August 2004 • NREL/SR-510-27310

Subcontractor Report

Softwood Biomass to Ethanol Feasibility Study

Final Report: June 14, 1999

Merrick & Company
Aurora, Colorado

National Renewable Energy Laboratory
1617 Cole Boulevard, Golden, Colorado 80401-3393
303-275-3000 • www.nrel.gov

Operated for the U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
by Midwest Research Institute • Battelle

Contract No. DE-AC36-99-GO10337

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NREL Technical Monitor: K. Kadam

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Acknowledgments

This work was funded by the Bioconversion Element of the office of Fuels Development of the U.S. Department of Energy. As indicated below, this was a team effort with many individuals contributing to the endeavor.

Overall Project Management

Project Manager: Fran Ferraro, Merrick & Co.

Technical Monitor: Kiran Kadam, National Renewable Energy Laboratory (NREL)

Team Compositions

Compositions of teams making a contribution to various parts of the report are listed below:

Merrick & Co. (2450 S. Peoria Street, Aurora, CO 80014)
Fran Ferraro, Mike Kraft, Kurt Penka (Simons Engineering-a consultant to Merrick), Jim Sharpe, and Dick Voiles

NREL (1617 Cole Boulevard, Golden, CO 80401-3393)

Softwood Team
Kiran Kadam, Fred Keller, Quang Nguyen, Fannie Posey-Eddy, and Mel Tucker

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Eric Selya

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1. EXECUTIVE SUMMARY

Merrick & Company has evaluated the economic potential for a Softwood Biomass to Ethanol Facility. A conceptual ethanol plant located in Martell California is economically attractive, particularly when co-located with an existing power generating facility. The plant, sized for an expected feed capacity of 800 dry tons per day converts the carbohydrates in forest product waste materials to ethanol and uses the lignin and residual carbohydrates to generate steam and electricity.

This report documents the results of design and project evaluation work sponsored by the National Renewable Energy Laboratory (NREL) and performed by Merrick & Company, Architects and Engineers (Merrick), between March, 1998 and March, 1999. This project is a continuation of an effort begun in 1998 to study various aspects of ethanol related projects. Merrick has used NREL data and guidance to further develop cost estimates for the two stage dilute acid hydrolysis process for the production of ethanol from softwood.

The Softwood to Ethanol Feasibility Study discussed in this report is an extension of previous, generic, softwood to ethanol studies. The co-located case is applied to a specific site owned by Wheelabrator near Martell, California. A large amount of potential feed material is available in the area and the site contains an existing solid waste fired boiler and power generating equipment.

The evaluation of a specific site allowed better definition of a realistic installation and project. Staff consultations and site visits led to the selection of the portions of the Martell site for evaluation and the determination of which equipment was available and suitable.

Project Evaluation

The work accomplished during this project includes: process designs, heat and material balances, process flow diagrams, equipment selection, capital and operating cost estimates, and market assessments for the ethanol product. The specific co-located plant at Martell was evaluated to identify specific modifications required to the equipment to fit the existing plant requirements. Similar processes developed for other types of biomass to ethanol conversion were relied upon for reference and guidance. Also, plants were visited to witness similar operations and the equipment selected for similar service. Resulting economic analyses, detailed in the remaining sections of this report, conclude that the conceptual ethanol plant at Martell is economically attractive.

Process flow diagrams, feed composition and preparation, and each of the unit operations, from 1st stage prehydrolysis through dehydration of the ethanol/water azeotrope, are described in detail in the report.

Both capital and operating/maintenance costs were developed for the Martell site. The costs and anticipated revenues are presented as pro forma financial statements, with accompanying sensitivity analyses for varying feedstock prices.

Additionally, capital and operating cost estimates were developed for a stand-alone, green field plant utilizing the same feed stock. The results are reported for comparison purposes.

Conclusions and Recommendations

A co-located softwood to ethanol plant in the Martell area is an economically attractive concept. The plant will be constructed for a total capital investment of approximately $65 million. The economics are based on a total ethanol selling price of $1.20 per gallon, after incorporating the various tax credits and discounts associated with long term market relationships. To minimize market risk, long-term contractual relationships must be established regarding the sale of the ethanol. This appears to be reasonable.

Incorporating depreciation results in annual project net revenues of approximately $11.5 million. The resulting before-tax internal rate of return (IRR) is <u>about 36%</u> at 25% equity and 5% loan rate; the loan rate is lower than normal because of a subsidy available from the state of California.

Merrick recommends the following "next steps" in the development of this project:

- Establish a feedstock supply plan, exploring feedstock contracts and residue contracts.
- Establish an owner/operator organization for the ethanol facility to carry out further project development.
- Establish an updated project specification including more detailed and accurate feedstock composition and more definitive reuse of existing facilities. Update the project economic analysis: and
- Establish the financial basis regarding the project to ensure the economic evaluation is reasonable; and
- Set up market relationships that establish a contract basis for ethanol sales; and
- Confirm the utility cost to ensure the long term viability.

2. INTRODUCTION

a. SCOPE OF WORK

This report covers work performed during the period of May, 1998 through March, 1999. The objective of this work was to produce process designs, heat & material balances, process flow diagrams and capital & operating costs for two biomass to ethanol conversion plants. The biomass is assumed to be softwood forest thinnings.

One plant is stand-alone. That is, the lignin produced in the process is burned in a boiler which is a part of the plant design and produces the necessary power for the plant and sells excess power to the local grid. The cost of the boiler and turbine generator set are included in the cost estimate, as is the operating cost for this equipment. The boiler and turbine generator set are specifically sized to accommodate the lignin produced by the conversion plant.

The other plant considered is a plant located next to an existing Wheelabrator boiler and power generation facility that could easily be made capable of burning the lignin produced in the conversion process. The existing plant's boiler and generators are assumed to be adequate for burning the lignin residue. The existing forest waste feed system is partially diverted through the ethanol plant and returned as lignin residue to be mixed with the remaining forest waste feed stream. The capital and operating cost of the boiler and generator are not included in the estimate.

Additionally, the work scope included revising ASPEN PLUS models from previous NREL ethanol plant designs to conform with the softwood forest waste to ethanol designs. NREL developed the experimental data using softwood forest thinnings from the Quincy, CA area.

b. ASSEMBLY OF WORK PRODUCTS

This report collects the work of several organizations and individuals into coherent designs and cost estimates. Primary is the NREL work that established the basis and provided general processing methods.

Contributing organizations and individuals were:

- Ethanol handling and distillation - Fred Varani
- Water treating and feed water treating - Bob Hamilton
- Fermentation and associated processing - Joe Ruocco
- Solids conveying and handling - Kurt Penka
- Materials of construction - Bruce Craig
- Aspen Plus simulation - Vicky Putsche
- Heavy industrial practices and practicality - Merrick & Company

Merrick & Company coordinated the overall effort subject to NREL review and direction.

c. ENGINEERING

Based on the information and guidance supplied by NREL, a process was modeled for the conversion of softwood biomass to ethanol.

NREL provided a block flow diagram of the previous process model. The new process development areas, prehydrolysis through fermentation were developed by NREL with Heavy Industrial (equipment selection and process heat integration) experience input by Merrick. NREL furnished Updated Process Flow Diagrams and an ASPEN PLUS model for the plant. The process areas other than hydrolysis and fermentation were used "as is" from the previous model.

Within this framework various alternatives were considered and appropriate selections were made. For example three large, decanting centrifuges (beer column bottoms centrifuge S-601) were selected over multiple small centrifuges because it was felt that the maintenance and operating ease were optimized. In many cases several types of equipment could feasibly perform the necessary function and decisions had to be taken as to the type of equipment to be used for the estimate basis. Reliability and proven performance in similar service were considered the fundamental criteria for equipment selection with cost, ease of operation and similar factors also considered.

Similar processes developed for other types of biomass to ethanol conversion were relied upon for reference and guidance. Also, plants were visited to witness similar operations (Please see the trip reports in the appendix).

Equipment reliability was considered very important throughout the process development. The startup and operation of any first generation plant is extremely difficult and subject to schedule delays. If equipment is selected which has been proven in similar service, weeks of time can be saved in achieving design flow rates.

Similar thinking was applied to the overall plant efficiency. It is clearly necessary to demonstrate optimized plant efficiency in the design so that the economics will truly reflect achievable results. But even here it was felt that plant operability and reliability were paramount. If, for example, heat integration is taken to its limits the plant start up sequence may become cumbersome. Also, exchanger design might push the experience limits of manufacturers. A balance of efficiency and practical design was pursued in process development.

Considerable process evolution occurred in the chip washing, acid impregnation and hydrolysis area during the course of the project. This report includes the cost for hydrolysis equipment supplied in NREL Report TP-580-26157 [by Wooley, R., M. Ruth, J. Sheehan, H. Majdeski and A. Galvez (1999). Lignocellulosic Biomass to Ethanol Process Design and Economics, Utilizing Co-current Dilute Acid Prehydrolysis and Enzymatic Hydrolysis: Current and Futuristic Scenarios., National Renewable Energy Laboratory, Golden, Colorado.], and specific equipment pricing gathered by Merrick (see attached back-up data).

The plant design is based on 800 dtpd of biomass feed. Scaling of this design to other rates is practical if the rate is not too far different from the base rate. As the difference increases the associated risk of estimate inaccuracy increases. However, since the design is for commercial operation using equipment within the manufacturer's normal range of supply, the scaling risk is not exorbitant. Principal is the risk that a second (parallel) train of equipment will need to be added in some areas of the plant as the feed rate increases beyond the normal equipment size. The most appropriate equation for the scaling of costs to different throughputs was input to the estimated cost on an equipment-service by equipment-service basis based on flow rates provided by the Aspen Plus™ model.

When an appropriate site is located, firm price equipment quotations should be obtained to confirm the current estimated pricing.

d. COST ESTIMATES

Estimates for the equipment are based on selected vendor quotations and scaled equipment costs from previous plant models. The previous Aspen Plus™ plant models were a compilation of vendor quotations (for more specialized and complex equipment), and the ICARUS Process Evaluator program estimates (for common types of equipment, i.e., pumps, agitators, conveyors). The Aspen Plus™ model determines the flow rates of the various process flow streams. The cost of the equipment is determined using a selected scaling stream mass flow rate. Scaling exponents are selected for equipment and the scaled cost is calculated using an NREL developed spreadsheet.

Section 4 contains complete pro formas for both the co-located and stand alone cases. Co-location has very decided cost advantages both in capital and operating costs.

e. FUTURE WORK

During the course of the investigation many items were encountered which deserve further definition and evaluation. Among the most important of those are:

- The means of physically moving a slurry of acid impregnated wood chips and water into the hydrolyzers should be evaluated further. Although there are manufacturers who will design a screw press to do this, the hydrolyzer pressure must be held by the plug of moist solids in the barrel of the press. One manufacturer indicated that the liabilities involved with a plug failure are too great and they will not manufacture this equipment item. Other manufacturers will include a blast shield around the press to deflect any sudden pressure releases. It is felt that a system similar to an air lock system but using steam rather than compressed air may have safety and reliability advantages while still sufficiently approximating a continuous flow system. Similar digester feeders are currently used in the paper and pulp industries with good results so this is a workable system that needs further study. NREL is currently investigating this operation and any modifications necessary will be incorporated in future designs.

- Simplification of the second stage hydrolysis equipment may be possible. In-line steam injection (steam gun), followed by a holding tank for residence time, may possibly replace the expensive second stage hydrolyzer. Heat distribution through the slurry is a potential problem.

- Consideration should be given to other potential host sites for a co-located plant.

- The transport of lignin from the centrifuges to the combustion chamber is deserving of further work as it is not yet defined in detail. One thought was to mix the wet lignin with wood chips so that the dewatering screw presses would be more effective.

- The cost estimate includes a chilled water system allowing fermentor operation at 30°C (86°F) even on hot summer days. A benefit evaluation of this system should be done to see if the few weeks of use each year justifies its cost.

3. PROCESS DESCRIPTION

a. BLOCK FLOW DIAGRAM

Following this section is a block flow diagram which illustrates the major processing steps and flow paths in the plant. It may be a useful reference drawing, along with the Process Flow Diagrams, when reading the process description.

b. WOOD CHIP PREPARATION

The selected design feed rate for the plant is 800 dtpd softwood biomass. The design feed is milled wood chips, generally with a 1/2 inch maximum dimension but containing some slivers that are 2 to 3 inches long.

Wood chips arrive at the site by truck and semi-trailer. Vehicles will be weighed with and without load on an above ground platform scale with a capacity of 100 tons. The vehicles are unloaded on a back-on type hydraulic dumper which can lift both truck and trailer to dump the load into a receiving hopper. The chips are metered out of the hopper onto a belt conveyor which in turn discharges to one of two stacker conveyors.

The stackers deliver the chips to the storage pile. The unloading system is designed to operate 12 hours a day, 5 to 7 days per week

Bulldozers move the chips to form a 40 foot high pile with an area of approximately 150,000 square feet which is equal to a 30 day supply for the processing plant. A second pile of equal dimensions, with additional stacker and reclaim conveyors, would be required to provide a 2 months supply. Two bulldozers are included regardless of inventory to allow for peak delivery periods, to provide for proper pile rotation and maintenance. It is anticipated that two operators may be required during trucking hours and one during other times.

The dozers are used also to push chips into and over one of two reclaim chain conveyors. Using one conveyor at a time chips are reclaimed and fed to the screening system by belt conveyor. A tramp iron magnet is provided to catch stray magnetic metal and a scalping screen removes gross oversize and foreign material ahead of the screening process.

The initial process step in producing ethanol from biomass benefits from raw material particles being fairly thin. Wood chips should be in the order of 3 to 5 millimeter thick or less so as to allow the process chemicals to penetrate the fibers quickly. Such thin chips result when wood is cut into relatively short lengths along the grain, or no more than 12 millimeter long. Wood species, seasonal factors, moisture content and other variables influence chip thickness. It has been assumed that most incoming chips will be acceptable in thickness and do not require reprocessing.

All chips will pass over a thickness screen to screen out over-thick material. A roll screen with specially profiled roll surfaces is proposed for this step. Material rejected by the screen passes first through an air density separator which is a system that separates material by specific gravity. This eliminates any stones and other foreign objects which would damage downstream equipment. The over-thick chips are then introduced into a special chip slicer which cuts chips along the grain to a preset thickness. An alternate machine is a chip crusher which compresses chips to create fissures which allow more rapid penetration of the fiber by the process chemicals. The chip reclaim and screening system are designed to operate more or less continuously, or at least 20 hours per day.

In order to allow for equipment maintenance and to guard against breakdowns a storage silo is provided. The silo will hold approx. 55,000 cu.ft. of screened chips which is equal to 8 hours of plant operation. Chips are metered and conveyed to the process plant on a continuous, 24 hour basis.

Several process alternatives were considered. A fully automated chip storage and reclaim system was discussed which would not require either bulldozers or operators. Such a system can provide full inventory control and material turn-over and eliminates material break-down due to bulldozer action. Fiber loss and operating cost savings are the main advantages. Because of high capital cost this option was not pursued. Alternatives for fiber preparation were also considered. As a substitute for screening and slicing of chips the use of hammermills was discussed. Running all chips through such equipment would require high energy input and would unnecessarily degrade the material. However, hammermills could be further evaluated for use after screening and to replace a slicer.

c. 1st STAGE PREHYDROLYSIS

Chips enter the Acid Impregnator (M-201) along with sulfuric acid, recycle water and acidic recycle water from screw press S-201. The impregnator is a mechanical flight mixer/conveyor. The control point for this device is approximately 1% acid by weight leaving the impregnator. It operates at 20-50°C and atmospheric pressure.

Following the Impregnator is a Plug Screw Feeder (S-201), possibly of the Sunds type. An evaluation of similar devices which require less energy or have a better safety history is indicated. The screw press feeder compresses the wood chip mass to form a plug at the Hydrolyzer (R-201) inlet. The plug can withstand the 12 atmosphere pressure in the hydrolyzer vessel. The plug is split upon entry into the Hydrolyzer by a lance which also actuates to check back flow should the plug fail. Liquids from the Plug Screw Feeder are recycled to the Acid Impregnator. The plug entering the Hydrolyzer contains about 60% water.

d. 1st STAGE HYDROLYSIS

In the Hydrolyzer the pressure is increased to approximately 12 atmospheres. Steam is directly injected into the process so that the process temperature approaches the saturated steam temperature at processing pressure (190°C). A residence time of 3 minutes is required at these conditions to achieve the necessary reaction and prevent loss of carbohydrate by over-reaction. NREL developed the experimental data for the acid hydrolysis process using the QLG feedstock.

e. 1st STAGE FLASH AND SEPARATION

Hydrolyzer product enters a flash tank for cooling and conversion of oligomers to monomers. The First Stage Oligomer Flash Tank Reactor (T-203) will operate at 135°C and 3.0 atm. A residence time of one hour is required. Because the pressure in the Flash Tank is lower than in the Hydrolyzer, steam will be generated (flashed) in the tank. Approximately 9,000 kg/hr. of low pressure steam will be produced which can be used for other process heating requirements. Please refer to Appendix A.1.

Liquid from the 1st Stage Flash Tank is sent to the 1st Stage Low Pressure Flash Tank (T-204) which operates at one atmosphere and approximately 101°C. Only 10 to 15 minutes of residence time is required in this Flash Tank.

Following the flash steps a hot counter-current washer (Interstage Washer, W-203) recovers hemicellulosic sugars.

After washing, a screw press (S-203) reduces the water content to approximately 60% and this material is sent to the second stage of hydrolysis. The liquid stream from this press is recycled to the Interstage Washer.

f. 2nd STAGE PREHYDROLYSIS

The 40% solids stream from the screw press downstream of the Interstage Washer is feed for the 2nd Stage of the hydrolysis section. The material is fed directly to the 2nd Stage Acid Impregnator (M-204) which has nearly the same specification as the 1st Stage. However, acid concentration is increased to result in approximately 1.6 % in the 2nd Stage Hydrolyzer. The operating temperature is 50°C. Following the Impregnator is a Plug Screw Feeder (S-202 for the 2nd Stage

Hydrolyzer (R-202). This Feeder must raise the pressure to 22.5 atmospheres. Liquids from the Plug Screw Feeder recycle to the 2nd Stage Acid Impregnator. The solids rich stream (40%) proceeds to Hydrolysis.

g. 2nd STAGE HYDROLYSIS

In the 2nd Stage Hydrolyzer (R-202) the pressure is increased to approximately 22.5 atmospheres. Steam is directly injected into the process so that the process temperature approaches the saturated steam temperature at processing pressure (220°C). A residence time of 3 minutes is required at these conditions to achieve the necessary reaction.

h. 2nd STAGE FLASH

Hydrolyzer product enters the 2nd Stage Oligomer Flash Tank Reactor (T-205) for cooling and conversion of oligomers to monomers. The Flash Tank will operate at 135°C and 3.0 atm. A residence time of one hour is required. Because the pressure in T-205 is lower than the Hydrolyzer pressure, steam will be generated (flashed) in the tank. Approximately 11,000 kg/hr. of low pressure steam will be produced which can be used for other process heating requirements. Please refer to Appendix A.1.

Liquid from T-205 is sent to the 2nd Stage Low Pressure Flash Tank (T-206) which operates at just over atmospheric pressure and approximately 101°C.
T-206 is equipped with an agitator. Only 10 to 15 minutes of residence time is required in this Flash Tank. Lime is added in the 2nd Stage Low Pressure Flash Tank.

From T-206 material proceeds directly to cooling and fermentation.

i. 1st STAGE NEUTRALIZATION AND FERMENTATION

First stage liquor from the Interstage Washer goes to the Neutralization Tank (T-209) where lime is added to raise the pH of the liquor to 4.5 pH. From T-209 liquor goes to S-222, Rotary Drum Filter for the removal of precipitates (gypsum, calcium oxalate, etc.) and other solids. This filter is a vacuum rotary drum type filter. Liquid from the filter is pumped (P-222 A/S) to H-201, Cooling Water Cooler and H-202, Chilled Water Cooler prior to entering the fermentors. Filtered solids are sent to offsite disposal.

Fermentation was assumed to consume the majority of the C5 and C6 sugars to produce ethanol. Commercial yeast with the ability to convert both C5 and C6 sugars should be available within the construction period of the facility.

All fermentors in the plant are large, low pressure, stainless steel vessels with conical bottoms and slow speed agitators. The 1st Stage Fermentors (F-300 & F301) operate in series. Temperature is controlled to 30°C with chilled water in external exchangers (H-300 & H-301) with continuous recirculation.

In the first fermentor yeast is propagated by air and corn steep liquor (CSL) injection. The yeast is adapted to the inhibitors in the liquor via a recycling loop in the first-stage fermentors. Enough yeast is produced to supply the needs of the second fermentor which does not have CSL or air injection.

Each fermentor has a residence time of 8 hours or a total of 16 hours for the 1st Stage.

j. 2nd STAGE FERMENTATION

The material leaving T-206, 2nd Stage Low Pressure Flash Tank, enters a chilled flight screw conveyor (C-201). The Chilled Slurry Screw Conveyor uses chilled water for the cooling medium. Temperature of the slurry will be 30°C leaving this conveyor which is the operating temperature of the fermentors. The cooled material is mixed with the fermentation product from the 1st Stage in the 2nd Stage Fermentors (F-302 & F-303). Sufficient yeast carries over from the first stage and there is no provision for CSL or air addition.

Second Stage fermentation consists of two continuous fermentors in series. Both fermentors are continuously agitated with slow speed mechanical mixers. Temperature is controlled with chilled water in external exchangers (H-302 & H303) with continuous recirculation. The recirculation pumps, P-302 & P-303 are of the progressive cavity type because of the high solids concentration.

Each fermentor has a residence time of 8 hours or a total of 16 hours for the 2nd Stage.

Overall ethanol yield from in the 1st stage fermentors and 2nd stage combined is 90% of the six-carbon sugars entering the fermentors. Ethanol is also produced from the five-carbon sugars at 85% (in the near future it is assumed that a genetically engineered yeast or bacteria will be available commercially to ferment both the five and six carbon sugars) already mentioned earlier and on the next page. Both conversions are included in this model.

Off gas from all four fermentors is combined and washed in a counter-current water column, (T-512) before being vented to the atmosphere. The off gas is washed to recover ethanol and is not washed for air emissions control.

k. DISTILLATION

Distillation was addressed by NREL in a recent report. Refer to NREL Report TP-580-26157 [by Wooley, R., M. Ruth, J. Sheehan, H. Majdeski and A. Galvez (1999). Lignocellulosic Biomass to Ethanol Process Design and Economics, Utilizing Co-current Dilute Acid Prehydrolysis and Enzymatic Hydrolysis: Current and Futuristic Scenarios., National Renewable Energy Laboratory, Golden, Colorado.]

l. DEHYDRATION

Dehydration was addressed by NREL in a recent report. Refer to NREL Report TP-580-26157 [by Wooley, R., M. Ruth, J. Sheehan, H. Majdeski and A. Galvez (1999). Lignocellulosic Biomass to Ethanol Process Design and Economics, Utilizing Co-current Dilute Acid Prehydrolysis and Enzymatic Hydrolysis: Current and Futuristic Scenarios., National Renewable Energy Laboratory, Golden, Colorado.]

m. LIGNIN SEPARATION AND WATER HANDLING

Water recirculation and waste water treatment are addressed in a separate report, titled " Waste Water Treatment Options for the Biomass-to-Ethanol Process", October 22, 1998 by Merrick & Co.

Lignin separation is accomplished in three, large, solid bowl, decanting centrifuges. The lignin is further dewatered in a screw press. Additional work should done in this area to optimize the process performance.

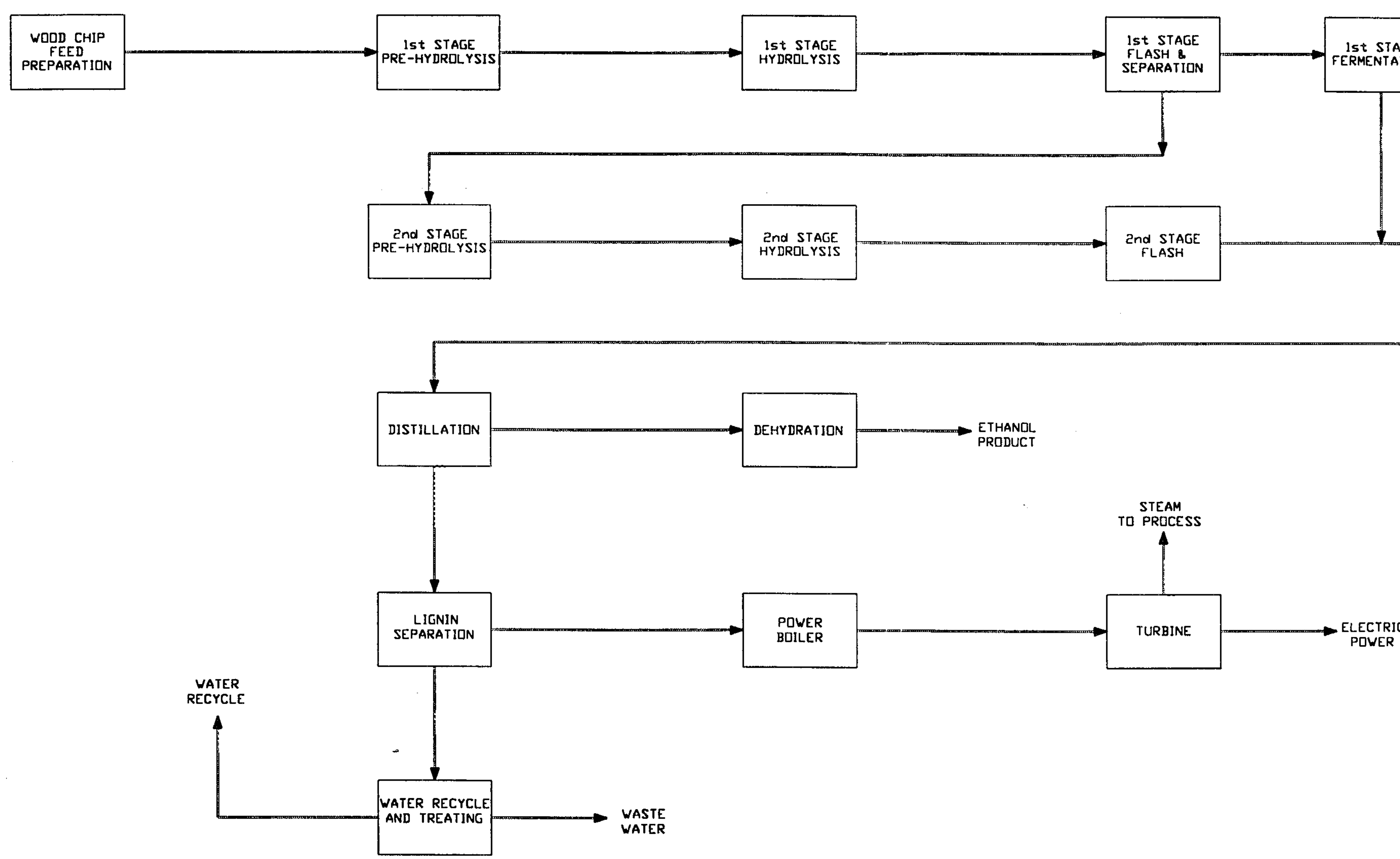
n. BOILER AND POWER GENERATION

The lignin powered boiler, steam turbine and power generator were addressed in a previous report "Biomass To-Ethanol. Total Energy Cycle Analysis", NREL Subcontract RCN 213-185-01-00 final report, Radian Corporation, Austin, Tx, November 22, 1991.

It was assumed that the lignin to be burned will be 50% solids and 50% water.

Soft wood Biomass to Ethanol Feasibility Study Process Summary Table	
Biomass feedrate	800 BDT/day
Dilute Acid Model:	G9810H
	Feedstock Composition (% Dry Weight)
Cellulose-Glucan	39.0%
Hemicellulose-Glucan *	4.3%
Xylan	7.4%
Galactan	2.8%
Arabinan	1.5%
Mannan	10.2%
Lignin	28.6%
Acetate	0.3%
Ash	0.9%
Extractives	5.0%
Total	100.0%
	1st Stage Acid Hydrolysis
Pressure	12.1 atm (178 psia)
Temperature	190 °C
Acid Concentration	0.7%
Residence Time	3 minutes
Sugar Yields:	
Glucose	0.0%
Xylose	70.2%
Mannose	86.9%
Galactose	81.1%
Arabinose	98.0%
	2nd Stage Acid Hydrolysis
Pressure	22.4 atm (331 psi)
Temperature	220 °C
Acid Concentration	1.6%
Residence Time	3 minutes
Sugar Yields: % of material entering stg. 2.	
Glucose	60.0%
Xylose	33.7%
Mannose	84.3%
Galactose	5.4%
Arabinose	0.0%

	Overal Hydrolysis Yield
Glucose	60.0%
Xylose	71.0%
Mannose	89.3%
Galactose	82.3%
Arabinose	98.0%
	Counter-Current Washing
Sugar Recovery	96.9%
Insoluble Solids lost to Sugar Stream	0.0%
Insoluble Solids Recovered in Stream to 2nd Stage Impregnator	98.0%
Wash Water Quantity	446 gpm
	Fermentation
1st Stage Fermentation Yield:	
Glucose--> Ethanol	90.0%
Xylose --> Ethanol	85.0%
Galactose-->Ethanol	90.0%
Mannose -->Ethanol	90.0%
Arabinose-->Ethanol	0.0%
2nd Stage Fermentation Yield:	
Glucose--> Ethanol	90.0%
Xylose --> Ethanol	85.0%
Galactose-->Ethanol	90.0%
Mannose -->Ethanol	90.0%
Arabinose-->Ethanol	0.0%
Overall Fermentation Yield:	
Glucose--> Ethanol	90.0%
Xylose --> Ethanol	85.0%
Galactose-->Ethanol	90.0%
Mannose -->Ethanol	90.0%
Arabinose-->Ethanol	0.0%
Overall Ethanol Yield	66 gallons per BDT feedstock
Ethanol Production	20,100,000 gallons/year
	* assumed 10% of glucan is from hemicellulose



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SOFTWOOD TO ETHANOL
BLOCK FLOW DIAGRAM

A

4. CAPITAL AND OPERATING COST

The following table is a summary of the economic assumptions and performance of the co-located plant. The co-located summary is presented because it has a more favorable economic performance than the stand-alone plant. The economic performance is calculated using a pro-forma spreadsheet developed by Merrick & Company and the pro-forma is attached.

a. Economic Evaluation Summary Table

Economic Evaluation of Two Stage Acid Hydrolysis Softwood -to-Ethanol Process
Table of Assumptions and Economic Performance;

CO-LOCATED CASE

Parameter	Base Case	
General Plant Data		
Plant Basis: Feedstock processed, dry metric t/yr	279,997	
Primary product	Fuel Ethanol	
Reference year of estimate	2000	
Plant location	California	
Plant life, years	20	
Plant on-stream factor, %	95.9	
Plant capacity, gal of formulated product per	20,098,616	
Economic Assumptions		
Construction period, years	1.5	
Startup period, months	1	
Ethanol selling price, $/gal	$1.20	
Owner equity financing, % of fixed capital	25%	
Loan term, years	15	
Number of annual compounding periods	1	
Nominal loan rate basis, %	5	
Process Data		
Feedstock		
Purchase cost, $/ton (dry basis)	20	(delivered)
Transportation cost, $/kg	0	
Moisture content, wt.% total	48	
Plant Personnel Data		
Operator's hourly rate, $	24.00	
Technician's hourly rate, $	24.00	
Non-skilled laborer's hourly rate, $	11.50	
Supervisor's hourly rate, $	29.80	
Payroll overhead factor, %	35	
Operators/day	14	
Technicians/day	2	
Supervisors/day	2	
Non-skilled laborers/day	9	
TOTAL O&M Labor Cost $/yr	**3,542,841**	

Operating Utilities	
Electricity $/yr (based on $0.05/KW Hr)	$2,728,320
Water $/yr (based on $0.001/lb)	$26,480
Waste Water Treating $/yr (based on $0.002/lb)	$79,440
300 PSIG Steam (based on $1.75/1000 lb)	$972,405
50 PSIG Steam (based on $0.50/1000 lb)	$203,742
TOTAL Utilities	**$4,010,388**
Raw Materials	
TOTAL Raw Materials $/yr	**$9,157,971**
Debt Service	
TOTAL Principal & Interest	**$6,781,997**
<u>TOTAL OPERATING COST $/yr</u>	**$21,383,750**
Ethanol production cost $/gal	**$1.00**
Product and Co-product Data	
Composition, %	
Ethanol	95
Denaturant	4.6
Water	0.4
Selling price, $/gal	**$1.20**
TOTAL Ethanol Sales (incl. tax credits)	**$24,118,339**
Electricity Produced, NET KW	0 for Co-located
Selling Price, $/KW*hr	$0.05
TOTAL Electricity Sales, $/year	**$0**
Energy Produced, NET MM BTU/Yr *	3,307,332
Selling Price, $/MM BTU **	$1.25
TOTAL BTU Sales, $/year	**$4,532,508**
TOTAL FACILITY SALES	**$28,650,848**
Economic Performance	
IRR, %	36%
Net capital investment, MM$	$64,808,641

* Energy produced is in the form of Lignin, digester off gas, and digester sludge

** Based on 8,000 BTU/lb and $20/ton for raw feedstock

Economic Evaluation Summary Table – CO-LOCATED CASE

Economic Evaluation of Two Stage Acid Hydrolysis Softwood-to-Ethanol Process
Cash Flow Analysis

Parameter	$ (millions)	Parameter	$ (millions)
Capital Costs			
Feedstock receiving (100)	3.249	Yard improvements, Civil/Structural	0.873
Materials processing (200)	13.291	OSBL utilities and service facilities	0
Fermentation (300)	5.095	Land	0
Distillation (500)	6.168	Indirect – Prorateable	1.611
Waste Water Treating (600)	10.123	Indirect – Process Development	0.920
Storage (700)	0.934	Field Expense	3.682
Boiler / Generation (800)	0.968	Home office constr. Fee	5.523
Utilities	5.324	Contingency	4.602
Purchased equipment	**30.520**	Startup, Permits, Fees	1.380
		Total fixed capital investment	**63.808**
Installed equipment	**46.029**	Working capital	1.058
		Net capital investment	64.808
		Financing, insurance, Misc.	5.586
		Total capital investment	**70.394**

Cash Flow Analysis			
Total annual income (sales of product & co-product)	**28.650**	**NET Annual operating income**	**7.267**
Annual manufacturing cost			
(a) Raw materials	9.158		
(b) Processing materials	0.0		
(c) Utilities	4.010		
(d) Operating labor	0.836		
(e) Facility Lease	0	**NET Operating cash flow**	**11.587**
(e) Labor related costs	0.73		
(g) Plant overhead	2.060		
(h) Sales related costs	0.041	**Annual cash income**	**4.806**
(i) Balance on borrowed capital	52.795		
(j) Principal payment	3.262		
(k) Interest payment	3.519		
Total product cost	**21.383**		

b. Pro Forma

The co-located facility assumes that a single owner would own and operate the ethanol facility and the bio-mass power plant.

The Martell California co-located site would be arranged as shown on the plot plan in relative close proximity to the current Wheelabrator 18 MW biomass power plant. The Ethanol plant would be located north and west of the chip pile - conveyor - boiler buildings. The current chip conveyor would be diverted/interrupted to allow a separate chip stream to the ethanol processing unit. The processed lignin would return to this conveyor for transport to the boiler facility. It is our understanding that the lignin could be processed in the existing boiler with minor modifications.

A major advantage of co-location is the use of existing facilities and processes. These particular advantages for the Martell site are;

1. Decrease the capital expenditure of the ethanol plant. The Martell site will allow use of the existing chip handling equipment and surge piles (area 100).

2. Decrease the capital expenditure of the ethanol plant. The Martell site will allow use of the existing boiler equipment, condensate equipment and boiler feed water chemical treatment (area 800) to produce steam.

3. Decrease in operator/security/maintenance personnel as the combined sites can utilize some of the same work force. The Martell power facility is assumed to provide a majority of these personell.

4. Shared chemical and utility costs will allow more aggressive negotiation with utility companies and suppliers. The utility costs were estimated to be half of the selling price of electricity and steam. The co-located facility would allow shared pricing of the steam and electricity costs with the boiler facility because the "sale" of the utilities would be an internal cost between the Martell facility and the wholly/majority owned Biomass to Ethanol facility.

5. Reduced management and administration labor costs.

6. Shared maintenance personnel and facilities.

The pro forma utility prices have been discussed with the personnel at Martell and these costs should be accurate for a minimum of a year.

Indirect construction costs were modeled as a percentage of the capital equipment costs based on similar type of projects and engineering experience. The indirect portion of the capital construction costs is estimated based on the experience Merrick has gathered on similar size projects. The indirect costs are defined as follows:

- Prorated – Includes fringe benefits, insurance, bonding, and overhead burdens. The prorated costs are adjusted to include the prorated costs of skid mounting equipment in a nearby industrial center.
- Process Development – Includes final development of the specialized portions of the process that may require additional study or research.
- Field Expenses – Normally this includes consumables, equip. rental, field services, temporary facilities, and supervision. The co-located site will have existing facilities that would be used for construction. The co-located site also has services (water, sewer, electric, phones, roadways, etc.) that would be used for construction. The co-located field expense was reduced since facilities and services are available.
- Home Office Construction Fee – Includes detail engineering of the plant, purchasing of the equipment and bulks, and field construction support.
- Contingency – Is an allowance for expected but undefined costs.
- Start-up, Permits, and Fees – Includes plant commissioning, construction permits and fees.
- NOTE: Indirect costs that are not included in the capital costs include;
    - Owner supervisory personnel for engineering, construction and start-up.
    - Engineering/Construction overtime pay.
    - Owner/Engineering scope changes.

c. Estimate Assumptions

Co-located

1. There are no land acquisition costs included.
2. There are no off site costs included (e.g. public road improvements, extension of power, water, telephone services)
3. There is a source of qualified construction personnel within daily driving distance of the site.
4. There exists adequate roads, rail roads, ship docks to allow equipment deliveries.
5. The costs of obtaining air and water permits is not included.
6. Soils are adequate for conventional foundation design.

Stand-alone

1. There are no land acquisition costs included.
2. There are no off site costs included (e.g. public road improvements, extension of power, water, telephone services)
3. There is a source of qualified construction personnel within daily driving distance of the site.
4. There exists adequate roads, rail roads, ship docks to allow equipment deliveries.
5. The costs of obtaining air and water permits is not included.
6. Soils are adequate for conventional foundation design.

NREL 2 STAGE DILUTE SULFURIC ACID HYDROLOSIS - PRO FORMA, Co-located Rev. 4

Underlying Assumptions & Input Variables 6/14/99

CURRENT SITUATION:

The Pro Forma models a CO-LOCATED Acid Hydrolysis Ethanol plant with a Combustion Reactor, Turbine, Generator system for an 800 BDTD plant

ETHANOL

The plant will convert wood chips to fuel grade ethanol utilizing acid hydrolosis.

Wood chip production levels of 63,979 kg/hr (str 101), produce estimated total output in equivalent kilograms of fuel grade ETOH

7,144	kg/hr.	=	60,009,600	kg / year (str 515)
2,393	gal/hr	=	20,098,616	gal / year

The model assumes renewal of the ethanol excise tax credit of $.54 per gallon to the blender and the small producer tax credit of $.10 per gallon through the year 2015 for a total ethanol value of

$1.20 per gallon or $0.40 per kg and **$24,118,339 per year TOTAL Ethanol sales**

LIGNIN

A Lignin coproduct is produced and used as Combustion Reactor fuel material. A total amount of Lignin in the stream (str 601) is 9,269 kg/hr = 77,860 metric ton / year is produced from the process and valued at 11,479 BTU/lb.

Total heating value of dry lignin is 235 MM BTU/hr

The water in the lignin stream must be vaporized at a net BTU cost for the stream (str 601). Water Vaporized is 30,877 kg/hr = 259,367 metric ton/year is vaporized at 1,100 BTU/lb loss (34) MM BTU/hr

The remainin 7,972 kg/hr of stream 601 has 18,462 BTU/kg value = 147 MM BTU/hr

Total heating value from stream 601 is 348 MM BTU/hr

LIGNIN Value/year = $3,652,150

METHANE

The digester produces (stream 615) 991 kg/hr Methane as boiler fuel. 52,148 BTU/kg CH4

Total heating value from Methane is 52 MM BTU/hr

Sale of METHANE to the co-located boiler based on BTU value of $2.00 MM BTU would

METHANE Value/year = $868,202

DIGESTER SLUDGE

The digester produces (stream 623) 233 kg/hr of sludge as boiler fuel = 2,254 BTU/lb

based on 9,845 btu/lb biomass and 70% water in the sludge. = 4,969 BTU/kg

Total heating value from sludge is 1.16 MM BTU/hr

SLUDGE Value/year = $12,157

Sale of these products to the co-located boiler based on BTU value to the boiler is **$4,532,508 per year**

Total projected facility sales would be $28,650,848 per year

B. CAPITAL INVESTMENT ASSUMPTIONS

1) Total capital investment

Civil Structural		872,833	
Area 100		3,249,766	
Area 200		13,291,414	
Area 300		5,095,688	
Area 500		6,168,265	
Area 600		10,122,971	
Area 700		934,981	
Area 800		968,430	
Area 1000		5,324,706	
Fixed Capital		$46,029,054	
INDIRECTS Prorateable	3.5%	$1,611,017	
Process Development	2.0%	$920,581	
Field Expense	8.0%	$3,682,324	
Home Office Constr. Fee	12.0%	$5,523,486	
Contingency	10.0%	$4,602,905	
Start-up, Permits, Fees	3.0%	$1,380,872	
Working Capital per estimate		$1,058,401	1 mos Raw matls. + O&M
Total Plant Cost		$64,808,641	
FEDERAL & STATE GRANTS		$0	
Net Capital Investment		**$64,808,641**	

NREL 2 STAGE DILUTE SULFURIC ACID HYDROLOSIS - PRO FORMA

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OPERATING COST ASSUMPTIONS 8,400 hr/yr

Utilities (Rates based on 20,098,616 gal/yr produced)

	Amount/hr	*Units*	*$/unit*	*Cost /hr.*	**Total Cost /yr**
Electricity	6,496	Kw-hr	$0.050	$325	$2,728,320
City process water (str 713)	2,627	kg	$0.001	$3	$26,480
Wastewater	2,627	kg	$0.004	$9	$79,440
300 PSIG steam (1/2 of $3.50/1000 lb)	30	mTon	$3.859	$116	$972,405
50 PSIG steam (1/2 of $1.00/1000 lb)	22	mTon	$1.103	$24	$203,742
Total Utilities				$477	$4,010,388

Raw Material Costs

	Amount/hr	*Units*	*$/unit*	*Cost /hr.*	**Total Cost /yr**
Wood Chips DRY (str 101less water)	33,333	kg	$0.022	$734.99	$6,173,938
Sulfuric Acid (str 710)	1,008	kg	$0.095	$95.76	$804,384
Calcium Oxide (Lime str 745)	705	kg	$0.060	$42.30	$355,320
Ammonia (str 717/311)	451	kg	$0.070	$31.57	$265,188
Corn Steep Liquor (str 735)	292	kg	$0.051	$14.89	$125,093
Cellulase Complex	0	kg	$3.000	$0.00	$0
Natural Gasoline (str 701)	342	kg	$0.210	$71.82	$603,288
Diesel (str 723)	170	kg	$0.330	$56.10	$471,240
WWT Chemicals	8	kg	$3.630	$29.04	$243,936
CW Chemicals	6	kg	$2.210	$13.26	$111,384
BFW Chemicals	0.5	kg	$1.000	$0.50	$4,200
Total Raw Materials				$1,090	$9,157,971

Processing Material Costs

	Amount/hr	*Units*	*$/unit*	*Cost /hr.*	**Total Cost /yr**
Antifoam	0	kg	$10.000	$0	$0
Total Processing Materials				$0	$0

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		Total Cost /yr.
Operations and Maintenance Costs - DRY HANDLING (area 100)		
Supervisors	0.5 ea/day*	$0
Operators	1 ea/day*	$0
Laborers	6 ea/day*	$0
Maintenance	2 ea/day*	$0
Operations and Maintenance Costs - HYDROLYSIS/FERMENTATION (area 200, 300, 500, 600)		
Supervisors	1 ea/day	$62,000
Operators	8 ea/day	$400,000
Laborers	1 ea/day	$24,000
Technicians	1 ea/day	$50,000
Maintenance	2 ea/day	$100,000
Operations and Maintenance Costs - POWER PLANT (area 800)		
Supervisors	0.5 ea/day*	$0
Operators	3 ea day*	$0
Laborers	2 ea/day*	$0
Technicians	1 ea/day*	$0
Maintenance	1 ea/day*	$0
Operations and Maintenance Costs - Utilities (area 700, 1000)		
Supervisors	0 ea/day	$0
Operators	2 ea/day	$100,000
Maintenance	2 ea/day	$100,000
	* - Martell site personell operate the feed & boiler areas	
	Total Operations and maintenance labor costs	$836,000
Other Operations and Maintenance Costs		
Payroll Overhead	35% of operating labor	$292,600
Maintenance Costs	2% of plant cost	$920,581.08
Operating Supplies	0.25% of plant cost	$115,072.64
Environmental	0.50% of plant cost	$230,145.27
Local Taxes	1% of plant cost	$460,290.54
Insurance	0.50% of plant cost	$230,145.27
Overhead Costs	40% of labor, supervision,maint cost	$334,400
Administrative Costs	1% of annual sales (less tax credits)	$82,404
Distribution and Sales	0.5% of annual sales (less tax credits)	$41,202
Total O&M Costs		$3,542,841

D. OTHER MODEL ASSUMPTIONS

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Average prevailing market price of fuel grade ETOH:		$0.40	per kg
Assumes renewal of the ethanol excise tax credit of $.54 per gallon		1.20	per gallon

and the small producer tax credit of $.10 per gallon through the year 2007
and Alaska State Tax credit of $.80 per gallon, $.41 per gallon fuel value includes $.10 discount to the blender.

	DRY	50% WET	
Price for Electricity Produced		$0.050	per KWhr
Price per million BTU		$2.000	per MM BTU
Price paid for wood chip feedstock - dry basis	$0.022	$0.011	per kg
	$22.05	$11.03	per metric ton
	$1.25		per MM BTU
Plant on-stream factor		0.959	
Plant operating hours per year		8400	
Depreciable Life of Capital Equipment		15	years
Average annual commodity escalation rate:		1.0%	
Average annual cost escalation rate:		3.0%	

1. There are no land acquisiton costs included.
2. There are no off site costs included (e.g. public road improvements, extensions of power, water, telephone services)
3. There is a source of qualified construction personnel within daily driving distance of the site.
4. There exist adequate roads, rail roads or ship docks to allow equipment delivery.
5. The costs for air and water permits are not included.
6. Soils are adequate for conventional foundation designs.

