ORNL/TM-11852

OAK RIDGE NATIONAL LABORATORY

MARTIN MARIETTA

The Ultimate Ethanol: Technoeconomic Evaluation of Ethanol Manufacture, Comparing Yeast vs *Zymomonas* Bacterium Fermentations

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MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

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THE ULTIMATE ETHANOL: TECHNOECONOMIC EVALUATION OF ETHANOL MANUFACTURE, COMPARING YEAST VS *ZYMOMONAS* BACTERIUM FERMENTATIONS

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Prepared for the

Office of Conservation and Renewable Energy
(EG 05 04 00 0)
U.S. Department of Energy
Washington, DC

and

National Corn Growers Association
St. Louis, Missouri

Date Published: August 1991

Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
managed by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-84OR21400

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EXECUTIVE SUMMARY

If ethanol could be produced at a low enough price to serve as the precursor to ethylene and butadiene, it and its derivatives could account for 159 billion lb, or 50% of the U.S. production of 316 billion lb of synthetic organic chemicals, presently valued at $113 billion. This use would consume 3.4 billion bu of corn, or ~40% of the corn crop.

Fermentation economics are presently very unfavorable as a result of softness in petrochemical feedstock prices relative to corn and deficiencies in the fermentation process. Rising demand for oil and continued deterioration of Middle East politics will take care of the first point, and commercialization of advanced fermentation technology now in research stages will improve fermentation economics.

During the heyday of gasohol in the late 1970s and early 1980s, a 60-million-gal fuel-grade ethanol plant could be built for a plant investment of ~$80 million, or $1.30/annual gal. Operating on corn at a net price of $0.038/lb equivalent glucose, the plant would earn a 30% pretax return on total investment at a selling price of $1.78/gal.

If that plant were to be built today, the investment would rise to $120 million, or $2.00/gal. The product would have to sell for $2.55/gal to yield a 30% return, as compared with the current selling prices of $2.15/gal for synthetic ethanol and $1.10/gal for fermentation grade.

Potential savings to be gained through application of advanced process engineering or genetic engineering of improved organisms were evaluated in this study.

The most rewarding development strategy appears to be to demonstrate at pilot scale the use of immobilized *Zymomonas mobilis* bacteria in a fluidized-bed bioreactor operating in a continuous mode over an extended period of time. The operating strategy should be aimed at increasing cell density to at least 50 g/L by retaining immobilized cells in the fermenter and/or by recycling after external separation from the broth. Throughput should be adjusted to control product concentration at ~110 g/L (i.e., as close to the threshold of inhibition as possible).

An existing plant retrofitted to the advanced technology, but operated in the batch mode, would appear to yield a cost-plus-return price of $1.69/gal based on a transfer price

for corn syrup of $0.065/lb of equivalent glucose. However, the price is subject to site economics and the overall financial strategy of the company.

A new, continuous plant could produce at ~$1.80/gal based on *Zymomonas* or at $1.97/gal based on *Saccharomyces* yeast.

There appears to be no inherent design limitation to effect the engineering improvements required in the advanced process operation.

The above scenario assumes that the presently available, product-inhibited organisms would be used. In a longer-term, more difficult research effort, it might be possible to reduce or eliminate product inhibition. As a result, price would be reduced further to $1.75 for the *Zymomonas* system or $1.85 for the yeast fermentation.

It is recommended that the engineering proveout of the advanced process be continued at a pilot scale and that a laboratory program aimed at reducing product inhibition and/or increasing specific productivity be initiated.

THE ULTIMATE ETHANOL
TECHNOECONOMIC EVALUATION OF ETHANOL MANUFACTURE, COMPARING YEAST VS *ZYMOMONAS* BACTERIUM FERMENTATIONS

1. INTRODUCTION

Since the Middle East oil crisis of 1973, many people in government, academia, and industry have been concerned about the strategic implications of a loss of a major source of crude oil for American industry. Accordingly, over the past decade a large number of research programs have been directed toward exploring the potential use of abundant renewable materials as basic feedstocks for fuels and chemicals. The Biocatalyst Project, administered by the Jet Propulsion Laboratory (JPL) as part of the Energy Conversion Utilization Technologies (ECUT) program of the Department of Energy (DOE), is now in the forefront of this effort.

This report represents the completion of a part of an overall project to evaluate the technical and economic status of several newly conceptualized processes for producing ethanol, butanol, acetone, acetic acid, and aerobically produced specialty chemicals, which are candidates for research support. The objectives of the project are to identify strengths and weaknesses in the proposed processes and to assist in developing an ongoing research strategy along economically relevant lines. The products to be studied presently comprise a collective U.S. market for 10.7 billion lb valued at $2.8 billion. If their manufacturing processes were converted from petroleum feedstocks to corn, they would consume 556 million bu.

If ethanol could be produced at a low enough price to serve as the precursor to ethylene and butadiene, it and its derivatives could account for 159 billion lb, or 50% of the U.S. production of 316 billion lb of synthetic organic chemicals, presently valued at $113 billion.[1] This use would consume 3.4 billion bu, or about 45% of the corn crop.

2. SCOPE OF THE STUDY

In the current technoeconomic study of the ethanol process, the state of the art for its fermentative manufacture by the yeast *Saccharomyces cerevisiae* was reviewed and compared with expected performance of the newer *Zymomonas mobilis* bacterium operating as immobilized cells in a fluidized-bed bioreactor.

From this, scenarios for an improved process were developed based on the expectations for adapting either system to reach plausible cell densities and effective concentration levels. The economics of these scenarios were then developed. The sensitivity of the economics to attaining, exceeding, or falling short of goals for key operating parameters was also determined. It is hoped that the results will provide a strong perspective as to the relative merits for supporting research on any of the alternatives and the direction the research should be channeled so as to be economically relevant and improve the technoeconomic position of the process.

3. MARKET POSITION

The United States now leads the major world producers of ethanol (Table 1).[2] Production of synthetic ethanol has declined while fermentation ethanol has increased over the past decade.

Table 1. Market position

	Production (10^6 gal)		
Producer	Synthetic	Fermentation	Total
United States	110	749	852
Western Europe	119	307	426
Japan	21	5	26

In the United States, the synthetic product was being supplanted by fermentation grades until oil prices dropped in the early 1980s. At present, the split of industrial market share is more difficult to predict.

The ethanol market is segmented into traditional uses for ethanol as a chemical intermediate or solvent; an octane enhancer for gasoline in the newer fuels; and, potentially, neat fuel for auto fleets and peak shaving fuel for power turbines. A further potential use might be as a feedstock for producing ethylene, as is presently practiced in Brazil and was practiced in the United States during World War II.

In 1985, chemical uses in the United States amounted to ~90 million gal. The market has dropped to ~40% of 1965 levels as a result of its demise in use as an intermediate for acetaldehyde. Other market uses have been stagnant over these years. Consumption has been for glycol ethers as surface-coating solvents; ethyl acrylates for use in emulsion polymers for surface coatings, adhesives, and polishes; vinegar; ethylamines for use in agricultural chemicals; and ethyl acetate as a solvent for surface coatings and plastics.

Solvent uses amounted to 100-120 million gal. This market has been essentially stagnant over the past two decades. The single largest solvent use has been in formulating toiletries and cosmetics, particularly for hair and scalp preparations. Changing hairstyles led to a severe decline in this use in the seventies. Use in coatings, the second largest solvent use, suffered over the seventies from the availability of cheap isopropyl alcohol. The fastest growing segment is for household cleaning solutions and industrial disinfectants. The original gasohol market was born by government edict on the presumption that ethanol could spare petroleum as a liquid fuel. Although that was not economically feasible, there was a quite valid use for ethanol over the past decade as an octane enhancer in gasoline in spite of the softness of the gasoline market. Since 1978, the use of ethanol as an octane enhancer has grown dramatically to an estimated 750 million gal.

4. HISTORICAL DEVELOPMENT

The fermentation of alcoholic beverages from sugars and starches has, of course, been practiced for thousands of years. Over the past century, fermentation was used exclusively for producing industrial ethanol until about 1930 when synthetic ethanol produced from ethylene by the indirect ethyl sulfate process was introduced. By 1975, this process had been completely replaced by the Shell process for the direct hydration of ethylene. Until the 1950s, the fermentation process commanded >50% of the market; but its share steadily diminished until the advent of gasohol following the energy crisis of 1973.

In the Shell process, ethylene gas and water vapor are reacted at 250° C and 1000 psi over a phosphoric acid catalyst. Yield is 97% at 4.2% conversion per pass. The process requires 0.63 lb of ethylene/lb of alcohol. Total capacity in Shell direct hydration plants in the United States, Western Europe, and Japan was 410 million gal in 1982. However, there has been a considerable shakeout of participants in the synthetic ethanol market over the past 13 years. U.S. capacity has dropped from a high of 318 million gal in 1965 to 211 million gal in 1983. Three producers are involved: Union Carbide at 120 million gal; National Distillers at 66 million gal; and Eastman Kodak at 25 million gal. It was said that Carbide was buying crude Brazilian alcohol in the seventies and refining it here while cutting back on its synthetic production. More recently, Carbide has been buying synthetic ethanol on a toll basis from Saudi Arabia. This production is based on ethylene produced from Saudi waste flare gas.

Industrial interest in fermentation chemicals had revived in the 1970s as a result of the oil crisis. In the United States, ethanol fermentation is now dominated by the plants operated by Archer-Daniels-Midland, which have a combined capacity of 220 million gal. Other entries over the past decade, such as the CPC International/Texaco venture at Pekin, Illinois; the Ashland Oil/Publicker Industries/Ohio Farm Bureau plant at South Point, Ohio; and Staley's new plant at Loudon, Tennessee, have been designed more conservatively at 40-60 million gal. These new plants are augmented by the capacity of the established industrial fermentation plants of Grain Processing Corporation and Midwest Solvents and by a myriad of smaller converted liquor distilleries that were pressed into service to participate in the gasohol market.

Unfortunately, the softening of oil prices in the 1980s removed the newly acquired competitive edge for renewable materials compared with fossil feedstocks and resulted in an almost complete loss of momentum in research in this area of biotechnology. Over the decade prior to 1973, the prices of ethylene and synthetic ethanol were relatively stable at $0.035/lb and $0.35/gal, respectively. However, soaring chemical prices resulting from the energy crisis of 1973 raised the price of ethylene to a peak of $0.26 in 1981.

Following this, it dropped back to $0.15/lb before rising to the 1Q89 price of $0.32 or $1.22/gal of synthetic ethanol.[3] This cost is more than the current $1.10 (depressed) price for fermentation ethanol. If the price continues to rise as expected, the economic pendulum may swing back in favor of the fermentation process.

5. BIOPROCESS PROBLEMS

In general, fermentation processes have two major problems: (1) inherently poor yields resulting from the production of by-products, including high levels of carbon dioxide and hydrogen needed to maintain the electronic balance of the metabolism of the organism, coupled with the current relatively high cost of renewable sugars and starches compared with the presently depressed prices for petroleum; and (2) the inhibition of most organisms by their own products, which causes the fermentation to shut down after reaching only low product concentrations, as a result of which the recovery of product from dilute aqueous solution is accordingly expensive.

6. RAW MATERIAL ECONOMICS

Raw material economics has always been one of the most important parameters in determining the commercial viability of fermentation processes. In the United States, corn is the principal substrate for fermentation ethanol, comprising 77% of the grain used and 68% of all substrates. Molasses, grapes, and sugarbeets are more widely used in Europe. Substrate cost per gallon of product is determined by the combination of substrate demand and price.

6.1 SUBSTRATE DEMAND

Product yield, as determined by fermentation stoichiometry, is obviously an important cost-determining factor. The stoichiometry for the simultaneous chemical reactions of the yeast and bacterium fermentations is outlined in Appendix A and summarized in Table 2 as mol/1000 mol ethanol formed.[4-9]

Table 2. Stoichiometry for simultaneous chemical reactions

	Saccharomyces	*Zymomonas*
Reacted		
Glucose	531.81	508.42
Water	67.91	16.49
Produced		
Ethanol	1000.00	1000.00
Glycerol	23.00	5.67
Acetic acid	8.60	5.41
Isoamyl alcohol	2.61	0.00
Lactic acid	1.10	1.03
Succinic acid	0.57	0.00
Acetaldehyde	1.50	0.00
Light ends	0.52	0.52
Carbon dioxide	1080.91	1017.53
Hydrogen	123.77	28.35

Thus, the theoretical yield of ethanol from glucose amounts to 48 wt % for the yeast system and 50 wt % for the bacterium. In practice, the actual approach to theoretical is 90-95% for the yeast and ~98% for the bacterium because of the consumption of glucose for cell growth and maintenance. The difference arises because *Z. mobilis* consumes only one net ATP per glucose whereas *S. cerevisiae* uses two. Hence, the cell yield per unit of glucose consumed for cells is twice as high for the bacterium as for the yeast.[10,11]

Overall, then, even though the organisms are operating close to their biological limit, carbon yields for either system are poor as a result of large losses to carbon dioxide and sundry other by-products. Actual glucose demands amount to 2.19-2.31 lb/lb ethanol, or 2.27-2.40 gal absolute alcohol/bu of corn for the yeast and ~2.03 lb/lb, or 2.59 gal/bu for the bacterium, giving the latter a 7-12% competitive advantage in raw material costs.

6.2 UNCERTAINTIES OF SUGAR PRICE

The cost of the sugar substrate is another very important element of cost, particularly if the engineering improvements of the process can be realized.

This study was based on the availability of a contract supply of a dilute 45% corn syrup from an adjoining wet mill at a transfer price of $0.065/lb equivalent glucose. Certainly the hydrolysis can be done better and more cheaply as part of a large wet mill than as the mash operation used in older distilleries. In addition, handling hydrolysis as part of the wet mill rather than in fermentation eliminates tying up expensive fermenters as slow hydrolyzers.

Unfortunately, transfer price information is considered proprietary by wet millers and is not forthcoming. However, a recent analysis of the feedstock costs for fermentation ethanol plants[12] provided the following cost data (Table 3).

Table 3. Analysis of feedstock costs

Period	Corn price* ($/bu)	Net corn ($/lb glucose)	Ethanol ($/gal)
1Q81-1Q83	2.78	0.035	1.71
1Q81-2Q86	2.86	0.039	1.62
2Q87-4Q88	1.79	0.009	1.11

*#2 yellow corn ex Chicago.

Such net corn figures do not include an allowance for the cost and investment needed to hydrolyze the starch.

To develop a transfer price that could be used to represent a stable period of corn prices, the following estimate was made by the author as an approximate, if not qualified, evaluation of substrate costs. The basis was an early 1980 plant processing 60,000 daily bu to produce 720 million annual lb of syrup (dry basis). The wet mill yield was assumed to be 31.6 lb starch/bu. Investment in the wet mill was estimated to be $40 million. As shown in Table 4, at a corn price of $2.60/bu, a sugar cost of ~$0.081/lb of starch appears to correspond to a correlation of published data shown in Fig. 1.

6.3 SUBSTRATE COMPETITIVENESS

It cannot be expected that the yield of ethanol from sugar can be increased over its present biological limit. Consequently, further competitiveness of corn-based processes will have to depend on increases in the cost of crude oil relative to corn.

Commercial acceptance of the enhanced fermentation process will ultimately depend on the direction taken by crude oil prices. This market is still soft at ~$17-$20/bbl. However, James McNabb of Conoco[13] has pointed out that OPEC is presently operating at only 60% of capacity. By the early 1990s, production is expected to reach 80%; market power will shift back from the buyer to the seller, with a corollary increase in oil prices. At that time, it is expected that the United States will be importing half of its oil supply instead of the 7% it imported at the time of the 1973 oil crisis. As a result, he forecasts that although oil prices will remain in the low $20s until 1990, they will reach the mid $30s by 1995 and $50/bbl by the year 2000 (Fig. 2). Other market watchers are also foretelling the start of the turnaround in oil prices.[14-19] Thus, a doubling of the price for ethanol over the next decade is not out of the question.

7. PRODUCT INHIBITION

As with most fermentations, both *S. cerevisiae* and *Z. mobilis* are inhibited by their own substrate and products. Fermentation kinetics and process inhibition have been

Table 4. Evaluation of substrate costs.

Item	Cost ($/lb glucose)
Corn @ $2.60/bu	0.074
Coproduct credits	
Corn oil 1.7 lb/bu @ $0.26/lb	(0.013)
60% Gluten meal 2.2 lb/bu @ $265/ton	(0.008)
Gluten feed 11.5 lb/bu @ $125/ton	(0.020)
Total credits	(0.041)
Net corn	0.033
Enzymes	0.006
Labor	0.007
Utilities	0.008
Maintenance, taxes & insurance	0.004
Depreciation	0.004
Net cost of manufacture	0.062
Selling, administrative & research	0.002
Earnings before taxes	0.017
Selling price	$0.081
Savings for contract 45% syrup	
Steam 1.15 lb/lb	(0.006)
Labor	(0.001)
Maintenance & depreciation	(0.001)
Sales, adm., & research	(0.001)
Earnings	(0.007)
Adjusted contract price	$0.065

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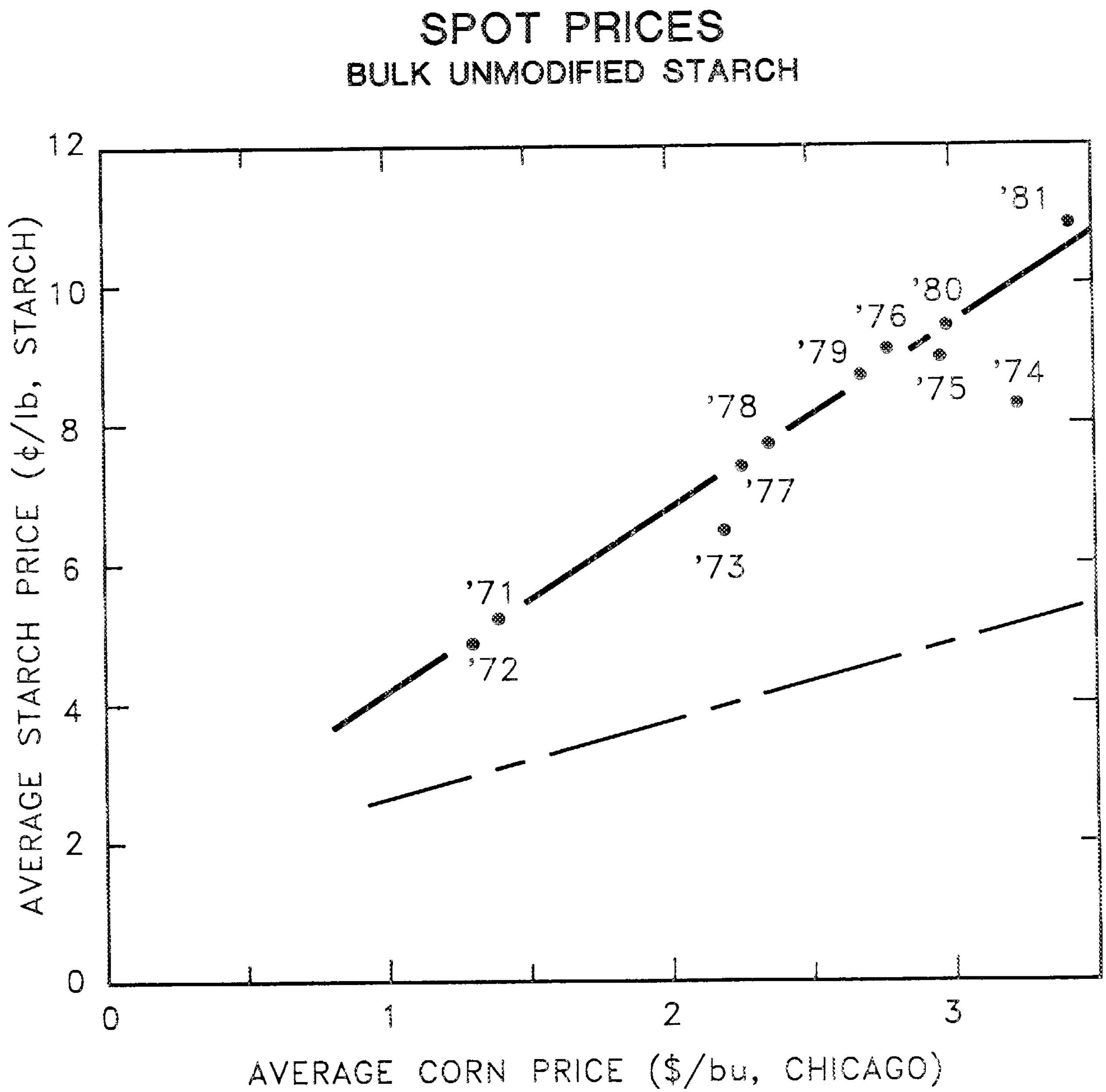


Fig. 1. CPC International, Inc., bulk unmodified starch spot prices.

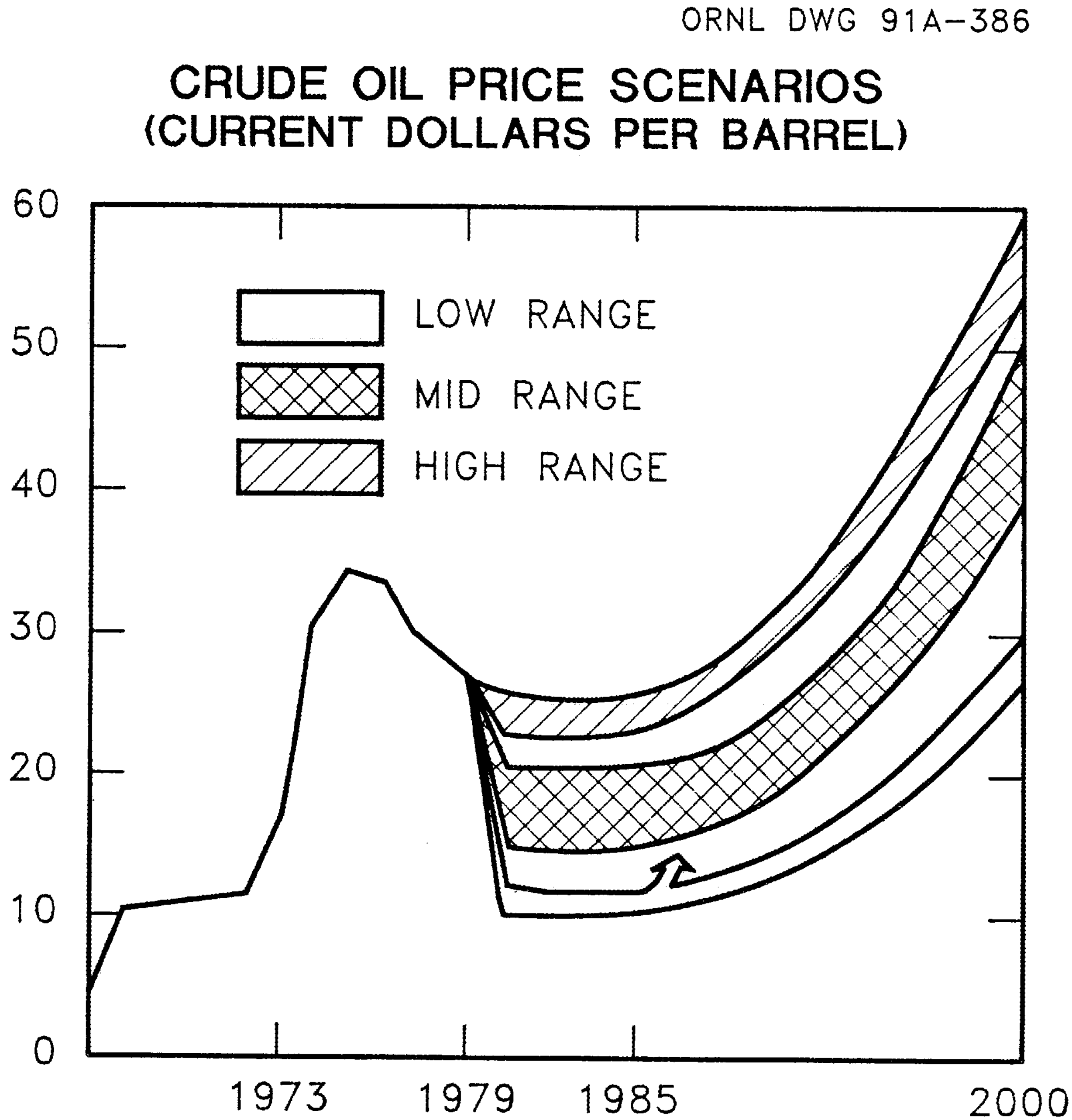


Fig. 2. Crude oil prices (September 1986) - used by permission of Conoco, Inc.

studied by a number of researchers for *Saccharomyces*[20-26] and *Zymomonas*.[27-37] Although agreement is not perfect, it appears that the yeast fermentation is totally inhibited by ethanol concentrations of ~105 g/L. The inhibitory cutoff for the bacterium is distinctly higher at 127 g/L. Furthermore, as shown in Fig. 3, the decay in specific productivity for *Zymomonas* is flat at 5.2 g product/g cells·L up to a concentration of 55 g/L, after which inhibition begins. For the yeast the maximum specificity of 1.5 g/g·L drops over the whole range of concentration. Thus, as product concentration increases, specific productivity decreases, as does the dilution rate for a fixed ratio of product to cells. This adverse effect has a profound influence on cost and leads to a trade-off between maximizing concentration and maximizing dilution rate.

One possible solution to the inhibition problem would be to integrate the fermentation and distillation sections of the process so as to increase productivity while removing the product from the field of fermentation as rapidly as it forms. This is an automatic consequence of converting from a batch to a continuous process in which a proportionate increase in cell density is effected either by immobilizing the cells, as in the Oak Ridge case,[43-45] to prevent their loss from the fermenter or by filtering the cells from the beer and recycling them while maintaining product concentration in the fermenter near the threshold of inhibition. The immobilization approach would be preferred because it would avoid passing cells through a filter and, possibly, a still with possible deactivation of cells by thermal or mechanical attrition with possible plugging of the trays of the still.

Thus, assuming that specific productivity (g product/g cell·h) remains constant at constant (but maximum allowable) product concentration, the higher the cell density the greater the volumetric productivity (g product/L·h), the shorter the fermentation time and, hence, the smaller the fermenter size and investment required for a desired design capacity; or, for an existing fermentation plant, the greater the throughput and production level.

Alternatively, new organisms might be genetically engineered to be less inhibited by product and/or have a higher specific productivity than the wild strain.

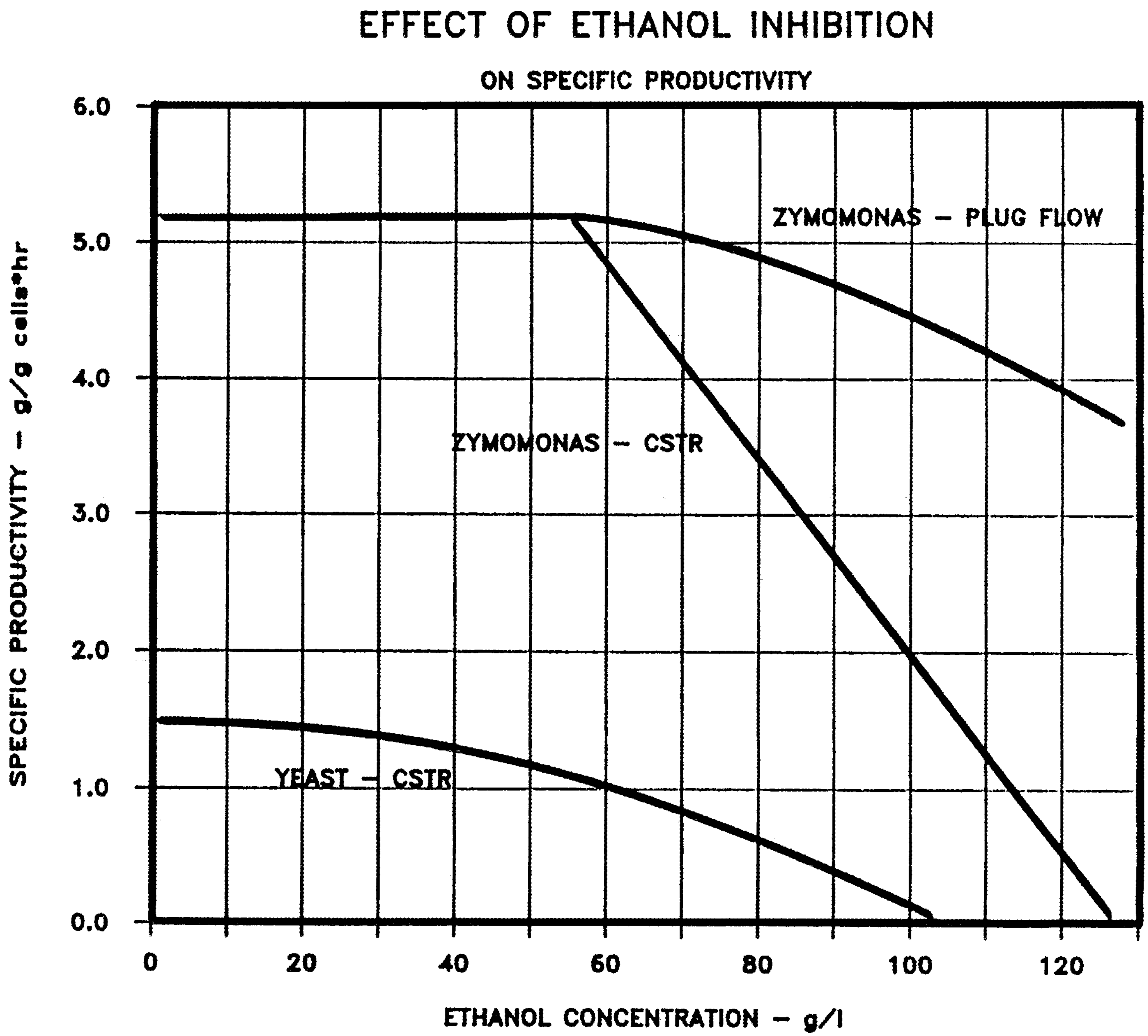


Fig. 3. Effect of ethanol inhibition on specific productivity

8. PROCESS SCENARIO FOR THIS STUDY

This study was based on using a fluidized-bed bioreactor similar in design to the Oak Ridge approach. A flow sheet for the process model is shown in Fig. 4. Beer leaving the fermenter train is passed to a filter unit to separate cells from broth. The cell slurry is recycled except for a purge bleed equal to the amount produced.

A standard distillation train was assumed for the basecase. Greater heat economy might be realized by a more elaborate heat recovery scheme.[38,39] It would be interesting to compare the conventional design with cases based on using the Dartmouth Intermediate Heat Pumps and Optimal Sidestream Return (IHOSR) distillation process.[40]

In either design, the cell-free broth enters the first (beer) still of the distillation train, wherein the ethanol azeotrope and low-boiling impurities are separated from salts, high-boiling by-products, and water. The aqueous tails from the stripping section are sent to waste disposal. No recovery of purged cells as distillers grains was assumed in this model. Fuel oils (amyl alcohols, mainly 3-methyl-1-butanol) are removed as a sidestream drawoff from the beer still. Low boilers are separated overhead in a refiner, and the azeotrope is sent to a dehydration column to recover absolute ethanol.

9. OPERATING SCENARIO

It was assumed that the plant would be sited in the Midwest adjoining a corn wet mill with dilute, not-evaporated, 45% syrup supplied over the fence by pipeline. Capacity was sized to a 60-million-gal-per-year absolute ethanol plant with a midpoint of construction in 1984 and operation in 1988 at 90% utility. The investment estimates include a 30% contingency for undeveloped design, etc. This uncertainty level is on the high side for designs based on reaming out existing facilities and on the low side for designs scaled up from semiworks data. Cost factors and financial viewpoints for the operation were chosen to represent those commonly used by large chemical companies in producing commodity products. Technical and financial data for the cases evaluated are provided in the appendixes.

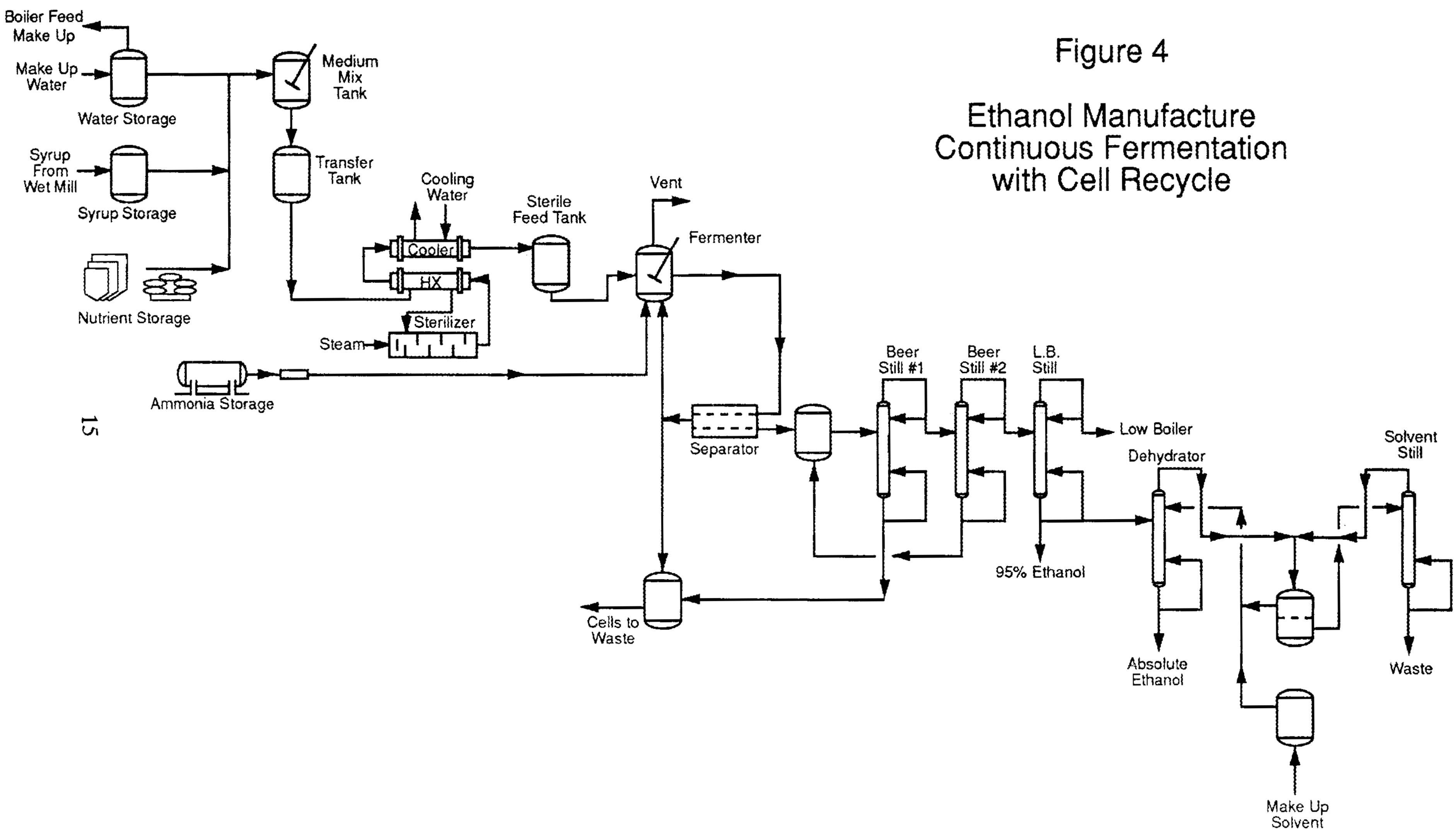


Fig. 4. Ethanol manufacture continuous fermentation with cell recycle.

