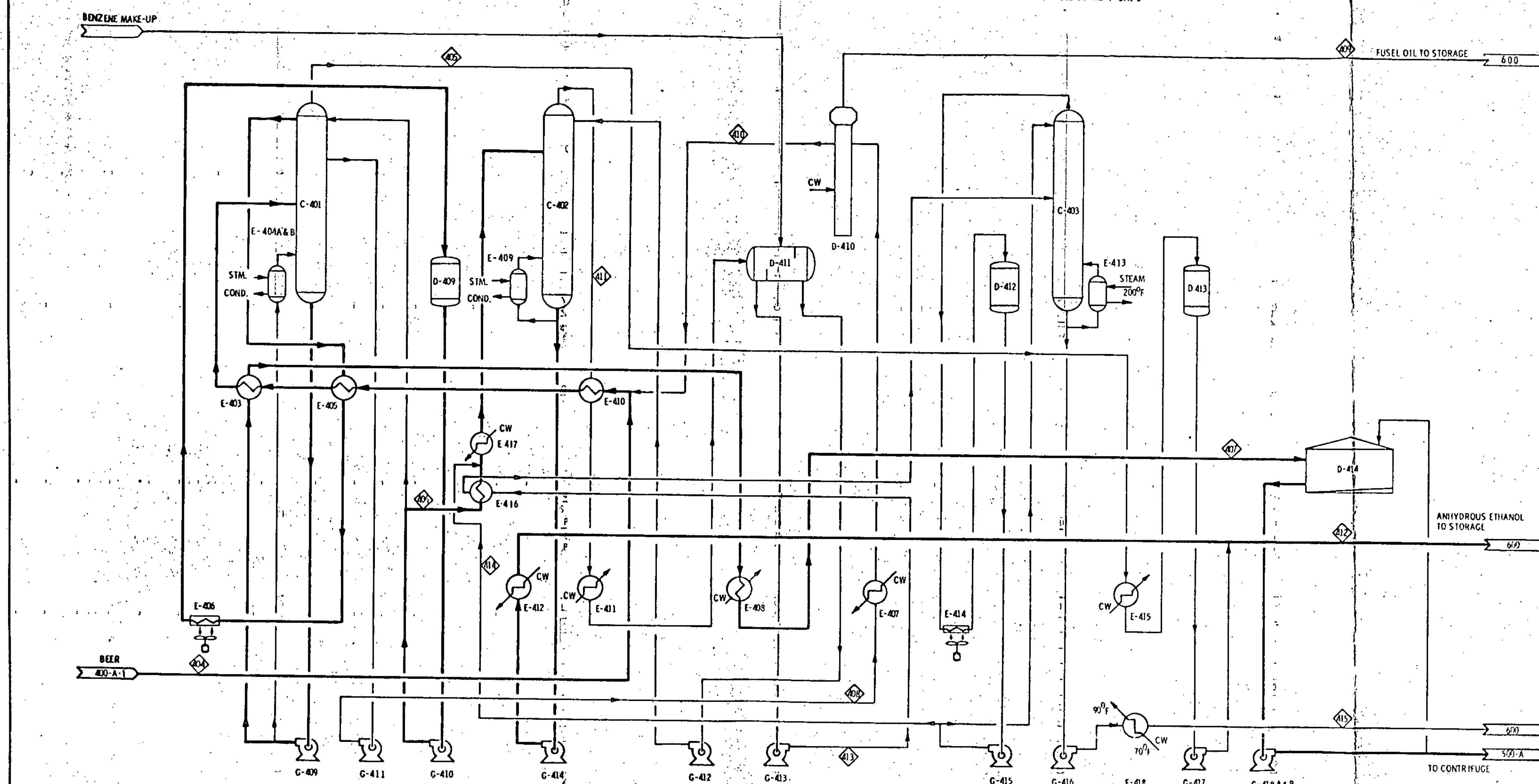
D-411
AZEO. OVERHEAD PHASE SEPARATOR
10,000 GAL CAP
9'-4" DIA. X 20' T-T
WITH SPLASH PLATE, BAFFLES & VORTEX BREAKERS

D-412
H. C. STRIPPER OVERHEAD ACCUMULATOR
1500 GAL CAP
4'-7" DIA X 12' T-T

E-413
H. C. STRIPPER REBOILER
THERMOSIPHON - TYPE
550 SQ FT HTA
1" DIA 16 BWG TUBES x 12' L
DUTY = 6.8 MM BTU/HR
STEAM = 225°F SAT'D

D-413
ALDEHYDE DEGASSER/ACCUMULATOR
420 GAL CAP
3'-0" DIA X 8' T-T

D-414
WHOLE STILLAGE TANK
27,200 GAL CAP
17'-0" DIA X 16'H
CONE ROOF, SLOPE BOTTOM



E-406
B. S. OVERHEAD SECONDARY CONDENSER (AIR-COOLED)
2 DOWNFLOW INCLINED BUNDLES
12' L X 12' W X 42" DEEP
13 ROWS, 1" DIA 12 BWG
FINNED TUBES
3700 SQ FT HTA (BARE METAL)
DUTY = 37.5 MM BTU/HR
150 H P FAN

E-412
ANHYDROUS ETHANOL COOLER
SHELL & TUBE TYPE
180 SQ FT HTA
2 TUBE PASSES
5/8" DIA 18 BWG X 20'L
DUTY = 0.9 MM BTU/HR

E-411
AZEO COL OVERHEAD SECONDARY CONDENSER
HORIZONTAL IN-SHELL TYPE
3000 SQ FT HTA
4 TUBE PASSES
1" DIA 16 BWG x 20' L
DUTY = 26.7 MM BTU/HR

E-408
STILLAGE COOLER
PLATE-TYPE
675 SQ FT HTA
DUTY = 8.96 MM BTU/HR

E-407
FUSEL OIL COOLER
SHELL & TUBE TYPE
10 SQ FT HTA
1 TUBE PASS
5/8" DIA. 18 BWG X 8'L
DUTY = 0.03 MM BTU/HR

E-414
STRIPPER OVERHEAD CONDENSER (AIR-COOLED)
2 DOWNFLOW INCLINED BUNDLES
10'L X 4'W X 40" DEEP
12 ROWS, 1" DIA 12 BWG
FINNED TUBES
1130 SQ FT HTA
DUTY = 6.43 MM BTU/HR
30 HP FAN

E-415
ALDEHYDE CONDENSER
HORIZONTAL IN-TUBE TYPE
115 SQ FT HTA
1 TUBE PASS
5/8" DIA. 18 BWG X 20'L
DUTY = 0.14 MM BTU/HR
(CHILLED WATER)

E-418
STRIPPER BOTTOMS COOLER
1 PASS SHELL & TUBE
20 SQ FT HTA
DUTY = 0.15 MM BTU/HR
5/8" DIA BWG X 8'L

G-409
BEER STILL BOTTOMS PUMP
1000 GPM CAP
ΔP=45 PSI

G-411
FUSEL OIL PUMP
1 GPM CAP
ΔP=50 PSI

G-410
B. S. REFLUX/PRODUCT PUMP
300 GPM CAP
ΔP=55 PSI

G-414
ANHYDROUS ETHANOL PRODUCT PUMP
50 GPM CAP
ΔP=55 PSI

G-412
AZEO. COLUMN REFLUX PUMP
300 GPM CAP
ΔP=55 PSI

G-413
STRIPPER FEED PUMP
25 GPM CAP
ΔP=35 PSI

G-415
STRIPPER REFLUX/PRODUCT PUMP
60 GPM CAP
ΔP=85 PSI

G-416
STRIPPER BOTTOMS PUMP
5 GPM CAP
ΔP=55 PSI

G-417
ALDEHYDE PRODUCT PUMP
2 GPM CAP
ΔP=35 PSI

G-418A&B
WHOLE STILLAGE PUMPS
300 GPM CAP
ΔP=25 PSI
(2 UNITS)

COMPONENTS	404 BEER STILL FEED LB/HR	%WT	405 ALDEHYDE LB/HR	%WT	406 AZEOTROPIC COL. FEED LB/HR	%WT	407 WHOLE STILLAGE LB/HR	%WT	408 FUSEL OIL LB/HR	%WT
WATER	139,187	85.25			2,284	11.93	136,933	95.57	15	4.12
SOLIDS-SOLUBLE	5,448	3.34					5,448	3.80		
YEAST, PROTEIN & FIBER	859	0.53					859	0.60		
ETHANOL	16,900	10.35			16,860	88.07	40	0.03	28	7.69
CARBON DIOXIDE	107	0.06	107	19.3						
FUSEL OIL	321	0.20							321	88.19
ALDEHYDE	447	0.27	447	80.7						
BENZENE										
TOTAL	163,269	100.00	554	100.00	19,144	100.00	143,280	100.00	364	100.00

COMPONENTS	409 FUSEL OIL (WASHED) LB/HR	%WT	410 FUSEL OIL WASH WATER LB/HR	%WT	411 AZEOTROPIC COL. OVHD LB/HR	%WT	412 ANHYDROUS ETHANOL LB/HR	%WT	413 STRIPPER FEED LB/HR	%WT	414 STRIPPER OVHD LB/HR	%WT	415 STRIPPER BTMS LB/HR	%WT
WATER	tr		45	61.6	3,643	2.82	tr		2,390	27.26	106	1.64	2,284	99.7
SOLIDS-SOLUBLE														
YEAST, PROTEIN & FIBER														
ETHANOL	tr		28	38.4	29,459	22.80	16,853	100	5,672	64.70	5,665	87.48	7	0.3
CARBON DIOXIDE														
FUSEL OIL	321	100.00	tr	tr										
ALDEHYDE														
BENZENE					96,104	74.38	tr		705	8.04	705	10.88	tr	tr
TOTAL	321	100.00	73	100.0	129,206	100.00	16,853	100	8,767	100.00	6,476	100.00	2,291	100.00

FIG. 2.5

NO.	DATE	REVISIONS	BY	CHKD
0		ISSUED FOR REPORT	WM	HWL

SCALE NONE | DESIGNED RIASAN | DRAWN KAWAGON

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SAN FRANCISCO

DEPARTMENT OF ENERGY

FLOW DIAGRAM
20 MM GAL/YR NOMINAL ETHANOL FACILITY
SUGAR BEET RECOVERY

JOB No.	DRAWING No.	REV.
13412	400-A-2	0

34 x 44 "E" SIZE

D-403 A&B
YEAST VESSELS
1700 GAL CAP EA
6' DIA X8' H
WITH TOP MOUNTED
AGITATOR
MAT'L 304 SS
(2UNITS)

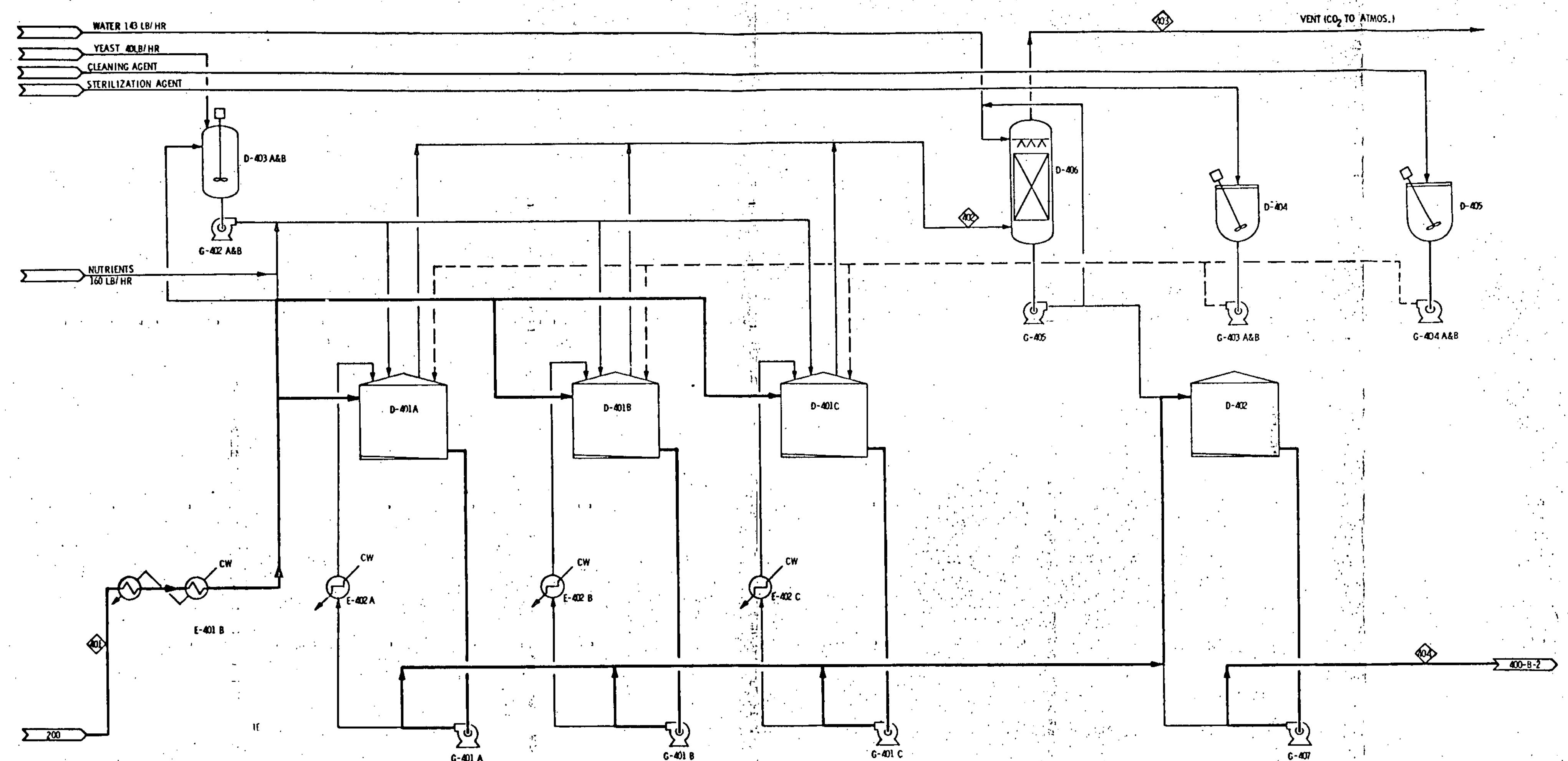
D-401 A-J
FERMENTERS
169, 300 GAL CAP EA
31' DIA. x30' H
CONE ROOF
SLOPED BOTTOM
MAT'L 304 SS
(10 UNITS)