NREL 2 STAGE DILUTE SULFURIC ACID HYDROLOSIS - PRO FORMA Rev. 4

Underlying Assumptions & Input Variables 6/14/99

A. CURRENT SITUATION:

The Pro Forma models a CO-LOCATED Acid Hydrolysis Ethanol plant with a Combustion Reactor, Turbine, Generator system for an 800 BDTD plant

ETHANOL

The plant will convert wood chips to fuel grade ethanol utilizing acid hydrolosis.
Wood chip production levels of 141,074 lb/hr (str 101), produce estimated total output in equivalent kilograms of fuel grade ETOH 15,753 lb/hr 132,321,168 lb / year (str 515)
2,393 gal/hr = 20,098,616 gal / year

The model assumes renewal of the ethanol excise tax credit of $.54 per gallon to the blender and the small producer tax credit of $.10 per gallon through the year 2015 for a total ethanol value of $1.20 per gallon or **TOTAL ETHANOL SALES WOULD BE $24,118,339 per year**

LIGNIN

A Lignin coproduct is produced and used as Combustion Reactor fuel material. A total amount of Lignin in the stream (str 601)
20,438 lb/hr = 85,840 ton / year is produced from the process and valued at 11,479 BTU/lb.
Total heating value of dry lignin is 235 MM BTU/hr
The water in the lignin stream must be vaporized at a net BTU cost for the stream (str 601). Water vaporized is
68,084 lb/hr = 285,952 ton/year is vaporized at 1,100 BTU/lb loss = (34) MM BTU/hr
The remaini 17,578 lb/hr of stream 601 has 8,373 BTU/lb value = 147 MM BTU/hr
Total heating value from stream 601 is 348 MM BTU/hr
LIGNIN Value/year = $3,652,150

METHANE

The digester produces (stream 615) 2,185 lb/hr Methane as boiler fuel. 23,650 BTU/lb CH4
Total heating value from Methane is 52 MM BTU/hr
Sale of METHANE to the co-located boiler based on BTU value of $2.00 MM BTU would
METHANE Value/year = $868,202

DIGESTER SLUDGE

The digester produces (stream 623) 514 lb/hr of sludge as boiler fuel = 2,254 BTU/lb
based on 9,845 btu/lb biomass and 70% water in the sludge. = 4,969 BTU/kg
Total heating value from sludge is 1 MM BTU/hr
SLUDGE Value/year = $12,157

Sale of these products to the co-located boiler based on BTU value to the boiler is **$4,532,508 per year**

Total projected facility sales would $28,650,848 per year

B. CAPITAL INVESTMENT ASSUMPTIONS

1) Total capital investment

Civil Structural		872,833	
Area 100		3,249,766	
Area 200		13,291,414	
Area 300		5,095,688	
Area 500		6,168,265	
Area 600		10,122,971	
Area 700		934,981	
Area 800		968,430	
Area 1000		5,324,706	
Fixed Capital		$46,029,054	
INDIRECTS Prorateable	3.5%	$1,611,017	
Process Development	2.0%	$920,581	
Field Expense	8.0%	$3,682,324	
Home Office Constr. Fee	12.0%	$5,523,486	
Contingency	10.0%	$4,602,905	
Start-up, Permits, Fees	3.0%	$1,380,872	
Working Capital per estimate		$1,058,401	1 mos Raw matls. + O&M
Total Plant Cost		$64,808,641	
FEDERAL & STATE GRANTS		$0	
Net Capital Investment		**$64,808,641**	

Note: Indirect Capital Costs are adjusted to account for location specific construction issues.

NREL 2 STAGE DILUTE SULFURIC ACID HYDROLOSIS - PRO FORMA

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C. OPERATING COST ASSUMPTIONS 8,400 hr/yr

Utilities (Rates based on 20,098,616 gal/yr produced)

	Amount/hr	*Units*	*$/unit*	*Cost /hr.*	**Total Cost /yr**
Electricity	6,496	Kw-hr	$0.050	$325	$2,728,320
City process water	5,793	lb	$0.001	$3	$26,480
Wastewater	5,793	lb	$0.002	$9	$79,440
300 PSIG steam (1/2 of $3.50/1000 lb	66	1000 lb	$1.75	$116	$972,405
50 PSIG steam (1/2 of $1.00/1000 lb)	49	1000 lb	$0.50	$24	$203,742
Total Utilities				$477	$4,010,388

Raw Material Costs

	Amount/hr	*Units*	*$/unit*	*Cost /hr.*	**Total Cost /yr**
Wood Chips DRY (45% str 101)	73,499	lb	$0.010	$734.99	$6,173,938
Sulfuric Acid (str 710)	2,223	lb	$0.043	$95.76	$804,384
Calcium Oxide (Lime)	1,555	lb	$0.027	$42.30	$355,320
Ammonia (str 717/311)	994	lb	$0.032	$31.57	$265,188
Corn Steep Liquor (str 735)	644	lb	$0.023	$14.89	$125,093
Cellulase Complex	0	lb	$1.361	$0.00	$0
Natural Gasoline (str 701)	754	lb	$0.095	$71.82	$603,288
Diesel (str 723)	375	lb	$0.150	$56.10	$471,240
WWT Chemicals	18	lb	$1.646	$29.04	$243,936
CW Chemicals	13	lb	$1.002	$13.26	$111,384
BFW Chemicals	1	lb	$0.454	$0.50	$4,200
Total Raw Materials				$1,090	$9,157,971

Processing Material Costs

	Amount/hr	*Units*	*$/unit*	*Cost /hr.*	**Total Cost /yr**
Antifoam	0	lb	$4.530	$0	$0
Total Processing Materials				$0	$0

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		Total Cost /yr.
Operations and Maintenance Costs - DRY HANDLING (area 100)		
Supervisors	0.5 ea/day	$0
Operators	1 ea/day	$0
Laborers	6 ea/day	$0
Maintenance	2 ea/day	$0
Operations and Maintenance Costs - HYDROLYSIS/FERMENTATION (area 200, 300, 500, 600)		
Supervisors	1 ea/day	$62,000
Operators	8 ea/day	$400,000
Laborers	1 ea/day	$24,000
Technicians	1 ea/day	$50,000
Maintenance	2 ea/day	$100,000
Operations and Maintenance Costs - POWER PLANT (area 800)		
Supervisors	0.5 ea/day	$0
Operators	3 ea day	$0
Laborers	2 ea/day	$0
Technicians	1 ea/day	$0
Maintenance	1 ea/day	$0
Operations and Maintenance Costs - Utilities (area 700, 1000)		
Supervisors	0 ea/day	$0
Operators	2 ea/day	$100,000
Maintenance	2 ea/day	$100,000
	Total Operations and maintenance labor costs	$836,000
Other Operations and Maintenance Costs		
Payroll Overhead	35% of operating labor	$292,600
Maintenance Costs	2% of plant cost	$920,581
Operating Supplies	0.25% of plant cost	$115,073
Environmental	0.50% of plant cost	$230,145
Local Taxes	1% of plant cost	$460,291
Insurance	0.50% of plant cost	$230,145
Overhead Costs	40% of labor, supervision,maint cost	$334,400
Administrative Costs	1% of annual sales	$82,404
Distribution and Sales	0.5% of annual sales	$41,202
Total O&M Costs		$3,542,841

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D. OTHER MODEL ASSUMPTIONS

Average prevailing market price of fuel grade ETOH:		$0.40	per kg
Assumes renewal of the ethanol excise tax credit of $.54 per gallon and the small producer tax credit of $.10 per gallon		1.20	per gallon

	DRY	50% WET	
Price for Lignin coproduct (DRY, 11,000 BTU/lb)	$0.01	$0.007	per lb
	$27.50	$13.75	per Ton
	$1.25		per MM BTU
Price for Electricity Produced		$0.050	per KWhr
Price per million BTU		$2.000	per MM BTU

	DRY	50% WET	
Price paid for wood chip feedstock - dry basis	$0.010	$0.005	per lb
	$20.00	$10.00	per ton
Plant on-stream factor		0.959	
Plant operating hours per year		8,400	
Depreciable Life of Capital Equipment		15	years
Average annual commodity escalation rate:		1.0%	
Average annual cost escalation rate:		3.0%	

1. There are no land acquisiton costs included.
2. There are no off site costs included (e.g. public road improvements, extensions of power, water, telephone services)
3. There is a source of qualified construction personnel within daily driving distance of the site.
4. There exist adequate roads, rail roads or ship docks to allow equipment delivery.
5. The costs for air and water permits are not included.
6. Soils are adequate for conventional foundation designs.

CASE 1: Produce Fuel Grade Ethanol Martell Co-located Plant Rev. 4 6/14/99

Capital Investment:		month1	month2	month3	month4	month5	month6	month7	month8	month9	month10	month11	month12	month13	month14	month15	month16	month17	month18	TOTAL
Total Fixed Capital Cost		$3,500,000	$3,500,000	$3,500,000	$3,500,000	$3,500,000	$3,500,000	$3,500,000	$3,500,000	$3,500,000	$3,500,000	$3,500,000	$3,500,000	$3,500,000	$3,500,000	$3,500,000	$3,500,000	$3,500,000	$5,308,641	$64,808,641
Construction Financing & Fees @10%			29,167	58,333	87,500	116,667	145,833	175,000	204,167	233,333	262,500	291,667	320,833	350,000	379,167	408,333	437,500	466,667	233,333	4,200,000
Loan Origination Fee @	2.0%	1,296,173																		1,296,173
Legal Fees		40,000																	0	40,000
Builder's All Risk/General Liability		50,000																	0	50,000
Working Capital																			0	0
Total Capital Investment Required		$4,886,173	$3,529,167	$3,558,333	$3,587,500	$3,616,667	$3,645,833	$3,675,000	$3,704,167	$3,733,333	$3,762,500	$3,791,667	$3,820,833	$3,850,000	$3,879,167	$3,908,333	$3,937,500	$3,966,667	$5,541,974	$70,394,814

					11,000						
		Year 1:	Year 2:	Year 3:	Year 4:	Year 5:	Year 6:	Year 7:	Year 8:	Year 9:	Year 10:
Operating Projection:		1999 / 2000	2000/2001	2001/2002	2002/2003	2003/2004	2004/2005	2005/2006	2006/2007	2007/2008	2008/2009
gal of fuel grade ethanol produced		20,098,616	20,098,616	20,098,616	20,098,616	20,098,616	20,098,616	20,098,616	20,098,616	20,098,616	20,098,616
Contract sale price per gallon		$1.100	$1.111	$1.122	$1.133	$1.145	$1.156	$1.168	$1.179	$1.191	$1.203
Gross Annual Revenue		$22,108,478	$22,329,562	$22,552,858	$22,778,387	$23,006,170	$23,236,232	$23,468,594	$23,703,280	$23,940,313	$24,179,716
Small Ethanol Producer Tax Credit											
@	$0.1000 per gallon	$2,009,862	$2,009,862	$2,009,862	$2,009,862	$2,009,862	$2,009,862	$2,009,862	$2,009,862	$2,009,862	$2,009,862
Total projected ethanol sales and credit		$24,118,339	$24,339,424	$24,562,720	$24,788,248	$25,016,032	$25,246,094	$25,478,456	$25,713,142	$25,950,175	$26,189,578
B Value of electricity		$0.05	$0.051	$0.051	$0.052	$0.052	$0.053	$0.053	$0.054	$0.054	$0.055
Gross Annual LIGNIN/BTU Revenue		$4,532,508	$4,577,834	$4,577,834	$4,577,834	$4,577,834	$4,577,834	$4,577,834	$4,577,834	$4,577,834	$4,577,834
Gross Sales and Credit		$28,650,848	$28,917,257	$29,140,553	$29,366,082	$29,593,866	$29,823,927	$30,056,290	$30,290,976	$30,528,008	$30,767,411
Operating Expenses:											
Utilities		4,010,388	4,130,699	4,254,620	4,382,259	4,513,727	4,649,138	4,788,613	4,932,271	5,080,239	5,232,646
Raw Materials		9,157,971	9,249,551	9,342,046	9,435,467	9,529,821	9,625,120	9,721,371	9,818,585	9,916,770	10,015,938
Processing Materials		0	0	0	0	0	0	0	0	0	0
Operation & Maintenance		3,542,841	3,649,127	3,758,600	3,871,358	3,987,499	4,107,124	4,230,338	4,357,248	4,487,965	4,622,604
Property Tax @	0.50% Book Value	351,974	330,371	308,768	287,165	265,563	243,960	222,357	200,754	179,151	157,548
Depreciation		4,320,576	4,320,576	4,320,576	4,320,576	4,320,576	4,320,576	4,320,576	4,320,576	4,320,576	4,320,576
Total Operating Expense		$21,383,750	$21,680,324	$21,984,611	$22,296,825	$22,617,186	$22,945,918	$23,283,254	$23,629,433	$23,984,702	$24,349,313
Net Operating Income		$7,267,098	$7,236,934	$7,155,942	$7,069,256	$6,976,680	$6,878,009	$6,773,036	$6,661,542	$6,543,306	$6,418,099
Net Operating Cash Flow		$11,587,674	$11,557,510	$11,476,518	$11,389,832	$11,297,256	$11,198,586	$11,093,612	$10,982,118	$10,863,883	$10,738,675

	Year 11:	Year 12:	Year 13:	Year 14:	Year 15:	Year 16:	Year 17:	Year 18:	Year 19:	Year 20:
Operating Projection:	2006 / 2007	2007 / 2008	2008 / 2009	2009 / 2009	2010 / 2011	2011 / 2012	2012 / 2013	2013 / 2014	2014 / 2015	2015 / 2016
gal of fuel grade ethanol produced	20,098,616	20,098,616	20,098,616	20,098,616	20,098,616	20,098,616	20,098,616	20,098,616	20,098,616	20,098,616
Contract sale price per gallon	$1.215	$1.227	$1.240	$1.252	$1.264	$1.277	$1.290	$1.303	$1.316	$1.329
Gross Annual Revenue	$24,421,514	$24,665,729	$24,912,386	$25,161,510	$25,413,125	$25,667,256	$25,923,929	$26,183,168	$26,445,000	$26,709,450
Small Ethanol Producer Tax Credit @ $0.1000 per gallon	$2,009,862	$2,009,862	$2,009,862	$2,009,862	$2,009,862	$2,009,862	$2,009,862	$2,009,862	$2,009,862	$2,009,862
Total projected ethanol sales and credit	$26,431,375	$26,675,590	$26,922,248	$27,171,371	$27,422,987	$27,677,118	$27,933,790	$28,193,030	$28,454,861	$28,719,311
B Value of electricity	$0.055	$0.056	$0.056	$0.057	$0.057	$0.058	$0.059	$0.059	$0.060	$0.060
Gross Annual LIGNIN/BTU Revenue	$4,577,834	$4,577,834	$4,577,834	$4,577,834	$4,577,834	$4,577,834	$4,577,834	$4,577,834	$4,577,834	$4,577,834
Gross Sales and Credit	$31,009,209	$31,253,424	$31,500,081	$31,749,205	$32,000,820	$32,254,951	$32,511,624	$32,770,863	$33,032,695	$33,297,145
Operating Expenses:										
Utilities	5,389,626	5,551,314	5,717,854	5,889,389	6,066,071	6,248,053	6,435,495	6,628,560	6,827,417	7,032,239
Raw Materials	10,116,097	10,217,258	10,319,431	10,422,625	10,526,852	10,632,120	10,738,441	10,845,826	10,954,284	11,063,827
Processing Materials	0	0	0	0	0	0	0	0	0	0
Operation & Maintenance	4,761,282	4,904,121	5,051,245	5,202,782	5,358,865	5,519,631	5,685,220	5,855,777	6,031,450	6,212,394
Property Tax @ 0.50% Book Value	135,945	114,342	92,740	71,137	49,534	49,534	49,534	49,534	49,534	49,534
Depreciation	4,320,576	4,320,576	4,320,576	4,320,576	4,320,576	0	0	0	0	0
Total Operating Expense	$24,723,527	$25,107,612	$25,501,845	$25,906,509	$26,321,898	$22,449,338	$22,908,690	$23,379,696	$23,862,684	$24,357,993
Net Operating Income	$6,285,682	$6,145,812	$5,998,236	$5,842,696	$5,678,922	$9,805,613	$9,602,934	$9,391,167	$9,170,010	$8,939,152
Net Operating Cash Flow	$10,606,258	$10,466,388	$10,318,812	$10,163,272	$9,999,498	$9,805,613	$9,602,934	$9,391,167	$9,170,010	$8,939,152

CASE 1: Hypothetical Financing Scenarios:

CASE 1A: 100% Debt Financing

Amortization [redacted] yrs	Year 1:	Year 2:	Year 3:	Year 4:	Year 5:	Year 6:	Year 7:	Year 8:	Year 9:	Year 10:
Interest Rate [redacted]	1999 / 2000	2000/2001	2001/2002	2002/2003	2003/2004	2004/2005	2005/2006	2006/2007	2007/2008	2008/2009
Net Operating Cash Flow *(from above)*	11,587,674	11,557,510	11,476,518	11,389,832	11,297,256	11,198,586	11,093,612	10,982,118	10,863,883	10,738,675
Debt Interest	3,519,741	3,356,628	3,185,359	3,005,527	2,816,704	2,618,439	2,410,261	2,191,675	1,962,158	1,721,167
Debt Principal	3,262,257	3,425,370	3,596,638	3,776,470	3,965,293	4,163,558	4,371,736	4,590,323	4,819,839	5,060,831
Total Debt Service	6,781,997	6,781,997	6,781,997	6,781,997	6,781,997	6,781,997	6,781,997	6,781,997	6,781,997	6,781,997
Net Cash Flow after Debt Service	4,805,676	4,775,512	4,694,521	4,607,835	4,515,259	4,416,588	4,311,614	4,200,121	4,081,885	3,956,677
Debt Service Coverage Ratio	*1.71*	*1.70*	*1.69*	*1.68*	*1.67*	*1.65*	*1.64*	*1.62*	*1.60*	*1.58*
Total Pre-tax Net Cash Flow *(20 yrs)*	$108,918,805									

	Year 11:	Year 12:	Year 13:	Year 14:	Year 15:	Year 16:	Year 17:	Year 18:	Year 19:	Year 20:
	2006 / 2007	2007 / 2008	2008 / 2009	2009 / 2009	2010 / 2011	2011 / 2012	2012 / 2013	2013 / 2014	2014 / 2015	2015 / 2016
Net Operating Cash Flow *(from above)*	10,606,258	10,466,388	10,318,812	10,163,272	9,999,498	9,805,613	9,602,934	9,391,167	9,170,010	8,939,152
Debt Interest	1,468,125	1,202,431	923,453	630,526	322,952	0	0	0	0	0
Debt Principal	5,313,872	5,579,566	5,858,544	6,151,472	6,459,045	(0)	(0)	(0)	(0)	(0)
Total Debt Service	6,781,997	6,781,997	6,781,997	6,781,997	6,781,997	0	0	0	0	0
Net Cash Flow after Debt Service	3,824,260	3,684,390	3,536,815	3,381,274	3,217,501	9,805,613	9,602,934	9,391,167	9,170,010	8,939,152

CASE 1B: 100% Cash Financing

	Year 0:	Year 1:	Year 2:	Year 3:	Year 4:	Year 5:	Year 6:	Year 7:	Year 8:	Year 9:	Year 10:	Year 11:	Year 12:	Year 13:	Year 14:	Year 15:	Year 16:	Year 17:	Year 18:	Year 19:	Year 20:
Net Cash Flow	(70,394,814)	11,587,674	11,557,510	11,476,518	11,389,832	11,297,256	11,198,586	11,093,612	10,982,118	10,863,883	10,738,675	10,606,258	10,466,388	10,318,812	10,163,272	9,999,498	9,805,613	9,602,934	9,391,167	9,170,010	8,939,152

Total Pre-tax Net Cash Flow *(20 yrs)*	$140,253,952
IRR @ 100% CASH	14.71%
Payback Period *(Pre-tax; undiscounted)*	(6.1) years

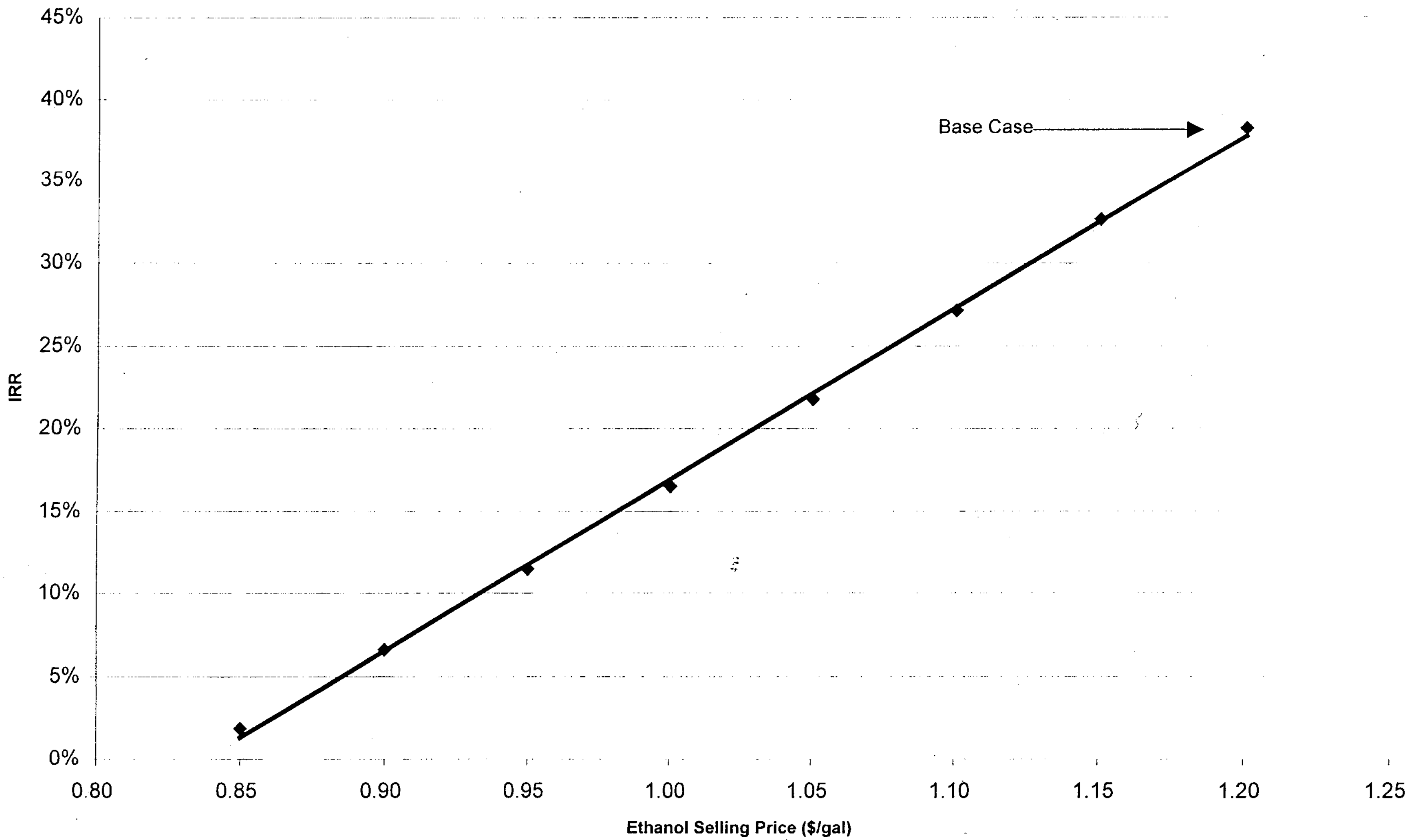
CASE 1C: Combined Equity & Debt Financing

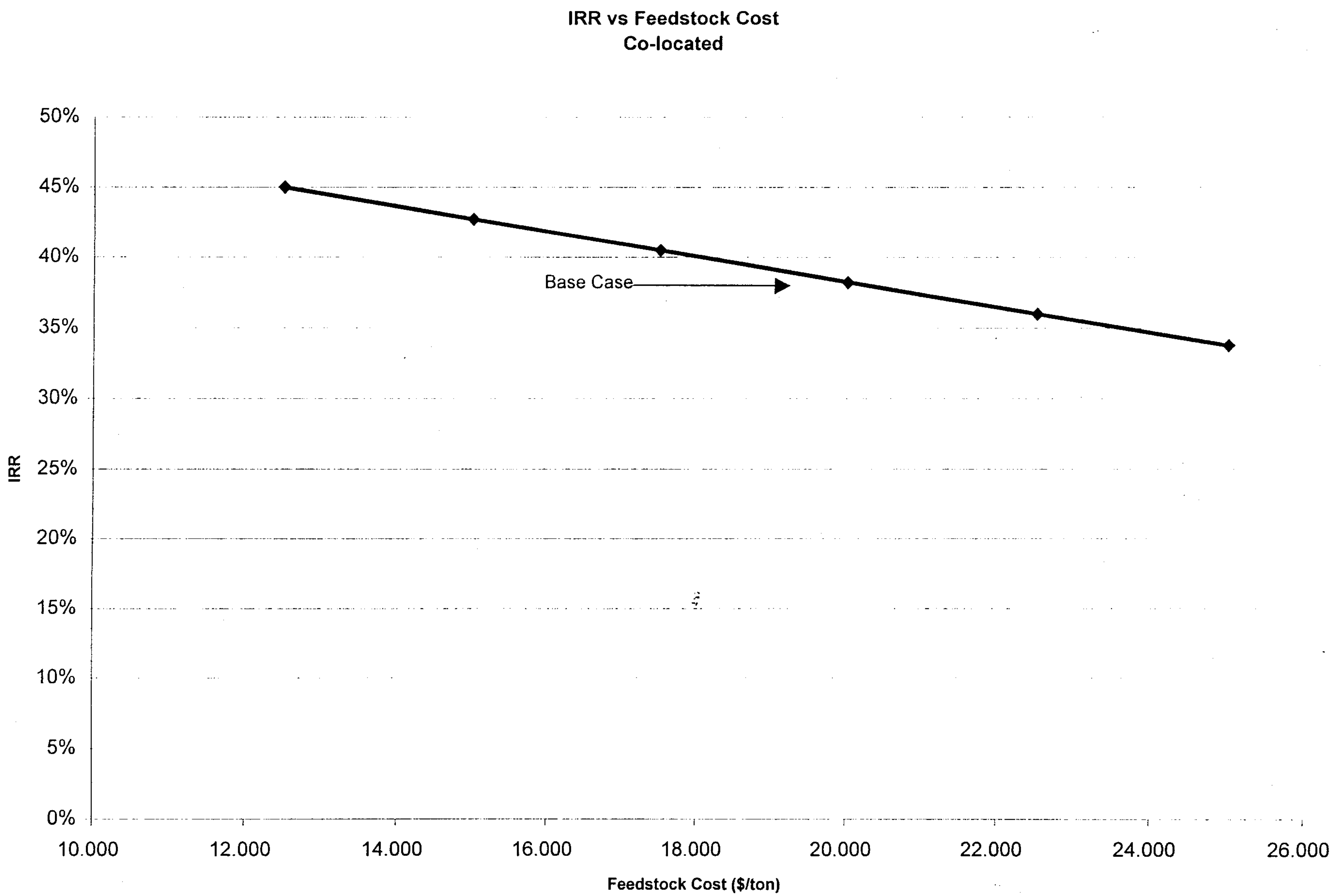
Equity Portion	[redacted]	$17,598,703	Amortization	[redacted] yrs
Debt Portion		$52,796,110	Interest Rate	

	Year 0: 1997/1998	Year 1: 1999 / 2000	Year 2: 2000/2001	Year 3: 2001/2002	Year 4: 2002/2003	Year 5: 2003/2004	Year 6: 2004/2005	Year 7: 2005/2006	Year 8: 2006/2007	Year 9: 2007/2008	Year 10: 2008/2009	Year 11: 2006 / 2007	Year 12: 2007 / 2008	Year 13: 2008 / 2009	Year 14: 2009 / 2009	Year 15: 2010 / 2011	Year 16: 2011 / 2012	Year 17: 2012 / 2013	Year 18: 2013 / 2014	Year 19: 2014 / 2015	Year 20: 2015 / 2016
Net Operating Cash Flow	0	11,587,674	11,557,510	11,476,518	11,389,832	11,297,256	11,198,586	11,093,612	10,982,118	10,863,883	10,738,675	10,606,258	10,466,388	10,318,812	10,163,272	9,999,498	9,805,613	9,602,934	9,391,167	9,170,010	8,939,152
Debt Interest		2,639,806	2,517,471	2,389,020	2,254,146	2,112,528	1,963,829	1,807,696	1,643,756	1,471,619	1,290,875	1,101,094	901,824	692,590	472,894	242,214	0	0	0	0	0
Debt Principal		2,446,693	2,569,027	2,697,479	2,832,352	2,973,970	3,122,669	3,278,802	3,442,742	3,614,879	3,795,623	3,985,404	4,184,675	4,393,908	4,613,604	4,844,284	(0)	(0)	(0)	(0)	(0)
Total Debt Service		5,086,498	5,086,498	5,086,498	5,086,498	5,086,498	5,086,498	5,086,498	5,086,498	5,086,498	5,086,498	5,086,498	5,086,498	5,086,498	5,086,498	5,086,498	0	0	0	0	0
Net Cash Flow	(17,598,703)	6,501,176	6,471,012	6,390,020	6,303,334	6,210,758	6,112,087	6,007,114	5,895,620	5,777,384	5,652,177	5,519,760	5,379,890	5,232,314	5,076,774	4,913,000	9,805,613	9,602,934	9,391,167	9,170,010	8,939,152
Debt Service Coverage Ratio		*2.28*	*2.27*	*2.26*	*2.24*	*2.22*	*2.20*	*2.18*	*2.16*	*2.14*	*2.11*	*2.09*	*2.06*	*2.03*	*2.00*	*1.97*	*#DIV/0!*	*#DIV/0!*	*#DIV/0!*	*#DIV/0!*	*#DIV/0!*

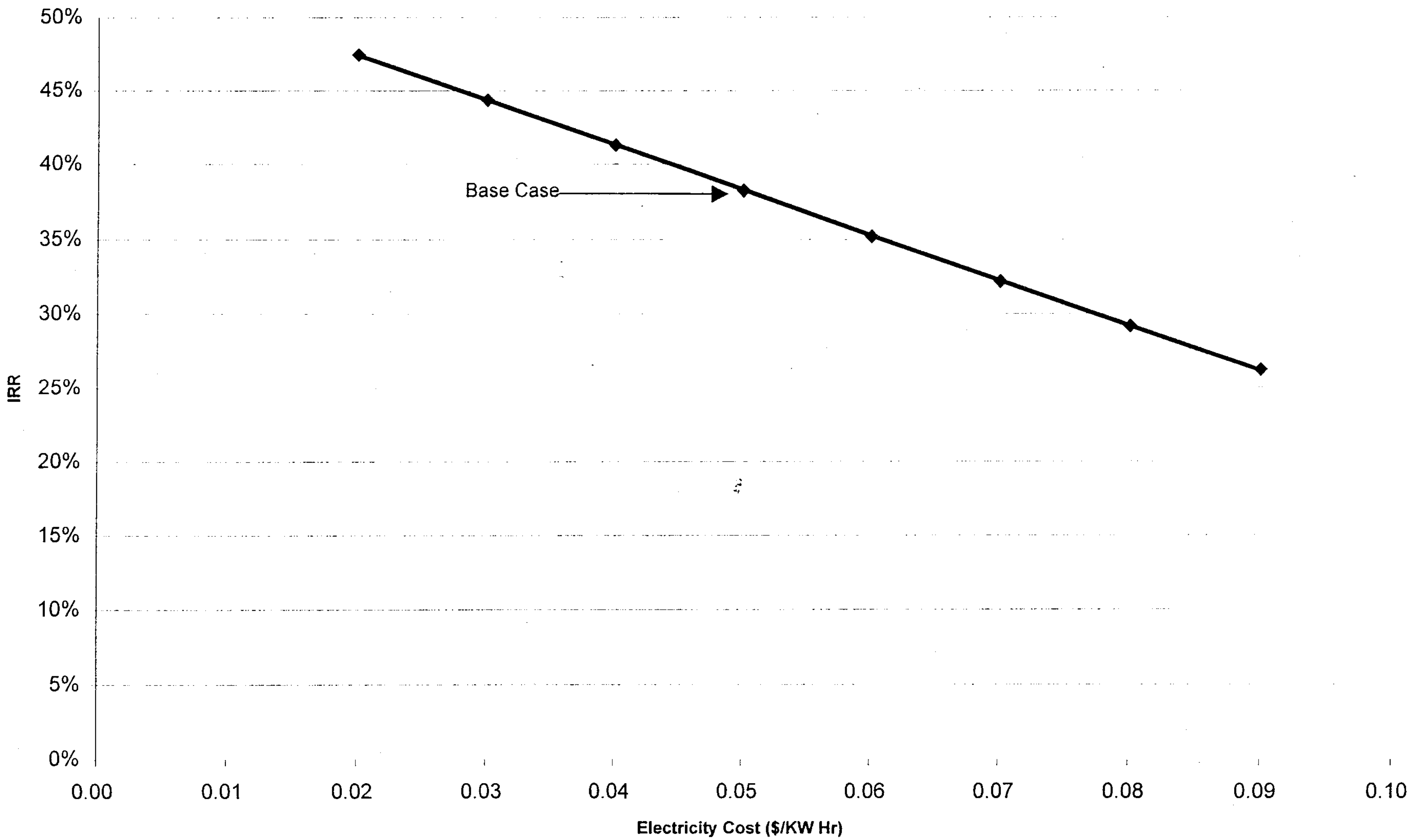
Total Pre-tax Net Cash Flow *(20 yrs)*	$116,752,592
Internal Rate of Return *(IRR Pre-Tax)*	36%

IRR vs Ethanol Selling Price
Co-located

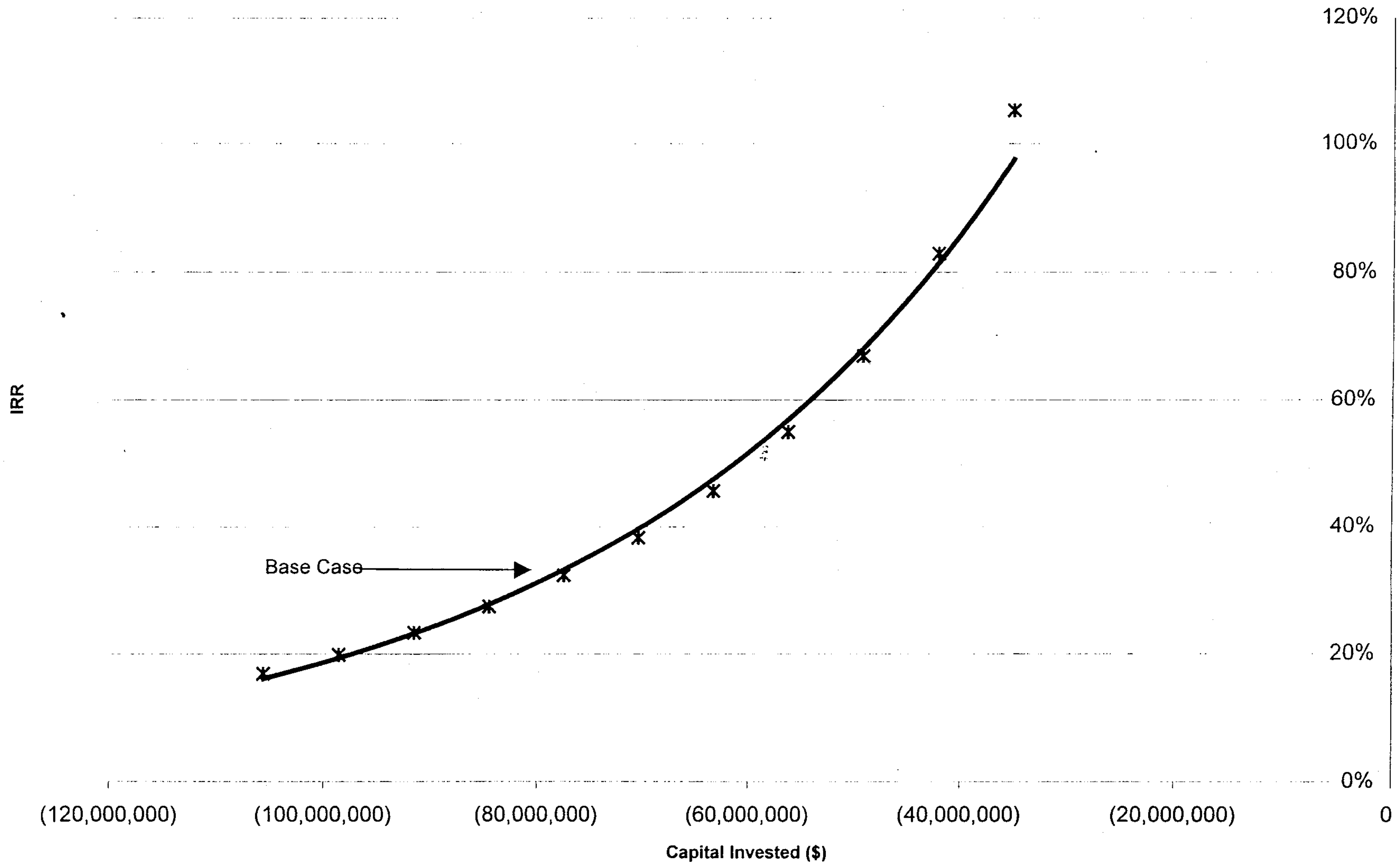


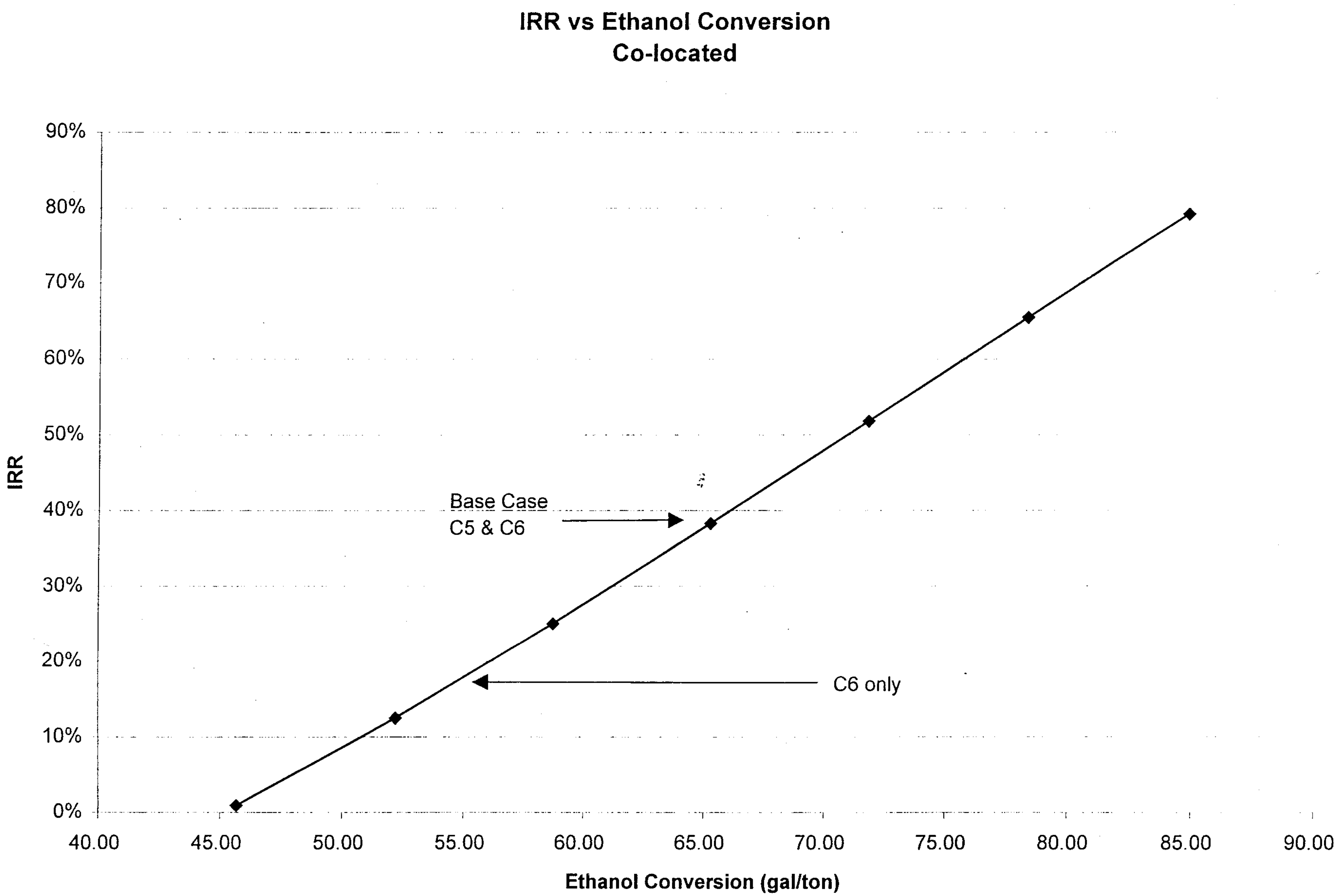

IRR vs Feedstock Cost
Co-located
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
IRR
Base Case
10.000
12.000
14.000
16.000
18.000
20.000
22.000
24.000
26.000
Feedstock Cost ($/ton)

IRR vs Electricity Cost
Co-located



IRR vs Capital Invested
Co-located




IRR vs Ethanol Conversion
Co-located
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
IRR
Base Case
C5 & C6
C6 only
40.00
45.00
50.00
55.00
60.00
65.00
70.00
75.00
80.00
85.00
90.00
Ethanol Conversion (gal/ton)

SENSITIVITY TABLE
CO-LOCATED

OPERATING CASH FLOW $	RATE OF RETURN	FEED PRICE DRY $/TON	ETHANOL SALE $/GAL	ELECTRICITY SALE $/KW	%	CAPITAL INVEST
3,783,398	#NUM!	20.000	0.80	0.05		
4,788,328	2%	20.000	0.85	0.05		
5,793,259	7%	20.000	0.90	0.05		
6,798,190	11%	20.000	0.95	0.05		
7,803,121	17%	20.000	1.00	0.05		
8,808,052	22%	20.000	1.05	0.05		
9,812,982	27%	20.000	1.10	0.05		
10,817,913	33%	20.000	1.15	0.05		
11,822,844	38%	20.000	1.20	0.05	BASE CASE	
13,026,762	45%	12.500	1.20	0.05		
12,625,456	43%	15.000	1.20	0.05		
12,224,150	40%	17.500	1.20	0.05		
11,822,844	38%	20.000	1.20	0.05		
11,421,538	36%	22.500	1.20	0.05		
11,020,232	34%	25.000	1.20	0.05		
13,459,836	47%	20.000	1.20	0.02		
12,914,172	44%	20.000	1.20	0.03		
12,368,508	41%	20.000	1.20	0.04		
11,822,844	38%	20.000	1.20	0.05		
11,277,180	35%	20.000	1.20	0.06		
10,731,516	32%	20.000	1.20	0.07		
10,185,852	29%	20.000	1.20	0.08		
9,640,188	26%	20.000	1.20	0.09		
11,822,844	105%	20.000	1.20	0.05	50%	(35,197,407)
11,822,844	83%	20.000	1.20	0.05	60%	(42,236,888)
11,822,844	67%	20.000	1.20	0.05	70%	(49,276,370)
11,822,844	55%	20.000	1.20	0.05	80%	(56,315,851)
11,822,844	46%	20.000	1.20	0.05	90%	(63,355,332)
11,822,844	38%	20.000	1.20	0.05	100%	(70,394,814)
11,822,844	32%	20.000	1.20	0.05	110%	(77,434,295)
11,822,844	27%	20.000	1.20	0.05	120%	(84,473,776)
11,822,844	23%	20.000	1.20	0.05	130%	(91,513,258)
11,822,844	20%	20.000	1.20	0.05	140%	(98,552,739)
11,822,844	17%	20.000	1.20	0.05	150%	(105,592,220)

% EQUITY	25%	
LOAN TERM	15	YEARS
Interest Rate	5.0%	

gal per ton	Ethanol Produced

c. Equipment List

Please see the following pages.