10. PROCESS DEVELOPMENT STRATEGY

Hopefully, an organism might be genetically engineered that is not inhibited by product. However, this goal may be very difficult to attain.

Short of this, then, the best fermentation strategy appears to be to control product concentration at the optimum level vis-a-vis product inhibition while operating at as high a cell density as is physically and/or biologically possible. Assuming a constant specific productivity at an optimum product concentration, this operating strategy fixes dilution rate at a maximum level and minimizes fermenter size and investment. An attempt was made in this study to define the optima within the limitations of published data.

10.1 BATCH MODE

In the operation of the conventional batch fermenter, it is well known that as the product accumulates in the fermenter a point is reached at which product inhibition of the functioning of the organism shuts down the fermentation. The amount of product produced is controlled by the volume of the fermenter at the maximum attainable product concentration -- usually a low amount.

In view of this limitation of the batch system, many researchers have evaluated the advantages of removing product from the batch fermenter "as fast as it forms" by various means in order to sustain the fermentation over a longer period. In such cases, additional substrate must be added in such a manner as to not adversely affect the fermentation by substrate inhibition. This condition usually results in the use of a fed-batch mode.

In effect, however, this approach actually represents a conversion of the batch mode to a continuous mode in which cells are prevented from leaving the fermenter. Thus, in any continuous system, the product is always being removed from the fermenter as fast as it forms.

10.2 CONTINUOUS MODE

It appears then that the development of a continuous fermentation system is a fundamental requirement for improving the economic viability of the ethanol process. Continuous operation has been demonstrated at less than commercial scale by Bajpai and Margaritis,[29] Ghose and Tyagi,[21,41] Wilke,[20,24,42] Davison and Scott,[43,44] and others.

Scott and Davison[45] are operating a rack-scale 2.5-m fluidized-bed bioreactor at the Oak Ridge National Laboratory (ORNL). The process is based on *Z. mobilis* immobilized within 1.0-1.5 mm K-carrageenan beads at cell loadings of 15-50 g/L beads (6.6-22 g/L fermenter). The fermenter is operated in a continuous mode at 30° C and pH 5.0. It was reported that plug-flow kinetics is achieved. Yield was reported to be 0.49 g ethanol/g glucose converted, or 97.5% of the theoretical yield. Glucose spill is <0.1% at an ethanol concentration of 74 g/L and a volumetric productivity of 60 g/L·h. Volumetric productivity is normally in the range 50-120 g/L·h but has reached 186 g/L·h with 95% glucose conversion by recycling cells to higher density. This performance is in sharp contrast with the volumetric productivities of 1-2 g/L·h usually reported by conventional yeast-based plants.

11. FUEL ETHANOL PLANTS OF THE SEVENTIES

The period of the late 1970s marked the heyday of construction of new fuel ethanol plants or retrofitting of former liquor distilleries. A case presented in Appendix B was based on a 60-million-gal yeast-based plant with a midpoint of construction of 1976 and operating in 1980. Cell recycle was not included. Thus, the case is an attempt to reconstruct the economics for the plants that now constitute the fuel alcohol industry.

Investment in this plant in 1976 dollars amounted to $1.57/annual gal, comprising $1.31 for direct and allocated plant investment and $0.26 for working capital. Of the plant investment, the cost of twelve 500,000-gal fermenters accounted for 46%.

The cost of manufacture (mill cost) amounted to $1.00/gal at a cost of sales of $1.26. This cost performance leads to a pretax return on investment of 30% for a selling price of $1.79/gal. Raw materials comprise 58% of cost of manufacture and 32% of selling price. Capital-related charges account for 37% of selling price.

This case is compared in Table 5 with several estimates made in about 1980 by various organizations: a task force of the American Institute of Chemical Engineers chaired by I.B. Margiloff of Publicker Industries;[46] a study commissioned by DOE;[47] and a study made by the Katzen organization for a plant with maximum energy recovery.[38,39,48] Agreement is generally good considering the diverse viewpoints and bases.

12. EFFECT OF VENTURE TIMING

If the plants described in the preceding section were to be built today, costs would be substantially higher. Construction costs for a plant with a midpoint of construction of 1984 would be 73% higher than the plant built in 1976. Also, the cost assumed for substrate in 1988 was almost twice that used in the earlier estimate. This point is discussed later. As a net result, the selling price in 1988 would have to be $2.55/gal to yield a 30% pretax return as compared with currently distressed prices of $1.10/gal for fuel alcohol.[49] This may be one reason why new plants are not being built.

The estimate for 1988 operation is compared with that for 1980 in Table 6. The effects of raw material and capital charges are clear. **The 1988 estimate serves as the basecase in this study for comparison with the estimates made for more advanced technology**. It is described in detail in Appendix C.

13. ECONOMIC POTENTIAL OF ADVANCED FERMENTER SYSTEMS

The economic model for the advanced fermenter system was used to explore the potential advantages of operating with cell recycle and/or improved specific productivity for both inhibited and noninhibited systems of either *S. cerevisiae* or *Z. mobilis* under either batch or continuous modes.

The conversion economics of the ethanol fermentation process can be improved in two ways: (1) by increasing product concentration or (2) by increasing fermentation rate.

Table 5. Comparison of estimates
Ethanol process economics
Batch fermentation - no cell recycle

Estimate		AIChE	DOE	KATZEN	BioEn-Gene-Er Associates
Capacity, Million GPY		40	50	50	60
Midpoint of construction				1981	1976
Investment, $/gal					
Direct & alloc. plant invest.				1.28	1.31
Working capital				0.12	0.26
Total investment				1.40	1.57
Cost, $/gal	Operating year	1980	1983	1983	1980
Corn		1.12	1.20	1.09	
By-product credits		(0.50)	(0.60)	(0.47)	—
Net corn		0.62	0.60	0.63	0.56*
Other raw materials		0.14	0.07	0.02	0.01
Total raw materials		0.76	0.67	0.65	0.57
Utilities		0.19	0.20	0.11	0.22
Labor-related		0.07	0.08	0.06	0.06
Capital-related			0.17	0.21	0.15
		0.43			
Cost of manufacture			1.12	1.03	1.00
SE, D, R&D, adm, & IC		—	0.18	0.18	0.26
Cost of sales		1.43	1.30	1.21	1.26
Pretax earnings @ 30% ROI				0.47	0.53
Selling price				1.68	1.79

*Syrup ex wet mill at $0.038/lb equivalent glucose.

Table 6. Effect of venture timing
60 million GPY ethanol manufacture
Inhibited *Saccharomyces* yeast
Batch fermentation - no cell recycle

Midpoint of construction	1976	1984
Construction cost index	74	128
Operating year	1980	1988
Substrate cost, $/lb equiv. glucose	0.038	0.065
Investment, $/million		
Direct permanent investment	54.5	91.1
Allocated power, services & general	24.1	26.8
Working capital	15.4	22.1
Total investment	94.1	140.0
Cost, $/gal		
Raw materials	0.57	0.95
Utilities	0.22	0.15
Labor-related	0.06	0.10
Capital-related	0.14	0.23
Cost of manufacture	0.99	1.42
SE, D, R&D, adm, & I.C.	0.27	0.35
Cost of sales	1.26	1.78
Pretax earnings based on 39% ROI	0.52	0.78
By-product credits	0.00	0.00
Selling price	1.78	2.55

Of the two, increasing product concentration has the greater effect on cost. At any desired production level, the reciprocal of concentration -- liters/gram--represents the volume of the equipment required for the complete process: media preparation, fermentation, product recovery, and product refining. Hence, concentration has a dominant effect on total process investment.

Fermentation rate affects only fermenter volume and investment. However, since fermenter investment usually accounts for a large part of total investment, the effect of rate on cost can be very large, indeed. At a fixed production level and product concentration, fermentation rate can be increased and fermenter volume decreased by increasing cell density, increasing specific productivity, or both.

Increasing cell density by containing the cells in an immobilized state in the fermenter or by recycling involves the appropriate engineering of the system under the constraints of broth viscosity and organism viability. However, increasing specific productivity involves producing a genetic change in the organism, which may be difficult to achieve in practice. Nevertheless, both approaches have merit and need to be pursued.

13.1 INHIBITED BATCH SYSTEMS WITHOUT CELL RECYCLE

Inhibited systems exhibit a minimum in cost as product concentration is increased up to the point of total inhibition. This effect is shown for the batch systems in Table 7 for a situation involving little or no cell recycle. (Cell density was held constant during the calculation of sensitivity, which means the cases at low concentrations had a small cell recycle involved.)

It should be noted that for the batch system, the term "dilution rate" refers to the reciprocal of the sum of batch time plus turnaround time [i.e., 1/(bt+tt)]. For the large fermenters used in the models, a turnaround time of 12 h was used for draining, cleaning, sterilizing, refilling, and inoculating the fermenter after each batch run. This loss of time is not incurred in continuous operation, which, as will be seen, has a large effect on cost.

It should also be noted that specific productivity as used in this study refers to run time only, whereas volumetric productivity and dilution rate take into account the turnaround time for batch operation.

Table 7. Ethanol from *S. cerevisiae* and *Z. mobilis* in an inhibited batch system
Effect of product concentration

Product conc. (g/L)	Specific prod'ity (g/g·h)	Volume prod'ity (g/L·h)	Dilution rate (1/h)	Total cost ($/gal)	Capital cost ($/gal)	Fermenter invest'mt ($million)	Ferm inv/ tot plant invest'mt (%)
S. cerevisiae							
40	1.28		0.045	2.78	1.13	52	38
50	1.17		0.038	2.62	1.03	48	40
60	1.04		0.032	2.53	0.97	48	42
70	0.84		0.025	2.51	0.96	52	46
80	0.63		0.018	2.56	1.02	63	53
90	0.38		0.011	2.82	1.24	94	64
100	0.12		0.004	4.29	2.53	255	83
Z. mobilis							
50	5.2	3.1	0.063	2.37	0.87	29	29
60	4.8	3.5	0.059	2.25	0.79	26	28
70	4.1	3.7	0.053	2.18	0.74	25	29
80	3.4	3.7	0.046	2.13	0.71	25	31
90	2.7	3.5	0.039	2.11	0.70	26	33
100	2.0	3.0	0.030	2.12	0.71	30	37
110	1.2	2.3	0.021	2.19	0.78	41	46
120	0.5	1.1	0.009	2.57	1.11	84	64

2.4 g/L cell density

For the yeast, specific productivity and dilution rate are decreased tenfold. However, because of the opposing effects of concentration versus productivity, volumetric productivity is maximized and fermenter investment is minimized at ~55 g/L. Capital charges and total cost are minimized at a higher concentration of ~70 g/L as a result of the effect of concentration on the rest of the plant as well.

The results for *Zymomonas* were similar except that the costs for the bacterium cases were always lower as a result of higher specific productivities, with a minimum cost of ~$2.11/gal compared with a minimum of $2.51 for the yeast. In addition, the bacterium can operate at concentrations higher than the yeast cutoff.

13.2 INHIBITED BATCH SYSTEMS WITH CELL RECYCLE

Cost is very sensitive to the recycle of cells. As shown in Table 8, cost decreases with increases in cell density at any product concentration. This effect mainly results from a concomitant reduction in fermenter investment. Total flow through a fermenter and specific productivity are fixed, irrespective of cell density, by fixing product concentration and annual production rate. Consequently, as cell density is increased by recycle, fermentation time and volume (investment) can be correspondingly decreased in the design to balance production rate at a constant specific productivity.

For any product concentration, then, it is clearly desirable to operate at as high a cell recycle rate as possible. For example, Wilke operated at yeast concentrations up to 124 g dry wt/L at a volumetric productivity of 82 g/L·h;[20] and Rogers reported operating with *Zymomonas* densities of 40 g/L for >50 h[32] at a volumetric productivity of 120 g/L·h. However, cell densities above these may produce unacceptable viscosities and adverse effects on the organism in the fermenter. This is an important point for further research clarification.

As a practical matter, it does not appear from the projections of Table 4 that increasing cell densities much above 50 g/L would have a significant effect on reducing further the cost of the product. At that cell density, the cost of ethanol by the yeast system at a concentration of 90 g/L would be $2.09/gal compared with $1.90 for the bacterium system at 110 g/L of product.

Table 8. Ethanol from *S. cerevisiae* and *Z. mobilis* in an inhibited batch system
Effect of product concentration and cell recycle on cost-plus-return

Product conc. (g/L)	Cost-plus-return ($/gal)					
	Cell density (g/L)					
	5	10	20	50	100	150
S. cerevisiae						
40	2.69	2.62	2.58	2.54	2.51	2.49
50	2.52	2.45	2.41	2.37	2.34	2.33
60	2.42	2.33	2.29	2.26	2.23	2.22
70	2.37	2.27	2.21	2.17	2.15	2.14
80	2.37	2.24	2.17	2.12	2.09	2.08
90	2.51	2.28	2.16	2.09	2.05	2.04
100	3.37	2.69	2.35	2.14	2.06	2.03
Z. mobilis						
50	2.33	2.31	2.30	2.28	2.26	2.24
60	2.21	2.19	2.18	2.16	2.15	2.13
70	2.13	2.11	2.10	2.08	2.06	2.05
80	2.07	2.05	2.03	2.02	2.00	1.99
90	2.04	2.00	1.99	1.97	1.95	1.95
100	2.02	1.97	1.95	1.93	1.92	1.91
110	2.04	1.97	1.93	1.90	1.89	1.88
120	2.21	2.04	1.95	1.90	1.87	1.86

13.3 INHIBITED CONSTANT-ENVIRONMENT CONTINUOUS SYSTEMS WITHOUT CELL RECYCLE

The very real advantage of operating in a continuous mode can be seen from the data of Table 9. It can be seen that volumetric productivity and dilution rate have values quite higher at low product concentrations than the respective cases for batch operation. The difference is related to batch turnaround time. At low concentrations, fermenter residence time is low and the relative adverse effect of turnaround is high, thus limiting dilution rates to low values. At high concentrations, fermenter time is very high and the effect of turnaround becomes insignificant, so that dilution rates for batch versus continuous operation approach each other.

Turnaround imposes a strict ceiling on effective dilution rate for batch operation. Thus, even at a fermenter time of zero, the dilution rate is held to 0.083 h^{-1} (1/12 h). Continuous operation is not so constrained and can approach effective dilution rates near infinity, at which point the cost of fermenters becomes insignificant relative to total plant investment.

For operation without cell recycle in a constant-environment continuous mode, the yeast exhibits a minimum cost-plus-return price of $2.36/gal at a product concentration of ~65 g/L. The corresponding minimum price for the *Zymomonas* system is $2.00 at 85 g/L.

13.4 INHIBITED CONSTANT-ENVIRONMENT CONTINUOUS SYSTEMS WITH CELL RECYCLE

The corresponding data for operation with cell recycle in a constant-environment continuous system are shown in Table 10. For this case, the minimum cost for the yeast at a cell density of 50 g/L is $1.97/gal at a product density of 90 g/L. For the bacterium, the minimum for a cell density of 50 g/L is $1.81 at 110 g/L. These data are plotted in Figs. 5 and 6. As cell density is increased, the minimum in cost moves toward higher product concentrations.

Table 9. Ethanol from *S. cerevisiae* and *Z. mobilis*
Inhibited continuous system
Effect of product concentration

Product conc. (g/L)	Specific prod'ity (g/g·h)	Volume prod'ity (g/L·h)	Dilution rate (1/h)	Total cost ($/gal)	Capital cost ($/gal)	Fermenter invest'mt ($million)	Ferm inv/ tot plant invest'mt (%)
S. cerevisiae							
40	1.28		0.097	2.52	0.91	24	22
50	1.17		0.071	2.41	0.85	26	26
60	1.04		0.052	2.36	0.82	29	31
70	0.84		0.036	2.36	0.83	36	37
80	0.63		0.024	2.42	0.90	49	46
90	0.38		0.013	2.69	1.14	81	60
100	0.12		0.004	4.15	2.42	244	83
Z. mobilis (constant environment)							
50	5.2	12.7	0.254	2.17	0.69	7	9
60	4.8	11.8	0.197	2.08	0.64	8	11
70	4.1	10.1	0.144	2.03	0.61	9	13
80	3.4	8.3	0.104	2.00	0.60	11	16
90	2.7	6.5	0.072	2.00	0.60	14	21
100	2.0	4.8	0.048	2.01	0.62	19	28
110	1.2	3.0	0.027	2.10	0.70	31	39
120	0.5	1.2	0.010	2.48	1.04	75	61
	2.4 g/L cell density						

Table 10. Ethanol from *S. cerevisiae* and *Z. mobilis*
Inhibited continuous system
Effect of product concentration and cell recycle
on cost-plus-return

Product conc. (g/L)	Cost ($/gal) — Cell density (g/L) 5	10	20	50	100	150
S. cerevisiae						
40	2.43	2.37	2.33	2.29	2.26	2.24
50	2.32	2.24	2.20	2.17	2.14	2.12
60	2.25	2.16	2.12	2.08	2.06	2.05
70	2.23	2.12	2.07	2.03	2.01	2.00
80	2.25	2.11	2.04	1.99	1.97	1.95
90	2.39	2.16	2.05	1.97	1.94	1.93
100	3.27	2.59	2.25	2.04	1.96	1.93
Z. mobilis (constant environment)						
50	2.13	2.11	2.09	2.08	2.05	
60	2.04	2.02	2.01	1.99	1.98	
70	1.99	1.96	1.95	1.93	1.92	
80	1.95	1.92	1.91	1.89	1.87	
90	1.923	1.89	1.87	1.86	1.84	
100	1.917	1.872	1.85	1.83	1.81	
110	1.94	1.873	1.84	1.810	1.795	
120	2.12	1.95	1.87	1.810	1.786	

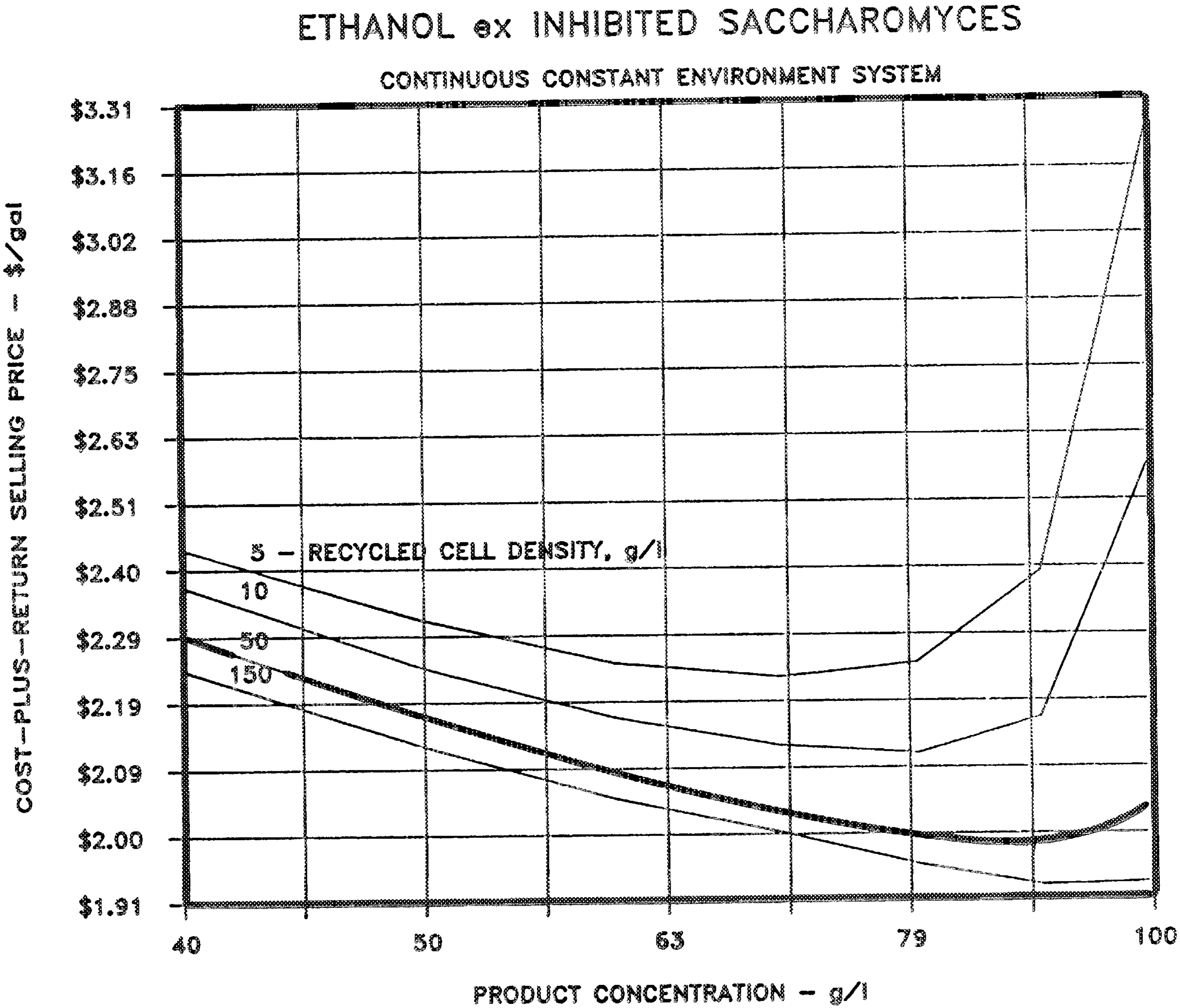


Fig. 5. Ethanol ex inhibited *Saccharomyces* continuous constant environment system.

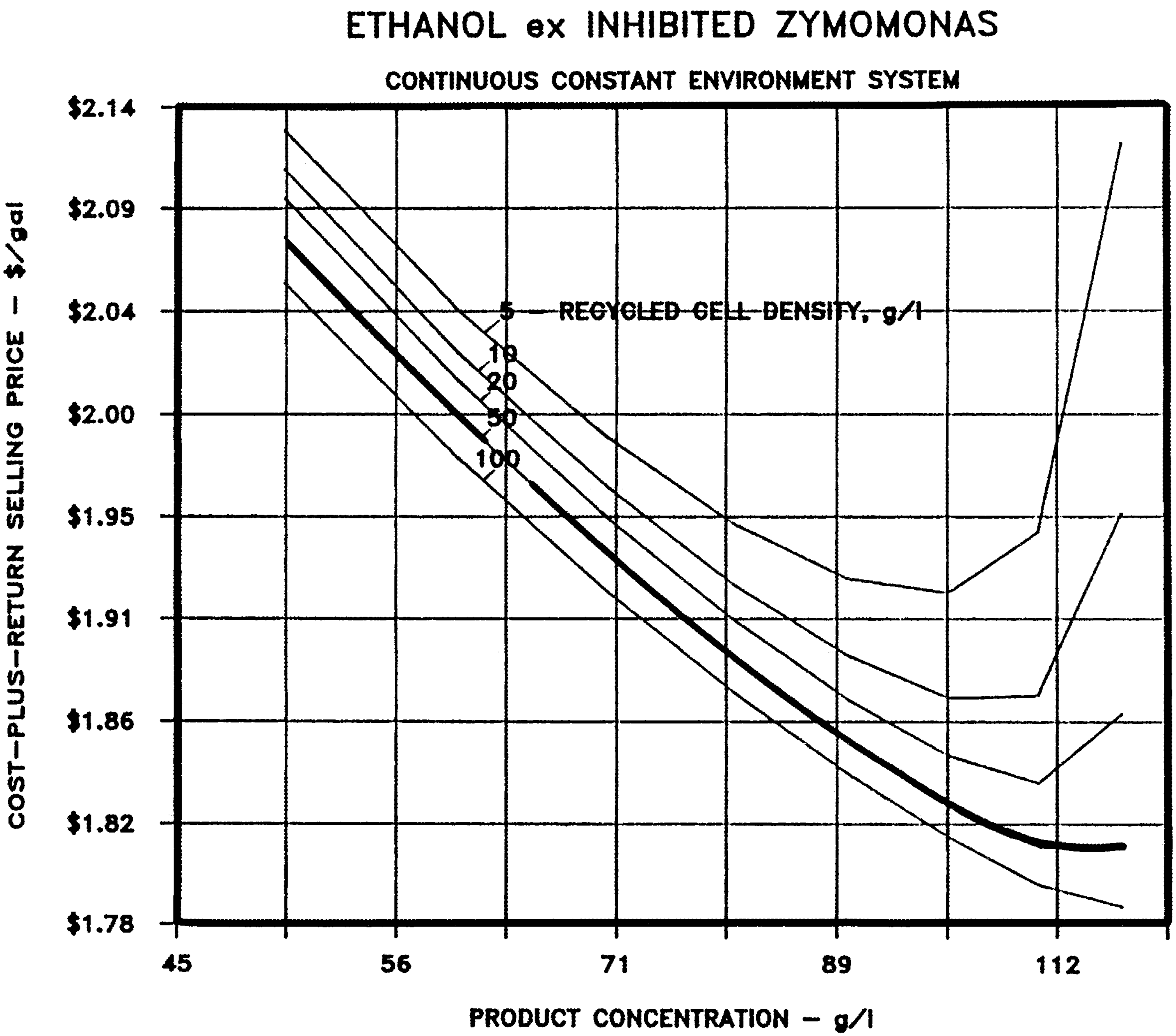


Fig. 6. Ethanol ex inhibited *Zymomonas* continuous constant environment system.

13.5 INHIBITED PLUG-FLOW CONTINUOUS SYSTEMS WITH CELL RECYCLE

It is well known that the kinetics of any first-order reaction system are favored by operating in a plug-flow regime. The effect on specific productivity of *Zymomonas* is shown in Fig. 3. The cost data for plug flow operation with *Zymomonas* are shown in Tables 11 and 12 and Fig. 7. In contrast to constant-environment operation (Table 9), the decay in volumetric productivity and dilution rate with increases in product concentration is much less severe. Neither are minima exhibited within the field of the data shown. Minima have to exist with any inhibited system, but in this case occur at concentrations very close to total inhibition.

Without cell recycle, the case for using plug flow is very strong. Thus, plug flow at a cell density of 50 g/L and product concentration of 110 g/L exhibits a cost of $1.89/gal compared with a minimum cost of $2.00 for the constant environment case at the same cell density of 50 g/L but at an optimum product concentration of 85 g/L.

With the preferred cell recycle mode, the advantage of plug flow is lost, as shown in Table 13. At high cell densities, both regimes are approaching an effectively infinite dilution rate even at product concentrations up to 110 g/L, which would otherwise favor plug flow. At high dilution rate, the effect of fermenter investment is minimal. As a result, both regimes exhibit costs of ~$1.80/gal at a product concentration of 110 g/L.

13.6 NONINHIBITED CONTINUOUS SYSTEMS

It would be admittedly difficult to engineer an organism that is not inhibited by product. However, if this could be accomplished with *Zymomonas* or *S. cerevisiae*, cost would be reduced further according to the cost projections of Table 14 and Figs. 8 and 9. These depict a continuous system operating at various combinations of product concentration and dilution rates.

Dilution rate can be controlled independently of concentration by constraining or recycling cells to higher cell densities and/or by developing an organism with a higher specific productivity. For dilution rates below 0.083 h^{-1} the data can also be used to represent batch operation. At high product concentrations dilution rates above 0.1 h^{-1} converge near an infinite dilution rate.

Table 11. Ethanol from *Z. mobilis*
Inhibited continuous system - plug flow
Effect of product concentration

Product conc. (g/L)	Specific prod'ity (g/g·h)	Volume prod'ity (g/L·h)	Dilution rate (1/h)	Total cost ($/gal)	Capital cost ($/gal)	Fermenter invest'mt ($million)	Ferm inv/ tot plant invest'mt (%)
	0.51	25.3	0.211	1.81	0.46	4	7
50	5.2	12.7	0.254	2.16	0.69	7	9
60	5.2	12.7	0.211	2.08	0.64	7	10
70	5.1	12.4	0.177	2.01	0.60	7	11
80	4.9	12.0	0.150	1.97	0.57	8	12
90	4.7	11.5	0.128	1.93	0.55	8	13
100	4.5	10.9	0.109	1.91	0.53	8	14
110	4.2	10.3	0.093	1.89	0.52	9	16
120	3.9	9.6	0.080	1.87	0.51	10	17

2.4 g/L cell density

Table 12. Ethanol from *Z. mobilis*
Inhibited continuous system - plug flow
Effect of product concentration and cell recycle
on cost-plus-return

Product conc. (g/L)	Cost ($/gal)				
	Cell Density (g/L)				
	5	10	20	50	100
50	2.13	2.11	2.09	2.08	2.05
60	2.04	2.02	2.01	1.99	1.98
70	1.98	1.96	1.95	1.93	1.92
80	1.93	1.91	1.90	1.89	1.87
90	1.90	1.88	1.86	1.85	1.84
100	1.87	1.85	1.84	1.82	1.81
110	1.85	1.82	1.81	1.80	1.79
120	1.83	1.81	1.79	1.78	1.77

Table 13. Ethanol from *Z. mobilis*
Inhibited continuous system - constant environment and plug flow
Effect of product concentration

Product conc. (g/L)	Specific prod'ity (g/g·h)	Volume prod'ity (g/L·h)	Dilution rate (1/h)	Total cost ($/gal)	Capital cost ($/gal)	Fermenter invest'mt ($million)	Ferm inv/ tot plant invest'mt (%)
Constant environment							
50	5.2	260.0	5.200	2.08	0.63	0.35	0.5
60	4.8	241.9	4.032	1.99	0.57	0.38	0.6
70	4.1	205.8	2.940	1.93	0.53	0.45	0.7
80	3.4	169.7	2.122	1.89	0.50	0.54	1.0
90	2.7	133.6	1.485	1.86	0.48	0.69	1.3
100	2.0	97.5	0.975	1.83	0.47	0.94	1.8
110	1.2	61.4	0.558	1.81	0.46	1.50	3.0
120	0.5	25.3	0.211	1.81	0.46	3.64	7.3
	50.0 g/L cell density						
Plug flow							
50	5.2	260.0	5.200	2.07	0.62	0.35	0.5
60	5.2	259.2	4.321	1.99	0.57	0.35	0.5
70	5.1	254.2	3.631	1.93	0.53	0.36	0.6
80	4.9	245.9	3.074	1.89	0.50	0.37	0.7
90	4.7	235.4	2.616	1.85	0.48	0.39	0.7
100	4.5	223.4	2.234	1.82	0.46	0.41	0.8
110	4.2	210.3	1.912	1.80	0.45	0.44	0.9
120	3.9	196.4	1.637	1.78	0.43	0.47	1.0
	50.0 g/L cell density						

Table 14. Ethanol from *S. cerevisiae* and *Z. mobilis*
Noninhibited continuous system
Effect of product concentration and dilution rate
on cost-plus-return

Product conc. (g/L)	cost ($/gal)					
	Dilution rate (1/h)					
	0.01	0.03	0.06	0.10	0.20	100000
S. cerevisiae						
40	4.41	3.00	2.64	2.50	2.40	2.29
50	3.87	2.74	2.45	2.34	2.25	2.17
60	3.50	2.55	2.32	2.22	2.15	2.08
80	3.04	2.33	2.15	2.08	2.03	1.97
100	2.76	2.19	2.05	1.99	1.95	1.91
150	2.39	2.01	1.92	1.88	1.85	1.82
300	2.04	1.85	1.80	1.78	1.77	1.75
Z. mobilis						
40	4.31	2.90	2.55	2.41	2.30	2.20
50	3.77	2.64	2.36	2.24	2.16	2.07
60	3.41	2.46	2.23	2.13	2.06	1.99
80	2.95	2.24	2.06	1.99	1.94	1.88
100	2.67	2.10	1.96	1.91	1.86	1.82
150	2.30	1.92	1.83	1.79	1.76	1.73
300	1.95	1.76	1.71	1.69	1.68	1.66

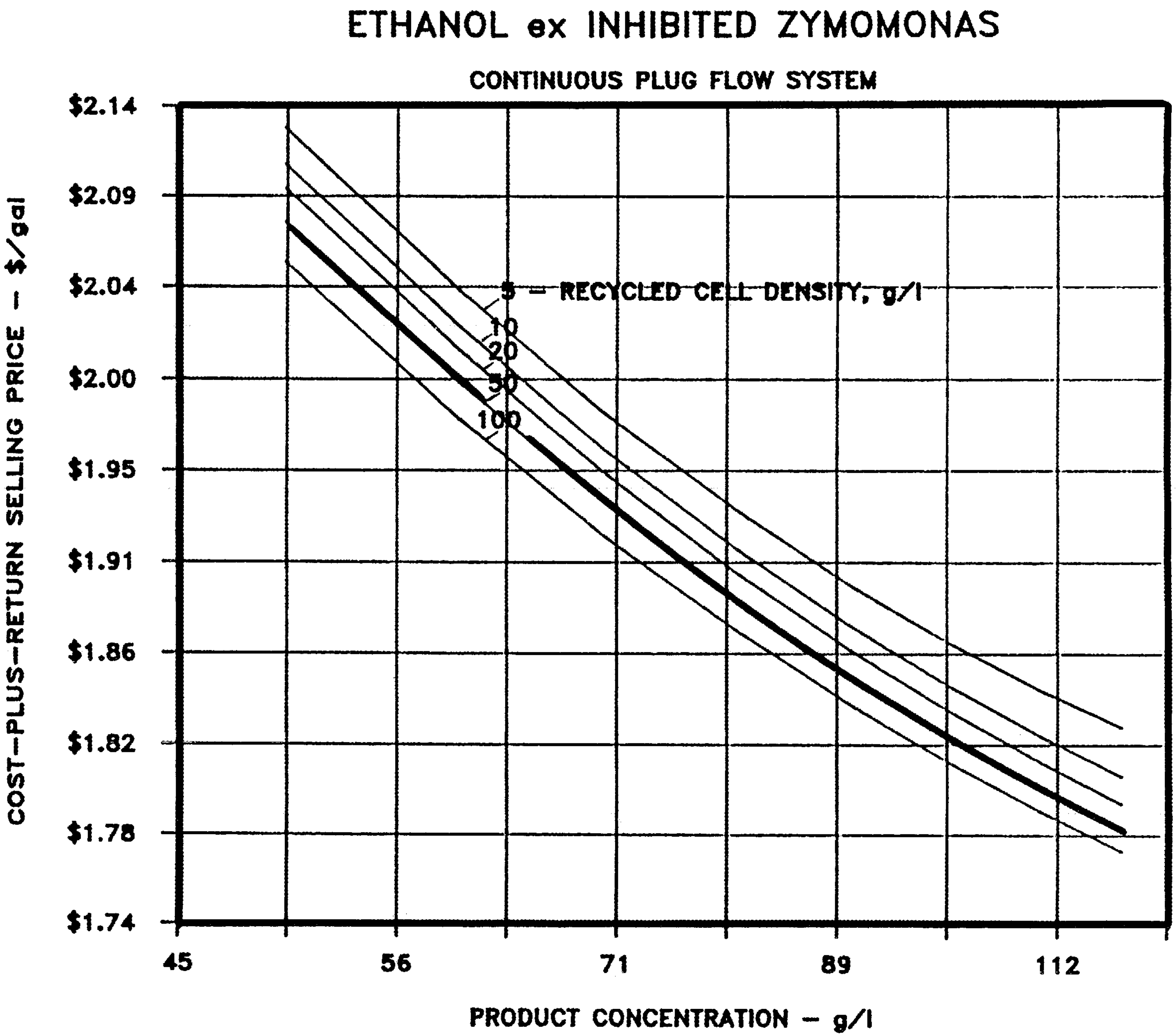


Fig. 7. Ethanol ex inhibited *Zymomonas* continuous plug flow system.