D-406
CO_2 SCRUBBER
5' DIA. x 18' H
5 PERFORATED PLATE TRAYS
MAT'L 316 SS (TRAYS)

D-402
BEER TANK WELL
228, 000 GAL CAP
36' DIA X36' H
CONE ROOF,
SLOPED BOTTOM

D-404
STERILANT MIXER TANK
10, 000 GAL CAP
12' DIA x12' H
WITH TOP MOUNTED
AGITATOR

D-405
CLEANING AGENT
MIXER TANK
10, 000 GAL CAP
12' DIA. x12' H
WITH TOP MOUNTED
AGITATOR



E-401 A&B
FERMENTER FEED
COOLERS
PLATE-TYPE
5580 SQ FT HTA EA
TOTAL DUTY = 10.3 MM BTU/HR
MAT'L 304 SS
(2UNITS)

G-402 A-B
SCREW PUMPS
WITH VARIABLE
DRIVE 20 GPM
MAT'L 304 S.S.
(2 UNITS)

E-402 A-E
MASH COOLERS
PLATE-TYPE
1620 SQ FT HTA EA
DUTY= 22MM BTU/D
MAT'L 304 SS
(5UNITS)

G-401 A-E
MASH PUMPS
1500 GPMCAP
ΔP=40 PSI
MAT'L 304SS
(5 UNITS)

G-405
SCRUBBER RECYCLE
100 GPM CAP
ΔP= 30 PSI
MAT'L 304SS

G-403 A&B
STERILANT PUMPS
200 GPM CAP
ΔP=50PSI
(2UNITS)

G-407
BEER RECIRCULATING
PUMP
1000 GPM CAP
ΔP=50 PSI
MAT'L 304SS

G-404 A&B
CLEANING AGENT
PUMPS
300GPM. CAP
ΔP=50 PSI
(2UNITS)

STREAM	401 FERMENTER FEED		402 FERMENTER GAS		403 SCRUBBER OFF-GAS		404 BEER STILL FEED	
COMPONENTS	LB/ HR	%WT	LB/ HR	%WT	LB/ HR	%WT	LB/ HR	%WT
WATER	116, 089	69.4	336	1.9	143	0.8	116, 475	77.7
SOLIDS - SOLUBLE	179	0.1					179	0.1
YEAST, PROTEIN&FIBER	14, 868	8.9					15, 563	10.4
ETHANOL			96	0.5	49	0.3	16, 874	11.2
CARBON DIOXIDE	tr	tr	17, 150	97.4	17, 149	98.7	115	0.1
FUSEL OIL							321	0.2
ALDEHYDE			33	0.2	32	0.2	449	0.3
GLUCOSE	36, 030	21.6						
TOTAL	167, 166	100.0	17, 615	100.0	17, 373	100.0	149, 976	100.0

FIG 2.6

No.	DATE	REVISIONS	BY	CHKD
0	1-24-80	ISSUED FOR REPORT	WM	HWL

SCALE NONE · DESIGNED RIASAN/W.M. · DRAWN W. MASON

BECHTEL
SAN FRANCISCO

DEPARTMENT OF ENERGY

FLOW DIAGRAM
20 MM GAL /YR NOMINAL ETHANOL FACILITY
POTATO FERMENTATION

JOB No.	DRAWING No.	REV.
13412	400 - B - 1	0

34x44 "E" SIZE

E-403
FEED/BOTTOMS INTERCHANGER
PLATE-TYPE
5325 SQ FT HTA
DUTY =5.5MM BTU/HR

C-401
BEER STILL
8' DIA. x 172' T-T
83 SIEVE TRAYS @ 24" TRAY SPACING
REFLUX - TRAY 1
SIDE DRAW - TRAY 9
FEED TRAY 42
MAT'L: 304 SS TRAYS 42 - 83

D-409
B.S. OVERHEAD ACCUMULATOR
5500 GAL CAP
8'-0" DIA. X 15' T-T

E-409
AZEO COLUMN REBOILER
THERMOSIPHON - TYPE
8/00 SQ FT HTA
1" DIA. 16 BWG TUBES X16'L
DUTY =33.6 MM BTU/HR
STEAM = 200°F SAT'D

C-402
AZEOTROPIC DISTILLATION COLUMN
9'-6" DIA. x 112' T-T
53 VALVE TRAYS
@ 24" SPACING
REFLUX - TRAY 1
FEED-TRAY 5

D-410
FUSEL OIL WASHER
845 GAL CAP.
3'-0" DIA. x 16' T-T WITH
4'-0" DIA. X 3' T-T
SETTLING DRUM

C-403
HYDROCARBON STRIPPER
3'-6" DIA. X 60' T-T
27 VALVE TRAYS
@ 24" SPACING
REFLUX - TRAY 1
FEED-TRAY 11

E-404 A&B
REBOILERS (2)
FORCED CIRCULATION
PLATE-TYPE
6291 SQ. FT. HTA. EA.
DUTY = 44 MM BTU/HR
STEAM =250°F SAT'D

E-405
B.S. OVERHEAD CONDENSER (PARTIAL)/FEED PREHEATER
HORIZONTIAL IN-SHELL TYPE
2450 SQ. FT. HTA.
6 TUBE PASSES
1" DIA. X 16 BWG X 24' L
DUTY = 5 MM BTU/HR

E-416
AZEO/STRIPPER FEED INTERCHANGER
SHELL & TUBE TYPE
85 SQ. FT. HTA.
2 TUBE PASSES,
5/8" DIA., 18 BWG. X 18' L
DUTY=0.34MM BTU/HR

E-417
AZEO-FEED SUBCOOLER
SHELL & TUBE TYPE
60 SQ FT HTA
2 TUBE PASSES
5/8" DIA BWG X8' L
DUTY=0.5 MM BTU/HR

E-410
AZEO-COL. OVERHEAD CONDENSER (PARTIAL)
HORIZONTAL IN-SHELL TYPE
2600 SQ. FT. HTA.
6 TUBE PASSES
1" DIA. 16 BWG X 24' L
DUTY = 10 MM BTU/HR

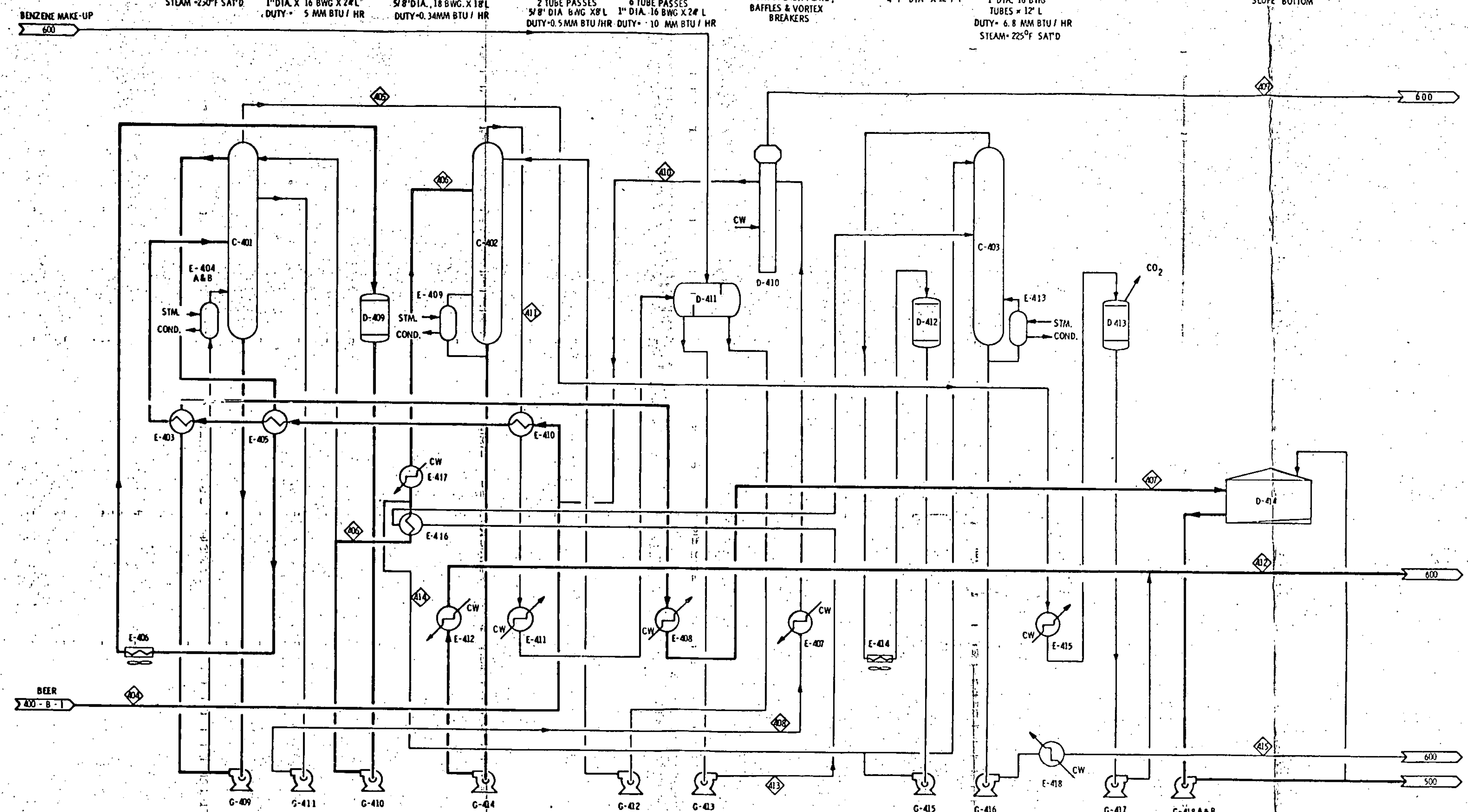
D-411
AZEO. OVERHEAD PHASE SEPARATOR
10,000 GAL CAP
9'-4" DIA. X 20' T-T
WITH SPLASH PLATE, BAFFLES & VORTEX BREAKERS

D-412
H.C. STRIPPER OVERHEAD ACCUMULATOR
1500 GAL CAP
4'-7" DIA X 12' T-T

E-413
H.C. STRIPPER REBOILER
THERMOSIPHON -TYPE
550 SQ FT HTA
1" DIA. 16 BWG TUBES x 12' L
DUTY = 6.8 MM BTU/HR
STEAM = 225°F SAT'D

D-413
ALDEHYDE DEGASSER/ACCUMULATOR
420 GAL CAP
3'-0" DIA X 8' T-T

D-414
WHOLE STILLAGE TANK
27,200 GAL CAP
17'-0" DIA. X 16'H
CONE ROOF, SLOPE BOTTOM



E-406
B.S. OVERHEAD SECONDARY CONDENSER (AIR-COOLED)
2 DOWNFLOW INCLINED BUNDLE
12' L X 12' W X 42" DEEP
13 ROWS, 1" DIA. 12 BWG
FINNED TUBES
3700 SQ. FT. HTA. (BARE METAL)
DUTY = 38 MM BTU/HR
150 H P FAN

E-412
ANHYDROUS ETHANOL COOLER
SHELL & TUBE TYPE
180 SQ FT HTA
2 TUBE PASSES
5/8" DIA. 18 BWG X 20' L
DUTY= 0.9MM BTU/HR

E-411
AZEO COL OVERHEAD SECONDARY CONDENSER
HORIZONTAL IN-SHELL TYPE
3000 SQ FT HTA
4 TUBE PASSES
1" DIA. 16 BWG x 20' L
DUTY = 27 MM BTU/HR

