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April 1983

Process Design and Economics for Ethanol from Corn Stover via Dilute Acid Hydrolysis

Development of a Base-Case Flowsheet for Parametric Analysis of Acid Hydrolysis Processes

A Subcontract Report

Chem Systems Inc.
New York, New York

Prepared Under Subcontract No. BK-9-8281-01

SERI

Solar Energy Research Institute
A Division of Midwest Research Institute

1617 Cole Boulevard
Golden, Colorado 80401

Operated for the
U.S. Department of Energy
under Contract No. EG-77-C-01-4042

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SERI Technical Monitor: Larry Douglas

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FOREWORD

This report describes work completed in February 1981 on a base case flow sheet for an alcohol fuels plant that produces 50 million gal/yr of ethanol by the dilute acid hydrolysis of corn stover. The design was used as the basis upon which Chem Systems Inc. developed the program for acid hydrolysis process simulation. The report presents a detailed description of the plant, capital equipment costs, and process economics. The project was funded under Solar Energy Research Institute Subcontract No. BK-9-8281-01 and managed by the Alcohol Fuels Program Office.

W. Hoagland

W. Hoagland
Alcohol Fuels Program Office

Approved for

SOLAR ENERGY RESEARCH INSTITUTE

Clayton S. Smith

Clayton S. Smith, Manager
Solar Fuels and Chemicals Research Division

SUMMARY

Objective

The objective of this report is to present a detailed flow sheet (including material and energy balances), capital cost estimate, and economic analysis of a plant producing 50 million gal/yr of ethanol from corn stover. The flow sheet allows identification of important research areas and serves as the basis for a process simulation model.

Discussion

This report presents a flow sheet for a cellulose-to-ethanol plant utilizing high-temperature dilute-acid hydrolysis. The process can be divided into six sections: pretreatment, hydrolysis, fermentation, purification, carbon dioxide recovery, and heat generation and waste treatment. In the pretreatment section, the raw corn stover undergoes steam explosion, the lignin is extracted by ethanol extraction, and the amorphous five- and six-carbon sugars removed in prehydrolysis. The crystalline cellulose is hydrolyzed in the hydrolysis reactor. The sugar solution from the prehydrolysis and hydrolysis sections is neutralized and fermented to carbon dioxide and ethanol in a train of continuous fermenters. The ethanol is recovered by a distillation process, and the carbon dioxide is cleaned and liquified. The unreacted solids and various waste streams are either burned or sent to the waste pond.

Capital and operating costs estimates are developed for the plant, and the total plant cost is estimated to be $236 million. The prime costs are heat generation, pretreatment, and hydrolysis. The ethanol produced costs $3.60/gal. Elimination of the lignin solvent extraction step and the prefermentation sugar concentration steps are recommended to reduce both the capital investment and energy usage of the plant. **Note that the system described in the report was not optimized. Instead it was configured to include a large number of processing steps, not all of which would be included in the same plant, in order to provide a basis for the coding of a simulation program. The ethanol costs reported are therefore much greater than would be achieved in an optimized system.**

Conclusions

A base case acid hydrolysis plant for producing ethanol from corn stover was designed. The plant design was a nonoptimized first approximation, and as such, does not produce ethanol at a competitive cost. However, it serves as a basis for further optimization and improvement.

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I. INTRODUCTION AND SUMMARY

Chem Systems has completed a process design and economic evaluation of a prototype ethanol from cellulose plant via dilute acid hydrolysis of corn stover for the Solar Energy Research Institute under Work Order No. XK-1-1001-1 of BOA Subcontract No. BK-9-8281-01. The process design is for 50 million gallons per year of ethanol and the economics are on a third quarter-1980 basis in a U.S. Gulf Coast location.

The prototype process is divided into six sections:

- Section 100 - Pretreatment
- Section 200 - Hydrolysis
- Section 300 - Fermentation
- Section 400 - Purification
- Section 500 - Carbon Dioxide Recovery
- Section 600 - Heat Generation and Waste Treatment

The pretreatment section consists of raw materials handling and storage, steam explosion, lignin extraction, acid prehydrolysis in a plug flow reactor (PFR) and solvent recovery. The hydrolysis section contains a dilute acid hydrolysis PFR with recycle, product neutralization and concentration of the resulting sugar solution. Included in the fermentation section are detoxification, yeast preparation and continuous cascade fermentation with yeast recycle. The dilute ethanol product is purified by concentration in a beer still and then dehydrated by azcotropic distillation with benzene in the purification section. The carbon dioxide recovery section produces a liquid product from fermenter off-gas. In the waste treatment section, steam is raised from the combustion of some waste process streams and the remainder are treated for disposal.

A detailed process description for this plant is presented in Section II along with the basis for design of major units, process flowsheets and complete material balance.

In Section III, the plant capital costs are presented, based on the results of an Icarus CØST run which is detailed in the appendix. Consumption of raw materials and utilities derived from detailed heat and material balances are also analyzed in this section and a cost of production analysis is presented. An equivalent analysis for an alternate case involving improved lignin extraction efficiency is also presented.

The economics for the base case and the improved lignin extraction case are summarized in Table I-1. The base case ethanol sales price is $4.35 per gallon and improving the lignin extraction step reduces the sales price to $3.63 per gallon. The costs associated with steam consumption are the major contributors to these high values. There is considerable room for process optimization and recommendations for improving the ethanol from cellulose economics are discussed in Section III.

TABLE I-1

MANUFACTURING COST SUMMARY
FOR
ETHANOL FROM CELLULOSE
(Third Quarter-1980)
50 Million Gallons/Year

	Base Case	Improved Lignin Extraction
Investment, $MM		
Battery Limits	180.1	102.2
Offsites	128.4	94.1
Total fixed investment	236.5	196.3
	¢/Gallon Ethanol	
Raw Materials and By-Products		
Corn Stover @ 1.5 ¢/lb	75.00	75.00
Sulfuric Acid @ 4.0 ¢/lb	13.41	13.41
Calcium Hydroxide @ 1.6 ¢/lb	4.04	4.04
Carbon Dioxide @ 2.5 ¢/lb	(17.75)	(17.75)
SCP @ 13.0 ¢/lb	(2.44)	(2.44)
Catalyst and chemicals	5.40	0.20
Total net raw materials	77.66	72.46
Utilities	89.50	63.69
Operating Costs	15.49	14.79
Overhead Expenses	65.60	55.90
Cost of Production	248.3	207.1
Sales price at 15% DCF	435.3	363.4

II. PROCESS DESIGN

A. Process Description

This section provides a process description of a plant designed to produce 50 million gallons per year of anhydrous ethanol from corn stover. Figures II-1 through II-6 are process flowsheets for the plant and should be referred to with the following process descriptions. The detailed material balance is located in the section following the process flowsheets. The design basis for the major processing units is detailed in Section II-B.

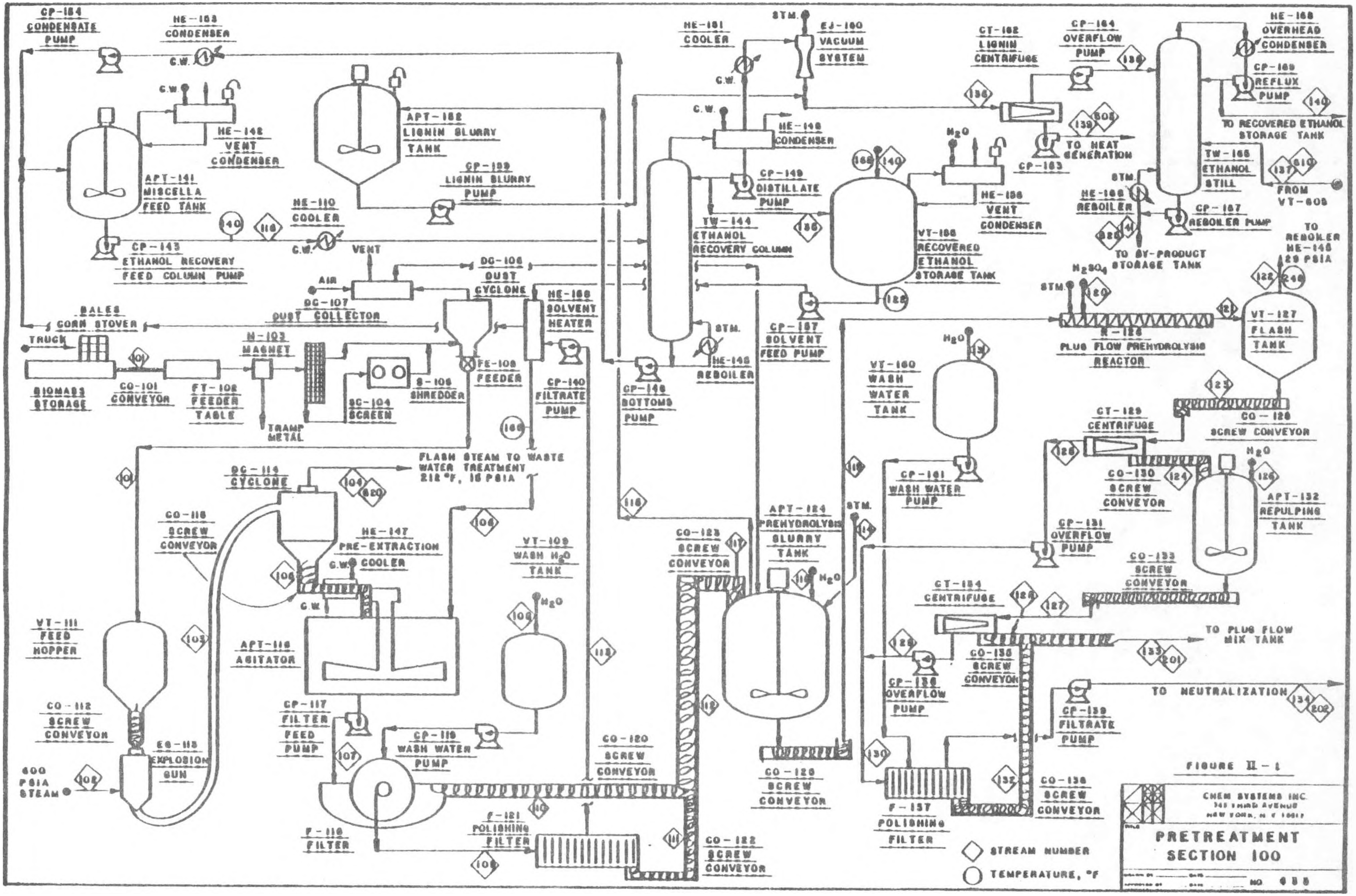
1. Pretreatment Section (Section 100) (Figure II-1)

The pretreatment section can be subdivided into five subsections:

- Raw materials storage and handling
- Steam explosion
- Lignin extraction
- Prehydrolysis
- Solvent recovery

Corn stover is transferred from the storage area via a conveyor to a feeder table, FT-102. The feeder table serves to spread and cut the stover into coarse particles, whereupon a magnet removes any tramp metal. The stover then passes over a 10 mesh screen, SC-104, removing any fines which are sent to the cyclone, DC-106. The larger particles are conveyed to a shredder, S-105, which shreds the stover into nominal 10 mesh size particles. The shredded stover is then conveyed to the cyclone where impurities and dust are removed, and a feeder then transfers the stover to the feed hopper, VT-111, prior to steam explosion (Stream - 101).

The steam explosion pretreatment is a high pressure, rapid, batch process where steam cooks the stover for very short times (approximately 5 seconds), then explosively decompresses the material through a nozzle,


CP-184 CONDENSATE PUMP
HE-183 CONDENSER
APT-141 MISCELLA FEED TANK
HE-142 VENT CONDENSER
APT-182 LIGNIN SLURRY TANK
CP-139 LIGNIN SLURRY PUMP
HE-110 COOLER
CP-143 ETHANOL RECOVERY FEED COLUMN PUMP
HE-181 COOLER
EJ-180 VACUUM SYSTEM
HE-148 CONDENSER
CP-149 DISTILLATE PUMP
TW-144 ETHANOL RECOVERY COLUMN
HE-186 VENT CONDENSER
VT-188 RECOVERED ETHANOL STORAGE TANK
CT-182 LIGNIN CENTRIFUGE
CP-164 OVERFLOW PUMP
CP-183
TO HEAT GENERATION
HE-168 OVERHEAD CONDENSER
CP-169 REFLUX PUMP
TO RECOVERED ETHANOL STORAGE TANK
TW-166 ETHANOL STILL
FROM VT-608
HE-166 REBOILER
CP-167 REBOILER PUMP
TO BY-PRODUCT STORAGE TANK
TO REBOILER HE-146 29 PSIA
DG-106 DUST CYCLONE
DC-107 DUST COLLECTOR
HE-166 SOLVENT HEATER
BALES CORN STOVER
TRUCK
BIOMASS STORAGE
CO-101 CONVEYOR
FT-102 FEEDER TABLE
M-103 MAGNET
TRAMP METAL
SC-104 SCREEN
S-106 SHREDDER
FE-108 FEEDER
CP-140 FILTRATE PUMP
CP-146 BOTTOMS PUMP
HE-146 REBOILER
CP-137 SOLVENT FEED PUMP
R-126 PLUG FLOW PREHYDROLYSIS REACTOR
VT-127 FLASH TANK
VT-160 WASH WATER TANK
CP-161 WASH WATER PUMP
CT-129 CENTRIFUGE
CO-128 SCREW CONVEYOR
CO-130 SCREW CONVEYOR
APT-132 REPULPING TANK
CP-131 OVERFLOW PUMP
CO-133 SCREW CONVEYOR
FLASH STEAM TO WASTE WATER TREATMENT 212 °F, 16 PSIA
DC-114 CYCLONE
CO-116 SCREW CONVEYOR
HE-147 PRE-EXTRACTION COOLER
VT-109 WASH H2O TANK
APT-124 PREHYDROLYSIS SLURRY TANK
CO-123 SCREW CONVEYOR
CT-134 CENTRIFUGE
TO PLUG FLOW MIX TANK
VT-111 FEED HOPPER
APT-116 AGITATOR
CO-136 SCREW CONVEYOR
CP-136 OVERFLOW PUMP
TO NEUTRALIZATION
CO-112 SCREW CONVEYOR
EG-113 EXPLOSION GUN
600 PSIA STEAM
CP-117 FILTER FEED PUMP
CP-119 WASH WATER PUMP
CO-120 SCREW CONVEYOR
CP-139 FILTRATE PUMP
CO-126 SCREW CONVEYOR
F-118 FILTER
F-121 POLISHING FILTER
CO-122 SCREW CONVEYOR
F-137 POLISHING FILTER
CO-138 SCREW CONVEYOR
STREAM NUMBER
TEMPERATURE, °F
FIGURE II-1
CHEM SYSTEMS INC.
PRETREATMENT SECTION 100

separating the constituent components of the corn stover. Steam at 920°F and 600 psia is supplied to the explosion gun, EG-113. The steam exploded product (Stream 103) is then sent to a cyclone, DC-114, where some of the steam flashes along with any volatile byproducts formed during steam explosion. Cook time in the explosion gun is kept as short as possible to minimize the harmful degradation of hemicellulose and cellulose, but is sufficiently long to produce approximately 70 percent delignification. Following flashing in the cyclone, some of the steam remains condensed and the wet solid is screw conveyed to the agitator (Stream 105).

The steam exploded corn stover is cooled to 165°F prior to extraction by a cooling jacket, HE-147, around the screw conveyor. The agitator, APT-116, serves as a continuous solids-liquid contactor in which ethanol is added (Stream 106) at 165°F in a ratio of 33:1 to the soluble lignin. Effective solids-liquid contacting is attained in the agitator by use of raking of solids at the bottom of the vessel towards the middle where they are air lifted to the top of the vessel and evenly distributed through the liquid by launderers. Completely mixed slurry is continuously removed by filter feed pump, CP-117, to a rotary vacuum filter, F-118, which removes the bulk of the suspended solids with the filtrate, containing the ethanol and extracted lignin (Stream 109), going to a polishing filter. The filter bottoms (Stream 110) containing mostly cellulose, hemicellulose and the other insolubles as well as some ethanol is steam stripped, removing the remaining ethanol, in the screw conveyor, CO-123, with the vapor stream (Stream 115) going to the solvent recovery system. The polishing filter, F-121, removes any remaining solids, sending the filtrate (Stream 113) to the solvent recovery system and the filter bottoms (Stream 111) is joined with the previous filter bottoms (Stream 110) to form the feed to the prehydrolysis slurry tank (Stream 112).

In the prehydrolysis slurry tank, APT-124, the stover is diluted to a 15 percent slurry and pumped to the prehydrolysis plug flow reactor (PFR), R-126, where heat and sulfuric acid are added to bring the reactor conditions to 284°F and 0.5 weight percent acid. Under these relatively mild conditions virtually all the hemicellulose and amorphous cellulose are converted to sugars almost instantaneously. Pressure in the reactor is controlled at 30 psia so that no boiling occurs, and upon leaving the PFR (Stream 121) the contents are quenched to 248°F in a flash tank, VT-127. Some of the water and volatiles are flashed, leaving the unreacted solids and water solubles to be pumped to a series of centrifuging and filtering steps (Stream 123). Centrifuging with repulping and recentrifuging, followed by a polishing filter step recovers 99.5 percent of the solids including the cellulose, ash and remaining lignin, which is then screw conveyed (Stream 133) to the plug flow mix tank prior to hydrolysis. Approximately 95 percent of the solubles are recovered in the separations, including the hemicellulose pentoses and hexoses and amorphous cellulose hexoses which are pumped to the neutralization section (Stream 134).

The ethanol-water vapor (stream 115) is condensed in HE-153 in the miscella feed tank, APT-141. From there, it is cooled to 122°F and pumped to the ethanol recovery column, TW-144, which is similar in design to the rectification column in the distillation section. However, it operates under a partial vacuum to keep the temperature in the column relatively low to prevent polymerization of the lignin. TW-144 operates at 122°F and 5 psia and recovers approximately 98 percent of the ethanol in the overheads. The recovered ethanol in the overheads (Stream 135) is 80 weight percent and is condensed in HE-148 and sent to the recovered ethanol storage tank, VT-155. The recovered ethanol is preheated in HE-158 by the hot filtrate from the polishing filter (Stream 113) and recycled back to the agitator. The lignin slurry is recovered as still bottoms from TW-144 and sent to the lignin slurry tank, VT-152. The lignin slurry is then pumped to a lignin centrifuge, CT-162, to be separated into solid and liquid streams. The overflow (Stream 138), which contains the majority of the ethanol lost in TW-144, is sent to an ethanol still, TW-165, along with an ethanol stream (Stream 137) from Section 600 which recovers most of the ethanol as distillate to be sent to VT-155 (Stream 140). The bottoms from CT-162 are sent to Section

600, Heat Generation (Stream 139). The bottoms from TW-165 contain toxic substances and are sent to waste water processing in Section 600 (Stream 141).

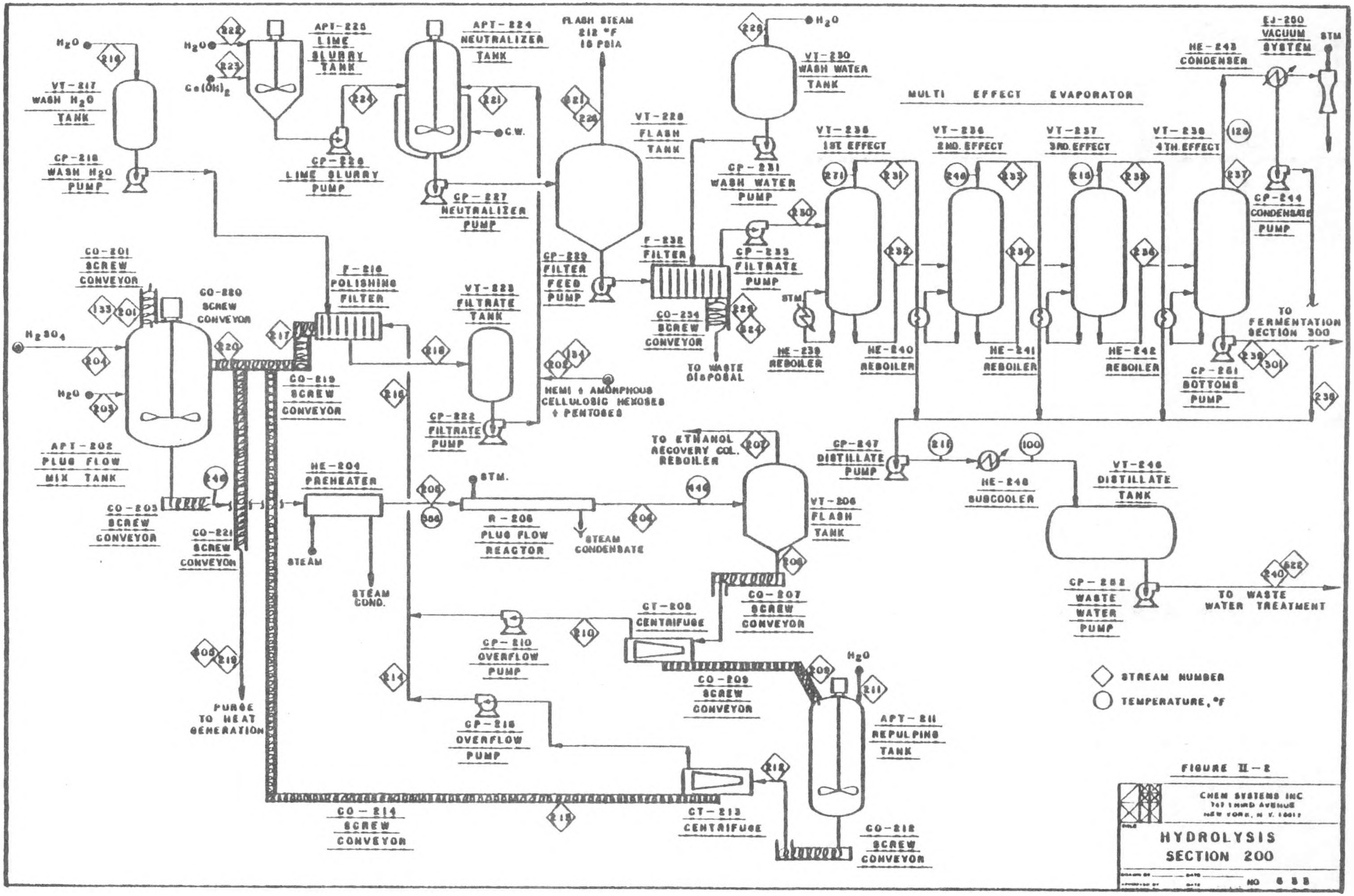
2. Hydrolysis Section (Section 200) (Figure II-2)

The hydrolysis section can be subdivided into three subsections:

- Hydrolysis
- Neutralization
- Concentration

The filter cake containing the cellulose (Stream 201) is sent to a nearly identical PFR system for hydrolysis, however, reactor conditions are 446^{O}F, one weight percent sulfuric acid, 0.2 minutes residence time and 500 psia. Sulfuric acid is added in the plug flow mix tank, APT-202 (Stream 204), however the temperature is held below the reaction temperature until steam heats the PFR, R-205, to 446^{O}F. The PFR is a double pipe, tubular, screw-conveyed reactor as is the prehydrolysis PFR, with the biomass slurry in the inner pipe and steam in the outer pipe. Yield of glucose is approximately 45 mole percent from cellulose, per pass through the reactor. The PFR product (Stream 296) is then flashed to 248^{O}F and centrifuged and filtered as in the prehydrolysis section. Ninety percent of the unreacted cellulose, which constitutes 44 percent of the inlet cellulose per pass, is recycled back to the plug flow mix tank. The recycle stream increases the total conversion of inlet cellulose to glucose to approximately 80 weight percent. The unreacted solids purge (Stream 219) is sent to the heat generation system. The filtrate, containing approximately 2.5 percent glucose is combined with the filtrate from prehydrolysis (Stream 202) and sent to the neutralization tank, APT-224.

The acidic sugar solution is then neutralized by addition of calcium hydroxide pumped from a lime slurry tank, APT-225.



VT-217 WASH H2O TANK
CP-218 WASH H2O PUMP
APT-225 LIME SLURRY TANK
Ca(OH)2
CP-226 LIME SLURRY PUMP
APT-224 NEUTRALIZER TANK
C.W.
CP-227 NEUTRALIZER PUMP
FLASH STEAM 212 °F 15 PSIA
VT-228 FLASH TANK
CP-229 FILTER FEED PUMP
VT-230 WASH WATER TANK
CP-231 WASH WATER PUMP
F-232 FILTER
CP-233 FILTRATE PUMP
CO-234 SCREW CONVEYOR
TO WASTE DISPOSAL
MULTI EFFECT EVAPORATOR
VT-235 1ST EFFECT
VT-236 2ND. EFFECT
VT-237 3RD. EFFECT
VT-238 4TH. EFFECT
HE-239 REBOILER
HE-240 REBOILER
HE-241 REBOILER
HE-242 REBOILER
HE-243 CONDENSER
EJ-200 VACUUM SYSTEM
STM
CP-244 CONDENSATE PUMP
TO FERMENTATION SECTION 300
CP-251 BOTTOMS PUMP
CP-247 DISTILLATE PUMP
HE-248 SUBCOOLER
VT-246 DISTILLATE TANK
CP-252 WASTE WATER PUMP
TO WASTE WATER TREATMENT
CO-201 SCREW CONVEYOR
CO-220 SCREW CONVEYOR
F-216 POLISHING FILTER
VT-223 FILTRATE TANK
CP-222 FILTRATE PUMP
HEMI + AMORPHOUS CELLULOSIC HEXOSES + PENTOSES
H2SO4
H2O
APT-202 PLUG FLOW MIX TANK
CO-219 SCREW CONVEYOR
CO-203 SCREW CONVEYOR
CO-221 SCREW CONVEYOR
HE-204 PREHEATER
STEAM
STEAM COND.
STM.
R-205 PLUG FLOW REACTOR
STEAM CONDENSATE
TO ETHANOL RECOVERY COL. REBOILER
VT-206 FLASH TANK
CO-207 SCREW CONVEYOR
CT-208 CENTRIFUGE
CP-210 OVERFLOW PUMP
CO-209 SCREW CONVEYOR
APT-211 REPULPING TANK
CP-215 OVERFLOW PUMP
CT-213 CENTRIFUGE
CO-212 SCREW CONVEYOR
CO-214 SCREW CONVEYOR
PURGE TO HEAT GENERATION
STREAM NUMBER
TEMPERATURE, °F
FIGURE II-2
CHEM SYSTEMS INC
HYDROLYSIS SECTION 200

Neutralization takes place at 248°F and the pH in APT-224 is controlled such that a pH of 4.0 will result following concentration to 20 percent glucose prior to fermentation. The heat evolved during neutralization is removed by a cooling jacket on APT-224. The product (stream 225) is flashed to 212°F and 15 psia in VT-228 and filtered in F-232 to remove the calcium sulfate formed during neutralization.

The neutralized sugar solution (Stream 230) is then concentrated to 20 weight percent glucose in a quadruple effect, forward feed evaporator, VT-235 to VT-238, with the last effect operating under a partial vacuum of 2 psia. The distillate is cooled to 100°F and sent to the waste water treatment system (Stream 240).