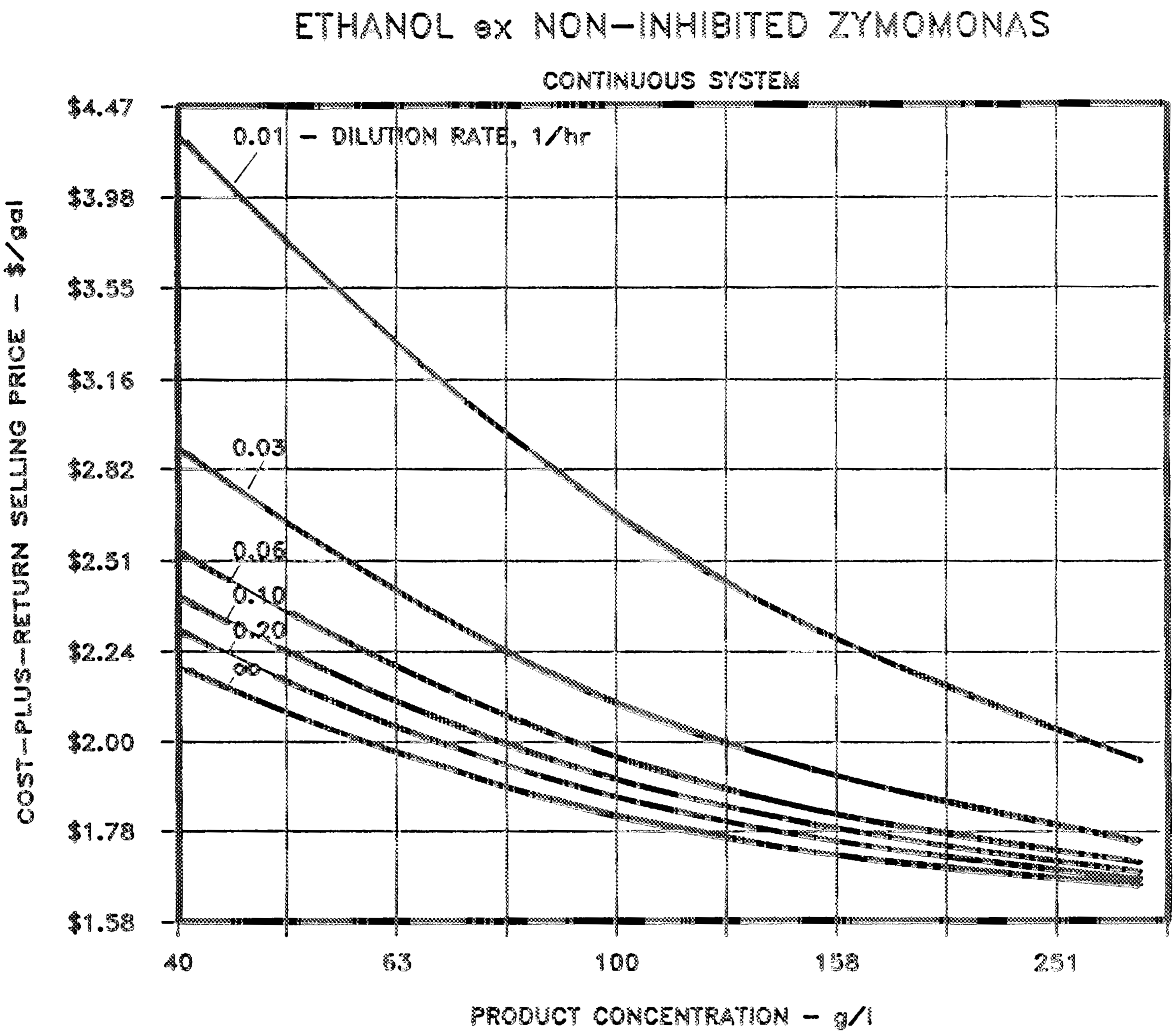


Fig. 8. Ethanol ex noninhibited *Zymomonas* continuous system.

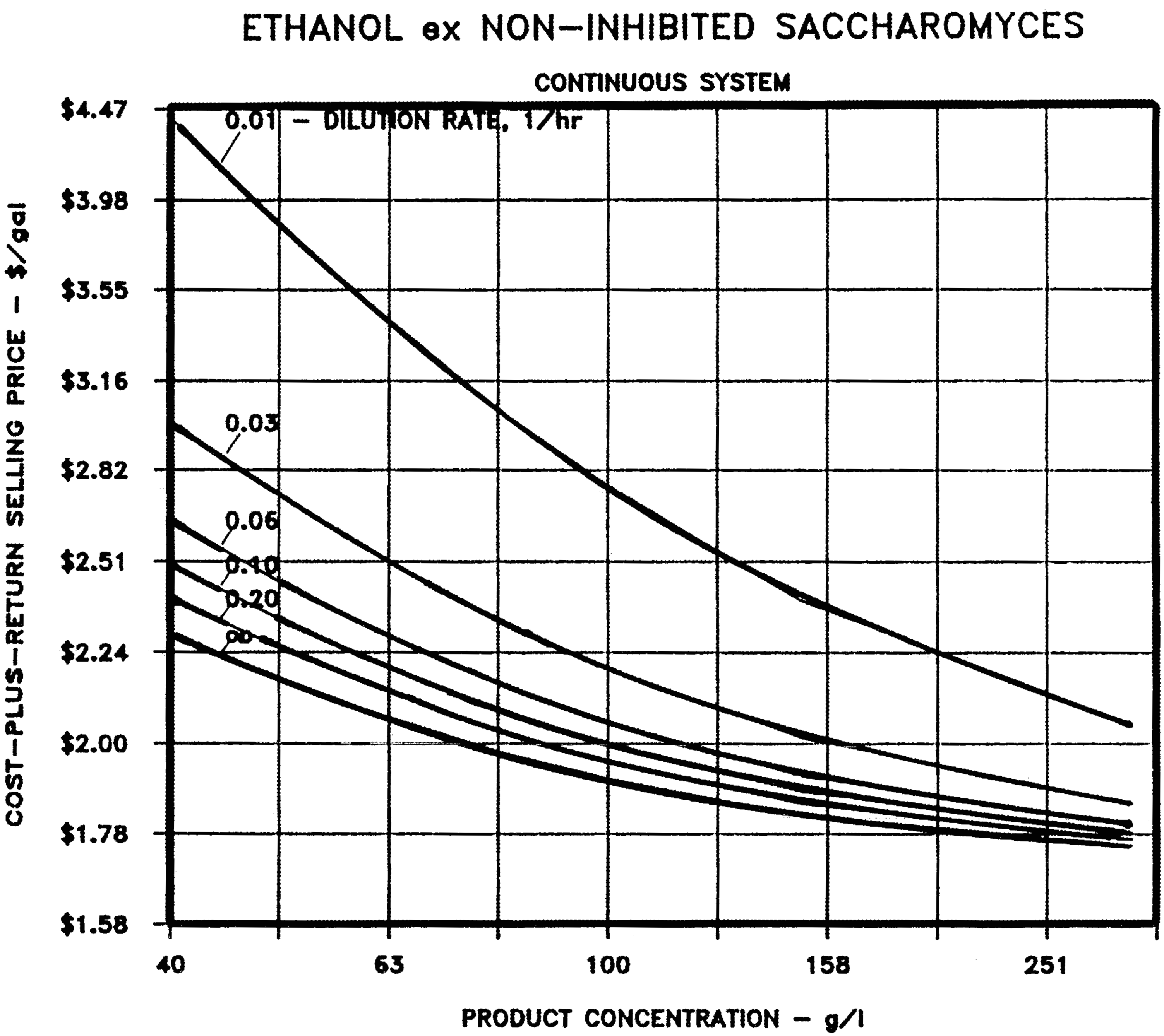


Fig. 9. Ethanol ex noninhibited *Saccharomyces* continuous constant environment system.

For a dilution rate of 0.1 h^{-1} at a product concentration of 150 g/L, the cost of ethanol from *Zymomonas* would be reduced to $1.79/gal -- a reduction of 30% below the $2.55/gal basecase cost for the current commercial state of the art. The corresponding cost for the yeast system would be $1.88 -- a 26% reduction.

13.7 EFFECT OF SUGAR PRICE

As noted earlier, the transfer price for glucose in the form of corn syrup is uncertain but quite important to the overall economics of the product. The sensitivity of cost-plus-return price to changes in the price of equivalent glucose is shown in Table 15 and Fig. 10 for an inhibited *Zymomonas* operating in a continuous constant-environment system. At the assumed price of $0.065/lb, ethanol price would be $2.00/gal, and substrate cost would account for 71% of the cost of manufacture and 44% of selling price. However, at a bare "net corn" price of $0.038/lb sugar, the alcohol could sell for as little as $1.56/gal. Conversely, at a list price for syrup of $0.12/lb, the ethanol would have to sell for $2.56/gal. Clearly, the leverage of sugar price is very high.

13.8 GLYCERINE RECOVERY?

With the exception of carbon dioxide, glycerine is formed at the highest concentration of any of the chemical by-products of the ethanol fermentation process (i.e., at 4.6 wt % for yeast and at 1.1 wt % for *Zymomonas*). A brief study was made of the economic feasibility of recovering glycerine in the distillation train of the yeast system. This requires the addition of a large still and reboiler to separate water and other lower boilers overhead from the glycerine in the tails. A smaller still is also required to remove glycerine overhead from residual salts and acids. It does not appear economical to recover glycerine in this way because both expense and investment are adversely affected. The cases with and without recovery compare as follows (Table 16).

Table 15. Ethanol from *Z. mobilis*
Inhibited continuous system - constant environment
Effect of sugar price

Sugar price ($/lb)	Substrate			Selling price ($/gal)
	$/gal	Cost of mfg. (%)	Selling price (%)	
0.000	0.00	0	0	0.95
0.020	0.27	43	21	1.27
0.038	0.52	59	33	1.56
0.065	0.88	71	44	2.00
0.080	1.09	75	49	2.24
0.100	1.36	79	53	2.56
0.120	1.63	82	57	1.89

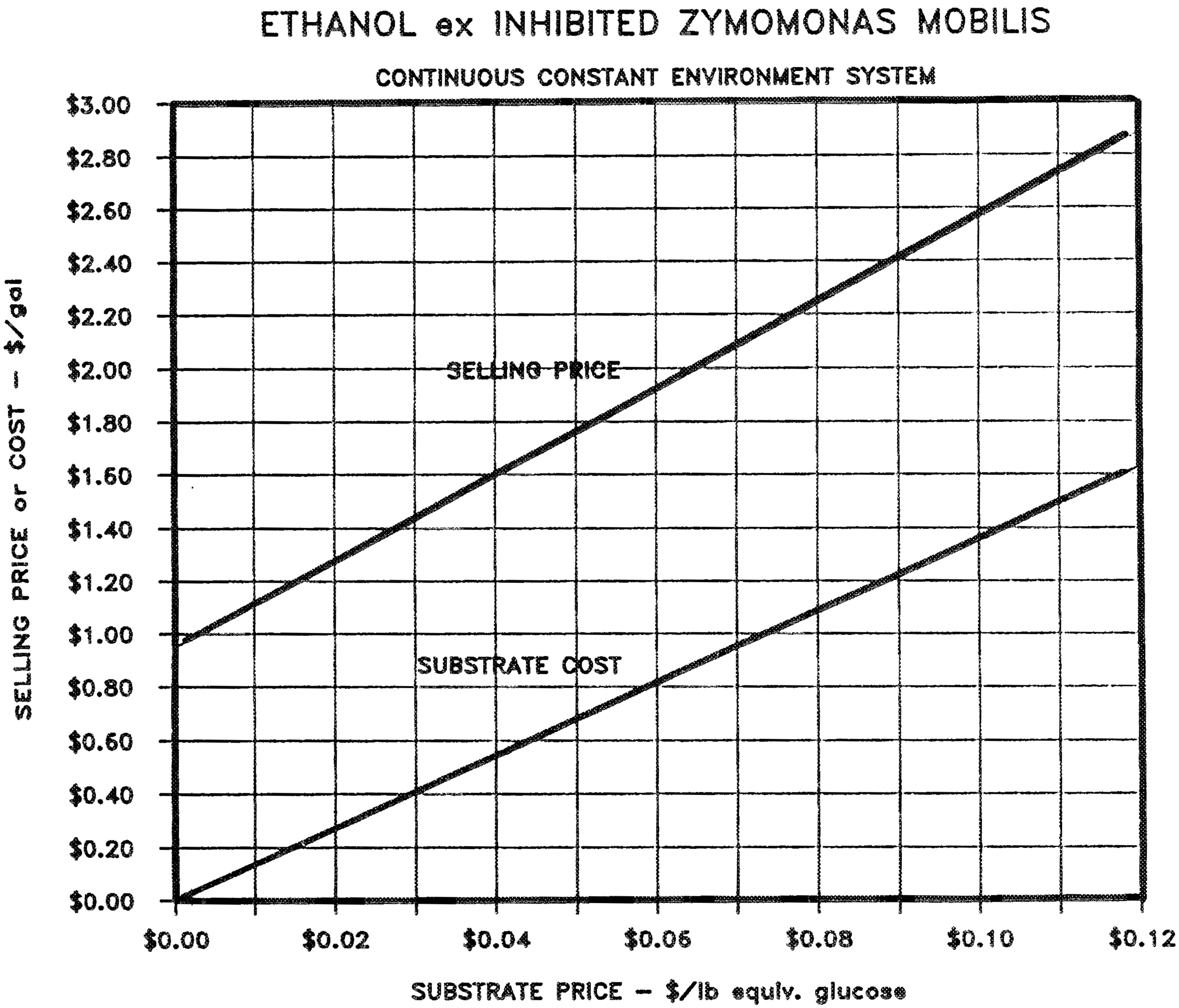


Fig. 10. Ethanol ex inhibited *Zymomonas Mobilis* continuous constant environment system.

Table 16. Glycerine recovery

Cost factor ($/gal)	Cost ($/gal)		
	No recovery	Recovery	Difference
Expense			
Steam	0.190	0.525	$0.335
Cooling water	0.013	0.036	0.023
Capital related	0.150	0.218	0.068
Subtotal	0.353	0.779	0.426
Cost of manufacture	1.002	1.428	0.426
Cost of sales	1.272	1.742	0.470
Earnings @ 30% ROI	0.538	0.840	0.302
Glycerine credit	0.000	(0.492)	(0.492)
Net expense			$0.280
Investment			
H.B. still #1	0.000	0.182	0.182
H.B. still #2	0.000	0.001	0.001
Glycerine storage	0.000	0.004	0.004
Steam	0.302	0.837	0.535
Cooling water	0.022	0.061	0.058
General & services	0.046	0.122	0.076
Working capital	0.260	0.330	0.070
Total investment affected			0.926

14. STRATEGIES FOR INTRODUCING THE ADVANCED TECHNOLOGY

Obviously, much needs to be done in research at rack scale and pilot plant scale to prove out the projections described in this study. If that can be realized, however, a first step toward implementing the new systems might be to retrofit an existing fuel grade ethanol plant.

14.1 RETROFITTING EXISTING PLANTS

It is beyond the scope of this study to evaluate the nuances of retrofitting existing plants. Too much depends on the design of the plant and the financial aspects of the supporting or ancillary businesses of the operator.

However, as a first approximation, a case was developed in 1988 based on introducing an inhibited *Zymomonas* in a batch plant built around 1976. A sugar transfer price of $0.065 was assumed -- the same as for the 1984 basecase but almost twice as high as the sugar price basis used in the 1976 plant of Table 6. The results of this case are shown in Table 17. Product cost would be $1.67 by recycling to a cell density of 50 g/L at a product concentration of 110 g/L. This cost is, in fact, lower than the 1980 price of $1.78 even though the substrate cost is much higher.

For such a saving to be realistically obtained, the operator would have to exercise one of several options:

o Transfer the now excess fermenter investment off the ethanol books by writing down in place and taking the tax saving or applying the excess equipment to another venture.

o Expand the investment base in medium preparation and product recovery and distillation to match the increased fermenter capacity at a higher production rate.

None of these options may be of interest to incumbent operators. It is suggested that studies be made pertinent to specific plant cases to develop a better picture of retrofitting possibilities.

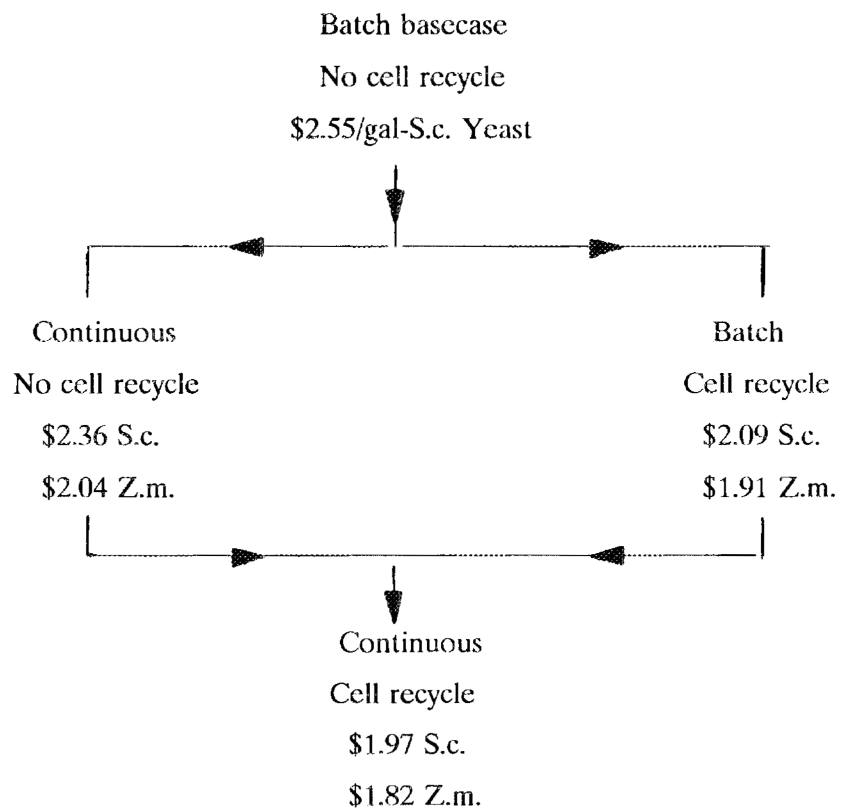
14.2 DESIGN OF NEW PLANTS

The most advantageous strategy for retrofitting or for the stepwise introduction of the new technology in new plants appears to follow the right-side path of the following alternatives for an inhibited system:

Table 17. Ethanol from *Z. mobilis*
Retrofitted plant* - inhibited batch system
Effect of product concentration and cell recycle
on cost-plus-return

Product conc. (g/L)	Cost ($/gal) Cell density (g/L) 5	10	20	50	100
50	1.96	1.94	1.93	1.92	1.90
60	1.88	1.87	1.86	1.85	1.83
70	1.83	1.82	1.81	1.80	1.78
80	1.79	1.78	1.77	1.76	1.75
90	1.76	1.75	1.74	1.73	1.72
100	1.73	1.72	1.71	1.70	1.69
110	1.71	1.70	1.69	1.69	1.68
120	1.70	1.69	1.68	1.67	1.66
120	1.70	1.69	1.68	1.67	1.66

*MPC - 1976; Operating Year - 1988; Substrate @ $0.065/lb.



The financial performance of these cases is summarized in Tables 18 and 19. The best cases for the yeast and bacterium systems are detailed in Appendixes D and E.

15. RECOMMENDATIONS

It appeared from the results of the study that improvements to either yeast or bacterium processes could be effective in reducing the cost of producing ethanol to commercially acceptable levels. However, the *Zymomonas* process would appear to be the better choice for development. Accordingly, the following recommendations are made as a guide to further research in this area:

Table 18. Optimized process conditions
60 million GPY ethanol manufacture
Inhibited *Zymomonas* bacterium
1984 MPC - 1988 operating year

MODE	Batch	Continuous	Continuous	Batch	Continuous	Continuous
Product concentration, g/L	90	90	90	110	110	110
Cell recycle	No	No	No	Yes	Yes	Yes
Cell density, g/L	1.8	1.8	1.8	50	50	50
Kinetics - const. envirmt/plug flow	PF	CE	PF	PF	CE	PF
INVESTMENT, $million						
Direct permanent investmnt	61.7	49.4	41.3	39.8	29.7	28.7
Allocated power, services & gen.	22.7	22.7	22.7	19.6	19.6	19.6
Working capital	19.2	18.5	18.1	17.6	17.1	17.0
Total investment	103.6	90.7	82.1	77.0	66.4	65.3
COST, $/gal						
Raw materials	0.89	0.89	0.89	0.89	0.89	0.89
Utilities	0.12	0.12	0.12	0.11	0.11	0.11
Labor-related	0.10	0.10	0.10	0.10	0.10	0.10
Capital-related	0.16	0.13	0.11	0.11	0.09	0.08
Cost of manufacture	1.27	1.25	1.23	1.21	1.19	1.18
SE, D, R&D, adm, & I.C.	0.30	0.29	0.28	0.27	0.26	0.26
Cost of sales	1.58	1.54	1.51	1.48	1.45	1.44
Pretax earnings based on 30% ROI	0.58	0.50	0.46	0.43	0.37	0.36
By-product credits	0.00	0.00	0.00	0.00	0.00	0.00
Selling price	2.15	2.04	1.96	1.91	1.82	1.81

Table 19. Optimized process conditions
60 million GPY ethanol manufacture
Inhibited *Saccharomyces* yeast
1984 MPC - 1988 operating year

MODE	BATCH	BATCH	CONTINUOUS
Product concentration, g/L	70	90	90
Cell recycle	No	Yes	Yes
Cell density, g/L	2.6	50	50
INVESTMENT, $million			
Direct permanent investment	91.1	47.6	35.3
Allocated power, services & gen.	26.8	22.1	22.1
Working capital	22.1	19.2	18.5
Total investment	140.0	88.9	75.9
COST, $/gal			
Raw materials	0.95	0.95	0.95
Utilities	0.15	0.13	0.13
Labor-related	0.10	0.10	0.10
Capital-related	0.23	0.13	0.10
Cost of manufacture	1.42	1.30	1.27
SE, D, R&D, adm, & I.C.	0.35	0.29	0.28
Cost of sales	1.75	1.59	1.55
Pretax earnings based on 30% ROI	0.78	0.49	0.42
By-product credits	0.00	0.00	0.00
Selling price	2.55	2.09	1.97

1. Demonstrate continuous operation of the fermentation process on a rack or pilot scale over an extended run time, say 1000 h.

2. Immobilize the cells and/or add a crossflow filter or similar separation device so as to retain the cells in the fermenter or recycle them to the desired maximum cell density while increasing flow through the fermenter to hold product concentration at its optimum level relative to feedback inhibition.

3. Consider the concurrent development of a genetically revised organism that is less inhibited by product and/or has an enhanced specific productivity.

4. Continue the comparative evaluation of the economics of processes based on either organism as new information is obtained from the research program.

16. CONCLUSIONS

Based on the economic analyses, it appears that the use of continuous fermentation in a fluidized bioreactor system coupled with cell immobilization and/or recycle could substantially reduce the cost of ethanol and, generically, other products that are now produced at low product concentrations and volumetric productivities as a result of product inhibition. Such an economic breakthrough cannot be realized until the system has been fully demonstrated in a continuous process over an extended period at pilot scale, optimized according to the findings of this study, and scaled up for the specific fermentation process of interest.

However, there appears to be no inherent design limitation in effecting the engineering improvements required in the process operation.

Such may not be the case in attempting to develop an organism with improved product tolerance and/or higher specific productivity. The goal is sufficiently important, however, to warrant the laboratory effort.

17. ACKNOWLEDGMENT

This work was jointly sponsored by the Jet Propulsion Laboratory (JPL) of California Institute of Technology and the National Corn Growers Association (NCGA). It was conducted under Contract No.958353 with JPL as part of its project on biocatalysis. The JPL project is a part of the ECUT program of DOE. The author wishes to thank Dr. James Eberhardt, DOE Director of ECUT; Dr. M. N. Dastoor, Manager of the Biocatalysis Program at JPL; and Mr. D. W. Ragsdale, Research Director for NCGA, for their input and support of the contracted study.

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APPENDIX A. PROCESS STOICHIOMETRY

STOICHIOMETRY FOR ETHANOL MANUFACTURE

(MOLES PER MOLE ETHANOL)

	GLUCOSE	ETHANOL	GLYCEROL	ACETIC ACID	ISOAMYL ALCOHOL	LACTIC ACID	SUCCINIC ACID
	C6H12O6	C2H6O	C3H8O3	C2H4O2	C5H12O	C3H6O3	C4H6O4
M.W.	180.156	46.068	92.094	60.052	88.146	90.078	118.088
BALANCED EQUATIONS							
1)	0.5	1					
2)	1		1				
3)	0.333333			1			
4)	2	1			1		
5)	0.5					1	
6)	1						1
7)	0.5						
8)	1			0.5			

SACCHAROMYCES CEREVISIAE STOICHIOMETRY
MOLS/1000 MOLS ETHANOL

	GLUCOSE	ETHANOL	GLYCEROL	ACETIC ACID	ISOAMYL ALCOHOL	LACTIC ACID	SUCCINIC ACID
1)	498.69	997.39	0.00	0.00	0.00	0.00	0.00
2)	23.00	0.00	23.00	0.00	0.00	0.00	0.00
3)	2.78	0.00	0.00	8.34	0.00	0.00	0.00
4)	5.23	2.61	0.00	0.00	2.61	0.00	0.00
5)	0.55	0.00	0.00	0.00	0.00	1.10	0.00
6)	0.57	0.00	0.00	0.00	0.00	0.00	0.57
7)	0.47	0.00	0.00	0.00	0.00	0.00	0.00
8)	0.52	0.00	0.00	0.26	0.00	0.00	0.00
SUM	531.81	1000.00	23.00	8.60	2.61	1.10	0.57
C	-3190.84	2000.00	69.00	17.20	13.07	3.30	2.28
H	-6381.68	6000.00	184.00	34.40	31.36	6.60	3.42
O	-3190.84	1000.00	69.00	17.20	2.61	3.30	2.28

ZYMOMONAS MOBILIS STOICHIOMETRY
MOLS/1000 MOLS ETHANOL

	GLUCOSE	ETHANOL	GLYCEROL	ACETIC ACID	ISOAMYL ALCOHOL	LACTIC ACID	SUCCINIC ACID
1)	500.00	1000.00	0.00	0.00	0.00	0.00	0.00
2)	5.67	0.00	5.67	0.00	0.00	0.00	0.00
3)	1.72	0.00	0.00	5.15	0.00	0.00	0.00
4)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5)	0.52	0.00	0.00	0.00	0.00	1.03	0.00
6)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8)	0.52	0.00	0.00	0.26	0.00	0.00	0.00
SUM	508.42	1000.00	5.67	5.41	0.00	1.03	0.00
C	-3050.54	2000.00	17.01	10.82	0.00	3.09	0.00
H	-6101.09	6000.00	45.36	21.65	0.00	6.18	0.00
O	-3050.54	1000.00	17.01	10.82	0.00	3.09	0.00

	ACETALD-DEHYDE	LIGHT ENDS*	CO2	WATER	H2
	C2H4O	C4H8O2	CO2	H2O	H2
M.W.	44.052	88.104	44.010	18.016	2.016

BALANCED EQUATIONS

	ACETALD-DEHYDE	LIGHT ENDS*	CO2	WATER	H2
1)			1		
2)			3	-3	5
3)					
4)			5		3
5)					
6)	1			1	
7)	1		1		1
8)		1	1	1	

SACCHAROMYCES CEREVISIAE STOICHIOMETRY
MOLS/1000 MOLS ETHANOL

	ACETALD-DEHYDE	LIGHT ENDS*	CO2	WATER	H2	TOTAL
1)	0.00	0.00	997.39	0.00	0.00	
2)	0.00	0.00	69.00	-69.00	115.00	
3)	0.00	0.00	0.00	0.00	0.00	
4)	0.00	0.00	13.07	0.00	7.84	
5)	0.00	0.00	0.00	0.00	0.00	
6)	0.57	0.00	0.00	0.57	0.00	
7)	0.93	0.00	0.93	0.00	0.93	
8)	0.00	0.52	0.52	0.52	0.00	
SUM	1.50	0.52	1080.91	-67.91	123.77	
C	3.00	2.09	1080.91	0.00	0.00	.00000000
H	6.00	4.18	0.00	-135.81	247.54	.00000000
O	1.50	1.05	2161.81	-67.91	0.00	.00000000

ZYMOMONAS MOBILIS STOICHIOMETRY
MOLS/1000 MOLS ETHANOL

	ACETALD-DEHYDE	LIGHT ENDS*	CO2	WATER	H2	TOTAL
1)	0.00	0.00	1000.00	0.00	0.00	
2)	0.00	0.00	17.01	-17.01	28.35	
3)	0.00	0.00	0.00	0.00	0.00	
4)	0.00	0.00	0.00	0.00	0.00	
5)	0.00	0.00	0.00	0.00	0.00	
6)	0.00	0.00	0.00	0.00	0.00	
7)	0.00	0.00	0.00	0.00	0.00	
8)	0.00	0.52	0.52	0.52	0.00	
SUM	0.00	0.52	1017.53	-16.49	28.35	
C	0.00	2.09	1017.53	0.00	0.00	.00000000
H	0.00	4.18	0.00	-32.97	56.70	.00000000
O	0.00	1.05	2035.07	-16.49	0.00	.00000000

APPENDIX B. 1970s BASECASE

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY
SUMMARY

	PRODUCTION LEVEL 53.96 MM GPY
INVESTMENT-$MILLION MPC = 1976	
Direct Permanent Investment	$54.7
Allocated Power, Services & General	$24.1
Working Capital	$15.5
Total Investment	$94.3
COST-$/GAL(1980)	
Raw Materials	$0.57
Utilities	$0.22
Labor-Related	$0.06
Capital-Related	$0.15
Cost of Manufacture	$1.00
SE, D, R&D, Adm, & I.C.	$0.27
Cost of Sales	$1.26
Pretax Earnings Based on: 30% Pretax ROI	$0.52
By-product Credits	$0.00
Selling Price	$1.79
FINANCIAL CRITERIA	
Net ROI 3rd Year (assumed)	16%
Investors Rate of Return (20 Operating Years)	25%
Year to Break Even - Annual Cash	1981
- Cumulative Cash	1983
- Cum. Disc. Cash (NPV)	1985
Net Present Value $MM (20 years @ 15%)	$41.0

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

INVESTMENT

CONDITIONS

Sited in Iowa on the Mississippi River adjacent to a corn wet mill and a utility power house for over-the-fence supply of syrup and power.