NREL SOFTWOOD 800 DTPD CASE (CO-LOCATED) Equipment List/Cost (Model G9810H-1)													
Section	Equip. No	Description	Quantity Reqd.	Capacity Each	Size Each	Unit Cost	Cost Source	Install. Factor	Total Cost	Unit Installation	Total Installation	Scaling Factor	Spares
A100	C-101	Chip conveyor to storage	0			$0			$0	$0	$0		
Wood Chip	C-102	Chip stackers	0			$0			$0	$0	$0		
Feed Handling	C-103	Reclaim conveyor	0			$0			$0	$0	$0		
	C-104	Conveyor to screening	1			$240,713	K Penka	1.75	$240,713	$180,535	$421,248	0.3	
	C-105	Conveyor to chip silo	1			$209,315	K Penka	1.75	$209,315	$156,986	$366,301	0.3	
	C-106	Chip conveyor to process	1			$209,315	K Penka	1.75	$209,315	$156,986	$366,301	0.3	
	C-107	Lignin conveyor to BF conveyor	1			$250,000	Est.	1.75	$250,000	$187,500	$437,500	0.3	
	M-101	Truck scale	0			$0			$0	$0	$0		
	M-102	Truck dumper	0			$0			$0	$0	$0		
	M-103	Chip receiving hopper	0			$0			$0	$0	$0		
	M-104	Bulldozer	0			$0			$0	$0	$0		
	M-105	Tramp iron magnet	1			$8,000	K Penka	1.75	$8,000	$6,000	$14,000	0	
	M-106	Air density separation system	1			$86,306	K Penka	1.75	$86,306	$64,730	$151,036	0.5	
	M-107	Chip slicer	1			$136,915	K Penka	1.75	$136,915	$102,686	$239,601	0.6	
	M-108	Chip silo	1			$383,363	K Penka	1.75	$383,363	$287,522	$670,885	0.6	
	M-109	Vibrating silo discharger	1			$78,493	K Penka	1.75	$78,493	$58,870	$137,363	0.3	
	M-110	Silo discharge feeder	1			$31,397	K Penka	1.75	$31,397	$23,548	$54,945	0.3	
	M-111	Belt scale	1			$5,233	K Penka	1.75	$5,233	$3,925	$9,158	0.3	
	S-101	Disc scalping screen	1			$26,164	K Penka	1.75	$26,164	$19,623	$45,787	0.3	
	S-102	Chip thickness screen	1			$115,123	K Penka	1.75	$115,123	$86,342	$201,465	0.3	
	S-103	Chip screen system chutes	1			$54,766	K Penka	1.75	$54,766	$41,075	$95,841	0.6	
	T-101	Rainwater collection and settling system	1			$21,906	Est.	1.75	$21,906	$16,430	$38,336	0.6	
		AREA 100 TOTAL							**$1,857,009**		**$3,249,766**		

NREL SOFTWOOD 800 DTPD CASE (CO-LOCATED) Equipment List/Cost (Model G9810H-1)														
Section	Equip. No	Description	Quantity Reqd.	Capacity Each	Size Each	Unit Cost	Cost Source	Install. Factor	Total Cost	Unit Installation	Total Installation	Scaling Factor	Spares
A200	A-206	Sterilization Tank Agitator	1			$13,497	ICARUS	1.20	$13,497	$2,699	$16,196	0.51	
Hydrolysis and	A-209	Overliming Tank Agitator	1			$16,573	ICARUS	1.30	$16,573	$4,972	$21,545	0.51	
lime addition	C-201	Screw conveyor	1			$10,866	ICARUS	1.30	$10,866	$3,260	$14,126	0.78	
	C-222	Gypsum conveyor	1			$1,789	ICARUS	1.30	$1,789	$537	$2,326	1	
	C-225	Lime solids feeder	1			$3,407	ICARUS	1.30	$3,407	$1,022	$4,429	0.6	
	C-226	Lime conveyor	1			$1,195	ICARUS	1.3	$1,195	$359	$1,554	1	
	H-201	Fermentation feed cooler	2			$169,550	ICARUS	1.30	$339,100	$50,865	$440,830	1	
	H-202	Fermentation feed chiller	2			$119,554	ICARUS	1.30	$239,108	$35,866	$310,840	1	
	M-201	Acid impregnator no.1	2			$350,000	VENDOR	1.30	$700,000	$105,000	$910,000		
	M-204	Acid impregnator no.2	2			$350,000	VENDOR	1.30	$700,000	$105,000	$910,000		
	M-224	Lime unloading pit	1			$13,280	ICARUS	1.75	$13,280	$9,960	$23,240	0.71	
	P-201	Sulfuric acid pump	1			$6,516	ICARUS	2.80	$13,032	$11,729	$18,245	0.79	1
	P-209	Neutralized hydrolyzate slurry pump	1			$16,245	ICARUS	2.80	$32,490	$29,241	$45,486	0.79	1
	P-222	Neutralized hydrolyzate liquor pump	1			$16,673	ICARUS	2.80	$33,346	$30,011	$46,684	0.79	1
	P-223	Pneumatic lime unloader	1			$54,057	ICARUS	1.40	$54,057	$21,623	$75,680	0.5	
	R-201	First stage hydrolysis reactor	1			$210,430	VENDOR	1.30	$210,430	$63,129	$273,559	0.6	
	R-202	Second stage hydrolysis reactor	1			$174,230	VENDOR	1.30	$174,230	$52,269	$226,499	0.6	
	S-201	First stage pre-reactor screw press	1			$1,564,000	VENDOR	1.30	$1,564,000	$469,200	$2,033,200		
	S-202	Second stage pre-reactor screw press	1			$1,976,000	VENDOR	1.30	$1,976,000	$592,800	$2,568,800		
	S-203	Inter stage pre-reactor screw press	2			$1,500,000	VENDOR	1.30	$3,000,000	$450,000	$3,900,000		
	S-205	Acid vent desicant filter	1			$547	ICARUS	1.60	$547	$328	$875	0.6	
	S-222	Rotary drum filter	1			$106,645	VENDOR	2.00	$106,645	$106,645	$213,290	0.39	
	T-201	Sulfuric acid process storage tank	1			$4,066	ICARUS	1.40	$4,066	$1,626	$5,692	0.71	
	T-203	Blowdown tank #1 (Oligomer)	1			$21,557	ICARUS	1.20	$21,557	$4,311	$25,868	0.93	
	T-204	First stage low pressure flash tank	1			$19,423	ICARUS	2.60	$19,423	$31,077	$50,500	0.93	
	T-205	Second stage flash tank (Oligomer)	1			$13,894	ICARUS	2.50	$13,894	$20,841	$34,735	0.71	
	T-206	Second stage low pressure flash tank	1			$11,432	ICARUS	2.50	$11,432	$17,148	$28,580	0.71	
	T-209	Overliming tank	1			$55,422	ICARUS	1.40	$55,422	$22,169	$77,591	0.71	
	T-2220	Lime storage bin	1			$77,726	ICARUS	1.30	$77,726	$23,318	$101,044	0.46	
	W-203	Inter stage washer	2			$350,000	VENDOR	1.30	$700,000	$105,000	$910,000		
		AREA 200 TOTAL							**$10,107,112**		**$13,291,414**		

NREL SOFTWOOD 800 DTPD CASE (CO-LOCATED)
Equipment List/Cost (Model G9810H-1)

Section	Equip. No	Description	Quantity Reqd.	Capacity Each	Size Each	Unit Cost	Cost Source	Install. Factor	Total Cost	Unit Installation	Total Installation	Scaling Factor	Spares
A300													
Production	A-300	First stage #1 fermenter agitator	2			$19,341	VENDOR	1.40	$38,682	$7,736	$54,155	0.51	
Fermentation	A-301	Second stage #1 fermenter agitator	2			$17,249	VENDOR	1.35	$34,498	$6,037	$46,572	0.51	
	A-302	First stage #2 fermenter agitator	2			$18,804	VENDOR	1.50	$37,608	$9,402	$56,412	0.51	
	A-303	Second stage #2 fermenter agitator	2			$18,804	VENDOR	1.35	$37,608	$6,581	$50,771	0.51	
	F-300	1st Stage fermenter No. 1	1			$294,847	VENDOR	2.80	$294,847	$530,725	$825,572	1	
	F-301	2nd Stage fermenter No. 1	1			$208,573	VENDOR	2.80	$208,573	$375,431	$584,004	1	
	F-302	1st Stage fermenter No. 2	1			$308,815	VENDOR	2.80	$308,815	$555,867	$864,682	1	
	F-303	2nd Stage fermenter No. 2	1			$315,678	VENDOR	2.80	$315,678	$568,220	$883,898	1	
	H-300	First stage #1 fermenter heat exchanger	1			$426,000	ICARUS	2.80	$426,000	$766,800	$1,192,800	0.78	
	H-301	Second stage #1 fermenter heat exchange	1			$20,000	ICARUS	2.50	$20,000	$30,000	$50,000	0.78	
	H-302	First stage #2 fermenter heat exchanger	1			$9,100	ICARUS	2.80	$9,100	$16,380	$25,480	0.78	
	H-303	Second stage #2 fermenter heat exchange	1			$31,455	ICARUS	2.40	$31,455	$44,037	$75,492	0.78	
	H-304	Distillation feed preheater	1			$161,363	VENDOR	1.80	$161,363	$129,090	$290,453	0.83	
	P-300	First stage #1 fermenter pump	1			$5,574	ICARUS	3.00	$5,574	$11,148	$16,722	0.79	
	P-301	Second stage #1 fermenter pump	1			$7,086	ICARUS	2.20	$7,086	$8,503	$15,589	0.79	
	P-302	First stage #2 fermenter pump	1			$7,086	ICARUS	2.90	$7,086	$13,463	$20,549	0.79	
	P-303	Second stage #2 fermenter pump	1			$7,086	ICARUS	2.50	$14,172	$10,629	$17,715	0.79	1
	P-304	Yeast recycle pump	1			$7,086	ICARUS	3.50	$7,086	$17,718	$24,801	0.79	
		AREA 300 TOTAL							$1,965,231		$5,095,668		

NREL SOFTWOOD 800 DTPD CASE (CO-LOCATED) Equipment List/Cost (Model G9810H-1)													
Section	Equip. No	Description	Quantity Reqd.	Capacity Each	Size Each	Unit Cost	Cost Source	Install. Factor	Total Cost	Unit Installation	Total Installation	Scaling Factor	Spares
A100	C-101	Chip conveyor to storage	0			$0			$0	$0	$0		
Wood Chip	C-102	Chip stackers	0			$0			$0	$0	$0		
Feed Handling	C-103	Reclaim conveyor	0			$0			$0	$0	$0		
	C-104	Conveyor to screening	1			$240,713	K Penka	1.75	$240,713	$180,535	$421,248	0.3	
	C-105	Conveyor to chip silo	1			$209,315	K Penka	1.75	$209,315	$156,986	$366,301	0.3	
	C-106	Chip conveyor to process	1			$209,315	K Penka	1.75	$209,315	$156,986	$366,301	0.3	
	C-107	Lignin conveyor to BF conveyor	1			$250,000	Est.	1.75	$250,000	$187,500	$437,500	0.3	
	M-101	Truck scale	0			$0			$0	$0	$0		
	M-102	Truck dumper	0			$0			$0	$0	$0		
	M-103	Chip receiving hopper	0			$0			$0	$0	$0		
	M-104	Bulldozer	0			$0			$0	$0	$0		
	M-105	Tramp iron magnet	1			$8,000	K Penka	1.75	$8,000	$6,000	$14,000	0	
	M-106	Air density separation system	1			$86,306	K Penka	1.75	$86,306	$64,730	$151,036	0.5	
	M-107	Chip slicer	1			$136,915	K Penka	1.75	$136,915	$102,686	$239,601	0.6	
	M-108	Chip silo	1			$383,363	K Penka	1.75	$383,363	$287,522	$670,885	0.6	
	M-109	Vibrating silo discharger	1			$78,493	K Penka	1.75	$78,493	$58,870	$137,363	0.3	
	M-110	Silo discharge feeder	1			$31,397	K Penka	1.75	$31,397	$23,548	$54,945	0.3	
	M-111	Belt scale	1			$5,233	K Penka	1.75	$5,233	$3,925	$9,158	0.3	
	S-101	Disc scalping screen	1			$26,164	K Penka	1.75	$26,164	$19,623	$45,787	0.3	
	S-102	Chip thickness screen	1			$115,123	K Penka	1.75	$115,123	$86,342	$201,465	0.3	
	S-103	Chip screen system chutes	1			$54,766	K Penka	1.75	$54,766	$41,075	$95,841	0.6	
	T-101	Rainwater collection and settling system	1			$21,906	Est.	1.75	$21,906	$16,430	$38,336	0.6	
		AREA 100 TOTAL							$1,857,009		$3,249,766		

NREL SOFTWOOD 800 DTPD CASE (CO-LOCATED)
Equipment List/Cost (Model G9810H-1)

Section	Equip. No	Description	Quantity Reqd.	Capacity Each	Size Each	Unit Cost	Cost Source	Install. Factor	Total Cost	Unit Installation	Total Installation	Scaling Factor	Spares
A200	A-206	Sterilization Tank Agitator	1			$13,497	ICARUS	1.20	$13,497	$2,699	$16,196	0.51	
Hydrolysis and	A-209	Overliming Tank Agitator	1			$16,573	ICARUS	1.30	$16,573	$4,972	$21,545	0.51	
lime addition	C-201	Screw conveyor	1			$10,866	ICARUS	1.30	$10,866	$3,260	$14,126	0.78	
	C-222	Gypsum conveyor	1			$1,789	ICARUS	1.30	$1,789	$537	$2,326	1	
	C-225	Lime solids feeder	1			$3,407	ICARUS	1.30	$3,407	$1,022	$4,429	0.6	
	C-226	Lime conveyor	1			$1,195	ICARUS	1.3	$1,195	$359	$1,554	1	
	H-201	Fermentation feed cooler	2			$169,550	ICARUS	1.30	$339,100	$50,865	$440,830	1	
	H-202	Fermentation feed chiller	2			$119,554	ICARUS	1.30	$239,108	$35,866	$310,840	1	
	M-201	Acid impregnator no.1	2			$350,000	VENDOR	1.30	$700,000	$105,000	$910,000		
	M-204	Acid impregnator no.2	2			$350,000	VENDOR	1.30	$700,000	$105,000	$910,000		
	M-224	Lime unloading pit	1			$13,280	ICARUS	1.75	$13,280	$9,960	$23,240	0.71	
	P-201	Sulfuric acid pump	1			$6,516	ICARUS	2.80	$13,032	$11,729	$18,245	0.79	1
	P-209	Neutralized hydrolyzate slurry pump	1			$16,245	ICARUS	2.80	$32,490	$29,241	$45,486	0.79	1
	P-222	Neutralized hydrolyzate liquor pump	1			$16,673	ICARUS	2.80	$33,346	$30,011	$46,684	0.79	1
	P-223	Pneumatic lime unloader	1			$54,057	ICARUS	1.40	$54,057	$21,623	$75,680	0.5	
	R-201	First stage hydrolysis reactor	1			$210,430	VENDOR	1.30	$210,430	$63,129	$273,559	0.6	
	R-202	Second stage hydrolysis reactor	1			$174,230	VENDOR	1.30	$174,230	$52,269	$226,499	0.6	
	S-201	First stage pre-reactor screw press	1			$1,564,000	VENDOR	1.30	$1,564,000	$469,200	$2,033,200		
	S-202	Second stage pre-reactor screw press	1			$1,976,000	VENDOR	1.30	$1,976,000	$592,800	$2,568,800		
	S-203	Inter stage pre-reactor screw press	2			$1,500,000	VENDOR	1.30	$3,000,000	$450,000	$3,900,000		
	S-205	Acid vent desicant filter	1			$547	ICARUS	1.60	$547	$328	$875	0.6	
	S-222	Rotary drum filter	1			$106,645	VENDOR	2.00	$106,645	$106,645	$213,290	0.39	
	T-201	Sulfuric acid process storage tank	1			$4,066	ICARUS	1.40	$4,066	$1,626	$5,692	0.71	
	T-203	Blowdown tank #1 (Oligomer)	1			$21,557	ICARUS	1.20	$21,557	$4,311	$25,868	0.93	
	T-204	First stage low pressure flash tank	1			$19,423	ICARUS	2.60	$19,423	$31,077	$50,500	0.93	
	T-205	Second stage flash tank (Oligomer)	1			$13,894	ICARUS	2.50	$13,894	$20,841	$34,735	0.71	
	T-206	Second stage low pressure flash tank	1			$11,432	ICARUS	2.50	$11,432	$17,148	$28,580	0.71	
	T-209	Overliming tank	1			$55,422	ICARUS	1.40	$55,422	$22,169	$77,591	0.71	
	T-2220	Lime storage bin	1			$77,726	ICARUS	1.30	$77,726	$23,318	$101,044	0.46	
	W-203	Inter stage washer	2			$350,000	VENDOR	1.30	$700,000	$105,000	$910,000		
		AREA 200 TOTAL							**$10,107,112**		**$13,291,414**		

NREL SOFTWOOD 800 DTPD CASE (CO-LOCATED) Equipment List/Cost (Model G9810H-1)													
Section	Equip. No	Description	Quantity Reqd.	Capacity Each	Size Each	Unit Cost	Cost Source	Install. Factor	Total Cost	Unit Installation	Total Installation	Scaling Factor	Spares
A300													
Production	A-300	First stage #1 fermenter agitator	2			$19,341	VENDOR	1.40	$38,682	$7,736	$54,155	0.51	
Fermentation	A-301	Second stage #1 fermenter agitator	2			$17,249	VENDOR	1.35	$34,498	$6,037	$46,572	0.51	
	A-302	First stage #2 fermenter agitator	2			$18,804	VENDOR	1.50	$37,608	$9,402	$56,412	0.51	
	A-303	Second stage #2 fermenter agitator	2			$18,804	VENDOR	1.35	$37,608	$6,581	$50,771	0.51	
	F-300	1st Stage fermenter No. 1	1			$294,847	VENDOR	2.80	$294,847	$530,725	$825,572	1	
	F-301	2nd Stage fermenter No. 1	1			$208,573	VENDOR	2.80	$208,573	$375,431	$584,004	1	
	F-302	1st Stage fermenter No. 2	1			$308,815	VENDOR	2.80	$308,815	$555,867	$864,682	1	
	F-303	2nd Stage fermenter No. 2	1			$315,678	VENDOR	2.80	$315,678	$568,220	$883,898	1	
	H-300	First stage #1 fermenter heat exchanger	1			$426,000	ICARUS	2.80	$426,000	$766,800	$1,192,800	0.78	
	H-301	Second stage #1 fermenter heat exchange	1			$20,000	ICARUS	2.50	$20,000	$30,000	$50,000	0.78	
	H-302	First stage #2 fermenter heat exchanger	1			$9,100	ICARUS	2.80	$9,100	$16,380	$25,480	0.78	
	H-303	Second stage #2 fermenter heat exchange	1			$31,455	ICARUS	2.40	$31,455	$44,037	$75,492	0.78	
	H-304	Distillation feed preheater	1			$161,363	VENDOR	1.80	$161,363	$129,090	$290,453	0.83	
	P-300	First stage #1 fermenter pump	1			$5,574	ICARUS	3.00	$5,574	$11,148	$16,722	0.79	
	P-301	Second stage #1 fermenter pump	1			$7,086	ICARUS	2.20	$7,086	$8,503	$15,589	0.79	
	P-302	First stage #2 fermenter pump	1			$7,086	ICARUS	2.90	$7,086	$13,463	$20,549	0.79	
	P-303	Second stage #2 fermenter pump	1			$7,086	ICARUS	2.50	$14,172	$10,629	$17,715	0.79	1
	P-304	Yeast recycle pump	1			$7,086	ICARUS	3.50	$7,086	$17,715	$24,801	0.79	
		AREA 300 TOTAL							$1,965,231		$5,095,668		

NREL SOFTWOOD 800 DTPD CASE (CO-LOCATED)
Equipment List/Cost (Model G9810H-1)

Section	Equip. No	Description	Quantity Reqd.	Capacity Each	Size Each	Unit Cost	Cost Source	Install. Factor	Total Cost	Unit Installation	Total Installation	Scaling Factor	Spares
	D-501	Beer Column	1			$371,000	VENDOR	2.10	$371,000	$408,100	$779,100	0.78	
	D-502	Rectification Column	1			$242,679	VENDOR	2.10	$242,679	$266,947	$509,626	0.78	
A500	E-501	1st Effect Evaporator	2			$214,404	ICARUS	2.10	$428,808	$235,844	$900,497	0.68	
Beer Distillation,	E-502	2nd Effect Evaporator	1			$214,391	ICARUS	2.10	$214,391	$235,830	$450,221	0.68	
Rectification, and	E-503	3rd Effect Evaporator	2			$214,391	ICARUS	2.10	$428,782	$235,830	$900,442	0.68	
Dehydration	H-501	Reboiler	1			$78,129	ICARUS	2.10	$78,129	$85,942	$164,071	0.68	
	H-502	Reboiler	1			$13,881	ICARUS	2.10	$13,881	$15,269	$29,150	0.68	
	H-504	Overhead Condenser	1			$4,937	ICARUS	2.10	$4,937	$5,431	$10,368	0.68	
	H-505	Overhead Condenser	1			$42,405	ICARUS	2.10	$42,405	$46,646	$89,051	0.68	
	H-512	Feed/Bottoms Exchanger	1			$22,043	ICARUS	2.10	$44,086	$24,247	$46,290	0.68	1
	H-517	Evaporator Condenser	2			$59,797	ICARUS	2.10	$119,594	$65,777	$251,147	0.68	
	M-503	Ethanol Dehydration Package	1			$1,291,368	ICARUS	1.00	$1,291,368	$0	$1,291,368	0.7	
	P-501	Bottoms Pump	1			$51,163	ICARUS	2.80	$102,326	$92,093	$143,256	0.79	1
	P-503	Reflux Pump	1			$340	ICARUS	2.80	$680	$612	$952	0.79	1
	P-504	Bottoms Pump	1			$4,386	ICARUS	2.80	$8,772	$7,895	$12,281	0.79	1
	P-505	Reflux Pump	1			$4,196	ICARUS	2.80	$8,392	$7,553	$11,749	0.79	1
	P-511	1st Effect Pump	2			$22,943	ICARUS	2.80	$45,886	$41,297	$128,481	0.79	
	P-512	2nd Effect Pump	2			$23,722	ICARUS	2.80	$47,444	$42,700	$132,843	0.79	
	P-513	3rd Effect Pump	2			$23,381	ICARUS	2.80	$46,762	$42,086	$130,934	0.79	
	P-514	Condensate Pump	1			$10,747	ICARUS	2.80	$21,494	$19,345	$30,092	0.79	1
	P-515	Scrubber Bottoms Pump	1			$1,254	ICARUS	2.80	$1,254	$2,257	$3,511	0.79	
	T-503	Overhead Receiver	1			$1,030	ICARUS	2.10	$1,030	$1,133	$2,163	0.93	
	T-505	Overhead Receiver	1			$21,519	ICARUS	2.10	$21,519	$23,671	$45,190	0.72	
	T-512	CO_2 Scrubber	1			$50,230	ICARUS	2.10	$50,230	$55,253	$105,483	0.78	
		AREA 500 TOTAL							**$3,635,849**		**$6,168,265**		

NREL SOFTWOOD 800 DTPD CASE (CO-LOCATED)
Equipment List/Cost (Model G9810H-1)

Section	Equip. No	Description	Quantity Reqd.	Capacity Each	Size Each	Unit Cost	Cost Source	Install. Factor	Total Cost	Unit Installation	Total Installation	Scaling Factor	Spares
A600	A-602	Equalization Basin Agitator	1			$19,894	ICARUS	1.20	$19,894	$3,979	$23,873	0.51	
Lignin Separation	A-606	Anaerobic Digestor Agitator	4			$30,300	ICARUS	1.20	$121,200	$24,240	$145,440	0.51	
& Wastewater	A-608	Aerobic Digestor Aerator	16			$31,250	VENDOR	1.40	$500,000	$200,000	$700,000	1	
Treatment	A-630	Recycled Water Tank Agitator	1			$3,311	VENDOR	1.30	$3,311	$993	$4,304	0.51	
	C-601	Lignin Wet Cake Screw	1			$12,456	ICARUS	1.40	$12,456	$4,982	$17,438	0.78	
	C-614	Aerobic Sludge Screw	1			$2,466	ICARUS	1.40	$2,466	$986	$3,452	0.78	
	H-602	Anaerobic Digestor Feed Cooler	1			$175,000	ICARUS	2.10	$175,000	$192,500	$367,500	0.68	
	M-604	Nutrient Feed System	1			$31,400	VENDOR	2.58	$31,400	$49,612	$81,012	1	
	M-606	Biogas Handling System	1			$11,702	VENDOR	1.68	$11,702	$7,957	$19,659	0.6	
	M-612	Filter Aid Addition System	1			$3,000	VENDOR	1.20	$3,000	$600	$3,600	1	
	P-602	Anaerobic Digestor Feed Pump	2			$6,568	ICARUS	2.80	$13,136	$23,645	$36,781	0.79	
	P-606	Aerobic Digestor Feed Pump	2			$6,179	ICARUS	2.80	$12,358	$22,244	$34,602	0.79	
	P-608	Aerobic Sludge Recycle Pump	1			$4,686	ICARUS	2.80	$4,686	$8,435	$13,121	0.79	
	P-610	Aerobic Sludge Pump	1			$4,686	ICARUS	2.80	$4,686	$8,435	$13,121	0.79	
	P-611	Aerobic Digestion Outlet Pump	2			$6,157	ICARUS	2.80	$12,314	$22,165	$34,479	0.79	
	P-614	Sludge Filtrate Recycle Pump	2			$2,568	ICARUS	2.80	$5,136	$9,245	$14,381	0.79	
	P-616	Treated Water Pump	2			$6,150	ICARUS	2.80	$12,300	$22,140	$34,440	0.79	
	P-630	Recycle Water Pump	2			$738	ICARUS	2.80	$1,476	$2,657	$4,133	0.79	
	S-600	Bar Screen	1			$90,468	VENDOR	1.20	$90,468	$18,094	$108,562	0.6	
	S-601	Beer Columns Bottom Centrifuge	3			$659,550	VENDOR	1.20	$1,978,650	$395,730	$2,374,380	0.6	
	S-614	Aerobic Sludge Belt Filter Press	1			$650,223	VENDOR	1.80	$650,223	$520,178	$1,170,401	0.72	
	T-602	Equilization Basin	1			$245,733	VENDOR	1.42	$245,733	$103,208	$348,941	0.51	
	T-606	Anaerobic Digestor	4			$881,081	VENDOR	1.04	$3,524,324	$140,973	$3,665,297	0.51	
	T-608	Aerobic Digestor	1			$635,173	VENDOR	1.00	$635,173	$0	$635,173	1	
	T-610	Clarifier	1			$122,335	VENDOR	1.96	$122,335	$117,442	$239,777	0.51	
	T-630	Recycle Water Tank	1			$6,146	VENDOR	1.40	$6,146	$2,458	$8,604	0.745	
	xxx	Flare	1			$13,000	VENDOR	1.58	$13,000	$7,500	$20,500	1	
		AREA 600 TOTAL							$8,212,573		$10,122,971		

NREL SOFTWOOD 800 DTPD CASE (CO-LOCATED) Equipment List/Cost (Model G9810H-1)														
Section	**Equip. No**	**Description**	**Quantity Reqd.**	**Capacity Each**	**Size Each**	**Unit Cost**	**Cost Source**	**Install. Factor**	**Total Cost**	**Unit Installation**	**Total Installation**	**Scaling Factor**	**Spares**
A700	A-701	In-line Ethanol Denaturant Mixer	1			$1,202	ICARUS	1.00	$1,202	$0	$1,202	0.48	
Storage	P-701	Ethanol Product Pump	2			$3,718	ICARUS	2.80	$11,154	$20,077	$31,231	0.79	1
	P-703	Sulfuric Acid Pump	1			$5,430	ICARUS	2.80	$10,860	$19,548	$30,408	0.79	1
	P-704	Firewater Pump	1			$8,659	ICARUS	2.80	$17,318	$31,172	$48,490	0.79	1
	P-706	Ammonia Pump	1			$2,344	ICARUS	2.80	$4,688	$8,438	$13,126	0.79	1
	P-708	Diesel Pump	1			$6,100	ICARUS	2.80	$12,200	$21,960	$34,160	0.79	1
	P-710	Gasoline Pump	1			$2,118	ICARUS	2.80	$4,236	$7,625	$11,861	0.79	1
	P-720	CSL Pump	1			$1,895	ICARUS	2.80	$3,790	$6,822	$10,612	0.79	1
	T-701	Ethanol Product Storage Tank	2			$101,922	VENDOR	1.40	$203,844	$81,538	$285,382	0.85	
	T-703	Sulfuric Acid Storage Tank	1			$33,094	ICARUS	1.20	$33,094	$6,619	$39,713	0.51	
	T-704	Firewater Storage Tank	1			$102,111	VENDOR	1.40	$102,111	$40,844	$142,955	0.85	
	T-706	Ammonia Storage Tank	1			$144,058	ICARUS	1.40	$144,058	$57,623	$201,681	0.72	
	T-708	Diesel Storage Tank	1			$14,400	ICARUS	1.40	$14,400	$5,760	$20,160	0.51	
	T-710	Gasoline Storage Tank	1			$26,739	ICARUS	1.40	$26,739	$10,696	$37,435	0.51	
	T-720	CSL Storage Tank	1			$18,975	ICARUS	1.40	$18,975	$7,590	$26,565	0.79	
		AREA 700 TOTAL							**$608,669**		**$934,981**		

NREL SOFTWOOD 800 DTPD CASE (CO-LOCATED) Equipment List/Cost (Model G9810H-1) Section	Equip. No	Description	Quantity Reqd.	Capacity Each	Size Each	Unit Cost	Cost Source	Install. Factor	Total Cost	Unit Installation	Total Installation	Scaling Factor	Spares
A800	H-811	BFW Preheater	0			$0			$0	$0	$0		
Boiler Feed	M-802	Combustion Airfan	0			$0			$0	$0	$0		
Drying,	M-803	Fluidized Bed Combustion Reactor	0			$0			$0	$0	$0		
Combustor &	M-804	Combustion Gas Baghouse	0			$0			$0	$0	$0		
Turbo Generator	M-811	Turbine/Generator	0			$0			$0	$0	$0		
	M-820	Demineralizer	0			$0			$0	$0	$0		
	M-822	Condensate Polisher	0			$0			$0	$0	$0		
	M-830	Hydrazine Addition Package	1			$11,156	ICARUS	1.40	$11,156	$4,462	$15,618	0.6	
	M-832	Ammonia Addition Package	1			$11,156	ICARUS	1.40	$11,156	$4,462	$15,618	0.6	
	M-834	Phosphate Addition Package	1			$11,156	ICARUS	1.40	$11,156	$4,462	$15,618	0.6	
	P-804	Condensate Pump	2			$3,395	ICARUS	4.00	$6,790	$20,370	$27,160	0.79	
	P-811	Turbine Condensate Pump	0			$0			$0	$0	$0		
	P-824	Deaerator Feed Pump	0			$0			$0	$0	$0		
	P-826	BFW Pump	0			$0			$0	$0	$0		
	P-828	Blowdown Pump	0			$0			$0	$0	$0		
	P-830	Hydrazine Transfer Pump	1			$1,042	ICARUS	4.00	$1,042	$3,126	$4,168	0.79	
	T-804	Condensate Collection Tank	1			$3,257	ICARUS	4.00	$3,257	$9,771	$13,028	0.71	
	T-824	Condensate Surge Drum	1			$11,741	ICARUS	3.00	$11,741	$23,482	$35,223	0.72	
	T-826	Deaerator	0			$0			$0	$0	$0		
	T-828	Blowdown Flash Drum	0			$0			$0	$0	$0		
	T-830	Hydrazine Drum	1			$4,249	ICARUS	4.00	$4,249	$12,747	$16,996	0.93	
		Misc. Transformers	1			$250,000	EST	1.50	$250,000	$125,000	$375,000		
		Misc. Piping	1			$300,000	EST	1.50	$300,000	$150,000	$450,000		
		AREA 800 TOTAL							**$310,547**		**$968,430**		

NREL SOFTWOOD 800 DTPD CASE (CO-LOCATED)
Equipment List/Cost (Model G9810H-1)

Section	Equip. No	Description	Quantity Reqd.	Capacity Each	Size Each	Unit Cost	Cost Source	Install. Factor	Total Cost	Unit Installation	Total Installation	Scaling Factor	Spares
A1000	A-1018	Sterilization Tank Agitator	1			$13,504	ICARUS	1.30	$13,504	$4,051	$17,555	0.51	
Cooling Water &	A-1020	Cleaning Tank Agitator	1			$13,504	ICARUS	1.30	$13,504	$4,051	$17,555	0.51	
Instrument Air	H-1010	Water Sterilizer	1			$1,501	ICARUS	1.40	$1,501	$600	$2,101	0.68	
	M-1002	Cooling Tower System	1			$814,399	ICARUS	1.20	$814,399	$162,880	$977,279	0.78	
	M-1004	Plant Air Compressor	2			$44,012	ICARUS	1.30	$132,036	$39,611	$171,647	0.34	1
	M-1006	Fermenter Air Compressor Package	2			$380,151	ICARUS	1.30	$1,140,453	$342,136	$1,482,589	0.34	1
	M-1008	Chilled Water Package	3			$380,000	ICARUS	1.20	$1,140,000	$228,000	$1,368,000	0.8	
	P-1002	Cooling Water Pump	1			$156,935	ICARUS	2.80	$313,870	$564,966	$878,836	0.79	1
	P-1010	Sterile Water Pump	2			$2,101	ICARUS	2.80	$4,202	$7,564	$11,766	0.79	
	P-1012	Make-up Water Pump	1			$4,535	ICARUS	2.80	$9,070	$16,326	$25,396	0.79	1
	P-1014	Process Water Circulating Pump	2			$5,188	ICARUS	2.80	$15,564	$28,015	$43,579	0.79	1
	P-1016	CIP/CS Supply Pump	2			$2,801	ICARUS	2.80	$5,602	$10,084	$15,686	0.79	
	P-1018	CIP/CS Return Pump	2			$2,802	ICARUS	2.80	$5,604	$10,087	$15,691	0.79	
	S-1004	Instrument Air Dryer	1			$7,777	ICARUS	1.30	$15,554	$4,666	$20,220	0.6	1
	T-1004	Plant Air Receiver	1			$6,721	ICARUS	1.30	$6,721	$2,016	$8,737	0.72	
	T-1005	Instrument Air Receiver	1			$0	ICARUS	0.00	$0	$0	$0		
	T-1010	Process Water Tank	1			$13,206	ICARUS	1.40	$13,206	$5,282	$18,488	0.71	
	T-1014	Process Water Tank	1			$119,645	ICARUS	1.40	$119,645	$47,858	$167,503	0.51	
	T-1016	Sterile Rinse Water Tank	1			$13,206	ICARUS	1.40	$13,206	$5,282	$18,488	0.71	
	T-1018	Sterilization Tank	1			$29,013	ICARUS	1.40	$29,013	$11,605	$40,618	0.71	
	T-1020	Cleaning Tank	1			$16,407	ICARUS	1.40	$16,407	$6,563	$22,970	0.71	
		AREA 1000 TOTAL							**$3,823,061**		**$5,324,705**		
		AREA 100 Through 1000 TOTAL							**$30,520,051**		**$45,156,202**		

NREL 2 STAGE DILUTE SULFURIC ACID HYDROLOSIS - PRO FORMA, Stánd Alone Rev. 4

Underlying Assumptions & Input Variables 6/14/99

CURRENT SITUATION:

The Pro Forma models a STAND ALONE Acid Hydrolysis Ethanol plant with a Combustion Reactor, Turbine, Generator system for an 800 BDTD plant

ETHANOL

The plant will convert wood chips to fuel grade ethanol utilizing acid hydrolosis.

Wood chip production levels of	63,979	kg/hr (str 101), produce estimated total output in				
equivalent kilograms of fuel grade ETOH		7,144	kg/hr.	=	60,009,600	kg / year (str 515)
		2,393	gal/hr	=	20,098,616	gal / year

The model assumes renewal of the ethanol excise tax credit of $.54 per gallon to the blender and the small producer tax credit of $.10 per gallon through the year 2015 for a total ethanol value of

$1.20 per gallon or $0.40 per kg and **$24,118,339** **per year TOTAL Ethanol sales**

ELECTRICITY

The electricity from heating value is 8,514 KW, based on the Aspen net output (after plant power consumption).

Electricity value based on $0.050 per KWhr is $3,575,880 per year

TOTAL ELECTRICITY SALES WOULD BE **$3,575,880** **per year**

Total projected facility sales would be **$27,694,219** **per year (less waste heat value)**

B. CAPITAL INVESTMENT ASSUMPTIONS

1) Total capital investment

Civil Structural		1,110,167	
Area 100		5,734,766	
Area 200		13,291,414	
Area 300		5,095,688	
Area 500		6,168,265	
Area 600		10,122,971	
Area 700		934,981	
Area 800		16,960,299	
Area 1000		5,324,705	
Fixed Capital		$64,743,256	
INDIRECTS Prorateable	3.5%	$2,266,014	
Process Development	2.0%	$1,294,865	
Field Expense	8.0%	$5,179,460	
Home Office Constr. Fee	12.0%	$7,769,191	
Contingency	10.0%	$6,474,326	
Start-up, Permits, Fees	3.0%	$1,942,298	
Working Capital per estimate		$1,228,805	1 mos Raw matls. + O&M
Total Plant Cost		$90,898,215	
FEDERAL & STATE GRANTS		$0	
Net Capital Investment		**$90,898,215**	

NREL 2 STAGE DILUTE SULFURIC ACID HYDROLOSIS - PRO FORMA

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PERATING COST ASSUMPTIONS 8,400 hr/yr

Utilities (Rates based on 20,098,616 gal/yr produced)

	Amount/hr	*Units*	*$/unit*	*Cost /hr.*	**Total Cost /yr**
Electricity**	0	Kw-hr	$0.050	$0	$0
City process water (str 713)	2,627	kg	$0.001	$3	$26,480
Wastewater	2,627	kg	$0.004	$9	$79,440
300 PSIG steam ($3.50/1000 lb)**	0	mTon	$7.718	$0	$0
50 PSIG steam ($1.00/1000 lb)**	0	mTon	$2.205	$0	$0
Total Utilities				$13	$105,921

** - Net Electricity and steam consumption are zero cost in this model.

Raw Material Costs

	Amount/hr	*Units*	*$/unit*	*Cost /hr.*	**Total Cost /yr**
Wood Chips DRY (str 101less water)	33,333	kg	$0.022	$734.99	$6,173,938
Sulfuric Acid (str 710)	1,008	kg	$0.095	$95.76	$804,384
Calcium Oxide (Lime str 745)	705	kg	$0.060	$42.30	$355,320
Ammonia (str 717/311)	451	kg	$0.070	$31.57	$265,188
Corn Steep Liquor (str 735)	292	kg	$0.051	$14.89	$125,093
Cellulase Complex	0	kg	$3.000	$0.00	$0
Natural Gasoline (str 701)	342	kg	$0.210	$71.82	$603,288
Diesel (str 723)	170	kg	$0.330	$56.10	$471,240
WWT Chemicals	8	kg	$3.630	$29.04	$243,936
CW Chemicals	6	kg	$2.210	$13.26	$111,384
BFW Chemicals	0.5	kg	$1.000	$0.50	$4,200
Total Raw Materials				$1,090	$9,157,971

Processing Material Costs

	Amount/hr	*Units*	*$/unit*	*Cost /hr.*	**Total Cost /yr**
Antifoam	0	kg	$10.000	$0	$0
Total Processing Materials				$0	$0

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		Total Cost /yr.
Operations and Maintenance Costs - DRY HANDLING (area 100)		
Supervisors	0.5 ea/day	$31,000
Operators	1 ea/day	$50,000
Laborers	6 ea/day	$144,000
Maintenance	2 ea/day	$100,000
Operations and Maintenance Costs - HYDROLYSIS/FERMENTATION (area 200, 300, 500, 600)		
Supervisors	1 ea/day	$62,000
Operators	8 ea/day	$400,000
Laborers	1 ea/day	$24,000
Technicians	1 ea/day	$50,000
Maintenance	2 ea/day	$100,000
Operations and Maintenance Costs - POWER PLANT (area 800)		
Supervisors	0.5 ea/day	$31,000
Operators	3 ea day	$150,000
Laborers	2 ea/day	$48,000
Technicians	1 ea/day	$110,000
Maintenance	1 ea/day	$50,000
Operations and Maintenance Costs - Utilities (area 700, 1000)		
Supervisors	0 ea/day	$0
Operators	2 ea/day	$100,000
Maintenance	2 ea/day	$100,000
	Total Operations and maintenance labor costs	$1,550,000
Other Operations and Maintenance Costs		
Payroll Overhead	35% of operating labor	$542,500
Maintenance Costs	2% of plant cost	$1,294,865.12
Operating Supplies	0.25% of plant cost	$161,858.14
Environmental	0.50% of plant cost	$323,716.28
Local Taxes	1% of plant cost	$647,432.56
Insurance	0.50% of plant cost	$323,716.28
Overhead Costs	40% of labor, supervision,maint cost	$620,000
Administrative Costs	1% of annual sales (less tax credits)	$82,404
Distribution and Sales	0.5% of annual sales (less tax credits)	$41,202
Total O&M Costs		$5,587,695

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D. OTHER MODEL ASSUMPTIONS

verage prevailing market price of fuel grade ETOH:		$0.40	per kg
Assumes renewal of the ethanol excise tax credit of $.54 per gallon and the small producer tax credit of $.10 per gallon through the year 2007 and $.56 per gallon fuel value includes $.10 discount to the blender.		1.20	per gallon
Price for Electricity Produced		$0.050	per KWhr
	DRY	50% WET	
Price paid for wood chip feedstock - dry basis	$0.022	$0.011	per kg
	$22.05	$11.03	per metric ton
Plant on-stream factor		0.959	
Plant operating hours per year		8400	
Depreciable Life of Capital Equipment		15	years
Average annual commodity escalation rate:		1.0%	
Average annual cost escalation rate:		3.0%	

1. There are no land acquisiton costs included.
2. There are no off site costs included (e.g. public road improvements, extensions of power, water, telephone services)
3. There is a source of qualified construction personnel within daily driving distance of the site.
4. There exist adequate roads, rail roads or ship docks to allow equipment delivery.
5. The costs for air and water permits are not included.
6. Soils are adequate for conventional foundation designs.

NREL 2 STAGE DILUTE SULFURIC ACID HYDROLOSIS - PRO FORMA Rev. 4

Underlying Assumptions & Input Variables 6/14/99

A. CURRENT SITUATION:

The Pro Forma models a STAND ALONE Acid Hydrolysis Ethanol plant with a Combustion Reactor, Turbine, Generator system for an 800 BDTD plant

ETHANOL

The plant will convert wood chips to fuel grade ethanol utilizing acid hydrolosis.

Wood chip production levels of	141,074	lb/hr (str 101), produce estimated total output in			
equivalent kilograms of fuel grade ETOH		15,753	lb/hr	132,321,168	lb / year (str 515)
		2,393	gal/hr =	20,098,616	gal / year

The model assumes renewal of the ethanol excise tax credit of \$.54 per gallon to the blender and the small producer tax credit of \$.10 per gallon through the year 2015 for a total ethanol value of \$1.20 per gallon or **TOTAL ETHANOL SALES WOULD BE \$24,118,339 per year**

ELECTRICITY

The electricity from heating value is 8,514 KW, based on the Aspen net output (after plant power consumption).

cycle power generation. Electricity value based on \$0.050 per KWhr is **\$3,575,880 per year**

TOTAL ELECTRICITY SALES WOULD BE \$3,575,880 per year

Total projected facility sales would \$27,694,219 per year

B. CAPITAL INVESTMENT ASSUMPTIONS

1) Total capital investment

Civil Structural		1,110,167	
Area 100		5,734,766	
Area 200		13,291,414	
Area 300		5,095,688	
Area 500		6,168,265	
Area 600		10,122,971	
Area 700		934,981	
Area 800		16,960,299	
Area 1000		5,324,705	
Fixed Capital		\$64,743,256	
INDIRECTS Prorateable	3.5%	\$2,266,014	
Process Development	2.0%	\$1,294,865	
Field Expense	8.0%	\$5,179,460	
Home Office Constr. Fee	12.0%	\$7,769,191	
Contingency	10.0%	\$6,474,326	
Start-up, Permits, Fees	3.0%	\$1,942,298	
Working Capital per estimate		\$1,228,805	1 mos Raw matls. + O&M
	Total Plant Cost	\$90,898,215	
	FEDERAL & STATE GRANTS	\$0	
	Net Capital Investment	**\$90,898,215**	

Note: Indirect Capital Costs are adjusted to account for location specific construction issues.

NREL 2 STAGE DILUTE SULFURIC ACID HYDROLOSIS - PRO FORMA

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C. OPERATING COST ASSUMPTIONS 8,400 hr/yr

Utilities (Rates based on 20,098,616 gal/yr produced)

	Amount/hr	*Units*	*$/unit*	*Cost /hr.*	**Total Cost /yr**
Electricity**	0	Kw-hr	$0.050	$0	$0
City process water	5,793	lb	$0.001	$3	$26,480
Wastewater	5,793	lb	$0.002	$9	$79,440
300 PSIG steam ($3.50/1000 lb)**	0	1000 lb	$3.500	$0	$0
50 PSIG steam ($1.00/1000 lb)**	0	1000 lb	$1.000	$0	$0
Total Utilities				$13	$105,921

** - Net Electricity and steam consumption are zero cost in this model.

Raw Material Costs

	Amount/hr	*Units*	*$/unit*	*Cost /hr.*	**Total Cost /yr**
Wood Chips DRY (45% str 101)	73,499	lb	$0.010	$734.99	$6,173,938
Sulfuric Acid (str 710)	2,223	lb	$0.043	$95.76	$804,384
Calcium Oxide (Lime)	1,555	lb	$0.027	$42.30	$355,320
Ammonia (str 717/311)	994	lb	$0.032	$31.57	$265,188
Corn Steep Liquor (str 735)	644	lb	$0.023	$14.89	$125,093
Cellulase Complex	0	lb	$1.361	$0.00	$0
Natural Gasoline (str 701)	754	lb	$0.095	$71.82	$603,288
Diesel (str 723)	375	lb	$0.150	$56.10	$471,240
WWT Chemicals	18	lb	$1.646	$29.04	$243,936
CW Chemicals	13	lb	$1.002	$13.26	$111,384
BFW Chemicals	1	lb	$0.454	$0.50	$4,200
Total Raw Materials				$1,090	$9,157,971

Processing Material Costs

	Amount/hr	*Units*	*$/unit*	*Cost /hr.*	**Total Cost /yr**
Antifoam	0	lb	$4.530	$0	$0
Total Processing Materials				$0	$0

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		Total Cost /yr.
Operations and Maintenance Costs - DRY HANDLING (area 100)		
Supervisors	0.5 ea/day	$31,000
Operators	1 ea/day	$50,000
Laborers	6 ea/day	$144,000
Maintenance	2 ea/day	$100,000
Operations and Maintenance Costs - HYDROLYSIS/FERMENTATION (area 200, 300, 500, 600)		
Supervisors	1 ea/day	$62,000
Operators	8 ea/day	$400,000
Laborers	1 ea/day	$24,000
Technicians	1 ea/day	$50,000
Maintenance	2 ea/day	$100,000
Operations and Maintenance Costs - POWER PLANT (area 800)		
Supervisors	0.5 ea/day	$31,000
Operators	3 ea day	$150,000
Laborers	2 ea/day	$48,000
Technicians	1 ea/day	$110,000
Maintenance	1 ea/day	$50,000
Operations and Maintenance Costs - Utilities (area 700, 1000)		
Supervisors	0 ea/day	$0
Operators	2 ea/day	$100,000
Maintenance	2 ea/day	$100,000
	Total Operations and maintenance labor costs	$1,550,000
Other Operations and Maintenance Costs		
Payroll Overhead	35% of operating labor	$542,500
Maintenance Costs	2% of plant cost	$1,294,865
Operating Supplies	0.25% of plant cost	$161,858
Environmental	0.50% of plant cost	$323,716
Local Taxes	1% of plant cost	$647,433
Insurance	0.50% of plant cost	$323,716
Overhead Costs	40% of labor, supervision,maint cost	$620,000
Administrative Costs	1% of annual sales	$82,404
Distribution and Sales	0.5% of annual sales	$41,202
Total O&M Costs		$5,587,695

D. OTHER MODEL ASSUMPTIONS

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Average prevailing market price of fuel grade ETOH:		$0.40	per kg
Assumes renewal of the ethanol excise tax credit of $.54 per gallon and the small producer tax credit of $.10 per gallon through the year 2007 and $.56 per gallon fuel value and includes $.10 discount to the blender.		1.20	per gallon
	DRY	50% WET	
Price for Electricity Produced		$0.050	per KWhr
	DRY	50% WET	
Price paid for wood chip feedstock - dry basis	$0.010	$0.005	per lb
	$20.00	$10.00	per ton
Plant on-stream factor		0.959	
Plant operating hours per year		8,400	
Depreciable Life of Capital Equipment		15	years
Average annual commodity escalation rate:		1.0%	
Average annual cost escalation rate:		3.0%	

1. There are no land acquisiton costs included.
2. There are no off site costs included (e.g. public road improvements, extensions of power, water, telephone services)
3. There is a source of qualified construction personnel within daily driving distance of the site.
4. There exist adequate roads, rail roads or ship docks to allow equipment delivery.
5. The costs for air and water permits are not included.
6. Soils are adequate for conventional foundation designs.