E-408
STILLAGE COOLER
PLATE-TYPE
675 SQ FT HTA
DUTY = 8 MM BTU/HR

E-407
FUSEL OIL COOLER
SHELL & TUBE TYPE
10 SQ FT HTA
1 TUBE PASS
5/8" DIA. 18 BWG X 8' L
DUTY= 0.03 MM BTU/HR

E-414
STRIPPER OVERHEAD CONDENSER (AIR-COOLED)
2 DOWNFLOW INCLINED BUNDLES
10' L X 4' W X 40" DEEP
12 ROWS, 1" DIA. 12 BWG
FINNED TUBES
1130 SQ FT HTA
DUTY= 6.4 MM BTU/HR
30 HP FAN

E-415
ALDEHYDE CONDENSER
HORIZONTAL IN-TUBE TYPE
115 SQ FT HTA
1 TUBE PASS
5/8" DIA. 18 BWG X 20' L
DUTY= 0.14 MM BTU/HR
(CHILLED WATER)

E-418
STRIPPER BOTTOMS COOLER
1 PASS SHELL AND TUBE
20 SQ FT HTA
DUTY = 0.15 MM BTU/HR
5/8" DIA. BWG X 8' L
MAT'L: 304 SS. TRAYS 42 - 83

G-409
BEER STILL BOTTOMS PUMP
1000 GPM CAP
ΔP=45 PSI

G-411
SIDE DRAW PUMP
1 GPM CAP
ΔP= 50 PSI

G-410
B.S. REFLUX/PRODUCT PUMP
300 GPM CAP
ΔP=55 PSI

G-414
ANHYDROUS ETHANOL PRODUCT PUMP
50 GPM CAP
ΔP=55 PSI

G-412
AZEO. COLUMN REFLUX PUMP
300 GPM CAP
ΔP=55 PSI

G-413
STRIPPER FEED PUMP
25 GPM. CAP.
ΔP=35 PSI

G-415
STRIPPER REFLUX/PRODUCT PUMP
60 GPM CAP
ΔP=85 PSI

G-416
STRIPPER BOTTOMS PUMP
5 GPM CAP
ΔP=55 PSI

G-417
ALDEHYDE PRODUCT PUMP
2 GPM CAP
ΔP=35 PSI

G-418 A&B
WHOLE STILLAGE PUMPS (2)
300 GPM CAP
ΔP=25 PSI

	404 BEER STILL FEED		405 ALDEHYDE		406 AZEOTROPIC COL. FEED		407 WHOLE STILLAGE		408 FUSEL OIL	
COMPONENTS	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT
WATER	116,475	77.66	tr	tr	2,294	11.99	114,211	87.86	15	4.12
SOLIDS-SOLUBLE	179	0.12					179	1377 PPM		
YEAST, PROTEIN & FIBER	15,563	10.38					15,563	11.97		
ETHANOL	16,874	11.25	tr	tr	16,840	88.01	34	262 PPM	28	7.69
CARBON DIOXIDE	115	0.08	115	20.39						
FUSEL OIL	321	0.21							321	88.19
ALDEHYDE	449	0.30	449	79.61						
BENZENE										
TOTAL	149,976	100.00	564	100.00	19,134	100.00	129,987	100.00	364	100.00

	409 FUSEL OIL (WASHED)		410 FUSEL OIL WASH WATER		411 AZEOTROPIC COL. OVHD		412 ANHYDROUS ETHANOL		413 STRIPPER FEED		414 STRIPPER OVHD		415 STRIPPER BTMS	
COMPONENTS	LB/HR.	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT
WATER	tr	tr	45	61.64	3,690	2.85			2,442	27.67	148	2.27	2,294	99.70
SOLIDS-SOLUBLE														
YEAST, PROTEIN & FIBER														
ETHANOL	tr	tr	28	38.36	29,483	22.80	16,840	100.00	5,679	64.36	5,672	86.95	7	0.30
CARBON DIOXIDE														
FUSEL OIL	321	100.00												
ALDEHYDE														
BENZENE					96,166	74.35	tr	tr	703	7.97	703	10.78		
TOTAL	321	100.00	73	100.00	129,339	100.00	16,840	100.00	8,824	100.00	6,523	100.00	2,301	100.00

FIG. 2.7

No.	DATE	REVISIONS	BY
0	1-24-80	ISSUED FOR REPORT	WM

SCALE NONE
DRAWN W. MASON

BECHTEL
SAN FRANCISCO

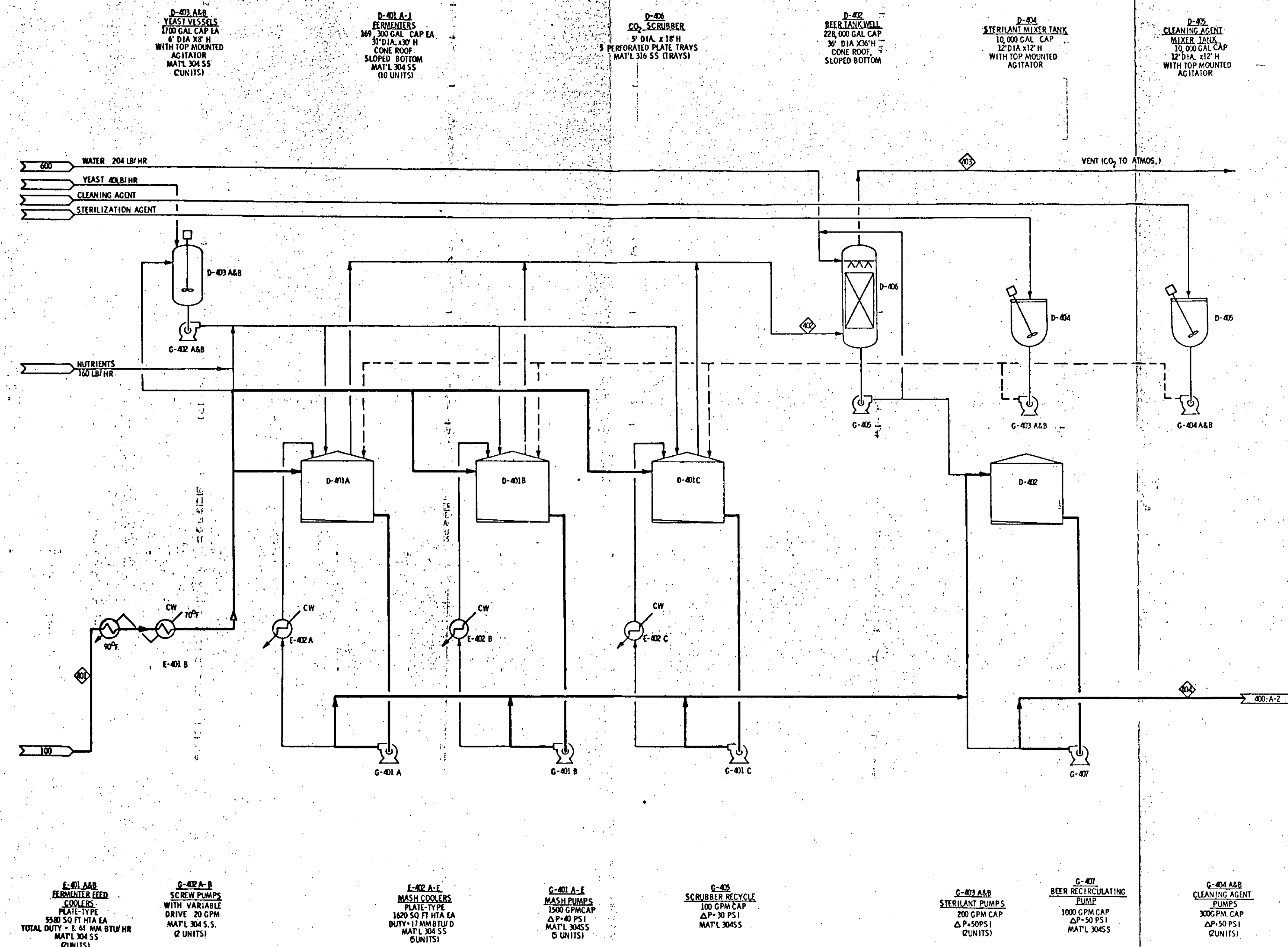
DEPARTMENT OF ENERGY

FLOW DIAGRAM
20 MM GAL/YR. NOMINAL ETHANOL FACILITY
POTATO ALCOHOL RECOVERY

JOB No.	DRAWING No.	REV.
13412	400 - B - 2	0

34 x 44 "E" SIZE

SIZE E



STREAM	401 FERMENTER FEED		402 FERMENTER GAS		403 SCRUBBER OFF-GAS		404 BEER STILL FEED	
COMPONENTS	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT
WATER	120,599	69.73	334	1.89	204	1.37	120,985	77.64
SOLIDS - SOLUBLE	5,237	3.03					5,237	3.36
YEAST,PROTEIN&FIBER	11,005	6.36					11,861	7.61
ETHANOL	40	0.02	117	0.66	70	0.40	16,911	10.85
CARBON DIOXIDE			17,208	97.20	17,207	98.20	82	0.05
FUSEL OIL			2.4	0.01	tr	tr	321	0.21
ALDEHYDE			41	0.24	40	0.23	441	0.28
GLUCOSE	36,074	20.86						
TOTAL	172,955	100.00	17,702.4	100.00	17,521	100.00	155,838	100.00

FIG. 2.8

NO.	DATE	REVISIONS	BY					
0	1-24-80	ISSUED FOR REPORT	S.E.	HWL				

SCALE NONE | DESIGNED RIASAN/W.M. | DRAWN W. MASON

BECHTEL
SAN FRANCISCO

DEPARTMENT OF ENERGY

FLOW DIAGRAM
20 MM GAL /YR NOMINAL ETHANOL FACILITY
WHEAT FERMENTATION

JOB No.	DRAWING No.	REV.
13412	400-C-1	0

34x44 "E" SIZE

E-403
FEED/BOTTOMS INTERCHANGER
PLATE-TYPE
5325 SQ FT HTA
DUTY = 6 MM BTU/HR

C-401
BEER STILL
8' DIA x 172' T-T
83 SIEVE TRAYS @
24" TRAY SPACING
REFLUX - TRAY 1
SIDE DRAW - TRAY 9
FEED TRAY 42
TRAYS 42-83: 304 SS

D-409
B. S. OVERHEAD ACCUMULATOR
5500 GAL CAP
8'-0" DIA X 15' T-T

E-409
AZEO COLUMN REBOILER
THERMOSIPHON - TYPE
8700 SQ. FT HTA
1" DIA. 16 BWG
TUBES X16'L
DUTY = 33.6 MM BTU/HR
STEAM = 200°F - SAT'D

C-402
AZEOTROPIC DISTILLATION COLUMN
9'-6" DIA x 112' T-T
53 VALVE TRAYS
@ 24" SPACING
REFLUX - TRAY 1
FEED-TRAY 5

D-410
FUSEL OIL WASHER
845 GAL CAP.
3'-0" DIA. x 16' T-T WITH
4'-0" DIA. X 3' T-T
SETTLING DRUM

C-403
HYDROCARBON STRIPPER
3'-6" DIA. X 60' T-T
27 VALVE TRAYS
@ 24" SPACING
REFLUX - TRAY 1
FEED-TRAY 11

E-404 A&B
REBOILERS (2)
FORCED CIRCULATION
PLATE-TYPE
6291 SQ FT HTA EA.
DUTY = 44.1 MM BTU/HR
STEAM = 250°F SAT'D

E-405
B. S. OVERHEAD CONDENSER (PARTIAL)/FEED PREHEATER
HORIZONTIAL IN-SHELL TYPE
2450 SQ FT HTA
6 TUBE PASSES
1" DIA. X 16 BWG X 24'L
DUTY = 4.95 MM BTU/HR

E-416
AZEO/STRIPPER FEED INTERCHANGER
SHELL & TUBE TYPE
85 SQ FT HTA
2 TUBE PASSES
5/8" DIA., 18 BWG X 18'L
DUTY=0.34 MM BTU/HR

E-417
AZEO-FEED SUBCOOLER
SHELL & TUBE TYPE
60 SQ FT HTA
2 TUBE PASSES
5/8" DIA BWG X8'L
DUTY=0.5MM BTU/HR

E-410
AZEO-COL. OVERHEAD CONDENSER (PARTIAL)
HORIZONTAL IN-SHELL TYPE
2600 SQ FT HTA
6 TUBE PASSES
1" DIA. 16 BWG X 24' L
DUTY = 9.43 MM BTU/HR