	UNITS	THIS CASE
CAPACITY @ 8000 HRS	MM GPY	60.0
MID-POINT OF CONSTRUCTION	YEAR	1976
CONSTRUCTION COST INDEX	1980=100	74
INVESTMENT CONTINGENCY	% INSTALLED *	30%
FERMENTER UNIT INVESTMENT	$/GR.GAL.-GROWTH	$0.00
	$/GR.GAL.-PROD'N	$6.32

*40% Recommended for new processes

DIRECT PERMANENT INVESTMENT

	SCALE FACTOR		THIS CASE $MM	THIS CASE $/ANN.GAL.
FERMENTATION SECTION				
Receiving, Prep & Sterilization	0.60		$6.34	$0.106
Air Compression & Aeration	0.60		0.00	0.000
Fermentation	0.89-1.00		36.23	0.604
Product/Cell Separation	0.75		2.06	0.034
Fermentation Sub-total			$44.62	$0.744
DISTILLATION SECTION	STILLS	HX'S		
Beer Still #1	$0.63	$2.07	$2.70	$0.045
Beer Still #2	0.24	0.44	0.67	0.011
Low-Boilers Still #1	0.15	0.10	0.24	0.004
Low-Boilers Still #2	0.00	0.00	0.00	0.000
Low-Boilers Still #3	0.00	0.00	0.00	0.000
High-Boilers Still #1	0.00	0.00	0.00	0.000
High-Boilers Still #2	0.00	0.00	0.00	0.000
Azeotrope Still	0.81	1.06	1.88	0.031
Benzene Dehydrator	0.17	0.06	0.23	0.004
Decanter			0.03	0.001
Distillation Subtotal			$5.75	$0.096
STORAGE SECTION				
Storage - Product			$4.34	$0.072
Storage - Byproduct #1			$0.00	0.000
Storage - Byproduct #2			$0.00	0.000
			$4.34	$0.072
TOTAL DIRECT PLANT			$54.71	$0.913

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

INVESTMENT

ALLOCATED PERMANENT INVESTMENT

	UNITS	API/UNIT BASECASE	API/UNIT THIS CASE	UNITS	$MM	$/ANN.GAL
ELECTRICITY	KW	$183	$183	1,170	$0.21	$0.004
STEAM	PPH	$45	$45	402,952	18.13	0.302
COOLING WATER	GPM	$52	$52	25,168	1.31	0.022
PROCESS WATER	GPM	$313	$313	838	0.26	0.004
WASTE DISPOSAL	MGPY	$3	$3	548,853	1.49	0.025
GEN'L & SERVICES	$MM	10%	10%	$27.2	2.72	0.045
TOTAL ALLOCATED PLANT					$24.12	$0.402
TOTAL PERMANENT INVESTMENT					$78.84	$1.315

WORKING CAPITAL

	BASIS	DAYS BASECASE	DAYS THIS CASE	$MM	$/ANN.GAL
RAW MAT'L INVENTORY	$RAW MATL	2	2	$0.23	$0.004
SEMI-FINISHED PRODUCT	$(R+M)/2	5	5	0.58	0.010
FINISHED PRODUCT	$COM	30	30	4.42	0.074
CASH	$(COS-D)	6	6	1.03	0.017
ACCOUNTS RCD.-TRADE	$SP	30	30	7.93	0.132
ACCOUNTS RCD.-MISC.	%COM	0.9%	0.9%	0.48	0.008
DEFERRED CHARGES	%COM	1.5%	1.5%	0.81	0.013
TOTAL WORKING CAPITAL				$15.49	$0.258

Note: R = raw materials; M or COM = cost of manufacture; COS = cost of sales; SP = selling price; D = depreciation.

	$MM	$/ANN.GAL
TOTAL INVESTMENT FOR RETURN	$94.33	$1.573

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

PRICES & COST FACTORS	BASECASE	INFLATION FACTOR	THIS CASE
Operating Year	1988	1980	1980
Raw Materials			
-Biosugar Syrup	$0.028 /lb. d.s.	1.37	$0.038 /lb. d.s.
-Anhyd. Ammonia	$0.046 /lb.	1.45	$0.066 /lb.
-Phosphoric Acid	$0.155 /lb.	1.92	$0.298 /lb.
-Potassium Chloride	$0.053 /lb.	1.92	$0.101 /lb.
-Minor Nutrients	$0.451 /lb.	1.92	$0.868 /lb.
Utilities			
-Electricity	$0.040 /KWH	0.75	$0.030 /KWH
-Steam	$2.20 /M lb.	1.62	$3.57 /M lb.
-Cooling Water	$0.04 /M gal.	1.62	$0.06 /M gal.
-Process Water	$0.50 /M gal.	1.62	$0.81 /M gal.
-Biodegradation	$0.04 /lb. d.s.	1.62	$0.06 /lb. d.s.
-Landfill	$0.05 /lb. d.s.	1.62	$0.08 /lb. d.s.
Labor-Related			
-Dir. Op. Wages & Ben.	$26.40 /man-hr.	0.60	$15.95 /man-hr.
-Dir. Salaries & Benefi	18 % DOW&B	--	18 % DOW&B
-Op. Supplies & Service	6 % DOW&B	--	6 % DOW&B
-GPOH on Operations	23 % DOWS&B	--	23 % DOWS&B
-Control Lab	$19.22 /man-hr.	0.60	$11.61 /man-hr.
-Tech. Assist. to Mfg.	$22.06 /man-hr.	0.60	$13.32 /man-hr.
Capital-Related			
-Maint. Wages & Ben.	1.7 % DPI	--	1.7 % DPI
-Maint. Salaries & Ben.	25 % MW&B	--	25 % MW&B
-Maint. Mat'l & Service	40 % MW&B	--	40 % MW&B
-Maint. Overhead	4 % MW&B	--	4 % MW&B
-GPOH on Maintenance	23 % MWS&B	--	23 % MWS&B
-Taxes & Insurance	0.3 % DPI	--	0.3 % DPI
-Depreciation - DPI	8 % DPI	--	8 % DPI
-Depreciation - APS&G	6 % APS&G	--	6 % APS&G
Cost of Manufacture			
-Selling Expense	3 % Sales	--	3 % Sales
-Distribution	$0.01 /lb.	--	$0.01 /lb.
-Research & Development	4.5 % Sales	--	4.5 % Sales
-Administrative Expense	2 % Sales	--	2 % Sales
-Incentive Compensation	6 % PTE	--	6 % PTE
Cost of Sales			
-Pretax Earnings	30 % TIFR	--	30 % TIFR
-Credit: Byproduct #1	$0.00 /lb.	1.92	$0.00 /lb.
-Credit: Byproduct #2	$0.00 /lb.	1.92	$0.00 /lb.
-Credit: Byproduct #3	$0.00 /lb.	1.92	$0.00 /lb.
-Product Selling Price	$0.00 /lb.	1.92	$0.00 /lb.

SALARIES & WAGES
CONTINUOUS FERMENTER CASE

DIRECT OPERATORS		250 MM PPY DAY SHIFT	ROTATING SHIFTS
SYRUP RECEIVING & TRANSFER		1	-
CHEMICALS RECEIVING & TRANSFER		3	-
INNOCULUM PREPARATION		1	-
MEDIUM PREPARATION		-	1
STERILIZATION		-	1
FERMENTATION			
-CONTROL ROOM		-	2
-PATROL		-	2
-AIR COMPRESSION & AMMONIA FEED		-	1
DISTILLATION		-	3
BEER FILTER & CELL RECYCLE		-	2
TOTAL DAY & 4.2-SHIFT OPERATORS		5	12
TOTAL OPERATORS		55	
CONTROL LABORATORY			
BIOLOGICAL ANALYSIS		-	1
CHEMICAL ANALYSIS		-	1
OTHER		-	-
TOTAL DAY & 4.2-SHIFT TECHNICIANS		0	8
TOTAL LAB FORCE INCL SUPERVISION @	20%	0.0	10.1
TOTAL LAB FORCE		10.1	
TECHNICAL ASSISTANCE TO MANUFACTURING			
PROCESS ENGINEERS		1	-

WAGES, SALARIES & BENEFITS SCHEDULE- 1988

OPERATING WAGES - $/HOUR	$20.14
TECHNICIANS - ANNUAL $	$30,500
PROCESS ENGINEERS - ANNUAL $	$35,000
PENSION - AS % OF COMPENSATION	8.1%
FICA	5.8%
UNEMPLOYMENT COMPENSATION	0.6%
GROUP LIFE INSURANCE	0.7%
MEDICAL INSURANCE	3.6%
DENTAL INSURANCE	0.8%
SAVINGS PLAN	2.5%
VACATION	7.4%
ILLNESS	1.4%
ABSENCE WITH PERMISSION	0.2%
TOTAL BENEFITS	31.1%

SALARIES & WAGES
CONTINUOUS FERMENTER CASE

DIRECT OPERATORS		MIN. FORCE DAY SHIFT	ROTATING SHIFTS
SYRUP RECEIVING & TRANSFER		1	-
CHEMICALS RECEIVING & TRANSFER			-
INNOCULUM PREPARATION		1	-
MEDIUM PREPARATION		1	-
STERILIZATION			-
FERMENTATION			
-CONTROL ROOM		-	1
-PATROL		-	1
-AIR COMPRESSION & AMMONIA FEED		-	1
DISTILLATION		-	1
BEER FILTER & CELL RECYCLE		-	1
TOTAL DAY & 4.2-SHIFT OPERATORS		3	5
TOTAL OPERATORS		24	
CONTROL LABORATORY			
BIOLOGICAL ANALYSIS		-	1
CHEMICAL ANALYSIS		-	1
OTHER		-	-
TOTAL DAY & 4.2-SHIFT TECHNICIANS		0	8
TOTAL LAB FORCE INCL SUPERVISION @	20%	0.0	10.1
TOTAL LAB FORCE		10.1	
TECHNICAL ASSISTANCE TO MANUFACTURING			
PROCESS ENGINEERS		1	-

WAGES, SALARIES & BENEFITS SCHEDULE- 1988

OPERATING WAGES - $/HOUR
TECHNICIANS - ANNUAL $
PROCESS ENGINEERS - ANNUAL $

PENSION - AS % OF COMPENSATION
FICA
UNEMPLOYMENT COMPENSATION
GROUP LIFE INSURANCE
MEDICAL INSURANCE
DENTAL INSURANCE
SAVINGS PLAN
VACATION
ILLNESS
ABSENCE WITH PERMISSION

TOTAL BENEFITS

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

1980 COST SHEET	RATE /UNIT	MILLION UNITS	$MILLION	$/gal
Raw Materials				
-Biosugar Syrup	$0.038 /lb. d.s.	783.22	30.06	0.557
-Anhyd. Ammonia	$0.066 /lb.	1.33	0.09	0.002
-Phosphoric Acid	$0.298 /lb.	1.11	0.33	0.006
-Potassium Chloride	$0.101 /lb.	0.84	0.09	0.002
-Minor Nutrients	$0.868 /lb.	0.38	0.33	0.006
Total Raw Materials			$30.90	$0.573
Utilities				
-Electricity	$0.030 /KWH	8.34	0.25	0.005
-Steam	$3.57 /M lb.	2.8722	10.24	0.190
-Cooling Water	$0.06 /M gal.	10.76	0.70	0.013
-Process Water	$0.81 /M gal.	0.36	0.29	0.005
-Biodegradation	$0.06 /lb. d.s.	5.01	0.32	0.006
-Landfill	$0.08 /lb. d.s.	0.00	0.00	0.000
Total Utilities			$11.81	$0.219
Labor-Related				
-Dir. Op. Wages & Ben.	$15.95 /man-hr.	0.124	1.99	0.037
-Dir. Salaries & Ben.	18 % DOW&B		0.36	0.007
-Op. Supplies & Service	6 % DOW&B		0.12	0.002
-GPOH on Operations	23 % DOWS&B		0.54	0.010
-Control Lab	$11.61 /man-hr.	0.020	0.23	0.004
-Tech. Assist. to Mfg.	$13.32 /man-hr.	0.002	0.03	.000
Total Labor			$3.26	$0.060
Capital-Related				
-Maint. Wages & Ben.	1.7 % DPI	$54.7	0.93	0.017
-Maint. Salaries & Ben.	25 % MW&B		0.23	0.004
-Maint. Mat'l & Service	40 % MW&B		0.37	0.007
-Maint. Overhead	4 % MW&B		0.04	0.001
-GPOH on Maintenance	23 % MWS&B		0.27	0.005
-Taxes & Insurance	0.3 % DPI	$54.7	0.16	0.003
-Depreciation - DPI	8 % DPI	$54.7	4.38	0.081
-Depreciation - APS&G	6 % APS&G	$24.1	1.45	0.027
Total Capital			$7.83	0.145
			-----	-----
Cost of Manufacture			$53.80	$0.997
-Selling Expense	3 % Sales	$96.5	2.90	0.054
-Distribution	$0.01 /lb.	355.1	3.55	0.066
-Research & Development	5 % Sales	$96.5	4.34	0.081
-Administrative Expense	2 % Sales	$96.5	1.93	0.036
-Incentive Compensation	6 % PTE	$28.3	1.70	0.031
			-----	-----
Cost of Sales			$68.22	$1.264
-Pretax Earnings	30.0 % TIFR	$94.3	28.30	0.524
-Credit: Byproduct #1	$0.00 /lb.	0.0	0.00	0.000
-Credit: Byproduct #2	$0.00 /lb.	0.0	0.00	0.000
-Credit: Byproduct #3	$0.00 /lb.	0.0	0.00	0.000
			-----	-----
Total Sales			$96.54	$1.789

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

CASH FLOW (MILLION DOLLARS/YEAR)

Scenario:

1. Investment split evenly over three construction years.
2. Plant operates at 50% of full scale the first year.
3. " " 75% " " the second year.
4. " " 100% " " the third year.
5. " " 100% " " thereafter.
6. Five year depreciation rate; half-year convention; (20, 32, 19.2, 11.5, 11.5, 5.8 %); taxes: 34% fed, 3% state.

YEAR	INVESTMENT PI	WC	DEP.	COST EX D	SALES	NET EARN	ANN CASH
1975	$18.24						($18.24)
1976	$18.24						($18.24)
1977	$18.24						($18.24)
1978		$15.49	$10.94	$35.96	$48.27	$0.86	($3.69)
1979			$17.51	$52.12	$72.41	$1.75	$19.26
1980			$10.51	$62.39	$96.54	$14.89	$25.40
1981			$6.29	$62.39	$96.54	$17.55	$23.84
1982			$6.29	$62.39	$96.54	$17.55	$23.84
1983			$3.17	$62.39	$96.54	$19.51	$22.69
1984				$62.39	$96.54	$21.51	$21.51
1985				$62.39	$96.54	$21.51	$21.51
1986				$62.39	$96.54	$21.51	$21.51
1987				$62.39	$96.54	$21.51	$21.51
1988				$62.39	$96.54	$21.51	$21.51
1989				$62.39	$96.54	$21.51	$21.51
1990				$62.39	$96.54	$21.51	$21.51
1991				$62.39	$96.54	$21.51	$21.51
1992				$62.39	$96.54	$21.51	$21.51
1993				$62.39	$96.54	$21.51	$21.51
1994				$62.39	$96.54	$21.51	$21.51
1995				$62.39	$96.54	$21.51	$21.51
1996				$62.39	$96.54	$21.51	$21.51
1997		($15.49)		$62.39	$96.54	$21.51	$37.00

NET RETURN ON INVESTMENT-3RD OPERATING YEAR = 15.6%

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

CASH FLOW (MILLION DOLLARS/YEAR)

Scenario:
1. Investment split evenly over three construction years.
2. Plant operates at 50% of full scale the first year.
3. " " 75% " " the second year.
4. " " 100% " " the third year.
5. " " 100% " " thereafter.
6. Five year depreciation rate; half-year convention; (20, 32, 19.2, 11.5, 11.5, 5.8 %); taxes: 34% fed, 3% state.

YEAR	CUM CASH	NPV @ 15%	%IRR
1975	($18.24)	($18.24)	--
1976	($36.48)	($34.10)	--
1977	($54.71)	($47.89)	--
1978	($58.40)	($50.31)	-124.9%
1979	($39.14)	($39.30)	-33.8%
1980	($13.74)	($26.67)	-7.5%
1981	$10.10	($16.37)	4.1%
1982	$33.94	($7.40)	10.9%
1983	$56.62	$0.01	15.0%
1984	$78.14	$6.13	17.6%
1985	$99.65	$11.45	19.4%
1986	$121.16	$16.07	20.7%
1987	$142.67	$20.09	21.7%
1988	$164.19	$23.59	22.4%
1989	$185.70	$26.63	22.9%
1990	$207.21	$29.27	23.3%
1991	$228.72	$31.57	23.6%
1992	$250.24	$33.57	23.9%
1993	$271.75	$35.31	24.1%
1994	$293.26	$36.82	24.2%
1995	$314.77	$38.13	24.3%
1996	$336.29	$39.28	24.4%
1997	$373.29	$40.99	24.5%

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

BASIC DATA

SCALE OF OPERATION

355.1	MM PPY	ANNUAL PRODUCTION LEVEL
54.0	MM GPY	" " "
394.6	MM PPY	ANNUAL CAPACITY
60.0	MM GPY	" "
90	%	OPERATING UTILITY
363.2	MM PPY	PRODUCT FORMED IN BEER
403.6	MM PPY	PRODUCT FORMED IN BEER AT CAPACITY
96.5	%	MOLAR YIELD-GLUC. TO PROD. IN BEER (E
2.16	lb/lb	GLUCOSE DEMAND/PROD (EXCL. SPILL)
46.07	MOL WT	PRODUCT MOLECULAR WEIGHT

PRODUCT STOICHIOMETRY

MOL. WT.	MOLES/MOL PRODUCT		COMPONENT
180.16	0.53181	/MOL PROD.	-GLUCOSE CONSUMED
32.00	0.00000	/MOL PROD.	-OXYGEN CONSUMED
17.02	0.00000	/MOL PROD.	-AMMONIA CONSUMED
44.05	0.00150	/MOL PROD.	-ACETALDEHYDE FORMED (#1)
.00		/MOL PROD.	-COMPONENT #2 FORMED
.00		/MOL PROD.	-COMPONENT #3 FORMED
.00		/MOL PROD.	-COMPONENT #4 FORMED
.00		/MOL PROD.	-COMPONENT #5 FORMED
88.10	0.00052	/MOL PROD.	-LIGHT ENDS FORMED (#6)
46.07	1.00000	/MOL PROD.	-ETHANOL FORMED (#7)
.00		/MOL PROD.	-COMPONENT #8 FORMED
.00		/MOL PROD.	-COMPONENT #9 FORMED
.00		/MOL PROD.	-COMPONENT #10 FORMED
18.02	-0.06791	/MOL PROD.	-WATER FORMED
60.05	0.00860	/MOL PROD.	-ACETIC ACID FORMED (#11)
88.15	0.00261	/MOL PROD.	-ISOAMYL ALCOHOL FORMED (#12)
92.09	0.02300	/MOL PROD.	-GLYCERINE FORMED (#13)
.00		/MOL PROD.	-COMPONENT #14 FORMED
90.08	0.00110	/MOL PROD.	-LACTIC ACID FORMED (#15)
118.09	0.00057	/MOL PROD.	-SUCCINIC ACID FORMED (#16)
.00		/MOL PROD.	-COMPONENT #17 FORMED
.00		/MOL PROD.	-COMPONENT #18 FORMED
.00		/MOL PROD.	-COMPONENT #19 FORMED
.00		/MOL PROD.	-COMPONENT #20 FORMED
44.01	1.08091	/MOL PROD.	-CARBON DIOXIDE FORMED
2.02	0.12377	/MOL PROD.	-HYDROGEN FORMED

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

BASIC DATA

NUTRIENTS IN FERMENTER FEED

8	%	-N IN CELLS AS %CHO
80.9	mg/g cells	-H3PO4
61.6	mg/g cells	-KCl
27.9	mg/g cells	-MINOR NUTRIENTS
23.6	mg/g cells	-MgSO4.7H2O
0.01	mg/g cells	-VITAMIN B1
1.25	mg/g cells	-KI
0.89	mg/g cells	-NiCl2
0.72	mg/g cells	-FeCl3.6H2O
0.55	mg/g cells	-CaCl2.2H2O
0.54	mg/g cells	-H3BO3
0.22	mg/g cells	-ZnSO4.7H2O
0.15	mg/g cells	-MnSO4.H2O
7.7	ug/g cells	-CuSO4.5H2O
5.4	ug/g cells	-NaMoO4.2H2O
4.3	ug/g cells	-CoCl2.6H2O

FERMENTATION

TYPE	0	(0 OR 1)	-ANAEROBIC (0) OR AEROBIC (1)
STAGES	0	(0 OR 1)	-CONCUR'NT (0) OR SEQUENT'AL (1)
CULTURE MODE	0	(0 OR 1)	-BATCH (0) OR CONTINUOUS (1)
PROD INHIBITION	0	(0 OR 1)	-WITH (0) OR WITHOUT (1)

CONDITIONS

STAGE: GROWTH	PRODUCTION		
33	33	C	-TEMPERATURE
6.5	6.5		-pH
0	80	g/l **	-PRODUCT CONCENTRATION IN BEER
2.777	3.028	g/l	-CELL DENSITY (CHO ONLY)
0.00	0.018	1/hr	-DILUTION RATE *
			-PRODUCT PRODUCTIVITY
	1.50	g/g*hr	-Max Specific, g/g cells*hr
	42	%	-Inhibition Factor, % Max
	0.63	g/g*hr	-Specific, g/g cells*hr
0.00	1.47	g/l*hr	-Volumetric, g/l*hr *
0.05	0.00	g/l*hr	-CELL PRODUCTIVITY (CHO ONLY)
2	0	mM/l*hr	-OXYGEN TRANSFERRED
5	0	mM/mM	-OXYGEN FED / OXYGEN STOICH. DEMAND
--	0.1	g/l	-GLUCOSE SPILL
5	5	C	-COOLING WATER TEMPERATURE
--	19	kcal/gmol	-HEAT EVOLVED-PRODUCT FORMATION
2	9	Btu/hr*gal	-HEAT REMOVED BY COOLING COILS
			* w/12 hrs batch mode turnaround

FERMENTERS

0	4,142,882	gallons	-ACTIVE VOLUME REQUIRED
15	15	% gross	-HEADSPACE
0	5,734,092	gallons	-GROSS VOLUME (incl. 15% spares)
0	500,000	gallons	-GROSS SIZE
0.0	11.5	units	-NUMBER OF UNITS

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

BASIC DATA

PRODUCT SEPARATION

250 g/l	-CELL CONC. (CHO) EX FILTER
0.053 gal/min*sf	-FILTER THROUGHPUT
23,674 sq ft	-FILTER SIZE

PRODUCT RECOVERY & PURIFICATION

97.8%(wt)%	-YIELD ACROSS REFINING

MATERIALS OF CONSTRUCTION

	CHOICES	SELECTION
FERMENTERS	1,3	1
STILLS	1,2,3,4,5	1
HEAT EXCHANGERS	1,3,5,6	1
STORAGE TANKS	1,3	1

FOR WHICH:
1=CARBON STEEL
2=CARBON STEEL w/304 SS TRAYS
3=304 STAINLESS STEEL
4=304L STAINLESS STEEL
5=316 STAINLESS STEEL
6=MONEL

RETURN ON INVESTMENT

To Calculate Selling Price Required to Provide a Fixed Return,
Enter the Desired Return on Investment: 30 %
OR
To Calculate the ROI Resulting from a Fixed Market Price,
Enter the Market Price for: 1988 /lb.

Enter an Investment Contingency to Represent
the Risk Level of the Basic Data 30 %

DISTILLATION DATA MATRIX

ITEM	COMPONENT	DEFAULT VALUE	IMPURITY #1	IMPURITY #2	LOWER BOIL PRODUCT #3
1	NAME				
2	PRIORITY AS REFINED PRODUCT	LIST 1-4			
3					
4	NORMAL BOILING PT, C				
5	LOSS/COLUMN, WT %	0.50			
6	LEVEL AS IMPURITY, WT%	0.20			
7	VAP PRESS TEMP, C	900			
8	VAPOR PRESS, mm Hg	800000			
9	HT VAPORIZATION, Btu/lb	215.0			
10	SENSIBLE HT (LIQ), Btu/(lb)	0.50			
11	MAX THERMAL STABILITY, C	150			
12	LN(ACTIVITY COEFFICIENTS)				
13	-COMP. #1 in:	*	xxxx	0.100	0.100
14	-COMP. #2 in:	*	0.100	xxxx	0.100
15	-COMP. #3 in:	*	0.100	0.100	xxxx
16	-COMP. #4 in:	*	0.100	0.100	0.100
17	-COMP. #5 in:	*	0.100	0.100	0.100
18	-COMP. #6 in:	*	0.100	0.100	0.100
19	-COMP. #7 in:	*	0.100	0.100	0.100
20	-COMP. #8 in:	*	0.100	0.100	0.100
21	-COMP. #9 in:	*	0.100	0.100	0.100
22	-COMP. #10 in:	*	0.100	0.100	0.100
23	-WATER in:	*	0.600	0.600	0.600
24	-COMP. #11 in:	*	0.100	0.100	0.100
25	-COMP. #12 in:	*	0.100	0.100	0.100
26	-COMP. #13 in:	*	0.100	0.100	0.100
27	-COMP. #14 in:	*	0.100	0.100	0.100
28	-COMP. #15 in:	*	0.100	0.100	0.100
29	-COMP. #16 in:	*	0.100	0.100	0.100
30	-COMP. #17 in:	*	0.100	0.100	0.100
31	-COMP. #18 in:	*	0.100	0.100	0.100
32	-COMP. #19 in:	*	0.100	0.100	0.100
33	-COMP. #20 in:	*	0.100	0.100	0.100

* The following values can be used in lieu of actual activity coefficients; however, the uncertainty of the calculation is raised significantly:

alcohol/alcohol; ketone/ketone; aldehyde/aldehyde = 0.1
aldehyde/ketone = 0.3
other organic/other organic = 0.5
alcohol/water = 0.6
other organic/water = 1.0

ITEM	COMPONENT	DEFAULT VALUE	IMPURITY #1	IMPURITY #2	LOWER BOIL PRODUCT #3
34	B(n) VAPOR PRESSURE CONST.		-2476.10	-2476.10	-2476.10
35	A(n) VAPOR PRESSURE CONST.		15.703	15.703	15.703
36	VAPOR PRESSURE @40 C		2422.2	2422.2	2422.2
37	VAPOR PRESSURE @120 C		12121.9	12121.9	12121.9

DISTILLATION DATA MATRIX

ITEM	COMPONENT	DEFAULT VALUE	IMPURITY #4	IMPURITY #5	IMPURITY #6
1	NAME			ACETALHD	LITE ENDS
2	PRIORITY AS REFINED PRODUCT	LIST			
3					
4	NORMAL BOILING PT, C			20.2	57.8
5	LOSS/COLUMN, WT %	0.50			
6	LEVEL AS IMPURITY, WT%	0.20		0.00	.00
7	VAP PRESS TEMP, C	900		-10.0	-0.5
8	VAPOR PRESS, mm Hg	800000		200.0	60.0
9	HT VAPORIZATION, Btu/lb	215.0		244.8	176.4
10	SENSIBLE HT (LIQ), Btu/(lb)	0.50		0.50	0.47
11	MAX THERMAL STABILITY, C	150			
12	LN(ACTIVITY COEFFICIENTS)				
13	-COMP. #1 in:	*			
14	-COMP. #2 in:	*			
15	-COMP. #3 in:	*			
16	-COMP. #4 in:	*	XXXX		
17	-COMP. #5 in:	*		XXXX	
18	-COMP. #6 in:	*			XXXX
19	-COMP. #7 in:	*			
20	-COMP. #8 in:	*			
21	-COMP. #9 in:	*			
22	-COMP. #10 in:	*			
23	-WATER in:	*			
24	-COMP. #11 in:	*			
25	-COMP. #12 in:	*			
26	-COMP. #13 in:	*			
27	-COMP. #14 in:	*			
28	-COMP. #15 in:	*			
29	-COMP. #16 in:	*			
30	-COMP. #17 in:	*			
31	-COMP. #18 in:	*			
32	-COMP. #19 in:	*			
33	-COMP. #20 in:	*			

* The following values can be used in lieu of actual activity coefficients; however, the uncertainty of the calculation is raised significantly:

  alcohol/alcohol; ketone/ketone; aldehyde/aldehyde = 0.1
  aldehyde/ketone = 0.3
  other organic/other organic = 0.5
  alcohol/water = 0.6
  other organic/water = 1.0

ITEM	COMPONENT	DEFAULT VALUE	IMPURITY #4	IMPURITY #5	IMPURITY #6
34	B(n) VAPOR PRESSURE CONST.		-2476.10	-3408.74	-3925.74
35	A(n) VAPOR PRESSURE CONST.		15.703	18.259	18.501
36	VAPOR PRESSURE @40 C		2422.2	1585.7	387.0
37	VAPOR PRESSURE @120 C		12121.9	14554.7	4972.0

DISTILLATION DATA MATRIX

ITEM	COMPONENT	DEFAULT VALUE	LOW BOIL PRODUCT #7	IMPURITY #8	IMPURITY #9
1	NAME		ETHANOL		
2	PRIORITY AS REFINED PRODUCT	LIST	1		
3					
4	NORMAL BOILING PT, C		78.4		
5	LOSS/COLUMN, WT %	0.50			
6	LEVEL AS IMPURITY, WT%	0.20			
7	VAP PRESS TEMP, C	900	18.0		
8	VAPOR PRESS, mm Hg	800000	40.0		
9	HT VAPORIZATION, Btu/lb	215.0	367.2		
10	SENSIBLE HT (LIQ), Btu/(lb)	0.50	0.68		
11	MAX THERMAL STABILITY, C	150			
12	LN(ACTIVITY COEFFICIENTS)				
13	-COMP. #1 in:	*	0.100	0.100	0.100
14	-COMP. #2 in:	*	0.100	0.100	0.100
15	-COMP. #3 in:	*	0.100	0.100	0.100
16	-COMP. #4 in:	*	0.100	0.100	0.100
17	-COMP. #5 in:	*	0.100	0.100	0.100
18	-COMP. #6 in:	*	0.100	0.100	0.100
19	-COMP. #7 in:	*	xxxx	0.100	0.100
20	-COMP. #8 in:	*	0.100	xxxx	0.100
21	-COMP. #9 in:	*	0.100	0.100	xxxx
22	-COMP. #10 in:	*	0.100	0.100	0.100
23	-WATER in:	*	0.600	0.600	0.600
24	-COMP. #11 in:	*	0.100	0.100	0.100
25	-COMP. #12 in:	*	0.100	0.100	0.100
26	-COMP. #13 in:	*	0.100	0.100	0.100
27	-COMP. #14 in:	*	0.100	0.100	0.100
28	-COMP. #15 in:	*	0.100	0.100	0.100
29	-COMP. #16 in:	*	0.100	0.100	0.100
30	-COMP. #17 in:	*	0.100	0.100	0.100
31	-COMP. #18 in:	*	0.100	0.100	0.100
32	-COMP. #19 in:	*	0.100	0.100	0.100
33	-COMP. #20 in:	*	0.100	0.100	0.100

* The following values can be used in lieu of actual activity coefficients; however, the uncertainty of the calculation is raised significantly:

alcohol/alcohol; ketone/ketone; aldehyde/aldehyde = 0.1
aldehyde/ketone = 0.3
other organic/other organic = 0.5
alcohol/water = 0.6
other organic/water = 1.0

ITEM	COMPONENT	DEFAULT VALUE	#7	#8	#9
34	B(n) VAPOR PRESSURE CONST.		-4984.94	-2476.10	-2476.10
35	A(n) VAPOR PRESSURE CONST.		20.819	15.703	15.703
36	VAPOR PRESSURE @40 C		133.3	2422.2	2422.2
37	VAPOR PRESSURE @120 C		3411.6	12121.9	12121.9

DISTILLATION DATA MATRIX

ITEM	COMPONENT	DEFAULT VALUE	IMPURITY #10	WATER	IMPURITY #11
1	NAME				ACET ACD
2	PRIORITY AS REFINED PRODUCT	LIST			
3					
4	NORMAL BOILING PT, C			100.0	118.1
5	LOSS/COLUMN, WT %	0.50			
6	LEVEL AS IMPURITY, WT%	0.20			
7	VAP PRESS TEMP, C	900		30.0	20.0
8	VAPOR PRESS, mm Hg	800000		31.8	11.7
9	HT VAPORIZATION, Btu/lb	215.0		970.3	174.2
10	SENSIBLE HT (LIQ), Btu/(lb)	0.50		1.00	0.52
11	MAX THERMAL STABILITY, C	150			
12	LN(ACTIVITY COEFFICIENTS)				
13	-COMP. #1 in:	*	0.100	0.600	0.100
14	-COMP. #2 in:	*	0.100	0.600	0.100
15	-COMP. #3 in:	*	0.100	0.600	0.100
16	-COMP. #4 in:	*	0.100	0.600	0.100
17	-COMP. #5 in:	*	0.100	0.600	0.100
18	-COMP. #6 in:	*	0.100	0.600	0.100
19	-COMP. #7 in:	*	0.100	0.600	0.100
20	-COMP. #8 in:	*	0.100	0.600	0.100
21	-COMP. #9 in:	*	0.100	0.600	0.100
22	-COMP. #10 in:	*	xxxx	0.600	0.100
23	-WATER in:	*	0.600	xxxx	0.600
24	-COMP. #11 in:	*	0.100	0.600	xxxx
25	-COMP. #12 in:	*	0.100	0.600	0.100
26	-COMP. #13 in:	*	0.100	0.600	0.100
27	-COMP. #14 in:	*	0.100	0.600	0.100
28	-COMP. #15 in:	*	0.100	0.600	0.100
29	-COMP. #16 in:	*	0.100	0.600	0.100
30	-COMP. #17 in:	*	0.100	0.600	0.100
31	-COMP. #18 in:	*	0.100	0.600	0.100
32	-COMP. #19 in:	*	0.100	0.600	0.100
33	-COMP. #20 in:	*	0.100	0.600	0.100