NREL 2 STAGE DILUTE SULFURIC ACID HYDROLOSIS - PRO FORMA, Stand Alone

..SE 1: Produce Fuel Grade Ethanol

Rev. 4 6/14/99

Capital Investment:		month1	month2	month3	month4	month5	month6	month7	month8	month9	month10	month11	month12	month13	month14	month15	month16	month17	month18	TOTAL
Total Fixed Capital Cost		$5,500,000	$5,500,000	$5,500,000	$5,500,000	$5,500,000	$5,500,000	$5,500,000	$5,500,000	$5,500,000	$5,500,000	$5,500,000	$5,500,000	$5,500,000	$5,500,000	$5,500,000	$5,500,000	$5,500,000	($2,601,785)	$90,898,215
Construction Financing & Fees @10%			45,833	91,667	137,500	183,333	229,167	275,000	320,833	366,667	412,500	458,333	504,167	550,000	595,833	641,667	687,500	733,333	366,667	6,600,000
Loan Origination Fee @	2.0%	1,817,964																		1,817,964
Legal Fees		40,000																	0	40,000
Builder's All Risk/General Liability		50,000																	0	50,000
Working Capital																			0	0
Total Capital Investment Required		$7,407,964	$5,545,833	$5,591,667	$5,637,500	$5,683,333	$5,729,167	$5,775,000	$5,820,833	$5,866,667	$5,912,500	$5,958,333	$6,004,167	$6,050,000	$6,095,833	$6,141,667	$6,187,500	$6,233,333	($2,235,118)	$99,406,179

11,000

Operating Projection:	Year 1: 1999 / 2000	Year 2: 2000/2001	Year 3: 2001/2002	Year 4: 2002/2003	Year 5: 2003/2004	Year 6: 2004/2005	Year 7: 2005/2006	Year 8: 2006/2007	Year 9: 2007/2008	Year 10: 2008/2009	Year 11: 2006 / 2007	Year 12: 2007 / 2008	Year 13: 2008 / 2009	Year 14: 2009 / 2009	Year 15: 2010 / 2011	Year 16: 2011 / 2012	Year 17: 2012 / 2013	Year 18: 2013 / 2014	Year 19: 2014 / 2015	Year 20: 2015 / 2016
gal of fuel grade ethanol produced	20,098,616	20,098,616	20,098,616	20,098,616	20,098,616	20,098,616	20,098,616	20,098,616	20,098,616	20,098,616	20,098,616	20,098,616	20,098,616	20,098,616	20,098,616	20,098,616	20,098,616	20,098,616	20,098,616	20,098,616
Contract sale price per gallon	$1.100	$1.111	$1.122	$1.133	$1.145	$1.156	$1.168	$1.179	$1.191	$1.203	$1.215	$1.227	$1.240	$1.252	$1.264	$1.277	$1.290	$1.303	$1.316	$1.329
Gross Annual Revenue	$22,108,478	$22,329,562	$22,552,858	$22,778,387	$23,006,170	$23,236,232	$23,468,594	$23,703,280	$23,940,313	$24,179,716	$24,421,514	$24,665,729	$24,912,386	$25,161,510	$25,413,125	$25,667,256	$25,923,929	$26,183,168	$26,445,000	$26,709,450
Small Ethanol Producer Tax Credit																				
@ $0.1000 per gallon	$2,009,862	$2,009,862	$2,009,862	$2,009,862	$2,009,862	$2,009,862	$2,009,862	$2,009,862	$2,009,862	$2,009,862	$2,009,862	$2,009,862	$2,009,862	$2,009,862	$2,009,862	$2,009,862	$2,009,862	$2,009,862	$2,009,862	$0
Total projected ethanol sales and credit	$24,118,339	$24,339,424	$24,562,720	$24,788,248	$25,016,032	$25,246,094	$25,478,456	$25,713,142	$25,950,175	$26,189,578	$26,431,375	$26,675,590	$26,922,248	$27,171,371	$27,422,987	$27,677,118	$27,933,790	$28,193,030	$28,454,861	$26,709,450
B Value of electricity	$0.05	$0.051	$0.051	$0.052	$0.052	$0.053	$0.053	$0.054	$0.054	$0.055	$0.055	$0.056	$0.056	$0.057	$0.057	$0.058	$0.059	$0.059	$0.060	$0.060
Gross Annual Electricity Revenue	$3,575,880	$3,611,639	$3,647,755	$3,684,233	$3,721,075	$3,758,286	$3,795,869	$3,833,827	$3,872,166	$3,910,887	$3,949,996	$3,989,496	$4,029,391	$4,069,685	$4,110,382	$4,151,486	$4,193,001	$4,234,931	$4,277,280	$4,320,053
Gross Sales and Credit	$27,694,219	$27,951,063	$28,210,475	$28,472,481	$28,737,107	$29,004,380	$29,274,325	$29,546,969	$29,822,340	$30,100,465	$30,381,371	$30,665,086	$30,951,639	$31,241,056	$31,533,368	$31,828,603	$32,126,791	$32,427,960	$32,732,141	$31,029,502
Operating Expenses:																				
Utilities	105,921	109,098	112,371	115,742	119,215	122,791	126,475	130,269	134,177	138,202	142,348	146,619	151,018	155,548	160,214	165,021	169,972	175,071	180,323	185,732
Raw Materials	9,157,971	9,249,551	9,342,046	9,435,467	9,529,821	9,625,120	9,721,371	9,818,585	9,916,770	10,015,938	10,116,097	10,217,258	10,319,431	10,422,625	10,526,852	10,632,120	10,738,441	10,845,826	10,954,284	11,063,827
Processing Materials	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Operation & Maintenance	5,587,695	5,755,326	5,927,985	6,105,825	6,289,000	6,477,670	6,672,000	6,872,160	7,078,325	7,290,674	7,509,395	7,734,676	7,966,717	8,205,718	8,451,890	8,705,447	8,966,610	9,235,608	9,512,676	9,798,057
Property Tax @ 0.50% Book Value	497,031	466,731	436,432	406,133	375,833	345,534	315,234	284,935	254,636	224,336	194,037	163,737	133,438	103,139	72,839	72,839	72,839	72,839	72,839	72,839
Depreciation	6,059,881	6,059,881	6,059,881	6,059,881	6,059,881	6,059,881	6,059,881	6,059,881	6,059,881	6,059,881	6,059,881	6,059,881	6,059,881	6,059,881	6,059,881	0	0	0	0	0
Total Operating Expense	$21,408,498	$21,640,587	$21,878,716	$22,123,048	$22,373,750	$22,630,995	$22,894,961	$23,165,830	$23,443,789	$23,729,032	$24,021,758	$24,322,172	$24,630,484	$24,946,911	$25,271,676	$19,575,427	$19,947,862	$20,329,344	$20,720,122	$21,120,455
C.																				
Net Operating Income	$6,285,721	$6,310,476	$6,331,759	$6,349,433	$6,363,357	$6,373,384	$6,379,364	$6,381,140	$6,378,552	$6,371,433	$6,359,613	$6,342,914	$6,321,154	$6,294,145	$6,261,692	$12,253,177	$12,178,929	$12,098,616	$12,012,019	$9,909,047
Net Operating Cash Flow	$12,345,602	$12,370,357	$12,391,640	$12,409,314	$12,423,238	$12,433,265	$12,439,245	$12,441,021	$12,438,433	$12,431,314	$12,419,494	$12,402,795	$12,381,035	$12,354,026	$12,321,573	$12,253,177	$12,178,929	$12,098,616	$12,012,019	$9,909,047

CASE 2: Hypothetical Financing Scenarios:

CASE 2A: 100% Debt Financing

Amortization [redacted] yrs

Interest Rate [redacted]

	Year 1: 1999 / 2000	Year 2: 2000/2001	Year 3: 2001/2002	Year 4: 2002/2003	Year 5: 2003/2004	Year 6: 2004/2005	Year 7: 2005/2006	Year 8: 2006/2007	Year 9: 2007/2008	Year 10: 2008/2009	Year 11: 2006 / 2007	Year 12: 2007 / 2008	Year 13: 2008 / 2009	Year 14: 2009 / 2009	Year 15: 2010 / 2011	Year 16: 2011 / 2012	Year 17: 2012 / 2013	Year 18: 2013 / 2014	Year 19: 2014 / 2015	Year 20: 2015 / 2016
Net Operating Cash Flow *(from above)*	12,345,602	12,370,357	12,391,640	12,409,314	12,423,238	12,433,265	12,439,245	12,441,021	12,438,433	12,431,314	12,419,494	12,402,795	12,381,035	12,354,026	12,321,573	12,253,177	12,178,929	12,098,616	12,012,019	9,909,047
Debt Interest	4,970,309	4,739,973	4,498,121	4,244,176	3,977,534	3,697,560	3,403,587	3,094,915	2,770,810	2,430,500	2,073,174	1,697,982	1,304,030	890,380	456,049	0	0	0	0	0
Debt Principal	4,606,710	4,837,045	5,078,898	5,332,842	5,599,484	5,879,459	6,173,432	6,482,103	6,806,208	7,146,519	7,503,845	7,879,037	8,272,989	8,686,638	9,120,970	(0)	(0)	(0)	(0)	(0)
Total Debt Service	9,577,019	9,577,019	9,577,019	9,577,019	9,577,019	9,577,019	9,577,019	9,577,019	9,577,019	9,577,019	9,577,019	9,577,019	9,577,019	9,577,019	9,577,019	0	0	0	0	0
Net Cash Flow after Debt Service	2,768,583	2,793,338	2,814,621	2,832,295	2,846,219	2,856,247	2,862,226	2,864,002	2,861,414	2,854,295	2,842,475	2,825,776	2,804,017	2,777,007	2,744,555	12,253,177	12,178,929	12,098,616	12,012,019	9,909,047
Debt Service Coverage Ratio	1.29	1.29	1.29	1.30	1.30	1.30	1.30	1.30	1.30	1.30										
Total Pre-tax Net Cash Flow *(20 yrs)*	$100,798,858																			

SE 2B: 100% Cash Financing

	Year 0:	Year 1:	Year 2:	Year 3:	Year 4:	Year 5:	Year 6:	Year 7:	Year 8:	Year 9:	Year 10:
Net Cash Flow	(99,406,179)	12,345,602	12,370,357	12,391,640	12,409,314	12,423,238	12,433,265	12,439,245	12,441,021	12,438,433	12,431,314

	Year 11:	Year 12:	Year 13:	Year 14:	Year 15:	Year 16:	Year 17:	Year 18:	Year 19:	Year 20:
Net Cash Flow	12,419,494	12,402,795	12,381,035	12,354,026	12,321,573	12,253,177	12,178,929	12,098,616	12,012,019	9,909,047

Total Pre-tax Net Cash Flow *(20 yrs)* $145,047,960
IRR @ 100% CASH 10.8%
Payback Period *(Pre-tax; undiscounted)* (8.1) years

CASE 2C: Combined Equity & Debt Financing

Equity Portion [redacted] $24,851,545 Amortization [redacted] yrs
Debt Portion $74,554,635 Interest Rate [redacted]

	Year 0: 1997/1998	Year 1: 1999 / 2000	Year 2: 2000/2001	Year 3: 2001/2002	Year 4: 2002/2003	Year 5: 2003/2004	Year 6: 2004/2005	Year 7: 2005/2006	Year 8: 2006/2007	Year 9: 2007/2008	Year 10: 2008/2009
Net Operating Cash Flow	0	12,345,602	12,370,357	12,391,640	12,409,314	12,423,238	12,433,265	12,439,245	12,441,021	12,438,433	12,431,314
Debt Interest		3,727,732	3,554,980	3,373,591	3,183,132	2,983,151	2,773,170	2,552,690	2,321,187	2,078,108	1,822,875
Debt Principal		3,455,032	3,627,784	3,809,173	3,999,632	4,199,613	4,409,594	4,630,074	4,861,577	5,104,656	5,359,889
Total Debt Service		7,182,764	7,182,764	7,182,764	7,182,764	7,182,764	7,182,764	7,182,764	7,182,764	7,182,764	7,182,764
Net Cash Flow	(24,851,545)	5,162,838	5,187,593	5,208,876	5,226,550	5,240,474	5,250,501	5,256,481	5,258,257	5,255,669	5,248,550
Debt Service Coverage Ratio		*1.72*	*1.72*	*1.73*	*1.73*	*1.73*	*1.73*	*1.73*	*1.73*	*1.73*	*1.73*

	Year 11: 2006 / 2007	Year 12: 2007 / 2008	Year 13: 2008 / 2009	Year 14: 2009 / 2009	Year 15: 2010 / 2011	Year 16: 2011 / 2012	Year 17: 2012 / 2013	Year 18: 2013 / 2014	Year 19: 2014 / 2015	Year 20: 2015 / 2016
Net Operating Cash Flow	12,419,494	12,402,795	12,381,035	12,354,026	12,321,573	12,253,177	12,178,929	12,098,616	12,012,019	9,909,047
Debt Interest	1,554,880	1,273,486	978,022	667,785	342,036	0	0	0	0	0
Debt Principal	5,627,884	5,909,278	6,204,742	6,514,979	6,840,728	(0)	(0)	(0)	(0)	(0)
Total Debt Service	7,182,764	7,182,764	7,182,764	7,182,764	7,182,764	0	0	0	0	0
Net Cash Flow	5,236,730	5,220,031	5,198,271	5,171,262	5,138,809	12,253,177	12,178,929	12,098,616	12,012,019	9,909,047
Debt Service Coverage Ratio	*1.73*	*1.73*	*1.72*	*1.72*	*1.72*	*#DIV/0!*	*#DIV/0!*	*#DIV/0!*	*#DIV/0!*	*#DIV/0!*

Total Pre-tax Net Cash Flow *(20 yrs)* $111,861,134

Internal Rate of Return *(IRR Pre-Tax)* 21%

APPENDIX A

HEAT OPTIMIZATION

HEAT OPTIMIZATION

OBJECTIVE

The softwood, biomass to ethanol process requires a great deal of heat transfer. In prehydrolysis and hydrolysis heat is added to the process. In flash and fermentation heat is withdrawn from the process. In distillation both heating and cooling are needed. In some cases heat transfer can be directly from process stream to process stream thus minimizing the amount of utility heating and cooling required.

Obviously much thought must be given to energy efficiency of the process and the amount of heat exchange equipment required. An evaluation of the potential for heat integration and efficiency was made to identify the probable need for the utility systems required to maintain heat balance.

DESCRIPTION

Heating and cooling requirements were calculated based on the Aspen model flow rates, temperatures and pressures with certain simplifying assumptions. These heat duties were compared in size and temperature level in order to find heat exchange matches which could enhance the energy efficiency of the process. Assumptions that were taken are:

1. Stream composition was simplified to "water" and "other than water."
2. Liquid water heat capacity was taken as 1.0 BTU/lb.- ^{O}F at all temperature levels in the process.
3. The heat capacity of "Other than water" was taken to be 0.3 BTU/lb.- ^{O}F at all temperature levels within the process.
4. All steam was considered to be saturated and steam tables were used to establish energy content.
5. Heat losses to the atmosphere due to insulation inadequacies were ignored.
6. Heat exchange equipment along with transfer coefficients were not defined at this stage.

Calculation results are graphically presented on the attached sheet.

CONCLUSIONS

Although the amount of heating required by the process and the amount of cooling required by the process are nearly the same, the temperature levels limit the amount of heat integration that can be accomplished. Major heat transfer duties are discussed below:

1st and 2nd Stage Hydrolysis

Hydrolysis requires the input of heat at a high temperature level. The temperature requirement exceeds the temperature of any of the process streams needing heat removal. Additionally, heat input at the Hydrolyzers is by the direct injection of steam. Hydrolysis heat must be supplied by high pressure steam.

Beer Column Reboiler

Similarly, this reboiler requires heat at a high temperature level and must therefore use high pressure steam for the heat source.

Preheat Exchanger and Rectifier Reboiler

Flash steam from Flash Tanks 1A and 2A contain nearly enough heat for these services and at nearly a high enough temperature level. It is believed that the flash steam can be supplemented with high pressure steam in order to make it usable in these services.

At least two methods of accomplishing the high pressure steam supplement are foreseen. First, there is the traditional method of using all the flash steam heat in one exchanger(s) and following this with a separate "trim" exchanger using high pressure steam.

A second method which may save significant exchanger cost is to use high pressure steam as motive steam in an ejector that takes suction on the flash steam. The discharge steam would be fixed at a pressure high enough to provide a thermal driving force for the required heat exchange. This method saves exchanger cost but is less flexible. Turn down situations would need to be evaluated during detail engineering.

Pre-steamer ***(Note that the prehydrolysis system has been simplified and there is no longer a presteamer in the process)***

Flash steam from Flash Tanks 1B and 2B, if supplemented with high pressure steam (as described above) could effectively supply this service. Since the Pre-steamer uses direct heat injection the heat source must be steam.

#1 Washer

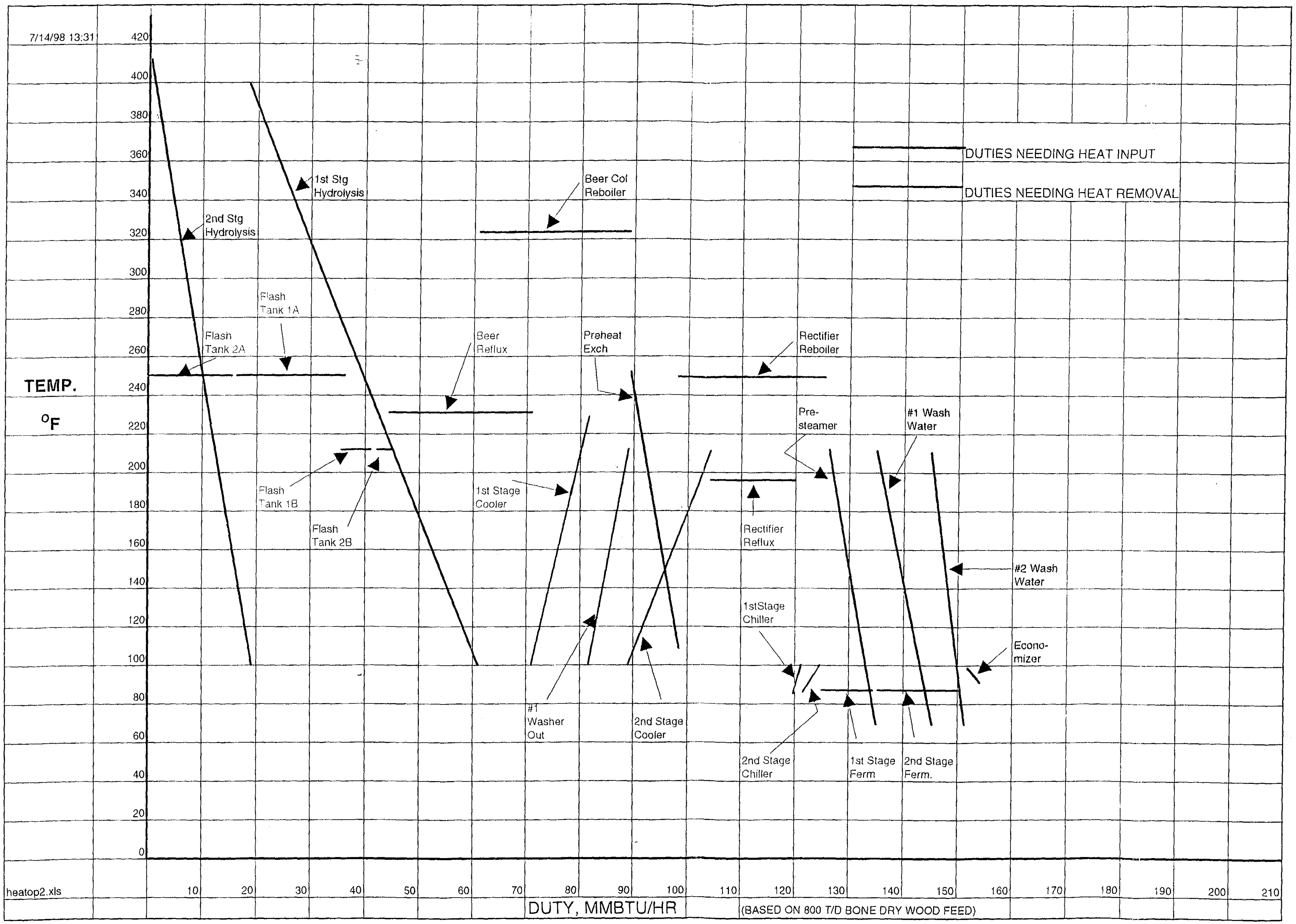
It is recommended that a feed/discharge exchanger be used to heat wash water supply and cool wash water discharge. Additional heating of the supply may be necessary.

Additional integration of heat usage can certainly be done but will need to be carefully evaluated as multiple exchangers may be required. Increased capital cost will need to be justified by the utility savings.

It may be prudent to consider air cooled exchangers rather than water cooled for the Rectifier reflux and possibly the Beer Column reflux (if suspended solids can be adequately handled in the header boxes).

The first and second stage coolers, upstream of the fermentors, are large cooling loads that currently are supplied by cooling water.

The fermentors have large cooling loads which are shown on the flow diagrams as being supplied by chilled water. It may be best to continue this design as it provides good control and reliability of cooling for the fermentors.



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TEMP. °F
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DUTIES NEEDING HEAT INPUT
DUTIES NEEDING HEAT REMOVAL
2nd Stg Hydrolysis
1st Stg Hydrolysis
Beer Col Reboiler
Flash Tank 1A
Flash Tank 2A
Beer Reflux
Preheat Exch
Rectifier Reboiler
Pre-steamer
#1 Wash Water
Flash Tank 1B
Flash Tank 2B
1st Stage Cooler
Rectifier Reflux
#2 Wash Water
1stStage Chiller
Econo-mizer
#1 Washer Out
2nd Stage Cooler
2nd Stage Chiller
1st Stage Ferm
2nd Stage Ferm.
heatop2.xls
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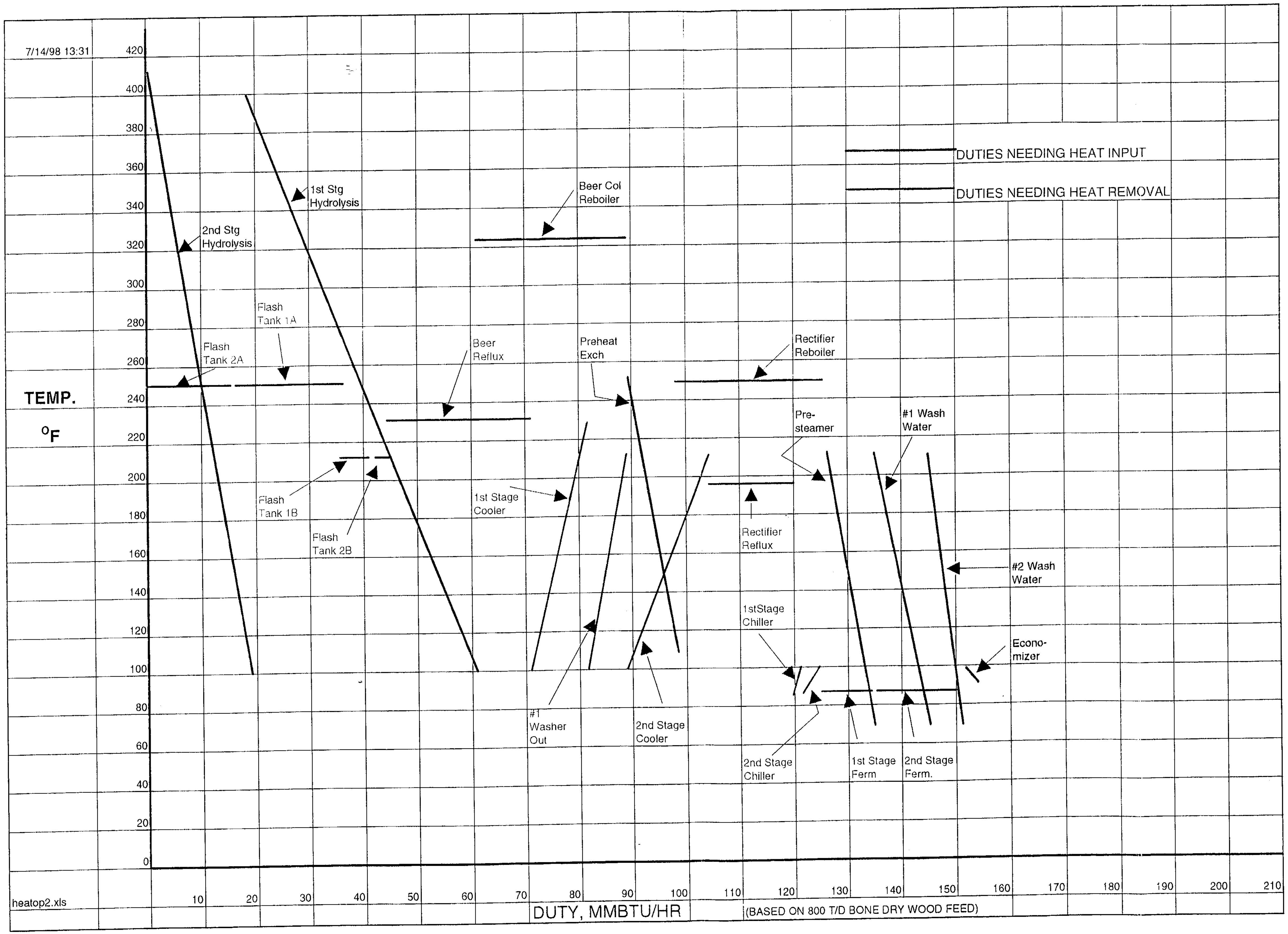
DUTY, MMBTU/HR
(BASED ON 800 T/D BONE DRY WOOD FEED)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DUTIES NEEDING HEAT INPUT
DUTIES NEEDING HEAT REMOVAL
2nd Stg Hydrolysis
1st Stg Hydrolysis
Beer Col Reboiler
Flash Tank 1A
Flash Tank 2A
Beer Reflux
Preheat Exch
Rectifier Reboiler
Pre-steamer
#1 Wash Water
Flash Tank 1B
Flash Tank 2B
1st Stage Cooler
Rectifier Reflux
#2 Wash Water
1stStage Chiller
Econo-mizer
#1 Washer Out
2nd Stage Cooler
2nd Stage Chiller
1st Stage Ferm
2nd Stage Ferm.
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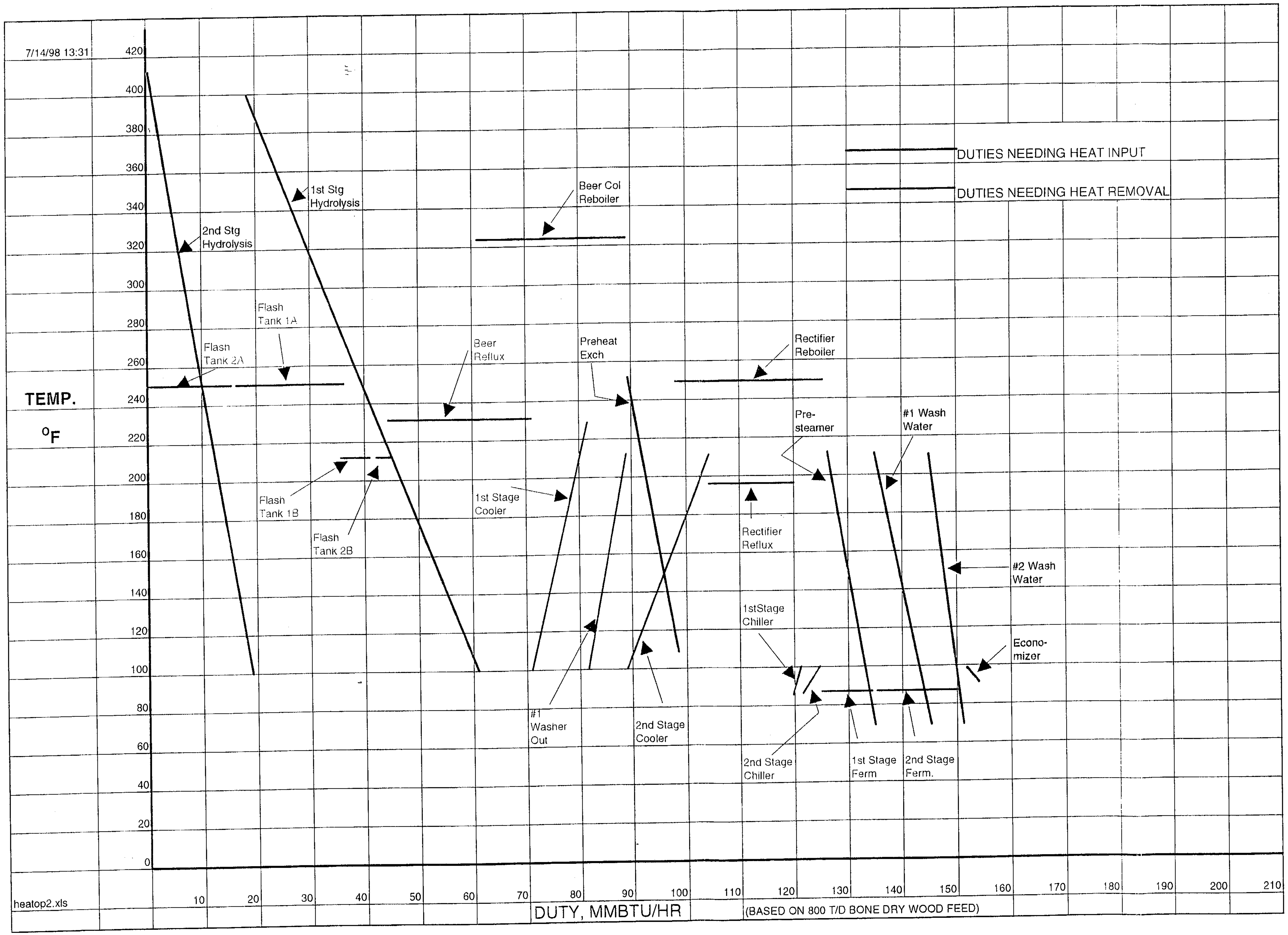
DUTY, MMBTU/HR
(BASED ON 800 T/D BONE DRY WOOD FEED)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DUTY, MMBTU/HR
(BASED ON 800 T/D BONE DRY WOOD FEED)
heatop2.xls
DUTIES NEEDING HEAT INPUT
DUTIES NEEDING HEAT REMOVAL
2nd Stg Hydrolysis
1st Stg Hydrolysis
Flash Tank 2A
Flash Tank 1A
Flash Tank 1B
Flash Tank 2B
Beer Reflux
Beer Col Reboiler
Preheat Exch
1st Stage Cooler
#1 Washer Out
2nd Stage Cooler
Rectifier Reboiler
Rectifier Reflux
Pre-steamer
#1 Wash Water
#2 Wash Water
1stStage Chiller
2nd Stage Chiller
1st Stage Ferm
2nd Stage Ferm.
Econo-mizer

APPENDIX B

TRIP REPORTS

1. HIGH PLAINS CORPORATION, YORK, NE

DATE:	**May 1, 1998**		
PROJECT:	**NREL Softwood to Ethanol**		**PROJ. NO.: 19013104**
LOCATION:	**High Plains Corp. Ethanol Plant - York, Nebraska**		
ATTENDEES:	**Kiran Kadam**	**NREL**	
	Quang Nguyen	**NREL**	
	Joe Ruocco	**Merrick**	
	Fran Ferraro	**Merrick**	
	Dick Voiles	**Merrick**	
	Rochelle Dageforde	**High Plains**	

The plant is a 100,000 gal/day design for the production of ethanol from corn or milo. Feed grain is delivered to the plant via truck. Of the approximately 40 million gallons/year production capability, up to 18 million gallons can be treated to Industrial Grade ethanol. The plant employs about 65 people:

- 5 people in administration
- less than 40 people in operations
- about 20 people in maintenance

High Plains has the capability to store up to 4.5 days of feed in 4 silos. They also use a single day bin to feed 3 hammermills that grind up to 45,000 bushels/day. The mills have dust control cyclones and a baghouse with pulse-jet cleaning of the bags. Recovered dust is added to the ground feed and travels with it. There are one Champion mill and two Schutte mills, each with screens on the outlet to control particle size of the grind. The grind is to a coarse flour. This is conveyed in an elevated screw conveyor system at the top of the pipe rack with access walkway on one side of the conveyor(s). Their conveyors were made by Caldwell of Kearney, NE. Following milling, recycle water from multiple sources (backset), ammonia for pH control and an α-amylase are added in a slurry tank which operates at about 150 °F. Next this slurry is pumped and mixed with steam in an eductor to bring the temperature to 225-250°F. The eductor discharges to the top of the cook tube or hydroheater which has a 20 minute residence time. The slurry is then pumped to the Flash Tank and flashed at a slight vacuum (the source of the vacuum is the Rectifier Tower overhead vacuum system) and the temperature falls to 190°F.

Glucoamylase is added to the slurry which is then held in liquifaction tanks (horizontal tanks having three mixers in each tank) and fed to the presaturator where sulfuric acid is added. There is a flash going into the second liquifaction tank and the presaturator operates at 150 °F. A side stream is taken for the production of yeast in a separate vessel.

Yeast is propagated for 8 hours and is used for two life cycles. The consumption of purchased yeast is only about 5 boxes per month (a box looked to be about 30 to 40 lbs.). They changed from Red Star yeast to Alltech All Yeast Super Start recently. Propagator yeast strength is 300 to 400 million cells per liter. From the Presaturator the mixture proceeds to the Sat Tank where it has a 20 minute residence time. From the Sat tank material goes through spiral heat exchangers (Scrolls) to reduce the temperature from 150 to 85^{O}F. There are actually 9 spiral exchangers - three parallel trains having three exchangers in series in each train.

The fermentors are 50 feet in diameter by 50 feet tall and have a 720,000 gal working volume in each. Fermentors go through a 60 hour cycle - 20 hours to fill, 20 hours residence and 20 hours to empty and CIP. During filling, at 10% full and 50% full, yeast is added from the yeast propagators. Fermentors have 64 loops of cooling coils in each. A batch normally is fermented to 13% alcohol. At about 14% alcohol the yeast dies in the fermentation. Gas evolved from the fermentors is scrubbed (counter-current) with water to remove particulates and soluble emissions and then vented to the atmosphere. The tanks upstream of the fermentors have atmospheric vents and do not require scrubbing.

A fermentor can become "hung" because, typically, the temperature got too high and killed the yeast. The fermentor is still pumped to the distillation section but it is high in sugar content and low in alcohol. When this material is recycled to the start of the process, the operators will reduce the amount of feed grain to compensate for the sugar already in the stream.

Fermentors can become contaminated with lactobacillus or acetobacter. If this happens (and it is experienced up to a few times per year) the fermentor is shocked with penicillin or virginmycin.

There are three fermentors and a fourth 720,000 gal vessel which functions as a surge vessel between fermentation and distillation. This surge vessel is called the Beer Well once its contents are about 13% alcohol.

Distillation is conventional having a Beer or Stripping Column with water and alcohol overhead and solids and water out the bottom. Stripper overhead feeds the middle of the Rectifier.

Rectifier overhead goes to mol sieve dryers (3 operating and one regen.) having an 8 min. cycle time. Changes in feed stock to the plant tend to affect the quantity of fusel oils produced but not the place where they concentrate in the tower.

This plant also has an industrial alcohol distillation unit which produces higher purity alcohol than required for fuels. It is fed with a stream taken from the second or third tray in the top of the Rectifier. Water is added as a wash/stripping agent and the alcohol re-distilled and dried.

Slurry from the Beer column bottoms is fed to evaporators which concentrate the stream to a syrup. The syrup feeds Sharples horizontal decanter type centrifuges and then goes to gas fired rotary dryers (kiln type). Solid product is used for animal feed. When a fermentor becomes hung it is still sent to the beer column and the bottoms becomes richer in sugars. Since the stillage is recycled to the slurry tank these sugars are recovered. During this time the grain is cut back in the fermentors because of the additional sugars in the recycle. It is necessary to disinfect the syrup tank with sodium bisulfite after one of these episodes.

Condensate from the evaporators having 1500 to 2000 mg/liter COD is feed to anaerobic digestion. Anaerobic digestion (methanators) consists of 4 - 30,000 gal. fiberglass vessels, in parallel, which provide 6 hours of residence time. Methanators are sized for 2 gal/sq.ft./min. of liquid flow. They are designed for 90 % COD reduction to less than 200 mg/liter COD and have only 3% sludge in the treated water. They operate at $95^{O}F$ and use caustic for pH control. The patented or proprietary devices in methantors are the devices in the top which allow gas and liquid out but retain the beads. Nutrients must be added to the methanators. A feed/effluent plate and frame exchanger cools the feed from $140^{O}F$ to $110^{O}F$ before a trim cooler (water cooled plate and frame exchanger) cools it to the $95^{O}F$ operating temperature.

Methanator liquid output goes to aeration ponds, then a pump, clarifier and into the city sewage system. The clarifier is a conventional circular, cone bottomed type with scrapers on the cone. Bottoms are returned to the aeration pond and water goes over a weir to the city sewer.

General plant items:

- The three highest maintenance items in the plant are:
    1. The mixers on the liquifaction tanks. If pH or enzyme concentration gets out of range, there is a sharp rise in viscosity which leads to mixer bushing failures, motor/drive overload and other problems. These mixers have bottom (steady) bushings.
    2. The centrifuges due to normal wear.
    3. The dryers and conveyors.
- Cooling tower blowdown is not treated but goes directly to the city sewers.
- Chilled water is provided by York self contained mechanical refrigeration machines. They are only needed in the summer. Normal chilled water temperature is $55^{O}F$.
- Total water usage (recycle and fresh) is 20 gal/bushel of feed. Most is for cooling tower makeup.
- The control system is Johnson - Yokogawa.

- The centrifuges and most centrifugal pumps are driven by variable speed electric motors.
- Seven streams feed water to the Recycle Tank - 25% of the evaporator condensate, most of the stillage (Beer Column Bottoms) and all of the Rectifier Column Bottoms go to this tank. From the Recycle Tank water is sent to the evaporators or to the Cook Tube.

2. SIERRA PACIFIC INDUSTRY, MARTELL, CA

DATE:	May 19, 1998	
PROJECT:	NREL Softwood to Ethanol	PROJ. NO.: 19013104
LOCATION:	Martell Cogeneration Plant - Martell, California	
ATTENDEES:	Kiran Kadam	NREL
	Mark Yancey	NREL
	Fran Ferraro	Merrick
	Bob Hamilton	Merrick
	Eric Selya	Wheelabrator Martell Inc.
	Alan Jacobson	TSS Consultants, Inc.
	Matt Turner	Pinnacle Environmental Solutions
	Dick Magnum	Amador County
	Frank Jerauld	Conservation District

The Martell site is located at the Sierra Pacific Industry lumber mill in Martell, California. The generating station produces 18 MW of electricity while burning variable amounts of agricultural wastes, municipal wastes, and forest trimmings with an average moisture content of 40-45%. The lignin residue from an ethanol plant could be burned in the boiler if the moisture content were similar. It is possible to obtain 11,500 BTU/dry LB lignin. The generating station capacity y is 140,000 dry tons per year of biomass and the station pays $15-$25 per DTPD for biomass delivered to the site. They receive an average of 17 DTPD per truck and 50 trucks per day. This translates into 140,000 dry tons per year and could be increased to 45,000 acres per year at 10 tons per acre. _There are existing utilities and infrastructure available at the Martell site that could potentially benefit an adjacent ethanol plant.

- Steam. The boiler generates 200,000 lbs/hr of steam at 900 psig. Extraction steam is available at 180-200 psig and 85-100 psig. Currently the power generating station supplies 20,000 lbs/hr at 180-200 psig to an adjacent particleboard plant. More export steam is available. The generating station has condensate polishers to remove corrosion products from the return condensate. It was estimated the cost of steam would be $2 -$4 /1000 lbs (use $4 for 200# and $2 for 50#). The generating station has two 5-day scheduled outages during the year. A few emergency outages are expected. This translates to 93% to 94% availability. A small package-type boiler may be necessary to ensure an uninterrupted steam supply for an ethanol plant. This plant is looking to modify a backup of gas firing for the boilers in the future.
- The generating station currently sells power to the grid at $0.05 /kW-hr. Further investigation would be necessary to determine if a power purchase agreement could be developed for an adjacent ethanol plant. During is off

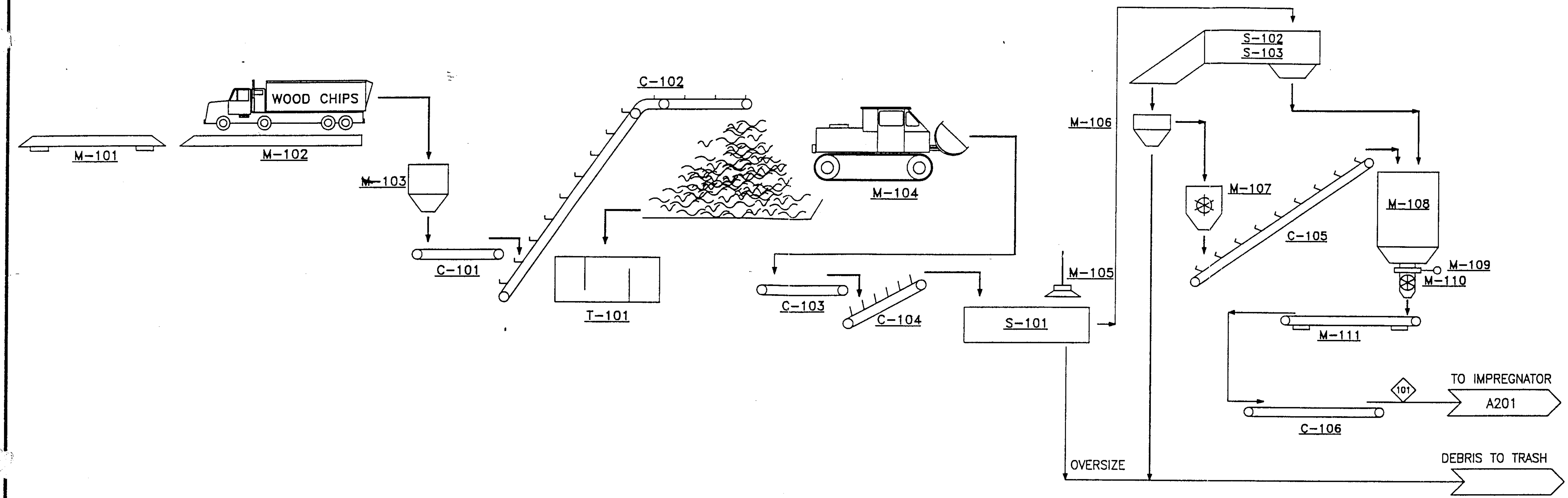
peak electric time, the plant sends steam for evaporation. Greenpower warrants $0.01 per kWh more than brown power.

- Cooling Water. The generating station utilizes a cooling tower for heat rejection operating at about 4 cycles of concentration. Summer operation includes use for dust suppression. This system could provide cooling water to an adjacent ethanol plant. The match would be good since there is less load on the cooling towers when steam is exported. The cooling tower is sized for turbogenerator operation at up to 18 MW of power generation without steam export (full condensing).
- Demineralized Water. Boiler makeup at the generating station is produced in parallel cation/anion demineralizers. There is some excess capacity in these units to provide demineralized water to an adjacent plant. However, additional storage would be required to allow production and storage of demineralized water during off-peak generating periods.
- Fire Protection. An perimeter loop is used for fire protection at the Martell site. This loop could be extended to an ethanol plant. There are minor fires that occur in the fuel pile therefore hose and water cannons are available and the chip storage is manned 24 hours per day.
- Site Security. Security in the area has not been a problem. However, the site is fenced and protected with a gated entrance. This same security could be extended to an adjacent facility.
- Rail Car Access. Rail car access is available at the Martell site and could serve an ethanol plant located there.
- Feed Receiving and Handling. This plant has the ability to handle a temporary fluctuation in the feed to 50% greater than normal feed without any modifications. If it is desired to operate at 75 - 100% over the normal feed, the hours would have to be extended and a second dump could be used.
- Fuel Preparation. Fuel to the power generating station is ground/milled to minus 3-inch. An ethanol plant would need minus ½-inch. However, it may be possible for the power generating station to provide feed stock to an ethanol plant by selectively sorting and screening the biomass. This plant does not have any fines problem with wood. They only have silt problems. Agricultural wastes such as prunings and nut shells are used as fuel along with urban pellets, sander dust, saw dust and forest thinnings. These fuels are made up of approximately 40-45% moisture. A two to three week excess supply of fuel is stored before summer.
- Water Supply. Ditch water is supplied to the power generating station in a 6-inch main through Sierra Pacific. Storage is in a holding pond. Although specific quantities were not discussed, adequate water for an ethanol plant was judged to be available. A 2 inch potable water system (from Johnson City) is in place as well. There is currently 75 GPM treatment capacity for makeup water.

- Wastewater Treatment. The power generating station has no large-scale wastewater treatment. Cooling tower blowdown, boiler blowdown, and neutralized demineralzer wastes are mixed in a (settling) pond prior to discharge. Any process wastewater generated by an ethanol plant would have to be treated separately. However, the existing rainfall runoff/detention pond system for the power generating station could probably be expanded to accommodate an adjacent ethanol plant.
- Siting. Sierra Pacific owns the power generating station site and the surrounding property. There has been industrial activity on the property for decades. Except for the typical California permitting procedures, no unusual siting problems are anticipated.
- Air Emissions. Multiple cyclones and electrostatic precipitator(s) are used on the exhaust to control particulate matter. NOx control is achieved by controlling the combustion air. The plant is currently monitored over a 3 hour average window. A 24 hour window is presently requested. This is due to the fact that the water cooled stationary grate must be cleaned 1-3 times per shift to remove the slag and sand in the process. When it is cleaned, air is allowed into the process and thereby causes inefficiencies and problems.
- Transfer of Wood from Piles to Site. Currently an underground conveyor is used to transport the wood from the piles which lie below a large overhead conveyor. This conveyor is 45 feet above the ground. The whole process is able to "store" up to 90 days worth of fuel on 5.38 acres. An underground recovery system will soon be changed to an overpile recovery system. This is due to the fact that it takes 12 hours to remove wood from the underground system so that it can be repaired if any problems occur.