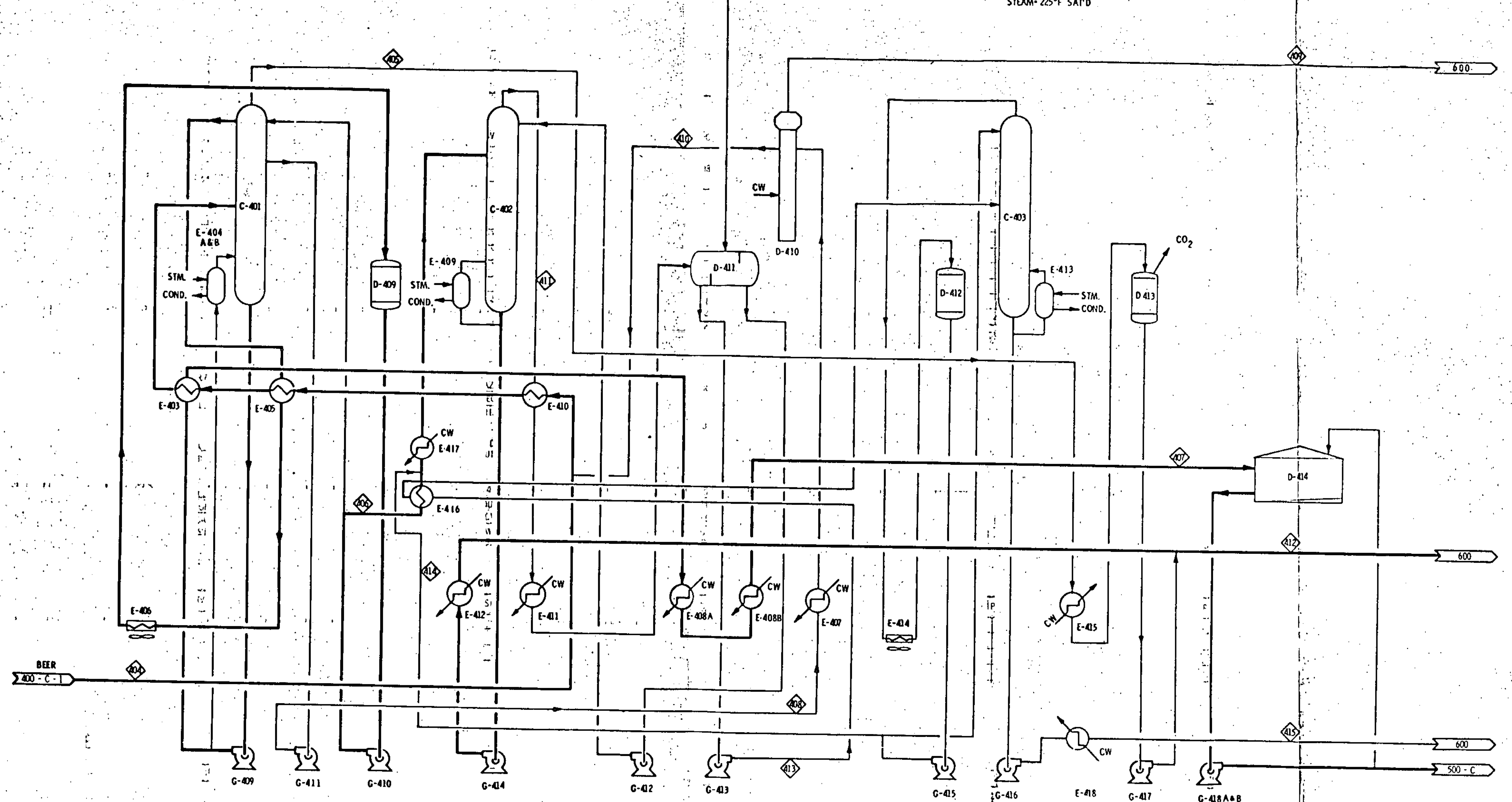
D-411
AZEO. OVERHEAD PHASE SEPARATOR
10,000 GAL CAP
9'-4" DIA. X 20' T-T
WITH SPLASH PLATE,
BAFFLES & VORTEX
BREAKERS

D-412
H.C. STRIPPER OVERHEAD ACCUMULATOR
1500 GAL CAP
4'-7" DIA X 12' T-T

E-413
H.C. STRIPPER REBOILER
THERMOSIPHON -TYPE
550 SQ FT HTA
1" DIA. 16 BWG
TUBES x 12' L
DUTY = 6.82 MM BTU/HR
STEAM = 225°F SAT'D

D-413
ALDEHYDE DEGASSER/ACCUMULATOR
420 GAL CAP
3'-0" DIA X 8' T-T

D-414
WHOLE STILLAGE TANK
27,200 GAL CAP
17'-0" DIA. X 16'H
CONE ROOF,
SLOPE BOTTOM



E-406
B. S. OVERHEAD SECONDARY CONDENSER (AIR-COOLED)
2 DOWNFLOW INCLINED BUNDLE
12' L X 12' W X 42" DEEP
13 ROWS, 1" DIA. 12 BWG
FINNED TUBES
3700 SQ FT HTA (BARE METAL)
DUTY = 38.2 MM BTU/HR
150 HP FAN

E-412
ANHYDROUS ETHANOL COOLER
SHELL & TUBE TYPE
180 SQ FT HTA
2 TUBE PASSES
5/8" DIA. 18 BWG X 20'L
DUTY=0.92 MM BTU/HR

E-411
AZEO COL OVERHEAD SECONDARY CONDENSER
HORIZONTAL IN-SHELL TYPE
3000 SQ FT HTA
4 TUBE PASSES
1" DIA. 16 BWG x 20' L
DUTY = 27.2 MM BTU/HR

E-408
STILLAGE COOLER
PLATE-TYPE
675 SQ FT HTA
DUTY = 4.2 MM BTU/HR
PLATE-TYPE 300 SQ FT HTA
DUTY=3.8 MM BTU/HR

E-407
FUSEL OIL COOLER
SHELL & TUBE TYPE
10 SQ FT HTA
1 TUBE PASS
5/8" DIA. 18 BWG X 8'L
DUTY = 0.03 MM BTU/HR

E-414
STRIPPER OVERHEAD CONDENSER (AIR-COOLED)
2 DOWNFLOW INCLINED BUNDLES
10'L X 4'W X 40" DEEP
12 ROWS, 1" DIA. 12 BWG
FINNED TUBES
1130 SQ FT HTA
DUTY = 6.42 MM BTU/HR
30 HP FAN

E-415
ALDEHYDE CONDENSER
HORIZONTAL IN-TUBE TYPE
115 SQ FT HTA
1 TUBE PASS
5/8" DIA. 18 BWG X 20'L
DUTY = 0.13 MM BTU/HR
(CHILLED WATER)

E-418
STRIPPER BOTTOMS COOLER
1 PASS SHELL & TUBE
20 SQ FT HTA
DUTY: 0.15 MM BTU/HR
5/8" DIA BWG X 8' L

G-409
BEER STILL BOTTOMS PUMP
1000 GPM CAP
ΔP=45 PSI

G-411
SIDE DRAW PUMP
1 GPM CAP
ΔP=50 PSI

G-410
B. S. REFLUX/PRODUCT PUMP
300 GPM CAP
ΔP=55 PSI

G-414
ANHYDROUS ETHANOL PRODUCT PUMP
50 GPM CAP
ΔP=55 PSI

G-412
AZEO. COLUMN REFLUX PUMP
300 GPM CAP
ΔP=55 PSI

G-413
STRIPPER FEED PUMP
25 GPM CAP
ΔP=35 PSI

G-415
STRIPPER REFLUX/PRODUCT PUMP
60 GPM CAP
ΔP=85 PSI

G-416
STRIPPER BOTTOMS PUMP
5 GPM CAP
ΔP=55 PSI

G-417
ALDEHYDE PRODUCT PUMP
2 GPM CAP
ΔP=35 PSI

G-418A&B
WHOLE STILLAGE PUMPS (2)
300 GPM CAP
ΔP=25 PSI

	404 BEER STILL FEED		405 ALDEHYDE		406 AZEOTROPIC COL. FEED		407 WHOLE STILLAGE		408 FUSEL OIL		409 FUSEL OIL (WASHED)		410 FUSEL OIL WASH WATER		411 AZEOTROPIC COL. OVHD		412 ANHYDROUS ETHANOL		413 STRIPPER FEED		414 STRIPPER OVHD		415 STRIPPER BTMS	
COMPONENTS	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT
WATER	120,985	77.64	tr	tr	2,283	11.92	118,733	87.39	15	4.12	tr		45	61.6	3,638	2.82	tr		2,387	27.29	104	1.61	2,283	99.7
SOLIDS-SOLUBLE	5,237	3.36					5,237	3.85																
YEAST, PROTEIN & FIBER	11,861	7.61					11,861	8.73																
ETHANOL	16,911	10.85	tr		16,872	88.08	40	0.03	28	7.69	tr		28	38.4	29,412	22.80	16,865	100.00	5,661	64.70	5,654	87.54	7	0.3
CARBON DIOXIDE	82	0.05	82	15.68																				
FUSEL OIL	321	0.21	tr						321	88.19	321	100.00	tr	tr										
ALDEHYDE	441	0.28	441	84.32																				
BENZENE															95,956	74.38			701	8.01	701	10.85	tr	tr
TOTAL	155,838	100.00	523	100.00	19,155	100.00	135,871	100.00	364	100.00	321	100.00	73	100.00	129,006	100.00	16,865	100.00	8,749	100.00	6,459	100.00	2,290	100.00

FIG. 2.9

NO.	DATE	REVISIONS	BY					
0	1-24-80	ISSUED FOR REPORT	SE WM	HWL				

SCALE NONE — DESIGNED RIASAN, MASON — DRAWN W MASON

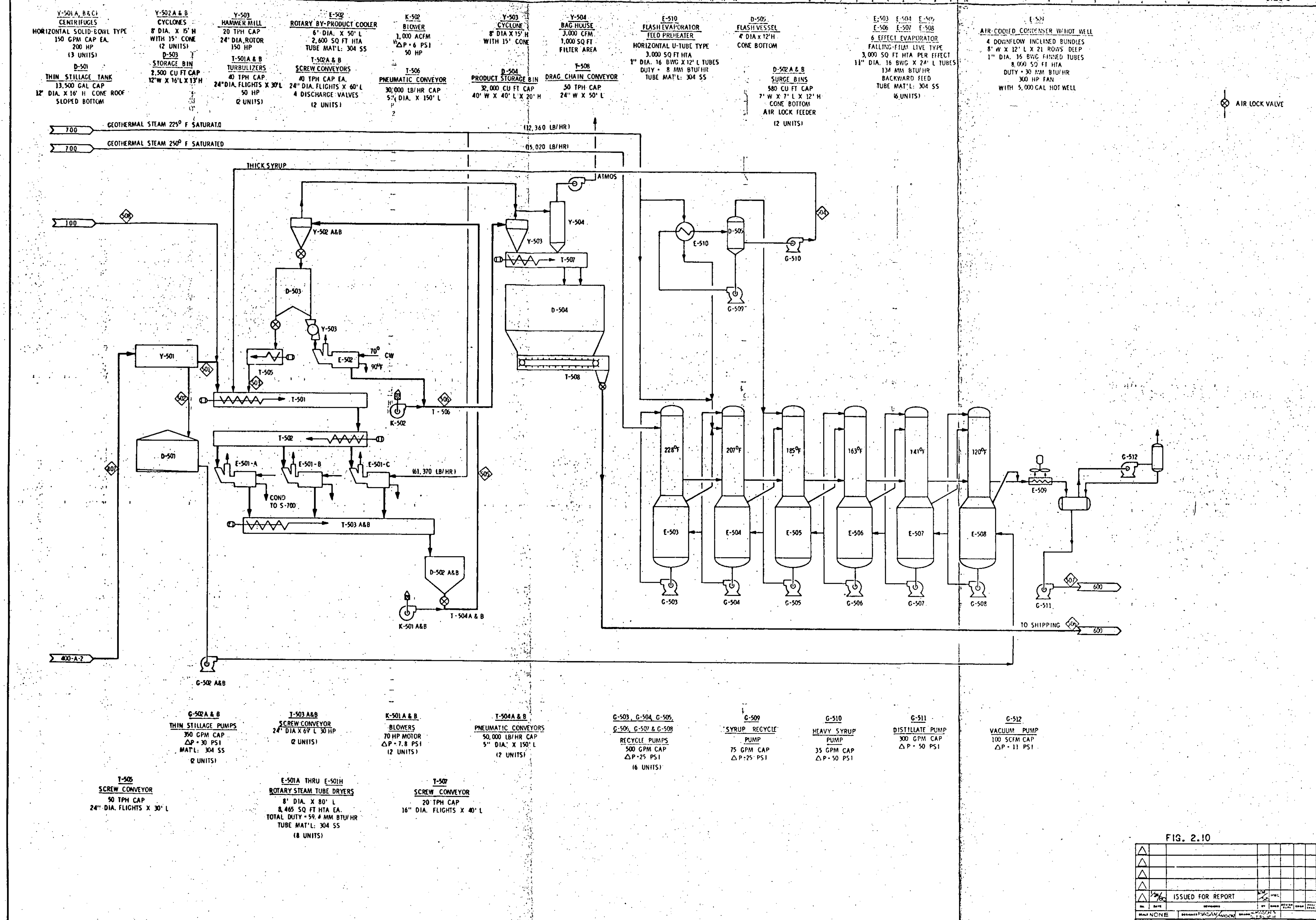
BECHTEL
SAN FRANCISCO

DEPARTMENT OF ENERGY

FLOW DIAGRAM
20 MM GAL/YR NOMINAL ETHANOL FACILITY
WHEAT ALCOHOL RECOVERY

JOB No.	DRAWING No.	REV.
13412	400 - C - 2	0

34 x 44 "E" SIZE



COMPONENTS	407 WHOLE STILLAGE LB/HR	WT	501 STILLAGE CAKE LB/HR	% WT	502 STILLAGE CENTRATE LB/HR	% WT	503 RECYCLE SOLIDS LB/HR	% WT	504 RECYCLE SYRUP LB/HR	% WT	505 BY PRODUCT TOTAL LB/HR	% WT	506 BY PRODUCT NET LB/HR	% WT	507 WASTE WATER LB/HR	% WT	508 PRESSED PULP LB/HR	% WT
ETHANOL	40	0.03	1	0.04	39	0.03									39	0.03	2	tr
WATER	136,993	99.57	1,487	62.48	135,446	96.13	4,779	10.00	5,415	50.00	6,873	10.00	2,095	10.00	130,031	99.97	50,183	80.00
BENZENE																		
SOLIDS-SOLUBLE	5,448	3.80	59	2.48	5,389	3.82	15,968	33.42	5,389	49.76	22,968	33.42	7,000	33.42			1,552	2.47
YEAST, PROTEIN, FIBER	859	0.60	833	35.00	26	0.02	27,039	56.58	26	0.24	38,892	56.58	11,853	56.58			10,994	17.53
TOTAL	143,280	100.00	2,380	100.00	140,900	100.00	47,786	100.00	10,830	100.00	68,733	100.00	20,948	100.00	130,070	100.00	62,731	100.00