* The following values can be used in lieu of actual activity coefficients; however, the uncertainty of the calculation is raised significantly:

alcohol/alcohol; ketone/ketone; aldehyde/aldehyde = 0.1
aldehyde/ketone = 0.3
other organic/other organic = 0.5
alcohol/water = 0.6
other organic/water = 1.0

ITEM	COMPONENT	DEFAULT VALUE	IMPURITY #10	WATER	IMPURITY #11
34	B(n) VAPOR PRESSURE CONST.		-2476.10	-5123.15	-4875.41
35	A(n) VAPOR PRESSURE CONST.		15.703	20.368	19.099
36	VAPOR PRESSURE @40 C		2422.2	54.6	33.9
37	VAPOR PRESSURE @120 C		12121.9	1528.9	807.2

DISTILLATION DATA MATRIX

ITEM	COMPONENT	DEFAULT VALUE	IMPURITY #12	IMPURITY #13	HIGH BOIL PRODUCT #14
1	NAME		I-AM ALK	GLYCERINE	
2	PRIORITY AS REFINED PRODUCT	LIST			
3					
4	NORMAL BOILING PT, C		130.5	290.0	
5	LOSS/COLUMN, WT %	0.50			
6	LEVEL AS IMPURITY, WT%	0.20			
7	VAP PRESS TEMP, C	900	40.8	153.8	
8	VAPOR PRESS, mm Hg	800000	10.0	5.0	
9	HT VAPORIZATION, Btu/lb	215.0	198.0	396.0	
10	SENSIBLE HT (LIQ), Btu/(lb)	0.50	0.72	0.58	
11	MAX THERMAL STABILITY, C	150			
12	LN(ACTIVITY COEFFICIENTS)				
13	-COMP. #1 in:	*	0.100	0.100	0.100
14	-COMP. #2 in:	*	0.100	0.100	0.100
15	-COMP. #3 in:	*	0.100	0.100	0.100
16	-COMP. #4 in:	*	0.100	0.100	0.100
17	-COMP. #5 in:	*	0.100	0.100	0.100
18	-COMP. #6 in:	*	0.100	0.100	0.100
19	-COMP. #7 in:	*	0.100	0.100	0.100
20	-COMP. #8 in:	*	0.100	0.100	0.100
21	-COMP. #9 in:	*	0.100	0.100	0.100
22	-COMP. #10 in:	*	0.100	0.100	0.100
23	-WATER in:	*	0.600	0.600	0.600
24	-COMP. #11 in:	*	0.100	0.100	0.100
25	-COMP. #12 in:	*	xxxx	0.100	0.100
26	-COMP. #13 in:	*	0.100	xxxx	0.100
27	-COMP. #14 in:	*	0.100	0.100	xxxx
28	-COMP. #15 in:	*	0.100	0.100	0.100
29	-COMP. #16 in:	*	0.100	0.100	0.100
30	-COMP. #17 in:	*	0.100	0.100	0.100
31	-COMP. #18 in:	*	0.100	0.100	0.100
32	-COMP. #19 in:	*	0.100	0.100	0.100
33	-COMP. #20 in:	*	0.100	0.100	0.100

* The following values can be used in lieu of actual activity coefficients; however, the uncertainty of the calculation is raised significantly:

alcohol/alcohol; ketone/ketone; aldehyde/aldehyde = 0.1
aldehyde/ketone = 0.3
other organic/other organic = 0.5
alcohol/water = 0.6
other organic/water = 1.0

ITEM	COMPONENT	DEFAULT VALUE	IMPURITY #12	IMPURITY #13	HIGH BOIL PRODUCT #14
34	B(n) VAPOR PRESSURE CONST.		-6113.16	-8863.29	-2476.10
35	A(n) VAPOR PRESSURE CONST.		21.784	22.376	15.703
36	VAPOR PRESSURE @40 C		9.5	.0	2422.2
37	VAPOR PRESSURE @120 C		507.0	0.8	12121.9

DISTILLATION DATA MATRIX

ITEM	COMPONENT	DEFAULT VALUE	IMPURITY #15	IMPURITY #16	IMPURITY #17
1	NAME		LAC ACD	SUC ACD	
2	PRIORITY AS REFINED PRODUCT	LIST			
3					
4	NORMAL BOILING PT, C				
5	LOSS/COLUMN, WT %	0.50			
6	LEVEL AS IMPURITY, WT%	0.20			
7	VAP PRESS TEMP, C	900			
8	VAPOR PRESS, mm Hg	800000			
9	HT VAPORIZATION, Btu/lb	215.0	540.0	396.0	
10	SENSIBLE HT (LIQ), Btu/(lb)	0.50	0.56	0.58	
11	MAX THERMAL STABILITY, C	150			
12	LN(ACTIVITY COEFFICIENTS)				
13	-COMP. #1 in:	*			
14	-COMP. #2 in:	*			
15	-COMP. #3 in:	*			
16	-COMP. #4 in:	*			
17	-COMP. #5 in:	*			
18	-COMP. #6 in:	*			
19	-COMP. #7 in:	*			
20	-COMP. #8 in:	*			
21	-COMP. #9 in:	*			
22	-COMP. #10 in:	*			
23	-WATER in:	*			
24	-COMP. #11 in:	*			
25	-COMP. #12 in:	*			
26	-COMP. #13 in:	*			
27	-COMP. #14 in:	*			
28	-COMP. #15 in:	*	xxxx		
29	-COMP. #16 in:	*		xxxx	
30	-COMP. #17 in:	*			xxxx
31	-COMP. #18 in:	*			
32	-COMP. #19 in:	*			
33	-COMP. #20 in:	*			

* The following values can be used in lieu of actual activity coefficients; however, the uncertainty of the calculation is raised significantly:

alcohol/alcohol; ketone/ketone; aldehyde/aldehyde = 0.1
aldehyde/ketone = 0.3
other organic/other organic = 0.5
alcohol/water = 0.6
other organic/water = 1.0

ITEM	COMPONENT	DEFAULT VALUE	IMPURITY #15	IMPURITY #16	IMPURITY #17
34	B(n) VAPOR PRESSURE CONST.		-2476.10	-2476.10	-2476.10
35	A(n) VAPOR PRESSURE CONST.		15.703	15.703	15.703
36	VAPOR PRESSURE @40 C		2422.2	2422.2	2422.2
37	VAPOR PRESSURE @120 C		12121.9	12121.9	12121.9

DISTILLATION DATA MATRIX

ITEM	COMPONENT	DEFAULT VALUE	---HIGHER BOIL PRODUCT #18	IMPURITY #19	IMPURITY #20
1	NAME				
2	PRIORITY AS REFINED PRODUCT	LIST			
3					
4	NORMAL BOILING PT, C				
5	LOSS/COLUMN, WT %	0.50			
6	LEVEL AS IMPURITY, WT%	0.20			
7	VAP PRESS TEMP, C	900			
8	VAPOR PRESS, mm Hg	800000			
9	HT VAPORIZATION, Btu/lb	215.0			
10	SENSIBLE HT (LIQ), Btu/(lb)	0.50			
11	MAX THERMAL STABILITY, C	150			
12	LN(ACTIVITY COEFFICIENTS)				
13	-COMP. #1 in:	*	0.100	0.100	0.100
14	-COMP. #2 in:	*	0.100	0.100	0.100
15	-COMP. #3 in:	*	0.100	0.100	0.100
16	-COMP. #4 in:	*	0.100	0.100	0.100
17	-COMP. #5 in:	*	0.100	0.100	0.100
18	-COMP. #6 in:	*	0.100	0.100	0.100
19	-COMP. #7 in:	*	0.100	0.100	0.100
20	-COMP. #8 in:	*	0.100	0.100	0.100
21	-COMP. #9 in:	*	0.100	0.100	0.100
22	-COMP. #10 in:	*	0.100	0.100	0.100
23	-WATER in:	*	0.600	0.600	0.600
24	-COMP. #11 in:	*	0.100	0.100	0.100
25	-COMP. #12 in:	*	0.100	0.100	0.100
26	-COMP. #13 in:	*	0.100	0.100	0.100
27	-COMP. #14 in:	*	0.100	0.100	0.100
28	-COMP. #15 in:	*	0.100	0.100	0.100
29	-COMP. #16 in:	*	0.100	0.100	0.100
30	-COMP. #17 in:	*	0.100	0.100	0.100
31	-COMP. #18 in:	*	xxxx	0.100	0.100
32	-COMP. #19 in:	*	0.100	xxxx	0.100
33	-COMP. #20 in:	*	0.100	0.100	xxxx

* The following values can be used in lieu of actual activity coefficients; however, the uncertainty of the calculation is raised significantly:

alcohol/alcohol; ketone/ketone; aldehyde/aldehyde = 0.1
aldehyde/ketone = 0.3
other organic/other organic = 0.5
alcohol/water = 0.6
other organic/water = 1.0

ITEM	COMPONENT	DEFAULT VALUE	#18	#19	#20
34	B(n) VAPOR PRESSURE CONST.		-2476.10	-2476.10	-2476.10
35	A(n) VAPOR PRESSURE CONST.		15.703	15.703	15.703
36	VAPOR PRESSURE @40 C		2422.2	2422.2	2422.2
37	VAPOR PRESSURE @120 C		12121.9	12121.9	12121.9

OFTEN USED PARAMETERS

(THOUSAND ANNUAL POUNDS)

403,563	PRODUCT FORMED
	FORMED WITH PRODUCT
579	-ACETALDEHYDE
0	-COMPONENT #2
0	-COMPONENT #3
0	-COMPONENT #4
0	-COMPONENT #5
404	-LIGHT ENDS
403,563	-ETHANOL (PRODUCT)
0	-COMPONENT #8
0	-COMPONENT #9
0	-COMPONENT #10
(10,717)	-WATER
4,524	-ACETIC ACID
2,018	-ISOAMYL ALCOHOL
18,555	-GLYCERINE
0	-COMPONENT #14
868	-LACTIC ACID
590	-SUCCINIC ACID
0	-COMPONENT #17
0	-COMPONENT #18
0	-COMPONENT #19
0	-COMPONENT #20
2,186	-HYDROGEN
416,726	-CARBON DIOXIDE
	CONSUMED FOR PRODUCT
839,295	-GLUCOSE
0	-AMMONIA
0	-OXYGEN
15,220	CELLS PRODUCED - CHO
1,392	CELLS PRODUCED - NH2
	FORMED WITH CELLS
9,127	-WATER-CHO
783	-WATER-NH2
9,910	-WATER-TOTAL
22,311	-CARBON DIOXIDE-CHO
	CONSUMED FOR CELLS
30,441	-GLUCOSE-CHO
1,479	-AMMONIA-NH2
16,226	-OXYGEN-CHO
696	-OXYGEN-NH2
16,922	-OXYGEN-TOTAL
84,609	OXYGEN FED-GROWTH
280,192	NITROGEN FED-GROWTH
67,687	OXYGEN VENT-GROWTH
280,192	NITROGEN VENT-GROWTH
22,311	CARBON DIOXIDE VENT-GROWTH
11,344	WATER VENT GROWTH

OFTEN USED PARAMETERS

(THOUSAND ANNUAL POUNDS)

0	OXYGEN FED-PROD'N
0	NITROGEN FED-PROD'N
0	OXYGEN VENT-PROD'N
0	NITROGEN VENT-PROD'N
416,726	CARBON DIOXIDE VENT-PROD'N
16,745	WATER VENT-PROD'N
433,472	PHI

WATER BALANCE

WATER IN:

MAKE UP WATER	3,317,840
BIOSUGAR SYRUP	1,305,361
STERILIZER STEAM	198,692
FORMED WITH CELLS	9,910
FORMED WITH PRODUCT	(10,717)
TOTAL IN	4,821,086

WATER OUT:

AQUEOUS WASTE	4,538,590
CONDENSATE MAKEUP TO P.H	198,692
FERMENTER VENTS	28,089
PURGED WITH CELLS	55,636
MOISTURE IN PRODUCTS	79
TOTAL OUT	4,821,086

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	1 CORN SYRUP	2 ANHYD AMMONIA	3 NUTRIENTS	4 MIX WATER	5 MIXED MEDIUM
P						
R	CELLS -CHO	0	0	0	0	0
O	-NH2	0	0	0	0	0
D	-MINERALS	0	0	0	0	0
U	-TOTAL	0	0	0	0	0
C	ACETALDEHYDE	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#0	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	LIGHT ENDS	0	0	0	0	0
#1	ETHANOL	0	0	0	0	0
	COMPONENT #8	0	0	0	0	0
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	0	0	0	0	0
	ACETIC ACID	0	0	0	0	0
	ISOAMYL ALCOHOL	0	0	0	0	0
	GLYCERINE	0	0	0	0	0
#0	COMPONENT #14	0	0	0	0	0
	LACTIC ACID	0	0	0	0	0
	SUCCINIC ACID	0	0	0	0	0
	COMPONENT #17	0	0	0	0	0
#0	COMPONENT #18	0	0	0	0	0
	COMPONENT #19	0	0	0	0	0
	BENZENE	0	0	0	0	0
	GLUCOSE	870,241	0	0	0	870,241
	AMMONIA	0	1,479	0	0	0
	PHOSPHORIC ACID	0	0	1,231	0	1,231
	POTASSIUM CHLORIDE	0	0	938	0	938
	MINOR NUTRIENTS	0	0	425	0	425
	WATER	1,305,361	0	0	3,119,148	4,424,509
	CARBON DIOXIDE	0	0	0	0	0
	OXYGEN	0	0	0	0	0
	NITROGEN	0	0	0	0	0
	HYDROGEN	0	0	0	0	0
	GRAND TOTAL	2,175,602	1,479	2,594	3,119,148	5,297,344
	CHECK ON TOTAL					
	TEMPERATURE, C	20	20	20	20	20
	PRESSURE, PSIA	14.7	14.7	14.7	20.8	25.0
	STATE	SOL'N	LIQUID	SOLIDS	LIQUID	SOL'N

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	6 HX SS EFFLUENT	7 STERILE MEDIUM	8 HX TS EFFLUENT	9 COOLER EFFLUENT	10 AIR TO FERM
P						
R	CELLS -CHO	0	0	0	0	0
O	-NH2	0	0	0	0	0
D	-MINERALS	0	0	0	0	0
U	-TOTAL	0	0	0	0	0
C	ACETALDEHYDE	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#0	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	LIGHT ENDS	0	0	0	0	0
#1	ETHANOL	0	0	0	0	0
	COMPONENT #8	0	0	0	0	0
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	0	0	0	0	0
	ACETIC ACID	0	0	0	0	0
	ISOAMYL ALCOHOL	0	0	0	0	0
	GLYCERINE	0	0	0	0	0
#0	COMPONENT #14	0	0	0	0	0
	LACTIC ACID	0	0	0	0	0
	SUCCINIC ACID	0	0	0	0	0
	COMPONENT #17	0	0	0	0	0
#0	COMPONENT #18	0	0	0	0	0
	COMPONENT #19	0	0	0	0	0
	BENZENE	0	0	0	0	0
	GLUCOSE	870,241	870,241	870,241	870,241	0
	AMMONIA	0	0	0	0	0
	PHOSPHORIC ACID	1,231	1,231	1,231	1,231	0
	POTASSIUM CHLORIDE	938	938	938	938	0
	MINOR NUTRIENTS	425	425	425	425	0
	WATER	4,424,509	4,623,201	4,623,201	4,623,201	0
	CARBON DIOXIDE	0	0	0	0	0
	OXYGEN	0	0	0	0	84,609
	NITROGEN	0	0	0	0	280,192
	HYDROGEN	0	0	0	0	0
	GRAND TOTAL	5,297,344	5,496,036	5,496,036	5,496,036	364,802
	CHECK ON TOTAL					
	TEMPERATURE, C	100	120	40	33	33
	PRESSURE, PSIA	25.0	25.0	25.0	25.0	60.0
	STATE	SOL'N	SOL'N	SOL'N	SOL'N	GAS

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	11 COMBINED FEED	12 BEER #1	13 BEER #2	14 VENT GROWTH	15 VENT PROD'N
P						
R	CELLS -CHO	0	15,220	15,221	0	0
O	-NH2	0	1,392	1,392	0	0
D	-MINERALS	0	425	425	0	0
U	-TOTAL	0	17,037	17,038	0	0
C	ACETALDEHYDE	0	0	0	0	579
T	COMPONENT #2	0	0	0	0	0
#0	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	LIGHT ENDS	0	0	404	0	0
#1	ETHANOL	0	0	403,563	0	0
	COMPONENT #8	0	0	0	0	0
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	0	0	0	0	0
	ACETIC ACID	0	0	4,524	0	0
	ISOAMYL ALCOHOL	0	0	2,018	0	0
	GLYCERINE	0	0	18,555	0	0
#0	COMPONENT #14	0	0	0	0	0
	LACTIC ACID	0	0	868	0	0
	SUCCINIC ACID	0	0	590	0	0
	COMPONENT #17	0	0	0	0	0
#0	COMPONENT #18	0	0	0	0	0
	COMPONENT #19	0	0	0	0	0
	BENZENE	0	0	0	0	0
	GLUCOSE	870,241	839,800	504	0	0
	AMMONIA	1,479	0	0	0	0
	PHOSPHORIC ACID	1,231	1,231	1,231	0	0
	POTASSIUM CHLORIDE	938	938	938	0	0
	MINOR NUTRIENTS	425	0	0	0	0
	WATER	4,623,201	4,621,767	4,594,306	11,344	16,745
	CARBON DIOXIDE	0	0	0	22,311	416,726
	OXYGEN	84,609	0	0	67,687	0
	NITROGEN	280,192	0	0	280,192	0
	HYDROGEN	0	0	0	0	2,186
	GRAND TOTAL	5,862,316	5,480,773	5,044,539	381,534	436,236
	CHECK ON TOTAL			5,044,539		
	TEMPERATURE, C	33	33	33	33	33
	PRESSURE, PSIA	--	44.7	44.7	14.7	14.7
	STATE	--	SLURRY	SLURRY	GAS	GAS

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	16 COMBINED VENT	17 CELL EFFLUENT	18 CELLS TO DISPOSAL	19 CELL RECYCLE	20 CRUDE FILTRATE
P						
R	CELLS -CHO	0	15,221	15,220	0	0
O	-NH2	0	1,392	1,392	0	0
D	-MINERALS	0	425	425	0	0
U	-TOTAL	0	17,038	17,037	0	0
C	ACETALDEHYDE	579	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#0	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	LIGHT ENDS	0	5	5	0	399
#1	ETHANOL	0	4,887	4,887	0	398,676
	COMPONENT #8	0	0	0	0	0
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	0	0	0	0	0
	ACETIC ACID	0	55	55	0	4,469
	ISOAMYL ALCOHOL	0	24	24	0	1,993
	GLYCERINE	0	225	225	0	18,331
#0	COMPONENT #14	0	0	0	0	0
	LACTIC ACID	0	11	11	0	857
	SUCCINIC ACID	0	7	7	0	583
	COMPONENT #17	0	0	0	0	0
#0	COMPONENT #18	0	0	0	0	0
	COMPONENT #19	0	0	0	0	0
	BENZENE	0	0	0	0	0
	GLUCOSE	0	6	6	0	498
	AMMONIA	0	0	0	0	0
	PHOSPHORIC ACID	0	15	15	0	1,216
	POTASSIUM CHLORIDE	0	11	11	0	926
	MINOR NUTRIENTS	0	0	0	0	0
	WATER	28,089	55,637	55,636	1	4,538,669
	CARBON DIOXIDE	439,037	0	0	0	0
	OXYGEN	67,687	0	0	0	0
	NITROGEN	280,192	0	0	0	0
	HYDROGEN	2,186	0	0	0	0
	GRAND TOTAL	817,771	77,921	77,919	2	4,966,618
	CHECK ON TOTAL		77,921		2	
	TEMPERATURE, C	33	33	33	33	33
	PRESSURE, PSIA	14.7	44.7	14.7	44.7	14.7
	STATE	GAS	SLURRY	SLURRY	SLURRY	SOL'N

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	21 BEER #1 FEED	22 BEER #1 MAKE	23 BEER #1 TAILS	24 BEER #2 MAKE
P					
R	CELLS -CHO	0	0	0	0
O	-NH2	0	0	0	0
D	-MINERALS	0	0	0	0
U	-TOTAL	0	0	0	0
C	ACETALDEHYDE	0	0	0	0
T	COMPONENT #2	0	0	0	0
#0	COMPONENT #3	0	0	0	0
	COMPONENT #4	0	0	0	0
	COMPONENT #5	0	0	0	0
	LIGHT ENDS	399	399	0	399
#1	ETHANOL	438,344	436,351	1,993	396,683
	COMPONENT #8	0	0	0	0
	COMPONENT #9	0	0	0	0
	COMPONENT #10	0	0	0	0
	ACETIC ACID	4,469	0	4,469	0
	ISOAMYL ALCOHOL	1,993	0	1,993	0
	GLYCERINE	18,331	0	18,331	0
#0	COMPONENT #14	0	0	0	0
	LACTIC ACID	857	0	857	0
	SUCCINIC ACID	583	0	583	0
	COMPONENT #17	0	0	0	0
#0	COMPONENT #18	0	0	0	0
	COMPONENT #19	0	0	0	0
	BENZENE	0	0	0	0
	GLUCOSE	498	0	498	0
	AMMONIA	0	0	0	0
	PHOSPHORIC ACID	1,216	0	1,216	0
	POTASSIUM CHLORIDE	926	0	926	0
	MINOR NUTRIENTS	0	0	0	0
	WATER	4,954,142	436,351	4,517,791	20,878
	CARBON DIOXIDE	0	0	0	0
	OXYGEN	0	0	0	0
	NITROGEN	0	0	0	0
	HYDROGEN	0	0	0	0
	GRAND TOTAL	5,421,759	873,100	4,548,659	417,959
	CHECK ON TOTAL				
	TEMPERATURE, C	--	109	120	99
	PRESSURE, PSIA	--	27.4	29.6	29.7
	STATE	SOL'N	SOL'N	SOL'N	SOL'N

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	25 BEER #2 TAILS	26 LBS #1 MAKE	27 LBS #1 TAILS	28 LBS #2 MAKE	29 LBS #2 TAILS
P						
R	CELLS -CHO	0	0	0	0	0
O	-NH2	0	0	0	0	0
D	-MINERALS	0	0	0	0	0
U	-TOTAL	0	0	0	0	0
C	ACETALDEHYDE	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#0	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	LIGHT ENDS	0	359	40	0	0
#1	ETHANOL	39,668	1,983	394,699	0	0
	COMPONENT #8	0	0	0	0	0
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	0	0	0	0	0
	ACETIC ACID	0	0	0	0	0
	ISOAMYL ALCOHOL	0	0	0	0	0
	GLYCERINE	0	0	0	0	0
#0	COMPONENT #14	0	0	0	0	0
	LACTIC ACID	0	0	0	0	0
	SUCCINIC ACID	0	0	0	0	0
	COMPONENT #17	0	0	0	0	0
#0	COMPONENT #18	0	0	0	0	0
	COMPONENT #19	0	0	0	0	0
	BENZENE	0	0	0	0	0
	GLUCOSE	0	0	0	0	0
	AMMONIA	0	0	0	0	0
	PHOSPHORIC ACID	0	0	0	0	0
	POTASSIUM CHLORIDE	0	0	0	0	0
	MINOR NUTRIENTS	0	0	0	0	0
	WATER	415,473	0	20,878	0	0
	CARBON DIOXIDE	0	0	0	0	0
	OXYGEN	0	0	0	0	0
	NITROGEN	0	0	0	0	0
	HYDROGEN	0	0	0	0	0
	GRAND TOTAL	455,141	2,342	415,617	0	0
	CHECK ON TOTAL					
	TEMPERATURE, C	120	111	120	(273)	120
	PRESSURE, PSIA	30.9	58.4	61.7	.0	.0
	STATE	SOL'N	SOL'N	SOL'N	SOL'N	SOL'N

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	30 LBS #3 MAKE	31 LBS #3 TAILS	32 HBS #1 MAKE	33 HBS #1 TAILS	34 HBS #2 MAKE
P						
R	CELLS -CHO	0	0	0	0	0
O	-NH2	0	0	0	0	0
D	-MINERALS	0	0	0	0	0
U	-TOTAL	0	0	0	0	0
C	ACETALDEHYDE	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#0	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	LIGHT ENDS	0	0	0	0	0
#1	ETHANOL	0	0	0	0	0
	COMPONENT #8	0	0	0	0	0
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	0	0	0	0	0
	ACETIC ACID	0	0	0	0	0
	ISOAMYL ALCOHOL	0	0	0	0	0
	GLYCERINE	0	0	0	0	0
#0	COMPONENT #14	0	0	0	0	0
	LACTIC ACID	0	0	0	0	0
	SUCCINIC ACID	0	0	0	583	0
	COMPONENT #17	0	0	0	0	0
#0	COMPONENT #18	0	0	0	0	0
	COMPONENT #19	0	0	0	0	0
	BENZENE	0	0	0	0	0
	GLUCOSE	0	0	0	498	0
	AMMONIA	0	0	0	0	0
	PHOSPHORIC ACID	0	0	0	1,216	0
	POTASSIUM CHLORIDE	0	0	0	926	0
	MINOR NUTRIENTS	0	0	0	0	0
	WATER	0	0	0	0	0
	CARBON DIOXIDE	0	0	0	0	0
	OXYGEN	0	0	0	0	0
	NITROGEN	0	0	0	0	0
	HYDROGEN	0	0	0	0	0
	GRAND TOTAL	0	0	0	3,223	0
	CHECK ON TOTAL					
	TEMPERATURE, C	(273)	120	(273)	150	(273)
	PRESSURE, PSIA	.0	.0	115.7	115.7	115.7
	STATE	SOL'N	SOL'N	SOL'N	SOL'N	SOL'N

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	35 HBS #2 TAILS	36 AZEO MAKE	37 AZEO TAILS	38 AZEO REFLUX	39 DECANTER FEED
P						
R	CELLS -CHO	0	0	0	0	0
O	-NH2	0	0	0	0	0
D	-MINERALS	0	0	0	0	0
U	-TOTAL	0	0	0	0	0
C	ACETALDEHYDE	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#0	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	LIGHT ENDS	0	0	0	0	0
#1	ETHANOL	0	258,657	394,595	258,553	316,936
	COMPONENT #8	0	0	0	0	0
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	0	0	0	0	0
	ACETIC ACID	0	0	0	0	0
	ISOAMYL ALCOHOL	0	0	0	0	0
	GLYCERINE	0	0	0	0	0
#0	COMPONENT #14	0	0	0	0	0
	LACTIC ACID	0	0	0	0	0
	SUCCINIC ACID	583	0	0	0	0
	COMPONENT #17	0	0	0	0	0
#0	COMPONENT #18	0	0	0	0	0
	COMPONENT #19	0	0	0	0	0
	BENZENE	0	1,750,849	2	1,750,850	1,756,225
	GLUCOSE	0	0	0	0	0
	AMMONIA	0	0	0	0	0
	PHOSPHORIC ACID	0	0	0	0	0
	POTASSIUM CHLORIDE	0	0	0	0	0
	MINOR NUTRIENTS	0	0	0	0	0
	WATER	0	47,267	79	26,468	74,762
	CARBON DIOXIDE	0	0	0	0	0
	OXYGEN	0	0	0	0	0
	NITROGEN	0	0	0	0	0
	HYDROGEN	0	0	0	0	0
	GRAND TOTAL	583	2,056,773	394,676	2,035,872	2,147,923
	CHECK ON TOTAL					
	TEMPERATURE, C	150				
	PRESSURE, PSIA	115.7				
	STATE	SOL'N	SOL'N	SOL'N	SOL'N	SOL'N

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	40 DECANTER UP LAYER	41 DECANTER LO LAYER	42 BENZENE MAKE	43 BENZENE TAILS	44 FUSEL OIL DRAW-OFF	45 REFINED PRODUCT
P							
R	CELLS -CHO	0	0	0	0	0	0
O	-NH2	0	0	0	0	0	0
D	-MINERALS	0	0	0	0	0	0
U	-TOTAL	0	0	0	0	0	0
C	ACETALDEHYDE	0	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0	0
#0	COMPONENT #3	0	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0	0
	LIGHT ENDS	0	0	0	0	0	0
#1	ETHANOL	258,553	58,383	58,279	104	0	394,595
	COMPONENT #8	0	0	0	0	0	0
	COMPONENT #9	0	0	0	0	0	0
	COMPONENT #10	0	0	0	0	0	0
	ACETIC ACID	0	0	0	0	0	0
	ISOAMYL ALCOHOL	0	0	0	0	0	0
	GLYCERINE	0	0	0	0	0	0
#0	COMPONENT #14	0	0	0	0	0	0
	LACTIC ACID	0	0	0	0	0	0
	SUCCINIC ACID	0	0	0	0	0	0
	COMPONENT #17	0	0	0	0	0	0
#0	COMPONENT #18	0	0	0	0	0	0
	COMPONENT #19	0	0	0	0	0	0
	BENZENE	1,750,853	5,377	5,377	0.21	0	2
	GLUCOSE	0	0	0	0	0	0
	AMMONIA	0	0	0	0	0	0
	PHOSPHORIC ACID	0	0	0	0	0	0
	POTASSIUM CHLORIDE	0	0	0	0	0	0
	MINOR NUTRIENTS	0	0	0	0	0	0
	WATER	26,468	48,294	27,495	20,799	0	79
	CARBON DIOXIDE	0	0	0	0	0	0
	OXYGEN	0	0	0	0	0	0
	NITROGEN	0	0	0	0	0	0
	HYDROGEN	0	0	0	0	0	0
	GRAND TOTAL	2,035,874	112,054	91,150	20,903	0	394,676
	CHECK ON TOTAL						
	TEMPERATURE, C						40
	PRESSURE, PSIA						14.7
	STATE	SOL'N	SOL'N	SOL'N	SOL'N	SOL'N	SOL'N

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	46 REFINED B.P.#1	47 REFINED B.P.#2	48 AQUEOUS WASTE	49 MAKE-UP WATER	50 MAKE-UP BENZENE
P						
R	CELLS -CHO	0	0	0	0	0
O	-NH2	0	0	0	0	0
D	-MINERALS	0	0	0	0	0
U	-TOTAL	0	0	0	0	0
C	ACETALDEHYDE	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#0	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	LIGHT ENDS	0	0	399	0	0
#1	ETHANOL	0	0	4,081	0	0
	COMPONENT #8	0	0	0	0	0
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	0	0	0	0	0
	ACETIC ACID	0	0	4,469	0	0
	ISOAMYL ALCOHOL	0	0	1,993	0	0
	GLYCERINE	0	0	18,331	0	0
#0	COMPONENT #14	0	0	0	0	0
	LACTIC ACID	0	0	857	0	0
	SUCCINIC ACID	0	0	583	0	0
	COMPONENT #17	0	0	0	0	0
#0	COMPONENT #18	0	0	0	0	0
	COMPONENT #19	0	0	0	0	0
	BENZENE	0	0	0	0	2
	GLUCOSE	0	0	498	0	0
	AMMONIA	0	0	0	0	0
	PHOSPHORIC ACID	0	0	1,216	0	0
	POTASSIUM CHLORIDE	0	0	926	0	0
	MINOR NUTRIENTS	0	0	0	0	0
	WATER	0	0	4,538,590	3,317,840	0
	CARBON DIOXIDE	0	0	0	0	0
	OXYGEN	0	0	0	0	0
	NITROGEN	0	0	0	0	0
	HYDROGEN	0	0	0	0	0
	GRAND TOTAL	0	0	4,571,944	3,317,840	2
	CHECK ON TOTAL					
	TEMPERATURE, C	40	40	40	20	20
	PRESSURE, PSIA	14.7	14.7	14.7	14.7	14.7
	STATE	SOL'N	SOL'N	SOL'N	LIQUID	LIQUID

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	51 STERILE STEAM	52 FERM'TR STEAM	53 DISTILL. STEAM	54 COND. MU P'WR H'SE	55 MEDIUM COOL WTR
P						
R	CELLS -CHO	0	0	0	0	0
O	-NH2	0	0	0	0	0
D	-MINERALS	0	0	0	0	0
U	-TOTAL	0	0	0	0	0
C	ACETALDEHYDE	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#0	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	LIGHT ENDS	0	0	0	0	0
#1	ETHANOL	0	0	0	0	0
	COMPONENT #8	0	0	0	0	0
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	0	0	0	0	0
	ACETIC ACID	0	0	0	0	0
	ISOAMYL ALCOHOL	0	0	0	0	0
	GLYCERINE	0	0	0	0	0
#0	COMPONENT #14	0	0	0	0	0
	LACTIC ACID	0	0	0	0	0
	SUCCINIC ACID	0	0	0	0	0
	COMPONENT #17	0	0	0	0	0
#0	COMPONENT #18	0	0	0	0	0
	COMPONENT #19	0	0	0	0	0
	BENZENE	0	0	0	0	0
	GLUCOSE	0	0	0	0	0
	AMMONIA	0	0	0	0	0
	PHOSPHORIC ACID	0	0	0	0	0
	POTASSIUM CHLORIDE	0	0	0	0	0
	MINOR NUTRIENTS	0	0	0	0	0
	WATER	198,692	0	2,992,687	198,692	2,564,817
	CARBON DIOXIDE	0	0	0	0	0
	OXYGEN	0	0	0	0	0
	NITROGEN	0	0	0	0	0
	HYDROGEN	0	0	0	0	0
	GRAND TOTAL	198,692	0	2,992,687	198,692	2,564,817
	CHECK ON TOTAL					
	TEMPERATURE, C	141	141	186	110	5
	PRESSURE, PSIA	64.7	64.7	164.7	20.8	14.7
	STATE	GAS	GAS	GAS	LIQUID	LIQUID