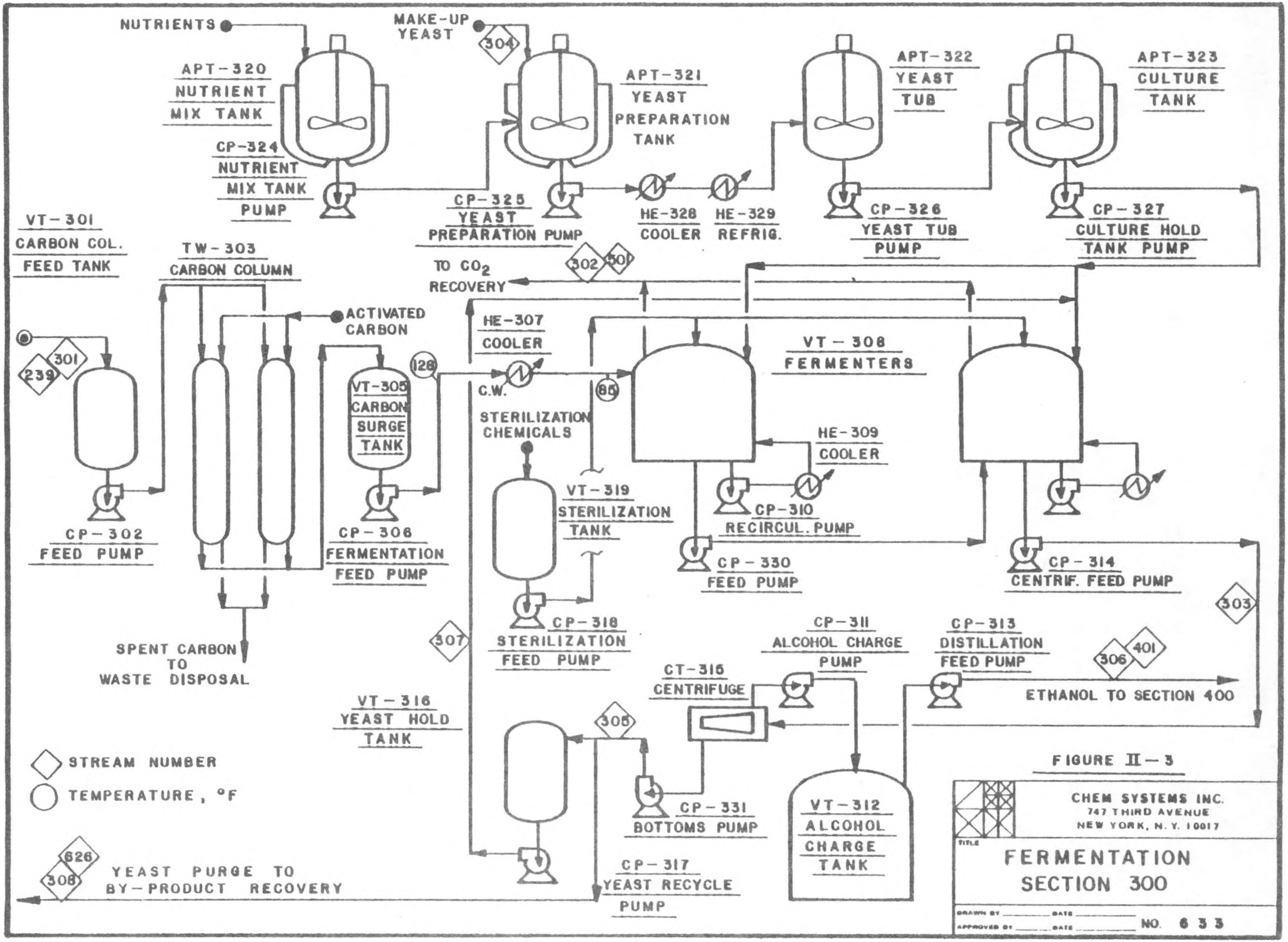
3. Fermentation (Section 300) (Figure II-3)

The fermentation section can be divided up into two subsections:

- Detoxification
- Fermentation

The concentrated sugar solution is passed through activated carbon columns, TW-303, to remove any toxic materials and cooled to 85°F in HE-307.

Fermentation takes place in a continuous cascade scheme. Three cascade trains, containing five fermentation tanks each, are utilized. Each train has a 50 percent capacity, with partial fermentation occurring in each tank until complete fermentation is realized in the last tank in each train. In this way, two trains are active at any one time, with the third train down for sterilization. Fermentation time is 24 hours. Yeast is separated from the ethanol product (Stream 303) by centrifugation with 82 percent of the yeast being recycled back to the fermenters. The heat evolved during ethanol formation is removed by recirculation of the fermenter contents through a refrigerated cooler,



NUTRIENTS
MAKE-UP YEAST
304
APT-320 NUTRIENT MIX TANK
APT-321 YEAST PREPARATION TANK
APT-322 YEAST TUB
APT-323 CULTURE TANK
CP-324 NUTRIENT MIX TANK PUMP
CP-325 YEAST PREPARATION PUMP
HE-328 COOLER
HE-329 REFRIG.
CP-326 YEAST TUB PUMP
CP-327 CULTURE HOLD TANK PUMP
VT-301 CARBON COL. FEED TANK
TW-303 CARBON COLUMN
TO CO2 RECOVERY
302
301
ACTIVATED CARBON
HE-307 COOLER
VT-308 FERMENTERS
239
301
126
VT-305 CARBON SURGE TANK
C.W.
85
STERILIZATION CHEMICALS
HE-309 COOLER
VT-319 STERILIZATION TANK
CP-310 RECIRCUL. PUMP
CP-302 FEED PUMP
CP-306 FERMENTATION FEED PUMP
CP-330 FEED PUMP
CP-314 CENTRIF. FEED PUMP
303
CP-318 STERILIZATION FEED PUMP
307
SPENT CARBON TO WASTE DISPOSAL
CP-311 ALCOHOL CHARGE PUMP
CP-313 DISTILLATION FEED PUMP
306
401
CT-315 CENTRIFUGE
ETHANOL TO SECTION 400
VT-316 YEAST HOLD TANK
305
STREAM NUMBER
TEMPERATURE, °F
CP-331 BOTTOMS PUMP
VT-312 ALCOHOL CHARGE TANK
FIGURE II-3
CHEM SYSTEMS INC.
747 THIRD AVENUE
NEW YORK, N.Y. 10017
TITLE
FERMENTATION SECTION 300
626
308
YEAST PURGE TO BY-PRODUCT RECOVERY
CP-317 YEAST RECYCLE PUMP
DRAWN BY
DATE
APPROVED BY
DATE
NO. 633

HE-309, utilizing well water at 60^{o}F as coolant. This also provides agitation in the fermenter. Make-up yeast is added to the fermenters (Stream 304) to offset yeast losses in the purge stream. During fermentation, 95 percent of the glucose is utilized to produce ethanol, at a weight percent conversion of 50 percent. The remaining 50 percent is converted to carbon dioxide which is removed to the carbon dioxide recovery system (Stream 302). Two percent of the glucose is consumed during fermentation to grow more yeast at a rate of 10 percent of the input yeast. The remaining 3 percent is converted into glycerol, fusel oils (higher alcohols), acetic acid and aldehydes. The product ethanol stream (Stream 306) contains 10.6 percent ethanol and is pumped to the alcohol charge tanks, VT-312, prior to purification.

4. <u>Purification Section (Section 400) (Figure II-4)</u>

The dilute beer feed from fermentation (Stream 401) undergoes a series of preheating steps which preheats the feed from 90^{o}F to 240^{o}F.

The first preheating step utilizes a portion of the condensing vapors from the overheads of the dehydration column, TW-418, in HE-411. The warmed feed is further preheated in HE-402 by a portion of the overhead vapors from the rectification column, TW-407. The final preheating step utilizes heat exchange with the bottoms of TW-407 in HE-401. The heated beer feed enters the rectification column, which operates at 55 psia. This column is composed of 30 sieve trays in the top section of the column and 30 disc and donut trays in the bottom section of the column. The non-volatile soluble and suspended solids work their way down the column and are removed from the bottom of the tower (Stream 403). The temperature of the bottoms is approximately 280^{o}F and, after cooling to 212^{o}F by preheating the feed, this stream is sent to Heat Generation (Section 600). It contains the bulk of the xyloses formed during prehydrolysis. The overhead from the rectification column (Stream 404) is the binary azeotrope of 94 percent ethanol and 6 percent water and is used to preheat the feed (Stream 405) and to reboil the dehydration and stripper columns (Streams 407 and 408).

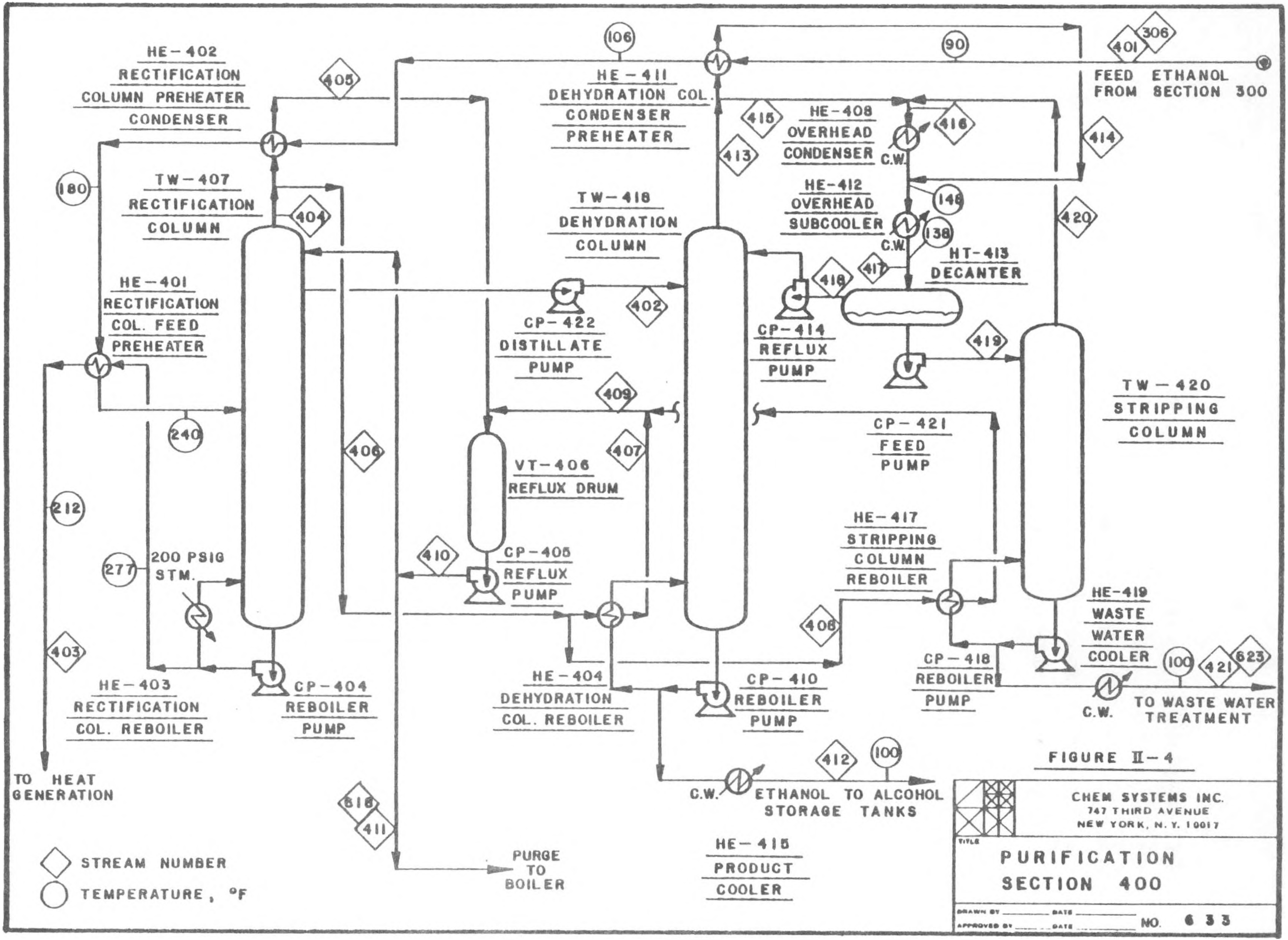


FIGURE II-4

PURIFICATION SECTION 400

Sufficient vapor is generated in the rectification column to supply all the heating needs of these two columns as well as a portion of the preheat requirement of the beer feed. Vapor condensate from the rectification column overhead is collected in reflux drum VT-406 and used as reflux in the rectification column. L/D for the rectification column is 4.4.

The distillate from the rectification column (Stream 402) enters the dehydration column, TW-418, which operates at essentially atmospheric pressure. The anhydrous ethanol product is pumped from the bottom of TW-418 and cooled to 100^{O}F in HE-415 prior to storage.

The overhead from TW-418 (Stream 413) is the tertiary minimum boiling azeotrope consisting of 18.5 percent ethanol, 7.5 percent water and 74.5 percent benzene at 148^{O}F. A portion of the vapors is condensed in the preheater condenser, HE-411. The remainder, as well as the overheads from the stripper, TW-420 (Streams 415 and 420), are condensed in HE-408. All the condensed vapors (Stream 417) are subcooled to 138^{O}F in HE-412 and pass into decanter HT-413 where they separate into two layers. The upper layer is the hydrocarbon-rich layer and is pumped back to TW-418 as reflux (Stream 418). The lower layer is the aqueous layer and is pumped to TW-420 as feed (Stream 419), where the remaining hydrocarbon and alcohol are stripped overhead and recycled to the decanter, HT-413 (Stream 420). The stripper bottoms, essentially water, are cooled and sent to the waste water treatment section.

Lights, such as aldehydes, produced in fermentation are effectively removed in the distillation system by withdrawing a small purge from the rectification column reflux (Stream 411). Fusel oils, also produced in the fermentation section, add to the heating value of the alcohol and are left in the product.

5. Carbon Dioxide Recovery (Section 500) (Figure II-5)

When sugars are fermented to ethanol, large quantities of carbon dioxide are produced as a by-product of cell respiration. As the fermenters are usually closed vessels, it is possible to collect the off-gas and recover liquefied carbon dioxide for sale.

The carbon dioxide generated in the fermentation vessels (Stream 501) passes through a foam trap to a low-pressure water scrubber where soluble impurities are removed. The scrubbed gas is then compressed 300 psig in a nonlubricated, reciprocating compressor. Depending on the design pressure of the fermenters, it may be necessary to boost off-gas pressure prior to water washing, using a rotary positive displacement compressor.

The compressed gas is deodorized in a twin-tower activated carbon absorption system to remove remaining impurities arising from the fermentation process. The carbon beds are periodically regenerated using live steam or hot air. The purified gas is then chilled and dried in a conventional alumina bed dryer system to a dew point of -60°C.

The dry gas passes to a low-temperature stripper-condenser system, where the carbon dioxide is liquefied and separated from the noncondensible gases, mainly oxygen, which are vented to the atmosphere. The pure liquid carbon dioxide from the base of the stripper-condenser is then subcooled and sent to storage (Stream 502), where it is maintained under a pressure of about 300 psig.

6. Heat Generation and Waste Treatment (Section 600) (Figure II-6)

The centrifuge bottoms from CT-162 (Stream 603), is joined with the stripper bottoms (Stream 606) and the hydrolysis purge (Stream 602), following flashing in VT-601. The lignin slurry is then preheated to 212°F using hot exhaust gases from the lignin boiler (Stream 628). A multiple effect evaporator, T-605, 606, 607 and 608 concentrates the

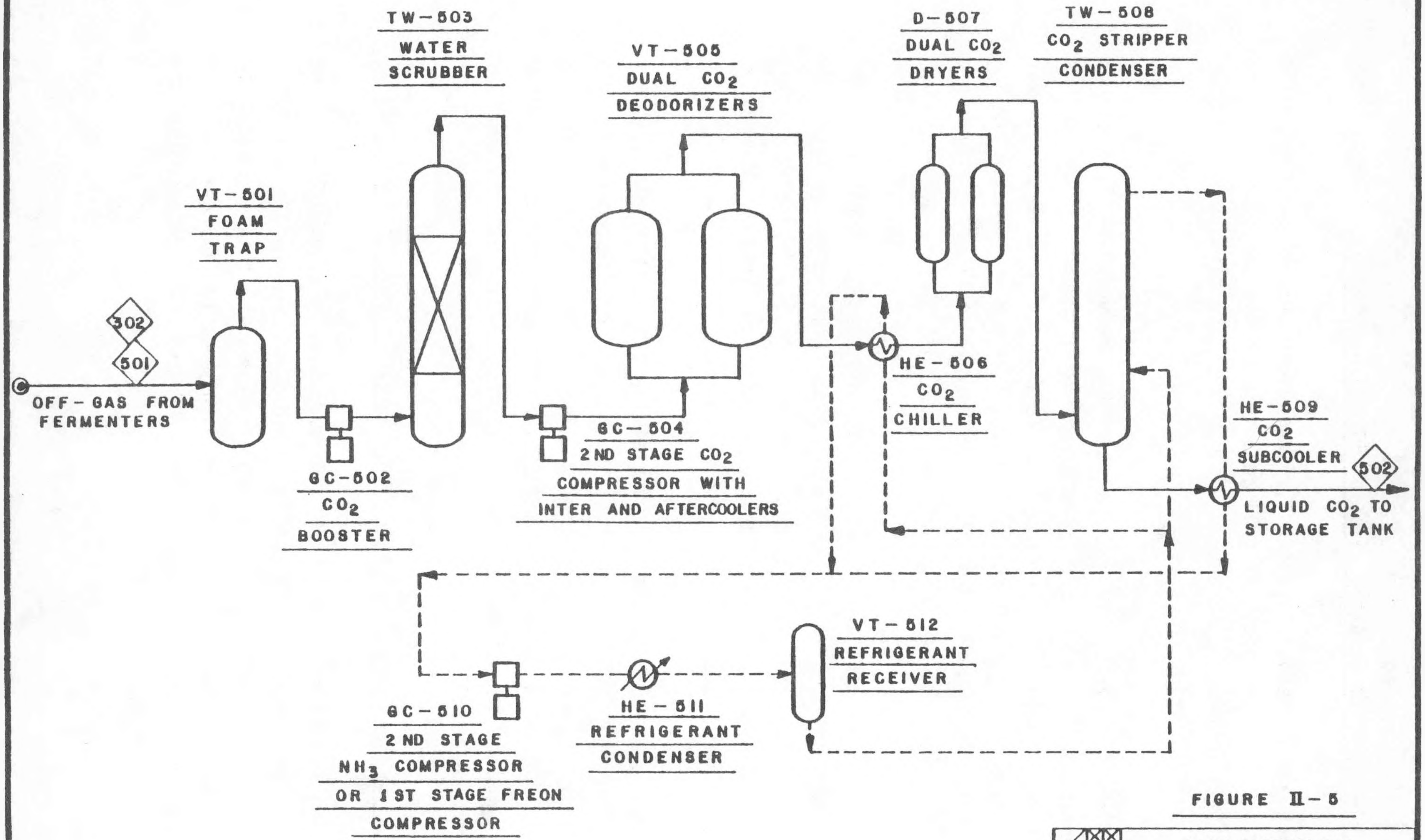
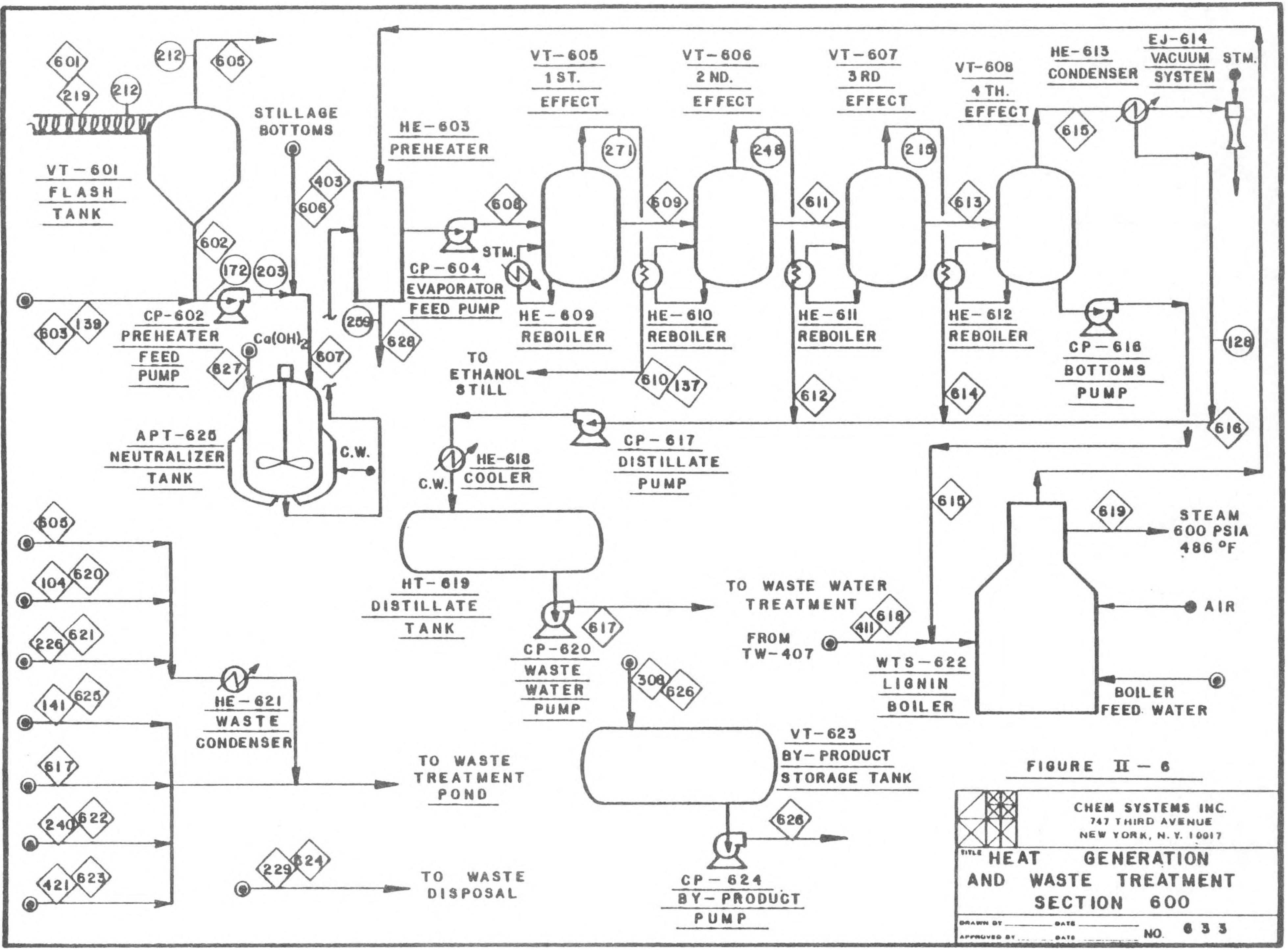


FIGURE II-5

CHEM SYSTEMS INC.
747 THIRD AVENUE
NEW YORK, N. Y. 10017

TITLE CARBON DIOXIDE RECOVERY SECTION 500

DRAWN BY ______ DATE ______
APPROVED BY ______ DATE ______ NO. 633


VT-601 FLASH TANK
STILLAGE BOTTOMS
HE-603 PREHEATER
VT-605 1 ST. EFFECT
VT-606 2 ND. EFFECT
VT-607 3 RD EFFECT
VT-608 4 TH. EFFECT
HE-613 CONDENSER
EJ-614 VACUUM SYSTEM
STM.
CP-602 PREHEATER FEED PUMP
Ca(OH)2
CP-604 EVAPORATOR FEED PUMP
HE-609 REBOILER
HE-610 REBOILER
HE-611 REBOILER
HE-612 REBOILER
CP-616 BOTTOMS PUMP
TO ETHANOL STILL
APT-625 NEUTRALIZER TANK
C.W.
HE-618 COOLER
CP-617 DISTILLATE PUMP
HT-619 DISTILLATE TANK
TO WASTE WATER TREATMENT
FROM TW-407
CP-620 WASTE WATER PUMP
STEAM 600 PSIA 486 °F
AIR
WTS-622 LIGNIN BOILER
BOILER FEED WATER
HE-621 WASTE CONDENSER
TO WASTE TREATMENT POND
VT-623 BY-PRODUCT STORAGE TANK
TO WASTE DISPOSAL
CP-624 BY-PRODUCT PUMP
FIGURE II - 6
CHEM SYSTEMS INC.
747 THIRD AVENUE
NEW YORK, N. Y. 10017
TITLE HEAT GENERATION AND WASTE TREATMENT SECTION 600
DRAWN BY DATE
APPROVED BY DATE
NO. 633

lignin slurry to 55 weight percent solids prior to entry (Stream 615) into the lignin boiler, WTS-622, as fuel. The lignin boiler produces 600 psia steam. The vapor from the first effect (Stream 610) is returned to ethanol still TW-165.

Various process waste streams, such as low level flash steam, are condensed in HE-621 and sent to a waste treatment pond, along with other liquid process waste streams. The filter bottoms following neutralization (Stream 624), containing mostly calcium sulfate is sent to an offsite waste disposal landfill. Approximately two percent of the ethanol produced is lost during processing and is combined with other waste streams in Section 600. Additional process equipment would be economically justified to recover much of this loss.

B. Design Basis

A process design has been developed for a plant producing 50 million gallons per year of ethanol from corn stover. It should be noted that no attempt was made to optimize the overall process for this base case model; thus, inefficiencies do exist.

I. Material Balance

The overall material balance was calculated using standard techniques with good engineering practice and satisfies the following constraints as well as those listed in Sections 100-600.

- Feed composition - Field dry corn stover:

	Weight Fraction
Cellulose	0.263
Hemicellulose	0.227
Lignin	0.070
Protein	0.030
Soluble carbohydrates	0.053
Ash	0.039
Extractives	0.011
Water	0.307
Total	1.000

- Constituent composition

	Weight Fraction
Cellulose	0.15 amorphous cellulose 0.85 crystalline cellulose 100 percent of cellulose is hexosan
Hemicellulose	0.71 pentosan 0.29 hexosan

II. Pretreatment (Section 100)

1. Steam Explosion

The following parameters were used for the design of the steam explosion section:

- steam requirement: 0.8 lbs steam/lb dry feedstock
- pressure in explosion gun: 560 psia
- temperature in explosion gun: 478°F
- cooking time: 5 seconds
- conversions: 0.18 weight percent to xylose
  1.3 weight percent to degradation products
- delignification: 70 percent

Assumptions:

- Iotech experimental data (1) form the basis for the xylose and degradation product conversions from hemicellulose and cellulose.

- Hemicellulose and cellulose are converted to sugars and degradation products according to the following reactions:

$$\text{(a) pentosan}_{132} \xrightarrow{+H_2O} \text{xylose}_{150} \xrightarrow{-3H_2O} \text{furfural}_{96} + \text{lignin} \xrightarrow{-H_2O} \text{pseudolignin}_{78}$$

$$\text{(b) hexosan}_{162} \xrightarrow{+H_2O} \text{glucose}_{180} \xrightarrow{-3H_2O} \text{HMF}_{126} + \text{lignin} \xrightarrow{-H_2O} \text{pseudolignin}_{108}$$

- No net glucose is formed within the operating range considered (5-32 seconds cooking time) and decomposition of cellulose does not occur.

- By Iotech's analytical method, all pentosans lost are reported as degradation products. The pentosan analysis converts the pentosan and xylose present to furfural, which is then measured and expressed as a pentosan equivalent. To get the true value for pentosans remaining, the amount of xyloses present must be sutracted, and the total pentoses lost will be the sum of the xyloses and degradation products formed.