FIG. 2.10

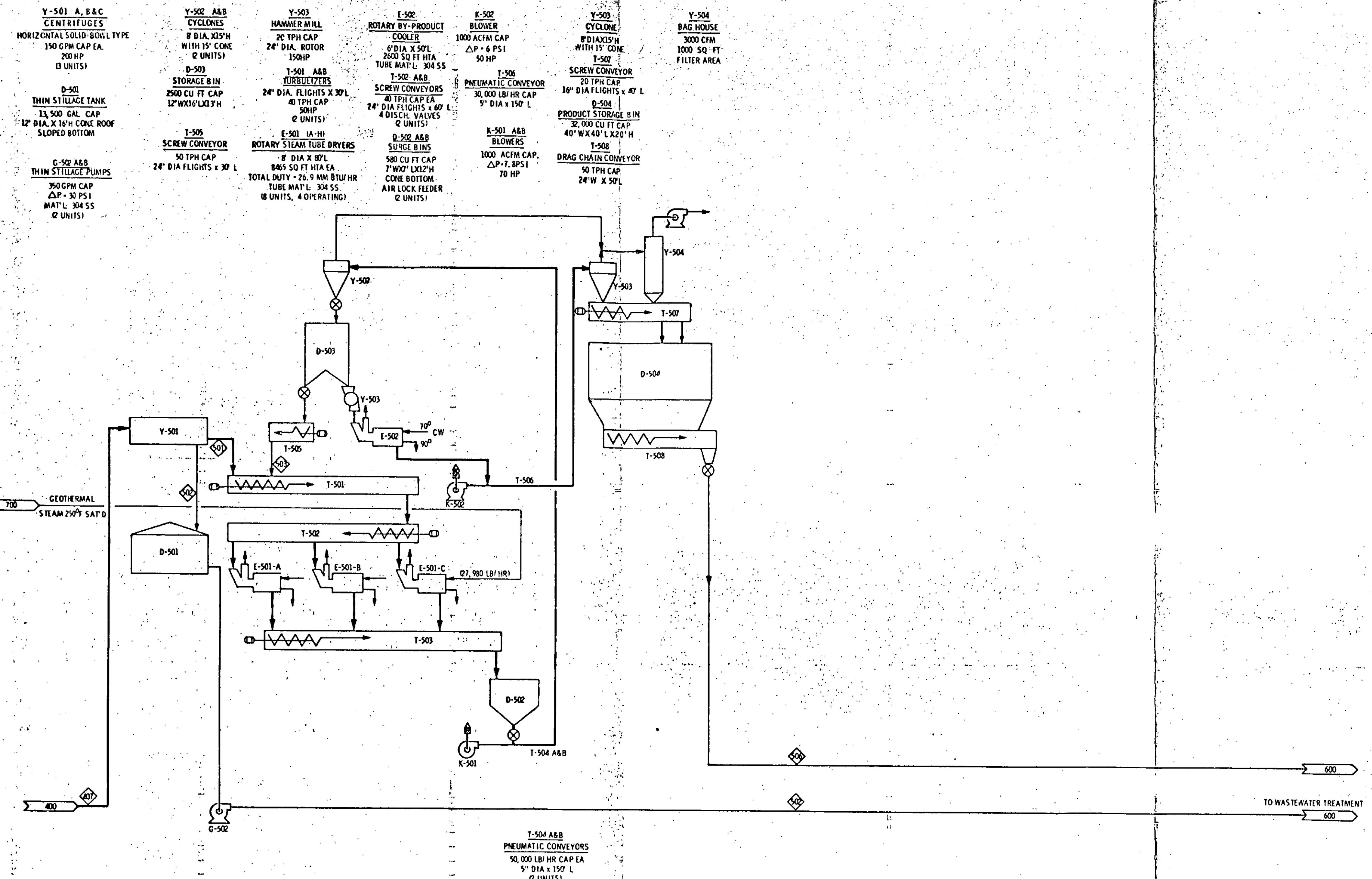
ISSUED FOR REPORT

BECHTEL
SAN FRANCISCO

DEPARTMENT OF ENERGY

FLOW DIAGRAM
20 MM GAL/YR NOMINAL ETHANOL FACILITY
SUGAR BEET ALCOHOL BY-PRODUCT

JOB NO. 13412 DRAWING NO. 500-A REV. 0



	407 WHOLE STILLAGE		501 STILLAGE CAKE		502 STILLAGE CENTRATE		503 RECYCLE SOLIDS		506 BY-PRODUCT-NET	
COMPONENTS	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT
ETHANOL	34	264 PPM	9	0.02	25	0.03			tr	
WATER	114,211	87.86	28,560	64.88	85,651	99.63	978	10.00	1,717	10.00
SOLIDS, SOLUBLE	179	1377 PPM	45	0.10	134	0.16				
YEAST, PROTEIN, FIBER	15,563	11.97	15,407	35.00	156	0.18	8,806	90.00	15,452	90.00
TOTAL	129,981	100.00	44,021	100.00	85,966	100.00	9,784	100.00	17,169	100.00

FIG. 2.11

No.	DATE	REVISIONS	BY	CHKD
0	1/24/80	ISSUED FOR REPORT	WM	JRL

SCALE NONE | DESIGNED RIASAN/MASON | DRAWN W MASON

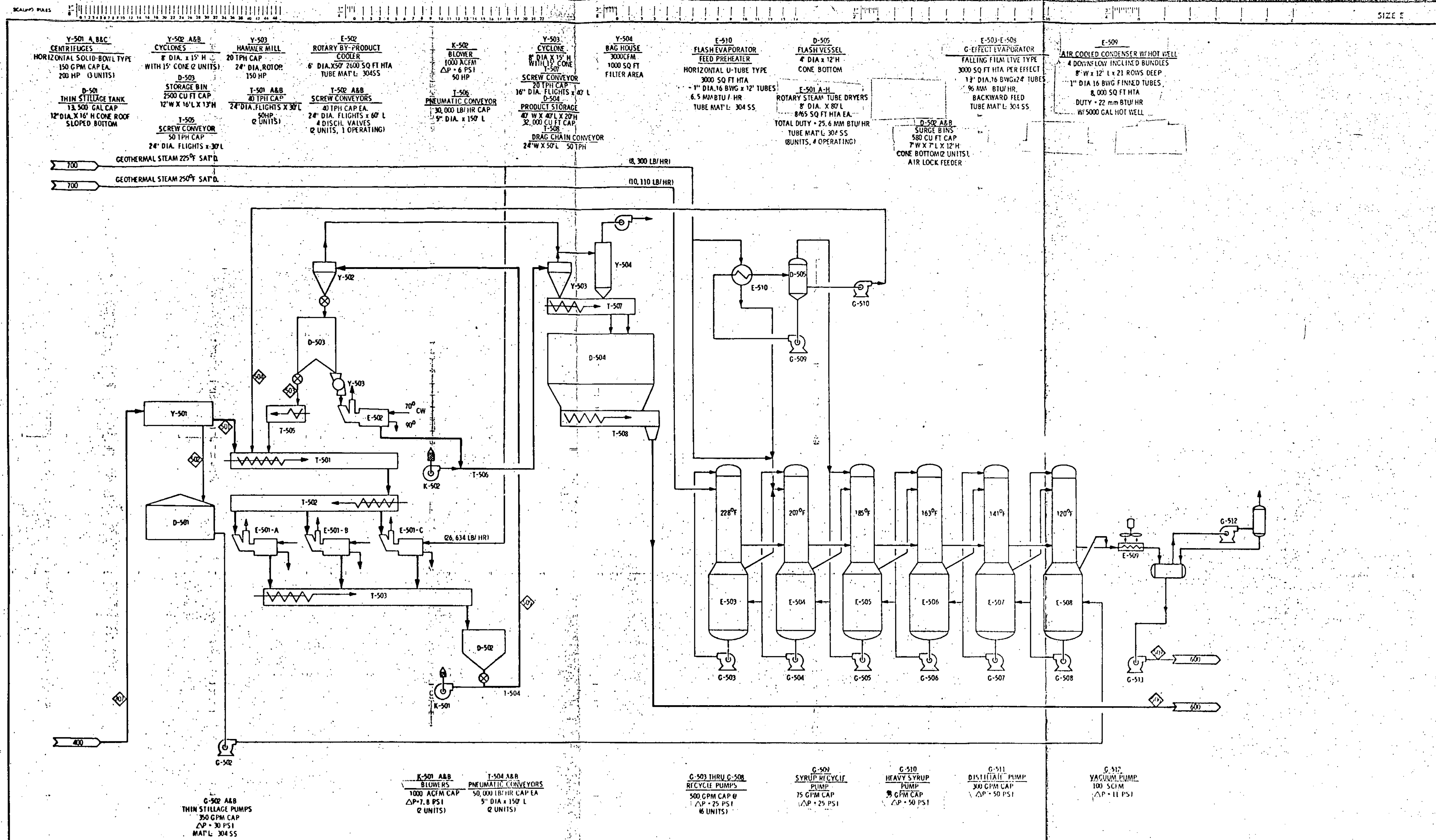
BECHTEL
SAN FRANCISCO

DEPARTMENT OF ENERGY

FLOW DIAGRAM
20 MM GAL/YR NOMINAL ETHANOL FACILITY
POTATO ALCOHOL BY-PRODUCT

JOB No.	DRAWING No.	REV.
13412	500-B	0

34 x 44 "E" SIZE



COMPONENTS	400 WHOLE STILLAGE		501 STILLAGE CAKE		502 STILLAGE CENTRATE		503 RECYCLE SOLIDS		504 RECYCLE SYRUP		505 BY PRODUCT TOTAL		506 BY PRODUCT -NET		507 WASTE WATER		508 PRESSED PULP	
	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT	LB/HR	%WT
ETHANOL	40	0.03	7	0.02	33	0.03	tr		tr						33	0.04		
WATER	118,733	87.39	20,875	62.23	97,858	95.63	2,782	10.00	4,437	50.00	4682	10.00	1,900	10.00	93,421	99.96		
BENZENE																		
SOLIDS-SOLUBLE	5,237	3.85	921	2.75	4,316	4.22	5,738	23.44	4,316	48.64	10,975	23.44	5,237	23.44				
YEAST, PROTEIN, FIBER	11,861	8.73	11,740	35.00	121	0.21	19,297	66.56	121	1.36	31,158	66.55	11,861	66.56				
TOTAL	135,871	100.0	33,543	100.00	102,328	100.00	27,817	100.00	8,874	100.00	46,815	100.00	18,998	100.00	93,454	100.00		