APPENDIX C

PROCESS FLOW DIAGRAMS



COMPONENT	UNITS	101
Total Flow	kg/hr	63,979
Insoluble Solids	%	52.1%
Soluble Solids	%	0.0%
Temperature	C	20
Pressure	atm	1.00
Vapor Fraction		0.00
Ethanol	kg/hr	
Water	kg/hr	30,646
Glucose (SS)	kg/hr	
Mannose (SS)	kg/hr	
Xylose (SS)	kg/hr	
Other Sugars (SS)	kg/hr	
Cellobiose (SS)	kg/hr	
Glucose Oligomers (SS)	kg/hr	
Xylose Oligomers (SS)	kg/hr	
Other Oligomers (SS)	kg/hr	
Corn Steep Liquor (SS)	kg/hr	
Others (Soluble Solids)	kg/hr	
Extractives	kg/hr	
Acetic Acid	kg/hr	
Sulfuric Acid	kg/hr	
Furfural	kg/hr	
HMF	kg/hr	
Carbon Dioxide	kg/hr	
Methane	kg/hr	
Oxygen	kg/hr	
Nitrogrn	kg/hr	
Ammonia	kg/hr	
NH4)H	kg/hr	
Others	kg/hr	
Cellulose (IS)	kg/hr	14,248
Mannan (IS)	kg/hr	3,356
Galactan (IS)	kg/hr	921
ylan (IS)	kg/hr	2,435
rabinan (IS)	kg/hr	494
east (IS)	kg/hr	
Biomass (IS)	kg/hr	
Extract Solids (IS)	kg/hr	1,645
Lignin (IS)	kg/hr	9,411
Gypsum (IS)	kg/hr	
Ca(OH)2 (IS)	kg/hr	
Others (Insoluble Solids)	kg/hr	823
Enthalpy Flow (millions)	Kcal/hr	-182.0
Average Density	g/ml	1.264

Eq. No.	Equipment Name	Req.	Spare	Equipment Type	Mat Const.
C-101	Chip Conveyor to Storage	1	0		
C-102	Chip Stacker	2	0		
C-103	Reclaim Conveyor	2	0		
C-104	Conveyor to Screening	1	0		
C-105	Conveyor to Chip Silo	1	0		
C-106	Chip Conveyor to Process	1	0		
M-101	Truck Scale	1	0		
M-102	Truck Dumper	1	0		
M-103	Truck Receiving Hopper	1	0		
M-104	Bulldozer	2	0		
M-105	Tramp Iron Magnet	1	0		
M-106	Air Density Separation System	1	0		
M-107	Chip Slicer	1	0		
M-108	Chip Silo	1	0		
M-109	Vibrating Silo Discharger	1	0		
M-110	Silo Discharge Feeder	1	0		
M-111	Belt Scale	1	0		
S-101	Disc Scalping Screen	1	0		
S-102	Chip Thickness Screen	1	0		
S-103	Chip Screen System Chutes	1	0		
T-101	Rain Water Collection System	1	0		

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SECTION A100
WOOD CHIP FEED HANDLING

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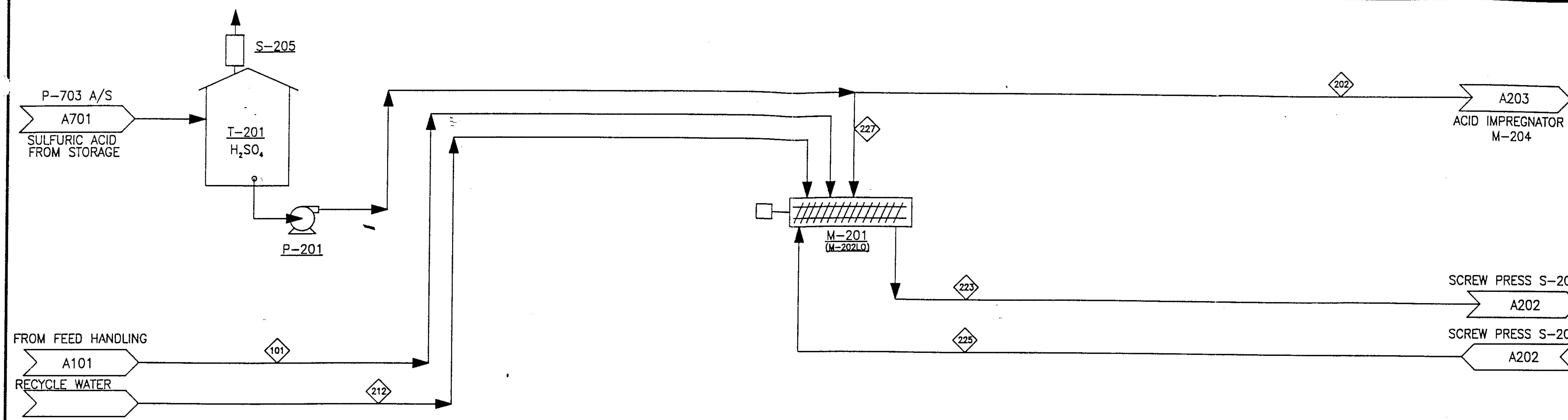

COMPONENT	UNITS	101	202	212	223	225	227
Total Flow	kg/hr	63,979	642	46,537	104,561	37,895	366
Insoluble Solids	%	52.1%	0.0%	0.0%	32.5%	1.8%	0.0%
Soluble Solids	%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%
Temperature	C	20	20	74	20	20	20
Pressure	atm	1.00	1.00	3.00	1.00	1.00	1.00
Vapor Fraction		0.00	0.00	0.00	0.00	0.00	0.00
Ethanol	kg/hr			41			
Water	kg/hr	30,646	45	46,156	69,827	36,835	26
Glucose (SS)	kg/hr				0	0	
Mannose (SS)	kg/hr				0	0	
Xylose (SS)	kg/hr				0	0	
Other Sugars (SS)	kg/hr			0	0	0	
Cellobiose (SS)	kg/hr						
Glucose Oligomers (SS)	kg/hr						
Xylose Oligomers (SS)	kg/hr						
Other Oligomers (SS)	kg/hr						
Corn Steep Liquor (SS)	kg/hr			59			
Others (Soluble Solids)	kg/hr						
Extractives	kg/hr						
Acetic Acid	kg/hr			151	0	0	
Sulfuric Acid	kg/hr		597		721	380	341
Furfural	kg/hr			14	0	0	
HMF	kg/hr			112	0	0	
Carbon Dioxide	kg/hr						
Methane	kg/hr						
Oxygen	kg/hr						
Nitrogrn	kg/hr						
Ammonia	kg/hr						
NH4)H	kg/hr						
Others	kg/hr			3			
Cellulose (IS)	kg/hr	14,248			14,539	291	
Mannan (IS)	kg/hr	3,356			3,425	68	
Galactan (IS)	kg/hr	921			940	19	
Xylan (IS)	kg/hr	2,435			2,485	50	
Arabinan (IS)	kg/hr	494			504	10	
Yeast (IS)	kg/hr						
Biomass (IS)	kg/hr						
Extract Solids (IS)	kg/hr	1,645			1,679	34	
Lignin (IS)	kg/hr	9,411			9,603	192	
Gypsum (IS)	kg/hr						
Ca(OH)2 (IS)	kg/hr						
Others (insoluble Solids)	kg/hr	823			839	17	
Enthalpy Flow (millions)	Kcal/hr	-182.0	-1.3	-173.3	-333.4	-141.8	-0.8
Average Density	g/ml	0.478	2.191	0.946	1.425	0.983	2.191

Eq. No.	Equipment Name	Req.	Spare	Equipment Type	Mat Const.
M-201	1st Stage Impregnator (M-202LO)	1	0		
S-205	Acid Vent Desicant Filter	1	0		
T-201	Sulfuric Acid Process Storage Tank	1	0		
P-201	Sulfuric Acid Pump	1	1		

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SECTION A200
1st STAGE ACID IMPREGNATION

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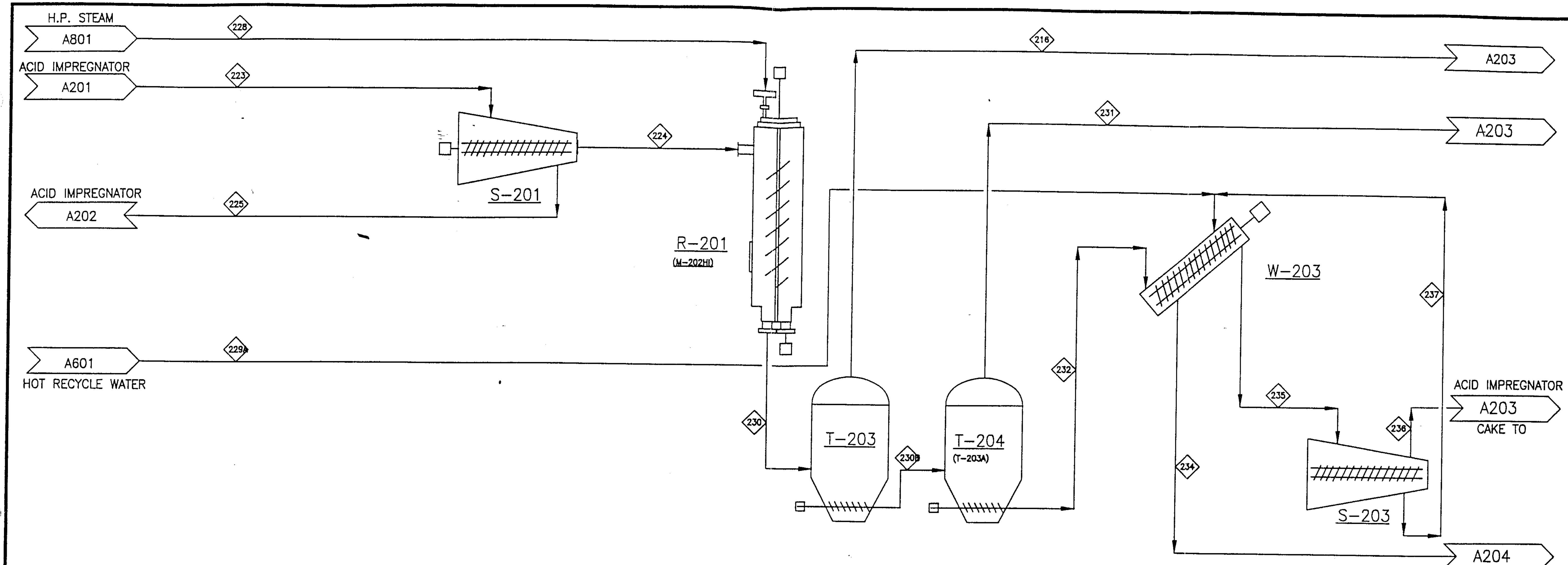

COMPONENT	UNITS	216	223	224	225	228	229A	230	230B	231	232	234	235	236	237
Total Flow	kg/hr	8,878	104,561	66,666	37,895	17,077	101,147	83,743	74,865	8,334	66,531	117,597	86,027	50,080	35,947
Insoluble Solids	%	0.0%	32.5%	50.0%	1.8%	0.0%	0.1%	30.2%	33.8%	0.0%	38.0%	0.0%	30.1%	50.6%	1.4%
Soluble Solids	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	7.7%	8.8%	0.0%	9.9%	5.8%	0.3%	0.2%	0.4%
Temperature	C	135	20	20	20	321	60	190	135	101	101	84	84	84	84
Pressure	atm	3.00	1.00	1.00	1.00	23.00	1.01	12.11	3.00	1.00	1.00	0.55	0.55	0.55	0.55
Vapor Fraction		1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.07	1.00	0.00	0.06	0.65	0.46	0.92
Ethanol	kg/hr						49					48	3	1	1
Water	kg/hr	8,850	69,827	32,993	36,835	17,077	99,375	49,460	40,514	8,307	32,206	106,975	59,872	24,605	35,267
Glucose (SS)	kg/hr		0	0	0		0						0	0	0
Mannose (SS)	kg/hr		0	0	0		8	2,572	3,242		3,242	3,207	104	43	61
Xylose (SS)	kg/hr	0	0	0	0		8	1,790	1,942	0	1,942	1,924	62	26	37
Other Sugars (SS)	kg/hr	0	0	0	0		96	1,274	1,380	0	1,380	1,456	47	19	28
Cellobiose (SS)	kg/hr						82					81	3	1	2
Glucose Oligomers (SS)	kg/hr						4	713	14		14	18	1	0	0
Xylose Oligomers (SS)	kg/hr	0					0	137	3		3	3	0	0	0
Other Oligomers (SS)	kg/hr														
Corn Steep Liquor (SS)	kg/hr						98					96	3	1	2
Others (Soluble Solids)	kg/hr														
Extractives	kg/hr						475	1,645	1,645		1,645	2,120			
Acetic Acid	kg/hr	28	0	0	0		295	527	498	27	471	756	24	10	14
Sulfuric Acid	kg/hr	0	721	341	380			341	340	0	340	336	11	4	6
Furfural	kg/hr		0	0	0		39					38	1	1	1
HMF	kg/hr		0	0	0		304					300	10	4	6
Carbon Dioxide	kg/hr						24					24	1	0	0
Methane	kg/hr														
Oxygen	kg/hr						0					0	0	0	0
Nitrogrn	kg/hr						0					0	0	0	0
Ammonia	kg/hr						0					0	0	0	0
NH4)H	kg/hr														
Others	kg/hr						216					213	7	3	4
Cellulose (IS)	kg/hr		14,539	14,248	291		17	14,248	14,248		14,248		14,556	14,265	291
Mannan (IS)	kg/hr		3,425	3,356	68			426	426		426		435	426	9
Galactan (IS)	kg/hr		940	921	19		1	172	172		172		177	173	4
Xylan (IS)	kg/hr		2,485	2,435	50		2	723	723		723		740	726	15
Arabinan (IS)	kg/hr		504	494	10		0	10	.10		10		10	10	0
Yeast (IS)	kg/hr						0					0			
Biomass (IS)	kg/hr														
Extract Solids (IS)	kg/hr		1,679	1,645	34										
Lignin (IS)	kg/hr		9,603	9,411	192		47	9,411	9,411		9,411		9,651	9,458	193
Gypsum (IS)	kg/hr						5						5	5	0
Ca(OH)2 (IS)	kg/hr														
Others (Insoluble Solids)	kg/hr		839	823	17		1	296	296		296		304	298	6
Enthalpy Flow (milions)	Kcal/hr	-28.0	-333.4	-191.6	-141.8	-52.4	-375.9	-244.0	-213.0	-26.4	-186.5	-412.7	-246.2	-131.4	-114.8
Average Density	g/ml	0.002	1.425	1.653	0.983	0.009	0.962	1.302	0.790	0.001	1.496	0.006	0.462	0.777	0.000

Eq. No.	Equipment Name	Req.	Spare	Equipment Type	Mat Const.
R-201	1st Stage Hydrolysis Reactor (M-202HI)	1	0		
S-201	1st Stage Pre-Reactor Screw Press	1	0		
S-203	Interstage Screw Press	1	0		
T-203	1st Stage Oligomer Flash Tank Reactor	1	0		
T-204	1st Stage Low Pressure Flash Tank (T-203A)	1	0		
W-203	Interstage Washer	1	0		

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SECTION A200
1st STAGE HYDROLYSIS

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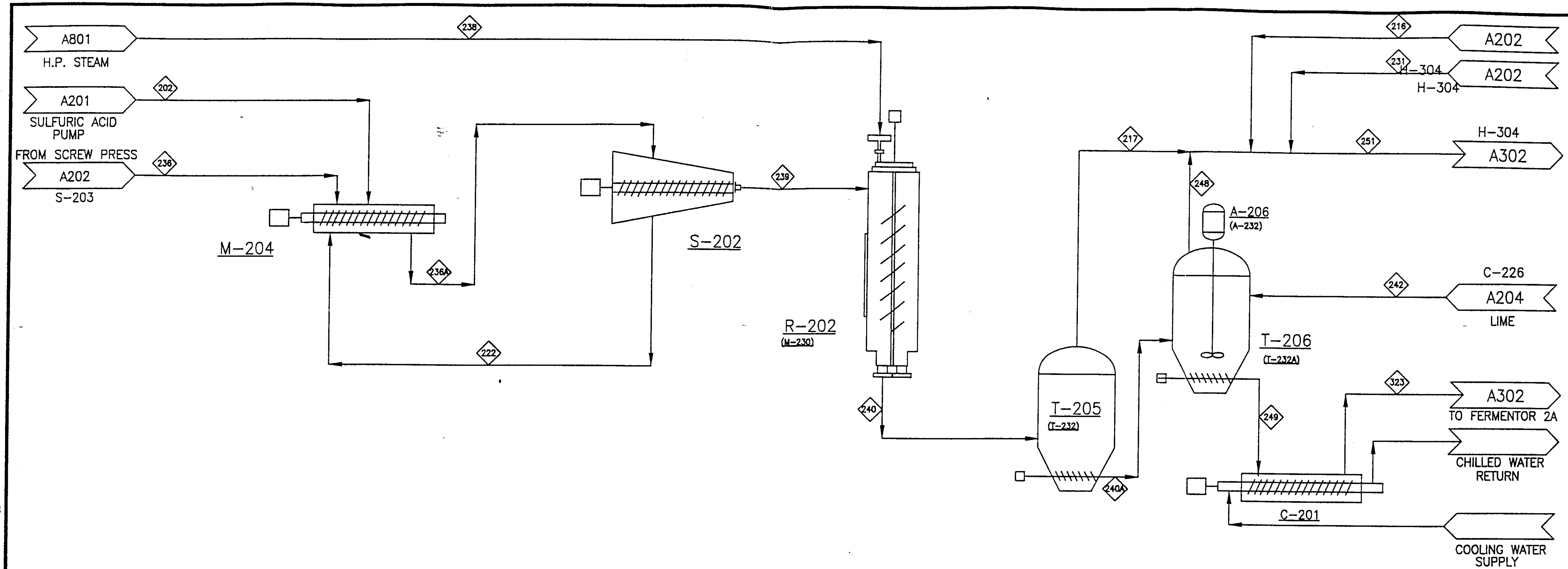

COMPONENT	UNITS	202	216	217	222	231	236	236A	238	239	240	240A	242	248	249	251	323
Total Flow	kg/hr	642	8,878	11,126	28,023	8,334	50,080	78,745	12,811	50,722	63,533	52,407	452	26,898	25,509	55,237	25,960
Insoluble Solids	%	0.0%	0.0%	0.0%	1.8%	0.0%	50.6%	32.9%	0.0%	50.0%	21.8%	26.4%	100.0%	0.0%	54.2%	0.0%	57.3%
Soluble Solids	%	0.0%	0.0%	0.0%	0.3%	0.0%	0.2%	0.2%	0.0%	0.2%	16.7%	20.2%	0.0%	0.0%	41.6%	0.0%	40.9%
Temperature	C	20	135	135	80	101	84	80	321	80	220	135	20	101	101	106	37
Pressure	atm	1.00	3.00	2.98	0.49	1.00	0.55	0.49	23.00	0.49	22.51	2.98	1.00	0.27	0.27	0.27	0.27
Vapor Fraction		0.00	1.00	1.00	0.00	1.00	0.46	0.00	1.00	0.00	0.00	0.00	0.00	1.00	0.00	1.00	0.00
Ethanol	kg/hr			1	1		1	2		1	1	0		0	0	1	0
Water	kg/hr	45	8,850	10,212	26,734	8,307	24,605	51,385	12,811	24,650	36,940	26,728	0	26,272	410	53,641	410
Glucose (SS)	kg/hr				0		0	0		0	9,510	9,510			9,976		9,976
Mannose (SS)	kg/hr				46		43	89		43	117	117			117		117
Xylose (SS)	kg/hr		0	0	28	0	26	53		26	39	39		0	39	0	39
Other Sugars (SS)	kg/hr		0	0	21	0	19	40		19	30	30		0	30	0	30
Cellobiose (SS)	kg/hr				1		1	2		1	453	453			453		453
Glucose Oligomers (SS)	kg/hr				0		0	1		0	428	428			9		9
Xylose Oligomers (SS)	kg/hr		0		0		0	0		0	0	0			0	0	0
Other Oligomers (SS)	kg/hr																
Corn Steep Liquor (SS)	kg/hr			0	1		1	3		1	1	1		1	0	1	0
Others (Soluble Solids)	kg/hr																
Extractives	kg/hr																
Acetic Acid	kg/hr		28	1	11	27	10	21		10	10	9		9	1	65	1
Sulfuric Acid	kg/hr	597	0	0	653	0	4	1,254		602	602	602		4	598	4	
Furfural	kg/hr			103	1		1	1		1	178	75		69	5	173	5
HMF	kg/hr			808	4		4	8		4	1,393	584		543	42	1,351	42
Carbon Dioxide	kg/hr			0	0		0	1		0	0	0		0	0	0	0
Methane	kg/hr																
Oxygen	kg/hr			0	0		0	0		0	0	0		0		0	
Nitrogm	kg/hr			0	0		0	0		0	0					0	
Ammonia	kg/hr			0	0		0	0		0	0	0		-0	0	0	0
NH4)H	kg/hr																
Others	kg/hr			0	3		3	6		3	3	3		1	2	1	2
Cellulose (IS)	kg/hr				291		14,265	14,556		14,265	3,424	3,424			3,424		3,424
Mannan (IS)	kg/hr				9		426	435		426							
Galactan (IS)	kg/hr				4		173	177		173	164	164			164		164
Xylan (IS)	kg/hr				15		726	740		726	469	469			469		469
Arabinan (IS)	kg/hr				0		10	10		10	10	10			10		10
Yeast (IS)	kg/hr																
Biomass (IS)	kg/hr																
Extract Solids (IS)	kg/hr																
Lignin (IS)	kg/hr				193		9,458	9,651		9,458	9,458	9,458			9,458		9,458
Gypsum (IS)	kg/hr				0		5	5		5	5	5			5		1,054
Ca(OH)2 (IS)	kg/hr												452				
Others (Insoluble Solids)	kg/hr				6		298	304		298	298	298			298		298
Enthalpy Flow (millions)	Kcal/hr	-1.3	-28.0	-32.6	-102.3	-26.4	-131.4	-247.9	-39.3	-145.5	-184.8	-152.3	-1.4	-83.6	-55.5	-170.6	-57.8
Average Density	g/ml	2.191	0.002	0.002	0.972	0.001	0.777	1.148	0.009	0.473	0.688	0.744		0.000	1.359	0.000	0.472

Eq. No.	Equipment Name	Req.	Spare	Equipment Type	Mat Const.
A-206	Sterilization Tank Agitator	1	0		
C-201	Chilled Slurry Screw Conveyor	1	0		
M-204	2nd Stage Impregnator	1	0		
R-202	2nd Stage Hydrolysis Reactor (M-230)	1	0		
S-202	2nd Stage Pre-Reactor Screw Press	1	0		
T-205	2nd Stage Oligomer Flash Tank Reactor (T-232)	1	0		
T-206	2nd Stage Low Pressure Flash Tank (T-232A)	1	0		

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A	INITIAL MERRICK DESIGN	10/98

NREL NATIONAL RENEWABLE ENERGY LABORATORY

Biotechnology Center For Fuels And Chemicals

SECTION A200
2nd STAGE HYDROLYSIS

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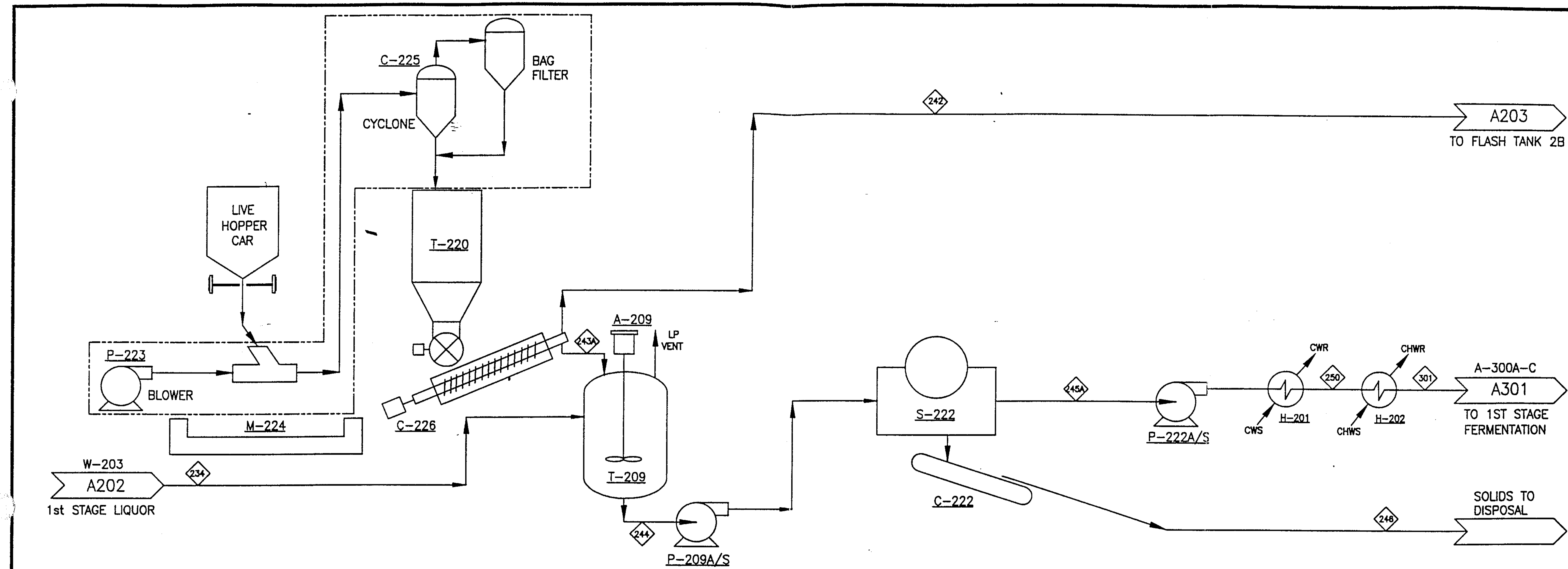

COMPONENT	UNITS	234	242	243A	244	245A	246	250	301
Total Flow	kg/hr	117,597	452	254	117,851	116,795	1,056	116,795	116,795
Insoluble Solids	%	0.0%	100.0%	100.0%	0.5%	0.0%	55.6%	0.0%	0.0%
Soluble Solids	%	5.8%	0.0%	0.0%	5.8%	5.8%	2.6%	5.8%	5.8%
Temperature	C	84	20	20	84	84	84	37	30
Pressure	atm	0.55	1.00	1.00	0.55	0.55	0.55	0.55	0.55
Vapor Fraction		0.06	0.00	0.00	0.07	0.07	0.03	0.00	0.00
Ethanol	kg/hr	48			48	48	0	48	48
Water	kg/hr	106,975	0	0	106,975	106,547	428	106,547	106,547
Glucose (SS)	kg/hr								
Mannose (SS)	kg/hr	3,207			3,207	3,194	13	3,194	3,194
Xylose (SS)	kg/hr	1,924			1,924	1,917	8	1,917	1,917
Other Sugars (SS)	kg/hr	1,456			1,456	1,450	6	1,450	1,450
Cellobiose (SS)	kg/hr	81			81	81	0	81	81
Glucose Oligomers (SS)	kg/hr	18			18	18	0	18	18
Xylose Oligomers (SS)	kg/hr	3			3	3	0	3	3
Other Oligomers (SS)	kg/hr								
Corn Steep Liquor (SS)	kg/hr	96			96	96	0	96	96
Others (Soluble Solids)	kg/hr								
Extractives	kg/hr	2,120			2,120	2,112	8	2,112	2,112
Acetic Acid	kg/hr	756			756	753	3	753	753
Sulfuric Acid	kg/hr	336							
Furfural	kg/hr	38			38	38	0	38	38
HMF	kg/hr	300			300	299	1	299	299
Carbon Dioxide	kg/hr	24			24	24	0	24	24
Methane	kg/hr								
Oxygen	kg/hr	0			0	0	0	0	0
Nitrogm	kg/hr	0			0	0	0	0	0
Ammonia	kg/hr	0			0	0	0	0	0
NH4)H	kg/hr								
Others	kg/hr	213			213	212	1	212	212
Cellulose (IS)	kg/hr								
Mannan (IS)	kg/hr								
Galactan (IS)	kg/hr								
Xylan (IS)	kg/hr								
Arabinan (IS)	kg/hr								
Yeast (IS)	kg/hr	0			0	0	0	0	0
Biomass (IS)	kg/hr								
Extract Solids (IS)	kg/hr								
Lignin (IS)	kg/hr								
Gypsum (IS)	kg/hr				590	3	587	3	3
Ca(OH)2 (IS)	kg/hr		452	254					
Others (Insoluble Solids)	kg/hr								
Enthalpy Flow (millions)	Kcal/hr	-412.7	-1.4	-0.8	-413.5	-410.2	-3.3	-419.3	-420.0
Average Density	g/ml	0.006		1.534	0.013	0.006	0.869	1.013	1.020

Eq. No.	Equipment Name	Req.	Spare	Equipment Type	Mat Const.
A-209	Neutralization Tank Agitator	1	0		
C-222	Gypsum Conveyor	1	0		
C-223	Lime Unloading Conveyor	1	0		
C-225	Lime Solids Feeder	1	0		
C-226	Lime Conveyor	1	0		
M-224	Lime Unloading Pit	1	0		
P-209	Hydrolyzate Slurry Pump	1	1		
P-222	Hydrolyzate Pump	1	1		
P-223	Lime Unloading Blower	1	0		
S-222	Gypsum Rotary Drum Filter	1	0		
T-209	Neutralization Tank	1	0		
T-220	Lime Storage Bin	1	0		

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SECTION A200
LIME HANDLING & NEUTRALIZATION

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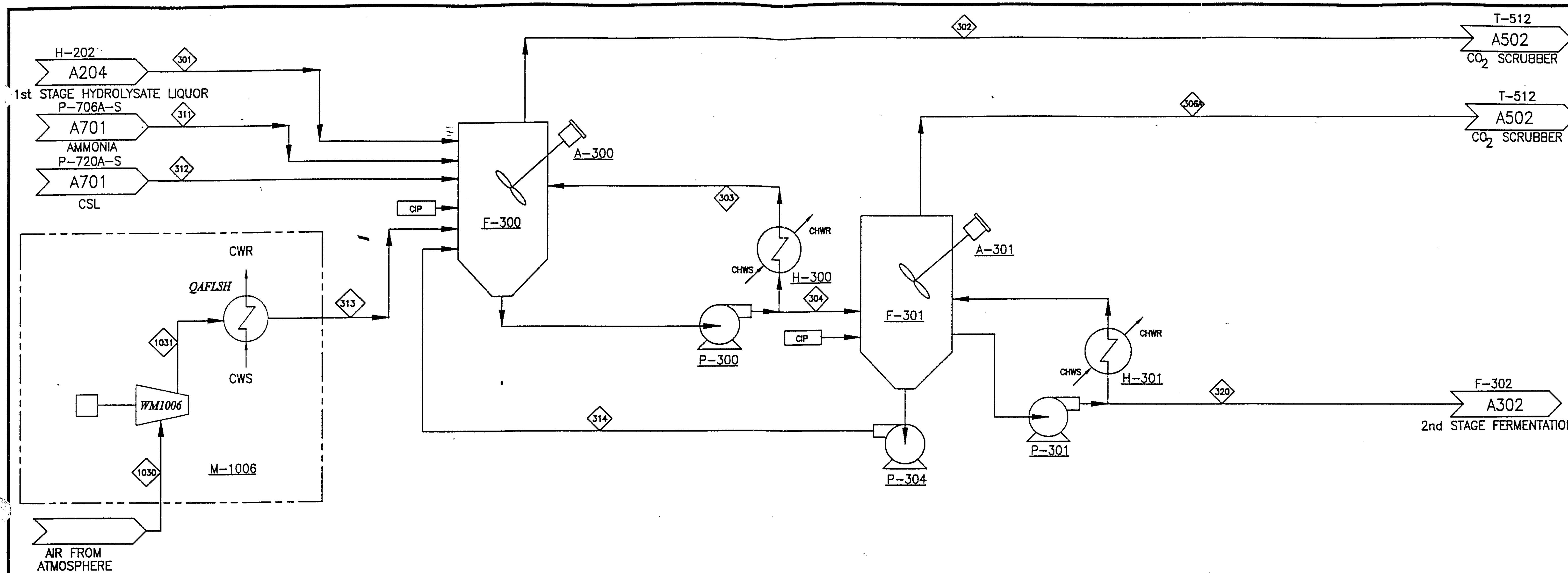

COMPONENT	UNITS	301	302	304	306A	311	312	313	314	320	1030	1031
Total Flow	kg/hr	116,795	2,819	143,793	203	452	292	355	28,718	114,872	355	355
Insoluble Solids	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Soluble Solids	%	5.8%	0.0%	2.0%	0.0%	0.0%	100.0%	0.0%	1.7%	1.7%	0.0%	0.0%
Temperature	C	30	32	32	32	20	20	40	32	32	20	169
Pressure	atm	0.55	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	3.00
Vapor Fraction		0.00	1.00	0.00	1.00	1.00	0.00	1.00	0.00	0.00	1.00	1.00
Ethanol	kg/hr	48	24	2,654	2				581	2,325		
Water	kg/hr	106,547	72	133,083	4				26,616	106,463		
Glucose (SS)	kg/hr											
Mannose (SS)	kg/hr	3,194		943					109	438		
Xylose (SS)	kg/hr	1,917		379					76	303		
Other Sugars (SS)	kg/hr	1,450		988					178	711		
Cellobiose (SS)	kg/hr	81		101					20	81		
Glucose Oligomers (SS)	kg/hr	18		23					5	18		
Xylose Oligomers (SS)	kg/hr	3		4					1	3		
Other Oligomers (SS)	kg/hr											
Corn Steep Liquor (SS)	kg/hr	96	0	485	0		292		97	388		
Others (Soluble Solids)	kg/hr											
Extractives	kg/hr	2,112		2,640					528	2,112		
Acetic Acid	kg/hr	753	0	946	0				189	757		
Sulfuric Acid	kg/hr											
Furfural	kg/hr	38	0	47	0				9	38		
HMF	kg/hr	299	2	371	0				74	297		
Carbon Dioxide	kg/hr	24	1,917	93	185				30	120		
Methane	kg/hr											
Oxygen	kg/hr	0	97	0	0			75	0	0	75	75
Nitrogrn	kg/hr	0	281	0	0			281	0	0	281	281
Ammonia	kg/hr	0	426	21	12	452			2	8		
NH4)H	kg/hr											
Others	kg/hr	212	0	954	0				191	763		
Cellulose (IS)	kg/hr											
Mannan (IS)	kg/hr											
Galactan (IS)	kg/hr											
Xylan (IS)	kg/hr											
Arabinan (IS)	kg/hr											
Yeast (IS)	kg/hr	0		57					11	45		
Biomass (IS)	kg/hr											
Extract Solids (IS)	kg/hr											
Lignin (IS)	kg/hr											
Gypsum (IS)	kg/hr	3		4					1	3		
Ca(OH)2 (IS)	kg/hr											
Others (Insoluble Solids)	kg/hr											
Enthalpy Flow (millions)	Kcal/hr	-420.0	-4.6	-521.0	-0.4	-0.3	-1.1	0.0	-104.1	-416.5	0.0	0.0
Average Density	g/ml	1.020	0.001	0.996	0.002	0.001	0.998	0.001	0.995	0.994	0.001	0.002

Eq. No.	Equipment Name	Req.	Spare	Equipment Type	Mat Const.
A-300	1st Stage Fermentor Agitator No. 1	1	0		
A-301	1st Stage Fermentor Agitator No. 2	1	0		
F-300	1st Stage Fermentor No. 1	1	0		
F-301	1st Stage Fermentor No. 2	1	0		
H-300	1st Stage Fermentor Cooler No. 1	1	0		
H-301	1st Stage Fermentor Cooler No. 2	1	0		
P-300	1st Stage Fermentor Recirculation Pump No. 1	1	1		
P-301	1st Stage Fermentor Recirculation Pump No. 2	1	1		
P-304	Yeast Recycle Pump	1	1		
M-1006	Fermentor Air Compressor Package	1	1	Centrifugal	CS

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A	INITIAL MERRICK DESIGN	10/98

NREL NATIONAL RENEWABLE ENERGY LABORATORY
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SECTION A300
SOLIDS FREE PRODUCTION FERMENTATION

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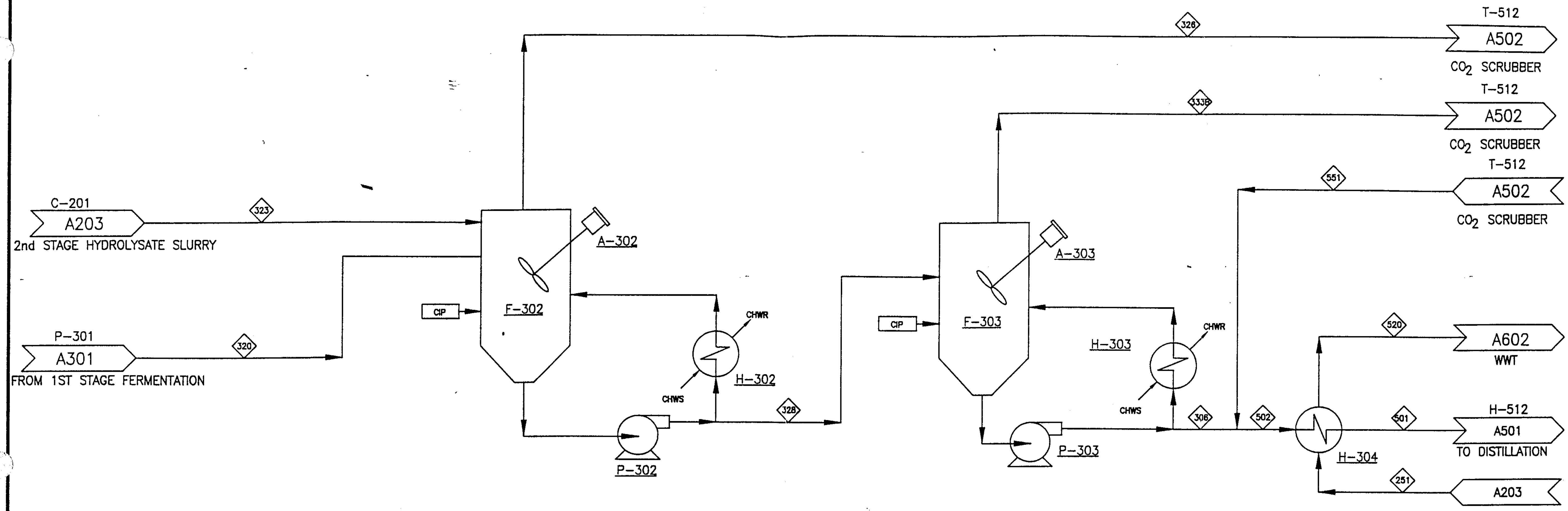

COMPONENT	UNITS	251	306	320	323	326	328	333B	501	502	520	551
Total Flow	kg/hr	55,237	136,070	114,872	25,960	4,763	136,070	0	141,594	141,594	55,237	5,524
Insoluble Solids	%	0.0%	11.0%	0.0%	57.3%	0.0%	11.0%	0.0%	10.5%	10.5%	0.0%	0.0%
Soluble Solids	%	0.0%	1.9%	1.7%	40.9%	0.0%	1.9%	0.0%	1.8%	1.8%	0.0%	0.0%
Temperature	C	106	32	32	37	32	32		95	32	67	31
Pressure	atm	0.27	1.00	1.00	0.27	1.00	1.00	1.00	4.00	0.90	0.27	0.90
Vapor Fraction		1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.77	0.00
Ethanol	kg/hr	1	7,061	2,325	0	87	7,061		7,187	7,187	1	126
Water	kg/hr	53,641	106,771	106,463	410	91	106,771		112,158	112,158	53,641	5,387
Glucose (SS)	kg/hr		853		9,976		853		853	853		
Mannose (SS)	kg/hr		49	438	117		49		49	49		
Xylose (SS)	kg/hr	0	51	303	39		51		51	51	0	
Other Sugars (SS)	kg/hr	0	621	711	30		621		621	621	0	
Cellobiose (SS)	kg/hr		534	81	453		534		534	534		
Glucose Oligomers (SS)	kg/hr		27	18	9		27		27	27		
Xylose Oligomers (SS)	kg/hr	0	3	3	0		3		3	3	0	
Other Oligomers (SS)	kg/hr											
Corn Steep Liquor (SS)	kg/hr	1	387	388	0	0	387		388	388	1	1
Others (Soluble Solids)	kg/hr											
Extractives	kg/hr		2,112	2,112			2,112		2,112	2,112		
Acetic Acid	kg/hr	65	757	757	1	0	757		757	757	65	1
Sulfuric Acid	kg/hr	4									4	
Furfural	kg/hr	173	43	38	5	0	43		44	44	173	0
HMF	kg/hr	1,351	337	297	42	2	337		341	341	1,351	4
Carbon Dioxide	kg/hr	0	162	120	0	4,566	162		167	167	0	5
Methane	kg/hr											
Oxygen	kg/hr	0	0	0		9	0		0	0	0	0
Nitrogrn	kg/hr	0	0	0		0	0		0	0	0	0
Ammonia	kg/hr	0	0	8	0	7	0		1	1	0	0
NH4)H	kg/hr											
Others	kg/hr	1	1,377	763	2	0	1,377		1,377	1,377	1	0
Cellulose (IS)	kg/hr		3,424		3,424		3,424		3,424	3,424		
Mannan (IS)	kg/hr											
Galactan (IS)	kg/hr		164		164		164		164	164		
Xylan (IS)	kg/hr		469		469		469		469	469		
Arabinan (IS)	kg/hr		10		10		10		10	10		
Yeast (IS)	kg/hr		45	45			45		45	45		
Biomass (IS)	kg/hr											
Extract Solids (IS)	kg/hr											
Lignin (IS)	kg/hr		9,458		9,458		9,458		9,458	9,458		
Gypsum (IS)	kg/hr		1,057	3	1,054		1,057		1,057	1,057		
Ca(OH)2 (IS)	kg/hr											
Others (Insoluble Solids)	kg/hr		298		298		298		298	298		
Enthalpy Flow (millions)	Kcal/hr	-170.6	-465.1	-416.5	-57.8	-10.1	-465.1		-477.9	-485.7	-178.4	-20.6
Average Density	g/ml	0.000	0.879	0.994	0.472	0.002	0.879	0.000	0.825	0.812	0.000	0.982

Eq. No.	Equipment Name	Req.	Spare	Equipment Type	Mat Const.
A-302	2nd Stage Fermentor Agitator No. 1	1	0		
A-303	2nd Stage Fermentor Agitator No. 2	1	0		
F-302	2nd Stage Fermentor No. 1	1	0		
F-303	2nd Stage Fermentor No. 2	1	0		
H-302	2nd Stage Fermentor Cooler No. 1	1	0		
H-303	2nd Stage Fermentor Cooler No. 2	1	0		
H-304	Distillation Feed Preheater	1	0		
P-302	2nd Stage Fermentor Recirculation Pump No. 1	1	1		
P-303	2nd Stage Fermentor Recirculation Pump No. 2	1	1		

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SECTION A300
SOLIDS CONTAINING PRODUCTION FERMENTATION

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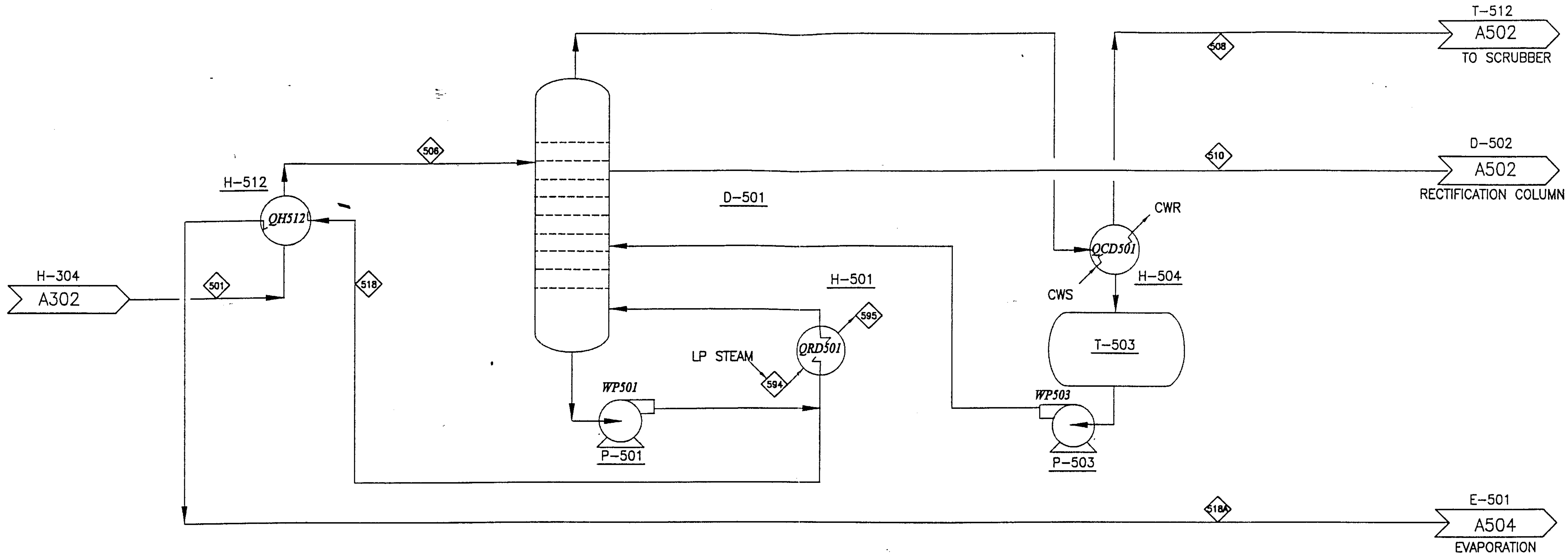

COMPONENT	UNITS	501	506	508	510	518	518A	594	595
Total Flow	kg/hr	141,594	141,594	170	18,609	122,815	122,815	19,926	19,926
Insoluble Solids	%	10.5%	10.5%	0.0%	0.0%	12.2%	12.2%	0.0%	0.0%
Soluble Solids	%	1.8%	1.8%	0.0%	0.2%	2.0%	2.0%	0.0%	0.0%
Temperature	C	95	100	60	114	122	117	149	148
Pressure	atm	4.00	4.76	1.86	1.93	2.10	2.10	4.42	4.42
Vapor Fraction		0.00	0.00	1.00	1.00	0.00	0.00	1.00	0.00
Ethanol	kg/hr	7,187	7,187	19	7,115	54	54		
Water	kg/hr	112,158	112,158	7	11,188	100,963	100,963	19,926	19,926
Glucose (SS)	kg/hr	853	853	0	0	853	853		
Mannose (SS)	kg/hr	49	49	0	0	49	49		
Xylose (SS)	kg/hr	51	51	0	0	51	51		
Other Sugars (SS)	kg/hr	621	621	0	0	621	621		
Cellobiose (SS)	kg/hr	534	534	0	0	534	534		
Glucose Oligomers (SS)	kg/hr	27	27	0	0	27	27		
Xylose Oligomers (SS)	kg/hr	3	3	0	0	3	3		
Other Oligomers (SS)	kg/hr								
Corn Steep Liquor (SS)	kg/hr	388	388	0	39	349	349		
Others (Soluble Solids)	kg/hr								
Extractives	kg/hr	2,112	2,112	0	0	2,112	2,112		
Acetic Acid	kg/hr	757	757	0	38	720	720		
Sulfuric Acid	kg/hr								
Furfural	kg/hr	44	44	0	23	20	20		
HMF	kg/hr	341	341	0	182	158	158		
Carbon Dioxide	kg/hr	167	167	143	24				
Methane	kg/hr								
Oxygen	kg/hr	0	0	0	0				
Nitrogm	kg/hr	0	0	0	0	0	0		
Ammonia	kg/hr	1	1	1	0				
NH4)H	kg/hr								
Others	kg/hr	1,377	1,377	0	1	1,376	1,376		
Cellulose (IS)	kg/hr	3,424	3,424			3,424	3,424		
Mannan (IS)	kg/hr								
Galactan (IS)	kg/hr	164	164			164	164		
Xylan (IS)	kg/hr	469	469			469	469		
Arabinan (IS)	kg/hr	10	10			10	10		
Yeast (IS)	kg/hr	45	45			45	45		
Biomass (IS)	kg/hr								
Extract Solids (IS)	kg/hr								
Lignin (IS)	kg/hr	9,458	9,458			9,458	9,458		
Gypsum (IS)	kg/hr	1,057	1,057			1,057	1,057		
Ca(OH)2 (IS)	kg/hr								
Others (Insoluble Solids)	kg/hr	298	298			298	298		
Enthalpy Flow (millions)	Kcal/hr	-477.9	-477.2	-0.4	-44.1	-422.6	-423.3	-62.8	-72.9
Average Density	g/ml	0.825	0.820	0.003	0.001	0.988	0.993	0.002	0.865

Eq. No.	Equipment Name	Req.	Spare	Equipment Type	Mat Const.
D-501	Beer Column	1	0	DISTILLATION	CS
H-501	Beer Column Reboiler	1	0	SHELL-TUBE	CS;A214
H-504	Beer Column Reflux Condenser	1	0	SHELL-TUBE	CS;A214
H-512	Beer Column Feed Interchange	2	0	SHELL-TUBE	CS;A214
P-501	Beer Column Reboiler/Bottoms Pump	2	1	CENTRIFUGAL	CS
P-503	Beer Column Reflux Pump	2	1	CENTRIFUGAL	CS
T-503	Beer Column Relfux Drum	1	0	HORIZONTAL-VESSEL	CS

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NREL NATIONAL RENEWABLE ENERGY LABORATORY
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SECTION A500
BEER DISTILLATION