- An equal weight percent of hemicellulosic hexosans are coverted to degradation products as are pentosans converted to xylose and degradation products.

- *In vitro* cellulose digestibility (IVCD) for corn stover follows the same relationship to delignification as found with hardwoods(1)(2).

- Xylose formation from hardwood is the same as from corn stover. This is a fair assumption, since the pentosan percentage is approximately the same for both.

2. Lignin Extraction

Agitator (APT-116)

- temperature: $165^{o}F$
- pressure: 15 psia
- solvent feed: 80 percent ethanol
  20 percent water

Filter (F-118)

- type: vacuum rotary drum with wash capability
- capacity: 2300 gpm
- filter area: 5400 ft^2
- filter rate: 30 lb/hr ft^2
- solids loading: 162,500 lbs/hr
- 95 percent recovery of solids
- 40 weight percent solids in bottoms*
- wash efficiency: 97.5 percent for 2 wash volumes

3. Prehydrolysis

Plug Flow Reactors (R-126)

- temperature: $284^{o}F$
- pressure: 52 psia
- acid concentration: 0.5 weight percent in aqueous phase
- type: double pipe screw conveyer
- feed: 15 weight percent solids slurry
- residence time: 0.2 minutes
- heat transfer area: 932 ft^2
- conversions: 95 mole percent to sugars
  5 mole percent to degradation products

---

*Press rolls or other equipment are likely to be required to achieve this high solid levels.

Centrifuge (CT-129)

- type: solid bowl decanting
- overflow capacity: 1875 gpm
- solids loading: 84,100 lbs/hr
- temperature: 248^{o}F
- pressure: 30 psia

Centrifuge (CT-134)

- type: solid bowl decanting
- overflow capacity: 425 gpm
- solids loading: 80,000 lbs/hr
- temperature: 248^{o}F
- pressure: 30 psia

Assumptions:

- All hemicellulose which remains following steam explosion is converted to pentoses, hexoses and degradation products according to the following reactions:

Sugar Formation

(a) pentosan $\xrightarrow{+H_2O}$ xylose

$$\underset{132}{C_5H_8O_4} + \underset{18}{H_2O} \longrightarrow \underset{150}{C_5H_{10}O_5}$$

(b) hexosan $\xrightarrow{+H_2O}$ glucose

$$\underset{162}{C_6H_{10}O_5} + \underset{18}{H_2O} \longrightarrow \underset{180}{C_6H_{12}O_6}$$

Sugar Degradation

(c) xylose → water + furfural

$$C_5H_{10}O_5 \longrightarrow 3H_2O + C_4H_3OCHO$$

150 → 54 + 96

(d) glucose → water + hydroxymethyl-2-furfuraldehyde

$$C_6H_{12}O_6 \longrightarrow 3H_2O + CHOHC_4H_3OCHO$$

180 → 54 + 126

- From the kinetics developed by Grethlein(3) for the conditions of prehydrolysis, 95 mol percent conversion of hemicellulose and amorphous cellulose is obtained almost instantaneously. The remaining 5 mol percent goes to degradation products.

- The amorphous cellulose, which constitutes approximately 15 percent of the total cellulose, is converted to glucose and degradation products in accordance with the same kinetics and conversions as the hemicellulose.

Assumptions:

- Centrifuge and filter bottoms are 40 weight percent solids; additional equipment, such as press rolls, may be required to achieve this high solids level
- Centrifuges and filters remove 95 percent of input solids as bottoms
- Filter wash efficiency of 97.5 percent for two wash volumes

4. Solvent Recovery System

Solvent Recovery Column (TW-144)

- feed temperature: 122°F
- feed pressure: 6 psia
- overhead temperature: 126°F
- bottoms temperature: 128°F
- overhead pressure: 5 psia
- bottoms pressure: 7 psia
- overhead composition: 80 weight percent ethanol, 20 weight percent water
- α average: 2.457
- minimum theoretical trays: 6
- actual theoretical trays: 13
- L/D minimum: 1.32
- L/D actual: 1.68
- condenser duty: 869×10^6 BTU/hr
- reboiler duty: 872×10^6 BTU/hr

Centrifuge (CT-129)

- type: solid bowl decanting
- overflow capacity: 565 gpm
- solids loading: 15,591 lbs/hr
- temperature: 128°F
- pressure: 15 psia

Ethanol Still (TW-165)

- feed temperature: 128°F
- feed pressure: 15 psia
- overhead temperature: 168°F
- bottoms temperature: 170°F
- overhead composition: 80 weight percent ethanol, 20 weight percent water

- average: 2.43
- minimum theoretical trays: 9
- actual theoretical trays: 17
- condenser duty: 62.5×10^6 BTU/hr
- reboiler duty: 74.2×10^6 BTU/hr

III. Hydrolysis (Section 200)

1. Hydrolysis

Plug Flow Reactors (R-205)

- temperature: 446^oF
- pressure: 410 psia
- acid concentration: 1 weight percent in aqueous phase
- type: double pipe, screw conveyed
- feed: 6 weight percent pure crystalline cellulose
  15 weight percent solids slurry
- residence time: 0.2 minutes
- heat transfer area: 3,750 ft^2
- conversions: 45 mole percent cellulose to glucose per pass
  44 mole percent cellulose unreacted per pass
  11 mole percent cellulose to degradation products
- recycle: 90 percent of recovered unreacted cellulose
- total conversion: 80 weight percent cellulose to glucose

Centrifuge (CT-208)

- type: solid bowl decanting
- overflow capacity: 2100 gpm
- solids loading: 218,805 lbs/hr
- temperature: 248^{o}F
- pressure: 30 psia

Centrifuge (CT-213)

- type: solid bowl decanting
- overflow capacity: 2600 gpm
- solids loading: 207,865 lbs/hr
- temperature: 248^{o}F
- pressure: 30 psia

Assumptions:

- Centrifuge and filter bottoms are 40 weight percent solids; additional equipment, such as press rolls, may be necessary to achieve this high solids level
- Centrifuges and filter recover 95 percent of input solids as bottoms
- Filter wash efficiency of 97.5 percent for two wash volumes

2. Neutralization

Neutralizer Tank (APT-224)

- temperature: 248^{o}F
- pressure: 30 psia
- feed: pH = 3.86

- Neutralization of the acidic sugar solution occurs according to the reaction:

$$Ca(OH)_2 + H_2SO_4 \longrightarrow CaSO_4 + 2H_2O$$

ΔH = -13.4 kcal/mole water formed

3. Concentration

Multi-Effect Evaporator (VT 235, VT-236, VT-237, and VT-238)

• total evaporative capacity:	$3x10^6$ lbs H_2O/hr
• feed glucose concentration:	2.5 weight percent
• product glucose concentration:	20 weight percent
• Pressures:	
steam chest first effect:	56 psia
steam chest second effect:	42 psia
steam chest third effect:	29 psia
steam chest fourth effect:	16 psia
vapor to condenser:	2 psia
• Vapor Temperatures:	
first effect:	271^{o}F
second effect:	248^{o}F
third effect:	215^{o}F
fourth effect:	128^{o}F
steam:	288^{o}F
• Total condenser duty:	864 x 10^6 BTU/hr

IV. Fermentation (Section 300)

Fermenters (VT-308)

• feed	20 weight percent glucose at 85^{o}F

- fermentation time: 24 hours
- terminal alcohol concentration 10.6 weight percent
- pH at start of fermentation: 4
- pH at completion of fermentation: 3.8
- 10 percent yeast production during fermentation
- 86 percent recycle of recovered yeast with 14 percent purge for production of single protein (SCP)
- yeast concentration in fermenters 300×10^6 cells/cm^3
- fresh yeast stock: 10 percent maximum, 50×10^6 cells/cm^3
- conversions: 95 percent of glucose converted to ethanol with 50 weight percent conversion.

  3 percent of glucose converted to glycerol with traces of fusel oils, acetic acid and aldehydes, with 50 weight percent conversion.

  2 percent of glucose goes towards yeast growth with 50 weight percent conversion.

  50 weight percent conversion of all glucose to carbon dioxide.

- cooling: external with spiral heat exchangers. Coolants are well water available at 60°F and cooling tower water in season with transitional combined usage. Agitation is provided by cooling circuit circulation pump.

Assumptions:

- The conversion of hexoses to ethanol via fermentation is represented by the ideal equation:

$$C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2$$

ΔH = 517 BTU/lb ethanol formed

Theoretical yield is 51 weight percent and, with yeast recycle, 98 percent of theoretical is obtained. Therefore, overall weight percent conversion to ethanol is 50 percent

- Centrifuge bottoms is 30 percent solids
- Centrifuge removes 95 percent of input solids

V. Purification (Section 400)

Rectification Column (TW-407)

• feed temperature:	240°F
• overhead composition:	94 weight percent ethanol 6 weight percent water
• overhead temperature:	221°F
• overhead pressure:	47 psia
• bottoms temperature:	277°F
• bottoms pressure:	51 psia
• L/D	4.4
• number of trays:	60
• tray type:	30 sieve plates at top of column 30 disc and donuts at bottom of column
• condenser duty:	96.5×10^6 BTU/hr
• reboiler duty:	108.1×10^6 BTU/hr

- steam requirement: 20 lbs/gallon ethanol

Dehydration Column (TW-418)

- entrainer: benzene
- feed: 94 weight percent ethanol
  6 weight percent water
- feed temperature: 220°F
- overhead composition: 18.5 percent ethanol
  74.0 percent benzene
  7.5 percent water
- overhead temperature: 148°F
- bottoms composition: anhydrous ethanol
- bottoms temperature: 181°F
- decanter compositions:

	aqueous phase	organic phase
ethanol	50 percent	11 percent
benzene	8 percent	87 percent
water	42 percent	2 percent

- decanter temperature: 138°F
- column pressure: 15 psia
- number of trays: 50
- tray type: sieve plate
- reboiler duty: 50.8×10^6 BTU/hr
- condenser duty: 53.9×10^6 BTU/hr

Stripping Column (TW-420)

- feed temperature: 138°F
- overhead temperature: 165°F
- bottoms temperature: 215°F
- number of trays: 30
- tray type: sieve plate
- reboiler duty: 2.6×10^6 BTU/hr
- condenser duty: 2.3×10^6 BTU/hr

Assumptions:

- 98.3 percent of ethanol recovered in rectification column distillate.
- 100 percent of ethanol recovered in bottoms of dehydration column.
- 90 percent of water from stripper feed is removed in stripper bottoms.
- Stripper bottoms is 100 percent water.

VI. Heat Generation (Section 600)

Multiple Effect Evaporator (VT-605, 606, 607, 608)

- number of effects: 4
- total evaporative capacity: 234,300 lbs/hr water
- pressures:
  - steam chest: 56 psia
  - steam chest: 42 psia
  - steam chest: 29 psia
  - steam chest: 16 psia
  - vapor to condenser: 2 psia
- vapor temperatures:
  - first effect: 271°F
  - second effect: 248°F
  - third effect: 215°F
  - fourth effect: 128°F
  - steam: 288°F
- total condenser duty: 84.5×10^6 BTU/hr

Lignin Boiler (WTS - 622)

- air requirement: 632,580 lbs/hr plus 5 percent excess

- total heat duty: 816×10^6 BTU/hr
- steam produced: 8.81×10^5 lbs/hr
- flue gas capacity: 7.62×10^5 lbs/hr
- flue gas composition:

oxygen	1 percent
nitrogen	67 percent
carbon dioxide	24 percent
water vapor	8 percent

- flue gas temperature:

maximum:	3390°F
exit:	275°F

Assumptions:

- complete combustion in lignin boiler
- 85 percent efficiency in lignin boiler

VII. Bibliography

1. Iotech Corporation, "Optimization of Steam Explosion Pretreatment", U.S. Department of Energy Fuels From Biomass Program, April 1980.
2. O'Neil, D.J., et al, "Design, Fabrication and Operation of a Biomass Fermentation Facility", Georgia Institute of Technology, First Quarterly Report, October-December 1978.
3. Grethlein, H.E., "Comparison of the Economics of Acid and Enzymatic Hydrolysis of Newsprint", Biotechnology and Bioengineering, Volume XX, Pages 503-525, 1978.

ETHANOL FROM CELLULOSE MATERIAL BALANCE

FOR

SOLAR ENERGY RESEARCH INSTITUTE

PREPARED BY

CHEM SYSTEMS, INC.

STREAM NO.		101		102		103		104		105	
	Mol Wt	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr
Water	18	95938	5329.9	173250	9625.0	269482	14971.2	78150	4341.7	191332	10629.6
Cellulose	162	82188	507.3	0	.0	82188	507.3	0	.0	82188	507.3
Hemicellulose	141	70937	503.1	0	.0	69902	495.8	0	.0	69902	495.8
Lignin	***	21875	***	0	.0	22124	***	0	.0	22124	***
Ash	***	12188	***	0	.0	12188	***	0	.0	12188	***
Other	***	12812	***	0	.0	12812	***	0	.0	12812	***
Sucrose	342	16562	48.4	0	.0	16347	47.8	0	.0	16347	47.8
Xylose	150	0	.0	0	.0	91	.6	0	.0	91	.6
Glucose	180	0	.0	0	.0	166	.9	0	.0	166	.9
Furfural	96	0	.0	0	.0	285	3.0	0	.0	285	3.0
HMF	126	0	.0	0	.0	165	1.3	0	.0	165	1.3
Pseudolignin	***	0	.0	0	.0	0	.0	0	.0	0	.0
Ethanol	46	0	.0	0	.0	0	.0	0	.0	0	.0
Sulfuric Acid	98	0	.0	0	.0	0	.0	0	.0	0	.0
Calcium Hydroxide	74	0	.0	0	.0	0	.0	0	.0	0	.0
Calcium Sulfate	136	0	.0	0	.0	0	.0	0	.0	0	.0
Yeast	***	0	.0	0	.0	0	.0	0	.0	0	.0
Carbon Dioxide	44	0	.0	0	.0	0	.0	0	.0	0	.0
Benzene	78	0	.0	0	.0	0	.0	0	.0	0	.0
Glycerol	92	0	.0	0	.0	0	.0	0	.0	0	.0
Fusel Oil	***	0	.0	0	.0	0	.0	0	.0	0	.0
Acetic Acid	60	0	.0	0	.0	0	.0	0	.0	0	.0
TOTAL		312500		173250		485750		78150		407600	

ETHANOL FROM CELLULOSE MATERIAL BALANCE

FOR

SOLAR ENERGY RESEARCH INSTITUTE

PREPARED BY

CHEM SYSTEMS, INC.

STREAM NO.		106		107		108		109		110	
	Mol Wt	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr
Water	18	127766	7098.1	319098	17727.7	487110	27061.7	418196	23233.1	239851	13325.1
Cellulose	162	0	.0	82188	507.3	0	.0	4109	25.4	78079	482.0
Hemicellulose	141	0	.0	69902	495.8	0	.0	3495	24.8	66407	471.0
Lignin	***	0	.0	22124	***	0	.0	15707	***	6415	***
Ash	***	0	.0	12188	***	0	.0	609	***	11579	***
Other	***	0	.0	12812	***	0	.0	12775	***	37	***
Sucrose	342	0	.0	16347	47.8	0	.0	16300	47.7	47	.1
Xylose	150	0	.0	91	.6	0	.0	91	.6	0	.0
Glucose	180	0	.0	166	.9	0	.0	165	.9	0	.0
Furfural	96	0	.0	285	3.0	0	.0	284	3.0	1	.0
HMF	126	0	.0	165	1.3	0	.0	164	1.3	0	.0
Pseudolignin	***	0	.0	0	.0	0	.0	0	.0	0	.0
Ethanol	46	511064	11110.1	511064	11110.1	0	.0	507446	11031.4	3618	78.7
Sulfuric Acid	98	0	.0	0	.0	0	.0	0	.0	0	.0
Calcium Hydroxide	74	0	.0	0	.0	0	.0	0	.0	0	.0
Calcium Sulfate	136	0	.0	0	.0	0	.0	0	.0	0	.0
Yeast	***	0	.0	0	.0	0	.0	0	.0	0	.0
Carbon Dioxide	44	0	.0	0	.0	0	.0	0	.0	0	.0
Benzene	78	0	.0	0	.0	0	.0	0	.0	0	.0
Glycerol	92	0	.0	0	.0	0	.0	0	.0	0	.0
Fusel Oil	***	0	.0	0	.0	0	.0	0	.0	0	.0
Acetic Acid	60	0	.0	0	.0	0	.0	0	.0	0	.0
TOTAL		638830		1046430		487110		979341		406034	

ETHANOL FROM CELLULOSE MATERIAL BALANCE

FOR

SOLAR ENERGY RESEARCH INSTITUTE

PREPARED BY

CHEM SYSTEMS, INC.

STREAM NO.		111		112		113		114		115	
	Mol Wt	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr
Water	18	5248	291.6	245099	13616.6	412948	22941.6	12958	719.9	3107	172.6
Cellulose	162	3904	24.1	81983	506.1	205	1.3	0	.0	0	.0
Hemicellulose	141	3320	23.5	69727	494.5	175	1.2	0	.0	0	.0
Lignin	***	508	***	6923	***	15201	***	0	.0	0	.0
Ash	***	579	***	12058	***	30	***	0	.0	0	.0
Other	***	160	***	197	***	12615	***	0	.0	0	.0
Sucrose	342	204	.6	251	.7	16096	47.1	0	.0	0	.0
Xylose	150	1	.0	1	.0	90	.6	0	.0	0	.0
Glucose	180	2	.0	3	.0	163	.9	0	.0	0	.0
Furfural	96	4	.0	5	.1	280	2.9	0	.0	0	.0
HMF	126	2	.0	3	.0	162	1.3	0	.0	0	.0
Pseudolignin	***	0	.0	0	.0	0	.0	0	.0	0	.0
Ethanol	46	6365	138.4	9983	217.0	501081	10893.1	0	.0	9983	217.0
Sulfuric Acid	98	0	.0	0	.0	0	.0	0	.0	0	.0
Calcium Hydroxide	74	0	.0	0	.0	0	.0	0	.0	0	.0
Calcium Sulfate	136	0	.0	0	.0	0	.0	0	.0	0	.0
Yeast	***	0	.0	0	.0	0	.0	0	.0	0	.0
Carbon Dioxide	44	0	.0	0	.0	0	.0	0	.0	0	.0
Benzene	78	0	.0	0	.0	0	.0	0	.0	0	.0
Glycerol	92	0	.0	0	.0	0	.0	0	.0	0	.0
Fusel Oil	***	0	.0	0	.0	0	.0	0	.0	0	.0
Acetic Acid	60	0	.0	0	.0	0	.0	0	.0	0	.0
TOTAL		20297		426233		959046		12958		13090	

ETHANOL FROM CELLULOSE MATERIAL BALANCE

FOR

SOLAR ENERGY RESEARCH INSTITUTE

PREPARED BY

CHEM SYSTEMS, INC.

STREAM NO.		116		117		118		119		120	
	Mol Wt	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr
Water	18	416055	23114.2	245099	13616.6	780911	43383.9	1035861	57547.8	0	.0
Cellulose	162	205	1.3	81983	506.1	0	.0	81983	506.1	0	.0
Hemicellulose	141	175	1.2	69727	494.5	0	.0	69727	494.5	0	.0
Lignin	***	15201	***	6923	***	0	.0	6823	***	0	.0
Ash	***	30	***	12058	***	0	.0	12058	***	0	.0
Other	***	12615	***	197	***	0	.0	197	***	0	.0
Sucrose	342	16096	47.1	251	.7	0	.0	251	.7	0	.0
Xylose	150	90	.6	1	.0	0	.0	0	.0	0	.0
Glucose	180	163	.9	3	.0	0	.0	0	.0	0	.0
Furfural	96	280	2.9	5	.1	0	.0	0	.0	0	.0
HMF	126	162	1.3	3	.0	0	.0	0	.0	0	.0
Pseudolignin	***	511064	***	0	.0	0	.0	0	.0	0	.0
Ethanol	46	0	.0	9983	217.0	0	.0	0	.0	0	.0
Sulfuric Acid	98	0	.0	0	.0	0	.0	0	.0	5205	53.1
Calcium Hydroxide	74	0	.0	0	.0	0	.0	0	.0	0	.0
Calcium Sulfate	136	0	.0	0	.0	0	.0	0	.0	0	.0
Yeast	***	0	.0	0	.0	0	.0	0	.0	0	.0
Carbon Dioxide	44	0	.0	0	.0	0	.0	0	.0	0	.0
Benzene	78	0	.0	0	.0	0	.0	0	.0	0	.0
Glycerol	92	0	.0	0	.0	0	.0	0	.0	0	.0
Fusel Oil	***	0	.0	0	.0	0	.0	0	.0	0	.0
Acetic Acid	60	0	.0	0	.0	0	.0	0	.0	0	.0
TOTAL		972136		426233		780911		1206900		5205	

ETHANOL FROM CELLULOSE MATERIAL BALANCE

FOR

SOLAR ENERGY RESEARCH INSTITUTE

PREPARED BY

CHEM SYSTEMS, INC.

STREAM NO.		121		122		123		124		125	
	Mol Wt	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr
Water	18	1027097	57060.9	41084	2282.4	986013	54778.5	114981	6387.8	871032	48390.7
Cellulose	162	69686	430.2	0	.0	69686	430.2	66202	408.7	3484	21.5
Hemicellulose	141	0	.0	0	.0	0	.0	0	.0	0	.0
Lignin	***	6823	***	0	.0	6823	***	6482	***	341	***
Ash	***	12058	***	0	.0	12058	***	11448	***	610	***
Other	***	197	***	0	.0	197	***	23	***	174	***
Sucrose	342	0	.0	0	.0	0	.0	0	.0	0	.0
Xylose	150	53427	356.2	0	.0	53427	356.2	6184	41.2	47243	315.0
Glucose	180	34541	191.9	0	.0	34541	191.9	4038	22.4	30503	169.5
Furfural	96	1800	18.8	0	.0	1800	18.8	215	2.2	1585	16.5
HMF	126	1273	10.1	0	.0	1273	10.1	151	1.2	1122	8.9
Pseudolignin	***	0	.0	0	.0	0	.0	0	.0	0	.0
Ethanol	46	0	.0	0	.0	0	.0	0	.0	4599	100.0
Sulfuric Acid	98	5205	53.1	0	.0	5205	53.1	606	6.2	0	.0
Calcium Hydroxide	74	0	.0	0	.0	0	.0	0	.0	0	.0
Calcium Sulfate	136	0	.0	0	.0	0	.0	0	.0	0	.0
Yeast	***	0	.0	0	.0	0	.0	0	.0	0	.0
Carbon Dioxide	44	0	.0	0	.0	0	.0	0	.0	0	.0
Benzene	78	0	.0	0	.0	0	.0	0	.0	0	.0
Glycerol	92	0	.0	0	.0	0	.0	0	.0	0	.0
Fusel Oil	***	0	.0	0	.0	0	.0	0	.0	0	.0
Acetic Acid	60	0	.0	0	.0	0	.0	0	.0	0	.0
TOTAL		1212107		41084		1171023		210330		960693	

ETHANOL FROM CELLULOSE MATERIAL BALANCE

FOR

SOLAR ENERGY RESEARCH INSTITUTE

PREPARED BY

CHEM SYSTEMS, INC.

STREAM NO.		126		127		128		129		130	
	Mol Wt	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr
Water	18	210330	11685.0	326222	18123.4	115889	6438.3	209422	11634.6	1080454	60025.2
Cellulose	162	0	.0	66202	408.7	62892	388.2	3310	20.4	6794	41.9
Hemicellulose	141	0	.0	0	.0	0	.0	0	.0	0	.0
Lignin	***	0	.0	6482	***	6158	***	324	***	665	***
Ash	***	0	.0	11448	***	10876	***	572	***	1182	***
Other	***	0	.0	23	***	8	***	15	***	189	***
Sucrose	342	0	.0	0	.0	0	.0	0	.0	0	.0
Xylose	150	0	.0	6148	41.0	2206	14.7	3978	26.5	51221	341.5
Glucose	180	0	.0	4038	22.4	1439	8.0	2599	14.4	33102	183.9
Furfural	96	0	.0	215	2.2	77	.8	138	1.4	1723	17.9
HMF	126	0	.0	151	1.2	54	.4	97	.8	1219	9.7
Pseudolignin	***	0	.0	0	.0	0	.0	0	.0	0	.0
Ethanol	46	0	.0	606	13.2	216	4.7	390	8.5	4989	108.5
Sulfuric Acid	98	0	.0	0	.0	0	.0	0	.0	0	.0
Calcium Hydroxide	74	0	.0	0	.0	0	.0	0	.0	0	.0
Calcium Sulfate	136	0	.0	0	.0	0	.0	0	.0	0	.0
Yeast	***	0	.0	0	.0	0	.0	0	.0	0	.0
Carbon Dioxide	44	0	.0	0	.0	0	.0	0	.0	0	.0
Benzene	78	0	.0	0	.0	0	.0	0	.0	0	.0
Glycerol	92	0	.0	0	.0	0	.0	0	.0	0	.0
Fusel Oil	***	0	.0	0	.0	0	.0	0	.0	0	.0
Acetic Acid	60	0	.0	0	.0	0	.0	0	.0	0	.0
TOTAL		210330		421535		199815		220845		1181538	

ETHANOL FROM CELLULOSE MATERIAL BALANCE

FOR

SOLAR ENERGY RESEARCH INSTITUTE

PREPARED BY

CHEM SYSTEMS, INC.

STREAM NO.		131		132		133		134		135	
	Mol Wt	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr
Water	18	24628	1368.2	12287	682.6	128176	7120.9	1092795	60710.8	125211	6956.2
Cellulose	162	0	.0	6454	39.8	69346	428.1	340	2.1	0	.0
Hemicellulose	141	0	.0	0	.0	0	.0	0	.0	0	.0
Lignin	***	0	.0	632	***	6790	***	33	***	0	.0
Ash	***	0	.0	1123	***	11999	***	59	***	0	.0
Other	***	0	.0	0	.0	8	***	189	***	0	.0
Sucrose	342	0	.0	0	.0	0	.0	0	.0	0	.0
Xylose	150	0	.0	14	.1	2220	14.8	51207	341.4	0	.0
Glucose	180	0	.0	9	.0	1448	8.0	33093	183.8	0	.0
Furfural	96	0	.0	0	.0	77	.8	1723	17.9	0	.0
HMF	126	0	.0	0	.0	54	.4	1219	9.7	0	.0
Pseudolignin	***	0	.0	0	.0	0	.0	0	.0	0	.0
Ethanol	46	0	.0	0	.0	0	.0	0	.0	500843	10887.9
Sulfuric Acid	98	0	.0	0	.0	217	2.2	4988	50.9	0	.0
Calcium Hydroxide	74	0	.0	0	.0	0	.0	0	.0	0	.0
Calcium Sulfate	136	0	.0	0	.0	0	.0	0	.0	0	.0
Yeast	***	0	.0	0	.0	0	.0	0	.0	0	.0
Carbon Dioxide	44	0	.0	0	.0	0	.0	0	.0	0	.0
Benzene	78	0	.0	0	.0	0	.0	0	.0	0	.0
Glycerol	92	0	.0	0	.0	0	.0	0	.0	0	.0
Fusel Oil	***	0	.0	0	.0	0	.0	0	.0	0	.0
Acetic Acid	60	0	.0	0	.0	0	.0	0	.0	0	.0
TOTAL		24628		20519		220335		1185646		626054	

ETHANOL FROM CELLULOSE MATERIAL BALANCE

FOR

SOLAR ENERGY RESEARCH INSTITUTE

PREPARED BY

CHEM SYSTEMS, INC.