FIG. 2.12

NO.	DATE	REVISIONS	BY	CHKD
0	1/24/80	ISSUED FOR REPORT	WM/SG	HOC

SCALE NONE | DESIGNER RIASAN/MASON | DRAWN MASON S. EELICH

BECHTEL
SAN FRANCISCO

DEPARTMENT OF ENERGY

FLOW DIAGRAM
20 MM GAL/YR NOMINAL ETHANOL FACILITY
WHEAT ALCOHOL BY-PRODUCT

JOB NO. 13412 | DRAWING NO. 500-C | REV. 0

34 x 44 "E" SIZE

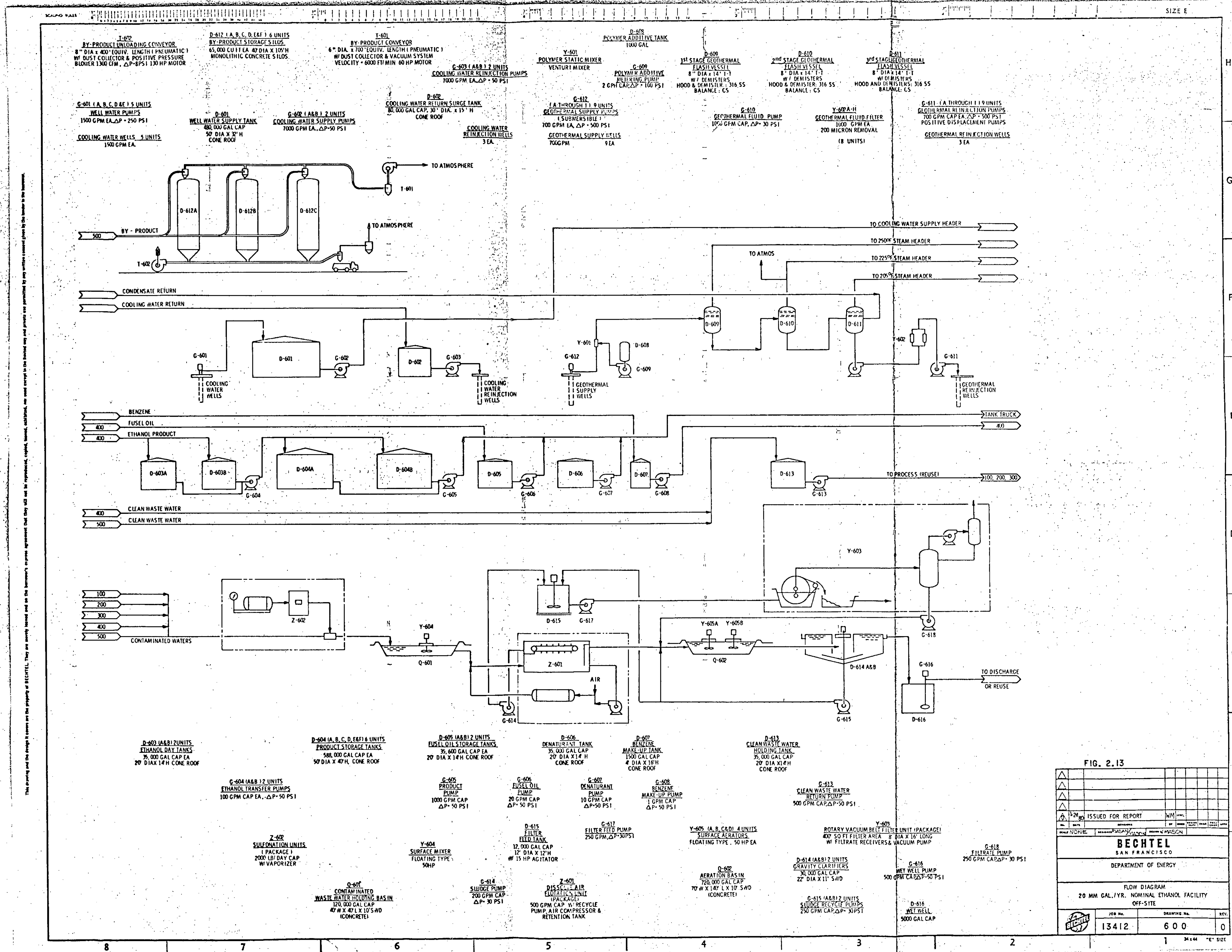

T-602
BY-PRODUCT UNLOADING CONVEYOR
D-612 (A, B, C, D, E&F) 6 UNITS
BY-PRODUCT STORAGE SILOS
65,000 CU FT EA 40' DIA X 105'H
MONOLITHIC CONCRETE SILOS
T-601
BY-PRODUCT CONVEYOR
G-603 (A&B) 2 UNITS
COOLING WATER REINJECTION PUMPS
7000 GPM EA. ΔP = 50 PSI
D-608
POLYMER ADDITIVE TANK
1000 GAL
Y-601
POLYMER STATIC MIXER
VENTURI MIXER
G-609
POLYMER ADDITIVE METERING PUMP
D-609
1st STAGE GEOTHERMAL FLASH VESSEL
D-610
2nd STAGE GEOTHERMAL FLASH VESSEL
D-611
3rd STAGE GEOTHERMAL FLASH VESSEL
G-601 (A, B, C, D & E) 5 UNITS
WELL WATER PUMPS
1500 GPM EA. ΔP = 250 PSI
COOLING WATER WELLS 5 UNITS
1500 GPM EA.
D-601
WELL WATER SUPPLY TANK
480,000 GAL CAP
50' DIA X 32' H
CONE ROOF
G-602 (A&B) 2 UNITS
COOLING WATER SUPPLY PUMPS
7000 GPM EA. ΔP = 50 PSI
D-602
COOLING WATER RETURN SURGE TANK
80,000 GAL CAP, 30' DIA. x 15' H
CONE ROOF
COOLING WATER REINJECTION WELLS
3 EA.
G-612
GEOTHERMAL SUPPLY PUMPS
GEOTHERMAL SUPPLY WELLS
G-610
GEOTHERMAL FLUID PUMP
Y-602
GEOTHERMAL FLUID FILTER
200 MICRON REMOVAL
G-611
GEOTHERMAL REINJECTION PUMPS
POSITIVE DISPLACEMENT PUMPS
GEOTHERMAL REINJECTION WELLS
3 EA
TO ATMOSPHERE
BY - PRODUCT
D-612A
D-612B
D-612C
TO COOLING WATER SUPPLY HEADER
TO 250 PSI STEAM HEADER
TO 225 PSI STEAM HEADER
TO 205 PSI STEAM HEADER
TO ATMOS
CONDENSATE RETURN
COOLING WATER RETURN
COOLING WATER WELLS
COOLING WATER REINJECTION WELLS
GEOTHERMAL SUPPLY WELLS
GEOTHERMAL REINJECTION WELLS
BENZENE
FUSEL OIL
ETHANOL PRODUCT
TANK TRUCK
TO PROCESS (REUSE)
100, 200, 300
D-603A
D-603B
D-604A
D-604B
D-605
D-606
D-607
D-613
CLEAN WASTE WATER
CONTAMINATED WATERS
Z-602
Y-604
Q-601
D-615
G-617
Z-601
AIR
G-614
Y-605A
Y-605B
Q-602
D-614 A&B
G-615
Y-603
G-618
G-616
D-616
TO DISCHARGE OR REUSE
D-603 (A&B) 2 UNITS
ETHANOL DAY TANKS
35,000 GAL CAP EA
20' DIA X 14' H CONE ROOF
D-604 (A, B, C, D, E&F) 6 UNITS
PRODUCT STORAGE TANKS
588,000 GAL CAP EA
50' DIA X 40' H, CONE ROOF
D-605 (A&B) 2 UNITS
FUSEL OIL STORAGE TANKS
35,000 GAL CAP EA
20' DIA X 14' H CONE ROOF
D-606
DENATURANT TANK
35,000 GAL CAP
20' DIA X 14' H
CONE ROOF
D-607
BENZENE MAKE-UP TANK
1500 GAL CAP
8' DIA X 16' H
CONE ROOF
D-613
CLEAN WASTE WATER HOLDING TANK
35,000 GAL CAP
20' DIA X 14' H
CONE ROOF
G-604 (A&B) 2 UNITS
ETHANOL TRANSFER PUMPS
100 GPM CAP EA. ΔP = 50 PSI
G-605
PRODUCT PUMP
1000 GPM CAP
ΔP = 50 PSI
G-606
FUSEL OIL PUMP
20 GPM CAP
ΔP = 50 PSI
G-607
DENATURANT PUMP
10 GPM CAP
ΔP = 50 PSI
G-608
BENZENE MAKE-UP PUMP
1 GPM CAP
ΔP = 50 PSI
G-613
CLEAN WASTE WATER RETURN PUMP
500 GPM CAP ΔP = 50 PSI
Z-602
SULFONATION UNITS
(PACKAGE)
2000 LB/DAY CAP
W/ VAPORIZER
Y-604
SURFACE MIXER
FLOATING TYPE
50HP
D-615
FILTER FEED TANK
12,000 GAL CAP
12' DIA X 12' H
W/ 15 HP AGITATOR
G-617
FILTER FEED PUMP
250 GPM ΔP = 30 PSI
Y-605 (A, B, C&D) 4 UNITS
SURFACE AERATORS
FLOATING TYPE, 50 HP EA
Y-603
ROTARY VACUUM BELT FILTER UNIT (PACKAGE)
W/ FILTRATE RECEIVERS & VACUUM PUMP
G-618
FILTRATE PUMP
250 GPM CAP ΔP = 30 PSI
Q-601
CONTAMINATED WASTE WATER HOLDING BASIN
120,000 GAL CAP
(CONCRETE)
G-614
SLUDGE PUMP
200 GPM CAP
ΔP = 30 PSI
Z-601
DISSOLVED AIR FLOTATION UNIT
(PACKAGE)
500 GPM CAP W/ RECYCLE
PUMP, AIR COMPRESSOR &
RETENTION TANK
Q-602
AERATION BASIN
720,000 GAL CAP
(CONCRETE)
D-614 (A&B) 2 UNITS
GRAVITY CLARIFIERS
30,000 GAL CAP
22' DIA X 11' SWD
G-615 (A&B) 2 UNITS
SLUDGE RECYCLE PUMPS
250 GPM CAP ΔP = 30 PSI
G-616
WET WELL PUMP
500 GPM CAP ΔP = 50 PSI
D-616
WET WELL
5000 GAL CAP
ISSUED FOR REPORT
BECHTEL
SAN FRANCISCO
DEPARTMENT OF ENERGY
FLOW DIAGRAM
20 MM GAL./YR. NOMINAL ETHANOL FACILITY
OFF-SITE
13412
600
0
SIZE E

FIG. 2.13

2.2.1 Design Basis

Table 2-1 presents the assumed composition of the winter wheat processed in the plant. As delivered, wheat is assumed to contain up to twenty percent (on a clean wheat basis) inert foreign matter, including rocks, sand and field dust. Dry cleaning removes this foreign matter.

Wheat is processed 24 hours per day, seven days per week at a design stream factor of 90 percent. Table 2-2 indicates the principal design basis for each process section. Figure 2.3 is a process flow diagram of wheat processing Section 300.

2.2.2 Receiving and Storage

Wheat is shipped from local elevators to the ethanol facility by end-dump trailer trucks. Upon arrival at the gate, the trucks are weighed and proceed to a dump station. A hydraulic truck lift elevates the truck and trailer, dumping the wheat into a hopper that is equipped with dust control hooding. An under-hopper belt conveyor transfers the wheat to a bucket elevator. The bucket elevator discharges wheat onto an elevated transfer conveyor which feeds four 90,000 bushel capacity storage bins. Total storage capacity is sufficient for two weeks operation.

2.2.3 Wheat Cleaning and Grinding

The stored wheat is cleaned dry and ground whole to prepare it as a substrate for starch conversion and fermentation. The wheat is pneumatically conveyed from the storage bins to a surge bin ahead of the scalper. The shaker-screen type scalper removed sticks, stones, stalks and similar offal present in the uncleaned wheat. The screened wheat then passes through an aspirator which employs currents of air directed through the dispersed falling wheat to separate light (dust, fibers, chaff) and heavy (sand) materials from the grain. The separated debris is collected for land disposal.

Table 2-1

AVERAGE WHEAT COMPOSITION

CLEAN BASIS

Component	% Weight
Moisture	9.50
Starch	61.45
Sugars	3.35
Protein & Fat	12.29
Fibers	9.56
Soluble Solids	10.05
Total	100.00

Table 2-2

PRINCIPAL DESIGN BASES - WHEAT PROCESSING

(3 months/year)

Receiving and Storage	
Receiving periods	daylight hours, 7-days per week
Carrier	20-ton net tractor-trailers (end dump)
Loads per day	29
Storage capacity	360,000 bushels (14-days)
Reclaim rate	1070 bushels per hour (dirty)
Cleaning and Grinding	
Type of cleaning	screening and gravity separation
Grinding capacity	1000 bushels per hour
Stage of milling	4 (roller mills)
Size reduction	-20 mesh (99%)
Starch Liquefaction	
Crude starch slurry	30% wt dry solids
pH	6.5
Temperature	221°F
Enzyme dosage	0.1% wt on D.S.
Cooking time & temperature	5 minutes @ 221°F
Holding time & temperature	90 minutes @ 203°F
Dextrose equivalent	10-14
Saccharification	
Enzyme dosage	0.15 gal/1000 lb D.S.
Holding time	45 hours
Temperature	140° F
pH	4.5
Starch conversion	95+%

The cleaned wheat is fed by a rotary valve into a surge bin and then into a dump scale for weighing. The wheat is ground to -20 mesh in four stages of reduction by roller mills. No physical separation of kernel components is attempted. The ground wheat is discharged to a surge bin.