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	56 FERM'TR COOL WTR	52 DISTILL. COOL WTR
P			
R	CELLS -CHO	0	0
O	-NH2	0	0
D	-MINERALS	0	0
U	-TOTAL	0	0
C	ACETALDEHYDE	0	0
T	COMPONENT #2	0	0
#0	COMPONENT #3	0	0
	COMPONENT #4	0	0
	COMPONENT #5	0	0
	LIGHT ENDS	0	0
#1	ETHANOL	0	0
	COMPONENT #8	0	0
	COMPONENT #9	0	0
	COMPONENT #10	0	0
	ACETIC ACID	0	0
	ISOAMYL ALCOHOL	0	0
	GLYCERINE	0	0
#0	COMPONENT #14	0	0
	LACTIC ACID	0	0
	SUCCINIC ACID	0	0
	COMPONENT #17	0	0
#0	COMPONENT #18	0	0
	COMPONENT #19	0	0
	BENZENE	0	0
	GLUCOSE	0	0
	AMMONIA	0	0
	PHOSPHORIC ACID	0	0
	POTASSIUM CHLORIDE	0	0
	MINOR NUTRIENTS	0	0
	WATER	20,398,646	76,661,050
	CARBON DIOXIDE	0	0
	OXYGEN	0	0
	NITROGEN	0	0
	HYDROGEN	0	0
	GRAND TOTAL	20,398,646	76,661,050
	CHECK ON TOTAL		
	TEMPERATURE, C	5	0
	PRESSURE, PSIA	14.7	14.7
	STATE	LIQUID	LIQUID

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	20 CRUDE FILTRATE	21 BEER #1 FEED	22 BEER #1 MAKE	23 BEER #1 TAILS	24 BEER #2 MAKE
ACETALDEHYDE	0	0	0	0	0
COMPONENT #2	0	0	0	0	0
COMPONENT #3	0	0	0	0	0
COMPONENT #4	0	0	0	0	0
COMPONENT #5	0	0	0	0	0
LIGHT ENDS	5	5	5	0	5
ETHANOL	8,654	9,515	9,472	43	8,611
COMPONENT #8	0	0	0	0	0
COMPONENT #9	0	0	0	0	0
COMPONENT #10	0	0	0	0	0
ACETIC ACID	74	74	0	74	0
ISOAMYL ALCOHOL	23	23	0	23	0
GLYCERINE	199	199	0	199	0
COMPONENT #14	0	0	0	0	0
LACTIC ACID	10	10	0	10	0
SUCCINIC ACID	5	5	0	5	0
COMPONENT #17	0	0	0	0	0
COMPONENT #18	0	0	0	0	0
COMPONENT #19	0	0	0	0	0
BENZENE	0	0	0	0	0
WATER	251,924	274,986	24,220	250,765	1,159
	260,893	284,816	33,697	251,119	9,774
(Storage)	1,193	1,308	1,265	44	1,150
VAPOR PRESS 40(q)	57.3	57.3	76.8	54.7	124.1
(Storage)	29,758	32,696	32,361	359	29,423
VAPOR PRESS 120(q)	1590.4	1590.9	2059.3	1528.2	3191.6
B(q) V.P. CONSTANT	-5109.7	-5109.9	-5057.2	-5119.7	-4992.6
A(q) V.P. CONSTANT	20.373	20.374	20.498	20.359	20.772
TEMPERATURE C	33.0	40.3	107.9	120.0	96.8
PRESSURE mmHg	760	760	1,368	1,528	1,438

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	25 BEER #2 TAILS	26 LBS #1 MAKE	27 LBS #1 TAILS	28 LBS #2 MAKE	29 LBS #2 TAILS	30 LBS #3 MAKE
ACETALDEHYDE	0	0	0	0	0	0
COMPONENT #2	0	0	0	0	0	0
COMPONENT #3	0	0	0	0	0	0
COMPONENT #4	0	0	0	0	0	0
COMPONENT #5	0	0	0	0	0	0
LIGHT ENDS	0	4	0	0	0	0
ETHANOL	861	43	8,568	0	0	0
COMPONENT #8	0	0	0	0	0	0
COMPONENT #9	0	0	0	0	0	0
COMPONENT #10	0	0	0	0	0	0
ACETIC ACID	0	0	0	0	0	0
ISOAMYL ALCOHOL	0	0	0	0	0	0
GLYCERINE	0	0	0	0	0	0
COMPONENT #14	0	0	0	0	0	0
LACTIC ACID	0	0	0	0	0	0
SUCCINIC ACID	0	0	0	0	0	0
COMPONENT #17	0	0	0	0	0	0
COMPONENT #18	0	0	0	0	0	0
COMPONENT #19	0	0	0	0	0	0
BENZENE	0	0	0	0	0	0
WATER	23,061	0	1,159	0	0	0
	23,922	47	9,727	0	0	0
(Storage)	115	7	1,143	0	0	0
VAPOR PRESS 40(q)	57.5	155.3	124.0	.0	.0	.0
(Storage)	2,962	191	29,256	24	24	24
VAPOR PRESS 120(q)	1597.7	4060.9	3189.9	.0	.0	.0
B(q) V.P. CONSTANT	-5113.0	-5018.8	-4993.6	0.0	0.0	0.0
A(q) V.P. CONSTANT	20.387	21.080	20.774	-4.605	-4.605	-4.605
TEMPERATURE C	120.0	111.2	120.0	ERR	120.0	ERR
PRESSURE mmHg	1,598	3,030	3,190	(160)	0	(160)

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	31 LBS #3 TAILS	32 HBS #1 MAKE	33 HBS #1 TAILS	34 HBS #2 MAKE	35 HBS #2 TAILS	36 AZEO MAKE
ACETALDEHYDE	0	0	0	0	0	0
COMPONENT #2	0	0	0	0	0	0
COMPONENT #3	0	0	0	0	0	0
COMPONENT #4	0	0	0	0	0	0
COMPONENT #5	0	0	0	0	0	0
LIGHT ENDS	0	0	0	0	0	0
ETHANOL	0	0	0	0	0	5,615
COMPONENT #8	0	0	0	0	0	0
COMPONENT #9	0	0	0	0	0	0
COMPONENT #10	0	0	0	0	0	0
ACETIC ACID	0	0	0	0	0	0
ISOAMYL ALCOHOL	0	0	0	0	0	0
GLYCERINE	0	0	0	0	0	0
COMPONENT #14	0	0	0	0	0	0
LACTIC ACID	0	0	0	0	0	0
SUCCINIC ACID	0	0	5	0	5	0
COMPONENT #17	0	0	0	0	0	0
COMPONENT #18	0	0	0	0	0	0
COMPONENT #19	0	0	0	0	0	0
BENZENE	0	0	0	0	0	22,207
WATER	0	0	0	0	0	2,624
	0	0	5	0	5	30,445
(Storage)	0	0	12	0	12	
VAPOR PRESS 40(q)	.0	.0	2422.2	.0	2422.2	
(Storage)	24	24	24	24	24	
VAPOR PRESS 120(q)	.0	.0	4915.8	.0	4915.8	
B(q) V.P. CONSTANT	0.0	0.0	-1088.3	0.0	-1088.3	
A(q) V.P. CONSTANT	-4.605	-4.605	11.269	-4.605	11.269	
TEMPERATURE C	120.0	-273.0	150.0	-273.0	150.0	
PRESSURE mmHg	0	5,823	5,983	5,823	5,983	

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	37 AZEO TAILS	38 AZEO REFLUX	39 DECANTER FEED	40 DECANTER UP LAYER	41 DECANTER LO LAYER	42 BENZENE MAKE
ACETALDEHYDE	0					0
COMPONENT #2	0					0
COMPONENT #3	0					0
COMPONENT #4	0					0
COMPONENT #5	0					0
LIGHT ENDS	0					0
ETHANOL	8,565					1,265
COMPONENT #8	0					0
COMPONENT #9	0					0
COMPONENT #10	0					0
ACETIC ACID	0					0
ISOAMYL ALCOHOL	0					0
GLYCERINE	0					0
COMPONENT #14	0					0
LACTIC ACID	0					0
SUCCINIC ACID	0					0
COMPONENT #17	0					0
COMPONENT #18	0					0
COMPONENT #19	0					0
BENZENE	0					68
WATER	4					1,526
	8,570					2,859
(Storage) VAPOR PRESS 40(q)						
(Storage) VAPOR PRESS 120(q)						
B(q) V.P. CONSTANT						
A(q) V.P. CONSTANT						
TEMPERATURE C						
PRESSURE mmHg						

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	43 BENZENE TAILS
ACETALDEHYDE	0
COMPONENT #2	0
COMPONENT #3	0
COMPONENT #4	0
COMPONENT #5	0
LIGHT ENDS	0
ETHANOL	2
COMPONENT #8	0
COMPONENT #9	0
COMPONENT #10	0
ACETIC ACID	0
ISOAMYL ALCOHOL	0
GLYCERINE	0
COMPONENT #14	0
LACTIC ACID	0
SUCCINIC ACID	0
COMPONENT #17	0
COMPONENT #18	0
COMPONENT #19	0
BENZENE	0
WATER	1,154
	1,157

(Storage)
VAPOR PRESS 40(q)
(Storage)
VAPOR PRESS 120(q)
B(q) V.P. CONSTANT
A(q) V.P. CONSTANT
TEMPERATURE C
PRESSURE mmHg

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	20 CRUDE FILTRATE	22 BEER #1 MAKE	23 BEER #1 TAILS	24 BEER #2 MAKE	25 BEER #2 TAILS
K1 (COMPONENT #)		7	7	7	7
K2 (COMPONENT #)		WATER	WATER	WATER	WATER
V.P.(K1)		2279.9	3411.6	1538.7	3411.6
V.P.(K2)		1010.4	1528.9	674.5	1528.9
GAMMA-K1 IN K2		1.822	1.822	1.822	1.822
GAMMA-K2 IN K1		1.822	1.822	1.822	1.822
ALPHA		2.934	4.065	1.443	3.894
AVG COLUMN ALPHA		3.500		2.669	
MOL FRACT. K1 (MAKE OR TAILS)		0.281	0.00017	0.881	0.03599
MOL FRACT. K1 (FEED)		0.033		0.281	
MOL FRACT. K2 (MAKE OR TAILS)		0.719	1.000	0.119	0.964
ADJ. GAMMA-K1 IN K2		1.364	1.822	1.008	1.746
ADJ. GAMMA-K2 IN K1		1.049	1.000	1.594	1.001
MINIMUM REFLUX RATIO (ADJUSTE		0.5		0.2	
ACTUAL REFLUX RATIO		0.7		0.3	
MINIMUM THEOR. PLATES (INFINI		6		5	
THEORETICAL PLATES		14		12	
PLATE EFFICIENCY -%		50%		80%	
ACTUAL PLATES		28		15	
PRESSURE mm Hg (REVISED)		1,417		1,537	
TEMPERATURE C (REVISED)		109		99	
AVERAGE MOLECULAR WEIGHT		25.91	18.11	42.76	19.03
GAS DENSITY - LB/CF		0.0962	0.0705	0.1770	0.0774
CROSS SECTIONAL AREA - SQ FT		137.7		37.9	
COLUMN HEIGHT - FT		56.6		37.7	
COLUMN DIAMETER		13.2		7.0	
K1 (MPPY)		436,351		396,683	
Hv (HEAT VAPORIZ.-Btu/Lb)		668.5	966.4	397.1	917.7
Cp (HEAT CAPACITY - Btu/Lb/F)		0.840	0.997	0.696	0.972
HEAT LOAD - MM Btu/Hr		135.665	226.008	30.122	31.349
CONDENSER COOLING WATER - GPM		10053		2232	
CALANDRIA STEAM - MPPH (150 PSIG)			263.72		36.58
COLUMN COST - $1000 3Q86 MPC - BARE EQUIPMENT					
- ALL CARBON STEEL		$232.3		$87.8	
- C.S w/304 S.S. TRAYS		$255.5		$96.6	
- ALL 304 STAINLESS STEEL		$367.8		$140.8	
- ALL 304L STAINLESS STEEL		$404.6		$154.9	
- ALL 316 STAINLESS STEEL		$496.6		$190.1	
CONDENSER OR CALANDRIA SURFAC		11,939	12,556	3,048	1,742
COND. OR CALAND. COST - $1000 3Q86 MPC - BARE EQUIPMENT					
-CARBON STEEL		$374.1	$394.8	$99.8	$62.7
-304 STAINLESS STEEL		$523.8	$552.7	$139.8	$87.8
-316 STAINLESS STEEL		$561.2	$592.2	$149.7	$94.0
-MONEL		$729.5	$769.9	$194.7	$122.3
SUBTOTAL			4,534,356		442,447
SUBTOTAL			4,518,609		415,473
SUBTOTAL			4,517,791		415,473
MINIMUM REFLUX RATIO		0.5		0.2	
Cp SUBTOTAL #1		296,906	1,355	269,932	26,974

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	20 CRUDE FILTRATE	22 BEER #1 MAKE	23 BEER #1 TAILS	24 BEER #2 MAKE	25 BEER #2 TAILS
Cn SUBTOTAL #2		0	14,391	0	0
Cn SUBTOTAL #3		436,351	4,518,609	20,878	415,473
Cn CHECK		0.750	0.997	0.525	0.956
Hv SUBTOTAL #1		160,298	732	145,732	14,566
Hv SUBTOTAL #2		0	8,432	0	0
Hv SUBTOTAL #3		423,391	4,384,306	20,258	403,133
Hv CHECK		592.5	965.6	252.7	904.5
MIN. PLATES(NORMAL)					
COL.COST-C/S NORMAL					
COL.COST-S/S NORMAL					
MIN.REFLUX(NORMAL)					
C.S. AREA(NORMAL)					
HEAT LOAD(NORMAL)					
CON/CAL COST(NORMAL)					
REFLUX FACTOR		0.275		0.878	

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	20 CRUDE FILTRATE	26 LBS #1 MAKE	27 LBS #1 TAILS	28 LBS #2 MAKE	29 LBS #2 TAILS	30 LBS #3 MAKE
K1 (COMPONENT #)		6,5,4,3	6,5,4,3	3	3	2
K2 (COMPONENT #)		7	7	4,5,6	4,5,6	3
V.P.(K1)		3954.0	4972.0	ERR	12121.9	ERR
V.P.(K2)		2550.5	3411.6	ERR	14554.7	ERR
GAMMA-K1 IN K2		1.105	1.105	1.000	1.000	1.000
GAMMA-K2 IN K1		1.000	1.000	1.105	1.105	1.000
ALPHA		1.685	1.611	ERR	ERR	ERR
AVG COLUMN ALPHA		1.648		ERR		ERR
MOL FRACT. K1 (MAKE OR TAILS)		0.086	.000	ERR	ERR	ERR
MOL FRACT. K1 (FEED)		0.001		0.000		ERR
MOL FRACT. K2 (MAKE OR TAILS)		0.914	1.000	ERR	ERR	ERR
ADJ. GAMMA-K1 IN K2		1.087	1.105	ERR	ERR	ERR
ADJ. GAMMA-K2 IN K1		1.000	1.000	ERR	ERR	ERR
MINIMUM REFLUX RATIO (ADJUSTE		20.1		ERR		ERR
ACTUAL REFLUX RATIO		25.1		ERR		ERR
MINIMUM THEOR. PLATES (INFINI		15)		0		0
THEORETICAL PLATES		34		0		0
PLATE EFFICIENCY -%		80%		80%		80%
ACTUAL PLATES		42		0		0
PRESSURE mm Hg (REVISED)		3,021		0		0
TEMPERATURE C (REVISED)		111		(273)		(273)
AVERAGE MOLECULAR WEIGHT		49.70	42.73	ERR	ERR	ERR
GAS DENSITY - LB/CF		0.3911	0.3470	ERR	ERR	ERR
CROSS SECTIONAL AREA - SQ FT		2.9		0.0		0.0
COLUMN HEIGHT - FT		78.3		0.0		15.0
COLUMN DIAMETER		1.9		0.0		0.0
K1 (MPPY)		359		0		0
Hv (HEAT VAPORIZ.-Btu/Lb)		338.0	397.5	ERR	ERR	ERR
Cn (HEAT CAPACITY - Btu/Lb/F)		0.648	0.696	ERR	ERR	ERR
HEAT LOAD - MM Btu/Hr		3.133	4.679	0.000	0.000	0.000
CONDENSER COOLING WATER - GPM		232)		0		0
CALANDRIA STEAM - MPPH (150 PSIG)			5.46		0.00	
COLUMN COST - $1000 3Q86 MPC - BARE EQUIPMENT						
- ALL CARBON STEEL		$54.3		$0.0		$0.0
- C.S w/304 S.S. TRAYS		$59.7		$0.0		$0.0
- ALL 304 STAINLESS STEEL		$88.1		$0.0		$0.0
- ALL 304L STAINLESS STEEL		$96.9		$0.0		$0.0
- ALL 316 STAINLESS STEEL		$119.0		$0.0		$0.0
CONDENSER OR CALANDRIA SURFAC		268	260	0	0	0
COND. OR CALAND. COST - $1000 3Q86 MPC - BARE EQUIPMENT						
-CARBON STEEL		$18.3	$18.0	$0.0	$0.0	$0.0
-304 STAINLESS STEEL		$25.6	$25.2	$0.0	$0.0	$0.0
-316 STAINLESS STEEL		$27.4	$27.0	$0.0	$0.0	$0.0
-MONEL		$35.7	$35.1	$0.0	$0.0	$0.0
SUBTOTAL			289,273		0	
SUBTOTAL			20,878		0	
SUBTOTAL			20,878		0	
MINIMUM REFLUX RATIO		20.1		ERR		ERR
Cn SUBTOTAL #1		1,517	268,414	0	0	0

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	20 CRUDE FILTRATE	26 LBS #1 MAKE	27 LBS #1 TAILS	28 LBS #2 MAKE	29 LBS #2 TAILS	30 LBS #3 MAKE
Cn SUBTOTAL #2		0	0	0	0	0
Cn SUBTOTAL #3		0	20,878	0	0	0
Cn CHECK		0.500	0.525	ERR	ERR	ERR
Hv SUBTOTAL #1		792	144,941	0	0	0
Hv SUBTOTAL #2		0	0	0	0	0
Hv SUBTOTAL #3		0	20,258	0	0	0
Hv CHECK		215.0	252.9	ERR	ERR	ERR
MIN. PLATES(NORMAL)						
COL.COST-C/S NORMAL		54				
COL.COST-S/S NORMAL		88				
MIN.REFLUX(NORMAL)						
C.S. AREA(NORMAL)		3				
HEAT LOAD(NORMAL)			5			
CON/CAL COST(NORMAL)		18	18			
REFLUX FACTOR		0.080		ERR		ERR

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	20 CRUDE FILTRATE	31 LBS #3 TAILS	32 HBS #1 MAKE	33 HBS #1 TAILS	34 HBS #2 MAKE	35 HBS #2 TAILS
K1 (COMPONENT #)		2	WATER	WATER	14	14
K2 (COMPONENT #)		3	14	14	15,16,17 &18	15,16,17 &18
V.P.(K1)		1.0	ERR	3853.9	ERR	18951.1
V.P.(K2)		12121.9	ERR	18951.1	ERR	1.0
GAMMA-K1 IN K2		1.000	1.822	1.822	1.000	1.000
GAMMA-K2 IN K1		1.000	1.822	1.822	1.000	1.000
ALPHA		ERR	ERR	ERR	ERR	*********
AVG COLUMN ALPHA			ERR		ERR	
MOL FRACT. K1 (MAKE OR TAILS)		ERR	ERR	ERR	ERR	0.000
MOL FRACT. K1 (FEED)			1.000		0.000	
MOL FRACT. K2 (MAKE OR TAILS)		ERR	ERR	ERR	ERR	1.000
ADJ. GAMMA-K1 IN K2		ERR	ERR	ERR	ERR	1.000
ADJ. GAMMA-K2 IN K1		ERR	ERR	ERR	ERR	1.000
MINIMUM REFLUX RATIO (ADJUSTED)			ERR		ERR	
ACTUAL REFLUX RATIO			ERR		ERR	
MINIMUM THEOR. PLATES (INFINITE REFLUX			0		0	
THEORETICAL PLATES			0		0	
PLATE EFFICIENCY -%			80%		80%	
ACTUAL PLATES			0		0	
PRESSURE mm Hg (REVISED)			5,983		5,983	
TEMPERATURE C (REVISED)			(273)		(273)	
AVERAGE MOLECULAR WEIGHT		ERR	ERR	653.48	ERR	118.09
GAS DENSITY - LB/CF		ERR	ERR	9.2477	ERR	1.6711
CROSS SECTIONAL AREA - SQ FT			0.0		0.0	
COLUMN HEIGHT - FT			0.0		0.0	
COLUMN DIAMETER			0.0		0.0	
K1 (MPPY)			0		0	
Hv (HEAT VAPORIZ.-Btu/Lb)		ERR	ERR	396.0	ERR	396.0
Cn (HEAT CAPACITY - Btu/Lb/F)		ERR	ERR	0.580	ERR	0.580
HEAT LOAD - MM Btu/Hr		0.000	0.000	0.000	0.000	0.000
CONDENSER COOLING WATER - GPM (15 C dT			0		0	
CALANDRIA STEAM - MPPH (150 P		0.00		0.00		0.00
COLUMN COST - $1000 3Q86 MPC - BARE EQUIPMENT						
- ALL CARBON STEEL			$0.0		$0.0	
- C.S w/304 S.S. TRAYS			$0.0		$0.0	
- ALL 304 STAINLESS STEEL			$0.0		$0.0	
- ALL 304L STAINLESS STEEL			$0.0		$0.0	
- ALL 316 STAINLESS STEEL			$0.0		$0.0	
CONDENSER OR CALANDRIA SURFAC		0	0	0	0	0
COND. OR CALAND. COST - $1000 3Q86 MPC - BARE EQUIPMENT						
-CARBON STEEL		$0.0	$0.0	$0.0	$0.0	$0.0
-304 STAINLESS STEEL		$0.0	$0.0	$0.0	$0.0	$0.0
-316 STAINLESS STEEL		$0.0	$0.0	$0.0	$0.0	$0.0
-MONEL		$0.0	$0.0	$0.0	$0.0	$0.0
SUBTOTAL		0		338		338
SUBTOTAL		0		338		338
SUBTOTAL		0		0		0
MINIMUM REFLUX RATIO			ERR		ERR	
Cn SUBTOTAL #1		0	0	0	0	0

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	20 CRUDE FILTRATE	31 LBS #3 TAILS	32 HBS #1 MAKE	33 HBS #1 TAILS	34 HBS #2 MAKE	35 HBS #2 TAILS
Cn SUBTOTAL #2		0	0	0	0	0
Cn SUBTOTAL #3		0	0	338	0	338
Cn CHECK		ERR	ERR	0.500	ERR	0.500
Hv SUBTOTAL #1		0	0	0	0	0
Hv SUBTOTAL #2		0	0	0	0	0
Hv SUBTOTAL #3		0	0	231	0	231
Hv CHECK		ERR	ERR	215.0	ERR	215.0
MIN. PLATES(NORMAL)					ERR	
COL.COST-C/S NORMAL					0	
COL.COST-S/S NORMAL					0	
MIN.REFLUX(NORMAL)						
C.S. AREA(NORMAL)						
HEAT LOAD(NORMAL)						
CON/CAL COST(NORMAL)						
REFLUX FACTOR			ERR		ERR	

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	20 CRUDE FILTRATE	36 AZEO MAKE	37 AZEO TAILS	38 AZEO REFLUX	39 DECANTER FEED
K1 (COMPONENT #)					
K2 (COMPONENT #)					
V.P.(K1)					
V.P.(K2)					
GAMMA-K1 IN K2					
GAMMA-K2 IN K1					
ALPHA					
AVG COLUMN ALPHA					
MOL FRACT. K1 (MAKE OR TAILS)					
MOL FRACT. K1 (FEED)					
MOL FRACT. K2 (MAKE OR TAILS)					
ADJ. GAMMA-K1 IN K2					
ADJ. GAMMA-K2 IN K1					
MINIMUM REFLUX RATIO (ADJUSTED)					
ACTUAL REFLUX RATIO					
MINIMUM THEOR. PLATES (INFINITE REFLUX)					
THEORETICAL PLATES					
PLATE EFFICIENCY -%		80%			
ACTUAL PLATES		50			
PRESSURE mm Hg (REVISED)					
TEMPERATURE C (REVISED)					
AVERAGE MOLECULAR WEIGHT					
GAS DENSITY - LB/CF					
CROSS SECTIONAL AREA - SQ FT		93.7			
COLUMN HEIGHT - FT		90.0			
COLUMN DIAMETER		10.9			
K1 (MPPY)					
Hv (HEAT VAPORIZ.-Btu/Lb)					
Cp (HEAT CAPACITY - Btu/Lb/F)					
HEAT LOAD - MM Btu/Hr		61.616	54.868		
CONDENSER COOLING WATER - GPM		6849 (10 C delta T)			
CALANDRIA STEAM - MPPH (150 PSIG)			64.02		
COLUMN COST - $1000 3Q86 MPC - BARE EQUIPMENT					
- ALL CARBON STEEL		$301.5			
- C.S w/304 S.S. TRAYS		$331.6			
- ALL 304 STAINLESS STEEL		$476.6			
- ALL 304L STAINLESS STEEL		$524.2			
- ALL 316 STAINLESS STEEL		$643.4			
CONDENSER OR CALANDRIA SURFAC		9,520	3,048		
COND. OR CALAND. COST - $1000 3Q86 MPC - BARE EQUIPMENT					
-CARBON STEEL		$295.0	$99.8		
-304 STAINLESS STEEL		$413.1	$139.8		
-316 STAINLESS STEEL		$442.6	$149.7		
-MONEL		$575.3	$194.7		
SUBTOTAL					
SUBTOTAL					
SUBTOTAL					
MINIMUM REFLUX RATIO					
Cp SUBTOTAL #1					

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	20 CRUDE FILTRATE	36 AZEO MAKE	37 AZEO TAILS	38 AZEO REFLUX	39 DECANTER FEED
Cn SUBTOTAL #2					
Cn SUBTOTAL #3					
Cn CHECK					
Hv SUBTOTAL #1					
Hv SUBTOTAL #2					
Hv SUBTOTAL #3					
Hv CHECK					
MIN. PLATES(NORMAL)					
COL.COST-C/S NORMAL					
COL.COST-S/S NORMAL					
MIN.REFLUX(NORMAL)					
C.S. AREA(NORMAL)					
HEAT LOAD(NORMAL)					
CON/CAL COST(NORMAL)					
REFLUX FACTOR					

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	20 CRUDE FILTRATE	40 DECANTER UP LAYER	41 DECANTER LO LAYER	42 BENZENE MAKE	43 BENZENE TAILS
K1 (COMPONENT #)					
K2 (COMPONENT #)					
V.P.(K1)					
V.P.(K2)					
GAMMA-K1 IN K2					
GAMMA-K2 IN K1					
ALPHA					
AVG COLUMN ALPHA					
MOL FRACT. K1 (MAKE OR TAILS)					
MOL FRACT. K1 (FEED)					
MOL FRACT. K2 (MAKE OR TAILS)					
ADJ. GAMMA-K1 IN K2					
ADJ. GAMMA-K2 IN K1					
MINIMUM REFLUX RATIO (ADJUSTED)					
ACTUAL REFLUX RATIO					
MINIMUM THEOR. PLATES (INFINITE REFLUX)					
THEORETICAL PLATES					
PLATE EFFICIENCY -%					
ACTUAL PLATES				30	
PRESSURE mm Hg (REVISED)					
TEMPERATURE C (REVISED)					
AVERAGE MOLECULAR WEIGHT					
GAS DENSITY - LB/CF					
CROSS SECTIONAL AREA - SQ FT				7.0	
COLUMN HEIGHT - FT				60.0	
COLUMN DIAMETER				3.0	
K1 (MPPY)					
Hv (HEAT VAPORIZ.-Btu/Lb)					
Cn (HEAT CAPACITY - Btu/Lb/F)					
HEAT LOAD - MM Btu/Hr					6.925
CONDENSER COOLING WATER - GPMDECANTER VOLUME - GAL.					
CALANDRIA STEAM - MPPH (150 P		9,865			8.08
COLUMN COST - $1000 3Q86 MPC - BARE EQUIPMENT					
- ALL CARBON STEEL				$63.0	
- C.S w/304 S.S. TRAYS				$69.3	
- ALL 304 STAINLESS STEEL				$81.0	
- ALL 304L STAINLESS STEEL				$89.1	
- ALL 316 STAINLESS STEEL				$109.4	
CONDENSER OR CALANDRIA SURFACE - SQ FT					385
COND. OR CALAND. COST - $1000 3Q86 MPC - BARE EQUIPMENT					
-CARBON STEEL					$22.3
-304 STAINLESS STEEL					$31.2
-316 STAINLESS STEEL					$33.5
-MONEL					$43.5
SUBTOTAL					
SUBTOTAL					
SUBTOTAL					
MINIMUM REFLUX RATIO					
Cn SUBTOTAL #1					

APPENDIX C. 1980s BASECASE

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY
SUMMARY

	PRODUCTION LEVEL 54 MM GPY
INVESTMENT-$MILLION MPC = 1984	
Direct Permanent Investment	$91.1
Allocated Power, Services & General	$26.8
Working Capital	$22.1
Total Investment	$140.0
COST-$/GAL(1988)	
Raw Materials	$0.95
Utilities	$0.15
Labor-Related	$0.10
Capital-Related	$0.23
Cost of Manufacture	$1.42
SE, D, R&D, Adm, & I.C.	$0.35
Cost of Sales	$1.78
Pretax Earnings Based on: 30% Pretax ROI	$0.78
By-product Credits	$0.00
Selling Price	$2.55
FINANCIAL CRITERIA	
Net ROI 3rd Year (assumed)	16%
Investors Rate of Return (20 Operating Years)	23%
Year to Break Even - Annual Cash	1989
- Cumulative Cash	1991
- Cum. Disc. Cash (NPV)	1994
Net Present Value $MM (20 years @ 15%)	$56.7

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

INVESTMENT

CONDITIONS

Sited in Iowa on the Mississippi River adjacent to a corn wet mill and a utility power house for over-the-fence supply of syrup and power.

	UNITS	THIS CASE
CAPACITY @ 8000 HRS	MM GPY	60.1
MID-POINT OF CONSTRUCTION	YEAR	1984
CONSTRUCTION COST INDEX	1980=100	128
INVESTMENT CONTINGENCY	% INSTALLED *	30%
FERMENTER UNIT INVESTMENT	$/GR.GAL.-GROWTH	$0.00
	$/GR.GAL.-PROD'N	$10.94

*40% Recommended for new processes

DIRECT PERMANENT INVESTMENT

	SCALE FACTOR		THIS CASE $MM	THIS CASE $/ANN.GAL.
FERMENTATION SECTION				
Receiving, Prep & Sterilization	0.60		$11.90	$0.198
Air Compression & Aeration	0.60		0.00	0.000
Fermentation	0.89-1.00		57.29	0.954
Product/Cell Separation	0.75		3.94	0.066
Fermentation Sub-total			$73.14	$1.217
DISTILLATION SECTION	STILLS	HX'S		
Beer Still #1	$1.15	$4.03	$5.17	$0.086
Beer Still #2	0.41	0.76	1.17	0.019
Low-Boilers Still #1	0.25	0.17	0.42	0.007
Low-Boilers Still #2	0.00	0.00	0.00	0.000
Low-Boilers Still #3	0.00	0.00	0.00	0.000
High-Boilers Still #1	0.00	0.00	0.00	0.000
High-Boilers Still #2	0.00	0.00	0.00	0.000
Azeotrope Still	1.41	1.85	3.25	0.054
Benzene Dehydrator	0.29	0.10	0.40	0.007
Decanter			0.03	0.001
Distillation Subtotal			$10.45	$0.174
STORAGE SECTION				
Storage - Product			$7.53	$0.125
Storage - Byproduct #1			$0.00	0.000
Storage - Byproduct #2			$0.00	0.000
			$7.53	$0.125
TOTAL DIRECT PLANT			$91.11	$1.517

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

INVESTMENT

ALLOCATED PERMANENT INVESTMENT

	UNITS	API/UNIT BASECASE	API/UNIT THIS CASE	UNITS	$MM	$/ANN.GAL
ELECTRICITY	KW	$183	$183	1,164	$0.21	$0.004
STEAM	PPH	$45	$45	439,923	19.80	0.330
COOLING WATER	GPM	$52	$52	26,227	1.36	0.023
PROCESS WATER	GPM	$313	$313	1015	0.32	0.005
WASTE DISPOSAL	MGPY	$3	$3	635,570	1.72	0.029
GEN'L & SERVICES	$MM	10%	10%	$33.9	3.39	0.056
TOTAL ALLOCATED PLANT					$26.80	$0.446
TOTAL PERMANENT INVESTMENT					$117.91	$1.963

WORKING CAPITAL

	BASIS	DAYS BASECASE	DAYS THIS CASE	$MM	$/ANN.GAL
RAW MAT'L INVENTORY	$RAW MATL	2	2	$0.31	$0.005
SEMI-FINISHED PRODUCT	$(R+M)/2	5	5	0.88	0.015
FINISHED PRODUCT	$COM	30	30	6.32	0.105
CASH	$(COS-D)	6	6	1.43	0.024
ACCOUNTS RCD.-TRADE	$SP	30	30	11.35	0.189
ACCOUNTS RCD.-MISC.	%COM	0.9%	0.9%	0.69	0.012
DEFERRED CHARGES	%COM	1.5%	1.5%	1.15	0.019
TOTAL WORKING CAPITAL				$22.12	$0.368

Note: R = raw materials; M or COM = cost of manufacture;
COS = cost of sales; SP = selling price; D = depreciation.