STREAM NO.		136		137		138		139		140	
	Mol Wt	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr
Water	18	290844	16158.0	41531	2307.3	270260	15014.4	20584	1143.6	2555	141.9
Cellulose	162	205	1.3	0	.0	10	.1	195	1.2	0	.0
Hemicellulose	141	175	1.2	0	.0	9	.1	166	1.2	0	.0
Lignin	***	16001	***	0	.0	800	***	15201	***	0	.0
Ash	***	30	***	0	.0	1	***	29	***	0	.0
Other	***	12615	***	0	.0	11722	***	893	***	0	.0
Sucrose	342	16096	47.1	0	.0	14957	43.7	1139	3.3	0	.0
Xylose	150	90	.6	0	.0	84	.6	6	.0	0	.0
Glucose	180	163	.9	0	.0	152	.8	11	.1	0	.0
Furfural	96	280	2.9	0	.0	260	2.7	20	.2	0	.0
HMF	126	162	1.3	0	.0	151	1.2	11	.1	0	.0
Pseudolignin	***	0	.0	0	.0	0	.0	0	.0	0	.0
Ethanol	46	10221	222.2	1437	31.2	9498	206.5	723	15.7	10221	222.2
Sulfuric Acid	98	0	.0	0	.0	0	.0	0	.0	0	.0
Calcium Hydroxide	74	0	.0	0	.0	0	.0	0	.0	0	.0
Calcium Sulfate	136	0	.0	0	.0	0	.0	0	.0	0	.0
Yeast	***	0	.0	0	.0	0	.0	0	.0	0	.0
Carbon Dioxide	44	0	.0	0	.0	0	.0	0	.0	0	.0
Benzene	78	0	.0	0	.0	0	.0	0	.0	0	.0
Glycerol	92	0	.0	0	.0	0	.0	0	.0	0	.0
Fusel Oil	***	0	.0	0	.0	0	.0	0	.0	0	.0
Acetic Acid	60	0	.0	0	.0	0	.0	0	.0	0	.0
TOTAL		346882		42968		307904		38978		12776	

ETHANOL FROM CELLULOSE MATERIAL BALANCE

FOR

SOLAR ENERGY RESEARCH INSTITUTE

PREPARED BY

CHEM SYSTEMS, INC.

STREAM NO. 141

	Mol Wt	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr
Water	18	309236	17179.8								
Cellulose	162	10	.1								
Hemicellulose	141	9	.1								
Lignin	***	800	***								
Ash	***	1	***								
Other	***	11722	***								
Sucrose	342	14957	43.7								
Xylose	150	84	.6								
Glucose	180	152	.8								
Furfural	96	260	2.7								
HMF	126	151	1.2								
Pseudolignin	***	0	.0								
Ethanol	46	714	15.5								
Sulfuric Acid	98	0	.0								
Calcium Hydroxide	74	0	.0								
Calcium Sulfate	136	0	.0								
Yeast	***	0	.0								
Carbon Dioxide	44	0	.0								
Benzene	78	0	.0								
Glycerol	92	0	.0								
Fusel Oil	***	0	.0								
Acetic Acid	60	0	.0								
TOTAL		338096									

ETHANOL FROM CELLULOSE MATERIAL BALANCE

FOR

SOLAR ENERGY RESEARCH INSTITUTE

PREPARED BY

CHEM SYSTEMS, INC.

STREAM NO.		201		202		203		204		205	
	Mol Wt	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr
Water	18	128176	7120.9	1092795	60710.8	1210075	67226.4	0	.0	1643848	91324.9
Cellulose	162	69346	428.1	340	2.1	0	.0	0	.0	114436	706.4
Hemicellulose	141	0	.0	0	.0	0	.0	0	.0	0	.0
Lignin	***	6790	***	33	***	0	.0	0	.0	64976	***
Ash	***	11999	***	59	***	0	.0	0	.0	114823	***
Other	***	8	***	189	***	0	.0	0	.0	8	***
Sucrose	342	0	.0	0	.0	0	.0	0	.0	0	.0
Xylose	150	2220	14.8	51207	341.4	0	.0	0	.0	2220	14.8
Glucose	180	1448	8.0	33093	183.8	0	.0	0	.0	3770	20.9
Furfural	96	77	.8	1723	17.9	0	.0	0	.0	139	1.4
HMF	126	54	.4	1219	9.7	0	.0	0	.0	534	4.2
Pseudolignin	***	0	.0	0	.0	0	.0	0	.0	0	.0
Ethanol	46	0	.0	0	.0	0	.0	0	.0	0	.0
Sulfuric Acid	98	217	2.2	4988	50.9	0	.0	15690	160.1	16607	169.5
Calcium Hydroxide	74	0	.0	0	.0	0	.0	0	.0	0	.0
Calcium Sulfate	136	0	.0	0	.0	0	.0	0	.0	0	.0
Yeast	***	0	.0	0	.0	0	.0	0	.0	0	.0
Carbon Dioxide	44	0	.0	0	.0	0	.0	0	.0	0	.0
Benzene	78	0	.0	0	.0	0	.0	0	.0	0	.0
Glycerol	92	0	.0	0	.0	0	.0	0	.0	0	.0
Fusel Oil	***	0	.0	0	.0	0	.0	0	.0	0	.0
Acetic Acid	60	0	.0	0	.0	0	.0	0	.0	0	.0
TOTAL		220335		1185646		1210075		15690		1961361	

ETHANOL FROM CELLULOSE MATERIAL BALANCE

FOR

SOLAR ENERGY RESEARCH INSTITUTE

PREPARED BY

CHEM SYSTEMS, INC.

STREAM NO.		206		207		208		209		210	
	Mol Wt	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr
Water	18	1638093	91005.2	360380	20021.1	1277713	70984.1	306911	17050.6	970802	53933.4
Cellulose	162	114436	706.4	0	.0	50522	311.9	47996	296.3	2526	15.6
Hemicellulose	141	0	.0	0	.0	0	.0	0	.0	0	.0
Lignin	***	64976	***	0	.0	64976	***	61727	***	3249	***
Ash	***	114823	***	0	.0	114823	***	109082	***	5741	***
Other	***	8	***	0	.0	8	***	0	.0	8	***
Sucrose	342	0	.0	0	.0	0	.0	0	.0	0	.0
Xylose	150	0	.0	0	.0	0	.0	0	.0	0	.0
Glucose	180	58431	324.6	0	.0	58431	324.6	14035	78.0	44396	246.6
Furfural	96	1560	16.3	0	.0	1560	16.3	375	3.9	1185	12.3
HMF	126	12066	95.8	0	.0	12066	95.8	2898	23.0	9168	72.8
Pseudolignin	***	0	.0	0	.0	0	.0	0	.0	0	.0
Ethanol	46	0	.0	0	.0	0	.0	0	.0	0	.0
Sulfuric Acid	98	16607	169.5	0	.0	16607	169.5	3989	40.7	12618	128.8
Calcium Hydroxide	74	0	.0	0	.0	0	.0	0	.0	0	.0
Calcium Sulfate	136	0	.0	0	.0	0	.0	0	.0	0	.0
Yeast	***	0	.0	0	.0	0	.0	0	.0	0	.0
Carbon Dioxide	44	0	.0	0	.0	0	.0	0	.0	0	.0
Benzene	78	0	.0	0	.0	0	.0	0	.0	0	.0
Glycerol	92	0	.0	0	.0	0	.0	0	.0	0	.0
Fusel Oil	***	0	.0	0	.0	0	.0	0	.0	0	.0
Acetic Acid	60	0	.0	0	.0	0	.0	0	.0	0	.0
TOTAL		2021000		360380		1596706		547013		1049693	

ETHANOL FROM CELLULOSE MATERIAL BALANCE

FOR

SOLAR ENERGY RESEARCH INSTITUTE

PREPARED BY

CHEM SYSTEMS, INC.

STREAM NO.		211		212		213		214		215	
	Mol Wt	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr
Water	18	1276362	70909.0	1583273	87959.6	307660	17092.2	1275613	70867.4	2246415	124800.8
Cellulose	162	0	.0	47996	296.3	45596	281.5	2400	14.8	4926	30.4
Hemicellulose	141	0	.0	0	.0	0	.0	0	.0	0	.0
Lignin	***	0	.0	61727	***	58641	***	3086	***	6335	***
Ash	***	0	.0	109082	***	103628	***	5454	***	11196	***
Other	***	0	.0	0	.0	0	.0	0	.0	8	***
Sucrose	342	0	.0	0	.0	0	.0	0	.0	0	.0
Xylose	150	0	.0	0	.0	0	.0	0	.0	0	.0
Glucose	180	0	.0	14035	78.0	2727	15.1	11308	62.8	55704	309.5
Furfural	96	0	.0	375	3.9	73	.8	302	3.1	1487	15.5
HMF	126	0	.0	2898	23.0	563	4.5	2335	18.5	11503	91.3
Pseudolignin	***	0	.0	0	.0	0	.0	0	.0	0	.0
Ethanol	46	0	.0	0	.0	0	.0	0	.0	0	.0
Sulfuric Acid	98	0	.0	3989	40.7	775	7.9	3214	32.8	15832	161.6
Calcium Hydroxide	74	0	.0	0	.0	0	.0	0	.0	0	.0
Calcium Sulfate	136	0	.0	0	.0	0	.0	0	.0	0	.0
Yeast	***	0	.0	0	.0	0	.0	0	.0	0	.0
Carbon Dioxide	44	0	.0	0	.0	0	.0	0	.0	0	.0
Benzene	78	0	.0	0	.0	0	.0	0	.0	0	.0
Glycerol	92	0	.0	0	.0	0	.0	0	.0	0	.0
Fusel Oil	***	0	.0	0	.0	0	.0	0	.0	0	.0
Acetic Acid	60	0	.0	0	.0	0	.0	0	.0	0	.0
TOTAL		1276362		1823375		519663		1303712		2353406	

ETHANOL FROM CELLULOSE MATERIAL BALANCE

FOR

SOLAR ENERGY RESEARCH INSTITUTE

PREPARED BY

CHEM SYSTEMS, INC.

STREAM NO.		216		217		218		219		220	
	Mol Wt	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr
Water	18	64000	3555.6	31971	1776.2	2278444	126580.2	34034	1890.8	305597	16977.6
Cellulose	162	0	.0	4680	28.9	246	1.5	5186	32.0	45090	278.3
Hemicellulose	141	0	.0	0	.0	0	.0	0	.0	0	.0
Lignin	***	0	.0	6018	***	317	***	6473	***	58186	***
Ash	***	0	.0	10635	***	560	***	11439	***	102824	***
Other	***	0	.0	0	.0	8	***	0	.0	0	.0
Sucrose	342	0	.0	0	.0	0	.0	0	.0	0	.0
Xylose	150	0	.0	0	.0	0	.0	0	.0	0	.0
Glucose	180	0	.0	19	.1	55685	309.4	422	2.3	2324	12.9
Furfural	96	0	.0	1	.0	1486	15.5	12	.1	62	.6
HMF	126	0	.0	4	.0	11499	91.3	87	.7	480	3.8
Pseudolignin	***	0	.0	0	.0	0	.0	0	.0	0	.0
Ethanol	46	0	.0	0	.0	0	.0	0	.0	0	.0
Sulfuric Acid	98	0	.0	5	.1	15827	161.5	80	.8	700	7.1
Calcium Hydroxide	74	0	.0	0	.0	0	.0	0	.0	0	.0
Calcium Sulfate	136	0	.0	0	.0	0	.0	0	.0	0	.0
Yeast	***	0	.0	0	.0	0	.0	0	.0	0	.0
Carbon Dioxide	44	0	.0	0	.0	0	.0	0	.0	0	.0
Benzene	78	0	.0	0	.0	0	.0	0	.0	0	.0
Glycerol	92	0	.0	0	.0	0	.0	0	.0	0	.0
Fusel Oil	***	0	.0	0	.0	0	.0	0	.0	0	.0
Acetic Acid	60	0	.0	0	.0	0	.0	0	.0	0	.0
TOTAL		64000		53333		2364072		57733		515263	

ETHANOL FROM CELLULOSE MATERIAL BALANCE

FOR

SOLAR ENERGY RESEARCH INSTITUTE

PREPARED BY

CHEM SYSTEMS, INC.

STREAM NO.		221		222		223		224		225	
	Mol Wt	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr
Water	18	3371239	187291.1	14525	806.9	0	.0	14525	806.9	3392830	188490.6
Cellulose	162	586	3.6	0	.0	0	.0	0	.0	586	3.6
Hemicellulose	141	0	.0	0	.0	0	.0	0	.0	0	.0
Lignin	***	340	***	0	.0	0	.0	0	.0	340	***
Ash	***	619	***	0	.0	0	.0	0	.0	610	***
Other	***	197	***	0	.0	0	.0	0	.0	197	***
Sucrose	342	0	.0	0	.0	0	.0	0	.0	0	.0
Xylose	150	51207	341.4	0	.0	0	.0	0	.0	51207	341.4
Glucose	180	88778	493.2	0	.0	0	.0	0	.0	88778	493.2
Furfural	96	3209	33.4	0	.0	0	.0	0	.0	3209	33.4
HMF	126	12718	100.9	0	.0	0	.0	0	.0	12718	100.9
Pseudolignin	***	0	.0	0	.0	0	.0	0	.0	0	.0
Ethanol	46	0	.0	0	.0	0	.0	0	.0	0	.0
Sulfuric Acid	98	20815	212.4	0	.0	0	.0	0	.0	1579	16.1
Calcium Hydroxide	74	0	.0	0	.0	14525	196.3	14525	196.3	0	.0
Calcium Sulfate	136	0	.0	0	.0	0	.0	0	.0	26695	196.3
Yeast	***	0	.0	0	.0	0	.0	0	.0	0	.0
Carbon Dioxide	44	0	.0	0	.0	0	.0	0	.0	0	.0
Benzene	78	0	.0	0	.0	0	.0	0	.0	0	.0
Glycerol	92	0	.0	0	.0	0	.0	0	.0	0	.0
Fusel Oil	***	0	.0	0	.0	0	.0	0	.0	0	.0
Acetic Acid	60	0	.0	0	.0	0	.0	0	.0	0	.0
TOTAL		3549708		14525		14525		29050		3578749	

ETHANOL FROM CELLULOSE MATERIAL BALANCE

FOR

SOLAR ENERGY RESEARCH INSTITUTE

PREPARED BY

CHEM SYSTEMS, INC.

STREAM NO.		226		227		228		229		230	
	Mol Wt	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr
Water	18	135713	7539.6	3257117	180950.9	80514	4473.0	40210	2233.9	3297421	183190.1
Cellulose	162	0	.0	586	3.6	0	.0	557	3.4	29	.2
Hemicellulose	141	0	.0	0	.0	0	.0	0	.0	0	.0
Lignin	***	0	.0	340	***	0	.0	333	***	17	***
Ash	***	0	.0	619	***	0	.0	588	***	31	***
Other	***	0	.0	197	***	0	.0	0	.0	0	.0
Sucrose	342	0	.0	0	.0	0	.0	0	.0	0	.0
Xylose	150	0	.0	51207	341.4	0	.0	15	.1	50992	339.9
Glucose	180	0	.0	88778	493.2	0	.0	26	.1	88752	493.1
Furfural	96	0	.0	3209	33.4	0	.0	1	.0	3208	33.4
HMF	126	0	.0	12718	100.9	0	.0	4	.0	12714	100.9
Pseudolignin	***	0	.0	0	.0	0	.0	0	.0	0	.0
Ethanol	46	0	.0	0	.0	0	.0	0	.0	0	.0
Sulfuric Acid	98	0	.0	1570	16.0	0	.0	1	.0	1578	16.1
Calcium Hydroxide	74	0	.0	0	.0	0	.0	0	.0	0	.0
Calcium Sulfate	136	0	.0	26695	196.3	0	.0	25360	186.5	0	.0
Yeast	***	0	.0	0	.0	0	.0	0	.0	0	.0
Carbon Dioxide	44	0	.0	0	.0	0	.0	0	.0	0	.0
Benzene	78	0	.0	0	.0	0	.0	0	.0	0	.0
Glycerol	92	0	.0	0	.0	0	.0	0	.0	0	.0
Fusel Oil	***	0	.0	0	.0	0	.0	0	.0	0	.0
Acetic Acid	60	0	.0	0	.0	0	.0	0	.0	0	.0
TOTAL		135713		3443036		80514		67095		3454742	

ETHANOL FROM CELLULOSE MATERIAL BALANCE

FOR

SOLAR ENERGY RESEARCH INSTITUTE

PREPARED BY

CHEM SYSTEMS, INC.

STREAM NO.		231		232		233		234		235	
	Mol Wt	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr
Water	18	665911	36995.1	2631510	146195.0	722430	40135.0	1909080	106060.0	778059	43225.5
Cellulose	162	0	.0	29	.2	0	.0	29	.2	0	.0
Hemicellulose	141	0	.0	0	.0	0	.0	0	.0	0	.0
Lignin	***	0	.0	17	***	0	.0	17	***	0	.0
Ash	***	0	.0	31	***	0	.0	31	***	0	.0
Other	***	0	.0	0	.0	0	.0	0	.0	0	.0
Sucrose	342	0	.0	0	.0	0	.0	0	.0	0	.0
Xylose	150	0	.0	50992	339.9	0	.0	50992	339.9	0	.0
Glucose	180	0	.0	88752	493.1	0	.0	88752	493.1	0	.0
Furfural	96	0	.0	3208	33.4	0	.0	3208	33.4	0	.0
HMF	126	0	.0	12714	100.9	0	.0	12714	100.9	0	.0
Pseudolignin	***	0	.0	0	.0	0	.0	0	.0	0	.0
Ethanol	46	0	.0	0	.0	0	.0	0	.0	0	.0
Sulfuric Acid	98	0	.0	1578	16.1	0	.0	1578	16.1	0	.0
Calcium Hydroxide	74	0	.0	0	.0	0	.0	0	.0	0	.0
Calcium Sulfate	136	0	.0	0	.0	0	.0	0	.0	0	.0
Yeast	***	0	.0	0	.0	0	.0	0	.0	0	.0
Carbon Dioxide	44	0	.0	0	.0	0	.0	0	.0	0	.0
Benzene	78	0	.0	0	.0	0	.0	0	.0	0	.0
Glycerol	92	0	.0	0	.0	0	.0	0	.0	0	.0
Fusel Oil	***	0	.0	0	.0	0	.0	0	.0	0	.0
Acetic Acid	60	0	.0	0	.0	0	.0	0	.0	0	.0
TOTAL		665911		2788831		722430		2066401		778059	

ETHANOL FROM CELLULOSE MATERIAL BALANCE

FOR

SOLAR ENERGY RESEARCH INSTITUTE

PREPARED BY

CHEM SYSTEMS, INC.

STREAM NO.		236		237		238		239		240	
	Mol Wt	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr
Water	18	1131021	62834.5	846114	47006.3	846114	47006.3	284907	15828.2	3015514	167528.6
Cellulose	162	29	.2	0	.0	0	.0	29	.2	0	.0
Hemicellulose	141	0	.0	0	.0	0	.0	0	.0	0	.0
Lignin	***	17	***	0	.0	0	.0	17	***	0	.0
Ash	***	31	***	0	.0	0	.0	31	***	0	.0
Other	***	0	.0	0	.0	0	.0	0	.0	0	.0
Sucrose	342	0	.0	0	.0	0	.0	0	.0	0	.0
Xylose	150	50992	339.9	0	.0	0	.0	50992	339.9	0	.0
Glucose	180	88752	493.1	0	.0	0	.0	88752	493.1	0	.0
Furfural	96	3208	33.4	0	.0	0	.0	3208	33.4	0	.0
HMF	126	12714	100.9	0	.0	0	.0	12714	100.9	0	.0
Pseudolignin	***	0	.0	0	.0	0	.0	0	.0	0	.0
Ethanol	46	0	.0	0	.0	0	.0	0	.0	0	.0
Sulfuric Acid	98	1578	16.1	0	.0	0	.0	1578	16.1	0	.0
Calcium Hydroxide	74	0	.0	0	.0	0	.0	0	.0	0	.0
Calcium Sulfate	136	0	.0	0	.0	0	.0	0	.0	0	.0
Yeast	***	0	.0	0	.0	0	.0	0	.0	0	.0
Carbon Dioxide	44	0	.0	0	.0	0	.0	0	.0	0	.0
Benzene	78	0	.0	0	.0	0	.0	0	.0	0	.0
Glycerol	92	0	.0	0	.0	0	.0	0	.0	0	.0
Fusel Oil	***	0	.0	0	.0	0	.0	0	.0	0	.0
Acetic Acid	60	0	.0	0	.0	0	.0	0	.0	0	.0
TOTAL		1288342		846114		846114		442228		3015514	

ETHANOL FROM CELLULOSE MATERIAL BALANCE

FOR

SOLAR ENERGY RESEARCH INSTITUTE

PREPARED BY

CHEM SYSTEMS, INC.

STREAM NO.		301		302		303		304		305	
	Mol Wt	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr
Water	18	284907	15828.2	0	.0	315130	17507.2	459	25.5	34609	1922.7
Cellulose	162	29	.2	0	.0	187	1.2	0	.0	178	1.1
Hemicellulose	141	0	.0	0	.0	0	.0	0	.0	0	.0
Lignin	***	17	***	0	.0	110	***	0	.0	105	***
Ash	***	31	***	0	.0	200	***	0	.0	190	***
Other	***	0	.0	0	.0	202	***	0	.0	6	***
Sucrose	342	0	.0	0	.0	0	.0	0	.0	0	.0
Xylose	150	50992	339.9	0	.0	52342	348.9	0	.0	1570	10.5
Glucose	180	88752	493.1	0	.0	0	.0	0	.0	0	.0
Furfural	96	3208	33.4	0	.0	3293	34.3	0	.0	99	1.0
HMF	126	12714	100.9	0	.0	13051	103.6	0	.0	392	3.1
Pseudolignin	***	0	.0	0	.0	0	.0	0	.0	0	.0
Ethanol	46	0	.0	0	.0	43273	940.7	0	.0	1298	28.2
Sulfuric Acid	98	1578	16.1	0	.0	1620	16.5	0	.0	49	.5
Calcium Hydroxide	74	0	.0	0	.0	0	.0	0	.0	0	.0
Calcium Sulfate	136	0	.0	0	.0	8630	63.5	0	.0	8199	60.3
Yeast	***	0	.0	0	.0	8880	***	727	***	8436	***
Carbon Dioxide	44	0	.0	44376	1008.5	0	.0	0	.0	0	.0
Benzene	78	0	.0	0	.0	0	.0	0	.0	0	.0
Glycerol	92	0	.0	0	.0	1363	14.8	0	.0	41	.4
Fusel Oil	***	0	.0	0	.0	0	.0	0	.0	0	.0
Acetic Acid	60	0	.0	0	.0	0	.0	0	.0	0	.0
TOTAL		442228		44376		448281		1186		55172	

ETHANOL FROM CELLULOSE MATERIAL BALANCE

FOR

SOLAR ENERGY RESEARCH INSTITUTE

PREPARED BY

CHEM SYSTEMS, INC.

STREAM NO.		306		307		308					
	Mol Wt	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr
Water	18	280521	15584.5	29764	1653.6	4845	269.2				
Cellulose	162	9	.1	158	1.0	20	.1				
Hemicellulose	141	0	.0	0	.0	0	.0				
Lignin	***	5	***	93	***	12	***				
Ash	***	10	***	169	***	21	***				
Other	***	196	***	5	***	1	***				
Sucrose	342	0	.0	0	.0	0	.0				
Xylose	150	50772	338.5	1350	9.0	220	1.5				
Glucose	180	0	.0	0	.0	0	.0				
Furfural	96	3194	33.3	85	.9	14	.1				
HMF	126	12659	100.5	337	2.7	55	.4				
Pseudolignin	***	0	.0	0	.0	0	.0				
Ethanol	46	41975	912.5	1116	24.3	182	4.0				
Sulfuric Acid	98	1571	16.0	42	.4	7	.1				
Calcium Hydroxide	74	0	.0	0	.0	0	.0				
Calcium Sulfate	136	431	3.2	7295	53.6	904	6.6				
Yeast	***	444	***	7265	***	1171	***				
Carbon Dioxide	44	0	.0	0	.0	0	.0				
Benzene	78	0	.0	0	.0	0	.0				
Glycerol	92	1322	14.4	35	.4	6	.1				
Fusel Oil	***	0	.0	0	.0	0	.0				
Acetic Acid	60	0	.0	0	.0	0	.0				
TOTAL		393109		47714		7458					

ETHANOL FROM CELLULOSE MATERIAL BALANCE

FOR

SOLAR ENERGY RESEARCH INSTITUTE

PREPARED BY

CHEM SYSTEMS, INC.

STREAM NO.		401		402		403		404		405	
	Mol Wt	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr
Water	18	280521	15584.5	2634	146.3	277887	15438.2	11588	643.8	3721	206.7
Cellulose	162	9	.1	0	.0	9	.1	0	.0	0	.0
Hemicellulose	141	0	.0	0	.0	0	.0	0	.0	0	.0
Lignin	***	5	***	0	.0	5	***	0	.0	0	.0
Ash	***	10	***	0	.0	10	***	0	.0	0	.0
Other	***	196	***	0	.0	196	***	0	.0	0	.0
Sucrose	342	0	.0	0	.0	0	.0	0	.0	0	.0
Xylose	150	50772	338.5	0	.0	50772	338.5	0	.0	0	.0
Glucose	180	0	.0	0	.0	0	.0	0	.0	0	.0
Furfural	96	3194	33.3	0	.0	3194	33.3	0	.0	0	.0
HMF	126	12659	100.5	0	.0	12659	100.5	0	.0	0	.0
Pseudolignin	***	0	.0	0	.0	0	.0	0	.0	0	.0
Ethanol	46	41975	912.5	41261	897.0	714	15.5	181550	3946.7	58301	1267.4
Sulfuric Acid	98	1571	16.0	0	.0	1571	16.0	0	.0	0	.0
Calcium Hydroxide	74	0	.0	0	.0	0	.0	0	.0	0	.0
Calcium Sulfate	136	431	3.2	0	.0	431	3.2	0	.0	0	.0
Yeast	***	444	***	0	.0	444	***	0	.0	0	.0
Carbon Dioxide	44	0	.0	0	.0	0	.0	0	.0	0	.0
Benzene	78	0	.0	0	.0	0	.0	0	.0	0	.0
Glycerol	92	1322	14.4	0	.0	1322	14.4	0	.0	0	.0
Fusel Oil	***	0	.0	0	.0	0	.0	0	.0	0	.0
Acetic Acid	60	0	.0	0	.0	0	.0	0	.0	0	.0
TOTAL		393109		43895		349214		193138		62022	

ETHANOL FROM CELLULOSE MATERIAL BALANCE

FOR

SOLAR ENERGY RESEARCH INSTITUTE

PREPARED BY

CHEM SYSTEMS, INC.