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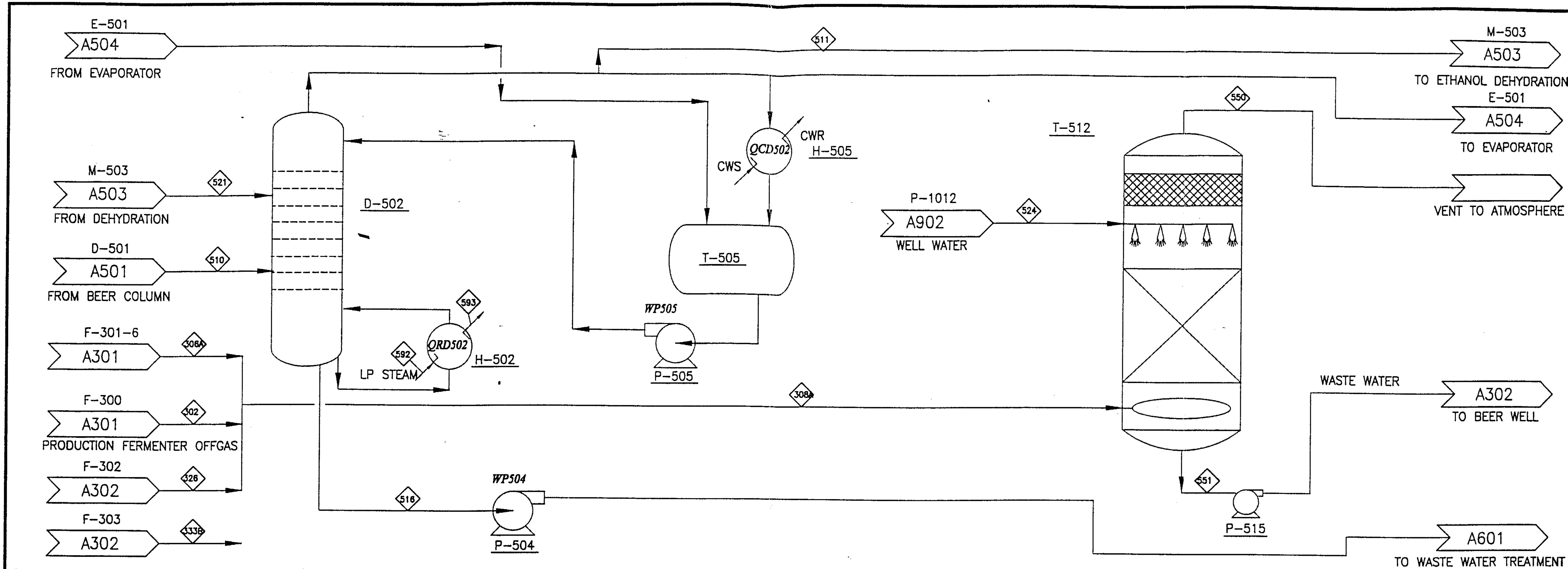

COMPONENT	UNITS	302	306A	308A	326	333B	510	511	516	521	524	550	551	592	593
Total Flow	kg/hr	2,819	203	7,785	4,763	0	18,609	9,618	11,465	2,473	5,310	7,740	5,524	2,599	2,599
Insoluble Solids	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Soluble Solids	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Temperature	C	32	32	32	32		114	92	121	70	13	21	31	149	148
Pressure	atm	1.00	1.00	1.00	1.00	1.00	1.93	1.70	8.05	1.53	1.00	0.90	0.90	4.42	4.42
Vapor Fraction		1.00	1.00	1.00	1.00	0.00	1.00	1.00	0.00	0.00	0.00	1.00	0.00	1.00	0.00
Ethanol	kg/hr	24	2	112	87		7,115	8,896	6	1,787		5	126		
Water	kg/hr	72	4	167	91		11,188	721	11,152	686	5,310	97	5,387	2,599	2,599
Glucose (SS)	kg/hr						0		0						
Mannose (SS)	kg/hr						0		0						
Xylose (SS)	kg/hr						0		0						
Other Sugars (SS)	kg/hr						0		0						
Cellobiose (SS)	kg/hr						0		0						
Glucose Oligomers (SS)	kg/hr						0		0						
Xylose Oligomers (SS)	kg/hr						0		0						
Other Oligomers (SS)	kg/hr														
Corn Steep Liquor (SS)	kg/hr	0	0	1	0		39		39			0	1		
Others (Soluble Solids)	kg/hr														
Extractives	kg/hr						0		0						
Acetic Acid	kg/hr	0	0	1	0		38		38			0	1		
Sulfuric Acid	kg/hr														
Furfural	kg/hr	0	0	0	0		23		23			0	0		
HMF	kg/hr	2	0	4	2		182		182			0	4		
Carbon Dioxide	kg/hr	1,917	185	6,668	4,566		24		24			6,806	5		
Methane	kg/hr														
Oxygen	kg/hr	97	0	106	9		0		0			106	0		
Nitrogrn	kg/hr	281	0	281	0		0		0			281	0		
Ammonia	kg/hr	426	12	445	7		0		0			445	0		
NH4)H	kg/hr														
Others	kg/hr	0	0	0	0		1		1			0	0		
Cellulose (IS)	kg/hr														
Mannan (IS)	kg/hr														
Galactan (IS)	kg/hr														
Xylan (IS)	kg/hr														
Arabinan (IS)	kg/hr														
Yeast (IS)	kg/hr														
Biomass (IS)	kg/hr														
Extract Solids (IS)	kg/hr														
Lignin (IS)	kg/hr														
Gypsum (IS)	kg/hr														
Ca(OH)2 (IS)	kg/hr														
Others (Insoluble Solids)	kg/hr														
Enthalpy Flow (millions)	Kcal/hr	-4.6	-0.4	-15.2	-10.1		-44.1	-12.9	-41.5	-5.1	-20.2	-15.1	-20.6	-8.2	-9.5
Average Density	g/ml	0.001	0.002	0.002	0.002	0.000	0.001	0.002	0.901	0.780	1.005	0.001	0.982	0.002	0.865

Eq. No.	Equipment Name	Req.	Spare	Equipment Type	Mat Const.
D-502	Rectification Column	1	0	DISTILLATION	CS
H-502	Rectification Column Reboiler	1	0	SHELL-TUBE	CS;A214
H-505	Rectification Column Condenser	1	0	SHELL-TUBE	CS
P-504	Rectification Column Bottoms Pump	2	1	CENTRIFUGAL	CS
P-505	Rectification Column Reflux Pump	2	1	CENTRIFUGAL	CS
P-515					
T-505	Rectification Column Reflux Drum	1	0	HORIZONTAL-VESSEL	CS
T-512					

VER.	DESCRIPTION	DATE
A	INITIAL MERRICK DESIGN	10/98

NREL NATIONAL RENEWABLE ENERGY LABORATORY
Biotechnology Center For Fuels And Chemicals

SECTION A500
RECTIFICATION DISTILL. & VENT SCRUBBER

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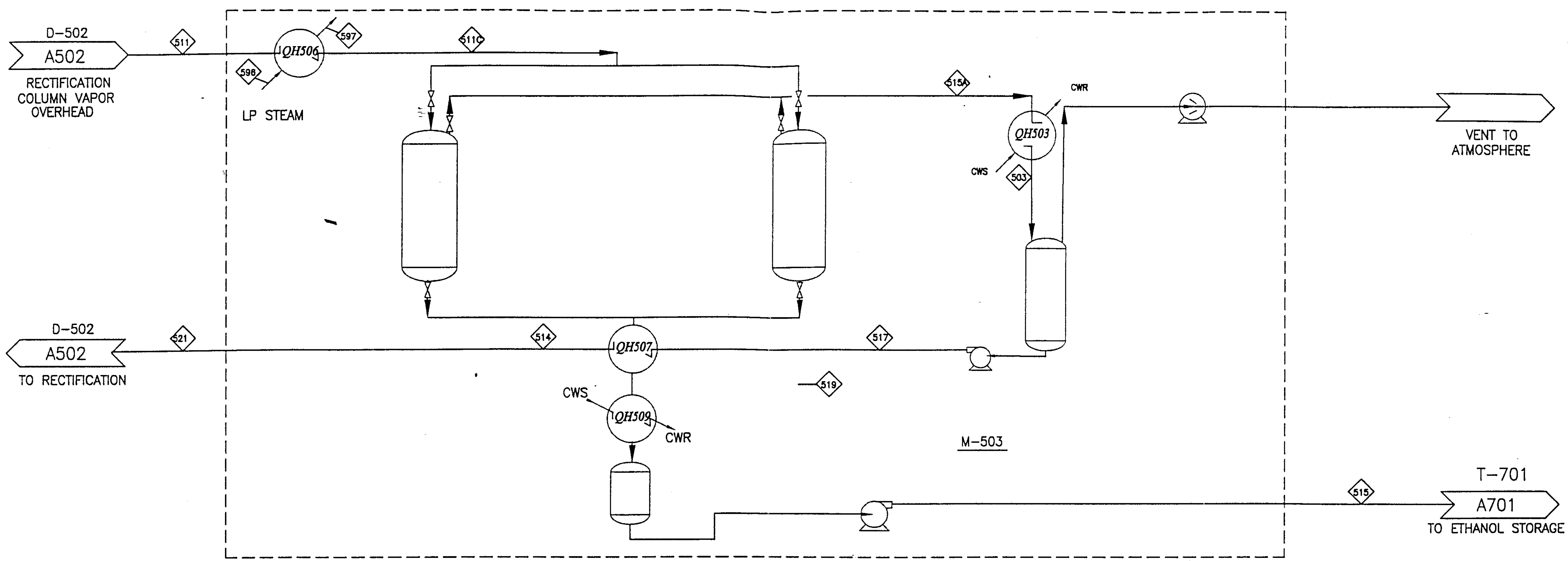

COMPONENT	UNITS	503	511	511C	514	515	517	519	521	596	597
Total Flow	kg/hr	141,594	9,618	9,618	7,144	7,144	2,473	7,144	2,473	182	182
Insoluble Solids	%	10.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Soluble Solids	%	1.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Temperature	C	32	92	116	116	38	35	92	70	149	148
Pressure	atm	0.90	1.70	1.70	1.70	1.00	0.14	1.44	1.53	4.42	4.42
Vapor Fraction		0.00	1.00	1.00	1.00	0.00	0.00	1.00	0.00	1.00	0.00
Ethanol	kg/hr	7,187	8,896	8,896	7,109	7,109	1,787	7,109	1,787		
Water	kg/hr	112,158	721	721	35	35	686	35	686	182	182
Glucose (SS)	kg/hr	853									
Mannose (SS)	kg/hr	49									
Xylose (SS)	kg/hr	51									
Other Sugars (SS)	kg/hr	621									
Cellobiose (SS)	kg/hr	534									
Glucose Oligomers (SS)	kg/hr	27									
Xylose Oligomers (SS)	kg/hr	3									
Other Oligomers (SS)	kg/hr										
Corn Steep Liquor (SS)	kg/hr	388									
Others (Soluble Solids)	kg/hr										
Extractives	kg/hr	2,112									
Acetic Acid	kg/hr	757									
Sulfuric Acid	kg/hr										
Furfural	kg/hr	44									
HMF	kg/hr	341									
Carbon Dioxide	kg/hr	167									
Methane	kg/hr										
Oxygen	kg/hr	0									
Nitrogrn	kg/hr	0									
Ammonia	kg/hr	1									
NH4)H	kg/hr										
Others	kg/hr	1,377									
Cellulose (IS)	kg/hr	3,424									
Mannan (IS)	kg/hr										
Galactan (IS)	kg/hr	164									
Xylan (IS)	kg/hr	469									
Arabinan (IS)	kg/hr	10									
Yeast (IS)	kg/hr	45									
Biomass (IS)	kg/hr										
Extract Solids (IS)	kg/hr										
Lignin (IS)	kg/hr	9,458									
Gypsum (IS)	kg/hr	1,057									
Ca(OH)2 (IS)	kg/hr										
Others (Insoluble Solids)	kg/hr	298									
Enthalpy Flow (millions)	Kcal/hr	-485.7	-12.9	-12.8	-8.5	-10.3	-5.1	-8.6	-5.1	-0.6	-0.7
Average Density	g/ml	0.812	0.002	0.002	0.002	0.757	0.821	0.002	0.780	0.002	0.865

Eq. No.	Equipment Name	Req.	Spare	Equipment Type	Mat Const.
M-503	Molecular Sieve	1	0	PACKAGE	CS

VER.	DESCRIPTION	DATE
A	INITIAL MERRICK DESIGN	10/98

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Biotechnology Center For Fuels And Chemicals

SECTION A500
ETHANOL DEHYDRATION

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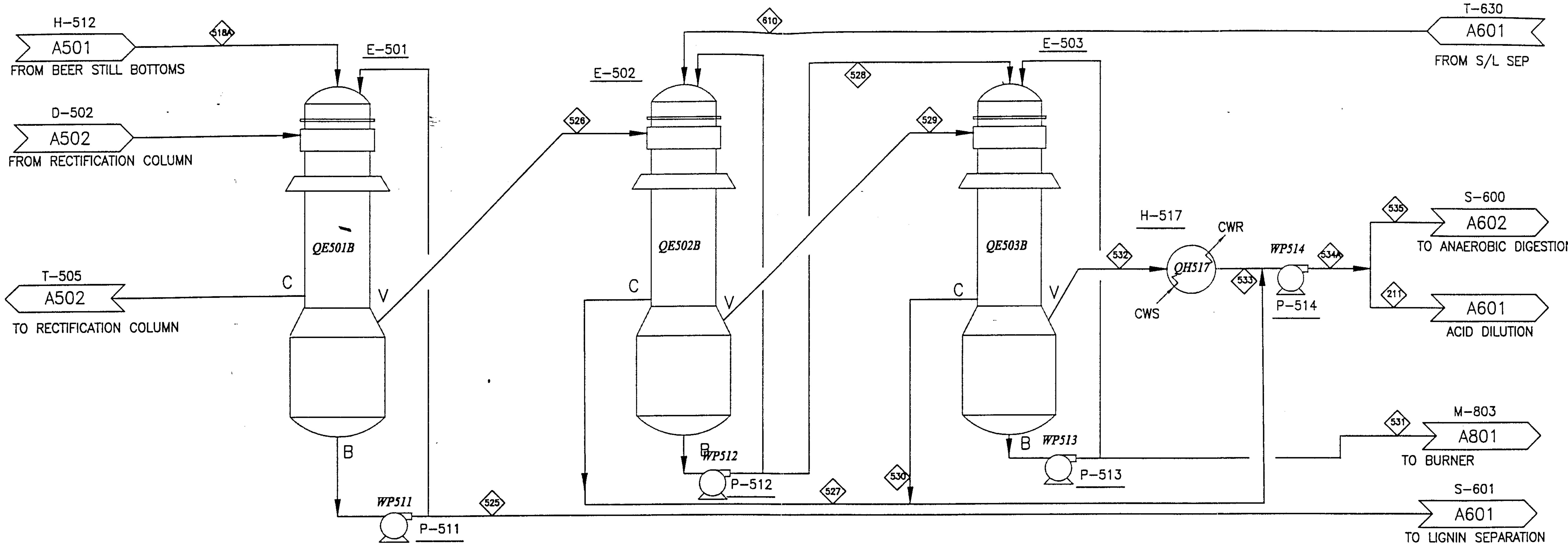

COMPONENT	UNITS	211	518A	525	526	527	528	529	530	531	532	533	534A	535	610
Total Flow	kg/hr	46,537	1	46,537	122,815	103,696	19,119	19,119	24,808	16,406	16,406	8,626	16,182	16,182	51,707
Insoluble Solids	%	0.0%	0.0%	0.0%	12.2%	14.4%	0.0%	0.0%	0.9%	0.0%	0.0%	2.6%	0.0%	0.0%	0.0%
Soluble Solids	%	0.1%	0.0%	0.1%	2.0%	2.3%	0.3%	0.3%	2.4%	0.0%	0.0%	6.9%	0.0%	0.0%	0.1%
Temperature	C	74	25	74	117	86	86	86	70	70	70	63	63	63	74
Pressure	atm	3.00	4.00	3.00	2.10	0.59	0.59	0.60	0.30	0.30	0.31	0.21	0.21	0.23	2.00
Vapor Fraction		0.00	1.00	0.00	0.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00
Ethanol	kg/hr	41		41	54	15	39	39	1	6	6	0	1	1	46
Water	kg/hr	46,156		46,156	100,963	82,090	18,873	18,873	21,644	16,333	16,333	5,565	16,079	16,079	51,285
Glucose (SS)	kg/hr				853	853									
Mannose (SS)	kg/hr				49	49			23			23			
Xylose (SS)	kg/hr				51	51			24			24			
Other Sugars (SS)	kg/hr	0		0	621	621	0	0	287			287	0	0	0
Cellobiose (SS)	kg/hr				534	534			247			247			
Glucose Oligomers (SS)	kg/hr				27	27			12			12			
Xylose Oligomers (SS)	kg/hr				3	3			1			1			
Other Oligomers (SS)	kg/hr														
Corn Steep Liquor (SS)	kg/hr	59		59	349	284	65	65							65
Others (Soluble Solids)	kg/hr														
Extractives	kg/hr				2,112	2,112			1,426			1,426			
Acetic Acid	kg/hr	151		151	720	688	32	32	279	39	39	183	96	96	168
Sulfuric Acid	kg/hr														
Furfural	kg/hr	14		14	20	8	12	12	1	3	3	0	1	1	16
HMF	kg/hr	112		112	158	62	96	96	5	24	24	0	4	4	125
Carbon Dioxide	kg/hr														
Methane	kg/hr		1												
Oxygen	kg/hr														
Nitrogrn	kg/hr				0										
Ammonia	kg/hr														
NH4)H	kg/hr														
Others	kg/hr	3		3	1,376	1,375	1	1	636	1	1	634	2	2	3
Cellulose (IS)	kg/hr				3,424	3,424			51			51			
Mannan (IS)	kg/hr														
Galactan (IS)	kg/hr				164	164			2			2			
Xylan (IS)	kg/hr				469	469			7			7			
Arabinan (IS)	kg/hr				10	10			0			0			
Yeast (IS)	kg/hr				45	45			1			1			
Biomass (IS)	kg/hr														
Extract Solids (IS)	kg/hr														
Lignin (IS)	kg/hr				9,458	9,458			142			142			
Gypsum (IS)	kg/hr				1,057	1,057			16			16			
Ca(OH)2 (IS)	kg/hr														
Others (Insoluble Solids)	kg/hr				298	298			4			4			
Enthalpy Flow (millions)	Kcal/hr	-173.3	0.0	-173.3	-423.3	-356.5	-60.4	-70.8	-86.5	-52.2	-61.2	-26.1	-51.5	-60.5	-192.5
Average Density	g/ml	0.946	0.003	0.946	0.993	1.030	0.000	0.934	0.987	0.000	0.949	1.073	0.000	0.956	0.946

Eq. No.	Equipment Name	Req.	Spare	Equipment Type	Mat Const.
E-501	1st Effect Evaporation	2	0		
E-502	2nd Effect Evaporation	2	0		
E-503	3rd Effect Evaporation	2	0		
H-517	Evaporator Condenser	2	0		
P-511	1st Effect Pump	2	0		
P-512	2nd Effect Pump	2	0		
P-513	3rd Effect Pump	2	0		
P-514	Condensate Pump	2	0		

VER.	DESCRIPTION	DATE
A	INITIAL MERRICK DESIGN	10/98

NATIONAL RENEWABLE ENERGY LABORATORY
Biotechnology Center For Fuels And Chemicals

SECTION A500
EVAPORATOR

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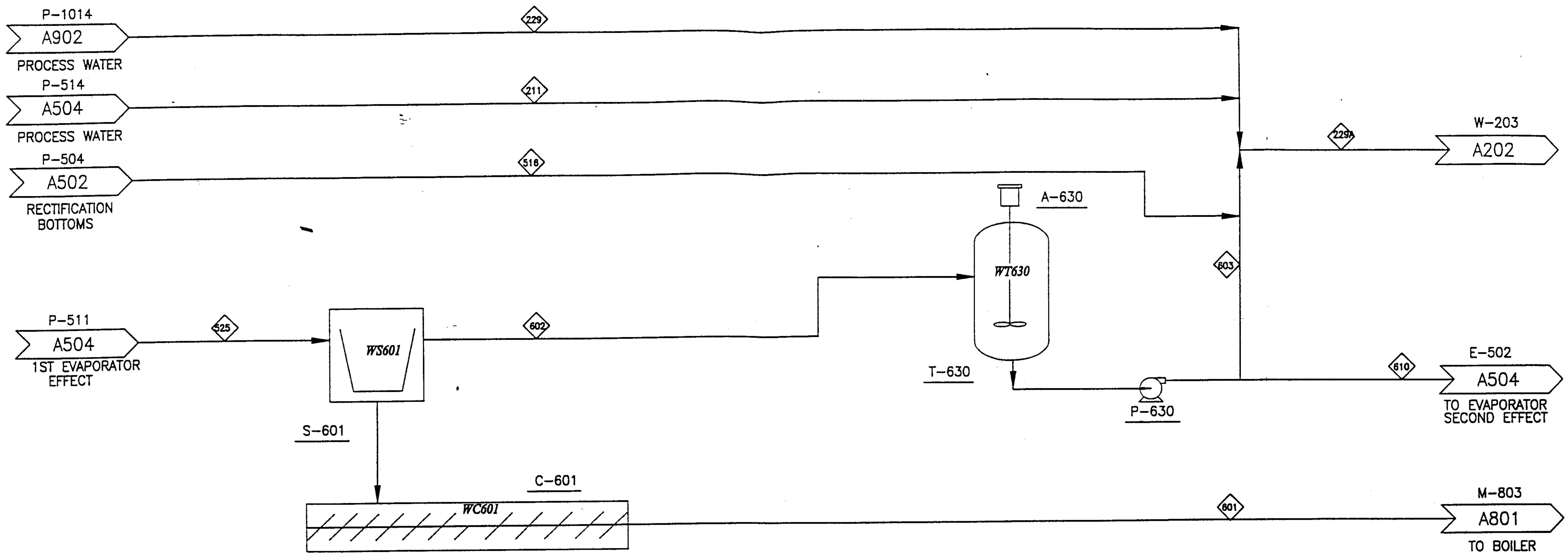

COMPONENT	UNITS	211	229	229A	516	525	601	602	603	610
Total Flow	kg/hr	46,537	29,407	101,147	11,465	103,698	48,743	54,952	13,738	41,214
Insoluble Solids	%	0.0%	0.0%	0.1%	0.0%	14.4%	30.0%	0.5%	0.5%	0.5%
Soluble Solids	%	0.1%	0.0%	0.3%	0.3%	2.3%	3.3%	1.4%	1.4%	1.4%
Temperature	C	74	20	60	121	86	40	40	40	40
Pressure	atm	3.00	1.01	1.01	8.05	0.59	3.20	3.20	3.20	3.20
Vapor Fraction		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ethanol	kg/hr	41		49	6	15	6	9	2	7
Water	kg/hr	46,156	29,407	99,375	11,152	82,090	31,454	50,636	12,659	37,977
Glucose (SS)	kg/hr			0	0	853	853			
Mannose (SS)	kg/hr			8	0	49	19	30	8	23
Xylose (SS)	kg/hr			8	0	51	20	32	8	24
Other Sugars (SS)	kg/hr	0		96	0	621	238	383	96	287
Cellobiose (SS)	kg/hr			82	0	534	204	329	82	247
Glucose Oligomers (SS)	kg/hr			4	0	27	10	16	4	12
Xylose Oligomers (SS)	kg/hr			0	0	3	1	2	0	1
Other Oligomers (SS)	kg/hr									
Corn Steep Liquor (SS)	kg/hr	59		98	39	284	284			
Others (Soluble Solids)	kg/hr									
Extractives	kg/hr			475	0	2,112	211	1,901	475	1,426
Acetic Acid	kg/hr	151		295	38	688	263	424	106	318
Sulfuric Acid	kg/hr									
Furfural	kg/hr	14		39	23	8	3	5	1	4
HMF	kg/hr	112		304	182	62	24	38	10	29
Carbon Dioxide	kg/hr			24	24					
Methane	kg/hr									
Oxygen	kg/hr			0	0					
Nitrogm	kg/hr			0	0					
Ammonia	kg/hr			0	0					
NH4)H	kg/hr									
Others	kg/hr	3		216	1	1,375	527	848	212	636
Cellulose (IS)	kg/hr			17		3,424	3,355	68	17	51
Mannan (IS)	kg/hr									
Galactan (IS)	kg/hr			1		164	161	3	1	2
Xylan (IS)	kg/hr			2		469	460	9	2	7
Arabinan (IS)	kg/hr			0		10	10	0	0	0
Yeast (IS)	kg/hr			0		45	44	1	0	1
Biomass (IS)	kg/hr									
Extract Solids (IS)	kg/hr									
Lignin (IS)	kg/hr			47		9,458	9,269	189	47	142
Gypsum (IS)	kg/hr			5		1,057	1,036	21	5	16
Ca(OH)2 (IS)	kg/hr									
Others (Insoluble Solids)	kg/hr			1		298	292	8	1	4
Enthalpy Flow (millions)	Kcal/hr	-173.3	-111.5	-375.9	-41.5	-356.5	-161.8	-198.4	-49.6	-148.8
Average Density	g/ml	0.946	0.998	0.962	0.901	1.030	0.698	0.994	0.994	1.006

Eq. No.	Equipment Name	Req.	Spare	Equipment Type	Mat Const.
A-630	Recycled Water Tank Agitator	1	0	FIXED-PROP	CS
C-601	Sludge Screw	2	0	SCREW	CS
P-630	Recycled Water Pump	2	1	CENTRIFUGAL	CS
S-601	Beer Column Bottoms Centrifuge	4	0	CENTRIFUGE	A285C
T-630	Recycled Water Tank	1	0	VERTICAL-VESSEL	A285C

VER.	DESCRIPTION	DATE
A	INITIAL MERRICK DESIGN	10/98

NREL NATIONAL RENEWABLE ENERGY LAORATORY
Biotechnology Center For Fuels And Chemicals

SECTION A600
LIGNIN SEPARATION & RECYCLE

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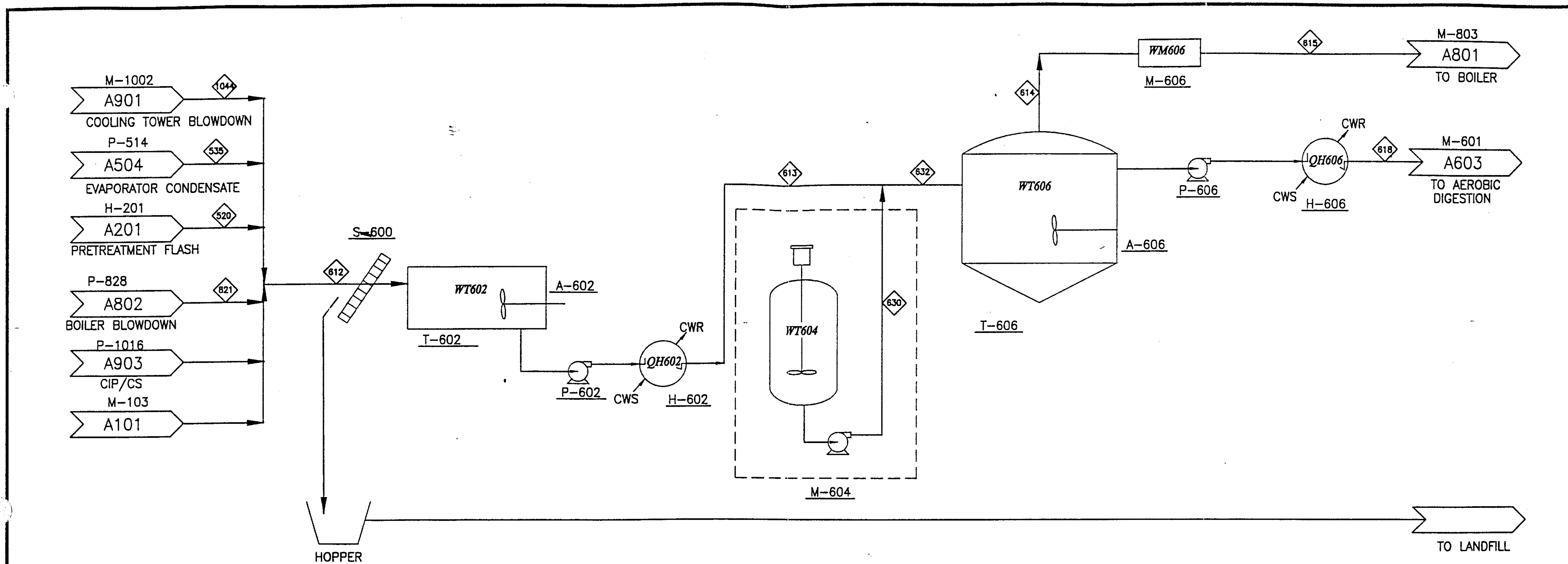


COMPONENT	UNITS	520	535	612	613	614	615	618	630	632	821	1044
Total Flow	kg/hr	1	55,237	5,171	93,925	93,925	993	993	91	94,016	2,900	30,618
Insoluble Solids	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Soluble Solids	%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Temperature	C	25	67	74	121	35	35	123	20	35	321	28
Pressure	atm	4.00	0.27	3.00	2.00	2.00	1.00	2.36	1.00	1.00	112.62	1.00
Vapor Fraction		1.00	0.77	0.00	0.36	0.00	1.00	1.00	0.00	0.00	0.00	0.00
Ethanol	kg/hr		1	5	6	6	0	0		6		
Water	kg/hr		53,641	5,128	92,287	92,287	44	44		92,287	2,900	30,618
Glucose (SS)	kg/hr											
Mannose (SS)	kg/hr											
Xylose (SS)	kg/hr		0		0	0				0		
Other Sugars (SS)	kg/hr		0	0	0	0				0		
Cellobiose (SS)	kg/hr											
Glucose Oligomers (SS)	kg/hr											
Xylose Oligomers (SS)	kg/hr		0		0	0				0		
Other Oligomers (SS)	kg/hr											
Corn Steep Liquor (SS)	kg/hr		1	7	8	8	0	0		8		
Others (Soluble Solids)	kg/hr											
Extractives	kg/hr											
Acetic Acid	kg/hr		65	17	82	82	0	0		82		
Sulfuric Acid	kg/hr		4		4	4				4		
Furfural	kg/hr		173	2	174	174	0	0		174		
HMF	kg/hr		1,351	12	1,363	1,363	1	1		1,363		
Carbon Dioxide	kg/hr		0		0	0	441	441		0		
Methane	kg/hr	1					507	507				
Oxygen	kg/hr		0		0	0	0	0		0		
Nitrogm	kg/hr		0		0	0	0	0		0		
Ammonia	kg/hr		0		0	0	0	0		0		
NH4)H	kg/hr											
Others	kg/hr		1	0	1	1	0	0	91	91		
Cellulose (IS)	kg/hr											
Mannan (IS)	kg/hr											
Galactan (IS)	kg/hr											
Xylan (IS)	kg/hr											
Arabinan (IS)	kg/hr											
Yeast (IS)	kg/hr											
Biomass (IS)	kg/hr											
Extract Solids (IS)	kg/hr											
Lignin (IS)	kg/hr											
Gypsum (IS)	kg/hr											
Ca(OH)2 (IS)	kg/hr											
Others (Insoluble Solids)	kg/hr											
Enthalpy Flow (millions)	Kcal/hr	0.0	-178.4	-19.3	-323.6	-349.5	-1.6	-1.6	-0.3	-349.8	-10.0	-115.9
Average Density	g/ml	0.003	0.000	0.946	0.003	0.990	0.001	0.002	0.998	0.990	0.665	0.991

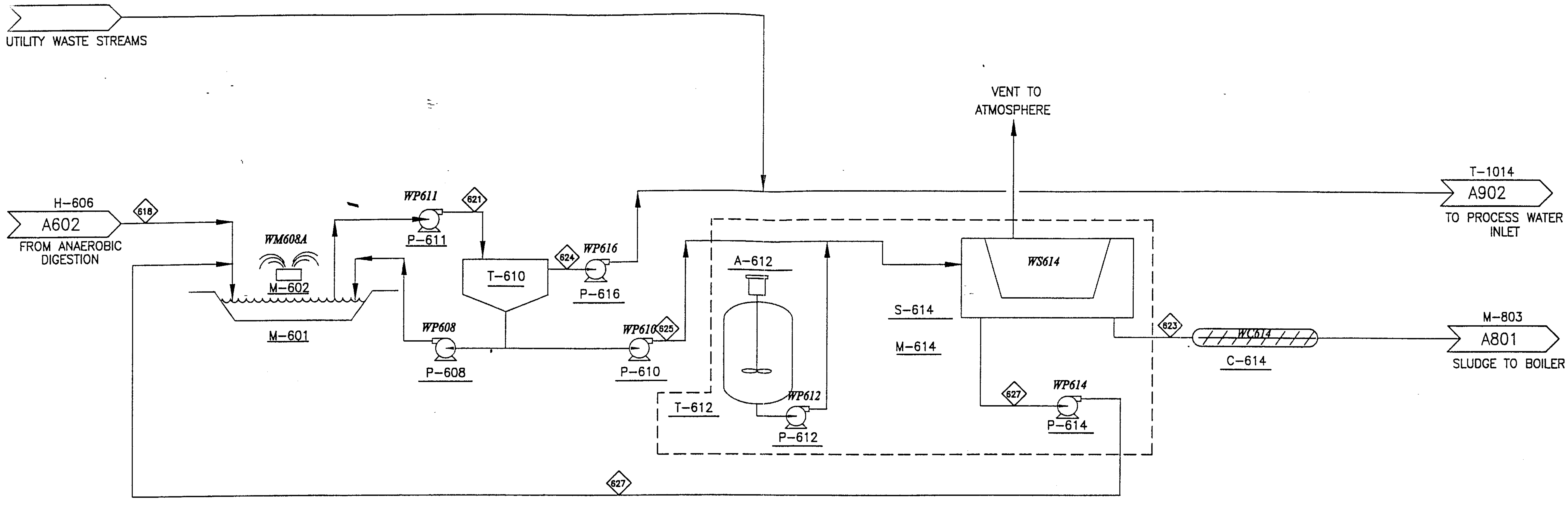
Eq. No.	Equipment Name	Req.	Spare	Equipment Type	Mat Const.
A-602	Equalization Basin Agitator	3	0	FIXED-PROP	A285C
A-606	Anaerobic Agitator	1	0	FIXED-PROP	A285C
H-602	Anaerobic Digestor Feed Cooler	1	0	SHELL-TUBE	CS
H-606	Aerobic Digestor Feed Cooler	1	0	SHELL-TUBE	CS
M-604	Nutrient Feed System	1	0	PACKAGE	CS
M-606	Biogas Handling System	1	0	PACKAGE	CS
P-602	Anaerobic Reactor Feed Pump	2	1	CENTRIFUGAL	CS
P-606	Aerobic Digestor Feed Pump	2	1	CENTRIFUGAL	CS
S-600	Bar Screen	1	0	SCREEN	CS
T-602	Equalization Basin	1	0	FLAT-BTM-STORAGE	A285C
T-606	Anaerobic Digestor	1	0	FLAT-BTM-STORAGE	A285C

VER.	DESCRIPTION	DATE
A	INITIAL MERRICK DESIGN	10/98

NREL NATIONAL RENEWABLE ENERGY LABORATORY
Biotechnology Center For Fuels And Chemicals

SECTION A600
ANAEROBIC DIGESTION

w9810d.xls | PFD-P300-A602 | A



COMPONENT	UNITS	618	621	623	624	625	627
Total Flow	kg/hr	93,023	93,640	335	91,664	1,976	1,642
Insoluble Solids	%	0.1%	0.1%	30.0%	0.0%	5.1%	0.0%
Soluble Solids	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Temperature	C	35	21	21	21	21	21
Pressure	atm	1.00	1.00	1.00	1.00	1.00	1.00
Vapor Fraction		0.00	0.00	0.00	0.00	0.00	0.00
Ethanol	kg/hr	0	0	0	0	0	0
Water	kg/hr	92,718	93,428	234	91,554	1,874	1,640
Glucose (SS)	kg/hr						
Mannose (SS)	kg/hr						
Xylose (SS)	kg/hr	0	0	0	0	0	0
Other Sugars (SS)	kg/hr	0	0	0	0	0	0
Cellobiose (SS)	kg/hr						
Glucose Oligomers (SS)	kg/hr						
Xylose Oligomers (SS)	kg/hr	0					
Other Oligomers (SS)	kg/hr						
Corn Steep Liquor (SS)	kg/hr	8	8	0	8	0	0
Others (Soluble Solids)	kg/hr						
Extractives	kg/hr						
Acetic Acid	kg/hr	6	1	0	1	0	0
Sulfuric Acid	kg/hr						
Furfural	kg/hr	12	1	0	1	0	0
HMF	kg/hr	95	8	0	8	0	0
Carbon Dioxide	kg/hr	25	0	0	0	0	0
Methane	kg/hr	1	0	0	0	0	0
Oxygen	kg/hr	0	1	0	1	0	0
Nitrogrn	kg/hr		1	0	1	0	0
Ammonia	kg/hr	0	0	0	0	0	0
NH4)H	kg/hr						
Others	kg/hr	92	92	0	90	2	2
Cellulose (IS)	kg/hr						
Mannan (IS)	kg/hr						
Galactan (IS)	kg/hr						
Xylan (IS)	kg/hr						
Arabinan (IS)	kg/hr						
Yeast (IS)	kg/hr						
Biomass (IS)	kg/hr	66	101	101		101	
Extract Solids (IS)	kg/hr						
Lignin (IS)	kg/hr						
Gypsum (IS)	kg/hr						
Ca(OH)2 (IS)	kg/hr						
Others (Insoluble Solids)	kg/hr						
Enthalpy Flow (millions)	Kcal/hr	-350.9	-354.7	-1.0	-347.5	-7.2	-6.2
Average Density	g/ml	0.985	0.999	0.698	0.997	0.947	0.997

Eq. No.	Equipment Name	Req.	Spare	Equipment Type	Mat Const.
A-608	Aerobic Digestor Agitator	2	0	FIXED-PROP	CS
A-612					
C-614	Sludge Screw	1	0	SCREW	CS
M-608	PSA O2 Generator	1	0	PACKAGE	CS
M-614	Belt Filter Press (5 pieces)	1	0	ROTARY-DRUM	A285C
P-608	Return Activated Sludge Pump	2	1	CENTRIFUGAL	CS
P-610	Waste Activated Sludge Pump	2	1	CENTRIFUGAL	CS
P-612					
P-614					
P-616					
S-614	Potable Water Pump	2	1	CENTRIFUGAL	CS
T-608	Aerobic Digestor	1	0	CONCRETE-STORAGE	CONCRETE
T-610	Clarifier	2	0	CLARIFIER	CONCRETE
T-612					

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SECTION A600
AEROBIC DIGESTION

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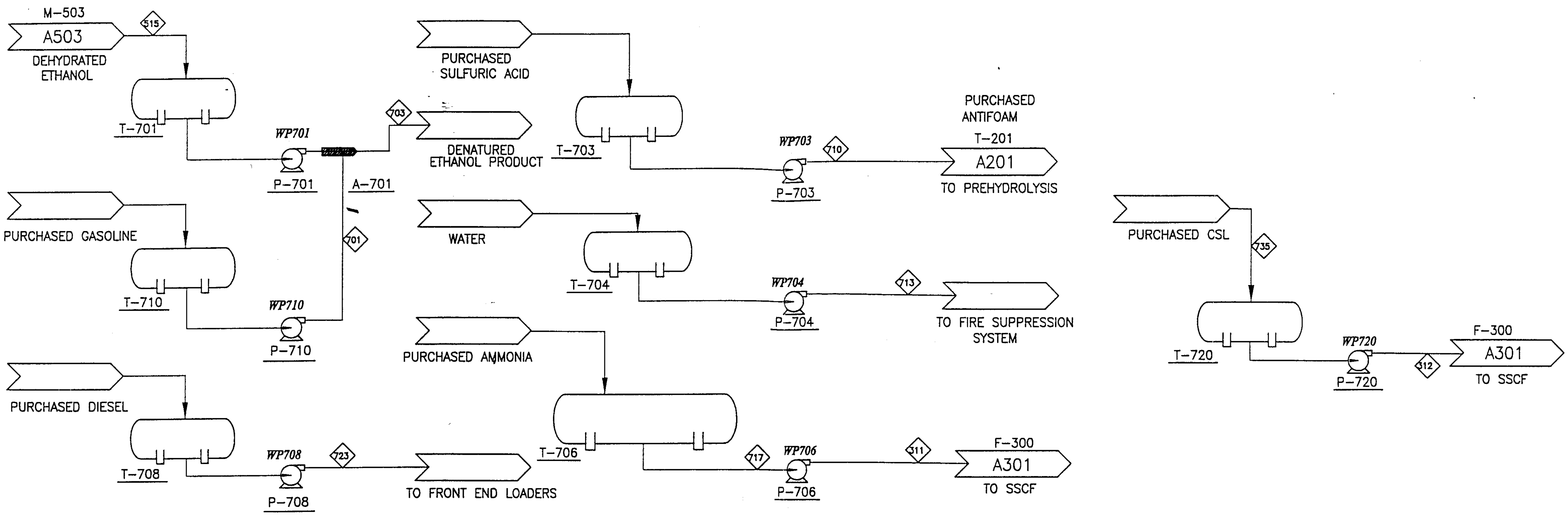

COMPONENT	UNITS	311	312	515	701	703	710	713	723	735
Total Flow	kg/hr	452	292	7,144	342	7,486	1,008	2,628	171	292
Insoluble Solids	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Soluble Solids	%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
Temperature	C	20	20	38	20	37	20	20	20	20
Pressure	atm	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Vapor Fraction		1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ethanol	kg/hr			7,109		7,109				
Water	kg/hr			35		35		2,628		
Glucose (SS)	kg/hr									
Mannose (SS)	kg/hr									
Xylose (SS)	kg/hr									
Other Sugars (SS)	kg/hr									
Cellobiose (SS)	kg/hr									
Glucose Oligomers (SS)	kg/hr									
Xylose Oligomers (SS)	kg/hr									
Other Oligomers (SS)	kg/hr									
Corn Steep Liquor (SS)	kg/hr		292							292
Others (Soluble Solids)	kg/hr									
Extractives	kg/hr									
Acetic Acid	kg/hr									
Sulfuric Acid	kg/hr						1,008			
Furfural	kg/hr									
HMF	kg/hr									
Carbon Dioxide	kg/hr									
Methane	kg/hr									
Oxygen	kg/hr									
Nitrogen	kg/hr									
Ammonia	kg/hr	452								
NH4)H	kg/hr									
Others	kg/hr				342	342			171	
Cellulose (IS)	kg/hr									
Mannan (IS)	kg/hr									
Galactan (IS)	kg/hr									
Xylan (IS)	kg/hr									
Arabinan (IS)	kg/hr									
Yeast (IS)	kg/hr									
Biomass (IS)	kg/hr									
Extract Solids (IS)	kg/hr									
Lignin (IS)	kg/hr									
Gypsum (IS)	kg/hr									
Ca(OH)2 (IS)	kg/hr									
Others (Insoluble Solids)	kg/hr									
Enthalpy Flow (millions)	Kcal/hr	-0.3	-1.1	-10.3	-0.2	-10.5	-1.9	-10.0	-0.1	-1.1
Average Density	g/ml	0.001	0.998	0.757	0.688	0.753	3.102	0.998	0.688	0.998

Eq. No.	Equipment Name	Req.	Spare	Equipment Type	Mat Const.
A-701	In-line Ethanol / Denaturant Mixer	1	0		
P-701	Ethanol Product Pump	2	1	CENTRIFUGAL	CS
P-703	Sulfuric Acid Pump	1	1	CENTRIFUGAL	SS304
P-704	Firewater Pump	1	1	CENTRIFUGAL	CS
P-706	Ammonia Pump	1	1	CENTRIFUGAL	CS
P-708	Diesel Pump	1	1	CENTRIFUGAL	CS
P-710	Gasoline Pump	1	1	CENTRIFUGAL	CS
P-720	CSL Pump	1	1	CENTRIFUGAL	CS
T-701	Ethanol Product Storage Tank	2	1	FLAT-BTM-STORAGE	A285C
T-703	Sulfuric Acid Storage Tank	1	0	FLAT-BTM-STORAGE	SS316
T-704	Firewater Storage Tank	1	0	FLAT-BTM-STORAGE	A285C
T-706	Ammonia Storage Tank	2	0	HORIZONTAL-STORAGE	A515
T-708	Diesel Storage Tank	1	0	FLAT-BTM-STORAGE	A285C
T-710	Gasoline Storage Tank	1	0	FLAT-BTM-STORAGE	A285C
T-720	CSL Storage Tank	1	0	HORIZONTAL-STORAGE	A285C

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SECTION A700
STORAGE

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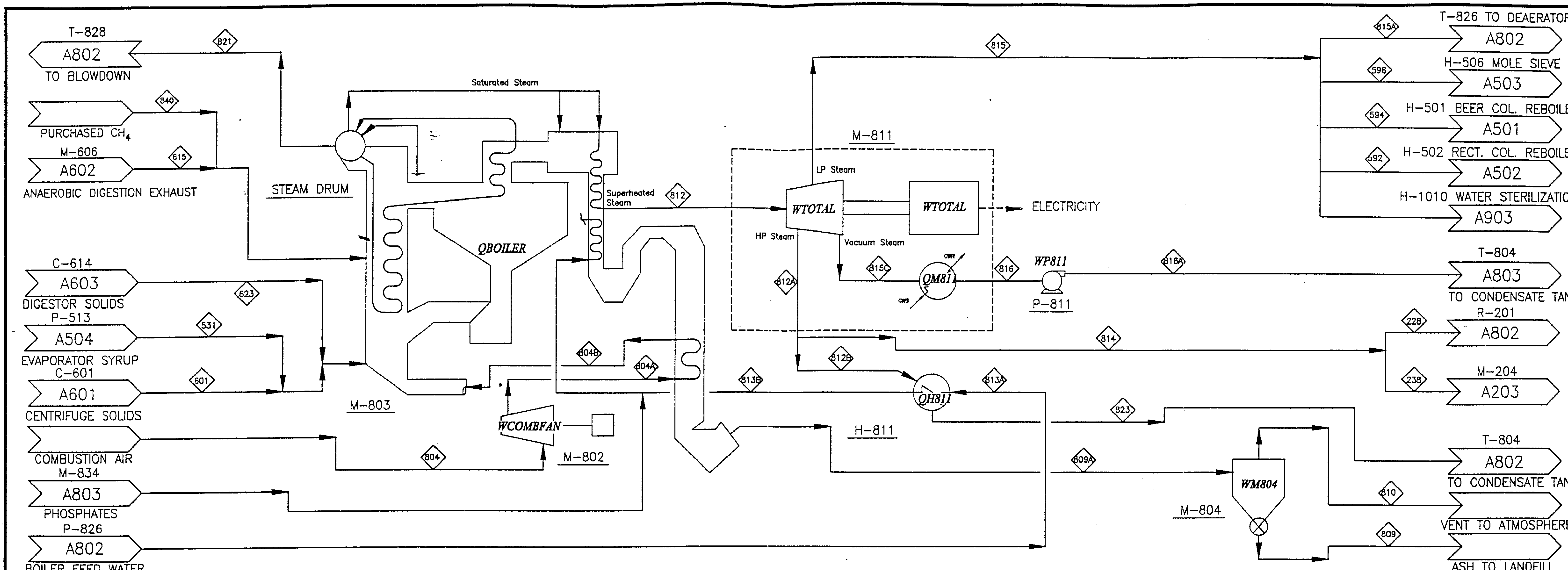