2.2.4 Liquefaction

A rotary valve feeds the crude wheat flour into a 10,000 gallon mixing tank. Warm condensate is added to make up a slurry containing 30 percent dry solids. Two percent sodium hydroxide is added to the mixed tank contents to adjust the slurry pH to 6.5. Alpha amylase is added to the crude starch slurry in-line as the slurry is pumped to three parallel steam injectors (hydroheaters). About 11,070 pounds per hour of 250° F steam is added to raise the slurry temperature to 221° F for gelatinization and cooking of the starch. The starch slurry is cooked for five minutes in a tubular coil and then flash-cooled to 203° F. The flash-cooled slurry enters a six-stage baffled hold tank which provides ninety minutes retention time. An agitator is provided in each baffled section to prevent settling of the suspended matter. The hold tank effluent is cooled in a plate-type exchanger to 140° F and five percent hydrochloric acid is added in-line to reduce the cooled slurry pH to 4.5.

2.2.5 Saccharification

Glucoamylase is added to the liquefied starch slurry to break down starch dextrins to fermentable glucose. This conversion takes place in five 170,000 gallon vessels providing about 45 hours total retention time. Each vessel has a steam jacket to maintain the contents at 140° F. Each vessel is also equipped with an agitator to mix the contents during the hold period.

The saccharification equipment is the same as that used for potato processing reported in the previous quarterly report. The glucose content of the saccharified slurry is about 20.8 percent.

The geothermal energy requirement for Section 300 is about 10.5 million Btu per hour or 4,110 Btu per gallon of ethanol product.

2.2.6 Fermentation and Distillation - Section 400

Figures 2.8 and 2.9 present the fermentation and distillation process flow diagrams for wheat processing. The equipment is identical to that used in beet and potato processing.

2.2.6.1 Fermentation

The fermentation reactions are the same as in the potato case. The saccharified slurry is cooled to 80° F prior to fermentation. Fermentation is carried out batchwise in ten 170,000 gallon fermenters to yield a net 2,555 gallons per hour of ethanol. Fermenter off-gas is water-scrubbed prior to atmospheric discharge. The fermenter product contains about 10.4 percent ethanol by weight.

2.2.6.2 Distillation

Distillation of the fermenter product is carried out in the same manner as in the beet and potato cases. Fermented beer from the beer well is preheated by exchange with the condensing vapors of the azeotropic column overhead and the beer still overhead and with the beer still bottoms. There is sufficient heat recovered to provide a bubble-point condition feed to the beer still.

The beer still is a 8 ft. I. D. by 172-ft high column containing 83 sieve trays. It is operated at a pressure of 25 psia at the bottom of the column which corresponds to about the maximum temperature that can be achieved using the available 250° F geothermal steam as the heating medium.

Steam to two forced-circulation plate-type reboilers provides the required 44 million Btu per hour heat input. Fusel oil concentrates in the upper part of the column and is removed as a side-draw, cooled, and water washed in a separate fusel oil washer. The alcohol and water recovered from the fusel oil is returned to the beer still feed. Washed fusel oil is pumped to storage. Aldehydes produced by side reactions in the fermentation are removed as an overhead stream and condensed. The aldehydes are reblended with the ethanol product. An 88 percent ethanol/ 12 percent water mixture is taken from tray 1 and condensed. Reflux is returned to the top tray and the product portion of the overhead is cooled to the bubble-point condition for feed to the azeotropic column. The beer still bottoms stream, mainly water and solids, is cooled and sent to the whole stillage tank.

The azeotropic distillation column is 9.5 ft ID by 112 ft high and contains 53 valve trays. Benzene is used to form a ternary azeotrope with the ethanol-water mixture in the column. Water is removed in the overhead stream. The overhead is condensed, cooled and collected in a phase separator. The benzene rich-layer is recycled to the top tray of the azeotropic column. The water-rich layer is fed to a hydrocarbon stripper. The azeotropic column bottoms is virtually 200 proof ethanol. This stream, about 2555 gallons per hour, is cooled and pumped to product storage. Heat for the thermosiphon reboiler is supplied by condensing sub-atmospheric 205° F steam.

The hydrocarbon stripper is a 3.5 ft I.D. by 60 ft high column containing 27 valve trays. The water-rich feed is stripped of benzene in the column yielding an aqueous bottoms stream containing about 0.3 weight percent ethanol. The hydrocarbon-rich overhead stream is condensed. Part is returned as reflux and part is recycled to the azeotropic column feed. Geothermal steam at 225° F is used in the stripper reboiler. The total geothermal energy requirement for Section 400 is about 84.5 million Btu/hr or 33,000 Btu per gallon of ethanol product.

2.2.7 Byproduct Recovery - Section 500

Figure 2.12 illustrates the by-product recovery scheme for wheat processing. The whole stillage contains insoluble solids (yeast, protein and fiber) and soluble solids, mostly originating from the wheat. The stillage is centrifuged to produce a thin stillage (centrate) and a 35 percent solids stream for drying. The thin stillage is collected in a tank for syrup recovery.

A six-effect evaporator system is used to concentrate the thin stillage to a medium syrup. Falling film type long tube vertical evaporator units are used. The system is operated with backward feed (to the sixth effect) and 250° F geothermal steam supplied to the first effect. Vapor from the first effect is supplemented with 225° F geothermal steam to provide the heat for evaporation in the second effect. Each effect has a recycle pump to provide uniform distribution of the liquor at the top of the tube bundle. The medium syrup concentrate from the first effect is sent to a flash evaporator for further concentration. Geothermal steam at 225° F is used to preheat the flash evaporator feed. Flash vapor is routed to the third evaporator effect and the heavy syrup (50 percent solids) is pumped to the solids drying system. Vapor from the first effect is condensed in an air-cooled condenser. A rotary vacuum pump maintains the condensate system at the desired condensing pressure. The combined condensate is pumped to Section 600. The syrup concentration system has an overall economy of about five.

The solids drying system produces a 10 percent moisture material that is to be sold as an animal feed. The centrifuged solids are mixed with heavy syrup and recycled dry solids in a turbulizer to produce a 40 percent moisture stream as the feed to the geothermal steam-tube dryers. Four rotary steam-tube dryers dry 35 tons per hour of feed to 10 percent moisture. Geothermal steam at 225° F is used as the heating medium. The dried material is collected in a surge bin. Part is recycled to the dryers. The net product, 19.5 tons per hour, is fed through a hammer mill for size reduction and then cooled prior to conveyance to the byproduct intermediate storage bin.

The geothermal energy requirements for byproduct recovery total about 43.2 million Btu per hour or about 16,900 Btu per gallon of ethanol product.

2.3 UTILITIES AND OFFSITES - SECTION 600

Section 600 contains product and byproduct storage facilities, cooling water supply and reinjection facilities and wastewater handling facilities. Figure 600 illustrates these systems which are common to all three feedstocks.

Dried solids from Section 500 are pneumatically conveyed to six storage silos each with a capacity of 1300 tons. Thirty days of storage is provided at the maximum production rate (beet case) of 10.5 tons per hour. The byproduct is shipped offsite in tractor-trailors which are loaded pneumatically at a loadout station.

Process and cooling water are supplied to the processing units from a well water system. Air coolers are used where practical to reduce the cooling water requirements. At design conditions the maximum cooling water demand is about 6000 gpm. Six of the total seven wells can provide this demand. A well water surge tank provides a 80 minute supply to the suction of the cooling water supply pumps (1-100 percent spare). Warm cooling water from the process exchangers is returned to a small surge tank from which it is returned to the groundwater aquifer through three reinjection wells.

Hydrocarbon storage facilities are isolated in a tank farm. Two 35,000 gal. ethanol dry tanks provide intermediate storage for ethanol from Section 400. Six product tanks provide an additional 3 1/2 million gallons of storage capacity equivalent to two months of production. Ethanol product is shipped from the plant in tank trucks. Denaturant is metered in during tank truck loading at the truck loading station. Vapor recovery systems are provided for the tanks and the loading station. Two fusel oil tanks also provide two months storage of fusel oil production. It can be blended with the product alcohol or shipped offsite by separate tank trucks. A 1500 gallon benzene tank provides the storage for a year's benzene makeup requirements.

Process wastewaters are segregated into two types, (1) clean condensates and, (2) contaminated wastes. Clean wastes are collected in a surge tank and pumped back to processing sections for reuse. These wastes contain only small amounts of ethanol as a contaminant and are used for flume, wash water and diffusion water makeup in beet processing and for starch slurry makeup in wheat processing. Only the hydrocarbon stripper bottoms is available as clean wastewater in the potato processing case. It normally would be used as part of the potato wash water.

Contaminated wastes include blowdown water from the silt ponds (beets and potatoes), potato mash centrate, fermenter cleaning wastes, stillage centrate (potatoes) and general wash down water. The peak waste flow is about 500 gpm (during potato processing). Waste treatment consists of equalization, dissolved air flotation (DAF) and activated sludge treatment. The mixed equalization basin provides four hours of detention. Most of the suspended matter is removed in a DAF unit. DAF effluent is biologically treated to remove soluble organics and the biological solids are removed in two parallel gravity clarifiers. Clarifier overflow is pumped either to discharge or to reuse in front end processing. The sludge streams are combined and vacuum filtered for onsite disposal in a landfill. A sulfonation unit is provided to detoxify the sterilization chemical used in fermenter cleaning.

2.4 MODIFICATIONS TO BEET PROCESSING - SECTION 100

Three significant modifications in the beet processing section were made since the first quarterly report: (1) change to a three-level geothermal steam system from a pressurized geothermal brine system to supply the plant's heat energy requirements (all feedstock cases), (2) change to a four-effect thin juice concentration system from a two-effect concentration system, and (3) change to a non-consumptive cooling water system from the proposed evaporative system.

The three-level geothermal steam system is more compatible with the energy needs of the ethanol production facility and is discussed in a subsequent section of this report.

The 4-effect thin juice concentration system (see Figure 2.1) reduces the geothermal energy requirement by increasing the steam economy through the use of more evaporator effects. The backward feed system does not generate steam for diffuser heating; so diffuser steam is now on a separate low pressure loop.

The use (non-consumptive) of well water for process cooling instead of an evaporative cooling system should be more compatible with the water-short environment of the Raft River area. At high process temperatures, air coolers instead of water coolers are used to minimize the groundwater pumping requirements. Maximum heat rejection to the groundwater will be about 60 million Btu per hour. The groundwater reinjection wells (see Figure 600) will need to be spaced properly so that the heat load is dissipated without significantly increasing the groundwater supply temperature.

2.5 GEOTHERMAL ENERGY REQUIREMENTS

Geothermal energy requirements (steam) for the production of ethanol from beets, from potatoes, and from wheat are summarized below. Beet conversion requires about 50 percent more geothermal energy than either of the other two feedstocks. The beet byproduct recovery section (Section 500-A) is a particularly large energy consumer. The higher (gross) heating value of ethanol is about 86,770 Btu per gallon. The geothermal energy input represents a fairly large part of the thermal energy value of the product ethanol.

	Beets MM Btu/hr	Potatoes MM Btu/hr	Wheat MM Btu/hr
Section 100	37.4	-	-
Section 200	-	17.4	-
Section 300	-	-	10.5
Section 400	84.7	84.4	84.5
Section 500	85.4	29.1	43.2
Total	207.5	130.9	138.2
Btu consumed/gal ethanol produced	81,180	51,250	54,030

Section 3

GEOTHERMAL RESOURCE REQUIREMENTS

3.1 PROCESS CONDITIONS

All process heating for the ethanol facility will be provided by steam at temperatures between 200° F and 250° F. As indicated in the first quarterly report[(1)], this heat can be supplied by geothermal fluid, in the form of fluid under pressure, steam produced by flashing, or a secondary working fluid.

While the Raft River geothermal fluid is low in salinity, it still has the potential to deposit scale on heat transfer surfaces. Much of the process equipment in the ethanol production plant incorporates heating surfaces, such as vessel jackets and hollow-flyte conveyors that are extremely difficult to de-scale. As a result, the direct use of hot geothermal fluid was discarded.

Binary fluid systems would essentially require doubling the overall plant heat transfer surface, and were thus eliminated as being too expensive.

Multiple temperature steam heating systems are routinely used in chemical process plants. Heat transfer rates with condensing steam are uniformly high, and not susceptible to appreciable fouling. In addition, control of heat to individual users is simple and uses equipment already familiar to the industry. Balancing heat flow at the various temperature levels can be done in such a way as to minimize geothermal fluid flow.

In order to provide clean steam from flashing geothermal fluid, it is necessary to separate the fluid droplets containing dissolved solids. This can be accomplished by employing separation technology now used in salt evaporators. Separation efficiencies over 99.9% in this type of equipment is typical. Flash vessels using evaporator de-entrainment design criteria should be able to provide steam containing less than 10 mg/l dissolved solids from geothermal sources.