STREAM NO.		406		407		408		409		410	
	Mol Wt	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr
Water	18	7869	437.2	7481	415.6	386	21.4	7869	437.2	11588	643.8
Cellulose	162	0	.0	0	.0	0	.0	0	.0	0	.0
Hemicellulose	141	0	.0	0	.0	0	.0	0	.0	0	.0
Lignin	***	0	.0	0	.0	0	.0	0	.0	0	.0
Ash	***	0	.0	0	.0	0	.0	0	.0	0	.0
Other	***	0	.0	0	.0	0	.0	0	.0	0	.0
Sucrose	342	0	.0	0	.0	0	.0	0	.0	0	.0
Xylose	150	0	.0	0	.0	0	.0	0	.0	0	.0
Glucose	180	0	.0	0	.0	0	.0	0	.0	0	.0
Furfural	96	0	.0	0	.0	0	.0	0	.0	0	.0
HMF	126	0	.0	0	.0	0	.0	0	.0	0	.0
Pseudolignin	***	0	.0	0	.0	0	.0	0	.0	0	.0
Ethanol	46	123249	2679.3	117201	2547.8	6047	131.5	123249	2679.3	181550	3946.7
Sulfuric Acid	98	0	.0	0	.0	0	.0	0	.0	0	.0
Calcium Hydroxide	74	0	.0	0	.0	0	.0	0	.0	0	.0
Calcium Sulfate	136	0	.0	0	.0	0	.0	0	.0	0	.0
Yeast	***	0	.0	0	.0	0	.0	0	.0	0	.0
Carbon Dioxide	44	0	.0	0	.0	0	.0	0	.0	0	.0
Benzene	78	0	.0	0	.0	0	.0	0	.0	0	.0
Glycerol	92	0	.0	0	.0	0	.0	0	.0	0	.0
Fusel Oil	***	0	.0	0	.0	0	.0	0	.0	0	.0
Acetic Acid	60	0	.0	0	.0	0	.0	0	.0	0	.0
TOTAL		131118		124682		6433		131118		193138	

ETHANOL FROM CELLULOSE MATERIAL BALANCE

FOR

SOLAR ENERGY RESEARCH INSTITUTE

PREPARED BY

CHEM SYSTEMS, INC.

STREAM NO.		411		412		413		414		415	
	Mol Wt	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr
Water	18	0	.0	0	.0	16439	913.3	1688	93.8	14751	819.5
Cellulose	162	0	.0	0	.0	0	.0	0	.0	0	.0
Hemicellulose	141	0	.0	0	.0	0	.0	0	.0	0	.0
Lignin	***	0	.0	0	.0	0	.0	0	.0	0	.0
Ash	***	0	.0	0	.0	0	.0	0	.0	0	.0
Other	***	0	.0	0	.0	0	.0	0	.0	0	.0
Sucrose	342	0	.0	0	.0	0	.0	0	.0	0	.0
Xylose	150	0	.0	0	.0	0	.0	0	.0	0	.0
Glucose	180	0	.0	0	.0	0	.0	0	.0	0	.0
Furfural	96	0	.0	0	.0	0	.0	0	.0	0	.0
HMF	126	0	.0	0	.0	0	.0	0	.0	0	.0
Pseudolignin	***	0	.0	0	.0	0	.0	0	.0	0	.0
Ethanol	46	0	.0	41261	897.0	43447	944.5	4461	97.0	38986	847.5
Sulfuric Acid	98	0	.0	0	.0	0	.0	0	.0	0	.0
Calcium Hydroxide	74	0	.0	0	.0	0	.0	0	.0	0	.0
Calcium Sulfate	136	0	.0	0	.0	0	.0	0	.0	0	.0
Yeast	***	0	.0	0	.0	0	.0	0	.0	0	.0
Carbon Dioxide	44	0	.0	0	.0	0	.0	0	.0	0	.0
Benzene	78	0	.0	0	.0	174961	2243.1	17965	230.3	156996	2012.8
Glycerol	92	0	.0	0	.0	0	.0	0	.0	0	.0
Fusel Oil	***	0	.0	0	.0	0	.0	0	.0	0	.0
Acetic Acid	60	0	.0	0	.0	0	.0	0	.0	0	.0
TOTAL		0		41261		234847		24114		210733	

ETHANOL FROM CELLULOSE MATERIAL BALANCE

FOR

SOLAR ENERGY RESEARCH INSTITUTE

PREPARED BY

CHEM SYSTEMS, INC.

STREAM NO.		416		417		418		419		420	
	Mol Wt	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr
Water	18	15014	834.1	16702	927.9	14068	781.6	2634	146.3	2371	131.7
Cellulose	162	0	.0	0	.0	0	.0	0	.0	0	.0
Hemicellulose	141	0	.0	0	.0	0	.0	0	.0	0	.0
Lignin	***	0	.0	0	.0	0	.0	0	.0	0	.0
Ash	***	0	.0	0	.0	0	.0	0	.0	0	.0
Other	***	0	.0	0	.0	0	.0	0	.0	0	.0
Sucrose	342	0	.0	0	.0	0	.0	0	.0	0	.0
Xylose	150	0	.0	0	.0	0	.0	0	.0	0	.0
Glucose	180	0	.0	0	.0	0	.0	0	.0	0	.0
Furfural	96	0	.0	0	.0	0	.0	0	.0	0	.0
HMF	126	0	.0	0	.0	0	.0	0	.0	0	.0
Pseudolignin	***	0	.0	0	.0	0	.0	0	.0	0	.0
Ethanol	46	44392	965.0	48853	1062.0	43477	945.2	5406	117.5	5406	117.5
Sulfuric Acid	98	0	.0	0	.0	0	.0	0	.0	0	.0
Calcium Hydroxide	74	0	.0	0	.0	0	.0	0	.0	0	.0
Calcium Sulfate	136	0	.0	0	.0	0	.0	0	.0	0	.0
Yeast	***	0	.0	0	.0	0	.0	0	.0	0	.0
Carbon Dioxide	44	0	.0	0	.0	0	.0	0	.0	0	.0
Benzene	78	157861	2023.9	175826	2254.2	174961	2243.1	865	11.1	865	11.1
Glycerol	92	0	.0	0	.0	0	.0	0	.0	0	.0
Fusel Oil	***	0	.0	0	.0	0	.0	0	.0	0	.0
Acetic Acid	60	0	.0	0	.0	0	.0	0	.0	0	.0
TOTAL		217267		241381		232506		8905		8642	

ETHANOL FROM CELLULOSE MATERIAL BALANCE

FOR

SOLAR ENERGY RESEARCH INSTITUTE

PREPARED BY

CHEM SYSTEMS, INC.

STREAM NO. 421

	Mol Wt	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr
Water	18	2371	131.7								
Cellulose	162	0	.0								
Hemicellulose	141	0	.0								
Lignin	***	0	.0								
Ash	***	0	.0								
Other	***	0	.0								
Sucrose	342	0	.0								
Xylose	150	0	.0								
Glucose	180	0	.0								
Furfural	96	0	.0								
HMF	126	0	.0								
Pseudolignin	***	0	.0								
Ethanol	46	0	.0								
Sulfuric Acid	98	0	.0								
Calcium Hydroxide	74	0	.0								
Calcium Sulfate	136	0	.0								
Yeast	***	0	.0								
Carbon Dioxide	44	0	.0								
Benzene	78	0	.0								
Glycerol	92	0	.0								
Fusel Oil	***	0	.0								
Acetic Acid	60	0	.0								
TOTAL		2371									

ETHANOL FROM CELLULOSE MATERIAL BALANCE

FOR

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PREPARED BY

CHEM SYSTEMS, INC.

STREAM NO.		501		502							
	Mol Wt	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr
Water	18	0	.0	0	.0						
Cellulose	162	0	.0	0	.0						
Hemicellulose	141	0	.0	0	.0						
Lignin	***	0	.0	0	.0						
Ash	***	0	.0	0	.0						
Other	***	0	.0	0	.0						
Sucrose	342	0	.0	0	.0						
Xylose	150	0	.0	0	.0						
Glucose	180	0	.0	0	.0						
Furfural	96	0	.0	0	.0						
HMF	126	0	.0	0	.0						
Pseudolignin	***	0	.0	0	.0						
Ethanol	46	0	.0	0	.0						
Sulfuric Acid	98	0	.0	0	.0						
Calcium Hydroxide	74	0	.0	0	.0						
Calcium Sulfate	136	0	.0	0	.0						
Yeast	***	0	.0	0	.0						
Carbon Dioxide	44	44376	1008.5	44376	1008.5						
Benzene	78	0	.0	0	.0						
Glycerol	92	0	.0	0	.0						
Fusel Oil	***	0	.0	0	.0						
Acetic Acid	60	0	.0	0	.0						
TOTAL		44376		44376							

ETHANOL FROM CELLULOSE MATERIAL BALANCE

FOR

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PREPARED BY

CHEM SYSTEMS, INC.

STREAM NO.		601		602		603		604		605	
	Mol Wt	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr
Water	18	34034	1890.8	32673	1815.2	20584	1143.6	53257	2958.7	1361	75.6
Cellulose	162	5186	32.0	5186	32.0	195	1.2	5381	33.2	0	.0
Hemicellulose	141	0	.0	0	.0	166	1.2	166	1.2	0	.0
Lignin	***	6473	***	6473	***	15201	***	21674	***	0	.0
Ash	***	11439	***	11439	***	29	***	11468	***	0	.0
Other	***	0	.0	0	.0	893	***	893	***	0	.0
Sucrose	342	0	.0	0	.0	1139	3.3	1139	3.3	0	.0
Xylose	150	0	.0	0	.0	6	.0	6	.0	0	.0
Glucose	180	422	2.3	422	2.3	11	.1	433	2.4	0	.0
Furfural	96	12	.1	12	.1	20	.2	32	.3	0	.0
HMF	126	87	.7	87	.7	11	.1	98	.8	0	.0
Pseudolignin	***	0	.0	0	.0	0	.0	0	.0	0	.0
Ethanol	46	0	.0	0	.0	723	15.7	723	15.7	0	.0
Sulfuric Acid	98	80	.8	80	.8	0	.0	80	.8	0	.0
Calcium Hydroxide	74	0	.0	0	.0	0	.0	0	.0	0	.0
Calcium Sulfate	136	0	.0	0	.0	0	.0	0	.0	0	.0
Yeast	***	0	.0	0	.0	0	.0	0	.0	0	.0
Carbon Dioxide	44	0	.0	0	.0	0	.0	0	.0	0	.0
Benzene	78	0	.0	0	.0	0	.0	0	.0	0	.0
Glycerol	92	0	.0	0	.0	0	.0	0	.0	0	.0
Fusel Oil	***	0	.0	0	.0	0	.0	0	.0	0	.0
Acetic Acid	60	0	.0	0	.0	0	.0	0	.0	0	.0
TOTAL		57733		56372		38978		95350		1361	

ETHANOL FROM CELLULOSE MATERIAL BALANCE

FOR

SOLAR ENERGY RESEARCH INSTITUTE

PREPARED BY

CHEM SYSTEMS, INC.

STREAM NO.		606		607		608		609		610	
	Mol Wt	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr
Water	18	277887	15438.2	331144	18396.9	331750	18430.6	290219	16123.3	41531	2307.3
Cellulose	162	9	.1	5390	33.3	5390	33.3	5390	33.3	0	.0
Hemicellulose	141	0	.0	166	1.2	166	1.2	166	1.2	0	.0
Lignin	***	5	***	21679	***	21679	***	21679	***	0	.0
Ash	***	10	***	11478	***	11478	***	11478	***	0	.0
Other	***	196	***	1089	***	1089	***	1089	***	0	.0
Sucrose	342	0	.0	1139	3.3	1139	3.3	1139	3.3	0	.0
Xylose	150	50772	338.5	50778	338.5	50778	338.5	50778	338.5	0	.0
Glucose	180	0	.0	433	2.4	433	2.4	433	2.4	0	.0
Furfural	96	3194	33.3	3226	33.6	3226	33.6	3226	33.6	0	.0
HMF	126	12659	100.5	12757	101.2	12757	101.2	12757	101.2	0	.0
Pseudolignin	***	0	.0	0	.0	0	.0	0	.0	0	.0
Ethanol	46	714	15.5	1437	31.2	1437	31.2	0	.0	1437	31.2
Sulfuric Acid	98	1571	16.0	1651	16.8	0	.0	0	.0	0	.0
Calcium Hydroxide	74	0	.0	0	.0	0	.0	0	.0	0	.0
Calcium Sulfate	136	431	3.2	431	3.2	2722	20.0	2722	20.0	0	.0
Yeast	***	444	***	444	***	444	***	444	***	0	.0
Carbon Dioxide	44	0	.0	0	.0	0	.0	0	.0	0	.0
Benzene	78	0	.0	0	.0	0	.0	0	.0	0	.0
Glycerol	92	1322	14.4	1322	14.4	1322	14.4	1322	14.4	0	.0
Fusel Oil	***	0	.0	0	.0	0	.0	0	.0	0	.0
Acetic Acid	60	0	.0	0	.0	0	.0	0	.0	0	.0
TOTAL		349214		444564		445810		402842		42968	

ETHANOL FROM CELLULOSE MATERIAL BALANCE

FOR

SOLAR ENERGY RESEARCH INSTITUTE

PREPARED BY

CHEM SYSTEMS, INC.

STREAM NO.		611		612		613		614		615	
	Mol Wt	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr
Water	18	240183	13343.5	50036	2779.8	179114	9950.8	61069	3392.7	96848	5380.4
Cellulose	162	5390	33.3	0	.0	5390	33.3	0	.0	5390	33.3
Hemicellulose	141	166	1.2	0	.0	166	1.2	0	.0	166	1.2
Lignin	***	21679	***	0	.0	21679	***	0	.0	21679	***
Ash	***	11478	***	0	.0	11478	***	0	.0	11478	***
Other	***	1089	***	0	.0	1089	***	0	.0	1089	***
Sucrose	342	1139	3.3	0	.0	1139	3.3	0	.0	1139	3.3
Xylose	150	50778	338.5	0	.0	50778	338.5	0	.0	50778	338.5
Glucose	180	433	2.4	0	.0	433	2.4	0	.0	433	2.4
Furfural	96	3226	33.6	0	.0	3226	33.6	0	.0	3226	33.6
HMF	126	12757	101.2	0	.0	12757	101.2	0	.0	12757	101.2
Pseudolignin	***	0	.0	0	.0	0	.0	0	.0	0	.0
Ethanol	46	0	.0	0	.0	0	.0	0	.0	0	.0
Sulfuric Acid	98	0	.0	0	.0	0	.0	0	.0	0	.0
Calcium Hydroxide	74	0	.0	0	.0	0	.0	0	.0	0	.0
Calcium Sulfate	136	2722	20.0	0	.0	2722	20.0	0	.0	2722	20.0
Yeast	***	444	***	0	.0	444	***	0	.0	444	***
Carbon Dioxide	44	0	.0	0	.0	0	.0	0	.0	0	.0
Benzene	78	0	.0	0	.0	0	.0	0	.0	0	.0
Glycerol	92	1322	14.4	0	.0	1322	14.4	0	.0	1322	14.4
Fusel Oil	***	0	.0	0	.0	0	.0	0	.0	0	.0
Acetic Acid	60	0	.0	0	.0	0	.0	0	.0	0	.0
TOTAL		352806		50036		291737		61069		209471	

ETHANOL FROM CELLULOSE MATERIAL BALANCE

FOR

SOLAR ENERGY RESEARCH INSTITUTE

PREPARED BY

CHEM SYSTEMS, INC.

STREAM NO.		616		617		618		619		620	
	Mol Wt	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr
Water	18	82266	4570.3	193371	10742.8	0	.0	881360	48964.4	78150	4341.7
Cellulose	162	0	.0	0	.0	0	.0	0	.0	0	.0
Hemicellulose	141	0	.0	0	.0	0	.0	0	.0	0	.0
Lignin	***	0	.0	0	.0	0	.0	0	.0	0	.0
Ash	***	0	.0	0	.0	0	.0	0	.0	0	.0
Other	***	0	.0	0	.0	0	.0	0	.0	0	.0
Sucrose	342	0	.0	0	.0	0	.0	0	.0	0	.0
Xylose	150	0	.0	0	.0	0	.0	0	.0	0	.0
Glucose	180	0	.0	0	.0	0	.0	0	.0	0	.0
Furfural	96	0	.0	0	.0	0	.0	0	.0	0	.0
HMF	126	0	.0	0	.0	0	.0	0	.0	0	.0
Pseudolignin	***	0	.0	0	.0	0	.0	0	.0	0	.0
Ethanol	46	0	.0	0	.0	0	.0	0	.0	0	.0
Sulfuric Acid	98	0	.0	0	.0	0	.0	0	.0	0	.0
Calcium Hydroxide	74	0	.0	0	.0	0	.0	0	.0	0	.0
Calcium Sulfate	136	0	.0	0	.0	0	.0	0	.0	0	.0
Yeast	***	0	.0	0	.0	0	.0	0	.0	0	.0
Carbon Dioxide	44	0	.0	0	.0	0	.0	0	.0	0	.0
Benzene	78	0	.0	0	.0	0	.0	0	.0	0	.0
Glycerol	92	0	.0	0	.0	0	.0	0	.0	0	.0
Fusel Oil	***	0	.0	0	.0	0	.0	0	.0	0	.0
Acetic Acid	60	0	.0	0	.0	0	.0	0	.0	0	.0
TOTAL		82266		193371		0		881360		78150	

ETHANOL FROM CELLULOSE MATERIAL BALANCE

FOR

SOLAR ENERGY RESEARCH INSTITUTE

PREPARED BY

CHEM SYSTEMS, INC.

STREAM NO.		621		622		623		624		625	
	Mol Wt	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr
Water	18	135713	7539.6	3015514	167528.6	2371	131.7	40210	2233.9	309236	17179.8
Cellulose	162	0	.0	0	.0	0	.0	557	3.4	10	.1
Hemicellulose	141	0	.0	0	.0	0	.0	0	.0	9	.1
Lignin	***	0	.0	0	.0	0	.0	333	***	800	***
Ash	***	0	.0	0	.0	0	.0	588	***	1	***
Other	***	0	.0	0	.0	0	.0	0	.0	11722	***
Sucrose	342	0	.0	0	.0	0	.0	0	.0	14957	43.7
Xylose	150	0	.0	0	.0	0	.0	15	.1	84	.6
Glucose	180	0	.0	0	.0	0	.0	26	.1	152	.8
Furfural	96	0	.0	0	.0	0	.0	1	.0	260	2.7
HMF	126	0	.0	0	.0	0	.0	4	.0	151	1.2
Pseudolignin	***	0	.0	0	.0	0	.0	0	.0	0	.0
Ethanol	46	0	.0	0	.0	0	.0	0	.0	714	15.5
Sulfuric Acid	98	0	.0	0	.0	0	.0	1	.0	0	.0
Calcium Hydroxide	74	0	.0	0	.0	0	.0	0	.0	0	.0
Calcium Sulfate	136	0	.0	0	.0	0	.0	25360	186.5	0	.0
Yeast	***	0	.0	0	.0	0	.0	0	.0	0	.0
Carbon Dioxide	44	0	.0	0	.0	0	.0	0	.0	0	.0
Benzene	78	0	.0	0	.0	0	.0	0	.0	0	.0
Glycerol	92	0	.0	0	.0	0	.0	0	.0	0	.0
Fusel Oil	***	0	.0	0	.0	0	.0	0	.0	0	.0
Acetic Acid	60	0	.0	0	.0	0	.0	0	.0	0	.0
TOTAL		135713		3015514		2371		67095		338096	

ETHANOL FROM CELLULOSE MATERIAL BALANCE

FOR

SOLAR ENERGY RESEARCH INSTITUTE

PREPARED BY

CHEM SYSTEMS, INC.

STREAM NO.		626		627		628					
	Mol Wt	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr	Lbs/Hr	Mols/Hr
Water	18	4845	269.2	0	.0	58536	3252.0				
Cellulose	162	20	.1	0	.0	0	.0				
Hemicellulose	141	0	.0	0	.0	0	.0				
Lignin	***	12	***	0	.0	0	.0				
Ash	***	21	***	0	.0	0	.0				
Other	***	1	***	0	.0	0	.0				
Sucrose	342	0	.0	0	.0	0	.0				
Xylose	150	220	1.5	0	.0	0	.0				
Glucose	180	0	.0	0	.0	0	.0				
Furfural	96	14	.1	0	.0	0	.0				
HMF	126	55	.4	0	.0	0	.0				
Pseudolignin	***	0	.0	0	.0	0	.0				
Ethanol	46	182	4.0	0	.0	0	.0				
Sulfuric Acid	98	7	.1	0	.0	0	.0				
Calcium Hydroxide	74	0	.0	1247	16.9	0	.0				
Calcium Sulfate	136	904	6.6	0	.0	0	.0				
Yeast	***	1171	***	0	.0	0	.0				
Carbon Dioxide	44	0	.0	0	.0	186579	4240.4				
Benzene	78	0	.0	0	.0	0	.0				
Glycerol	92	6	.1	0	.0	0	.0				
Fusel Oil	***	0	.0	0	.0	0	.0				
Acetic Acid	60	0	.0	0	.0	0	.0				
TOTAL		7458		1247		245115					

III. ECONOMIC EVALUATION

A. Introduction

A detailed cost analysis utilizing the ICARUS CØST computer program has been performed for the base case, 50 million gallon per year ethanol from cellulose plant described in Section II. Capital and operating costs, and cost of production of ethanol are high for the base case, since it is not an optimum design. The coal-fired steam system stands out as the major cost item, comprising almost 41 percent of the total plant cost and 75 percent of the OSBL costs.

An alternate case is examined based upon additional experimental information concerning the extraction of lignin with ethanol. The base case material balance and design uses an ethanol:lignin ratio of 33:1. From recent information, the ratio might be approximately 15:1. The economies of this higher efficiency lignin extraction case significantly reduce costs compared to the base case. The high efficiency lignin extraction case, may be more realistic if the extraction can be efficiently performed at the lower solvent:lignin value.

A brief discussion is included of suggested areas for optimization of various process steps. It is felt that optimization can significantly reduce the capital and operating costs compared to the cases described in this report, and preliminary estimates are given for a potential optimum process.

B. Base Case Economics

1. Capital Cost Estimate

A total investment cost for the production of 50 million gallons per year of ethanol from corn stover for the base case process described in Section II has been determined utilizing the ICARUS CØST program. The total cost is 236.5 million dollars on a third quarter 1980 basis. Of this, 108.1 million dollars is the inside battery limits (ISBL) cost and 128.4 million dollars is for outside battery limits (OSBL).

A detailed equipment list for all major equipment items is included in the appendix (Section IV). The list includes the design specifications for each item, including materials of construction, as well as an estimated purchase price on a third quarter 1980 basis. The item numbers on the lists are keyed to the process flowsheets and all major equipment items shown on the flowsheets are included on the list. Section 500, Carbon Dioxide Recovery System, is included as a complete package, known cost item, and is added to the cost generated by the ICARUS program.

A breakdown of ISBL capital costs is given in Table III-1. Offsites include capital for storage, a steam system, a cooling water system and miscellaneous items. Table III-2 gives a breakdown of offsites cost.

2. Production Cost Estimate

a. Cost of Production Summary

Table III-3 is a production cost analysis for the base case, 50 million gallon per year ethanol from cellulose plant. The plant basis is third quarter-1980 in a U.S. Gulf Coast location. Most of the items on the cost of production form are self-explanatory. Additional comments covering raw materials, products and utilities are presented in the following sub-sections.

TABLE III-1

ISBL CAPITAL COST SUMMARY
Base Case, 3rd Quarter 1980

	Amount ($)	Percent of Total Cost
1. Purchased Equipment		
Section 100	12,027,200	12.0
Section 200	14,923,600	14.9
Section 300	3,714,900	3.7
Section 400	1,478,100	1.4
Section 600	5,441,600	5.4
Section 900	81,600	0.1
	37,667,000	37.5
2. Equipment Setting	532,400	0.5
3. Piping	17,263,700	17.3
4. Civil	2,181,900	2.2
5. Steel	1,168,400	1.2
6. Instrumentation	3,959,700	4.0
7. Electrical	3,589,000	3.6
8. Insulation	6,213,500	6.2
9. Paint	761,900	0.8
Total Field Cost	73,337,500	73.2
Engineering	4,105,700	4.1
Construction Overhead	8,851,700	8.8
Bare Plant Cost	86,294,900	86.1
Contingencies	8,512,700	8.5
Contractor's Fee	2,561,400	2.5
Special Charges	2,938,000	2.9
Total	100,307,000	100.00
CO_2 Recovery System	7,800,000	
	108,107,000	

TABLE III-2

OFFSITES CAPITAL COST
ETHANOL FROM CELLULOSE PROCESS
Base Case

Item	Description	Cost ($) 3rd Quarter 1980
1. Storage	Ethanol (14 days, 2,100,000 gallons)	617,000
	Calcium hydroxide (14 days, 300,000 gallons)	143,000
	Sulfuric acid (14 days, 500,000 gallons)	211,000
	Yeast (14 days, 20,000 gallons)	47,000
	Corn stover (14 days, 9,000,000 gallons)	2,149,000
	Total storage	3,167,000
2. Steam System	1.6x106 lbs/hr, coal fired 600 psig saturated steam	96,000,000
3. Cooling Water System	205,000 gpm	12,440,000
4. Buildings	at 3.0% ISBL	2,957,100
5. General Utilities	at 5.0% ISBL	4,928,500
6. Site Development	at 3.0% ISBL	2,957,100
7. Piping	at 3.0% ISBL	2,957,100
8. Pollution Control	at 2.0% ISBL	1,971,400
9. CO_2 Recovery System Offsites		975,000
Total Offsites		128,353,200

TABLE III-3

COST OF PRODUCTION ESTIMATE FOR ETHANOL
PROCESS- ACID HYDROLYSIS

CAPITAL SUMMARY

BASIS		CAPITAL COST	$MILLION
Location:	U.S. Gulf Coast	Battery Limits	108.1
	3rd Quarter, 1980	Offsites	128.4
Capacity:	50.0 million gallons/yr		
	149,336 metric tons/yr	Total Fixed Inv.	236.5
Str.Time:	8000 hours per year	Working Capital	29.0

PRODUCTION COST SUMMARY

RAW MATERIALS	UNITS/ GALLON	PRICE, ¢/UNIT	ANNUAL COST, $M	CENTS/ GALLON	DOLLARS/ MET TON
Corn Stover, Lb	50.0000	1.5	37,500		
Sulfuric Acid, Lb	3.3520	4.0	6,704		
Calcium Hydr., Lb	2.5240	1.6	2,019		
Catalyst & Chemicals			2,700		
TOTAL RAW MATERIALS			48,923	97.85	327.60
UTILITIES					
Power, Kwh	1.9130	3.0	2,870		
Cooling Water, M Gal	1.9620	5.2	5,101		
Process Water, M Gal	.0797	52.0	2,072		
Boiler Feedwtr, M Gal	.0080	89.0	356		
Steam, 200psig, M Lb	.0222	268.0	2,975		
Steam, 50psig, M Lb	.2377	264.0	31,376		
TOTAL UTILITIES			44,750	89.50	299.66
OPERATING COSTS					
Labor, 46 Men @ $ 21,900		10 M/S	1,007		
Foremen, 9 Men @ $ 24,900		1 M/S	224		
Supervision, 1 Man @ $ 30,000		1 Man	30		
Maint., Material & Labor		6% of ISBL	6,486		
TOTAL OPERATING COST			7,747	15.49	51.88
OVERHEAD EXPENSES					
Direct Overhead	45% Lab. & Sup.		568		
Gen. Plant Overhead	65% Oper. Costs		5,036		
Insurance, Prop. Tax	1.5% Tot. Fix. Inv.		3,548		
Depreciation	10% ISBL + 10% OSBL		23,650		
TOTAL OVERHEAD EXPENSES			32,801	65.60	219.65
TOTAL COST OF PRODUCTION			134,222	268.44	898.79
BY-PRODUCT CREDIT					
Carbon Dioxide, Lb	7.1000	2.5	-8,875		
SCP, Lb	.1874	13.0	-1,218		
TOTAL BY-PRODUCT CREDIT			-10,093	-20.19	-67.59
NET COST OF PRODUCTION			124,129	248.26	831.20
SALES PRICE AT 15% DCF				435.3	

The discounted cash flow (DCF) analysis contains the following assumptions:

- Time of construction - 2 years with uniform expenditures of capital throughout this period.