	$MM	$/ANN.GAL
TOTAL INVESTMENT FOR RETURN	$140.04	$2.331

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

PRICES & COST FACTORS	BASECASE	INFLATION FACTOR	THIS CASE
Operating Year	1988	1988	1988
Raw Materials			
-Biosugar Syrup	$0.065 /lb. d.s.	1.00	$0.065 /lb. d.s.
-Anhyd. Ammonia	$0.046 /lb.	1.00	$0.046 /lb.
-Phosphoric Acid	$0.155 /lb.	1.00	$0.155 /lb.
-Potassium Chloride	$0.053 /lb.	1.00	$0.053 /lb.
-Minor Nutrients	$0.451 /lb.	1.00	$0.451 /lb.
Utilities			
-Electricity	$0.040 /KWH	1.00	$0.040 /KWH
-Steam	$2.20 /M lb.	1.00	$2.20 /M lb.
-Cooling Water	$0.04 /M gal.	1.00	$0.04 /M gal.
-Process Water	$0.50 /M gal.	1.00	$0.50 /M gal.
-Biodegradation	$0.04 /lb. d.s.	1.00	$0.04 /lb. d.s.
-Landfill	$0.05 /lb. d.s.	1.00	$0.05 /lb. d.s.
Labor-Related			
-Dir. Op. Wages & Ben.	$26.40 /man-hr.	1.00	$26.40 /man-hr.
-Dir. Salaries & Benefi	18 % DOW&B	--	18 % DOW&B
-Op. Supplies & Service	6 % DOW&B	--	6 % DOW&B
-GPOH on Operations	23 % DOWS&B	--	23 % DOWS&B
-Control Lab	$19.22 /man-hr.	1.00	$19.22 /man-hr.
-Tech. Assist. to Mfg.	$22.06 /man-hr.	1.00	$22.06 /man-hr.
Capital-Related			
-Maint. Wages & Ben.	1.7 % DPI	--	1.7 % DPI
-Maint. Salaries & Ben.	25 % MW&B	--	25 % MW&B
-Maint. Mat'l & Service	40 % MW&B	--	40 % MW&B
-Maint. Overhead	4 % MW&B	--	4 % MW&B
-GPOH on Maintenance	23 % MWS&B	--	23 % MWS&B
-Taxes & Insurance	0.3 % DPI	--	0.3 % DPI
-Depreciation - DPI	8 % DPI	--	8 % DPI
-Depreciation - APS&G	6 % APS&G	--	6 % APS&G
Cost of Manufacture			
-Selling Expense	3 % Sales	--	3 % Sales
-Distribution	$0.01 /lb.	--	$0.01 /lb.
-Research & Development	4.5 % Sales	--	4.5 % Sales
-Administrative Expense	2 % Sales	--	2 % Sales
-Incentive Compensation	6 % PTE	--	6 % PTE
Cost of Sales			
-Pretax Earnings	30 % TIFR	--	30 % TIFR
-Credit: Byproduct #1	$0.00 /lb.	1.00	$0.00 /lb.
-Credit: Byproduct #2	$0.00 /lb.	1.00	$0.00 /lb.
-Credit: Byproduct #3	$0.00 /lb.	1.00	$0.00 /lb.
-Product Selling Price	$0.00 /lb.	1.00	$0.00 /lb.

SALARIES & WAGES
CONTINUOUS FERMENTER CASE

		250 MM PPY DAY SHIFT	ROTATING SHIFTS
DIRECT OPERATORS			
SYRUP RECEIVING & TRANSFER		1	-
CHEMICALS RECEIVING & TRANSFER		3	-
INNOCULUM PREPARATION		1	-
MEDIUM PREPARATION		-	1
STERILIZATION		-	1
FERMENTATION			
-CONTROL ROOM		-	2
-PATROL		-	2
-AIR COMPRESSION & AMMONIA FEED		-	1
DISTILLATION		-	3
BEER FILTER & CELL RECYCLE		-	2
TOTAL DAY & 4.2-SHIFT OPERATORS		5	12
TOTAL OPERATORS		55	
CONTROL LABORATORY			
BIOLOGICAL ANALYSIS		-	1
CHEMICAL ANALYSIS		-	1
OTHER		-	-
TOTAL DAY & 4.2-SHIFT TECHNICIANS		0	8
TOTAL LAB FORCE INCL SUPERVISION @	20%	0.0	10.1
TOTAL LAB FORCE		10.1	
TECHNICAL ASSISTANCE TO MANUFACTURING			
PROCESS ENGINEERS		1	-

WAGES, SALARIES & BENEFITS SCHEDULE- 1988

OPERATING WAGES - $/HOUR	$20.14
TECHNICIANS - ANNUAL $	$30,500
PROCESS ENGINEERS - ANNUAL $	$35,000
PENSION - AS % OF COMPENSATION	8.1%
FICA	5.8%
UNEMPLOYMENT COMPENSATION	0.6%
GROUP LIFE INSURANCE	0.7%
MEDICAL INSURANCE	3.6%
DENTAL INSURANCE	0.8%
SAVINGS PLAN	2.5%
VACATION	7.4%
ILLNESS	1.4%
ABSENCE WITH PERMISSION	0.2%
TOTAL BENEFITS	31.1%

SALARIES & WAGES
CONTINUOUS FERMENTER CASE

DIRECT OPERATORS		MIN. FORCE DAY SHIFT	ROTATING SHIFTS
SYRUP RECEIVING & TRANSFER		1	-
CHEMICALS RECEIVING & TRANSFER			-
INNOCULUM PREPARATION		1	-
MEDIUM PREPARATION		1	-
STERILIZATION			-
FERMENTATION			
-CONTROL ROOM		-	1
-PATROL		-	1
-AIR COMPRESSION & AMMONIA FEED		-	1
DISTILLATION		-	1
BEER FILTER & CELL RECYCLE		-	1
TOTAL DAY & 4.2-SHIFT OPERATORS		3	5
TOTAL OPERATORS		24	

CONTROL LABORATORY			
BIOLOGICAL ANALYSIS		-	1
CHEMICAL ANALYSIS		-	1
OTHER		-	-
TOTAL DAY & 4.2-SHIFT TECHNICIANS		0	8
TOTAL LAB FORCE INCL SUPERVISION @	20%	0.0	10.1
TOTAL LAB FORCE		10.1	

TECHNICAL ASSISTANCE TO MANUFACTURING		
PROCESS ENGINEERS	1	-

WAGES, SALARIES & BENEFITS SCHEDULE- 1988

OPERATING WAGES - $/HOUR
TECHNICIANS - ANNUAL $
PROCESS ENGINEERS - ANNUAL $

PENSION - AS % OF COMPENSATION
FICA
UNEMPLOYMENT COMPENSATION
GROUP LIFE INSURANCE
MEDICAL INSURANCE
DENTAL INSURANCE
SAVINGS PLAN
VACATION
ILLNESS
ABSENCE WITH PERMISSION

TOTAL BENEFITS

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

1988 COST SHEET	RATE /UNIT	MILLION UNITS	$MILLION	$/gal
Raw Materials				
-Biosugar Syrup	$0.065 /lb. d.s.	779.45	50.66	0.937
-Anhyd. Ammonia	$0.046 /lb.	1.32	0.06	0.001
-Phosphoric Acid	$0.155 /lb.	1.10	0.17	0.003
-Potassium Chloride	$0.053 /lb.	0.84	0.04	0.001
-Minor Nutrients	$0.451 /lb.	0.38	0.17	0.003
Total Raw Materials			$51.11	$0.945
Utilities				
-Electricity	$0.040 /KWH	8.30	0.34	0.006
-Steam	$2.20 /M lb.	3.1358	6.90	0.128
-Cooling Water	$0.04 /M gal.	11.22	0.45	0.008
-Process Water	$0.50 /M gal.	0.43	0.22	0.004
-Biodegradation	$0.04 /lb. d.s.	4.75	0.19	0.004
-Landfill	$0.05 /lb. d.s.	0.00	0.00	0.000
Total Utilities			$8.09	$0.150
Labor-Related				
-Dir. Op. Wages & Ben.	$26.40 /man-hr.	0.125	3.29	0.061
-Dir. Salaries & Ben.	18 % DOW&B		0.59	0.011
-Op. Supplies & Service	6 % DOW&B		0.20	0.004
-GPOH on Operations	23 % DOWS&B		0.89	0.017
-Control Lab	$19.22 /man-hr.	0.020	0.39	0.007
-Tech. Assist. to Mfg.	$22.06 /man-hr.	0.002	0.04	0.001
Total Labor			$5.40	$0.100
Capital-Related				
-Maint. Wages & Ben.	1.7 % DPI	$91.1	1.55	0.029
-Maint. Salaries & Ben.	25 % MW&B		0.39	0.007
-Maint. Mat'l & Service	40 % MW&B		0.62	0.011
-Maint. Overhead	4 % MW&B		0.06	0.001
-GPOH on Maintenance	23 % MWS&B		0.45	0.008
-Taxes & Insurance	0.3 % DPI	$91.1	0.27	0.005
-Depreciation - DPI	8 % DPI	$91.1	7.29	0.135
-Depreciation - APS&G	6 % APS&G	$26.8	1.61	0.030
Total Capital			$12.23	0.226
			-----	-----
Cost of Manufacture			$76.84	$1.421
-Selling Expense	3 % Sales	$138.0	4.14	0.077
-Distribution	$0.01 /lb.	355.8	3.56	0.066
-Research & Development	5 % Sales	$138.0	6.21	0.115
-Administrative Expense	2 % Sales	$138.0	2.76	0.051
-Incentive Compensation	6 % PTE	$42.0	2.52	0.047
			-----	-----
Cost of Sales			$96.03	$1.776
-Pretax Earnings	30.0 % TIFR	$140.0	42.01	0.777
-Credit: Byproduct #1	$0.00 /lb.	0.0	0.00	0.000
-Credit: Byproduct #2	$0.00 /lb.	0.0	0.00	0.000
-Credit: Byproduct #3	$0.00 /lb.	0.0	0.00	0.000
			-----	-----
Total Sales			$138.04	$2.553

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

CASH FLOW (MILLION DOLLARS/YEAR)

Scenario:
1. Investment split evenly over three construction years.
2. Plant operates at 50% of full scale the first year.
3. " " 75% " " the second year.
4. " " 100% " " the third year.
5. " " 100% " " thereafter.
6. Five year depreciation rate; half-year convention; (20, 32, 19.2, 11.5, 11.5, 5.8 %); taxes: 34% fed, 3% state.

YEAR	INVESTMENT PI	WC	DEP.	COST EX D	SALES	NET EARN	ANN CASH
1983	$30.37						($30.37)
1984	$30.37						($30.37)
1985	$30.37						($30.37)
1986		$22.12	$18.22	$49.23	$69.02	$0.99	($2.91)
1987			$29.16	$70.82	$103.53	$2.24	$31.39
1988			$17.49	$87.13	$138.04	$21.05	$38.55
1989			$10.48	$87.13	$138.04	$25.47	$35.95
1990			$10.48	$87.13	$138.04	$25.47	$35.95
1991			$5.28	$87.13	$138.04	$28.74	$34.03
1992				$87.13	$138.04	$32.07	$32.07
1993				$87.13	$138.04	$32.07	$32.07
1994				$87.13	$138.04	$32.07	$32.07
1995				$87.13	$138.04	$32.07	$32.07
1996				$87.13	$138.04	$32.07	$32.07
1997				$87.13	$138.04	$32.07	$32.07
1998				$87.13	$138.04	$32.07	$32.07
1999				$87.13	$138.04	$32.07	$32.07
2000				$87.13	$138.04	$32.07	$32.07
2001				$87.13	$138.04	$32.07	$32.07
2002				$87.13	$138.04	$32.07	$32.07
2003				$87.13	$138.04	$32.07	$32.07
2004				$87.13	$138.04	$32.07	$32.07
2005		($22.12)		$87.13	$138.04	$32.07	$54.20

NET RETURN ON INVESTMENT-3RD OPERATING YEAR = 15.6%

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

CASH FLOW (MILLION DOLLARS/YEAR)

Scenario:
1. Investment split evenly over three construction years.
2. Plant operates at 50% of full scale the first year.
3. " " 75% " " the second year.
4. " " 100% " " the third year.
5. " " 100% " " thereafter.
6. Five year depreciation rate; half-year convention;
(20, 32, 19.2, 11.5, 11.5, 5.8 %); taxes: 34% fed, 3% state.

YEAR	CUM CASH	NPV @ 15%	%IRR
1983	($30.37)	($30.37)	--
1984	($60.74)	($56.78)	--
1985	($91.11)	($79.75)	--
1986	($94.03)	($81.66)	-110.6%
1987	($62.63)	($63.71)	-32.5%
1988	($24.09)	($44.55)	-8.2%
1989	$11.86	($29.01)	3.0%
1990	$47.81	($15.49)	9.7%
1991	$81.84	($4.37)	13.7%
1992	$113.91	$4.75	16.3%
1993	$145.99	$12.68	18.1%
1994	$178.06	$19.57	19.4%
1995	$210.13	$25.57	20.4%
1996	$242.20	$30.78	21.1%
1997	$274.28	$35.31	21.6%
1998	$306.35	$39.25	22.1%
1999	$338.42	$42.68	22.4%
2000	$370.49	$45.66	22.6%
2001	$402.57	$48.25	22.8%
2002	$434.64	$50.51	23.0%
2003	$466.71	$52.47	23.1%
2004	$498.78	$54.17	23.2%
2005	$552.98	$56.67	23.3%

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

BASIC DATA

SCALE OF OPERATION

355.8	MM PPY	ANNUAL PRODUCTION LEVEL
54.1	MM GPY	" " "
395.4	MM PPY	ANNUAL CAPACITY
60.1	MM GPY	" "
90	%	OPERATING UTILITY
361.4	MM PPY	PRODUCT FORMED IN BEER
401.6	MM PPY	PRODUCT FORMED IN BEER AT CAPACITY
96.5	%	MOLAR YIELD-GLUC. TO PROD. IN BEER (E
2.16	lb/lb	GLUCOSE DEMAND/PROD (EXCL. SPILL)
46.07	MOL WT	PRODUCT MOLECULAR WEIGHT

PRODUCT STOICHIOMETRY

MOL. WT.	MOLES/MOL PRODUCT		COMPONENT
180.16	0.53181	/MOL PROD.	-GLUCOSE CONSUMED
32.00	0.00000	/MOL PROD.	-OXYGEN CONSUMED
17.02	0.00000	/MOL PROD.	-AMMONIA CONSUMED
44.05	0.00150	/MOL PROD.	-ACETALDEHYDE FORMED (#1)
.00		/MOL PROD.	-COMPONENT #2 FORMED
.00		/MOL PROD.	-COMPONENT #3 FORMED
.00		/MOL PROD.	-COMPONENT #4 FORMED
.00		/MOL PROD.	-COMPONENT #5 FORMED
88.10	0.00052	/MOL PROD.	-LIGHT ENDS FORMED (#6)
46.07	1.00000	/MOL PROD.	-ETHANOL FORMED (#7)
.00		/MOL PROD.	-COMPONENT #8 FORMED
.00		/MOL PROD.	-COMPONENT #9 FORMED
.00		/MOL PROD.	-COMPONENT #10 FORMED
18.02	-0.06791	/MOL PROD.	-WATER FORMED
60.05	0.00860	/MOL PROD.	-ACETIC ACID FORMED (#11)
88.15	0.00261	/MOL PROD.	-ISOAMYL ALCOHOL FORMED (#12)
92.09	0.02300	/MOL PROD.	-GLYCERINE FORMED (#13)
.00		/MOL PROD.	-COMPONENT #14 FORMED
90.08	0.00110	/MOL PROD.	-LACTIC ACID FORMED (#15)
118.09	0.00057	/MOL PROD.	-SUCCINIC ACID FORMED (#16)
.00		/MOL PROD.	-COMPONENT #17 FORMED
.00		/MOL PROD.	-COMPONENT #18 FORMED
.00		/MOL PROD.	-COMPONENT #19 FORMED
.00		/MOL PROD.	-COMPONENT #20 FORMED
44.01	1.08091	/MOL PROD.	-CARBON DIOXIDE FORMED
2.02	0.12377	/MOL PROD.	-HYDROGEN FORMED

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

BASIC DATA

NUTRIENTS IN FERMENTER FEED

8	%	-N IN CELLS AS %CHO
80.9	mg/g cells	-H3PO4
61.6	mg/g cells	-KCl
27.9	mg/g cells	-MINOR NUTRIENTS
23.6	mg/g cells	-MgSO4.7H2O
0.01	mg/g cells	-VITAMIN B1
1.25	mg/g cells	-KI
0.89	mg/g cells	-NiCl2
0.72	mg/g cells	-FeCl3.6H2O
0.55	mg/g cells	-CaCl2.2H2O
0.54	mg/g cells	-H3BO3
0.22	mg/g cells	-ZnSO4.7H2O
0.15	mg/g cells	-MnSO4.H2O
7.7	ug/g cells	-CuSO4.5H2O
5.4	ug/g cells	-NaMoO4.2H2O
4.3	ug/g cells	-CoCl2.6H2O

FERMENTATION

TYPE	0 (0 OR 1)	-ANAEROBIC (0) OR AEROBIC (1)
STAGES	0 (0 OR 1)	-CONCUR'NT (0) OR SEQUENT'AL (1)
CULTURE MODE	0 (0 OR 1)	-BATCH (0) OR CONTINUOUS (1)
PROD INHIBITION	0 (0 OR 1)	-WITH (0) OR WITHOUT (1)

CONDITIONS

STAGE: GROWTH	PRODUCTION	
33	33 C	-TEMPERATURE
4.0	4.0	-pH
0	70 g/l **	-PRODUCT CONCENTRATION IN BEER
2.454	2.648 g/l	-CELL DENSITY (CHO ONLY)
0.00	0.023 1/hr	-DILUTION RATE * ERR
		-PRODUCT PRODUCTIVITY
	1.50 g/g*hr	-Max Specific, g/g cells*hr
	56 %	-Inhibition Factor, % Max
	0.84 g/g*hr	-Specific, g/g cells*hr
0.00	1.61 g/l*hr	-Volumetric, g/l*hr *
0.06	0.00 g/l*hr	-CELL PRODUCTIVITY (CHO ONLY)
2	0 mM/l*hr	-OXYGEN TRANSFERRED
5	0 mM/mM	-OXYGEN FED / OXYGEN STOICH. DEMAND
--	0.1 g/l	-GLUCOSE SPILL
5	5 C	-COOLING WATER TEMPERATURE
--	19 kcal/gmol	-HEAT EVOLVED-PRODUCT FORMATION
2	10 Btu/hr*gal	-HEAT REMOVED BY COOLING COILS
		* w/12 hrs batch mode turnaround

FERMENTERS

0	3,783,131 gallons	-ACTIVE VOLUME REQUIRED
15	15 % gross	-HEADSPACE
0	5,236,167 gallons	-GROSS VOLUME (incl. 15% spares)
0	500,000 gallons	-GROSS SIZE
0.0	10.5 units	-NUMBER OF UNITS

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

BASIC DATA

PRODUCT SEPARATION

500 g/l	-CELL CONC. (CHO) EX FILTER
0.053 gal/min*sf	-FILTER THROUGHPUT
27,120 sq ft	-FILTER SIZE

PRODUCT RECOVERY & PURIFICATION

98.5%(wt)%	-YIELD ACROSS REFINING

MATERIALS OF CONSTRUCTION

	CHOICES	SELECTION
FERMENTERS	1,3	1
STILLS	1,2,3,4,5	1
HEAT EXCHANGERS	1,3;5,6	1
STORAGE TANKS	1,3	1

FOR WHICH:

1=CARBON STEEL
2=CARBON STEEL w/304 SS TRAYS
3=304 STAINLESS STEEL
4=304L STAINLESS STEEL
5=316 STAINLESS STEEL
6=MONEL

RETURN ON INVESTMENT

To Calculate Selling Price Required to Provide a Fixed Return,
Enter the Desired Return on Investment: 30 %
OR
To Calculate the ROI Resulting from a Fixed Market Price,
Enter the Market Price for: 1988 /lb.

Enter an Investment Contingency to Represent
the Risk Level of the Basic Data 30 %

APPENDIX D. ADVANCED YEAST CASE

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY
SUMMARY

	PRODUCTION LEVEL 54 MM GPY
INVESTMENT-$MILLION MPC = 1984	
Direct Permanent Investment	$35.3
Allocated Power, Services & General	$22.1
Working Capital	$18.5
Total Investment	$75.9
COST-$/GAL(1988)	
Raw Materials	$0.95
Utilities	$0.13
Labor-Related	$0.10
Capital-Related	$0.10
Cost of Manufacture	$1.27
SE, D, R&D, Adm, & I.C.	$0.28
Cost of Sales	$1.55
Pretax Earnings Based on: 30% Pretax ROI	$0.42
By-product Credits	$0.00
Selling Price	$1.97
FINANCIAL CRITERIA	
Net ROI 3rd Year (assumed)	16%
Investors Rate of Return (20 Operating Years)	25%
Year to Break Even - Annual Cash	1989
- Cumulative Cash	1991
- Cum. Disc. Cash (NPV)	1993
Net Present Value $MM (20 years @ 15%)	$32.8

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

INVESTMENT

CONDITIONS

Sited in Iowa on the Mississippi River adjacent to a corn wet mill and a utility power house for over-the-fence supply of syrup and power.

	UNITS	THIS CASE
CAPACITY @ 8000 HRS	MM GPY	60.0
MID-POINT OF CONSTRUCTION	YEAR	1984
CONSTRUCTION COST INDEX	1980=100	128
INVESTMENT CONTINGENCY	% INSTALLED *	30%
FERMENTER UNIT INVESTMENT	$/GR.GAL.-GROWTH	$0.00
	$/GR.GAL.-PROD'N	$10.94

*40% Recommended for new processes

DIRECT PERMANENT INVESTMENT

	SCALE FACTOR		THIS CASE $MM	$/ANN.GAL.
FERMENTATION SECTION				
Receiving, Prep & Sterilization	0.60		$10.23	$0.171
Air Compression & Aeration	0.60		0.00	0.000
Fermentation	0.89-1.00		4.91	0.082
Product/Cell Separation	0.75		3.26	0.054
Fermentation Sub-total			$18.40	$0.307
DISTILLATION SECTION	STILLS	HX'S		
Beer Still #1	$1.01	$3.13	$4.14	$0.069
Beer Still #2	0.41	0.76	1.17	0.019
Low-Boilers Still #1	0.25	0.17	0.42	0.007
Low-Boilers Still #2	0.00	0.00	0.00	0.000
Low-Boilers Still #3	0.00	0.00	0.00	0.000
High-Boilers Still #1	0.00	0.00	0.00	0.000
High-Boilers Still #2	0.00	0.00	0.00	0.000
Azeotrope Still	1.41	1.84	3.25	0.054
Benzene Dehydrator	0.29	0.10	0.40	0.007
Decanter			0.03	0.001
Distillation Subtotal			$9.41	$0.157
STORAGE SECTION				
Storage - Product			$7.51	$0.125
Storage - Byproduct #1			$0.00	0.000
Storage - Byproduct #2			$0.00	0.000
			$7.51	$0.125
TOTAL DIRECT PLANT			$35.32	$0.589

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

INVESTMENT

ALLOCATED PERMANENT INVESTMENT

	UNITS	API/UNIT BASECASE	API/UNIT THIS CASE	UNITS	$MM	$/ANN.GAL
ELECTRICITY	KW	$183	$183	1,164	$0.21	$0.004
STEAM	PPH	$45	$45	363,573	16.36	0.273
COOLING WATER	GPM	$52	$52	24,005	1.25	0.021
PROCESS WATER	GPM	$313	$313	638	0.20	0.003
WASTE DISPOSAL	MGPY	$3	$3	456,170	1.24	0.021
GEN'L & SERVICES	$MM	10%	10%	$28.7	2.87	0.048
TOTAL ALLOCATED PLANT					$22.12	$0.369
TOTAL PERMANENT INVESTMENT					$57.44	$0.958

WORKING CAPITAL

	BASIS	DAYS BASECASE	DAYS THIS CASE	$MM	$/ANN.GAL
RAW MAT'L INVENTORY	$RAW MATL	2	2	$0.31	$0.005
SEMI-FINISHED PRODUCT	$(R+M)/2	5	5	0.82	0.014
FINISHED PRODUCT	$COM	30	30	5.65	0.094
CASH	$(COS-D)	6	6	1.31	0.022
ACCOUNTS RCD.-TRADE	$SP	30	30	8.76	0.146
ACCOUNTS RCD.-MISC.	%COM	0.9%	0.9%	0.62	0.010
DEFERRED CHARGES	%COM	1.5%	1.5%	1.03	0.017
TOTAL WORKING CAPITAL				$18.50	$0.308

Note: R = raw materials; M or COM = cost of manufacture;
COS = cost of sales; SP = selling price; D = depreciation.

	$MM	$/ANN.GAL
TOTAL INVESTMENT FOR RETURN	$75.94	$1.266

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

PRICES & COST FACTORS	BASECASE	INFLATION FACTOR	THIS CASE
Operating Year	1988	1988	1988
Raw Materials			
-Biosugar Syrup	$0.065 /lb. d.s.	1.00	$0.065 /lb. d.s.
-Anhyd. Ammonia	$0.046 /lb.	1.00	$0.046 /lb.
-Phosphoric Acid	$0.155 /lb.	1.00	$0.155 /lb.
-Potassium Chloride	$0.053 /lb.	1.00	$0.053 /lb.
-Minor Nutrients	$0.451 /lb.	1.00	$0.451 /lb.
Utilities			
-Electricity	$0.040 /KWH	1.00	$0.040 /KWH
-Steam	$2.20 /M lb.	1.00	$2.20 /M lb.
-Cooling Water	$0.04 /M gal.	1.00	$0.04 /M gal.
-Process Water	$0.50 /M gal.	1.00	$0.50 /M gal.
-Biodegradation	$0.04 /lb. d.s.	1.00	$0.04 /lb. d.s.
-Landfill	$0.05 /lb. d.s.	1.00	$0.05 /lb. d.s.
Labor-Related			
-Dir. Op. Wages & Ben.	$26.40 /man-hr.	1.00	$26.40 /man-hr.
-Dir. Salaries & Benefi	18 % DOW&B	--	18 % DOW&B
-Op. Supplies & Service	6 % DOW&B	--	6 % DOW&B
-GPOH on Operations	23 % DOWS&B	--	23 % DOWS&B
-Control Lab	$19.22 /man-hr.	1.00	$19.22 /man-hr.
-Tech. Assist. to Mfg.	$22.06 /man-hr.	1.00	$22.06 /man-hr.
Capital-Related			
-Maint. Wages & Ben.	1.7 % DPI	--	1.7 % DPI
-Maint. Salaries & Ben.	25 % MW&B	--	25 % MW&B
-Maint. Mat'l & Service	40 % MW&B	--	40 % MW&B
-Maint. Overhead	4 % MW&B	--	4 % MW&B
-GPOH on Maintenance	23 % MWS&B	--	23 % MWS&B
-Taxes & Insurance	0.3 % DPI	--	0.3 % DPI
-Depreciation - DPI	8 % DPI	--	8 % DPI
-Depreciation - APS&G	6 % APS&G	--	6 % APS&G
Cost of Manufacture			
-Selling Expense	3 % Sales	--	3 % Sales
-Distribution	$0.01 /lb.	--	$0.01 /lb.
-Research & Development	4.5 % Sales	--	4.5 % Sales
-Administrative Expense	2 % Sales	--	2 % Sales
-Incentive Compensation	6 % PTE	--	6 % PTE
Cost of Sales			
-Pretax Earnings	30 % TIFR	--	30 % TIFR
-Credit: Byproduct #1	$0.00 /lb.	1.00	$0.00 /lb.
-Credit: Byproduct #2	$0.00 /lb.	1.00	$0.00 /lb.
-Credit: Byproduct #3	$0.00 /lb.	1.00	$0.00 /lb.
-Product Selling Price	$0.00 /lb.	1.00	$0.00 /lb.

SALARIES & WAGES
CONTINUOUS FERMENTER CASE

		250 MM PPY DAY SHIFT	ROTATING SHIFTS
DIRECT OPERATORS			
SYRUP RECEIVING & TRANSFER		1	-
CHEMICALS RECEIVING & TRANSFER		3	-
INNOCULUM PREPARATION		1	-
MEDIUM PREPARATION		-	1
STERILIZATION		-	1
FERMENTATION			
-CONTROL ROOM		-	2
-PATROL		-	2
-AIR COMPRESSION & AMMONIA FEED		-	1
DISTILLATION		-	3
BEER FILTER & CELL RECYCLE		-	2
TOTAL DAY & 4.2-SHIFT OPERATORS		5	12
TOTAL OPERATORS		55	
CONTROL LABORATORY			
BIOLOGICAL ANALYSIS		-	1
CHEMICAL ANALYSIS		-	1
OTHER		-	-
TOTAL DAY & 4.2-SHIFT TECHNICIANS		0	8
TOTAL LAB FORCE INCL SUPERVISION @	20%	0.0	10.1
TOTAL LAB FORCE		10.1	
TECHNICAL ASSISTANCE TO MANUFACTURING			
PROCESS ENGINEERS		1	-

WAGES, SALARIES & BENEFITS SCHEDULE- 1988

OPERATING WAGES - $/HOUR	$20.14
TECHNICIANS - ANNUAL $	$30,500
PROCESS ENGINEERS - ANNUAL $	$35,000
PENSION - AS % OF COMPENSATION	8.1%
FICA	5.8%
UNEMPLOYMENT COMPENSATION	0.6%
GROUP LIFE INSURANCE	0.7%
MEDICAL INSURANCE	3.6%
DENTAL INSURANCE	0.8%
SAVINGS PLAN	2.5%
VACATION	7.4%
ILLNESS	1.4%
ABSENCE WITH PERMISSION	0.2%
TOTAL BENEFITS	31.1%

SALARIES & WAGES
CONTINUOUS FERMENTER CASE

		MIN. FORCE DAY SHIFT	ROTATING SHIFTS
DIRECT OPERATORS			
SYRUP RECEIVING & TRANSFER		1	-
CHEMICALS RECEIVING & TRANSFER			-
INNOCULUM PREPARATION		1	-
MEDIUM PREPARATION		1	-
STERILIZATION			-
FERMENTATION			
-CONTROL ROOM		-	1
-PATROL		-	1
-AIR COMPRESSION & AMMONIA FEED		-	1
DISTILLATION		-	1
BEER FILTER & CELL RECYCLE		-	1
TOTAL DAY & 4.2-SHIFT OPERATORS		3	5
TOTAL OPERATORS		24	
CONTROL LABORATORY			
BIOLOGICAL ANALYSIS		-	1
CHEMICAL ANALYSIS		-	1
OTHER		-	-
TOTAL DAY & 4.2-SHIFT TECHNICIANS		0	8
TOTAL LAB FORCE INCL SUPERVISION @	20%	0.0	10.1
TOTAL LAB FORCE		10.1	
TECHNICAL ASSISTANCE TO MANUFACTURING			
PROCESS ENGINEERS		1	-

WAGES, SALARIES & BENEFITS SCHEDULE- 1988

OPERATING WAGES - $/HOUR
TECHNICIANS - ANNUAL $
PROCESS ENGINEERS - ANNUAL $

PENSION - AS % OF COMPENSATION
FICA
UNEMPLOYMENT COMPENSATION
GROUP LIFE INSURANCE
MEDICAL INSURANCE
DENTAL INSURANCE
SAVINGS PLAN
VACATION
ILLNESS
ABSENCE WITH PERMISSION

TOTAL BENEFITS

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

1988 COST SHEET	RATE /UNIT	MILLION UNITS	$MILLION	$/gal
Raw Materials				
-Biosugar Syrup	$0.065 /lb. d.s.	779.34	50.66	0.939
-Anhyd. Ammonia	$0.046 /lb.	1.32	0.06	0.001
-Phosphoric Acid	$0.155 /lb.	1.10	0.17	0.003
-Potassium Chloride	$0.053 /lb.	0.84	0.04	0.001
-Minor Nutrients	$0.451 /lb.	0.38	0.17	0.003
Total Raw Materials			$51.10	$0.947
Utilities				
-Electricity	$0.040 /KWH	8.30	0.34	0.006
-Steam	$2.20 /M lb.	2.5915	5.70	0.106
-Cooling Water	$0.04 /M gal.	10.27	0.41	0.008
-Process Water	$0.50 /M gal.	0.27	0.14	0.003
-Biodegradation	$0.04 /lb. d.s.	4.80	0.19	0.004
-Landfill	$0.05 /lb. d.s.	0.00	0.00	0.000
Total Utilities			$6.78	$0.126
Labor-Related				
-Dir. Op. Wages & Ben.	$26.40 /man-hr.	0.124	3.29	0.061
-Dir. Salaries & Ben.	18 % DOW&B		0.59	0.011
-Op. Supplies & Service	6 % DOW&B		0.20	0.004
-GPOH on Operations	23 % DOWS&B		0.89	0.017
-Control Lab	$19.22 /man-hr.	0.020	0.39	0.007
-Tech. Assist. to Mfg.	$22.06 /man-hr.	0.002	0.04	0.001
Total Labor			$5.40	$0.100
Capital-Related				
-Maint. Wages & Ben.	1.7 % DPI	$35.3	0.60	0.011
-Maint. Salaries & Ben.	25 % MW&B		0.15	0.003
-Maint. Mat'l & Service	40 % MW&B		0.24	0.004
-Maint. Overhead	4 % MW&B		0.02	.000
-GPOH on Maintenance	23 % MWS&B		0.17	0.003
-Taxes & Insurance	0.3 % DPI	$35.3	0.11	0.002
-Depreciation - DPI	8 % DPI	$35.3	2.83	0.052
-Depreciation - APS&G	6 % APS&G	$22.1	1.33	0.025
Total Capital			$5.45	0.101
			-----	-----
Cost of Manufacture			$68.73	$1.273
-Selling Expense	3 % Sales	$106.6	3.20	0.059
-Distribution	$0.01 /lb.	355.2	3.55	0.066
-Research & Development	5 % Sales	$106.6	4.80	0.089
-Administrative Expense	2 % Sales	$106.6	2.13	0.039
-Incentive Compensation	6 % PTE	$22.8	1.37	0.025
			-----	-----
Cost of Sales			$83.77	$1.552
-Pretax Earnings	30.0 % TIFR	$75.9	22.79	0.422
-Credit: Byproduct #1	$0.00 /lb.	0.0	0.00	0.000
-Credit: Byproduct #2	$0.00 /lb.	0.0	0.00	0.000
-Credit: Byproduct #3	$0.00 /lb.	0.0	0.00	0.000
			-----	-----
Total Sales			$106.56	$1.974

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

CASH FLOW (MILLION DOLLARS/YEAR)

Scenario:

1. Investment split evenly over three construction years.
2. Plant operates at 50% of full scale the first year.
3. " " 75% " " the second year.
4. " " 100% " " the third year.
5. " " 100% " " thereafter.
6. Five year depreciation rate; half-year convention; (20, 32, 19.2, 11.5, 11.5, 5.8 %); taxes: 34% fed, 3% state.