3.2 GEOTHERMAL WATER FLOW REQUIREMENT

Using a multistage flashing system to provide heating steam to the process, the total geothermal fluid flow can be approximated by equation 3.1.

$$G = \frac{Q}{(h_1 - h_2)\ Cp} \qquad (3.1)$$

Where
G = geothermal brine flow
Q = heat requirement
h_1 = brine enthalpy at inlet to system
h_2 = brine enthalpy at discharge conditions
Cp = fluid heat capacity

In practice, this equation is used to calculate the fluid flow into each flash vessel, allowing for the vapor production in upstream vessels. The minimum fluid flow is then found where the enthalpy change for fluid flowing from stage to stage exactly matches the heat requirement for users at that temperature level.

3.3 GEOTHERMAL FLUID PROPERTIES AND SCALE CONTROL

The expected range of geothermal fluid chemical properties is shown in Table 3-1[(2)].

Scaling by calcium carbonate takes place in alkaline geothermal brine, such as at Raft River, when the brine pressure is dropped, allowing free carbon dioxide to be released. Deposition and fouling under these conditions can be dramatically severe, often causing plugging in process equipment and piping in a matter of days[(3)]. This phenomenon can be largely controlled by the addition of "threshold" type inhibitors to the brine, upstream of the flash point[(4)]. These inhibitors, typically organic

Table 3-1

EXPECTED GEOTHERMAL FLUID PROPERTIES

Constituent	Analysis Range, mg/l
Sodium	300 - 1000
Potassium	30 - 100
Calcium	30 - 130
Strontium	1 - 5
Magnesium	0.5 - 1.0
Lithium	1.0 - 3.5
Chloride	500 - 2000
Fluoride	4 - 6
Sulfate	30 - 50
Bicarbonate	25 - 50
Silica	125 - 150
pH	7.0 - 7.5

Potential scaling problems with this brine can be expected from three major species:

- Calcium Carbonate
- Strontium Sulfate
- Silica

phosphonates, acrylates, or polymers of maleic anhydride are added to the raw brine in concentration of 1 to 5 mg/l. A number of these compounds have been tested and found either biologically inert or FDA approved for use in drinking water[5].

Both strontium sulfate and silica in the geothermal brine will exceed their solubility limits when the brine is cooled. This would tend to cause deposition in heat exchangers, especially if the fluid velocities are low and residence time unknown. The "threshold" inhibitors have shown some effectiveness for strontium sulfate, but will not prevent silica deposition. Fortunately, however, in a flashing brine situation, the release of carbon dioxide causes the brine pH to increase, thus increasing silica solubility. In addition, the kinetics of silica deposition are extremely slow. If a system is designed so that silica solubility is not greatly exceeded, and if residence time is kept short, say less than one hour from the flashing point to reinjection, silica deposition is very unlikely.

Section 4

GEOTHERMAL ENERGY EXTRACTION SYSTEM

The geothermal energy supply system is designed to provide heat to the ethanol plant in such a way as to:

- Provide all heat users at the proper temperature level.
- Avoid scaling of process heat transfer equipment.
- Minimize geothermal brine flow requirements.

This is done through the use of a multistage flash steam supply. In some cases, large heat users such as the multi-effect evaporators for beet juice and stillage concentration are designed to accept steam at two temperature levels, in order to balance heat loads.

The multistage flash system provides steam at approximately 250° F, 225° F and 205° F. By transferring the energy from geothermal brine to the process with steam, scaling of complex heat transfer surfaces in dryers, jacketed vessels, and evaporators is avoided.

The design of the geothermal energy supply system is illustrated in the flow diagram for offsites (Figure 2.13). Geothermal fluid from each well is pumped individually to the energy extraction system. Here, a scale control additive is metered into the brine by a positive displacement pump and mixed with a static mixer. The fluid then flows to the first flash vessel, where the pressure is reduced to produce steam at 250° F. The flow of geothermal fluid is adjusted to maintain the 250° temperature.

The flashed liquid then flows to the second stage flash vessel, which is maintained at 225° F. A small amount of steam is vented to the atmosphere from the second stage for control purposes.

In the third stage, the liquid is flashed to approximately 205° F. The third stage temperature is allowed to float, depending on the steam demands.

From the third flash stage, the brine is withdrawn by a transfer pump, and routed through parallel multi-media filters for removal of any suspended solids. After filtration the liquid is routed to the individual reinjection wells, where high pressure pumps force the cooled liquid back into the receiving strata.

The flash vessels as well as major system piping are constructed of mild steel. The system is designed for 600 psig and full vacuum, according to ASME Section VIII code. The flash vessels, each 8 feet in diameter by 14 feet high are designed to handle up to 125% of the rated flow of flashing liquid. Each vessel is equipped with a two stage entrainment separator which can be washed with condensate to reduce the potential for plugging. The vessels are also equipped with manholes for inspection and cleaning access, if necessary.

Section 5

CAPITAL COST ESTIMATE

5.1 INTRODUCTION

The capital cost estimate for the overall ethanol production facility has been prepared. In order to provide a comparison, the three feedstocks cases were also costed as separate plants each with its own handling, fermentation, processing facilities sized individually to produce 20 million gallons/year of anhydrous ethanol. The cost of the geothermal production facility, including production wells, reinjection wells and energy extraction facilities, are estimated separately. Table 5-1 summarized the estimates:

Table 5-1

Construction Capital Cost Estimate Summary

	$MM
Overall ethanol plant	64.0
Ethanol plant using sugar beets only	51.6
" " " potatoes only	43.1
" " " wheat only	40.4
Geothermal facility	18.0

5.1.1 Ethanol Plant

The ethanol plant, as previously described, utilizing agricultural crops as its feedstock, is located on a site in the south central section of Idaho. The location has been chosen as the plant is designed to utilize the low temperature geothermal energy and feedstocks available in the area. The plant is sized to produce 20 million gallons of ethanol (200 proof) per year and its feedstocks are sugar beets, potatoes and wheat. The major facilities in the plant are three separate feedstock handling sections, fermentation and distillation, by-product processing, product storage, wastewater treatment, yard facilities and utilities. These three feedstocks are integrated to operate on a year-round basis and form the base case.

The three feedstocks are also considered as separate plants, each with its own handling, fermentation, processing, etc., facilities, sized individually to produce 20 million gallons of ethanol, still however operating on a year-round basis on the assumption that feedstocks are continually available. The impact of varying operating periods with different feedstocks to optimize capital write-offs will be addressed during the next quarter.

5.1.2 Geothermal Facility

In order to supply the heat requirements of the ethanol plant, the geothermal facility, including nine supply wells and nine reinjection wells, is located on a quarter square mile area near the ethanol plant. Also included in the facility are pumps, filters, flash tanks and piping for geothermal supply and condensate return.

5.2 ESTIMATE BASIS

The estimates are based on the conceptual design and engineering information prepared for the study in the form of engineering flow diagrams, outline specifications, and equipment lists. Estimating methods consistent with the conceptual nature of the design information were employed and rely on informal vendor contact as well as extrapolation from Bechtel historical information.

The cost estimate is composed of field costs, engineering services and contingency. The largest category, field costs, comprises the direct cost of permanent plant equipment and the indirect cost of temporary construction materials, supervision, etc. that are to be distributed across the entire facility. The estimate anticipates an engineer-constructor direct-hire operation employing field construction labor forces.

5.2.1 Pricing Levels

The estimate has been prepared at first quarter, 1980, price and wage levels. No allowance has been made for future escalation.

5.2.2 Field Construction Costs

The direct field construction costs of permanent plant equipment, materials, subcontracts and construction labor have been included in the estimate on the basis of the following discussion:

5.2.2.1 Equipment

Budgetary quotations based on conceptual designs and specifications were obtained verbally or in writing for approximately 70% of the equipment items. Some of the major items are:

- Beet Washer
- Continuous Slope Diffuser
- Pulp Presses
- Trash Screen and Sump
- Rock Catcher
- Beet Slicer
- Potato Mash Pump
- Rotary Steam-Tube Dryer

- Potato Mash Centrifuge
- Centrifugal Separator
- Distillation Columns and Trays
- Cooling Water Wells
- Vacuum Filter
- Gravity Clarifier
- Geothermal Wells & Pumps

5.2.2.2 Bulk Material

The cost of bulk materials including piping, instrumentation, electrical, civil and structural were estimated as a percentage of the mechanical equipment based on similar plants, historical information and recent studies.

5.2.2.3 Construction Labor

The construction labor costs for the installation of the plant equipment are based on labor contracts and fringe benefits for the South-Central Idaho area.

A composite rate of $17.00 per hour was used and is based on a craft mix appropriate to the type of construction, together with a 2-1/2% allowance for casual overtime. Sufficient manual labor to complete the project within the construction schedule is assumed to be available in the project vicinity.

5.2.2.4 Subcontracts

Subcontracts for equipment and materials commonly installed by sub-contracts were estimated and priced in accordance with Bechtel experience.

5.2.2.5 Indirect Field Costs

The indirect field costs represent those activities that cannot be ascribed the direct portions of the facility and thus are accounted for separately. They were estimated based on plants of a similar nature resulting in an assessment of 65% of direct labor costs.

The items covered by indirect field costs are:

- Temporary Construction Facilities: Temporary buildings, working areas, roads, parking areas, utility system and general purpose scaffolding.
- Miscellaneous Construction Services: General job clean-up, maintenance of construction equipment and tools, material handling and surveying.
- Construction Equipment and Supplies: Construction equipment, small tools, consumable supplies, and purchases utilities.
- Field Office: Field labor of craft supervision, engineering, procurement, scheduling, personnel administration, warehousing, first aid, and the costs of operating the field office.
- Preliminary Check-Out and Acceptance Testing: Testing of materials and equipment to insure that components and systems are operable.
- Project Insurance: Public liability, property damage, and builder's risk insurances.

5.2.3 Engineering Services

The engineering services include engineering costs, other home office costs and fee. Engineering includes preliminary engineering, optimization studies, specifications, detail engineering, vendor-drawing review, site investigation, and support to vendors. Other home office costs comprise procurement, estimating and scheduling services, quality assurance, acceptance testing, and construction and project management. Fee is included as a function of the total project cost.

The sum of these three categories falls into historically consistent percentages in the range of 10% - 20% depending on the complexity of the project. For this study a figure of 15% of field construction costs has been used as typical for a plant that, while new in concept, does not depart radically from basic engineering principles.

5.2.4 Contingency

Included in the estimate is a contingency that exists within the conceptual design in quantity, pricing or productivity and that is under the control of the constructor and within the defined scope of the project. Implicitly the allowance will be expended during the design and construction of the project and it cannot be considered as a source of funds for overruns or additions to the project scope.

Experience shows however, that it is quite difficult to assess the degree to which future processes are understood in the hardware sense. Thus, if the conceptual arrangement of the plant contains major uncertainties, or the design duty of plant components proves to be more severe than anticipated, or if additional major subsystems are ultimately found to be necessary, then the scope of the project is deemed to have been inadequately defined and this then would not be covered by the contingency allowance. A nominal figure of 20 percent has been used for this study.

5.3 QUALIFICATIONS

The following are the major items for which design data was not available when the estimate was prepared and required the use of historical data and previous studies:

- Site specific items which affect civil/structural costs.
- Piping, instrumentation and electrical systems.

5.4 EXCLUSIONS

The following items are excluded from the scope of the study and from the estimate:

- All facilities beyond the hypothetical site boundary.
- Any special construction such as widening and strengthening existing roads.
- Ecological and environmental considerations other than those incorporated in the present conceptual design.
- State and local taxes.
- Future escalation.
- Site investigation and land acquisition.
- Client engineering, and similar client costs.
- Allowance for funds during construction.
- Process royalties and licenses.
- Training of plant operators.
- Initial charges, stocks of operating supplies and spares.
- Plant startup and operations.

5.5 CONCEPTUAL ESTIMATE

The previous discussion of estimate bases and qualifications form the basis of the cost summaries contained in Table 5-2.

Table 5-2

CAPITAL COST SUMMARY

Base Case

FACILITY		$1000's
100	Sugar Beet Preparation	10,740
200	Potato Preparation	6,520
300	Wheat Preparation	1,500
400	Product Recovery	4,410
500	By Product Processing	10,010
600	Off-Site, Excluding Geothermal Facility	4,130
	Yard Facility and Utilities	3,700
TOTAL DIRECT COST		41,010
	Indirect Cost	5,500
TOTAL FIELD COST		46,510
	Engineering Services	6,990
	Contingency	10,500
TOTAL CONSTRUCTED COST		64,000
GEOTHERMAL FACILITY		18,000

All Price & Wage Levels at 1Q 1980

REFERENCES

1. S.C. May, et. al., "Ethanol Production for Automotive Usage Quarterly Report, DOE/ID/12050-1."

2. C.A. Allen, R.E. Chaney, and R.E. McAtee, "Geochemical Modeling at Raft River", Geothermal Resources Council Transactions, Vol. 3, September 1979.

3. T.E. Lindemuth, et. al., "Experience in Scale Control with East Mesa Geothermal Brine", Society of Petroleum Engineers, paper No. SPE 6605, 1976.

4. Bechtel Corporation, "Operation and Maintenance of the East Mesa Test Site", U.S. Bureau of Reclamation, Contract No. 14-06-300 2622, August 1977.

5. "Belgard EV", Ciba-Geigy Corp., Sept. 1978.