- Working capital, equivalent to four months production costs, is available at completion of construction, and is discounted at the same rate as the final DCF percentage. This is recovered at the end of the ten-year life of the project.

- Total federal and local taxes at 50 percent.

- Depreciation is straight line, over a ten-year period, with no salvage value for the plant.

- Cost of sales is 10 percent of the product selling price.

- A gradual sales build-up of 60 percent of capacity in the first year, 80 percent in the second and 100 percent in the third year onward.

Because of the manner in which the working capital is handled in the DCF calculations, the interest rate on working capital does not appear as separate item in the cost of production schedules.

The net cost of production for this prototype plant is $2.48 per gallon of ethanol. Raw materials, utilities and overhead expenses contribute significantly to this cost. The ethanol sales price at 15 percent DCF return on investment is $4.35 per gallon.

b. Products

Table III-4 summarizes the products and by-products of the base case process.

TABLE III-4

PRODUCT SUMMARY

Ethanol	50.0 MM gallons/year
Yeast (SCP)	9.4 MM pounds/year
Carbon Dioxide	355.0 MM pounds/year

c. Raw Materials

The major raw materials and chemicals and catalyst requirements are sumarized in Table III-5.

TABLE III-5

RAW MATERIALS SUMMARY

	MM lbs/year
1. Corn Stover (Field dry, 20% moisture)	2500.0
2. Sulfuric Acid (100%)	167.6
3. Calcium Hydroxide	126.2

CATALYST AND CHEMICALS SUMMARY

	Unit Price ($)	Lbs/yr	Annual Cost ($)
1. Makeup Yeast	0.45/lb	5,816,000	2,617,200
2. Activated Charcoal (arbitrary)	1.00/lb	10,000	10,000
3. Benzene (arbitrary)	1.75/gal	100,000	25,000
Total			2,652,200

d. Utilities

The production cost analysis shows the yearly consumption of utilities. These were calculated from the heat and material balances for the base case process. Table III-6 is an itemized breakdown of utilities consumption by plant section. Table III-7 is a detailed list by individual users of plant utilities.

TABLE III-6

OVERALL UTILITY SUMMARY BASE CASE

	Steam, Pounds/hr 30 PSIA	55 PSIA	200 PSIA	600 PSIA	Power, HP	Cooling Water, GPM	Process Water, GPM
Section 100	879,589	---	156,794	173,250	4,026	77,050	3,006
Section 200	(360,380)	896,500	258,374	215,311	5,791	95,570	5,290
Section 300	---	---	---	---	767	2,280	1
Section 400	---	---	128,273	---	126	4,175	4
Section 500	---	---	---	---	4,937	---	---
Section 600	---	70,000	(492,799)	(388,561)	380	25,340	---
Total	519,209	966,500	138,639	---	16,027	204,415	8,301
Yearly Consumption	4,153,672 (M Lbs)	7,732,000 (M Lbs)	1,109,112 (M Lbs)	---	95,649,136 (Kwh)	98,119,200 (Mgal)	3,984,500 (Mgal)
Per Gallon Ethanol	83.07 (Lbs)	154.64 (Lbs)	22.18 (Lbs)	---	1.913 (Kwh)	1.962 (M gal)	0.080 (M gal)

TABLE III-7

BASE CASE UTILITY SUMMARY-STEAM

Item	Name	Pounds Per Hour 30 Psia	55 Psia	200 Psia	600 Psia
EG-113	Steam explosion	---	---	---	173,250
HE-145	Solvent recovery reboiler	920,673	---	---	---
HE-166	Ethanol still reboiler	---	---	87,997	---
APT-124	Prehydrolysis slurry tank	---	---	12,958	---
R-125	Prehydrolysis PFR	---	---	143,836	---
VT-127	Prehydrolysis flash	(41,084)	---	---	---
Subtotal Section 100		879,589	---	244,791	173,250
HE-204	Hydrolysis preheater	---	---	258,374	---
R-205	Hydrolysis PFR	---	---	---	215,311
HE-239	Evaporator reboiler	---	896,500	---	---
VT-206	Hydrolysis flash	(360,380)	---	---	---
Subtotal Section 200		(360,380)	896,500	258,374	215,311
HE-403	Rect. column reboiler		---	128,273	---
Subtotal Section 400		---	---	128,273	---
HE-609	Evaporator reboiler	---	70,000	---	---
WTS-622	Lignin boiler	---	---	(492,799)	(388,561)
Subtotal Section 600		---	70,000	(492,799)	(388,561)
Plant Total		519,209	966,500	138,639	---
Yearly consumption (Mlbs)		4,153,672	7,732,000	1,109,112	---

TABLE III-7 (continued)

BASE CASE UTILITY SUMMARY-COOLING WATER (AVAILABLE AT 86°F)

Item 1	Name	GPM	T(°F)
HE-153	Stripped solvent condenser	600	25
HE-110	Feed cooler	1,010	25
HE-148	Condenser	69,430	25
HE-147	Pre-extraction cooler	1,020	25
HE-168	Condenser	4,990	25
Subtotal Section 100		77,050	
HE-243	Condenser	69,090	25
HE-248	Subcooler	26,480	25
Subtotal Section 200		95,570	
HE-307	Precooler	1,190	25
HE-309	Cooler	1,090	25
Subtotal Section 300		2,280	
HE-408	Overhead condenser	3,900	25
HE-412	Overhead subcooler	100	25
HE-415	Product cooler	155	25
HE-419	Waste water cooler	20	25
Subtotal Section 400		4,175	
HE-613	Condenser	6,750	25
HE-618	Subcooler	1,900	25
HE-621	Condenser	16,690	25
Subtotal Section 600		25,340	
Plant Total		204,415	
Yearly Requirement (M gal)		98,119,200	

TABLE III 7 (continued)

BASE CASE UTILITY SUMMARY-PROCESS WATER

		GPM
F-118	Filter wash	975
APT-124	Prehydrolysis slurry tank	1,560
APT-132	Repulping tank	420
F-137	Filter wash	50
VT-155	Ethanol tank	1
Subtotal Section 100		3,006
APT-202	Plug flow mix tank	2,420
APT-211	Repulping tank	2,550
F-216	Filter wash	130
APT-225	Lime slurry tank	30
F-232	Filter wash	160
Subtotal Section 200		5,290
APT-321	Yeast makeup	1
Subtotal Section 300		1
Subtotal Section 500		4
Plant Total		8,301
Yearly consumption (MGAL)		3,984,480

TABLE III-7 (continued)

BASE CASE UTILITY SUMMARY-POWER

ITEM	NAME	MOTOR HP
CR-195	Shredder	300
FE-108	Feeder	10
CO-112	Screw Conveyor	2
CO-115	Screw Conveyor	2
APT-116	Agitator	120
CP-117	Filter Feed Pumps	90
F-118	Rotary Drum Filters	30
CP-119	Wash Water Pumps	45
CP-120	Screw Conveyors	100
CO-122	Screw Conveyors	4
CO-123	Screw Conveyors	40
APT-124	Prehydrolysis Slurry Tank	40
CO-125	Screw Conveyors	75
R-126	Plug Flow Reactors	25
CO-128	Screw Conveyors	40
CT-129	Centrifuges	1,000
CO-130	Screw Conveyors	45
CP-131	Overflow Pumps	80
APT-132	Repulping Tank	40
CO-133	Screw Conveyors	10
CT-134	Centrifuge	250
CO-135	Screw Conveyor	5
CP-136	Overflow Pumps	20
CO-138	Screw Conveyors	4
CP-139	Filtrate Pumps	80
CP-162	Wash Water Pumps	3
APT-141	Miscella Feed Tanks	440
CP-146	Bottoms Pumps	45
CP-149	Distillate Pump	90
APT-152	Lignin Slurry Tanks	240
CP-159	Lignin Slurry Pump	25
CT-162	Lignin Centrifuge	250
CP-164	Overflow Pump	20
CP-163	Bottoms Pump	5
CP-169	Reflux Pump	15
CP-167	Reboiler Pump	20
CP-157	Solvent Feed Pump	40
CP-140	Filtrate Pump	60
CP-154	Condensate Pump	2
CO-170	Conveyor	2
CO-171	Conveyor	2
CO-172	Bucket Conveyor	10
CP-143	Feed Pump	300
	Subtotal Section 100	4,026

TABLE III-7 (continued)

BASE CASE UTILITY SUMMARY-POWER

ITEM	NAME	MOTOR HP
CO-201	Screw Conveyor	25
APT-202	Plug Flow Mix Tank	160
CO-203	Screw Conveyors	700
R-205	Plug Flow Reactors	280
CO-207	Screw Conveyors	60
CT-208	Centrifuges	1,000
CO-209	Screw Conveyors	20
CO-210	Overflow Pumps	120
APT-211	Repulping Tank	120
CO-212	Screw Conveyors	200
CT-213	Centrifuges	1,250
CO-214	Screw Conveyors	125
CP-215	Overflow Pumps	150
CO-219	Screw Conveyors	6
CO-220	Screw Conveyor	25
CO-221	Screw Conveyor	15
CP-218	Wash Water Pump	4
APT-225	Lime Slurry Tank	240
CP-226	Lime Slurry Pump	3
APT-224	Neutralizer Tank	440
CP-227	Neutralizer Pump	100
CP-229	Filter Feed Pump	120
CP-222	Filtrate Pump	125
CP-231	Wash Water Pump	9
CO-234	Screw Conveyor	9
CP-233	Filtrate Pump	225
CP-244	Condensate Pump	60
CP-245	Distillate Pump	200
	Subtotal Section 200	5,791
CP-302	Carbon Column Feed Pump	15
CP-306	Fermentation Feed Pump	15
CP-310	Fermenter Recirculation Pumps	200
CP-311	Alcohol Charge Pumps	60
CP-313	Distillation Feed Pump	60
CP-314	Centrifuge Feed Pumps	50
CP-317	Yeast Recycle Pumps	3
CP-331	Yeast Centrifuge Bottoms Pumps	4
CP-330	Fermenter Pumps	250
CP-324	Nutrient Mix Tank Pump	1
CP-325	Yeast Preparation Pump	1
CP-326	Yeast Tub Pump	15
CP-327	Culture Hold Tank Pump	10
APT-321	Yeast Preparation Tank	3
APT-320	Nutrient Mix Tank	5
APT-322	Yeast Tubs	75
	Subtotal Section 300	767

TABLE III-7 (continued)

BASE CASE UTILITY SUMMARY-POWER

ITEM	NAME	MOTOR HP
CP-405	Reboiler Pump	40
CP-406	Reflux Pump	40
CP-410	Reboiler Pump	10
CP-414	Reflux Pump	25
CP-418	Reboiler Pump	3
CP-421	Feed Pump	3
CP-422	Feed Pump	5
	Section 400 Subtotal	126
	Section 500 Subtotal	4,937
CP-602	Feed Pump	20
CP-604	Feed Pump	20
CP-617	Distillate Pump	15
CP-620	Wastee Water Pump	15
CP-616	Bottoms Pump	10
CP-625	By product Pump	250
APT-625	Neutralizer Tank	50
	Section 600 Subtotal	380
	Plant Total	16,027

Yearly Requirement (Kwh): $16{,}027 \times 0.746 \times 8000 \frac{hr}{yr} =$ 95,649,136

C. Alternative Case Economics-High Efficiency Lignin Extraction

1. Capital Cost Estimate

Additional information concerning the extraction of lignin with ethanol indicates an ethanol to lignin ratio of approximately 15:1 may be feasible, instead of the 33:1 used in the material balance and cost estimate for the base case. This changes capital and operating costs significantly. An estimate of the case utilizing the lower ratio reduces the size of equipment in the solvent recovery systems and significantly lowers the cost of the coal-fired steam boiler. Using an ethanol to lignin ratio of 15:1 gives a total cost of $196.3 million of which $102.2 million is ISBL and $94.1million is OSBL. ISBL and OSBL capital cost breakdowns for the reduced ethanol: lignin ratio case are summarized in Table III-8 and III-9 respectively.

TABLE III-8

ISBL CAPITAL COST SUMMARY WITH HIGH EFFICIENCY LIGNIN EXTRACTION

1. Purchased Equipment	Amount ($)	Percent of Total Cost
Section 100	9,577,200	10.1
Section 200	14,923,600	15.8
Section 300	3,714,900	39.9
Section 400	1,478,100	1.6
Section 600	5,441,600	5.8
Section 900	81,600	.1
	35,197,000	37.3
2. Equipment Setting	502,800	.5
3. Piping	16,537,500	17.5
4. Civil	2,097,900	2.2
5. Steel	1,094,300	1.2
6. Instrumentation	3,814,000	4.0
7. Electrical	3,480,300	3,6
8. Insulation	5,964,100	6.2
9. Paint	729,800	0.8
Total Field Cost	69,417,300	73.2
Engineering	3,836,500	4.1
Construction Overhead	8,271,300	8.8
Bare Plant Cost	81,525,100	86.1
Contingencies	7,954,500	8.5
Contractor's Fee	2,393,400	2.5
Special Charges	2,745,600	2.9
Total	94,364,600	100.00
CO_2 Recovery System	7,800,000	
Total ISBL	102,164,600	

TABLE III-9

OSBL CAPITAL COST SUMMARY WITH HIGH EFFICENCY LIGNIN EXTRACTION

ITEM	Description	Cost ($)
1. Storage	Same as Table III-2	3,167,000
2. Steam System	1.074 x 10^6 lbs/hr, coal fired complete system, 600 psig saturated steam	64,400,000
3. Cooling Water System	163,000 gpm	10,961,000
4. Buildings	at 3.0% ISBL	2,737,200
5. General Utilities	at 5.0% ISBL	5,562,000
6. Site Development	at 3.0% ISBL	2,737,200
7. Piping	at 3.0% ISBL	2,737,200
8. Polluution control	at 2.0% ISBL	1,824,800
9. CO_2 Recovery System Offsites		975,000
Total Offsites		94,101,400

2. Production Cost Estimate

a. Cost of Production Summary

Table III-10 is a production cost analysis for the high efficiency lignin extraction case. The plant basis is third quarter-1980 in a U.S. Gulf Coast location. Summaries of raw materials, products and utilities are presented in the following subsections.

The net cost of production for the high efficiency lignin extraction variation of this prototype plant is $2.07 per gallon of ethanol. Raw materials, utilities and overhead expenses still contribute significantly to this cost, but steam costs have decreased markedly from the base case. The ethanol sales price at 15 percent DCF return on investment is $3.63 per gallon.

b. Products

The products and by products for the high efficiency lignin extraction case are identical to those in the base case and are summarized in Table III-4.

TABLE III-10

COST OF PRODUCTION ESTIMATE FOR ETHANOL
PROCESS- ACID HYDROLYSIS

CAPITAL SUMMARY

BASIS		CAPITAL COST	$MILLION
Location:	U.S. Gulf Coast	Battery Limits	102.2
	3rd Quarter, 1980	Offsites	94.1
Capacity:	50.0 million gallons/yr		
	149,336 metric tons/yr	Total Fixed Inv.	196.3
Str.Time:	8000 hours per year	Working Capital	25.0

PRODUCTION COST SUMMARY

RAW MATERIALS	UNITS/ GALLON	PRICE, ¢/UNIT	ANNUAL COST, $M	CENTS/ GALLON	DOLLARS/ MET TON
Corn Stover, Lb	50.0000	1.5	37,500		
Sulfuric Acid, Lb	3.3520	4.0	6,704		
Calcium Hydr., Lb	2.5240	1.6	2,019		
Catalyst & Chemicals			100		
TOTAL RAW MATERIALS			46,323	92.65	310.19
UTILITIES					
Power, Kwh	1.8630	3.0	2,794		
Cooling Water, M Gal	1.5650	5.2	4,069		
Process Water, M Gal	.0797	52.0	2,072		
Boiler Feedwtr, M Gal	.0070	89.0	312		
Steam, 200psig, M Lb	.0145	268.0	1,943		
Steam, 50psig, M Lb	.1574	264.0	20,777		
TOTAL UTILITIES			31,967	63.93	214.06
OPERATING COSTS					
Labor, 46 Men @ $ 21,900	10 M/S		1,007		
Foremen, 9 Men @ $ 24,900	1 M/S		224		
Supervision, 1 Man @ $ 30,000	1 Man		30		
Maint., Material & Labor	6% of ISBL		6,132		
TOTAL OPERATING COST			7,393	14.79	49.51
OVERHEAD EXPENSES					
Direct Overhead	45% Lab. & Sup.		568		
Gen. Plant Overhead	65% Oper. Costs		4,806		
Insurance, Prop. Tax	1.5% Tot. Fix. Inv.		2,945		
Depreciation	10% ISBL + 10% OSBL		19,630		
TOTAL OVERHEAD EXPENSES			27,948	55.90	187.15
TOTAL COST OF PRODUCTION			113,632	227.26	760.91
BY-PRODUCT CREDIT					
Carbon Dioxide, Lb	7.1000	2.5	-8,875		
SCP, Lb	.1874	13.0	-1,218		
TOTAL BY-PRODUCT CREDIT			-10,093	-20.19	-67.59
NET COST OF PRODUCTION			103,539	207.08	693.33
SALES PRICE AT 15% DCF				363.4	

c. Raw Materials

The major raw materials and catalyst and chemicals are summarized in Table III-11. These will be the same as for the base case except that the by-product stream containing sucrose and soluble proteins (Stream 625) will be used as a yeast growth media in the Fermentation Section. This will eliminate the need for makeup yeast as a chemical requirement.

TABLE III-11

RAW MATERIALS SUMMARY

Same as in base case, Table III-5

CATALYST AND CHEMICALS SUMMARY

	Unit Price ($)	Lbs/yr	Annual Cost ($)
1. Activated Charcoal (arbitrary)	1.00/Lb	10,000	10,000
2. Benzene (arbitrary)	1..75/Gal	100,000	25,000
Total			35,000

d. Utilities

The production cost analysis shows the yearly consumption of utilities. These are calculated from the material and heat balances and are based upon an ethanol:lignin ratio of 15:1. Table III-12 is an itemized breakdown of utilities consumption by plant section. Table III-13 shows the changes from the base case for individual users of plant utilities.

TABLE III-12

HIGH EFFICIENCY LIGNIN EXTRACTION OVERALL UTILITY SUMMARY

	Steam, Pounds/hr				Power,	Cooling Water,	Process Water,
	30 PSIA	55 PSIA	200 PSIA	600 PSIA	HP	GPM	GPM
Section 100	377,404	---	156,794	173,250	3,611	35,690	3,006
Section 200	(360,380)	896,500	258,374	215,311	5,791	95,570	5,290
Section 300	---	---	---	---	767	2,280	1
Section 400	---	---	(128,273)	---	126	4,175	---
Section 500	---	---	---	---	4,937	---	4
Section 600	---	70,000	(492,799)	(388,561)	380	25,340	---
Total	17,024	966,500	90,642	---	15,612	163,057	8,301
Yearly Consumption (Mlbs)	136,192	7,732,000	725,136	---	93,172,416	78,267,360	3,984,500
	(M Lbs)	(M Lbs)	(M Lbs)		(Kwh)	(Mgal)	(Mgal)
Per Gallon Ethanol	2.724 (Lbs)	154.64 (Lbs)	14.503 (Lbs)	---	1.863 (Kwh)	1.565 (M gal)	0.080 (M gal)

TABLE III-13

UTILITY SUMMARY HIGH EFFICIENCY LIGNIN EXTRACTION
(Steam-Pounds per hour)

Item	Name	30 PSIA	55 PSIA	200 PSI	600 PSI
FG-113	Steam Explosion	---	---	---	173,250
HE-145	Solvent recovery reboiler	418,488	---	---	---
HE-166	Ethanol still reboiler	---	---	40,000	---
APT-124	Prehydrolysis Slurry Tank	---	---	12,958	---
R-126	Prehydrolysis PFR	---	---	143,836	---
VT-127	Prehydrolysis Flash	(41,084)	---	---	---
Subtotal Section 100		377,404	---	196,794	173,250
Subtotal Section 200		(360,380)	896,500	258,374	215,311
Subtotal Section 400		---	---	128,273	---
Subtotal Section 600		---	70,000	(492,799)	(388,561)
Plant Total		17,024	996,500	90,642	---
Yearly Consumption (MLBS)		136,192	7,732,000	725,136	---

(COOLING WATER (AVAILABLE AT 86^{o}F)

Item	Name	GPM	T(^{o}F)
HE-153	Stripped Solvent Cond.	300	25
HE-110	Feed Cooler	550	25
HE-148	Condenser	31,560	25
HE-147	Pre-Extraction Cooler	1,020	25
HE-168	Condenser	2,260	25
Subtotal Section 100		35,690	
Subtotal Section 200		95,570	
Subtotal Section 300		2,280	
Subtotal Section 400		4,175	
Subtotal Section 600		25,340	
Plant Total		163,057	
Yearly Consumption (MGAL)		78,267,360	

PROCESS WATER

	GPM
Subtotal Section 100	3,006
Subtotal Section 200	5,290
Subtotal Section 300	1
Subtotal Section 500	4
Plant Total	8,301
Yearly consumption (MGAL)	3,984,480

TABLE III-13 (continued)

POWER

Item	Name	Motor HP
CR-105	Shredder	300
FE-108	Feeder	10
CO-112	Screw Conveyor	2
CO-115	Screw Conveyor	2
APT-116	Agitator	80
CP-117	Filter Feed Pumps	90
F-118	Rotary Drum Filters	30
CP-119	Wash Water Pumps	45
CO-120	Screw Conveyors	100
CO-122	Screw Conveyors	4
CO-123	Screw Conveyors	40
APT-124	Prehydrolysis Slurry Tank	40
CO-125	Screw Coinveyors	75
R-126	Plug Flow Reactors	25
CO-128	Screw Conveyors	40
CT-129	Centrifuges	1000
CO-130	Screw Conveyors	45
CP-131	Overflow Pumps	80
APT-132	Repulping Tank	40
CO-133	Screw Conveyors	10
CO-134	Centrifuge	250
CO-135	Screw Conveyor	5
CP-136	Overflow Pumps	20
CO-138	Screw Conveyors	4
CP-139	Filtrate Pumps	80
CP-161	Wash Water Pumps	3
APT-141	Miscella Feed Tanks	280
CP-146	Bottoms Pumps	25
CP-149	Distillate Pumps	45
APT-152	Lignin Slurry Tanks	240
CP-159	Lignin Slurry Pump	25
CT-162	Lignin Centrifuge	250
CP-164	Overflow Pump	20
GP-163	Bottoms Pump	5
CP-169	Reflux Pump	15
CP-167	Reboiler Pump	20
CP-157	Solvent Feed Pump	40
CP-140	Filtrate Pump	60
CP-154	Condensate Pump	2
CO-170	Conveyor	2
CO-171	Conveyor	2
CO-172	Bucket Conveyor	10
CP-143	Feed Pump	150

TABLE III-13 (continued)

POWER

	Motor HP
Subtotal Section 100	3,611
Subtotal Section 200	5,791
Subtotal Section 300	767
Subtotal Section 400	126
Subtotal Section 500	4,937
Subtotal Section 600	380
Plant Total	15,612

Yearly requirement (KWH): $15,612 \times 0.746 \times 8000 \frac{hr}{yr} = 93,172,416$

D. Preliminary Optimization Analysis

It is important to state that the base case process described in this report is not intended to represent on optimun design; indeed the design basis chosen is perhaps the most complex and thus one of the most energy and capital intensive of any of the various potential pathways towards producing ethanol from cellulose by acid hydrolysis. Performing a detailed design and economic analysis on the most complex process facilitates the task of optimization, for it clarifies the impact of process inefficiencies and byproduct credits. The design and economic results from this process have revealed the following conclusions concerning optimization of various process steps:

1. Solvent extraction of lignin is apparently not economically feasible. This step is one of the most capital and energy intensive in the process, consuming approximately 460,000 pounds per hour of steam and 14.5 million dollars in ISBL capital costs alone, in addition to its effect on OSBL costs (most specifically the steam load on the coal boiler). While it is true that much of the low pressure steam (30 psia) is generated by the process, this steam could be better utilized for preheating elsewhere in the process. The advantage of having this step in the process is speculative at best. It is claimed by some that not allowing the lignin to contact the acid in hydrolysis and prehydrolysis gives it a high value as a byproduct for use as a chemical feedstock. This has yet to be demonstrated. Certainly utilizing the lignin as fuel at 5¢/lb cannot justify the additional cost of the solvent extraction step. Removal of the lignin prior to hydrolysis does not appear necessary in order to operate a recycle reactor, as long as high solids content (35-40 weight percent) can be effectively conveyed through the reactor, as in an extruder or screw conveyor type, and the recycle stream is not intolerably high.

2. Concentration of the sugar solutions resulting from prehydrolysis and hydrolysis consumes approximately 900,000 lbs/hr of steam, and involves a capital ISBL cost of 15 million dollars. By operating the prehydrolysis and hydrolysis sections at 35 weight percent slurry, concentration requirements (steam and capital costs) can be decreased by approximately 60 per cent. In addition, the steam requirements for heating the biomass slurry up to reaction temperature is also decreased, corresponding with the increased solids concentration in the prehydrolysis and hydrolysis sections. These gains will be offset somewhat by the necessity of utilizing an extruder or Stake type reactor which are expensive; however, it is believed that this will be minor in comparison to the savings, obtained in steam consumption, ISBL and OSBL capital costs.

3. Other areas of optimization in the hydrolysis and prehydrolysis section are the repulping dilution step following centrifuging which acts as a wash, and the percent recycle in the hydrolysis reactor. Maximum recovery of sugars results from high dilution during repulping, however this will result in increased concentration requirements. Optimization of this step is possible by varying the amount of dilution during repulping. Maximum glucose yields in the hydrolysis reactor are obtained at maximum tolerable recycle, which is limited by the buildup of inerts in the reactor. The presence of significant amounts of lignin in the reactor due to the elimination of the lignin extraction step will necessitate increasing the purge on the recycle. Ths will have the effect of limiting the buildup of solids in the reactor to a tolerable level and, decrease the maximum yield of glucose in the reactor. Increasing the purge will also allow for increased utilization of the purge stream, which contains significant amounts of lignin and unreacted cellulose, as a boiler fuel, thus reducing the steam load on the coal-fired boiler.

4. Incorporation of a water wash step prior to prehydrolysis will enable recovery of much of the soluble carbohydrates which constitute a significant part of corn stover. These soluble carbohydrates are primarily sucrose, which can be fermented to ethanol along with the glucose. Utilization of sucrose will essentially offset the sugar losses suffered in hydrolysis by reduction of the recycle and by reduction of the repulping wash step. No additional capital costs are incurred, since the equipment for the solvent extraction step is identical, to that required for the water wash step. In addition, feedstock requirements and plant throughput are unchanged from the base case.

5. Approximately two percent of the ethanol yield is currently lost in waste streams within Section 600 of the base case plant. It should be economically justifiable to recover this product, which would reduce plant equipment size, utilities and raw materials accordingly for a fixed plant capacity.

The above conclusions have resulted in the following preliminary design basis changes for an optimized cellulose to ethanol plant using corn stover as a feedstock.