COMPONENT	UNITS	228	238	531	592	594	596	601	615	804	804A	804B
Total Flow	kg/hr	17,077	12,811	8,626	2,599	19,926	182	48,743	993	193,635	193,635	193,635
Insoluble Solids	%	0.0%	0.0%	2.6%	0.0%	0.0%	0.0%	30.0%	0.0%	0.0%	0.0%	0.0%
Soluble Solids	%	0.0%	0.0%	6.9%	0.0%	0.0%	0.0%	3.3%	0.0%	0.0%	0.0%	0.0%
Temperature	C	321	321	63	149	149	149	40	123	27	31	234
Pressure	atm	23.00	23.00	0.21	4.42	4.42	4.42	3.20	2.36	0.98	1.01	1.01
Vapor Fraction		1.00	1.00	0.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00
Ethanol	kg/hr			0				6	0			
Water	kg/hr	17,077	12,811	5,565	2,599	19,926	182	31,454	44	1,936	1,936	1,936
Glucose (SS)	kg/hr							853				
Mannose (SS)	kg/hr			23				19				
Xylose (SS)	kg/hr			24				20				
Other Sugars (SS)	kg/hr			287				238				
Cellobiose (SS)	kg/hr			247				204				
Glucose Oligomers (SS)	kg/hr			12				10				
Xylose Oligomers (SS)	kg/hr			1				1				
Other Oligomers (SS)	kg/hr											
Corn Steep Liquor (SS)	kg/hr							284	0			
Others (Soluble Solids)	kg/hr											
Extractives	kg/hr			1,426				211				
Acetic Acid	kg/hr			183				263	0			
Sulfuric Acid	kg/hr											
Furfural	kg/hr			0				3	0			
HMF	kg/hr			0				24	1			
Carbon Dioxide	kg/hr								441			
Methane	kg/hr								507			
Oxygen	kg/hr								0	44,420	44,420	44,420
Nitrogrn	kg/hr								0	147,279	147,279	147,279
Ammonia	kg/hr								0			
NH4)H	kg/hr											
Others	kg/hr			634				527	0			
Cellulose (IS)	kg/hr			51				3,355				
Mannan (IS)	kg/hr											
Galactan (IS)	kg/hr			2				161				
Xylan (IS)	kg/hr			7				460				
Arabinan (IS)	kg/hr			0				10				
Yeast (IS)	kg/hr			1				44				
Biomass (IS)	kg/hr											
Extract Solids (IS)	kg/hr											
Lignin (IS)	kg/hr			142				9,269				
Gypsum (IS)	kg/hr			16				1,036				
Ca(OH)2 (IS)	kg/hr											
Others (Insoluble Solids)	kg/hr			4				292				
Enthalpy Flow (millions)	Kcal/hr	-52.4	-39.3	-26.1	-8.2	-62.8	-0.6	-161.8	-1.6	-6.1	-5.9	3.7
Average Density	g/ml	0.009	0.009	1.073	0.002	0.002	0.002	0.698	0.002	0.001	0.001	0.001

COMPONENT	UNITS	809	809A	810	812	812A	812B	812C	813A	813B	814	815
Total Flow	kg/hr	1,560	252,334	250,773	93,763	93,763	5,346	5,346	96,661	96,661	29,888	22,707
Insoluble Solids	%	100.0%	0.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Soluble Solids	%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Temperature	C		149	149	510	321	321	321	141	168	321	170
Pressure	atm		0.18	0.18	103.09	23.00	23.00	23.00	125.00	124.32	23.00	4.42
Vapor Fraction		0.00	0.99	1.00	1.00	1.00	1.00	1.00	0.00	0.00	1.00	1.00
Ethanol	kg/hr		0	0								
Water	kg/hr		55,223	55,223	93,763	93,763	5,346	5,346	96,661	96,661	29,888	22,707
Glucose (SS)	kg/hr		13	13								
Mannose (SS)	kg/hr		1	1								
Xylose (SS)	kg/hr		1	1								
Other Sugars (SS)	kg/hr		8	8								
Cellobiose (SS)	kg/hr		7	7								
Glucose Oligomers (SS)	kg/hr		0	0								
Xylose Oligomers (SS)	kg/hr		0	0								
Other Oligomers (SS)	kg/hr											
Corn Steep Liquor (SS)	kg/hr		284	284								
Others (Soluble Solids)	kg/hr											
Extractives	kg/hr		26	26								
Acetic Acid	kg/hr		7	7								
Sulfuric Acid	kg/hr		0	0								
Furfural	kg/hr		0	0								
HMF	kg/hr		0	0								
Carbon Dioxide	kg/hr		40,446	40,446								
Methane	kg/hr		8	8								
Oxygen	kg/hr		7,403	7,403								
Nitrogrn	kg/hr		147,288	147,288								
Ammonia	kg/hr		0	0								
NH4)H	kg/hr											
Others	kg/hr		52	52								
Cellulose (IS)	kg/hr	53	54	0								
Mannan (IS)	kg/hr											
Galactan (IS)	kg/hr	3	3	0								
Xylan (IS)	kg/hr	7	7	0								
Arabinan (IS)	kg/hr	0	0	0								
Yeast (IS)	kg/hr	1	1	0								
Biomass (IS)	kg/hr	2	2	0								
Extract Solids (IS)	kg/hr											
Lignin (IS)	kg/hr	148	148	0								
Gypsum (IS)	kg/hr	1,049	1,052	3								
Ca(OH)2 (IS)	kg/hr											
Others (Insoluble Solids)	kg/hr	298	299	1								
Enthalpy Flow (millions)	Kcal/hr	-4.3	-259.8	-255.5	-281.7	-289.1	-16.5	-16.5	-354.9	-352.1	-92.1	-71.5
Average Density	g/ml		0.000	0.000	0.031	0.009	0.009	0.009	0.932	0.906	0.009	0.002

Eq. No.	Equipment Name	Req.	Spare	Equipment Type	Mat Const.
H-811	BFW Preheater	1	0	SHELL-TUBE	A285C;A214
M-802	Combustion Air Fan	1		CENTRIFUGAL	CS
M-803	Fluidized Bed Combustion Reactor	1	0	MISCELLANEOUS	CS
M-804	Combustion Gas Baghouse	1	0	FABRIC-FILTER	A285C;FABRIC
M-811	Turbine/Generator	1	0	STEAM-TURBINE	
P-811	Turbine Condensate Pump	2	1	CENTRIFUGAL	CS

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SECTION A800
COMBUSTOR AND TURBO GENERATOR

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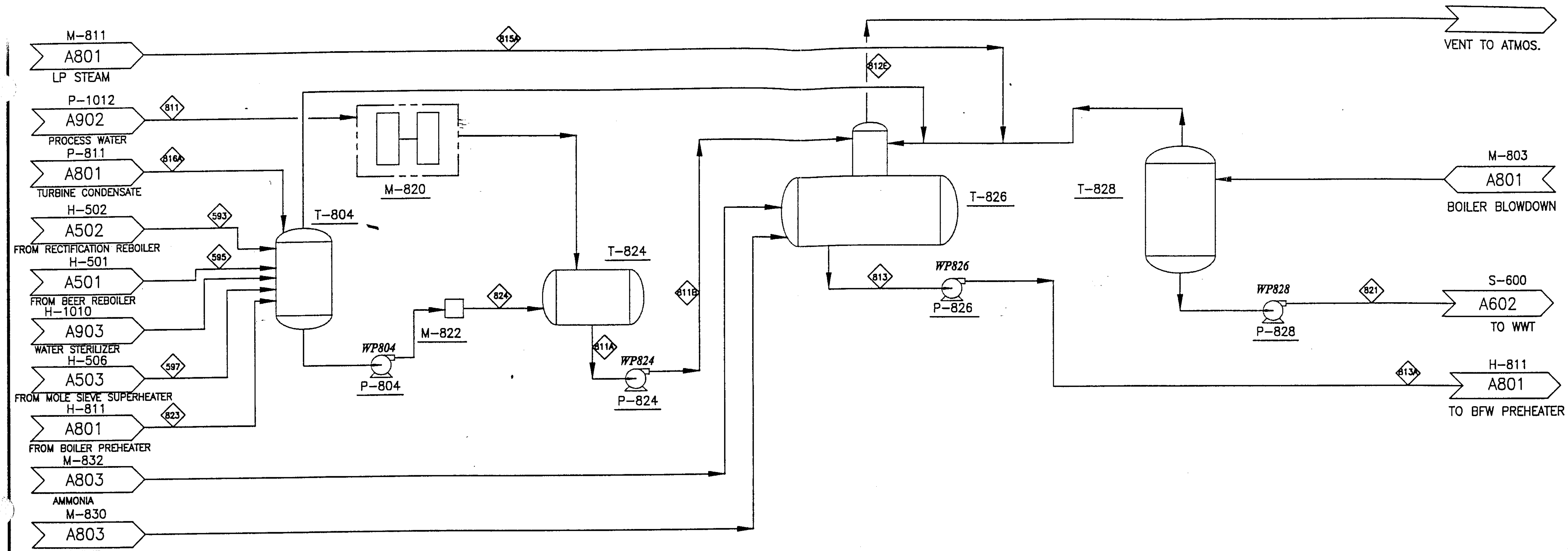

COMPONENT	UNITS	593	595	597	811	811A	811B	812E	813A	816A	821	823	824	823
Total Flow	kg/hr	2,599	19,926	182	32,788	85,056	85,056	0	96,661	24,217	2,900	5,346	22,705	5,346
Insoluble Solids	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Soluble Solids	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Temperature	C	148	148	148	20	67	67		141	49	321	219	116	219
Pressure	atm	4.42	4.42	4.42	3.40	1.70	3.40	3.40	125.00	4.20	112.62	22.32	1.70	22.32
Vapor Fraction		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ethanol	kg/hr													
Water	kg/hr	2,599	19,926	182	32,788	85,056	85,056		96,661	24,217	2,900	5,346	22,705	5,346
Glucose (SS)	kg/hr													
Mannose (SS)	kg/hr													
Xylose (SS)	kg/hr													
Other Sugars (SS)	kg/hr													
Cellobiose (SS)	kg/hr													
Glucose Oligomers (SS)	kg/hr													
Xylose Oligomers (SS)	kg/hr													
Other Oligomers (SS)	kg/hr													
Corn Steep Liquor (SS)	kg/hr													
Others (Soluble Solids)	kg/hr													
Extractives	kg/hr													
Acetic Acid	kg/hr													
Sulfuric Acid	kg/hr													
Furfural	kg/hr													
HMF	kg/hr													
Carbon Dioxide	kg/hr													
Methane	kg/hr													
Oxygen	kg/hr													
Nitrogen	kg/hr													
Ammonia	kg/hr													
NH4)H	kg/hr													
Others	kg/hr													
Cellulose (IS)	kg/hr													
Mannan (IS)	kg/hr													
Galactan (IS)	kg/hr													
Xylan (IS)	kg/hr													
Arabinan (IS)	kg/hr													
Yeast (IS)	kg/hr													
Biomass (IS)	kg/hr													
Extract Solids (IS)	kg/hr													
Lignin (IS)	kg/hr													
Gypsum (IS)	kg/hr													
Ca(OH)2 (IS)	kg/hr													
Others (Insoluble Solids)	kg/hr													
Enthalpy Flow (millions)	Kcal/hr	-9.5	-72.9	-0.7	-124.4	-318.8	-318.8		-354.9	-91.2	-10.0	-19.2	-84.0	-19.2
Average Density	g/ml	0.865	0.865	0.865	0.998	0.980	0.980		0.932	0.989	0.665	0.842	0.946	0.842

Eq. No.	Equipment Name	Req.	Spare	Equipment Type	Mat Const.
M-820	Demineralizer	2	0	PACKAGE	
M-822	Condensate Polisher	2	0	PACKAGE	
P-804	Condensate Pump	2	0	CENTRIFUGAL	CS
P-824	Deaerator Feed Pump	2	0	CENTRIFUGAL	CS
P-826	BFW Pump	2	0	CENTRIFUGAL	CS
P-828	Blowdown Pump	2	0	CENTRIFUGAL	CS
T-804	Condensate Collection Tank	1	0	VERTICAL-VESSEL	A285C
T-824	Condensate Surge Drum	1	0	HORIZONTAL-VESSEL	CS
T-826	Deaerator	1	0	HORIZONTAL-VESSEL	A515
T-828	Blowdown Flash Drum	1	0	HORIZONTAL-VESSEL	CS

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SECTION A800
BOILER FEED WATER PREPARATION

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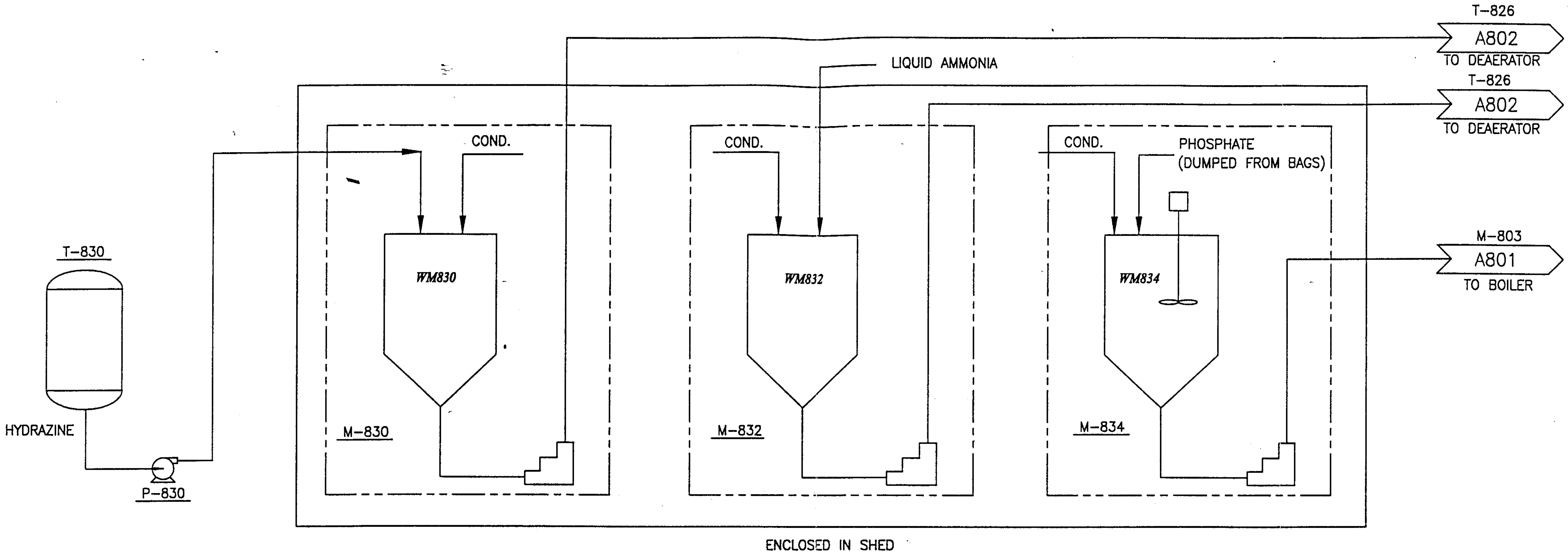

COMPONENT	UNITS
Total Flow	kg/hr
Insoluble Solids	%
Soluble Solids	%
Temperature	C
Pressure	atm
Vapor Fraction	
Ethanol	kg/hr
Water	kg/hr
Glucose (SS)	kg/hr
Mannose (SS)	kg/hr
Xylose (SS)	kg/hr
Other Sugars (SS)	kg/hr
Cellobiose (SS)	kg/hr
Glucose Oligomers (SS)	kg/hr
Xylose Oligomers (SS)	kg/hr
Other Oligomers (SS)	kg/hr
Corn Steep Liquor (SS)	kg/hr
Others (Soluble Solids)	kg/hr
Extractives	kg/hr
Acetic Acid	kg/hr
Sulfuric Acid	kg/hr
Furfural	kg/hr
HMF	kg/hr
Carbon Dioxide	kg/hr
Methane	kg/hr
Oxygen	kg/hr
Nitrogrn	kg/hr
Ammonia	kg/hr
NH4)H	kg/hr
Others	kg/hr
Cellulose (IS)	kg/hr
Mannan (IS)	kg/hr
Galactan (IS)	kg/hr
Xylan (IS)	kg/hr
Arabinan (IS)	kg/hr
Yeast (IS)	kg/hr
Biomass (IS)	kg/hr
Extract Solids (IS)	kg/hr
Lignin (IS)	kg/hr
Gypsum (IS)	kg/hr
Ca(OH)2 (IS)	kg/hr
Others (Insoluble Solids)	kg/hr
Enthalpy Flow (millions)	Kcal/hr
Average Density	g/ml

Eq. No.	Equipment Name	Req.	Spare	Equipment Type	Mat Const.
M-830	Hydrazine Addition Pkg.	1	0	PACKAGE	
M-832	Ammonia Addition Pkg	1	0	PACKAGE	
M-834	Phosphate Addition Pkg.	1	0	PACKAGE	
P-830	Hydrazine Transfer Pump	1	0	CENTRIFUGAL	CS
T-830	Hydrazine Drum	1	0	VERTICAL-VESSEL	SS316

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SECTION A800
BOILER FEED WATER CHEMICALS

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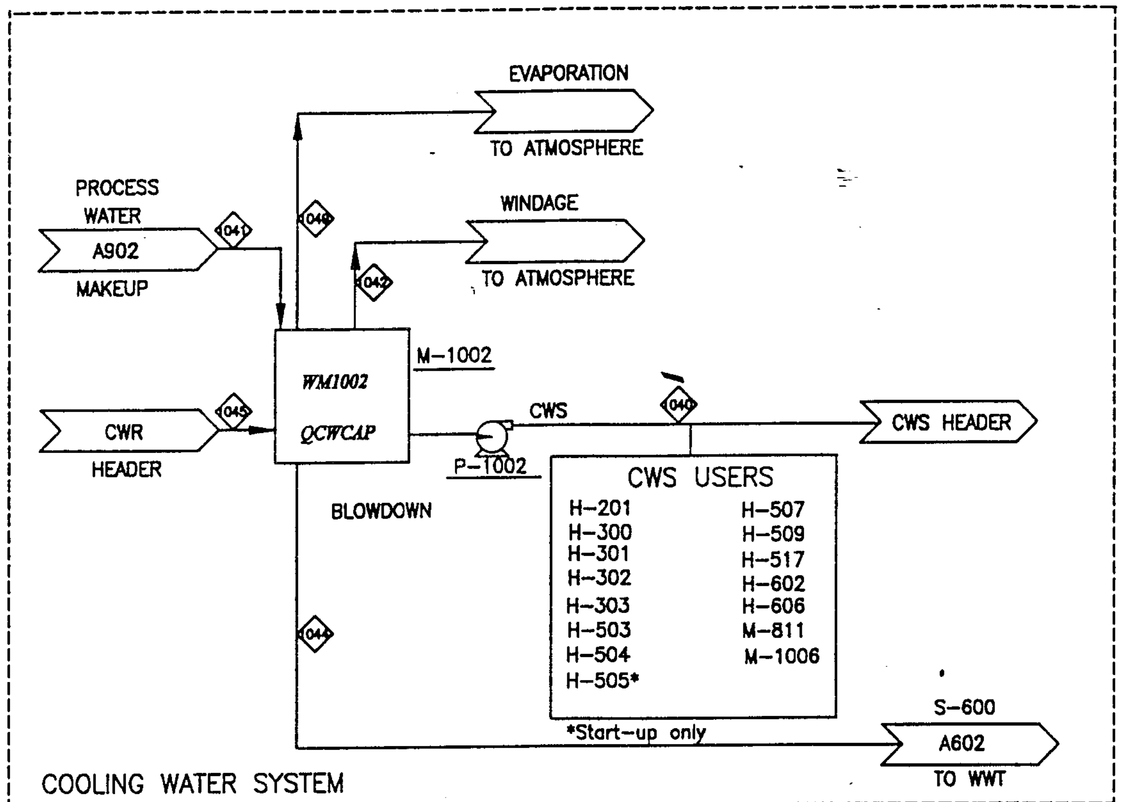

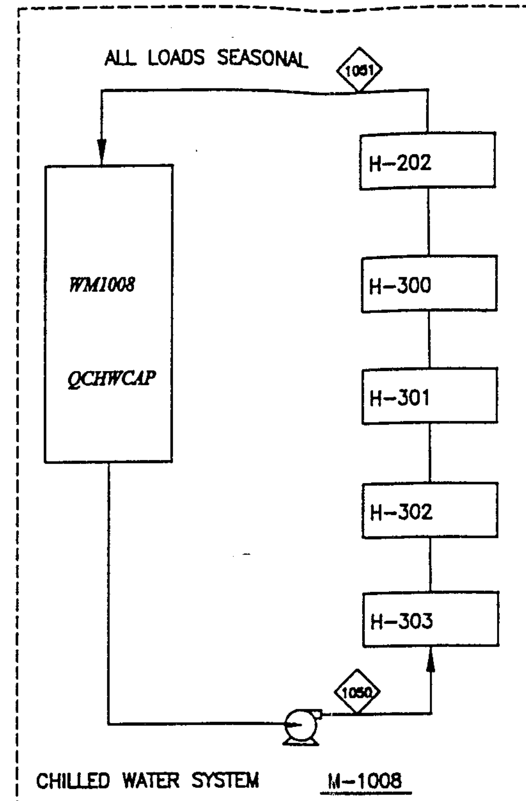

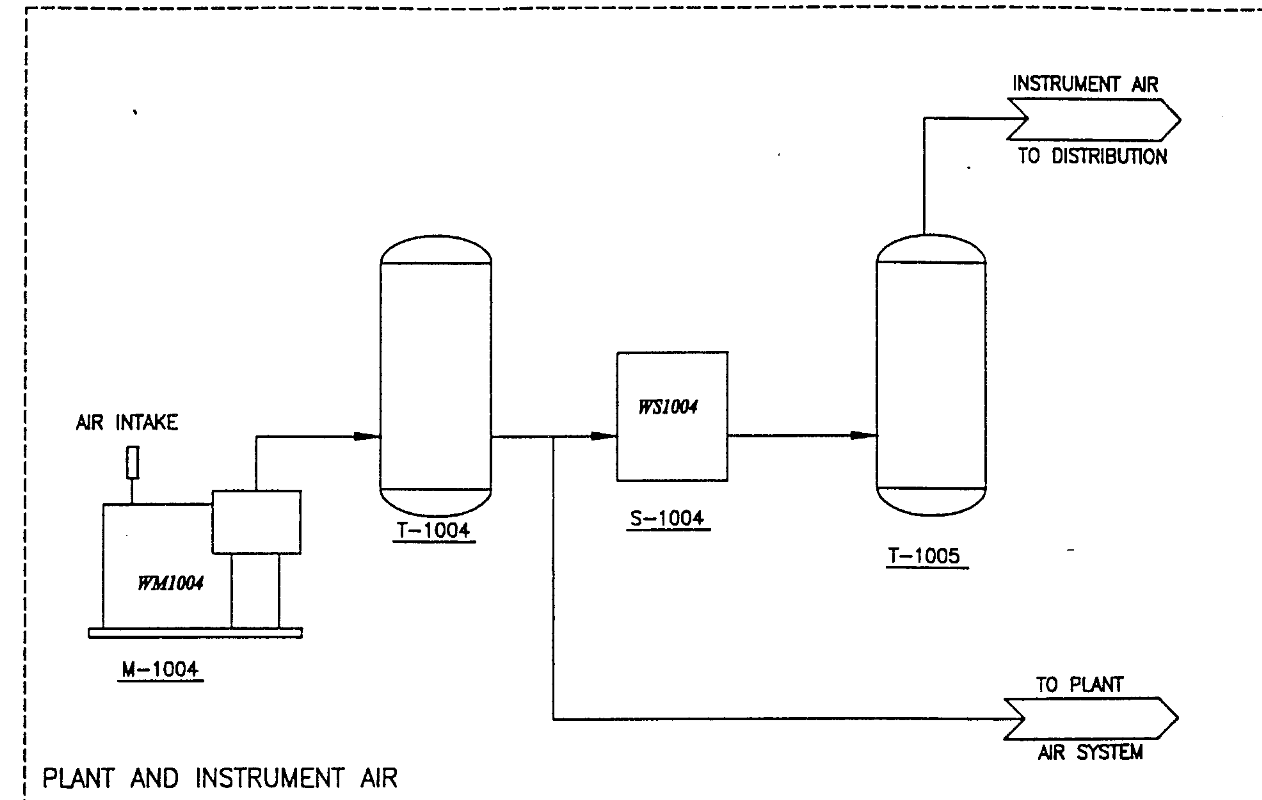

COMPONENT	UNITS	1040	1041	1042	1044	1045	1049	1050	1051
Total Flow	kg/hr	7,242,360	102,795	0	30,618	7,242,360	93,450	257,317	257,317
Insoluble Solids	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Soluble Solids	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Temperature	C	37	28	28	28	28	28	4	8
Pressure	atm	4.08	1.00	1.00	1.00	4.08	0.04	4.08	4.08
Vapor Fraction		0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
Ethanol	kg/hr								
Water	kg/hr	7,242,360	102,795	0	30,618	7,242,360	93,450	257,317	257,317
Glucose (SS)	kg/hr								
Mannose (SS)	kg/hr								
Xylose (SS)	kg/hr								
Other Sugars (SS)	kg/hr								
Cellobiose (SS)	kg/hr								
Glucose Oligomers (SS)	kg/hr								
Xylose Oligomers (SS)	kg/hr								
Other Oligomers (SS)	kg/hr								
Corn Steep Liquor (SS)	kg/hr								
Others (Soluble Solids)	kg/hr								
Extractives	kg/hr								
Acetic Acid	kg/hr								
Sulfuric Acid	kg/hr								
Furfural	kg/hr								
HMF	kg/hr								
Carbon Dioxide	kg/hr								
Methane	kg/hr								
Oxygen	kg/hr								
Nitrogrn	kg/hr								
Ammonia	kg/hr								
NH4)H	kg/hr								
Others	kg/hr								
Cellulose (IS)	kg/hr								
Mannan (IS)	kg/hr								
Galactan (IS)	kg/hr								
Xylan (IS)	kg/hr								
Arabinan (IS)	kg/hr								
Yeast (IS)	kg/hr								
Biomass (IS)	kg/hr								
Extract Solids (IS)	kg/hr								
Lignin (IS)	kg/hr								
Gypsum (IS)	kg/hr								
Ca(OH)2 (IS)	kg/hr								
Others (Insoluble Solids)	kg/hr								
Enthalpy Flow (millions)	Kcal/hr	-27350.5	-389.1	0.0	-115.9	-27411.4	-299.5	-979.5	-978.6
Average Density	g/ml	0.982	0.991	0.991	0.991	0.991	0.000	1.014	1.010

Eq. No.	Equipment Name	Req.	Spare	Equipment Type	Mat Const.
M-1002	Cooling Tower System	1	0	INDUCED-DRAFT	GALVSTEEL
M-1004	Plant Air Compressor	1	0	RECIPROCATING	CS
M-1008	Chilled Water System				
P-1002	Cooling Water Pumps	8	1	CENTRIFUGAL	CS
S-1004	Instrument Air Dryer	1	0	PACKAGE	CS
T-1004	Plant Air Receiver	1	0	HORIZONTAL-VESSEL	CS
T-1005	Instrument Air Receiver	1	0	HORIZONTAL-VESSEL	CS
M-1006	Fermentor Air Compressor Package	2	1	CENTRIFUGAL	CS
M-1008	Chilled Water Package	1	0	CENTRIFUGAL	CS

VER.	DESCRIPTION	DATE
A	INITIAL MERRICK DESIGN	10/98

NREL NATIONAL RENEWABLE ENERGY LABORATORY
Biotechnology Center For Fuels And Chemicals

SECTION A900
COOLING WATER PLANT & INSTRUMENT AIR SYSTEMS

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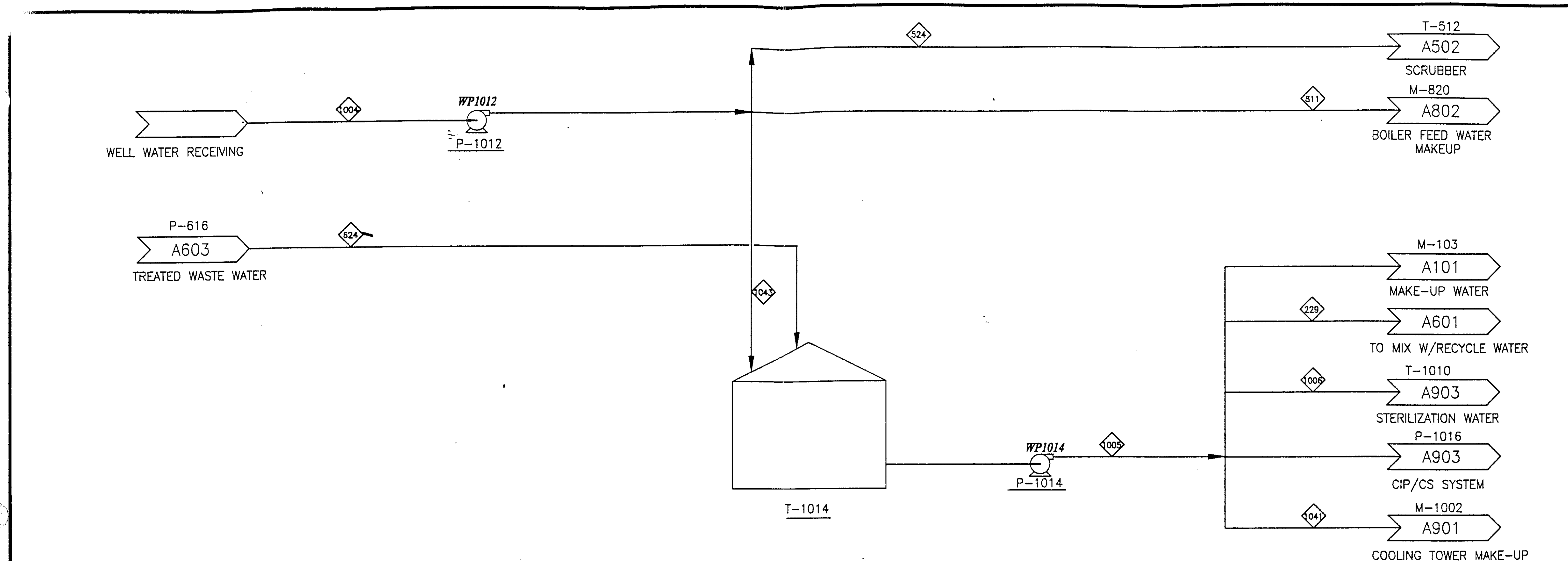

COMPONENT	UNITS	229	524	624	811	1004	1005	1006	1041
Total Flow	kg/hr	29,407	5,310	91,664	32,788	81,101	134,668	63	102,795
Insoluble Solids	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Soluble Solids	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Temperature	C	20	13	21	20	26	23	20	28
Pressure	atm	1.01	1.00	1.00	3.40	1.00	1.00	1.00	1.00
Vapor Fraction		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ethanol	kg/hr			0			0		
Water	kg/hr	29,407	5,310	91,554	32,788	81,101	134,558	63	102,795
Glucose (SS)	kg/hr								
Mannose (SS)	kg/hr								
Xylose (SS)	kg/hr			0			0		
Other Sugars (SS)	kg/hr			0			0		
Cellobiose (SS)	kg/hr								
Glucose Oligomers (SS)	kg/hr								
Xylose Oligomers (SS)	kg/hr								
Other Oligomers (SS)	kg/hr								
Corn Steep Liquor (SS)	kg/hr			8			8		
Others (Soluble Solids)	kg/hr								
Extractives	kg/hr								
Acetic Acid	kg/hr			1			1		
Sulfuric Acid	kg/hr								
Furfural	kg/hr			1			1		
HMF	kg/hr			8			8		
Carbon Dioxide	kg/hr			0			0		
Methane	kg/hr			0			0		
Oxygen	kg/hr			1			1		
Nitrogrn	kg/hr			1			1		
Ammonia	kg/hr			0			0		
NH4)H	kg/hr								
Others	kg/hr			90			90		
Cellulose (IS)	kg/hr								
Mannan (IS)	kg/hr								
Galactan (IS)	kg/hr								
Xylan (IS)	kg/hr								
Arabinan (IS)	kg/hr								
Yeast (IS)	kg/hr								
Biomass (IS)	kg/hr								
Extract Solids (IS)	kg/hr								
Lignin (IS)	kg/hr								
Gypsum (IS)	kg/hr								
Ca(OH)2 (IS)	kg/hr								
Others (Insoluble Solids)	kg/hr								
Enthalpy Flow (millions)	Kcal/hr	-111.5	-20.2	-347.5	-124.4	-307.1	-510.2	-0.2	-389.1
Average Density	g/ml	0.998	1.005	0.997	0.998	0.993	0.995	0.998	0.991

Eq. No.	Equipment Name	Req.	Spare	Equipment Type	Mat Const.
P-1012	Make-up Water Pump	1	1	CENTRIFUGAL	CS
P-1014	Process Water Circulating Pump	1	1	CENTRIFUGAL	CS
T-1014	Process Water Tank	1	0	FLAT-BTM-STORAGE	CS

VER.	DESCRIPTION	DATE
A	INITIAL MERRICK DESIGN	10/98

NATIONAL RENEWABLE ENERGY LABORATORY

Biotechnical Center For Fuels And Chemicals

SECTION A900
PROCESS WATER

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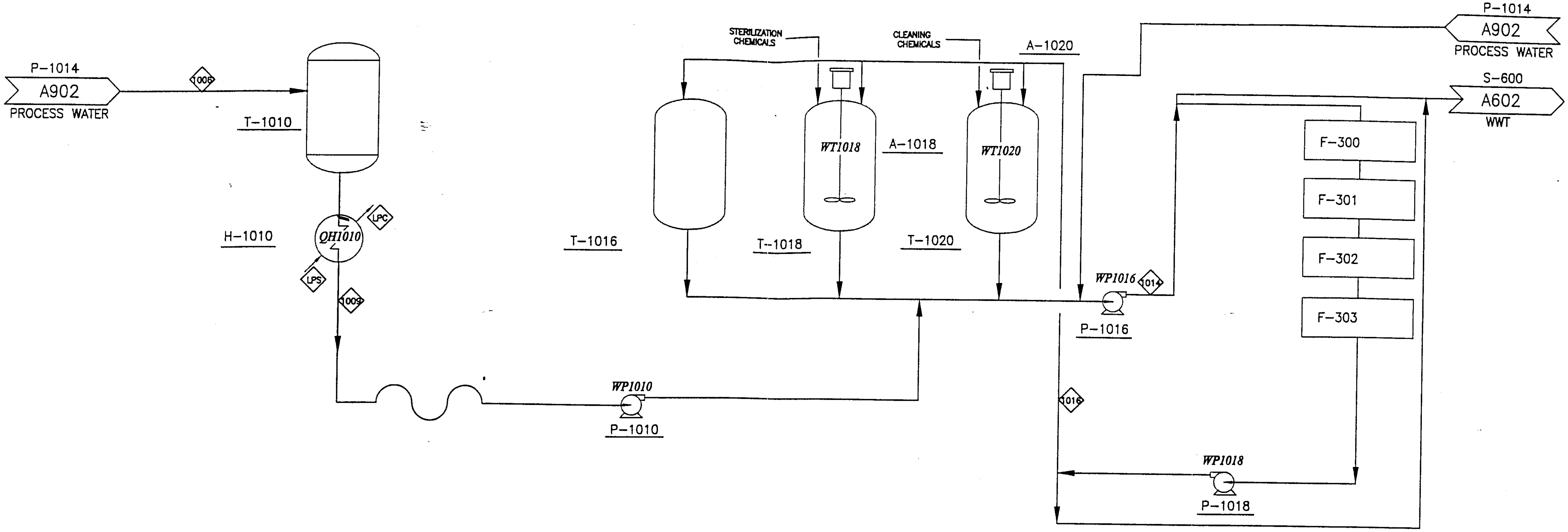

COMPONENT	UNITS	1006	1009	1014	1016
Total Flow	kg/hr	63	63	63	63
Insoluble Solids	%	0.0%	0.0%	0.0%	0.0%
Soluble Solids	%	0.0%	0.0%	0.0%	0.0%
Temperature	C	20	121	20	20
Pressure	atm	1.00	1.00	1.00	1.00
Vapor Fraction		0.00	1.00	0.00	0.00
Ethanol	kg/hr				
Water	kg/hr	63	63	63	63
Glucose (SS)	kg/hr				
Mannose (SS)	kg/hr				
Xylose (SS)	kg/hr				
Other Sugars (SS)	kg/hr				
Cellobiose (SS)	kg/hr				
Glucose Oligomers (SS)	kg/hr				
Xylose Oligomers (SS)	kg/hr				
Other Oligomers (SS)	kg/hr				
Corn Steep Liquor (SS)	kg/hr				
Others (Soluble Solids)	kg/hr				
Extractives	kg/hr				
Acetic Acid	kg/hr				
Sulfuric Acid	kg/hr				
Furfural	kg/hr				
HMF	kg/hr				
Carbon Dioxide	kg/hr				
Methane	kg/hr				
Oxygen	kg/hr				
Nitrogrn	kg/hr				
Ammonia	kg/hr				
NH4)H	kg/hr				
Others	kg/hr				
Cellulose (IS)	kg/hr				
Mannan (IS)	kg/hr				
Galactan (IS)	kg/hr				
Xylan (IS)	kg/hr				
Arabinan (IS)	kg/hr				
Yeast (IS)	kg/hr				
Biomass (IS)	kg/hr				
Extract Solids (IS)	kg/hr				
Lignin (IS)	kg/hr				
Gypsum (IS)	kg/hr				
Ca(OH)2 (IS)	kg/hr				
Others (Insoluble Solids)	kg/hr				
Enthalpy Flow (millions)	Kcal/hr	-0.2	-0.2	-0.2	-0.2
Average Density	g/ml	0.998	0.001	0.998	0.998

Eq. No.	Equipment Name	Req.	Spare	Equipment Type	Mat Const.
A-1018	Sterilization Tank Agitator	1	0	FIXED-PROP	SS304
A-1020	Cleaning Tank Agitator	1	0	FIXED-PROP	SS304
H-1010	Water Sterilizer	1	0	DOUBLE-PIPE	CS
P-1010	Sterile Water Pump	2	1	CENTRIFUGAL	CS
P-1016	CIP/CS Supply Pump	1	1	CENTRIFUGAL	SS304
P-1018	CIP/CS Return Pump	1	1	CENTRIFUGAL	SS304
T-1010	Sterile Water Tank	1	0	VERTICAL-VESSEL	A285C
T-1016	Sterile Rinse Water Tank	1	0	VERTICAL-VESSEL	A285C
T-1018	Sterilization Tank	1	0	VERTICAL-VESSEL	SS304
T-1020	Cleaning Tank	1	0	VERTICAL-VESSEL	A285C

VER.	DESCRIPTION	DATE
A	INITIAL MERRICK DESIGN	10/98

NREL NATIONAL RENEWABLE ENERGY LABORATORY
Biotechnology Center For Fuels And Chemicals

SECTION A900
STERILE WATER AND CIP/CS SYSTEMS

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APPENDIX D

CHIP HANDLING REPORT

Ethanol Process - Wood Chip Handling
Area Description - 800 ODT/D Production Level

Wood chips arrive at the site by truck and semi-trailer. Vehicles will be weighed with and without load on an above ground platform scale with a capacity of 100 tons. The vehicles are unloaded on a back-on type hydraulic dumper which can lift both truck and trailer to dump the load into a receiving hopper. The chips are metered out of the hopper onto a belt conveyor which in turn discharges to one of two stacker conveyors.
The stackers deliver the chips to the storage pile. The unloading system is designed to operate 12 hours a day, 5 to 7 days per week

Bulldozers move the chips to form a 40 foot high pile with an area of approximately 150,000 square feet which is equal to a 30 day supply for the processing plant. A second pile of equal dimensions, with additional stacker and reclaim conveyors, would be required to provide a 2 months supply. Two bulldozers are included regardless of inventory to allow for peak delivery periods, to provide for proper pile rotation and maintenance. It is anticipated that two operators may be required during trucking hours and one during other times.

The dozers are used also to push chips into and over one of two reclaim chain conveyors. Using one conveyor at a time chips are reclaimed and fed to the screening system by belt conveyor. A tramp iron magnet is provided to catch stray magnetic metal and a scalping screen removes gross oversize and foreign material ahead of the screening process.

The initial process step in producing ethanol from biomass benefits from raw material particles being fairly thin. Wood chips should be in the order of 3 to 5 millimeter thick or less so as to allow the process chemicals to penetrate the fibers quickly. Such thin chips result when wood is cut into relatively short lengths along the grain, or no more than 12 millimeter long. Wood species, seasonal factors, moisture content and other variables influence chip thickness. It has been assumed that most incoming chips will be acceptable in thickness and do not require reprocessing.

All chips will pass over a thickness screen to screen out overthick material. A roll screen with specially profiled roll surfaces is proposed for this step. Material rejected by the screen passes first through an air density separator which is a system that separates material by specific gravity. This eliminates any stones and other foreign objects which would damage downstream equipment. The overthick chips are then introduced into a special chip slicer which cuts chips along the grain to a preset thickness. An alternate machine is a chip crusher which compresses chips to create fissures which allow more rapid penetration of the fiber by the process chemicals. The chip reclaim and screening system are designed to operate more or less continuously, or at least 20 hours per day.

In order to allow for equipment maintenance and to guard against breakdowns a storage silo is provided. The silo will hold approx. 55,000cu.ft. of screened chips which is equal to 8 hours of plant operation. Chips are metered and conveyed to the process plant on a continuous, 24 hour basis.

Several process alternates were considered. A fully automated chip storage and reclaim system was discussed which would not require either bulldozers or operators. Such a system can provide full inventory control and material turn-over and eliminates material break-down due to bulldozer action. Fiber loss and operating cost savings are the main advantages. Because of high capital cost this option was not pursued. Alternates for fiber preparation were also considered. As a substitute for screening and slicing of chips the use of hammermills was discussed. Running all chips through such equipment would require high energy input and would unnecessarily degrade the material. However, hammermills could be further evaluated for use after screening and to replace a slicer.

S

EQUIPMENT LIST

CLIENT: Merrick Engineering PROJECT NO.: E188

PROJECT: Ethanol Process - Chip Handling DATE: 23-Jun-98

AREA: Area 2

EQUIP NO	EQUIPMENT ITEMS DESCRIPTION	HP	RPM	EQUIP COST	REMARKS
LAST ROW		20	MTRS		
81	PAGE TOTALS	810	HP	3,208,000	
24					
25	Truck Scale, incl. Data Processing Equipment			50,000	100 ton Capacity, pitless type
26	Truck Dumper			160,000	Truck plus Trailer, Phelps Ind. or eq.
27	Motor	60			
28	Motor	60			
29	Chip Receiving Hopper			140,000	
30					
31	Motor	30			
32	Chip Conveyor to Storage			260,000	42" Belt x 530 ft. lg. w. fixed tripper
33	Motor	60			
34	No.1 Chip Stacker			95,000	42" Belt x 130 ft. lg.

S

EQUIPMENT LIST

CLIENT: Merrick Engineering — PROJECT NO.: E188

PROJECT: Ethanol Process - Chip Handling — DATE: 23-Jun-98

AREA: Area 2

EQUIP NO	EQUIPMENT ITEMS DESCRIPTION	HP	RPM	EQUIP COST	REMARKS
35	Motor	20			
36	No.2 Chip Stacker			95,000	42" Belt x 130 ft. lg.
37	Motor	20			
38	No.1 Bulldozer c/w Chip Blade			350,000	
39	No.2 Bulldozer c/w Chip Blade			350,000	
40	No.1 Chip Reclaim Conveyor			110,000	Chain Conveyor, 80 ft. lg.
41	Motor	30			
42	No.2 Chip Reclaim Conveyor			110,000	Chain Conveyor, 80 ft. lg.
43	Motor	30			
44	Conveyor to Screening System			230,000	30" Belt x 620 ft. lg.
45	Motor	50			
46	Tramp Iron Magnet			8,000	

S

EQUIPMENT LIST

CLIENT: Merrick Engineering
PROJECT NO.: E188

PROJECT: Ethanol Process - Chip Handling
DATE: 23-Jun-98

AREA: Area 2

EQUIP NO	EQUIPMENT ITEMS DESCRIPTION	HP	RPM	EQUIP COST	REMARKS
47	Disc Scalping Screen			25,000	For Trash Removal
48	Motor	10			
49	Motor	10			
50	Chip Thickness Screen			110,000	Acrowood Roll Screen
51	Motor	10			
52	Motor	10			
53	Air Density Separation System			80,000	Acrowood
54	Motor, Blower	125			
55	Motor, Feeder	10			
56	Chip Slicer or Cracker (Option)			125,000	Acrowood
57	Motor	150			
58	Chutes, Chip Screen System			50,000	Allowance

S

EQUIPMENT LIST

CLIENT: Merrick Engineering
PROJECT: Ethanol Process - Chip Handling
AREA: Area 2

PROJECT NO.: E188
DATE: 23-Jun-98

EQUIP NO	EQUIPMENT ITEMS DESCRIPTION	HP	RPM	EQUIP COST	REMARKS
59	Building, Chip Screen System, incl. 3 floor levels w. equipment support steel and access platforms				50' x 50' 70' high, partially enclosed, w. buildings
60	Conveyor to Chip Silo			200,000	30" Belt x 420 ft. lg.
61	Motor	50			
62	Chip Silo, erected, foundation not incl.			350,000	Concrete, 40' dia' x 90' high, 8 hrs storage (55,000 cu.ft.)
63	Vibrating Silo Discharger			75,000	
64	Motor	10			
65	Feeder, Silo Discharge			30,000	Screw
66	Motor	15			
67	Chip Conveyor to Process			200,000	30" Belt x 400 ft.lg.
68	Motor	50			
69	Belt Scale			5,000	
70					

S

EQUIPMENT LIST

CLIENT: Merrick Engineering PROJECT NO.: E188
PROJECT: Ethanol Process - Chip Handling DATE: 23-Jun-98
AREA: Area 2

EQUIP NO	EQUIPMENT ITEMS DESCRIPTION	HP	RPM	EQUIP COST	REMARKS
71					
72					
73					
74					
75					
76					
77					
78					
79					
80					
81					

SIMONS

CALCULATION SHEET

P.O. BOX 1286, ATLANTA, GEORGIA, U.S.A. 30301, 404-370-3200

BY ________ DATE ________

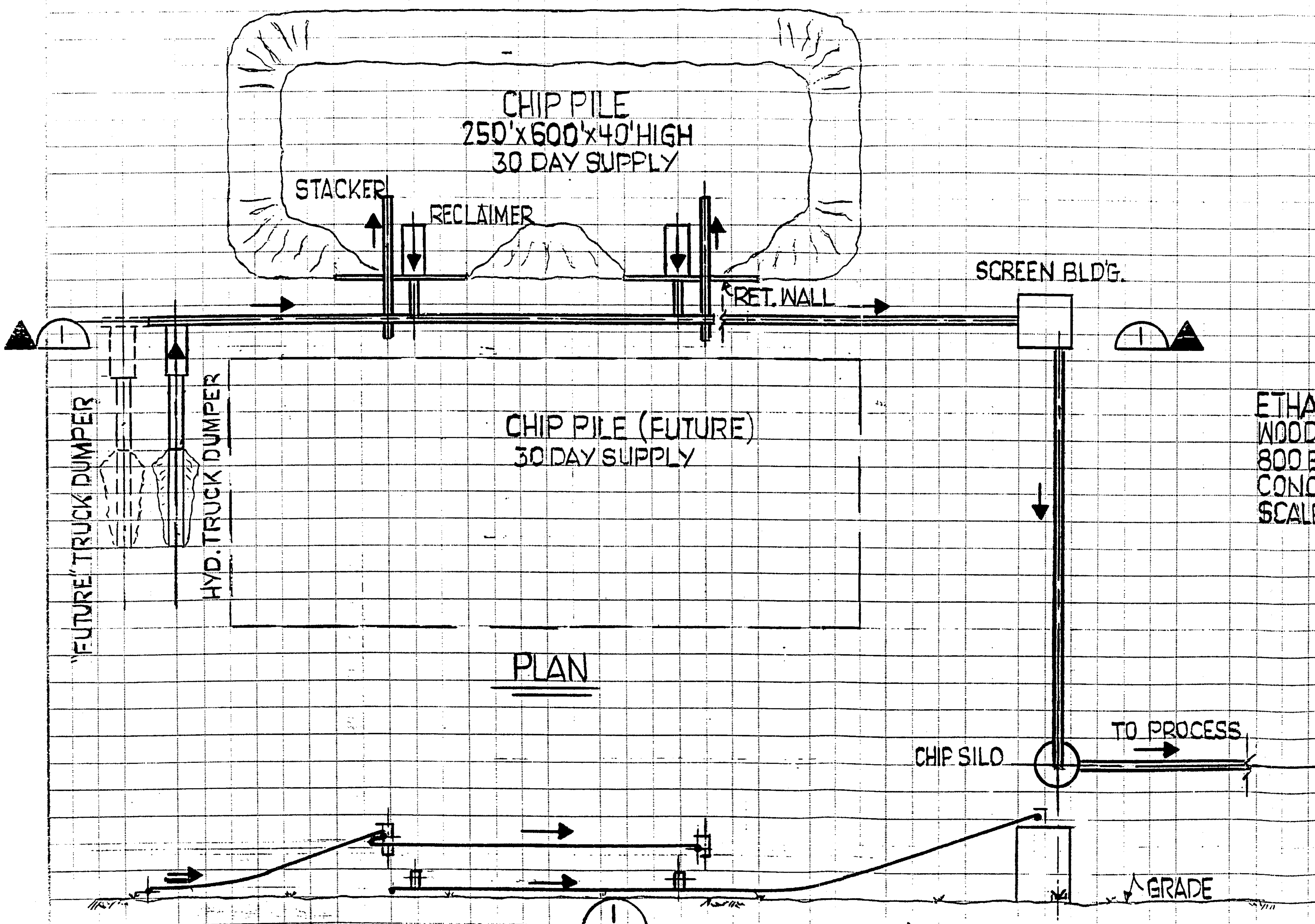
CHKD. BY ________ DATE ________

SUBJECT MERRICK ENGINEERING, AURORA, CO.