- No solvent extraction of lignin.
- Water wash prior to prehydrolysis at a ratio of 3:1, water to dry corn stover.
- 35 weight percent solids in prehydrolysis and hydrolysis.
- Utilization of Stake-type reactors for prehydrolysis and hydrolysis (assuming development of reactors which are designed for 500 psia and short residence times).
- Hydrolysis recycle of 50 percent with 50 percent purge.
- Fermentation of sucrose to ethanol.
- Utilization of stillage bottoms (xylose) and yeast purge as animal feed (assuming removel HMF and furfural below toxic levels).

- Preheat steam explosion and prehydrolysis feed with hydrolysis flash steam.

This preliminary design basis for an optimized process indicates the general direction in which the optimization should be carried out. The design and material and energy balances will be investigated utilizing the computer model developed for the base case, changing the various process steps and design parameters as desired. In this manner, optimization of the various process steps can be carried out quickly.

A preliminary analysis of the capital costs for an optimized plant indicates total capital costs in the range of 120-140 million dollars with the most significant savings being realized by the reduction of the coal-fired boiler steam capacity from one million pounds per hour to approximately 400,000 pounds per hour. This will also significantly decrease operating costs and cost of production of the ethanol product.

IV. APPENDIX

A. Major Equipment Specifications and Costs

The following is a detailed equipment list and capital cost summary for all major process equipment required to produce 50 million gallons per year of ethanol via dilute acid hydrolysis of corn stover. This listing is the result of an Icarus CØST run for the base case prototype plant on a third quarter-1980 basis. Major equipment is listed by section and keyed to the item numbers shown on the flowsheets. Section 500, Carbon Dioxide Recovery, is considered a package unit and is not included within this listing.

SECTION 100 PRETREATMENT

E Q U I P M E N T   L I S T

I T E M N A M E	APP.NO.	CAPACITY	MAT'L	EQUIPMENT ITEM TYPE	S I Z E	PURCHASED EQUIPMENT COST
SCREEN	VS -104		CS	SIFTER-1	15.00 SQ FT 60.00 IN DIA 2.50 HP 710 LBS (TOTAL WT.)	7000
SHREDDER (4) ITEMS	CR -105	40.00 TPH	CS	HAMMER-MED	8X34 SIZE 75.00 HP 4400 LBS (TOTAL WT.)	74800
DUST CYCLONE	DC -106	100.00 CFM	CS	CYCLONE	45.00 IN DIA 2.50 IN H2O 2900 LBS (TOTAL WT.)	11600
DUST COLLECTOR	DC -107	100.00 CFM	CS	CLOTH BAY	2000 SQ FT 0.050 AIR/MEDIA RATIO 6500 LBS (TOTAL WT.)	18700
FEEDER	FE -108	312500.0 LBS/HR	A285C	ROTARY	24 IN SIZE 10.00 HP 8.00 RPM 5100 LBS (TOTAL WT.)	26000
FEED HOPPER $=0	VT -111	30000.00 GAL	CS	CYLINDER	15.00 FT DIA 22.70 FT HT 7.00 PSIG 150.00 DEG F 0.31 INCHES THICK 27900 LBS (TOTAL WT.)	0
SCREW CONVEYOR $=0 (5) ITEMS	CO -112	32.00 TPH	CS	SCREW	10.00 FT LG 14.00 IN DIA 2.00 HP 50.00 LBS/CU FT 1500 LBS (TOTAL WT.)	0
STEAM EXPLOSION GUN						

SECTION 100 PRETREATMENT

E Q U I P M E N T   L I S T

I T E M N A M E	APP.NO.	CAPACITY	MAT'L	EQUIPMENT ITEM TYPE	S I Z E	PURCHASED EQUIPMENT COST
$=110645. . (5) ITEMS	VT -113	350.00 GAL	CS	CYLINDER	4.00 FT DIA 3.72 FT HT 15.00 PSIG 400.00 DEG F 0.31 INCHES THICK 1900 LBS (TOTAL WT.)	1110645
(2) ITEMS $=0	DC -114	27650.00 CFM	CS	CYCLONE	60.00 IN DIA 2.50 IN H2O 4500 LBS (TOTAL WT.)	0
SCREW CONVEYOR (2) ITEMS $=0	CO -115	105.00 TPH	CS	SCREW	10.00 FT LG 24.00 IN DIA 5.00 HP 50.00 LBS/CU FT 3700 LBS (TOTAL WT.)	0
PRE EXTRACTION COOLER (2) ITEMS	HE -147		A285C	ONE SCREW	350.00 SQ FT	124600
AGITATOR (3) ITEMS	APT-116	12000.00 GAL	CS	MIXER	11.50 FT DIA 16.00 FT HT 40.00 HP 51.00 RPM 15.00 PSIG 650.00 DEG F 1.38 INCHES THICK 75,900 LBS (TOTAL WT.) 1116107 REYNOLDS NUMBER 14.85 FT FLUID DEPTH 90.00 PSIG JACKET PRES	346500
FILTER FEED PUMP A+B (12) ITEMS	CP -117	400.00 GPM	304SF	AVS-MEDIUM	75.00 FT HD 200.00 DEG F 15.00 HP 1750.00 RPM 900 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	34800
FILTER (3) ITEMS	F -118		CS	ROTY-DRUM	900.00 SQ FT 10.00 HP 1800.00 RPM 40300 LBS (TOTAL WT.)	331200

SECTION 100 PRETREATMENT

E Q U I P M E N T   L I S T

I T E M N A M E	APP.NO.	CAPACITY	MAT'L	EQUIPMENT ITEM TYPE	S I Z E	PURCHASED EQUIPMENT COST
WASH WATER PUMP A+B (12) ITEMS	CP -119	175.00 GPM	304SF	AVS-MEDIUM	75.00 FT HD 150.00 DEG F 7.50 HP 1750.00 RPM 710 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	28800
WASH WATER TANK	VT -109	75000.00 GAL	CS	CYLINDER	17.50 FT DIA 41.69 FT HT 7.00 PSIG 150.00 DEG F 0.38 INCHES THICK 76400 LBS (TOTAL WT.)	77000
SCREW CONVEYOR (2) ITEMS	CO -120	205.00 TPH	CS	SCREW	50.00 FT LG 24.00 IN DIA 50.00 HP 50.00 LBS/CU FT 7400 LBS (TOTAL WT.)	25200
POLISHING FILTER (2) ITEMS	F -121		CS	LEAF-WET	275.00 SQ FT 3300 LBS (TOTAL WT.)	49400
SCREW CONVEYOR (2) ITEMS	CO -122	10.00 TPH	CS	SCREW	10.00 FT LG 9.00 IN DIA 2.00 HP 50.00 LBS/CU FT 760 LBS (TOTAL WT.)	3800
SCREW CONVEYOR (2) ITEMS	CO -123	215.00 TPH	CS	SCREW	20.00 FT LG 24.00 IN DIA 20.00 HP 50.00 LBS/CU FT 4600 LBS (TOTAL WT.)	15400
PREHYDROLYSIS SLURRY TANK	APT-124	12000.00 GAL	CS	MIXER	11.50 FT DIA 16.00 FT HT 40.00 HP 51.00 RPM 15.00 PSIG 650.00 DEG F 1.38 INCHES THICK 75900 LBS (TOTAL WT.) 1116107 REYNOLDS NUMBER 14.84 FT FLUID DEPTH 90.00 PSIG JACKET PRES	115500

SECTION 100 PRETREATMENT
E Q U I P M E N T   L I S T

I T E M N A M E	APP.NO.	CAPACITY	MAT'L	EQUIPMENT ITEM TYPE	S I Z E	PURCHASED EQUIPMENT COST
SCREW CONVEYOR (5) ITEMS	CO -125	121.00 TPH	SS316	SCREW	25.00 FT LG 24.00 IN DIA 15.00 HP 50.00 LBS/CU FT 5100 LBS (TOTAL WT.)	180000
PLUG FLOW PREHYDROLYSIS REACTOR (5) ITEMS	CO -126	121.00 TPH	SS316	SCREW	10.00 FT LG 24.00 IN DIA 5.00 HP 50.00 LBS/CU FT 3700 LBS (TOTAL WT.)	80500
FLASH TANK	VT -127	13000.00 GAL	EPLCS	CYLINDER	11.00 FT DIA 18.29 FT HT 30.00 PSIG 325.00 DEG F 0.19 INCHES THICK 13700 LBS (TOTAL WT.)	25100
SCREW CONVEYOR (4) ITEMS	CO -128	146.00 TPH	SS316	SCREW	15.00 FT LG 24.00 IN DIA 10.00 HP 50.00 LBS/CU FT 4100 LBS (TOTAL WT.)	90800
CENTRIFUGE (4) ITEMS	CT -129		SS	SOLID BOWL	54.00 IN DIA 70.00 IN LONG 250.00 HP 34600 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	1369200
SCREW CONVEYOR (4) ITEMS	CO -130	105.00 TPH	SS316	SCREW	15.00 FT LG 24.00 IN DIA 7.50 HP 50.00 LBS/CU FT 4100 LBS (TOTAL WT.)	90800

SECTION 100 PRETREATMENT

E Q U I P M E N T   L I S T

I T E M N A M E	APP.NO.	CAPACITY	MAT'L	EQUIPMENT ITEM TYPE	S I Z E	PURCHASED EQUIPMENT COST
OVERFLOW PUMP A+B (8) ITEMS	CP -131	600.00 GPM	HAST	AVS-MEDIUM	100.00 FT HD 285.00 DEG F 20.00 HP 1750.00 RPM 1100 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	57600
REPULPING TANK	APT-132	10000.00 GAL	EPLCS	MIXER	11.00 FT DIA 15.00 FT HT 40.00 HP 52.00 RPM 15.00 PSIG 650.00 DEG F 1.25 INCHES THICK 66900 LBS (TOTAL WT.) 1046963 REYNOLDS NUMBER 13.70 FT FLUID DEPTH 90.00 PSIG JACKET PRES	114700
SCREW CONVEYOR (2) ITEMS	CO -133	106.00 TPH	SS316	SCREW	10.00 FT LG 24.00 IN DIA 5.00 HP 50.00 LBS/CU FT 3700 LBS (TOTAL WT.)	32200
CENTRIFUGE	CT -134		SS	SOLID BOWL	54.00 IN DIA 70.00 IN LONG 250.00 HP 34600 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	342300
SCREW CONVEYOR	CO -135	100.00 TPH	SS316	SCREW	10.00 FT LG 24.00 IN DIA 5.00 HP 50.00 LBS/CU FT 3700 LBS (TOTAL WT.)	16100
OVERFLOW PUMP A+B (2) ITEMS	CP -136	450.00 GPM	HAST	AVS-MEDIUM	100.00 FT HD 285.00 DEG F 20.00 HP 1750.00 RPM 1000 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	13600

SECTION 100 PRETREATMENT

E Q U I P M E N T   L I S T

ITEM NAME	APP.NO.	CAPACITY	MAT'L	EQUIPMENT ITEM TYPE	SIZE	PURCHASED EQUIPMENT COST
POLISHING FILTER (2) ITEMS	F -137		SS316	LEAF-WET	275.00 SQ FT 3300 LBS (TOTAL WT.)	74000
SCREW CONVEYOR (2) ITEMS	CO -138	11.00 TPH	SS316	SCREW	30.00 FT LG 9.00 IN DIA 2.00 HP 50.00 LBS/CU FT 1500 LBS (TOTAL WT.)	24400
FILTRATE PUMP A+B (4) ITEMS	CP -139	1200.00 GPM	HAST	AVS-MEDIUM	100.00 FT HD 285.00 DEG F 40.00 HP 1750.00 RPM 1500 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	38000
WASH WATER TANK	VT -160	5000.00 GAL	CS	CYLINDER	8.00 FT DIA 13.30 FT HT 7.00 PSIG 150.00 DEG F 0.31 INCHES THICK 7400 LBS (TOTAL WT.)	10600
WASH WATER PUMP A+B (4) ITEMS	CP -161	50.00 GPM	304SF	AVS-LOW	75.00 FT HD 150.00 DEG F 1.50 HP 1150.00 RPM 580 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	8000
MISCELLA FEED TANK (11) ITEMS	APT-141	12000.0 GAL	CS	MIXER	11.50 FT DIA 16 .00 FT HT 40.00 HP 51 .00 RPM 15.00 PSIG 650.00 DEG F 1.38 INCHES THICK 75900 LBS (TOTAL WT.) 1116107 REYNOLDS NUMBER 14.84 FT FLUID DEPTH 90.00 PSIG JACKET PRES	,1270500

SECTION 100 PRETREATMENT
E Q U I P M E N T   L I S T

ITEM NAME	APP.NO.	CAPACITY	MAT'L	EQUIPMENT ITEM TYPE	SIZE	PURCHASED EQUIPMENT COST
ETHANOL RECOVERY COLUMN FEED PUMP A+B (12) ITEMS	CP -143	400.00 GPM	304SF	AVS-MEDIUM	150.00 FT HD 200.00 DEG F 25.00 HP 1750.00 RPM 1100 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	44400
COOLER	HE -110		304S	FIXED-T-S	2829 SQ FT A285C SHELL BEM TEMA TYPE 150.00 PSIG SHELL PRESS 650.00 DEG F SHELL TEMP 32.00 IN DIA 20.00 FT LG 7.00 PSIG TUBE PRESS 650.00 DEG F TUBE TEMP 1.00 INCH TUBE OD 20.00 FEET TUBE LENGTH 14900 LBS (TOTAL WT.)	61700
BOTTOMS PUMP A+B (12) ITEMS	CP -146	125.00 GPM	304SF	AVS-MEDIUM	150.00 FT HD 150.00 DEG F 7.50 HP 1750.00 RPM 800 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	32400
CONDENSER (6) ITEMS	HE -148		304S	FIXED-T-S	12620 SQ FT A285C SHELL BEM TEMA TYPE 150.00 PSIG SHELL PRESS 650.00 DEG F SHELL TEMP 39.00 IN DIA 60.00 FT LG 7.00 PSIG TUBE PRESS 650.00 DEG F TUBE TEMP 1.00 INCH TUBE OD 60.00 FEET TUBE LENGTH 46800 LBS (TOTAL WT.)	1161000
DISTILLATE PUMP A+B (12) ITEMS	CP -149	425.00 GPM	304SF	AVS-MEDIUM	100.00 FT HD 150.00 DEG F 15.00 HP 1750.00 RPM 950 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	37200

SECTION 100 PRETREATMENT
E Q U I P M E N T   L I S T

I T E M N A M E	APP.NO.	CAPACITY	MAT'L	EQUIPMENT ITEM TYPE	S I Z E	PURCHASED EQUIPMENT COST
STEAM EJECTOR (6) ITEMS	EJ -150		CS	SINGLE STG	225.00 LBS AIR/HR 250.00 MM HG	7800
LIGNIN SLURRY TANK (6) ITEMS	APT-152	12000.00 GAL	CS	MIXER	11.50 FT DIA 16.00 FT HT 40.00 HP 52.00 RPM 15.00 PSIG 650.00 DEG F 1.38 INCHES THICK 75900 LBS (TOTAL WT.) 1116107 REYNOLDS NUMBER 15 .84 FT FLUID DEPTH 90.00 PSIG JACKET PRES	1451200
LIGNIN SLURRY PUMP A+B (2) ITEMS	CP -159	650.00 GPM	304SF	AVS-MEDIUM	100.00 FT HD 150.00 DEG F 25.00 HP 1750.00 RPM 1100 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	7400
LIGNIN CENTRIFUGE	CT -162		SS	SOLID BOWL	54.00 IN DIA 70.00 IN LONG 250.00 HP 34600 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	342300
OVERFLOW PUMP A+B (2) ITEMS	CP -164	600.00 GPM	304SF	AVS-MEDIUM	100.00 FT HD 150.00 DEG F 20.00 HP 1750.00 RPM 1100 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	7000

SECTION 100 PRETREATMENT
E Q U I P M E N T   L I S T

I T E M N A M E	APP.NO.	CAPACITY	MAT'L	EQUIPMENT ITEM TYPE	S I Z E	PURCHASED EQUIPMENT COST
BOTTOMS PUMP A+B (2) ITEMS	GP -163	75.00 GPM	CS		5.00 HP 87.00 RPM 320 LBS (TOTAL WT.)	4400
CONDENSER	HE -168		304S	FIXED-T-S	2020 SQ FT A285C SHELL BEM TEMA TYPE 150.00 PSIG SHELL PRESS 650.00 DEG F SHELL TEMP 27.00 IN DIA 20.00 FT LG 7.00 PSIG TUBE PRESS 650.00 DEG F TUBE TEMP 1.00 INCH TUBE OD 20.00 FEET TUBE LENGTH 11000 LBS (TOTAL WT.)	42900
REFLUX PUMP A+B (2) ITEMS	CP -169	325.00 GPM	CS	AVS-MEDIUM	100.00 FT HD 200.00 DEG F 15.00 HP 1750.00 RPM 920 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	6600
REBOILER	HE -166		304S	FIXED-T-S	636 SQ FT SS304 SHELL BEM TEMA TYPE 150.00 PSIG SHELL PRESS 650.00 DEG F SHELL TEMP 24.00 IN DIA 8.00 FT LG 300.00 PSIG TUBE PRESS 650.00 DEG F TUBE TEMP 1.00 INCH TUBE OD 8.00 FEET TUBE LENGTH 6000 LBS (TOTAL WT.)	31400
REBOILER PUMP A+B (2) ITEMS	CP -167	600.00 GPM	304SF	AVS-MEDIUM	100.00 FT HD 200.00 DEG F 20.00 HP 1750.00 RPM 1100 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	7000

SECTION 100 PRETREATMENT
EQUIPMENT LIST

ITEM NAME	APP.NO.	CAPACITY	MAT'L	EQUIPMENT ITEM TYPE	SIZE	PURCHASED EQUIPMENT COST
RECOVERED ETHANOL STORAGE TANK	VT -155	95000.00 GAL	CS	CYLINDER	17.50 FT DIA 52.80 FT HT 7.00 PSIG 200.00 DEG F 0.56 INCHES THICK 116500 LBS (TOTAL WT.)	110900
SOLVENT FEED PUMP A+B (2) ITEMS	CP -157	1600.00 GPM	304SF	AVS-MEDIUM	75.00 FT HD 200.00 DEG F 40.00 HP 1750.00 RPM 1600 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	10200
SOLVENT HEATER	HE -158		304S	FIXED-T-S	4071 SQ FT A285C SHELL BEM TEMA TYPE 150.00 PSIG SHELL PRESS 650.00 DEG F SHELL TEMP 38.00 IN DIA 20.00 FT LG 7.00 PSIG TUBE PRESS 650.00 DEG F TUBE TEMP 1.00 INCH TUBE OD 20.00 FEET TUBE LENGTH 20000 LBS (TOTAL WT.)	86200
FILTRATE PUMP A+B (4) ITEMS	CP -140	1100.00 GPM	304SF	AVS-MEDIUM	75.00 FT HD 200.00 DEG F 30.00 HP 1750.00 RPM 1300 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	16800
CONDENSER	HE -153		304S	FIXED-T-S	190 SQ FT SS304 SHELL BEM TEMA TYPE 150.00 PSIG SHELL PRESS 650.00 DEG F SHELL TEMP 10.00 IN DIA 20.00 FT LG 7.00 PSIG TUBE PRESS 650.00 DEG F TUBE TEMP 1.00 INCH TUBE OD 20.00 FEET TUBE LENGTH 2100 LBS (TOTAL WT.)	9800

SECTION 100 PRETREATMENT

EQUIPMENT LIST

ITEM NAME	APP.NO.	CAPACITY	MAT'L	EQUIPMENT ITEM TYPE	SIZE	PURCHASED EQUIPMENT COST
CONDENSATE PUMP A+B (2) ITEMS	CP -154	35.00 GPM	304SF	AVS-LOW	50.00 FT HD 250.00 DEG F 1.50 HP 1150.00 RPM 510 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	3400
CONVEYOR	CO -170	160.00 TPH	CS	OPEN BELT	50.00 FT LG 24.00 IN W 2.00 HP 1750.00 RPM 360.00 FT/MIN 1 SECT'N 2800 LBS (TOTAL WT.)	19800
CONVEYOR	CO -171	160.00 TPH	CS	OPEN BELT	25.00 FT LG 24.00 IN W 2.00 HP 1750.00 RPM 360.00 FT/MIN 1 SECT'N 2700 LBS (TOTAL WT.)	19000
BUCKET CONVEYOR	CO -172	160.00 TPH	CS	CONT-BKT-L	25.00 FT LONG 10.00 HP 20X8 IN BUCKET SIZE 5400 LBS (TOTAL WT.)	10900
ETHANOL STILL	TW -165		SS304	SIEVE TRAY	12.00 FT DIA 47.00 FT HT 17 TRAYS A285C SHELL 24 IN TRAY SPACING 7.00 PSIG 200.00 DEG F 0.38 INCHES THICK 64300 LBS (TOTAL WT.)	133900
ETHANOL RECOVERY COLUMN (6) ITEMS	TW -144		SS304	VALVE TRAY	15.00 FT DIA 43.00 FT HT 15 TRAYS A285C SHELL 24 IN TRAY SPACING -15.00 PSIG 150.00 DEG F 0.56 INCHES THICK 116700 LBS (TOTAL WT.)	1233000

SECTION 100 PRETREATMENT
E Q U I P M E N T   L I S T

I T E M N A M E	APP.NO.	CAPACITY	MAT'L	EQUIPMENT ITEM TYPE	S I Z E	PURCHASED EQUIPMENT COST
REBOILER (6) ITEMS	HE -145		304S	FIXED-T-S	2317 SQ FT PER SHELL	967200
					2 SHELLS	
					SS304 SHELL MATERIAL	
					BEM TEMA TYPE	
					30.00 PSIG SHELL PRESS	
					300.00 DEG F SHELL TEMP	
					46.00 IN DIA 8.00 FT LG	
					-15.00 PSIG TUBE PRESS	
					150.00 DEG F TUBE TEMP	
					1.00 INCH TUBE OD	
					8.00 FEET TUBE LENGTH	
					30600 LBS (TOTAL WT.)	

SECTION 200 HYDROLYSIS
E Q U I P M E N T   L I S T

I T E M N A M E	APP.NO.	CAPACITY	MAT'L	EQUIPMENT ITEM TYPE	S I Z E	PURCHASED EQUIPMENT COST
SCREW CONVEYOR	CO -201	110.00 TPH	SS316	SCREW	50.00 FT LG 24.00 IN DIA 25.00 HP 50.00 LBS/CU FT 7400 LBS (TOTAL WT.)	69300
PLUG FLOW MIX TANK (4) ITEMS	APT-202	10000.00 GAL	EPLCS	MIXER	11.50 FT DIA 16.00 FT HT 40.00 HP 52.00 RPM 15.00 PSIG 650.00 DEG F 1.38 INCHES THICK 759 00 LBS (TOTAL WT.) 1116107 REYNOLDS NUMBER 14.84 FT FLUID DEPTH 90.00 PSIG JACKET PRES	458800
SCREW CONVEYOR (7) ITEMS	CO -203	140.00 TPH	SS316	SCREW	25.00 FT LG 24.00 IN DIA 100.00 HP 50.00 LBS/CU FT 5100 LBS (TOTAL WT.)	158900
HYDROLSIS PREHEATER	HE -204		HASTB	FIXED-T-S	1334 SQ FT A285C SHELL BEM TEMA TYPE 150.00 PSIG SHELL PRESS 650.00 DEG F SHELL TEMP 22.00 IN DIA 20.00 FT LG 225.00 PSIG TUBE PRESS 400.00 DEG F TUBE TEMP 1.00 INCH TUBE OD 20.00 FFET TUBE LENGTH 8900 LBS (TOTAL WT.)	149300
PLUG FLOW REACTOR (7) ITEMS	CO -205	980.00 TPH	SS316	SCREW	10.00 FT LG 24.00 IN DIA 40.00 HP 50.00 LBS/CU FT 3700 LBS (TOTAL WT.)	112700

SECTION 100 PRETREATMENT
E Q U I P M E N T   L I S T

I T E M N A M E	APP.NO.	CAPACITY	MAT'L	EQUIPMENT ITEM TYPE	S I Z E	PURCHASED EQUIPMENT COST
REBOILER (6) ITEMS	HE -145		304S	FIXED-T-S	2317 SQ FT PER SHELL	967200
					2 SHELLS	
					SS304 SHELL MATERIAL	
					BEM TEMA TYPE	
					30.00 PSIG SHELL PRESS	
					300.00 DEG F SHELL TEMP	
					46.00 IN DIA 8.00 FT LG	
					-15.00 PSIG TUBE PRESS	
					150.00 DEG F TUBE TEMP	
					1.00 INCH TUBE OD	
					8.00 FEET TUBE LENGTH	
					30600 LBS (TOTAL WT.)	

SECTION 200 HYDROLYSIS

EQUIPMENT LIST

ITEM NAME	APP.NO.	CAPACITY	MAT'L	EQUIPMENT ITEM TYPE	SIZE	PURCHASED EQUIPMENT COST
SCREW CONVEYOR	CO -201	110.00 TPH	SS316	SCREW	50.00 FT LG 24.00 IN DIA 25.00 HP 50.00 LBS/CU FT 7400 LBS (TOTAL WT.)	69300
PLUG FLOW MIX TANK (4) ITEMS	APT-202	10000.00 GAL	EPLCS	MIXER	11.50 FT DIA 16.00 FT HT 40.00 HP 52.00 RPM 15.00 PSIG 650.00 DEG F 1.38 INCHES THICK 759 00 LBS (TOTAL WT.) 1116107 REYNOLDS NUMBER 14.84 FT FLUID DEPTH 90.00 PSIG JACKET PRES	458800
SCREW CONVEYOR (7) ITEMS	CO -203	140.00 TPH	SS316	SCREW	25.00 FT LG 24.00 IN DIA 100.00 HP 50.00 LBS/CU FT 5100 LBS (TOTAL WT.)	158900
HYDROLSIS PREHEATER	HE -204		HASTB	FIXED-T-S	1334 SQ FT A285C SHELL BEM TEMA TYPF 150.00 PSIG SHELL PRESS 650.00 DEG F SHELL TEMP 22.00 IN DIA 20.00 FT LG 225.00 PSIG TUBE PRESS 400.00 DEG F TUBE TEMP 1.00 INCH TUBE OD 20.00 FFET TUBE LENGTH 8900 LBS (TOTAL WT.)	149300
PLUG FLOW REACTOR (7) ITEMS	CO -205	980.00 TPH	SS316	SCREW	10.00 FT LG 24.00 IN DIA 40.00 HP 50.00 LBS/CU FT 3700 LBS (TOTAL WT.)	112700

SECTION 200 HYDROLYSIS

E Q U I P M E N T   L I S T

I T E M N A M E	APP.NO.	CAPACITY	MAT'L	EQUIPMENT ITEM TYPE	S I Z E	PURCHASED EQUIPMENT COST
FLASH TANK	VT -206	20000.00 GAL	EPLCS	CYLINDER	13.00 FT DIA 20.14 FT HT 50.00 PSIG 500.00 DEG F 0.38 INCHES THICK 25200 LBS (TOTAL WT.)	38200
SCREW CONVEYOR (8) ITEMS	CO -207	100.00 TPH	SS316	SCREW	15.00 FT LG 24.00 IN DIA 7.50 HP 50.00 LBS/CU FT 4100 LBS (TOTAL WT.)	181600
CENTRIFUGE (4) ITEMS	CT -208		SS	SOLID BOWL	54.00 IN DIA 70.00 IN LONG 250.00 HP 34600 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	1369200
SCREW CONVEYOR (4) ITEMS	CO -209	70.00 TPH	SS316	SCREW	15.00 FT LG 20.00 IN DIA 5.00 HP 50.00 LBS/CU FT 3200 LBS (TOTAL WT.)	71600
OVERFLOW PUMP A+B (8) ITEMS	CP -210	600.00 GPM	HAST	AVS-HIGH	150.00 FT HD 285.00 DEG F 30.00 HP 3500.00 RPM 1000 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	50400
REPULPING TANK (3) ITEMS	APT-211	12000.00 GAL	EPLCS	MIXER	11.00 FT DIA 15.00 FT HT 40.00 HP 52.00 RPM 15.00 PSIG 650.00 DEG F 1.25 INCHES THICK 66900 LBS (TOTAL WT.) 1046963 REYNOLDS NUMBER 13.70 FT FLUID DEPTH 90.00 PSIG JACKET PRES	346500

SECTION 200 HYDROLYSIS
E Q U I P M E N T   L I S T

I T E M N A M E	APP.NO.	CAPACITY	MAT'L	EQUIPMENT ITEM TYPE	S I Z E	PURCHASED EQUIPMENT COST
SCREW CONVEYOR (10) ITEMS	CO -212	93.00 TPH	SS316	SCREW	24.00 FT LG 20.00 IN DIA 20.00 HP 50.00 LBS/CU FT 3900 LBS (TOTAL WT.)	274000
CENTRIFUGE (5) ITEMS	CT -213		SS	SOLID BOWL	54.00 IN DIA 70.00 IN LONG 250.00 HP 34600 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	1711500
SCREW CONVEYOR (5) ITEMS	CO -214	55.00 TPH	SS316	SCREW	100.00 FT LG 18.00 IN DIA 25.00 HP 50.00 LBS/CU FT 9500 LBS (TOTAL WT.)	473500
OVERFLOW PUMP A+B (10) ITEMS	CP -215	600.00 GPM	HAST	AVS-HIGH	150.00 FT HD 285.00 DEG F 30.00 HP 3500.00 RPM 1000 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	63000
POLISHING FILTER (3) ITEMS	F -216		SS316	LEAF-WET	400.00 SQ FT 4400 LBS (TOTAL WT.)	128400
SCREW CONVEYOR (3) ITEMS	CO -219	9.00 TPH	SS316	SCREW	10.00 FT LG 10.00 IN DIA 2.00 HP 50.00 LBS/CU FT 900 LBS (TOTAL WT.)	14700
SCREW CONVEYOR						

SECTION 200 HYDROLYSIS
E Q U I P M E N T   L I S T

ITEM NAME	APP.NO.	CAPACITY	MAT'L	EQUIPMENT ITEM TYPE	SIZE	PURCHASED EQUIPMENT COST
	CO -220	260.00 TPH	SS316	SCREW	24.00 FT LG 20.00 IN DIA 25.00 HP 50.00 LBS/CU FT 3900 LBS (TOTAL WT.)	27400
SCREW CONVEYOR	CO -221	30.00 TPH	SS316	SCREW	100.00 FT LG 14.00 IN DIA 15.00 HP 50.00 LBS/CU FT 7800 LBS (TOTAL WT.)	69200
WASH WATER TANK	VT -217	25000.00 GAL	CS	CYLINDER	14.00 FT DIA 21.71 FT HT 7.00 PSIG 150.00 DEG F 0.31 INCHES THICK 25100 LBS (TOTAL WT.)	31000
WASH WATER PUMP A+B (6) ITEMS	CP -218	50.00 GPM	304SF	AVS-MEDIUM	75.00 FT HD 150.00 DEG F 1.50 HP 1750.00 RPM 590 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	12000
LIME SLURRY TANK (2) ITEMS	APT-225	12 000.00 GAL	CS	MIXER	11.50 FT DIA 16.00 FT HT 40.00 HP 52 .00 RPM 15 .00 PSIG 650.00 DEG F 1 .38 INCHES THICK 75900 LBS (TOTAL WT.) 1116107 REYNOLDS NUMBER 14 .84 FT FLUID DEPTH 90.00 PSIG JACKET PRES	231000
LIME SLURRY PUMP A+B (2) ITEMS	CP -226	50.00 GPM	CS	AVS-MEDIUM	75.00 FT HD 150.00 DEG F 3.00 HP 1750.00 RPM 610 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	4600

SECTION 200 HYDROLYSIS
EQUIPMENT LIST

ITEM NAME	APP.NO.	CAPACITY	MAT'L	EQUIPMENT ITEM TYPE	SIZE	PURCHASED EQUIPMENT COST
NEUTRALIZER TANK (11) ITEMS	APT-224	10000.0 GAL	EPLCS	MIXER	11.00 FT DIA 15.00 FT HT 40.00 HP 52.00 RPM 15.00 PSIG 650.00 DEG F 1.25 INCHES THICK 66900 LBS (TOTAL WT.) 1046963 REYNOLDS NUMBER 13.70 FT FLUID DEPTH 90.00 PSIG JACKET PRES	1261700
NEUTRALIZER PUMP A+B (2) ITEMS	CP -227	7000.00 GPM	SS304	CENTRIF-M	75.00 FT HD 285.00 DEG F 200.00 HP 1800.00 RPM 4300 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	33400
FLASH TANK	VT -228	35000.00 GAL	SS304	CYLINDER	16.00 FT DIA 23.27 FT HT 30.00 PSIG 285.00 DEG F 0.31 INCHES THICK 31200 LBS (TOTAL WT.)	79000
FILTER FEED PUMP A+B (6) ITEMS	CP -229	1550.00 GPM	304SF	AVS-MEDIUM	75.00 FT HD 250.00 DEG F 40.00 HP 1750.00 RPM 1500 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	30600
FILTER (3) ITEMS	F -232		SS316	LEAF-WET	450.00 SQ FT 4800 LBS (TOTAL WT.)	134100
FILTRATE TANK	VT -223	70000.00 GAL	EPLCS	CYLINDER	17.50 FT DIA 38.91 FT HT 30.00 PSIG 285.00 DEG F 0.38 INCHES THICK 74500 LBS (TOTAL WT.)	91400

SECTION 200 HYDROLYSIS

EQUIPMENT LIST

ITEM NAME	APP.NO.	CAPACITY	MAT'L	EQUIPMENT ITEM TYPE	SIZE	PURCHASED EQUIPMENT COST
FILTRATE PUMP A+B (2) ITEMS	CP -222	4700.00 GPM	SS304	CENTRIF-M	75.00 FT HD 285.00 DEG F 125.00 HP 1800.00 RPM 3000 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	23000
WASH WATER TANK	VT -230	30000.00 GAL	CS	CYLINDER	15.00 FT DIA 22.70 FT HT 7.00 PSIG 150.00 DEG F 0.31 INCHES THICK 27900 LBS (TOTAL WT.)	34300
WASH WATER PUMP A+B (6) ITEMS	CP -231	75.00 GPM	304SF	AVS-MEDIUM	75.00 FT HD 150.00 DEG F 3.00 HP 1750.00 RPM 620 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	12600
SCREW CONVEYOR (3) ITEMS	CO -234	11.00 TPH	SS316	SCREW	50.00 FT LG 9.00 IN DIA 3.00 HP 50.00 LBS/CU FT 2200 LBS (TOTAL WT.)	60300
FILTRATE PUMP A+B (6) ITEMS	CP -233	2300.00 GPM	SS304	CENTRIF-M	100.00 FT HD 250.00 DEG F 75.00 HP 1800.00 RPM 1900 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	42600
FIRST EFFECT (5) ITEMS	VT -235	9660.00 GAL	SS304	CYLINDER	7.40 FT DIA 30.00 FT HT 45.00 PSIG 300.00 DEG F 0.19 INCHES THICK 8400 LBS (TOTAL WT.)	125000

SECTION 200 HYDROLYSIS

E Q U I P M E N T   L I S T

I T E M N A M E	APP.NO.	CAPACITY	MAT'L	EQUIPMENT ITEM TYPE	S I Z E	PURCHASED EQUIPMENT COST
SECOND EFFECT (5) ITEMS	VT -236	11860.00 GAL	SS304	CYLINDER	8.20 FT DIA 30.00 FT HT 25.00 PSIG 275.00 DEG F 0.19 INCHES THICK 12300 LBS (TOTAL WT.)	164000
THIRD EFFECT (5) ITEMS	VT -237	14920.00 GAL	SS304	CYLINDER	9.20 FT DIA 30.00 FT HT 7.00 PSIG 250.00 DEG F 0.19 INCHES THICK 13900 LBS (TOTAL WT.)	183000
FOURTH EFFECT (5) ITEMS	VT -238	59430.00 GAL	SS304	CYLINDER	17.00 FT DIA 35.00 FT HT -15.00 PSIG 150.00 DEG F 0.50 INCHES THICK 97500 LBS (TOTAL WT.)	969500
CONDENSATE PUMP A+B (2) ITEMS	CP -244	1700.00 GPM	304SF	AVS-MEDIUM	100.00 FT HD 150.00 DEG F 60.00 HP 1750.00 RPM 1800 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	12400
DISTILLATE PUMP A+B (2) ITEMS	CP -247	6100.00 GPM	SS304	CENTRIF-M	100.00 FT HD 250.00 DEG F 200.00 HP 1800.00 RPM 4000 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	31400
DISTILLATE TANK	VT -246	375000.0 GAL	CS	CYLINDER	35.00 FT DIA 52.11 FT HT 7.00 PSIG 250.00 DEG F 0.47 IN THICK (AVG) 287500 LBS (TOTAL WT.) INCLUDES FIELD ERECTION BY VENDOR	390500

SECTION 200 HYDROLYSIS
E Q U I P M E N T   L I S T

I T E M N A M E	APP.NO.	CAPACITY	MAT'L	EQUIPMENT ITEM TYPE	S I Z E	PURCHASED EQUIPMENT COST
STEAM EJECTOR (5) ITEMS	EJ -250		CS	SINGLE STG	250.00 LBS AIR/HR 100.00 MM HG	9500
REBOILER	HE -242		304S	FIXED-T-S	2307 SQ FT PER SHELL 6 SHELLS SS304 SHELL MATERIAL BEM TEMA TYPE -15.00 PSIG SHELL PRESS 150.00 DEG F SHELL TEMP 46.00 IN DIA 8.00 FT LG 7.00 PSIG TUBE PRESS 250.00 DEG F TUBE TEMP 1.00 INCH TUBE OD 8.00 FEET TUBE LENGTH 87600 LBS (TOTAL WT.)	455300
REBOILER	HE -241		304S	FIXED-T-S	2304 SQ FT PER SHELL 8 SHELLS SS304 SHELL MATERIAL BEM TEMA TYPE 7.00 PSIG SHELL PRESS 250.00 DEG F SHELL TEMP 46.00 IN DIA 8.00 FT LG 25.00 PSIG TUBE PRESS 275.00 DEG F TUBE TEMP 1.00 INCH TUBE OD 8.00 FEET TUBE LENGTH 116800 LBS (TOTAL WT.)	610600
REBOILER	HE -240		304S	FIXED-T-S	2451 SQ FT PER SHELL 8 SHELLS SS304 SHELL MATERIAL BEM TEMA TYPE 25.00 PSIG SHELL PRESS 275.00 DEG F SHELL TEMP 47.00 IN DIA 8.00 FT LG 45.00 PSIG TUBE PRESS 300.00 DEG F TUBE TEMP 1.00 INCH TUBE OD 8.00 FEET TUBE LENGTH 123200 LBS (TOTAL WT.)	658700

SECTION 200 HYDROLYSIS
E Q U I P M E N T   L I S T

I T E M N A M E	APP.NO.	CAPACITY	MAT'L	EQUIPMENT ITEM TYPE	S I Z E	PURCHASED EQUIPMENT COST
REBOILER	HE -239		304S	FIXED-T-S	2308 SQ FT PER SHELL 7 SHELLS SS304 SHELL MATERIAL BEM TEMA TYPE 45.00 PSIG SHELL PRESS 300.00 DEG F SHELL TEMP 46.00 IN DIA 8.00 FT LG 65.00 PSIG TUBE PRESS 325.00 DEG F TUBE TEMP 1.00 INCH TUBE OD 8.00 FEET TUBE LENGTH 105700 LBS (TOTAL WT.)	572600
CONDENSER	HE -243		304S	FIXED-T-S	17379 SQ FT PER SHELL 4 SHELLS A285C SHELL MATERIAL BEM TEMA TYPE -15.00 PSIG SHELL PRESS 150.00 DEG F SHELL TEMP 46.00 IN DIA 60.00 FT LG 7.00 PSIG TUBE PRESS 150.00 DEG F TUBE TEMP 1.00 INCH TUBE OD 60.00 FEET TUBE LENGTH 252000 LBS (TOTAL WT.)	1005100
SUBCOOLER	HE -248		304S	FIXED-T-S	15702 SQ FT PER SHELL 2 SHELLS A285C SHELL MATERIAL BEM TEMA TYPE 7.00 PSIG SHELL PRESS 250.00 DEG F SHELL TEMP 43.00 IN DIA 60.00 FT LG 7.00 PSIG TUBE PRESS 150.00 DEG F TUBE TEMP 1.00 INCH TUBE OD 60.00 FEET TUBE LENGTH 106400 LBS (TOTAL WT.)	444400

SECTION 300 FERMENTATION

E Q U I P M E N T   L I S T

I T E M N A M E	APP.NO.	CAPACITY	MAT'L	EQUIPMENT ITEM TYPE	S I Z E	PURCHASED EQUIPMENT COST
CARBON COLUMN FEED TANK	VT -301	40000.00 GAL	CS	CYLINDER	16.00 FT DIA 26.60 FT HT 7.00 PSIG 150.00 DEG F 0.31 INCHES THICK 34100 LBS (TOTAL WT.)	41100
CARBON COLUMN FEED PUMP A+B (2) ITEMS	CP -302	625.00 GPM	304SF	AVS-LOW	75.00 FT HD 150.00 DEG F 15.00 HP 1150.00 RPM 1100 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	7200
CARBON COLUMN (2) ITEMS	TW -303		CS	PACKED	4.50 FT DIA 15.00 FT HT 15.00 PSIG 650.00 DEG F ACT-C PACKING TYPE 10.00 FT PACKING HT 0.25 INCHES THICK 6100 LBS (TOTAL WT. LESS PACKING)	30400
CARBON COLUMN SURGE TANK	VT -305	40000.00 GAL	CS	CYLINDER	16.00 FT DIA 26.60 FT HT 7.00 PSIG 150.00 DEG F 0.31 INCHES THICK 34100 LBS (TOTAL WT.)	41100
FERMENTATION COOLER	HE -307		304S	FIXED-T-S	1975 SQ FT A285C SHELL BEM TEMA TYPE 150.00 PSIG SHELL PRESS 650.00 DEG F SHELL TEMP 27.00 IN DIA 20.00 FT LG 7.00 PSIG TUBE PRESS 650.00 DEG F TUBE TEMP 1.00 INCH TUBE OD 20.00 FEET TUBE LENGTH 10900 LBS (TOTAL WT.)	42300

SECTION 300 FERMENTATION
E Q U I P M E N T   L I S T

I T E M N A M E	APP.NO.	CAPACITY	MAT'L	EQUIPMENT ITEM TYPE	S I Z E	PURCHASED EQUIPMENT COST
FERMENTATION FEED PUMP A+B (2) ITEMS	CP -306	625.00 GPM	304SF	AVS-LOW	75.00 FT HD 150.00 DEG F 15.00 HP 1150.00 RPM 1100 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	7200
FERMENTERS (15) ITEMS	VT -308	100000.0 GAL	CS	CYLINDER	17.50 FT DIA 55.58 FT HT 7.00 PSIG 150.00 DEG F 0.56 INCHES THICK 120100 LBS (TOTAL WT.)	1707000
FERMENTER COOLERS (15) ITEMS	HE -309		SS304	SPIRAL PLT	450.00 SQ FT 7.00 PSI	265500
FERMENTER RECIRCULATION PUMP A+B (30) ITEMS	CP -310	350.00 GPM	304SF	AVS-MEDIUM	150.00 FT HD 150.00 DEG F 20.00 HP 1750.00 RPM 1000 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	102000
ALCOHOL CHARGE PUMP A+B (6) ITEMS	CP -311	350.00 GPM	304SF	AVS-MEDIUM	150.00 FT HD 150.00 DEG F 20.00 HP 1750.00 RPM 1000 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	20400
ALCOHOL CHARGE TANK (3) ITEMS	VT -312	150000.0 GAL	CS	CYLINDER	17.50 FT DIA 83.37 FT HT 7.00 PSIG 150.00 DEG F 0.47 IN THICK (AVG) 145500 LBS (TOTAL WT.)	405900
DISTILLATION FEED PUMP A+B (6) ITEMS	CP -313	350.00 GPM	304SF	AVS-MEDIUM	150.00 FT HD 150.00 DEG F 20.00 HP 1750.00 RPM 1000 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	20400

SECTION 300 FERMENTATION
E Q U I P M E N T   L I S T

I T E M N A M E	APP.NO.	CAPACITY	MAT'L	EQUIPMENT ITEM TYPE	S I Z E	PURCHASED EQUIPMENT COST
CENTRIFUGE FEED PUMP A+B (4) ITEMS	CP -314	425.00 GPM	304SF	AVS-MEDIUM	150.00 FT HD 150.00 DEG F 25.00 HP 1750.00 RPM 1100 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	14800
YEAST CENTRIFUGE (2) ITEMS	CT -315		CS	DISK	15.00 IN BOWL DIAMETER	231000
YEAST HOLD TANK	VT -316	12000.00 GAL	CS	CYLINDER	11.00 FT DIA 16.88 FT HT 7.00 PSIG 150.00 DEG F 0.31 INCHES THICK 16900 LBS (TOTAL WT.)	22200
YEAST RECYCLE PUMP A+B (4) ITEMS	CP -317	50.00 GPM	304SF	AVS-LOW	75.00 FT HD 150.00 DEG F 1.50 HP 1150.00 RPM 580 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	8000
YEAST CENTRIFUGE BOTTOMS PUMP A+B (4) ITEMS	CP -331	65.00 GPM	304SF	AVS-LOW	75.00 FT HD 150.00 DEG F 2.00 HP 1150.00 RPM 610 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	8000
FERMENTER PUMP A+B (30) ITEMS	CP -330	400.00 GPM	304SF	AVS-MEDIUM	185.00 FT HD 150.00 DEG F 25.00 HP 1750.00 RPM 1100 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	111000
NUTRIENT MIX TANK PUMP A+B						

SECTION 300 FERMENTATION
E Q U I P M E N T   L I S T

I T E M N A M E	APP.NO.	CAPACITY	MAT'L	EQUIPMENT ITEM TYPE	S I Z E	PURCHASED EQUIPMENT COST
(2) ITEMS	CP -324	50.00 GPM	304SF	AVS-LOW	50.00 FT HD 150.00 DEG F 1.00 HP 1150.00 RPM 490 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	3400
YEAST PREPARATION PUMP A+B (2) ITEMS	CP -325	50.00 GPM	304SF	AVS-LOW	50.00 FT HD 150.00 DEG F 1.00 HP 1150.00 RPM 490 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	3400
YEAST TUB PUMP A+B (6) ITEMS	CP -326	50.00 GPM	304SF	AVS-MEDIUM	185.00 FT HD 150.00 DEG F 5.00 HP 1750.00 RPM 760 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	15600
CULTURE HOLD TANK PUMP A+B (4) ITEMS	CP -327	50.00 GPM	304SF	AVS-MEDIUM	185.00 FT HD 150.00 DEG F 5.00 HP 1750.00 RPM 760 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	10400
YEAST PREPARATION COOLER	HE -328		SS304	SPIRAL PLT	50.00 SQ FT 7.00 PSI	4500
YEAST PREPARATION REFRIGERATOR	HE -329		SS304	SPIRAL PLT	50.00 SQ FT 7.00 PSI	4500
CULTURE HLD TNK (2) ITEM>	APT-323	500.00 GAL	CS	JACKETED	4.50 FT DIA 5.00 FT HT 3.00 HP 872.00 RPM 50.00 PSIG 275.00 DEG F 0.50 INCHES THICK 0.13 SS304 CLAD 5900 LBS (TOTAL WT.) 1349523 REYNOLDS NUMBER 3.74 FT FLUID DEPTH 90.00 PSIG JACKET PRES	23600

SECTION 300 FERMENTATION
EQUIPMENT LIST

ITEM NAME	APP.NO.	CAPACITY	MAT'L	EQUIPMENT ITEM TYPE	SIZE	PURCHASED EQUIPMENT COST
YEAST PREPARATION TANK	APT-321	300.00 GAL	CS	JACKETED	4.00 FT DIA 5.00 FT HT 3.00 HP 944.00 RPM 50.00 PSIG 275.00 DEG F 0.44 INCHES THICK 0.13 SS304 CLAD 4900 LBS (TOTAL WT.) 1154332 REYNOLDS NUMBER 3.09 FT FLUID DEPTH 90.00 PSIG JACKET PRES	21700
NUTRIENT MIX TANK	APT-320	600.00 GAL	CS	JACKETED	4.50 FT DIA 6.00 FT HT 5.00 HP 910.00 RPM 50.00 PSIG 275.00 DEG F 0.50 INCHES THICK 0.13 SS304 CLAD 6700 LBS (TOTAL WT.) 1408333 REYNOLDS NUMBER 4.09 FT FLUID DEPTH 90.00 PSIG JACKET PRES	26600
YEAST TUB (3) ITEMS	APT-322	5000.00 GAL	CS	JACKETED	8.50 FT DIA 13.00 FT HT 25.00 HP 67.00 RPM 50.00 PSIG 275.00 DEG F 0.94 INCHES THICK 0.13 SS304 CLAD 33400 LBS (TOTAL WT.) 827886 REYNOLDS NUMBER 11.04 FT FLUID DEPTH 90.00 PSIG JACKET PRES	272700

SECTION 400 PURIFICATION
E Q U I P M E N T   L I S T

I T E M N A M E	APP.NO.	CAPACITY	MAT'L	EQUIPMENT ITEM TYPE	S I Z E	PURCHASED EQUIPMENT COST
RECTIFICATION COLUMN PREHEATER	HE -401		304S	FIXED-T-S	1450 SQ FT SS304 SHELL BEM TEMA TYPE 150.00 PSIG SHELL PRESS 650.00 DEG F SHELL TEMP 23.00 IN DIA 20.00 FT LG 75.00 PSIG TUBE PRESS 650.00 DEG F TUBE TEMP 1.00 INCH TUBE OD 20.00 FEET TUBE LENGTH 8100 LBS (TOTAL WT.)	38400
RECTIFICATION COLUMN PREHEATER CONDENSER	HE -402		304S	FIXED-T-S	763 SQ FT SS304 SHELL BEM TEMA TYPE 150.00 PSIG SHELL PRESS 650.00 DEG F SHELL TEMP 18.00 IN DIA 20.00 FT LG 75.00 PSIG TUBE PRESS 650.00 DEG F TUBE TEMP 1.00 INCH TUBE OD 20.00 FEET TUBE LENGTH 5600 LBS (TOTAL WT.)	24400
RECTIFICATION COLUMN REBOILER	HE -403		304S	FIXED-T-S	1890 SQ FT A285C SHELL BEM TEMA TYPE 150.00 PSIG SHELL PRESS 650.00 DEG F SHELL TEMP 41.00 IN DIA 8.00 FT LG 150.00 PSIG TUBE PRESS 650.00 DEG F TUBE TEMP 1.00 INCH TUBE OD 8.00 FEET TUBE LENGTH 15500 LBS (TOTAL WT.)	70200
RECTIFICATION COLUMN REBOILER PUMP A+B (2) ITEMS	CP -404	3500.00 GPM	SS304	CENTRIF-T	30.00 FT HD 350.00 DEG F 40.00 HP 3600.00 RPM 1600 LBS (TOTAL WT.) INCLUDES TURBINE DRIVER	17000

SECTION 400 PURIFICATION
E Q U I P M E N T   L I S T

I T E M N A M E	APP.NO.	CAPACITY	MAT'L	EQUIPMENT ITEM TYPE	S I Z E	PURCHASED EQUIPMENT COST
RECTIFICATION COLUMN REFLUX PUMP A+B (2) ITEMS	CP -405	650.00 GPM	304SF	AVS-MEDIUM	170.00 FT HD 275.00 DEG F 40.00 HP 1750.00 RPM 1400 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	9200
RECTIFICATION COLUMN REFLUX DRUM	VT -406	1100.00 GAL	SS304	CYLINDER	6.00 FT DIA 5.00 FT HT 75.00 PSIG 275.00 DEG F 0.25 INCHES THICK 2800 LBS (TOTAL WT.)	8400
DEHYDRATION COLUMN OVERHEAD CONDENSER	HE -408		A 214	FIXED-T-S	7205 SQ FT SS304 SHELL BEM TEMA TYPE 150.00 PSIG SHELL PRESS 650.00 DEG F SHELL TEMP 42.00 IN DIA 30.00 FT LG 7.00 PSIG TUBE PRESS 650.00 DEG F TUBE TEMP 1.00 INCH TUBE OD 30.00 FEET TUBE LENGTH 34800 LBS (TOTAL WT.)	77200
DEHYDRATION COLUMN REBOILER (2) ITEMS	HE -409		304S	FIXED-T-S	4232 SQ FT SS304 SHELL BEM TEMA TYPE 150.00 PSIG SHELL PRESS 650.00 DEG F SHELL TEMP 45.00 IN DIA 15.00 FT LG 12.00 PSIG TUBE PRESS 650.00 DEG F TUBE TEMP 1.00 INCH TUBE OD 15.00 FEET TUBE LENGTH 23100 LBS (TOTAL WT.)	244600
DEHYDRATION COLUMN REBOILER PUMP A+B (2) ITEMS	CP -410	1000.00 GPM	304SF	AVS-HIGH	30.00 FT HD 350.00 DEG F 10.00 HP 3500.00 RPM 610 LBS (TOTAL WT.) INCLUDES MOTOR DRIVER	4200

SECTION 900 INTERCON PIPING

OPERATIONAL UNIT BULK REPORT

BULK ORIGIN	BULK ITEM SYMBOL	DESCRIPTION	MAT'L	DESIGN DATA		MATERIAL COST($)	DIRECT LABOR MANHOURS	DIRECT LABOR COST($)	TOTAL (SUBCONTRACT) COST($)
-	OU	INSTRUMENT TESTING				0.	4	53.	53.
-	OU	INSTRUMENT RUNS,TRAYS,PANELS				0.	54	802.	802.
B/S- BL	PAD			25.0 FT LG	25.0 FT W	2822.	108	1338.	4159.
-	US	ELECTRICAL TESTING				0.	1	10.	10.
-	PD	** SUBSTATION REF NO 0 **				635327.	4219	59006.	694333.
-	PD	** MAIN SUBSTATION **				228711.	1572	21587.	250298.
-	PD	TRANSMISSION LINES				3842.	202	2389.	6231.
-	PD	69 KV OIL CIRCUIT BRKR				53695.	39	550.	54245.
-	MS	ELECTRICAL TESTING				0.	59	849.	849.
-	MP	PANEL INSTRUMENTS				534119.	0	0.	534119.
-	MP	112 FOOT PANEL				168001.	1300	18772.	186773.
-	MP	BACK UP POWER SUPPLY				3673.	0	0.	3673.
-	MP	INSTRUMENT TESTING				0.	91	1266.	1266.
-	OU	ROTATING EQUIP SPARE PARTS				81592.	0	0.	81592.