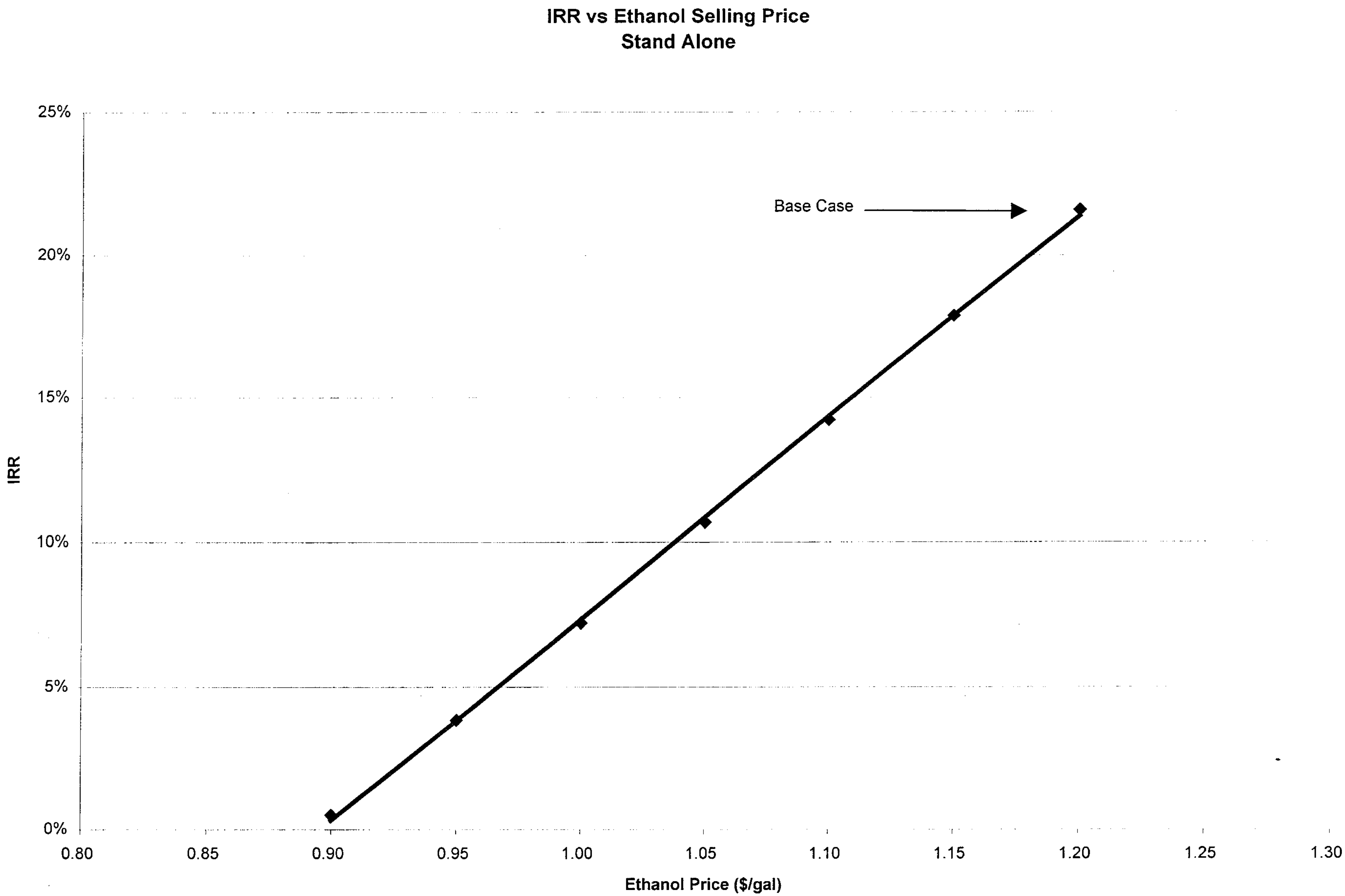
WOOD CHIP HANDLING

SHEET NO. 1 OF 1

JOB NO. E-188



ETHANOL PLANT
WOOD CHIP HANDLING
800 B.D.T./DAY
CONCEPTUAL SITE PLAN
SCALE 1"=10' JUNE 1998


IRR vs Ethanol Selling Price
Stand Alone
Base Case
25%
20%
15%
10%
5%
0%
IRR
0.80
0.85
0.90
0.95
1.00
1.05
1.10
1.15
1.20
1.25
1.30
Ethanol Price ($/gal)

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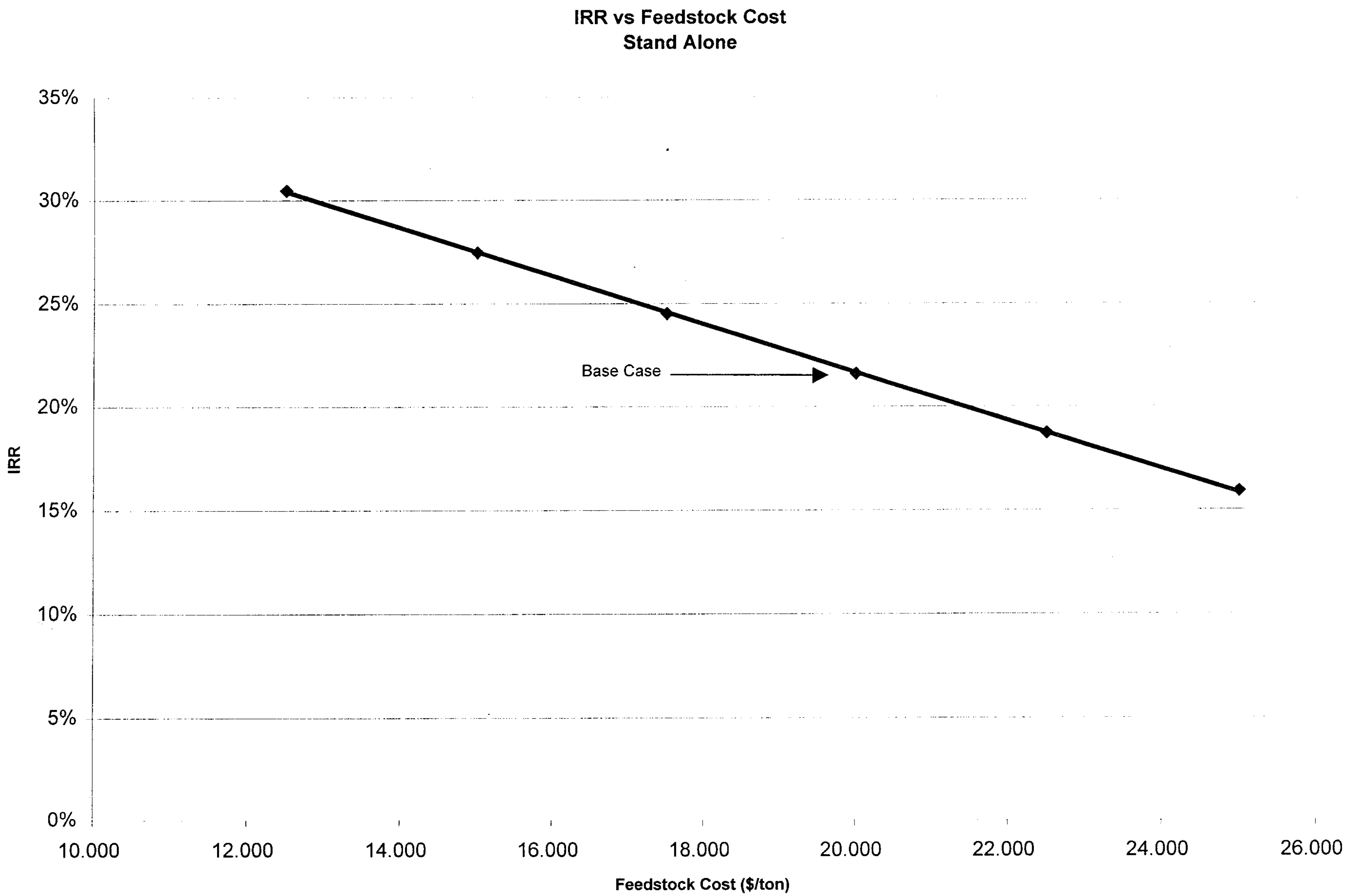
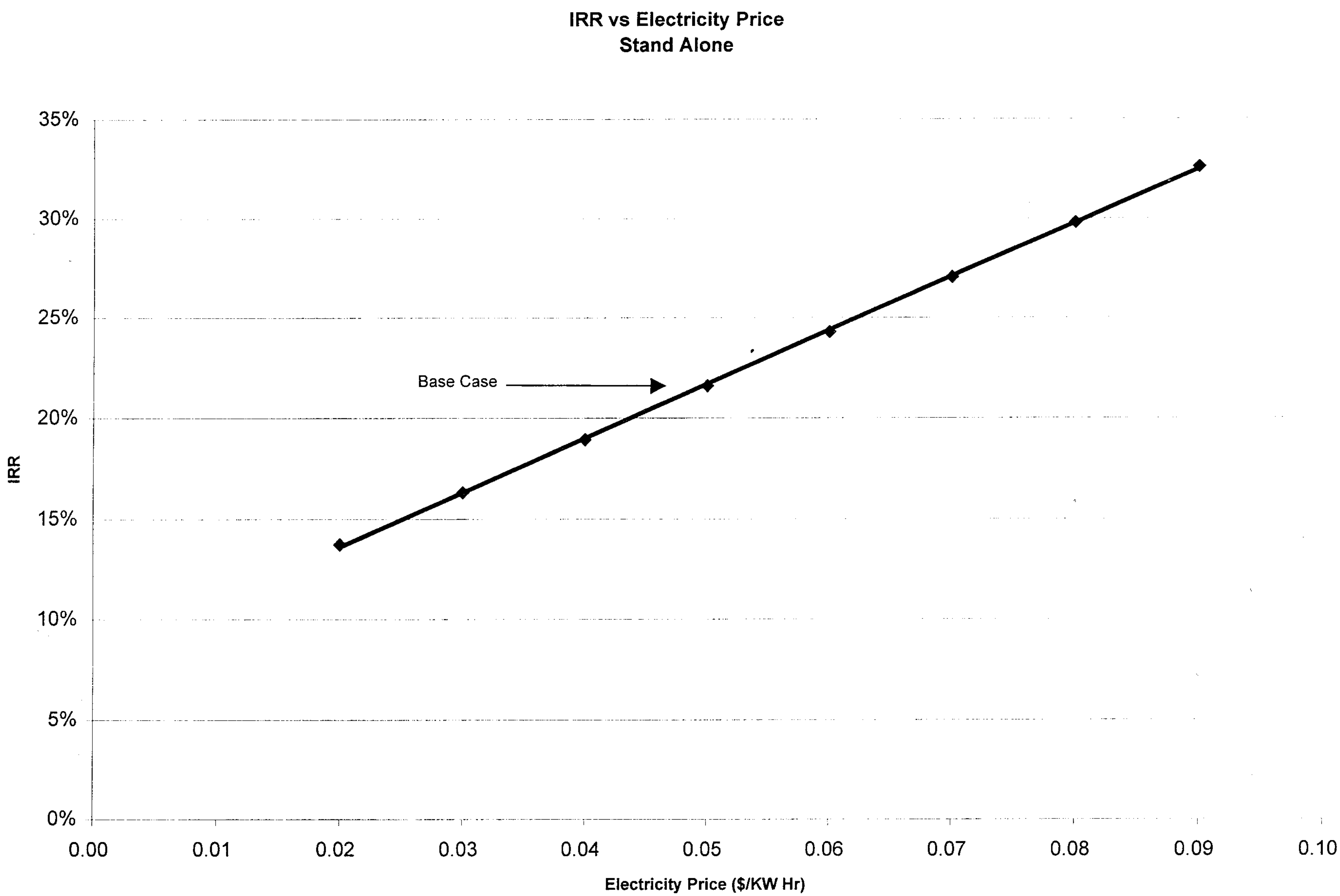
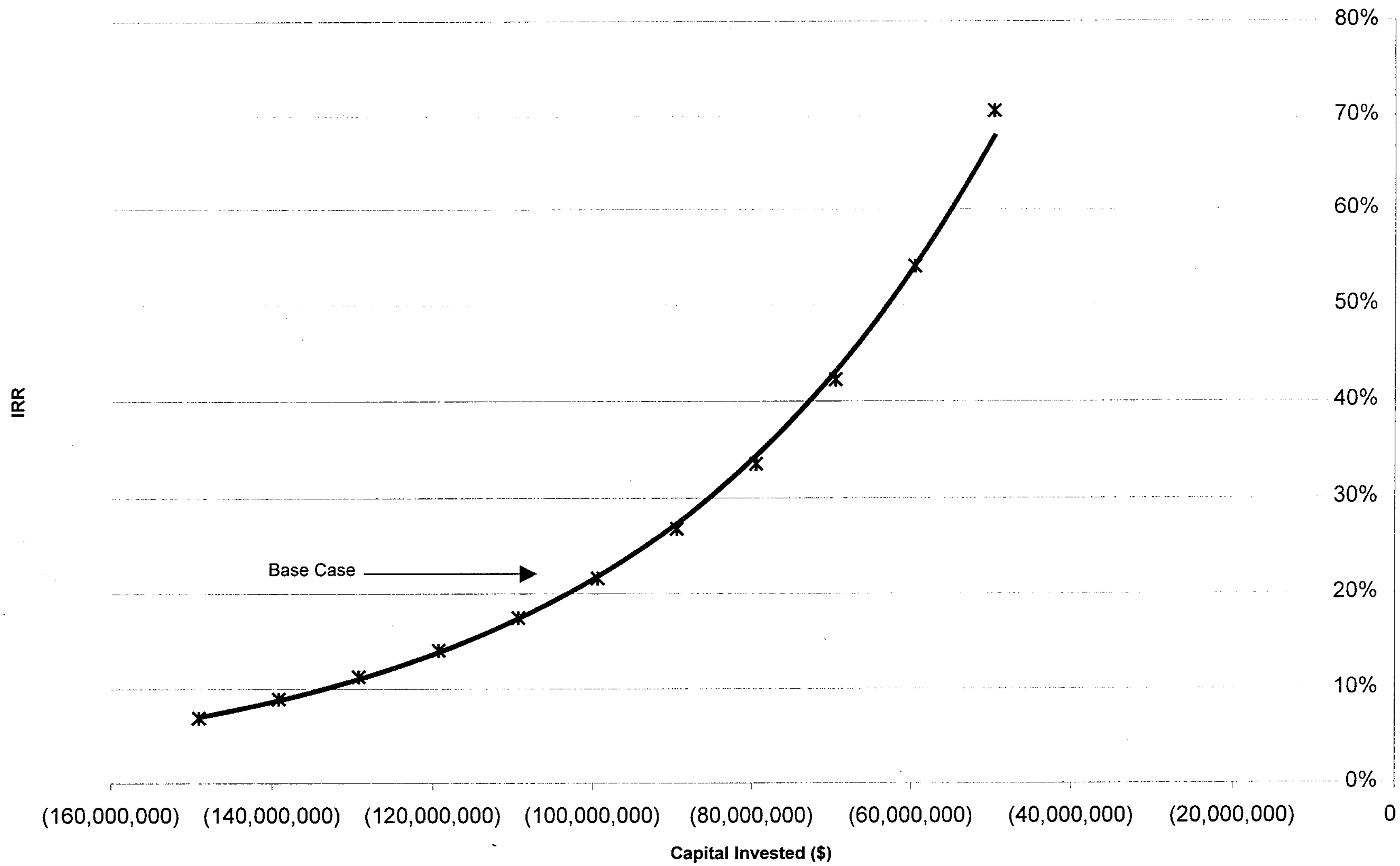


IRR vs Feedstock Cost
Stand Alone
35%
30%
25%
20%
15%
10%
5%
0%
IRR
Base Case
10.000
12.000
14.000
16.000
18.000
20.000
22.000
24.000
26.000
Feedstock Cost ($/ton)



IRR vs Electricity Price
Stand Alone
35%
30%
25%
20%
15%
10%
5%
0%
IRR
Base Case
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
Electricity Price ($/KW Hr)

IRR vs Capital Invested
Stand Alone



SENSITIVITY TABLE
STAND-ALONE

OPERATING CASH FLOW $	RATE OF RETURN	FEED PRICE DRY $/TON	ETHANOL SALE $/GAL	ELECTRICITY SALE $/KW		
4,306,155	#DIV/0!	20.000	0.80	0.05		
5,311,086	#NUM!	20.000	0.85	0.05		
6,316,017	1%	20.000	0.90	0.05		
7,320,948	4%	20.000	0.95	0.05		
8,325,879	7%	20.000	1.00	0.05		
9,330,809	11%	20.000	1.05	0.05		
10,335,740	14%	20.000	1.10	0.05		
11,340,671	18%	20.000	1.15	0.05		
12,345,602	22%	20.000	1.20	0.05		BASE CASE
14,660,829	30%	12.500	1.20	0.05		
13,889,086	27%	15.000	1.20	0.05		
13,117,344	25%	17.500	1.20	0.05		
12,345,602	22%	20.000	1.20	0.05		
11,573,859	19%	22.500	1.20	0.05		
10,802,117	16%	25.000	1.20	0.05		
10,200,074	14%	20.000	1.20	0.02		
10,915,250	16%	20.000	1.20	0.03		
11,630,426	19%	20.000	1.20	0.04		
12,345,602	22%	20.000	1.20	0.05		
13,060,778	24%	20.000	1.20	0.06		
13,775,954	27%	20.000	1.20	0.07		
14,491,130	30%	20.000	1.20	0.08		
15,206,306	33%	20.000	1.20	0.09		
					%	CAPITAL INVEST
12,345,602	71%	20.000	1.20	0.05	50%	(49,703,090)
12,345,602	54%	20.000	1.20	0.05	60%	(59,643,708)
12,345,602	42%	20.000	1.20	0.05	70%	(69,584,326)
12,345,602	33%	20.000	1.20	0.05	80%	(79,524,943)
12,345,602	27%	20.000	1.20	0.05	90%	(89,465,561)
12,345,602	22%	20.000	1.20	0.05	100%	(99,406,179)
12,345,602	17%	20.000	1.20	0.05	110%	(109,346,797)
12,345,602	14%	20.000	1.20	0.05	120%	(119,287,415)
12,345,602	11%	20.000	1.20	0.05	130%	(129,228,033)
12,345,602	9%	20.000	1.20	0.05	140%	(139,168,651)
12,345,602	7%	20.000	1.20	0.05	150%	(149,109,269)

% EQUITY
LOAN TERM YEARS
Interest Rate

NREL SOFTWOOD 800 DTPD CASE (STAND ALONE)
Equipment List/Cost (Model G9810H-1)

Section	Equip. No.	Description	Quantity Reqd.	Capacity Each	Size Each	Unit Cost	Cost Source	Install. Factor	Total Cost	Unit Installation	Total Installation	Scaling Factor	Spares
A100	C-101	Chip conveyor to storage	1			$260,000	K Penka	1.75	$260,000	$195,000	$455,000	0	
Wood Chip	C-102	Chip stackers	2			$95,000	K Penka	1.75	$190,000	$71,250	$332,500	0	
Feed Handling	C-103	Reclaim conveyor	2			$110,000	K Penka	1.75	$220,000	$82,500	$385,000	0	
	C-104	Conveyor to screening	1			$240,713	K Penka	1.75	$240,713	$180,535	$421,248	0.3	
	C-105	Conveyor to chip silo	1			$209,315	K Penka	1.75	$209,315	$156,986	$366,301	0.3	
	C-106	Chip conveyor to process	1			$209,315	K Penka	1.75	$209,315	$156,986	$366,301	0.3	
	C-107	Lignin conveyor to BF conveyor	1			$250,000	Est.	1.75	$250,000	$187,500	$437,500	0.3	
	M-101	Truck scale	1			$50,000	K Penka	1.75	$50,000	$37,500	$87,500	0	
	M-102	Truck dumper	1			$160,000	K Penka	1.75	$160,000	$120,000	$280,000	0	
	M-103	Chip receiving hopper	1			$140,000	K Penka	1.75	$140,000	$105,000	$245,000	0	
	M-104	Bulldozer	2			$350,000	K Penka	1.00	$700,000	$0	$700,000	1	
	M-105	Tramp iron magnet	1			$8,000	K Penka	1.75	$8,000	$6,000	$14,000	0	
	M-106	Air density separation system	1			$86,306	K Penka	1.75	$86,306	$64,730	$151,036	0.5	
	M-107	Chip slicer	1			$136,915	K Penka	1.75	$136,915	$102,686	$239,601	0.6	
	M-108	Chip silo	1			$383,363	K Penka	1.75	$383,363	$287,522	$670,885	0.6	
	M-109	Vibrating silo discharger	1			$78,493	K Penka	1.75	$78,493	$58,870	$137,363	0.3	
	M-110	Silo discharge feeder	1			$31,397	K Penka	1.75	$31,397	$23,548	$54,945	0.3	
	M-111	Belt scale	1			$5,233	K Penka	1.75	$5,233	$3,925	$9,158	0.3	
	S-101	Disc scalping screen	1			$26,164	K Penka	1.75	$26,164	$19,623	$45,787	0.3	
	S-102	Chip thickness screen	1			$115,123	K Penka	1.75	$115,123	$86,342	$201,465	0.3	
	S-103	Chip screen system chutes	1			$54,766	K Penka	1.75	$54,766	$41,075	$95,841	0.6	
	T-101	Rainwater collection and settling system	1			$21,906	Est.	1.75	$21,906	$16,430	$38,336	0.6	
		AREA 100 TOTAL							**$3,577,009**		**$5,734,766**		
A200	A-206	Sterilization Tank Agitator	1			$13,497	ICARUS	1.20	$13,497	$2,699	$16,196	0.51	
Hydrolysis and	A-209	Overliming Tank Agitator	1			$16,573	ICARUS	1.30	$16,573	$4,972	$21,545	0.51	
lime addition	C-201	Screw conveyor	1			$10,866	ICARUS	1.30	$10,866	$3,260	$14,126	0.78	
	C-222	Gypsum conveyor	1			$1,789	ICARUS	1.30	$1,789	$537	$2,326	1	
	C-225	Lime solids feeder	1			$3,407	ICARUS	1.30	$3,407	$1,022	$4,429	0.6	
	C-226	Lime conveyor	1			$1,195	ICARUS	1.3	$1,195	$359	$1,554	1	
	H-201	Fermentation feed cooler	2			$169,550	ICARUS	1.30	$339,100	$50,865	$440,830	1	
	H-202	Fermentation feed chiller	2			$119,554	ICARUS	1.30	$239,108	$35,866	$310,840	1	
	M-201	Acid impregnator no.1	2			$350,000	VENDOR	1.30	$700,000	$105,000	$910,000		
	M-204	Acid impregnator no.2	2			$350,000	VENDOR	1.30	$700,000	$105,000	$910,000		
	M-224	Lime unloading pit	1			$13,280	ICARUS	1.75	$13,280	$9,960	$23,240	0.71	
	P-201	Sulfuric acid pump	1			$6,516	ICARUS	2.80	$13,032	$11,729	$18,245	0.79	1
	P-209	Neutralized hydrolyzate slurry pump	1			$16,245	ICARUS	2.80	$32,490	$29,241	$45,486	0.79	1
	P-222	Neutralized hydrolyzate liquor pump	1			$16,673	ICARUS	2.80	$33,346	$30,011	$46,684	0.79	1
	P-223	Pneumatic lime unloader	1			$54,057	ICARUS	1.40	$54,057	$21,623	$75,680	0.5	
	R-201	First stage hydrolysis reactor	1			$210,430	VENDOR	1.30	$210,430	$63,129	$273,559	0.6	
	R-202	Second stage hydrolysis reactor	1			$174,230	VENDOR	1.30	$174,230	$52,269	$226,499	0.6	
	S-201	First stage pre-reactor screw press	1			$1,564,000	VENDOR	1.30	$1,564,000	$469,200	$2,033,200		
	S-202	Second stage pre-reactor screw press	1			$1,976,000	VENDOR	1.30	$1,976,000	$592,800	$2,568,800		
	S-203	Inter stage pre-reactor screw press	2			$1,500,000	VENDOR	1.30	$3,000,000	$450,000	$3,900,000		
	S-205	Acid vent desicant filter	1			$547	ICARUS	1.60	$547	$328	$875	0.6	
	S-222	Rotary drum filter	1			$106,645	VENDOR	2.00	$106,645	$106,645	$213,290	0.39	
	T-201	Sulfuric acid process storage tank	1			$4,066	ICARUS	1.40	$4,066	$1,626	$5,692	0.71	

NREL SOFTWOOD 800 DTPD CASE (STAND ALONE) Equipment List/Cost (Model G9810H-1)														
Section	Equip. No.	Description	Quantity Reqd.	Capacity Each	Size Each	Unit Cost	Cost Source	Install. Factor	Total Cost	Unit Installation	Total Installation	Scaling Factor	Spares
	T-203	Blowdown tank #1 (Oligomer)	1			$21,557	ICARUS	1.20	$21,557	$4,311	$25,868	0.93	
	T-204	First stage low pressure flash tank	1			$19,423	ICARUS	2.60	$19,423	$31,077	$50,500	0.93	
	T-205	Second stage flash tank (Oligomer)	1			$13,894	ICARUS	2.50	$13,894	$20,841	$34,735	0.71	
	T-206	Second stage low pressure flash tank	1			$11,432	ICARUS	2.50	$11,432	$17,148	$28,580	0.71	
	T-209	Overliming tank	1			$55,422	ICARUS	1.40	$55,422	$22,169	$77,591	0.71	
	T-2220	Lime storage bin	1			$77,726	ICARUS	1.30	$77,726	$23,318	$101,044	0.46	
	W-203	Inter stage washer	2			$350,000	VENDOR	1.30	$700,000	$105,000	$910,000		
		AREA 200 TOTAL							**$10,107,112**		**$13,291,414**		
A300 Production Fermentation	A-300	First stage #1 fermenter agitator	2			$19,341	VENDOR	1.40	$38,682	$7,736	$54,155	0.51	
	A-301	Second stage #1 fermenter agitator	2			$17,249	VENDOR	1.35	$34,498	$6,037	$46,572	0.51	
	A-302	First stage #2 fermenter agitator	2			$18,804	VENDOR	1.50	$37,608	$9,402	$56,412	0.51	
	A-303	Second stage #2 fermenter agitator	2			$18,804	VENDOR	1.35	$37,608	$6,581	$50,771	0.51	
	F-300	1st Stage fermenter No. 1	1			$294,847	VENDOR	2.80	$294,847	$530,725	$825,572	1	
	F-301	2nd Stage fermenter No. 1	1			$208,573	VENDOR	2.80	$208,573	$375,431	$584,004	1	
	F-302	1st Stage fermenter No. 2	1			$308,815	VENDOR	2.80	$308,815	$555,867	$864,682	1	
	F-303	2nd Stage fermenter No. 2	1			$315,678	VENDOR	2.80	$315,678	$568,220	$883,898	1	
	H-300	First stage #1 fermenter heat exchanger	1			$426,000	ICARUS	2.80	$426,000	$766,800	$1,192,800	0.78	
	H-301	Second stage #1 fermenter heat exchange	1			$20,000	ICARUS	2.50	$20,000	$30,000	$50,000	0.78	
	H-302	First stage #2 fermentor heat exchanger	1			$9,100	ICARUS	2.80	$9,100	$16,380	$25,480	0.78	
	H-303	Second stage #2 fermenter heat exchange	1			$31,455	ICARUS	2.40	$31,455	$44,037	$75,492	0.78	
	H-304	Distillation feed preheater	1			$161,363	VENDOR	1.80	$161,363	$129,090	$290,453	0.83	
	P-300	First stage #1 fermenter pump	1			$5,574	ICARUS	3.00	$5,574	$11,148	$16,722	0.79	
	P-301	Second stage #1 fermenter pump	1			$7,086	ICARUS	2.20	$7,086	$8,503	$15,589	0.79	
	P-302	First stage #2 fermentor pump	1			$7,086	ICARUS	2.90	$7,086	$13,463	$20,549	0.79	
	P-303	Second stage #2 fermentor pump	1			$7,088	ICARUS	2.50	$14,172	$10,629	$17,716	0.79	1
	P-304	Yeast recycle pump	1			$7,086	ICARUS	3.50	$7,086	$17,715	$24,801	0.79	
		AREA 300 TOTAL							**$1,965,231**		**$5,095,668**		
	D-501	Beer Column	1			$371,000	VENDOR	2.10	$371,000	$408,100	$779,100	0.78	
	D-502	Rectification Column	1			$242,679	VENDOR	2.10	$242,679	$266,947	$509,626	0.78	
A500 Beer Distillation, Rectification, and Dehydration	E-501	1st Effect Evaporator	2			$214,404	ICARUS	2.10	$428,808	$235,844	$900,497	0.68	
	E-502	2nd Effect Evaporator	1			$214,391	ICARUS	2.10	$214,391	$235,830	$450,221	0.68	
	E-503	3rd Effect Evaporator	2			$214,391	ICARUS	2.10	$428,782	$235,830	$900,442	0.68	
	H-501	Reboiler	1			$78,129	ICARUS	2.10	$78,129	$85,942	$164,071	0.68	
	H-502	Reboiler	1			$13,881	ICARUS	2.10	$13,881	$15,269	$29,150	0.68	
	H-504	Overhead Condenser	1			$4,937	ICARUS	2.10	$4,937	$5,431	$10,368	0.68	
	H-505	Overhead Condenser	1			$42,405	ICARUS	2.10	$42,405	$46,646	$89,051	0.68	
	H-512	Feed/Bottoms Exchanger	1			$22,043	ICARUS	2.10	$44,086	$24,247	$46,290	0.68	1
	H-517	Evaporator Condenser	2			$59,797	ICARUS	2.10	$119,594	$65,777	$251,147	0.68	
	M-503	Ethanol Dehydration Package	1			$1,291,368	ICARUS	1.00	$1,291,368	$0	$1,291,368	0.7	
	P-501	Bottoms Pump	1			$51,163	ICARUS	2.80	$102,326	$92,093	$143,256	0.79	1
	P-503	Reflux Pump	1			$340	ICARUS	2.80	$680	$612	$952	0.79	1
	P-504	Bottoms Pump	1			$4,386	ICARUS	2.80	$8,772	$7,895	$12,281	0.79	1
	P-505	Reflux Pump	1			$4,196	ICARUS	2.80	$8,392	$7,553	$11,749	0.79	1
	P-511	1st Effect Pump	2			$22,943	ICARUS	2.80	$45,886	$41,297	$128,481	0.79	

NREL SOFTWOOD 800 DTPD CASE (STAND ALONE)
Equipment List/Cost (Model G9810H-1)

Section	Equip. No.	Description	Quantity Reqd.	Capacity Each	Size Each	Unit Cost	Cost Source	Install. Factor	Total Cost	Unit Installation	Total Installation	Scaling Factor	Spares
	P-512	2nd Effect Pump	2			$23,722	ICARUS	2.80	$47,444	$42,700	$132,843	0.79	
	P-513	3rd Effect Pump	2			$23,381	ICARUS	2.80	$46,762	$42,086	$130,934	0.79	
	P-514	Condensate Pump	1			$10,747	ICARUS	2.80	$21,494	$19,345	$30,092	0.79	1
	P-515	Scrubber Bottoms Pump	1			$1,254	ICARUS	2.80	$1,254	$2,257	$3,511	0.79	
	T-503	Overhead Receiver	1			$1,030	ICARUS	2.10	$1,030	$1,133	$2,163	0.93	
	T-505	Overhead Receiver	1			$21,519	ICARUS	2.10	$21,519	$23,671	$45,190	0.72	
	T-512	CO_2 Scrubber	1			$50,230	ICARUS	2.10	$50,230	$55,253	$105,483	0.78	
		AREA 500 TOTAL							$3,635,849		$6,168,265		
A600	A-602	Equalization Basin Agitator	1			$19,894	ICARUS	1.20	$19,894	$3,979	$23,873	0.51	
Lignin Separation	A-606	Anaerobic Digestor Agitator	4			$30,300	ICARUS	1.20	$121,200	$24,240	$145,440	0.61	
& Wastewater	A-608	Aerobic Digestor Aerator	16			$31,250	VENDOR	1.40	$500,000	$200,000	$700,000	1	
Treatment	A-630	Recycled Water Tank Agitator	1			$3,311	VENDOR	1.30	$3,311	$993	$4,304	0.51	
	C-601	Lignin Wet Cake Screw	1			$12,456	ICARUS	1.40	$12,456	$4,982	$17,438	0.78	
	C-614	Aerobic Sludge Screw	1			$2,466	ICARUS	1.40	$2,466	$986	$3,452	0.78	
	H-602	Anaerobic Digestor Feed Cooler	1			$175,000	ICARUS	2.10	$175,000	$192,500	$367,500	0.68	
	M-604	Nutrient Feed System	1			$31,400	VENDOR	2.58	$31,400	$49,612	$81,012	1	
	M-606	Biogas Handling System	1			$11,702	VENDOR	1.68	$11,702	$7,957	$19,659	0.6	
	M-612	Filter Aid Addition System	1			$3,000	VENDOR	1.20	$3,000	$600	$3,600	1	
	P-602	Anaerobic Digestor Feed Pump	2			$6,568	ICARUS	2.80	$13,136	$23,645	$36,781	0.79	
	P-606	Aerobic Digestor Feed Pump	2			$6,179	ICARUS	2.80	$12,358	$22,244	$34,602	0.79	
	P-608	Aerobic Sludge Recycle Pump	1			$4,686	ICARUS	2.80	$4,686	$8,435	$13,121	0.79	
	P-610	Aerobic Sludge Pump	1			$4,686	ICARUS	2.80	$4,686	$8,435	$13,121	0.79	
	P-611	Aerobic Digestion Outlet Pump	2			$6,157	ICARUS	2.80	$12,314	$22,165	$34,479	0.79	
	P-614	Sludge Filtrate Recycle Pump	2			$2,568	ICARUS	2.80	$5,136	$9,245	$14,381	0.79	
	P-616	Treated Water Pump	2			$6,150	ICARUS	2.80	$12,300	$22,140	$34,440	0.79	
	P-630	Recycle Water Pump	2			$738	ICARUS	2.80	$1,476	$2,657	$4,133	0.79	
	S-600	Bar Screen	1			$90,468	VENDOR	1.20	$90,468	$18,094	$108,562	0.6	
	S-601	Beer Columns Bottom Centrifuge	3			$659,550	VENDOR	1.20	$1,978,650	$395,730	$2,374,380	0.6	
	S-614	Aerobic Sludge Belt Filter Press	1			$650,223	VENDOR	1.80	$650,223	$520,178	$1,170,401	0.72	
	T-602	Equilization Basin	1			$245,733	VENDOR	1.42	$245,733	$103,208	$348,941	0.51	
	T-606	Anaerobic Digestor	4			$881,081	VENDOR	1.04	$3,524,324	$140,973	$3,665,297	0.61	
	T-608	Aerobic Digestor	1			$635,173	VENDOR	1.00	$635,173	$0	$635,173	1	
	T-610	Clarifier	1			$122,335	VENDOR	1.96	$122,335	$117,442	$239,777	0.51	
	T-630	Recycle Water Tank	1			$6,146	VENDOR	1.40	$6,146	$2,458	$8,604	0.745	
	xxx	Flare	1			$13,000	VENDOR	1.58	$13,000	$7,500	$20,500	1	
		AREA 600 TOTAL							$8,212,573		$10,122,971		
A700	A-701	In-line Ethanol Denaturant Mixer	1			$1,202	ICARUS	1.00	$1,202	$0	$1,202	0.48	
Storage	P-701	Ethanol Product Pump	2			$3,718	ICARUS	2.80	$11,154	$20,077	$31,231	0.79	1
	P-703	Sulfuric Acid Pump	1			$5,430	ICARUS	2.80	$10,860	$19,548	$30,408	0.79	1
	P-704	Firewater Pump	1			$8,659	ICARUS	2.80	$17,318	$31,172	$48,490	0.79	1
	P-706	Ammonia Pump	1			$2,344	ICARUS	2.80	$4,688	$8,438	$13,126	0.79	1
	P-708	Diesel Pump	1			$6,100	ICARUS	2.80	$12,200	$21,960	$34,160	0.79	1
	P-710	Gasoline Pump	1			$2,118	ICARUS	2.80	$4,236	$7,625	$11,861	0.79	1
	P-720	CSL Pump	1			$1,895	ICARUS	2.80	$3,790	$6,822	$10,612	0.79	1

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Section	Equip. No.	Description	Quantity Reqd.	Capacity Each	Size Each	Unit Cost	Cost Source	Install. Factor	Total Cost	Unit Installation	Total Installation	Scaling Factor	Spares
	T-701	Ethanol Product Storage Tank	2			$101,922	VENDOR	1.40	$203,844	$81,538	$285,382	0.85	
	T-703	Sulfuric Acid Storage Tank	1			$33,094	ICARUS	1.20	$33,094	$6,619	$39,713	0.51	
	T-704	Firewater Storage Tank	1			$102,111	VENDOR	1.40	$102,111	$40,844	$142,955	0.85	
	T-706	Ammonia Storage Tank	1			$144,058	ICARUS	1.40	$144,058	$57,623	$201,681	0.72	
	T-708	Diesel Storage Tank	1			$14,400	ICARUS	1.40	$14,400	$5,760	$20,160	0.51	
	T-710	Gasoline Storage Tank	1			$26,739	ICARUS	1.40	$26,739	$10,696	$37,435	0.51	
	T-720	CSL Storage Tank	1			$18,975	ICARUS	1.40	$18,975	$7,590	$26,565	0.79	
		AREA 700 TOTAL							**$608,669**		**$934,981**		
A800	H-811	BFW Preheater	1			$8,108	ICARUS	3.87	$8,108	$23,294	$31,402	0.68	
Boiler Feed	M-802	Combustion Airfan	1			$1,731,651	ICARUS	1.40	$1,731,651	$692,660	$2,424,311	0.79	
Drying,	M-803	Fluidized Bed Combustion Reactor	1			$9,631,760	ICARUS	1.00	$9,631,760	$0	$9,631,760	0.7	
Combustor &	M-804	Combustion Gas Baghouse	1			$520,020	ICARUS	1.13	$520,020	$69,683	$589,703	0.6	
Turbo Generator	M-811	Turbine/Generator	1			$2,849,458	ICARUS	1.15	$2,849,458	$433,118	$3,282,576	0.76	
	M-820	Demineralizer	2			$95,819	ICARUS	1.20	$191,638	$38,328	$229,966	0.6	
	M-822	Condensate Polisher	2			$54,357	ICARUS	1.20	$108,714	$21,743	$130,457	0.6	
	M-830	Hydrazine Addition Package	1			$11,156	ICARUS	1.40	$11,156	$4,462	$15,618	0.6	
	M-832	Ammonia Addition Package	1			$11,156	ICARUS	1.40	$11,156	$4,462	$15,618	0.6	
	M-834	Phosphate Addition Package	1			$11,156	ICARUS	1.40	$11,156	$4,462	$15,618	0.6	
	P-804	Condensate Pump	2			$3,395	ICARUS	4.00	$6,790	$20,370	$27,160	0.79	
	P-811	Turbine Condensate Pump	2			$1,847	ICARUS	4.00	$3,694	$11,082	$14,776	0.79	
	P-824	Deaerator Feed Pump	2			$4,347	ICARUS	4.00	$8,694	$26,082	$34,776	0.79	
	P-826	BFW Pump	2			$110,526	VENDOR	1.50	$221,052	$110,526	$331,578	0.79	
	P-828	Blowdown Pump	2			$2,282	ICARUS	4.00	$4,564	$13,692	$18,256	0.79	
	P-830	Hydrazine Transfer Pump	1			$1,042	ICARUS	4.00	$1,042	$3,126	$4,168	0.79	
	T-804	Condensate Collection Tank	1			$3,257	ICARUS	4.00	$3,257	$9,771	$13,028	0.71	
	T-824	Condensate Surge Drum	1			$11,741	ICARUS	3.00	$11,741	$23,482	$35,223	0.72	
	T-826	Deaerator	1			$20,315	ICARUS	4.00	$20,315	$60,945	$81,260	0.72	
	T-828	Blowdown Flash Drum	1			$4,012	ICARUS	4.00	$4,012	$12,036	$16,048	0.72	
	T-830	Hydrazine Drum	1			$4,249	ICARUS	4.00	$4,249	$12,747	$16,996	0.93	
		AREA 800 TOTAL							**$15,364,227**		**$16,960,299**		
A1000	A-1018	Sterilization Tank Agitator	1			$13,504	ICARUS	1.30	$13,504	$4,051	$17,555	0.51	
Cooling Water &	A-1020	Cleaning Tank Agitator	1			$13,504	ICARUS	1.30	$13,504	$4,051	$17,555	0.51	
Instrument Air	H-1010	Water Sterilizer	1			$1,501	ICARUS	1.40	$1,501	$600	$2,101	0.68	
	M-1002	Cooling Tower System	1			$814,399	ICARUS	1.20	$814,399	$162,880	$977,279	0.78	
	M-1004	Plant Air Compressor	2			$44,012	ICARUS	1.30	$132,036	$39,611	$171,647	0.34	1
	M-1006	Fermenter Air Compressor Package	2			$380,151	ICARUS	1.30	$1,140,453	$342,136	$1,482,589	0.34	1
	M-1008	Chilled Water Package	3			$380,000	ICARUS	1.20	$1,140,000	$228,000	$1,368,000	0.8	
	P-1002	Cooling Water Pump	1			$156,935	ICARUS	2.80	$313,870	$564,966	$878,836	0.79	1
	P-1010	Sterile Water Pump	2			$2,101	ICARUS	2.80	$4,202	$7,564	$11,766	0.79	
	P-1012	Make-up Water Pump	1			$4,535	ICARUS	2.80	$9,070	$16,326	$25,396	0.79	1
	P-1014	Process Water Circulating Pump	2			$5,188	ICARUS	2.80	$15,564	$28,015	$43,579	0.79	1
	P-1016	CIP/CS Supply Pump	2			$2,801	ICARUS	2.80	$5,602	$10,084	$15,686	0.79	
	P-1018	CIP/CS Return Pump	2			$2,802	ICARUS	2.80	$5,604	$10,087	$15,691	0.79	
	S-1004	Instrument Air Dryer	1			$7,777	ICARUS	1.30	$15,554	$4,666	$20,220	0.6	1
	T-1004	Plant Air Receiver	1			$6,721	ICARUS	1.30	$6,721	$2,016	$8,737	0.72	

NREL SOFTWOOD 800 DTPD CASE (STAND ALONE)
Equipment List/Cost (Model G9810H-1)

Section	Equip. No.	Description	Quantity Reqd.	Capacity Each	Size Each	Unit Cost	Cost Source	Install. Factor	Total Cost	Unit Installation	Total Installation	Scaling Factor	Spares
	T-1005	Instrument Air Receiver	1			$0	ICARUS	0.00	$0	$0	$0		
	T-1010	Process Water Tank	1			$13,206	ICARUS	1.40	$13,206	$5,282	$18,488	0.71	
	T-1014	Process Water Tank	1			$119,645	ICARUS	1.40	$119,645	$47,858	$167,503	0.51	
	T-1016	Sterile Rinse Water Tank	1			$13,206	ICARUS	1.40	$13,206	$5,282	$18,488	0.71	
	T-1018	Sterilization Tank	1			$29,013	ICARUS	1.40	$29,013	$11,605	$40,618	0.71	
	T-1020	Cleaning Tank	1			$16,407	ICARUS	1.40	$16,407	$6,563	$22,970	0.71	
		AREA 1000 TOTAL							$3,823,061		$5,324,705		
		AREA 100 Through 1000 TOTAL							$47,293,731		$63,633,070		

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14. ABSTRACT *(Maximum 200 Words)*
This report documents the results of design and project evaluation work which is a continuation of an effort begun in 1998 to study various aspects of ethanol related projects. Merrick has used NREL data and guidance to further develop cost estimates for the two stage dilute acid hydrolysis process for the production of ethanol from softwood. The Software to Ethanol Feasibility Study discussed in this report is an extension or previous, generic, software to ethanol studies.

15. SUBJECT TERMS
Merrick & Company; biomass; ethanol; softwood

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