YEAR	INVESTMENT PI	INVESTMENT WC	DEP.	COST EX D	SALES	NET EARN	ANN CASH
1983	$11.77						($11.77)
1984	$11.77						($11.77)
1985	$11.77						($11.77)
1986		$18.50	$7.06	$44.94	$53.28	$0.81	($10.63)
1987			$11.30	$65.41	$79.92	$2.02	$13.32
1988			$6.78	$79.62	$106.56	$12.71	$19.49
1989			$4.06	$79.62	$106.56	$14.42	$18.48
1990			$4.06	$79.62	$106.56	$14.42	$18.48
1991			$2.05	$79.62	$106.56	$15.69	$17.74
1992				$79.62	$106.56	$16.98	$16.98
1993				$79.62	$106.56	$16.98	$16.98
1994				$79.62	$106.56	$16.98	$16.98
1995				$79.62	$106.56	$16.98	$16.98
1996				$79.62	$106.56	$16.98	$16.98
1997				$79.62	$106.56	$16.98	$16.98
1998				$79.62	$106.56	$16.98	$16.98
1999				$79.62	$106.56	$16.98	$16.98
2000				$79.62	$106.56	$16.98	$16.98
2001				$79.62	$106.56	$16.98	$16.98
2002				$79.62	$106.56	$16.98	$16.98
2003				$79.62	$106.56	$16.98	$16.98
2004				$79.62	$106.56	$16.98	$16.98
2005		($18.50)		$79.62	$106.56	$16.98	$35.47

NET RETURN ON INVESTMENT-3RD OPERATING YEAR = 15.6%

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

CASH FLOW (MILLION DOLLARS/YEAR)

Scenario:
1. Investment split evenly over three construction years.
2. Plant operates at 50% of full scale the first year.
3. " " 75% " " the second year.
4. " " 100% " " the third year.
5. " " 100% " " thereafter.
6. Five year depreciation rate; half-year convention; (20, 32, 19.2, 11.5, 11.5, 5.8 %); taxes: 34% fed, 3% state.

YEAR	CUM CASH	NPV @ 15%	%IRR
1983	($11.77)	($11.77)	--
1984	($23.54)	($22.01)	--
1985	($35.32)	($30.91)	--
1986	($45.94)	($37.90)	-194.9%
1987	($32.62)	($30.28)	-43.0%
1988	($13.13)	($20.59)	-10.4%
1989	$5.35	($12.60)	3.1%
1990	$23.83	($5.66)	10.6%
1991	$41.56	$0.14	15.1%
1992	$58.54	$4.97	17.9%
1993	$75.52	$9.16	19.9%
1994	$92.49	$12.81	21.3%
1995	$109.47	$15.99	22.3%
1996	$126.45	$18.75	23.0%
1997	$143.43	$21.15	23.6%
1998	$160.40	$23.23	24.0%
1999	$177.38	$25.05	24.3%
2000	$194.36	$26.62	24.5%
2001	$211.33	$28.00	24.7%
2002	$228.31	$29.19	24.9%
2003	$245.29	$30.23	25.0%
2004	$262.27	$31.13	25.1%
2005	$297.74	$32.77	25.2%

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

BASIC DATA

SCALE OF OPERATION

355.2	MM PPY	ANNUAL PRODUCTION LEVEL
54.0	MM GPY	" " "
394.6	MM PPY	ANNUAL CAPACITY
60.0	MM GPY	" "
90	%	OPERATING UTILITY
361.4	MM PPY	PRODUCT FORMED IN BEER
401.6	MM PPY	PRODUCT FORMED IN BEER AT CAPACITY
96.5	%	MOLAR YIELD-GLUC. TO PROD. IN BEER (E
2.16	lb/lb	GLUCOSE DEMAND/PROD (EXCL. SPILL)
46.07	MOL WT	PRODUCT MOLECULAR WEIGHT

PRODUCT STOICHIOMETRY

MOL. WT.	MOLES/MOL PRODUCT		COMPONENT
180.16	0.53181	/MOL PROD.	-GLUCOSE CONSUMED
32.00	0.00000	/MOL PROD.	-OXYGEN CONSUMED
17.02	0.00000	/MOL PROD.	-AMMONIA CONSUMED
44.05	0.00150	/MOL PROD.	-ACETALDEHYDE FORMED (#1)
.00		/MOL PROD.	-COMPONENT #2 FORMED
.00		/MOL PROD.	-COMPONENT #3 FORMED
.00		/MOL PROD.	-COMPONENT #4 FORMED
.00		/MOL PROD.	-COMPONENT #5 FORMED
88.10	0.00052	/MOL PROD.	-LIGHT ENDS FORMED (#6)
46.07	1.00000	/MOL PROD.	-ETHANOL FORMED (#7)
.00		/MOL PROD.	-COMPONENT #8 FORMED
.00		/MOL PROD.	-COMPONENT #9 FORMED
.00		/MOL PROD.	-COMPONENT #10 FORMED
18.02	-0.06791	/MOL PROD.	-WATER FORMED
60.05	0.00860	/MOL PROD.	-ACETIC ACID FORMED (#11)
88.15	0.00261	/MOL PROD.	-ISOAMYL ALCOHOL FORMED (#12)
92.09	0.02300	/MOL PROD.	-GLYCERINE FORMED (#13)
.00		/MOL PROD.	-COMPONENT #14 FORMED
90.08	0.00110	/MOL PROD.	-LACTIC ACID FORMED (#15)
118.09	0.00057	/MOL PROD.	-SUCCINIC ACID FORMED (#16)
.00		/MOL PROD.	-COMPONENT #17 FORMED
.00		/MOL PROD.	-COMPONENT #18 FORMED
.00		/MOL PROD.	-COMPONENT #19 FORMED
.00		/MOL PROD.	-COMPONENT #20 FORMED
44.01	1.08091	/MOL PROD.	-CARBON DIOXIDE FORMED
2.02	0.12377	/MOL PROD.	-HYDROGEN FORMED

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

BASIC DATA

```
NUTRIENTS IN FERMENTER FEED
                        8 %              -N IN CELLS AS %CHO
                     80.9 mg/g cells     -H3PO4
                     61.6 mg/g cells     -KCl
                     27.9 mg/g cells     -MINOR NUTRIENTS
                     23.6 mg/g cells      -MgSO4.7H2O
                     0.01 mg/g cells      -VITAMIN B1
                     1.25 mg/g cells      -KI
                     0.89 mg/g cells      -NiCl2
                     0.72 mg/g cells      -FeCl3.6H2O
                     0.55 mg/g cells      -CaCl2.2H2O
                     0.54 mg/g cells      -H3BO3
                     0.22 mg/g cells      -ZnSO4.7H2O
                     0.15 mg/g cells      -MnSO4.H2O
                      7.7 ug/g cells      -CuSO4.5H2O
                      5.4 ug/g cells      -NaMoO4.2H2O
                      4.3 ug/g cells      -CoCl2.6H2O

FERMENTATION
   TYPE                 0 (0 OR 1)     -ANAEROBIC (0) OR AEROBIC (1)
   STAGES               0 (0 OR 1)     -CONCUR'NT (0) OR SEQUENT'AL (1)
   CULTURE MODE         1 (0 OR 1)     -BATCH (0) OR CONTINUOUS (1)
   PROD INHIBITION      0 (0 OR 1)     -WITH (0) OR WITHOUT (1)
   CONDITIONS
     STAGE: GROWTH   PRODUCTION
             33          33  C         -TEMPERATURE
            4.0         4.0            -pH
              0          90 g/l **     -PRODUCT CONCENTRATION IN BEER

          3.239      50.000 g/l        -CELL DENSITY (CHO ONLY)
           0.00       0.208 1/hr       -DILUTION RATE *       ERR
                                       -PRODUCT PRODUCTIVITY
                       1.50 g/g*hr        -Max Specific, g/g cells*hr
                         25 %             -Inhibition Factor, % Max
                       0.38 g/g*hr        -Specific, g/g cells*hr
           0.00       18.75 g/l*hr        -Volumetric, g/l*hr  *
           0.67        0.00 g/l*hr     -CELL PRODUCTIVITY (CHO ONLY)
             23           0 mM/l*hr    -OXYGEN TRANSFERRED
              5           0 mM/mM      -OXYGEN FED / OXYGEN STOICH. DEMAND
             --         0.1 g/l        -GLUCOSE SPILL
              5           5  C         -COOLING WATER TEMPERATURE
             --          19 kcal/gmol  -HEAT EVOLVED-PRODUCT FORMATION
             29         114 Btu/hr*gal -HEAT REMOVED BY COOLING COILS
                                       * w/12 hrs batch mode turnaround
FERMENTERS
              0     324,063 gallons    -ACTIVE VOLUME REQUIRED
             15          15 % gross    -HEADSPACE
              0     448,531 gallons    -GROSS VOLUME (incl. 15% spares)
              0     500,000 gallons    -GROSS SIZE
            0.0         0.9 units      -NUMBER OF UNITS
```

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

BASIC DATA

PRODUCT SEPARATION

500 g/l	-CELL CONC. (CHO) EX FILTER
0.053 gal/min*sf	-FILTER THROUGHPUT
19,994 sq ft	-FILTER SIZE

PRODUCT RECOVERY & PURIFICATION

98.3%(wt)%	-YIELD ACROSS REFINING

MATERIALS OF CONSTRUCTION

	CHOICES	SELECTION
FERMENTERS	1,3	1
STILLS	1,2,3,4,5	1
HEAT EXCHANGERS	1,3,5,6	1
STORAGE TANKS	1,3	1

FOR WHICH:

1=CARBON STEEL
2=CARBON STEEL w/304 SS TRAYS
3=304 STAINLESS STEEL
4=304L STAINLESS STEEL
5=316 STAINLESS STEEL
6=MONEL

RETURN ON INVESTMENT

To Calculate Selling Price Required to Provide a Fixed Return,
Enter the Desired Return on Investment: 30 %
OR
To Calculate the ROI Resulting from a Fixed Market Price,
Enter the Market Price for: 1988 /lb.

Enter an Investment Contingency to Represent
the Risk Level of the Basic Data 30 %

DISTILLATION DATA MATRIX

ITEM	COMPONENT	DEFAULT VALUE	IMPURITY #1	IMPURITY #2	LOWER BOIL PRODUCT #3
1	NAME				
2	PRIORITY AS REFINED PRODUCT	LIST 1-4			
3					
4	NORMAL BOILING PT, C				
5	LOSS/COLUMN, WT %	0.50			
6	LEVEL AS IMPURITY, WT%	0.20			
7	VAP PRESS TEMP, C	900			
8	VAPOR PRESS, mm Hg	800000			
9	HT VAPORIZATION, Btu/lb	215.0			
10	SENSIBLE HT (LIQ), Btu/(lb)	0.50			
11	MAX THERMAL STABILITY, C	150			
12	LN(ACTIVITY COEFFICIENTS)				
13	-COMP. #1 in:	*	xxxx	0.100	0.100
14	-COMP. #2 in:	*	0.100	xxxx	0.100
15	-COMP. #3 in:	*	0.100	0.100	xxxx
16	-COMP. #4 in:	*	0.100	0.100	0.100
17	-COMP. #5 in:	*	0.100	0.100	0.100
18	-COMP. #6 in:	*	0.100	0.100	0.100
19	-COMP. #7 in:	*	0.100	0.100	0.100
20	-COMP. #8 in:	*	0.100	0.100	0.100
21	-COMP. #9 in:	*	0.100	0.100	0.100
22	-COMP. #10 in:	*	0.100	0.100	0.100
23	-WATER in:	*	0.600	0.600	0.600
24	-COMP. #11 in:	*	0.100	0.100	0.100
25	-COMP. #12 in:	*	0.100	0.100	0.100
26	-COMP. #13 in:	*	0.100	0.100	0.100
27	-COMP. #14 in:	*	0.100	0.100	0.100
28	-COMP. #15 in:	*	0.100	0.100	0.100
29	-COMP. #16 in:	*	0.100	0.100	0.100
30	-COMP. #17 in:	*	0.100	0.100	0.100
31	-COMP. #18 in:	*	0.100	0.100	0.100
32	-COMP. #19 in:	*	0.100	0.100	0.100
33	-COMP. #20 in:	*	0.100	0.100	0.100

* The following values can be used in lieu of actual activity coefficients; however, the uncertainty of the calculation is raised significantly:

  alcohol/alcohol; ketone/ketone; aldehyde/aldehyde = 0.1
  aldehyde/ketone = 0.3
  other organic/other organic = 0.5
  alcohol/water = 0.6
  other organic/water = 1.0

ITEM	COMPONENT	DEFAULT VALUE	IMPURITY #1	IMPURITY #2	LOWER BOIL PRODUCT #3
34	B(n) VAPOR PRESSURE CONST.		-2476.10	-2476.10	-2476.10
35	A(n) VAPOR PRESSURE CONST.		15.703	15.703	15.703
36	VAPOR PRESSURE @40 C		2422.2	2422.2	2422.2
37	VAPOR PRESSURE @120 C		12121.9	12121.9	12121.9

DISTILLATION DATA MATRIX

ITEM	COMPONENT	DEFAULT VALUE	IMPURITY #4	IMPURITY #5	IMPURITY #6
1	NAME			ACETALHD	LITE ENDS
2	PRIORITY AS REFINED PRODUCT	LIST			
3					
4	NORMAL BOILING PT, C			20.2	57.8
5	LOSS/COLUMN, WT %	0.50			
6	LEVEL AS IMPURITY, WT%	0.20		0.00	.00
7	VAP PRESS TEMP, C	900		-10.0	-0.5
8	VAPOR PRESS, mm Hg	800000		200.0	60.0
9	HT VAPORIZATION, Btu/lb	215.0		244.8	176.4
10	SENSIBLE HT (LIQ), Btu/(lb)	0.50		0.50	0.47
11	MAX THERMAL STABILITY, C	150			
12	LN(ACTIVITY COEFFICIENTS)				
13	-COMP. #1 in:	*			
14	-COMP. #2 in:	*			
15	-COMP. #3 in:	*			
16	-COMP. #4 in:	*	xxxx		
17	-COMP. #5 in:	*		xxxx	
18	-COMP. #6 in:	*			xxxx
19	-COMP. #7 in:	*			
20	-COMP. #8 in:	*			
21	-COMP. #9 in:	*			
22	-COMP. #10 in:	*			
23	-WATER in:	*			
24	-COMP. #11 in:	*			
25	-COMP. #12 in:	*			
26	-COMP. #13 in:	*			
27	-COMP. #14 in:	*			
28	-COMP. #15 in:	*			
29	-COMP. #16 in:	*			
30	-COMP. #17 in:	*			
31	-COMP. #18 in:	*			
32	-COMP. #19 in:	*			
33	-COMP. #20 in:	*			

* The following values can be used in lieu of actual activity coefficients; however, the uncertainty of the calculation is raised significantly:

  alcohol/alcohol; ketone/ketone; aldehyde/aldehyde = 0.1
  aldehyde/ketone = 0.3
  other organic/other organic = 0.5
  alcohol/water = 0.6
  other organic/water = 1.0

ITEM	COMPONENT	DEFAULT VALUE	IMPURITY #4	IMPURITY #5	IMPURITY #6
34	B(n) VAPOR PRESSURE CONST.		-2476.10	-3408.74	-3925.74
35	A(n) VAPOR PRESSURE CONST.		15.703	18.259	18.501
36	VAPOR PRESSURE @40 C		2422.2	1585.7	387.0
37	VAPOR PRESSURE @120 C		12121.9	14554.7	4972.0

DISTILLATION DATA MATRIX

ITEM	COMPONENT	DEFAULT VALUE	--------LOW BOIL PRODUCT #7	IMPURITY #8	IMPURITY #9
1	NAME		ETHANOL		
2	PRIORITY AS REFINED PRODUCT	LIST	1		
3					
4	NORMAL BOILING PT, C		78.4		
5	LOSS/COLUMN, WT %	0.50			
6	LEVEL AS IMPURITY, WT%	0.20			
7	VAP PRESS TEMP, C	900	18.0		
8	VAPOR PRESS, mm Hg	800000	40.0		
9	HT VAPORIZATION, Btu/lb	215.0	367.2		
10	SENSIBLE HT (LIQ), Btu/(lb)	0.50	0.68		
11	MAX THERMAL STABILITY, C	150			
12	LN(ACTIVITY COEFFICIENTS)				
13	-COMP. #1 in:	*	0.100	0.100	0.100
14	-COMP. #2 in:	*	0.100	0.100	0.100
15	-COMP. #3 in:	*	0.100	0.100	0.100
16	-COMP. #4 in:	*	0.100	0.100	0.100
17	-COMP. #5 in:	*	0.100	0.100	0.100
18	-COMP. #6 in:	*	0.100	0.100	0.100
19	-COMP. #7 in:	*	xxxx	0.100	0.100
20	-COMP. #8 in:	*	0.100	xxxx	0.100
21	-COMP. #9 in:	*	0.100	0.100	xxxx
22	-COMP. #10 in:	*	0.100	0.100	0.100
23	-WATER in:	*	0.600	0.600	0.600
24	-COMP. #11 in:	*	0.100	0.100	0.100
25	-COMP. #12 in:	*	0.100	0.100	0.100
26	-COMP. #13 in:	*	0.100	0.100	0.100
27	-COMP. #14 in:	*	0.100	0.100	0.100
28	-COMP. #15 in:	*	0.100	0.100	0.100
29	-COMP. #16 in:	*	0.100	0.100	0.100
30	-COMP. #17 in:	*	0.100	0.100	0.100
31	-COMP. #18 in:	*	0.100	0.100	0.100
32	-COMP. #19 in:	*	0.100	0.100	0.100
33	-COMP. #20 in:	*	0.100	0.100	0.100

* The following values can be used in lieu of actual activity coefficients; however, the uncertainty of the calculation is raised significantly:

alcohol/alcohol; ketone/ketone; aldehyde/aldehyde = 0.1
aldehyde/ketone = 0.3
other organic/other organic = 0.5
alcohol/water = 0.6
other organic/water = 1.0

ITEM	COMPONENT	DEFAULT VALUE	PRODUCT #7	IMPURITY #8	IMPURITY #9
34	B(n) VAPOR PRESSURE CONST.		-4984.94	-2476.10	-2476.10
35	A(n) VAPOR PRESSURE CONST.		20.819	15.703	15.703
36	VAPOR PRESSURE @40 C		133.3	2422.2	2422.2
37	VAPOR PRESSURE @120 C		3411.6	12121.9	12121.9

DISTILLATION DATA MATRIX

ITEM	COMPONENT	DEFAULT VALUE	IMPURITY #10	WATER	IMPURITY #11
1	NAME				ACET ACD
2	PRIORITY AS REFINED PRODUCT	LIST			
3					
4	NORMAL BOILING PT, C			100.0	118.1
5	LOSS/COLUMN, WT %	0.50			
6	LEVEL AS IMPURITY, WT%	0.20			
7	VAP PRESS TEMP, C	900		30.0	20.0
8	VAPOR PRESS, mm Hg	800000		31.8	11.7
9	HT VAPORIZATION, Btu/lb	215.0		970.3	174.2
10	SENSIBLE HT (LIQ), Btu/(lb)	0.50		1.00	0.52
11	MAX THERMAL STABILITY, C	150			
12	LN(ACTIVITY COEFFICIENTS)				
13	-COMP. #1 in:	*	0.100	0.600	0.100
14	-COMP. #2 in:	*	0.100	0.600	0.100
15	-COMP. #3 in:	*	0.100	0.600	0.100
16	-COMP. #4 in:	*	0.100	0.600	0.100
17	-COMP. #5 in:	*	0.100	0.600	0.100
18	-COMP. #6 in:	*	0.100	0.600	0.100
19	-COMP. #7 in:	*	0.100	0.600	0.100
20	-COMP. #8 in:	*	0.100	0.600	0.100
21	-COMP. #9 in:	*	0.100	0.600	0.100
22	-COMP. #10 in:	*	xxxx	0.600	0.100
23	-WATER in:	*	0.600	xxxx	0.600
24	-COMP. #11 in:	*	0.100	0.600	xxxx
25	-COMP. #12 in:	*	0.100	0.600	0.100
26	-COMP. #13 in:	*	0.100	0.600	0.100
27	-COMP. #14 in:	*	0.100	0.600	0.100
28	-COMP. #15 in:	*	0.100	0.600	0.100
29	-COMP. #16 in:	*	0.100	0.600	0.100
30	-COMP. #17 in:	*	0.100	0.600	0.100
31	-COMP. #18 in:	*	0.100	0.600	0.100
32	-COMP. #19 in:	*	0.100	0.600	0.100
33	-COMP. #20 in:	*	0.100	0.600	0.100

* The following values can be used in lieu of actual activity coefficients; however, the uncertainty of the calculation is raised significantly:

alcohol/alcohol; ketone/ketone; aldehyde/aldehyde = 0.1
aldehyde/ketone = 0.3
other organic/other organic = 0.5
alcohol/water = 0.6
other organic/water = 1.0

34	B(n) VAPOR PRESSURE CONST.	-2476.10	-5123.15	-4875.41
35	A(n) VAPOR PRESSURE CONST.	15.703	20.368	19.099
36	VAPOR PRESSURE @40 C	2422.2	54.6	33.9
37	VAPOR PRESSURE @120 C	12121.9	1528.9	807.2

DISTILLATION DATA MATRIX

ITEM	COMPONENT	DEFAULT VALUE	IMPURITY #12	IMPURITY #13	HIGH BOIL PRODUCT #14
1	NAME		I-AM ALK	GLYCERINE	
2	PRIORITY AS REFINED PRODUCT	LIST			
3					
4	NORMAL BOILING PT, C		130.5	290.0	
5	LOSS/COLUMN, WT %	0.50			
6	LEVEL AS IMPURITY, WT%	0.20			
7	VAP PRESS TEMP, C	900	40.8	153.8	
8	VAPOR PRESS, mm Hg	800000	10.0	5.0	
9	HT VAPORIZATION, Btu/lb	215.0	198.0	396.0	
10	SENSIBLE HT (LIQ), Btu/(lb)	0.50	0.72	0.58	
11	MAX THERMAL STABILITY, C	150			
12	LN(ACTIVITY COEFFICIENTS)				
13	-COMP. #1 in:	*	0.100	0.100	0.100
14	-COMP. #2 in:	*	0.100	0.100	0.100
15	-COMP. #3 in:	*	0.100	0.100	0.100
16	-COMP. #4 in:	*	0.100	0.100	0.100
17	-COMP. #5 in:	*	0.100	0.100	0.100
18	-COMP. #6 in:	*	0.100	0.100	0.100
19	-COMP. #7 in:	*	0.100	0.100	0.100
20	-COMP. #8 in:	*	0.100	0.100	0.100
21	-COMP. #9 in:	*	0.100	0.100	0.100
22	-COMP. #10 in:	*	0.100	0.100	0.100
23	-WATER in:	*	0.600	0.600	0.600
24	-COMP. #11 in:	*	0.100	0.100	0.100
25	-COMP. #12 in:	*	xxxx	0.100	0.100
26	-COMP. #13 in:	*	0.100	xxxx	0.100
27	-COMP. #14 in:	*	0.100	0.100	xxxx
28	-COMP. #15 in:	*	0.100	0.100	0.100
29	-COMP. #16 in:	*	0.100	0.100	0.100
30	-COMP. #17 in:	*	0.100	0.100	0.100
31	-COMP. #18 in:	*	0.100	0.100	0.100
32	-COMP. #19 in:	*	0.100	0.100	0.100
33	-COMP. #20 in:	*	0.100	0.100	0.100

* The following values can be used in lieu of actual activity coefficients; however, the uncertainty of the calculation is raised significantly:

alcohol/alcohol; ketone/ketone; aldehyde/aldehyde = 0.1
aldehyde/ketone = 0.3
other organic/other organic = 0.5
alcohol/water = 0.6
other organic/water = 1.0

ITEM	COMPONENT	DEFAULT VALUE	IMPURITY #12	IMPURITY #13	HIGH BOIL PRODUCT #14
34	B(n) VAPOR PRESSURE CONST.		-6113.16	-8863.29	-2476.10
35	A(n) VAPOR PRESSURE CONST.		21.784	22.376	15.703
36	VAPOR PRESSURE @40 C		9.5	.0	2422.2
37	VAPOR PRESSURE @120 C		507.0	0.8	12121.9

DISTILLATION DATA MATRIX

ITEM	COMPONENT	DEFAULT VALUE	IMPURITY #15	IMPURITY #16	IMPURITY #17
1	NAME		LAC ACD	SUC ACD	
2	PRIORITY AS REFINED PRODUCT	LIST			
3					
4	NORMAL BOILING PT, C				
5	LOSS/COLUMN, WT %	0.50			
6	LEVEL AS IMPURITY, WT%	0.20			
7	VAP PRESS TEMP, C	900			
8	VAPOR PRESS, mm Hg	800000			
9	HT VAPORIZATION, Btu/lb	215.0	540.0	396.0	
10	SENSIBLE HT (LIQ), Btu/(lb)	0.50	0.56	0.58	
11	MAX THERMAL STABILITY, C	150			
12	LN(ACTIVITY COEFFICIENTS)				
13	-COMP. #1 in:	*			
14	-COMP. #2 in:	*			
15	-COMP. #3 in:	*			
16	-COMP. #4 in:	*			
17	-COMP. #5 in:	*			
18	-COMP. #6 in:	*			
19	-COMP. #7 in:	*			
20	-COMP. #8 in:	*			
21	-COMP. #9 in:	*			
22	-COMP. #10 in:	*			
23	-WATER in:	*			
24	-COMP. #11 in:	*			
25	-COMP. #12 in:	*			
26	-COMP. #13 in:	*			
27	-COMP. #14 in:	*			
28	-COMP. #15 in:	*	xxxx		
29	-COMP. #16 in:	*		xxxx	
30	-COMP. #17 in:	*			xxxx
31	-COMP. #18 in:	*			
32	-COMP. #19 in:	*			
33	-COMP. #20 in:	*			

* The following values can be used in lieu of actual activity coefficients; however, the uncertainty of the calculation is raised significantly:

alcohol/alcohol; ketone/ketone; aldehyde/aldehyde = 0.1
aldehyde/ketone = 0.3
other organic/other organic = 0.5
alcohol/water = 0.6
other organic/water = 1.0

ITEM	COMPONENT	DEFAULT VALUE	IMPURITY #15	IMPURITY #16	IMPURITY #17
34	B(n) VAPOR PRESSURE CONST.		-2476.10	-2476.10	-2476.10
35	A(n) VAPOR PRESSURE CONST.		15.703	15.703	15.703
36	VAPOR PRESSURE @40 C		2422.2	2422.2	2422.2
37	VAPOR PRESSURE @120 C		12121.9	12121.9	12121.9

DISTILLATION DATA MATRIX

ITEM	COMPONENT	DEFAULT VALUE	------------------HIGHER BOIL PRODUCT #18	IMPURITY #19	IMPURITY #20
1	NAME				
2	PRIORITY AS REFINED PRODUCT	LIST			
3					
4	NORMAL BOILING PT, C				
5	LOSS/COLUMN, WT %	0.50			
6	LEVEL AS IMPURITY, WT%	0.20			
7	VAP PRESS TEMP, C	900			
8	VAPOR PRESS, mm Hg	800000			
9	HT VAPORIZATION, Btu/lb	215.0			
10	SENSIBLE HT (LIQ), Btu/(lb)	0.50			
11	MAX THERMAL STABILITY, C	150			
12	LN(ACTIVITY COEFFICIENTS)				
13	-COMP. #1 in:	*	0.100	0.100	0.100
14	-COMP. #2 in:	*	0.100	0.100	0.100
15	-COMP. #3 in:	*	0.100	0.100	0.100
16	-COMP. #4 in:	*	0.100	0.100	0.100
17	-COMP. #5 in:	*	0.100	0.100	0.100
18	-COMP. #6 in:	*	0.100	0.100	0.100
19	-COMP. #7 in:	*	0.100	0.100	0.100
20	-COMP. #8 in:	*	0.100	0.100	0.100
21	-COMP. #9 in:	*	0.100	0.100	0.100
22	-COMP. #10 in:	*	0.100	0.100	0.100
23	-WATER in:	*	0.600	0.600	0.600
24	-COMP. #11 in:	*	0.100	0.100	0.100
25	-COMP. #12 in:	*	0.100	0.100	0.100
26	-COMP. #13 in:	*	0.100	0.100	0.100
27	-COMP. #14 in:	*	0.100	0.100	0.100
28	-COMP. #15 in:	*	0.100	0.100	0.100
29	-COMP. #16 in:	*	0.100	0.100	0.100
30	-COMP. #17 in:	*	0.100	0.100	0.100
31	-COMP. #18 in:	*	xxxx	0.100	0.100
32	-COMP. #19 in:	*	0.100	xxxx	0.100
33	-COMP. #20 in:	*	0.100	0.100	xxxx

* The following values can be used in lieu of actual activity coefficients; however, the uncertainty of the calculation is raised significantly:

alcohol/alcohol; ketone/ketone; aldehyde/aldehyde = 0.1
aldehyde/ketone = 0.3
other organic/other organic = 0.5
alcohol/water = 0.6
other organic/water = 1.0

ITEM	COMPONENT	DEFAULT VALUE	PRODUCT #18	IMPURITY #19	IMPURITY #20
34	B(n) VAPOR PRESSURE CONST.		-2476.10	-2476.10	-2476.10
35	A(n) VAPOR PRESSURE CONST.		15.703	15.703	15.703
36	VAPOR PRESSURE @40 C		2422.2	2422.2	2422.2
37	VAPOR PRESSURE @120 C		12121.9	12121.9	12121.9

OFTEN USED PARAMETERS

(THOUSAND ANNUAL POUNDS)

401,590	PRODUCT FORMED
	FORMED WITH PRODUCT
576	-ACETALDEHYDE
0	-COMPONENT #2
0	-COMPONENT #3
0	-COMPONENT #4
0	-COMPONENT #5
402	-LIGHT ENDS
401,590	-ETHANOL (PRODUCT)
0	-COMPONENT #8
0	-COMPONENT #9
0	-COMPONENT #10
(10,665)	-WATER
4,502	-ACETIC ACID
2,008	-ISOAMYL ALCOHOL
18,465	-GLYCERINE
0	-COMPONENT #14
864	-LACTIC ACID
587	-SUCCINIC ACID
0	-COMPONENT #17
0	-COMPONENT #18
0	-COMPONENT #19
0	-COMPONENT #20
2,175	-HYDROGEN
414,689	-CARBON DIOXIDE
	CONSUMED FOR PRODUCT
835,192	-GLUCOSE
0	-AMMONIA
0	-OXYGEN
15,146	CELLS PRODUCED - CHO
1,385	CELLS PRODUCED - NH2
	FORMED WITH CELLS
9,083	-WATER-CHO
779	-WATER-NH2
9,861	-WATER-TOTAL
22,202	-CARBON DIOXIDE-CHO
	CONSUMED FOR CELLS
30,292	-GLUCOSE-CHO
1,471	-AMMONIA-NH2
16,147	-OXYGEN-CHO
692	-OXYGEN-NH2
16,839	-OXYGEN-TOTAL
84,196	OXYGEN FED-GROWTH
278,822	NITROGEN FED-GROWTH
67,356	OXYGEN VENT-GROWTH
278,822	NITROGEN VENT-GROWTH
22,202	CARBON DIOXIDE VENT-GROWTH
11,288	WATER VENT GROWTH

OFTEN USED PARAMETERS

(THOUSAND ANNUAL POUNDS)

0	OXYGEN FED-PROD'N
0	NITROGEN FED-PROD'N
0	OXYGEN VENT-PROD'N
0	NITROGEN VENT-PROD'N
414,689	CARBON DIOXIDE VENT-PROD'N
16,663	WATER VENT-PROD'N
431,352	PHI

WATER BALANCE

WATER IN:

MAKE UP WATER	2,523,783
BIOSUGAR SYRUP	1,298,896
STERILIZER STEAM	169,595
FORMED WITH CELLS	9,861
FORMED WITH PRODUCT	(10,665)
TOTAL IN	3,991,470

WATER OUT:

AQUEOUS WASTE	3,766,642
CONDENSATE MAKEUP TO P.H	169,595
FERMENTER VENTS	27,952
PURGED WITH CELLS	27,202
MOISTURE IN PRODUCTS	79
TOTAL OUT	3,991,470

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	1 CORN SYRUP	2 ANHYD AMMONIA	3 NUTRIENTS	4 MIX WATER	5 MIXED MEDIUM
P						
R	CELLS -CHO	0	0	0	0	0
O	-NH2	0	0	0	0	0
D	-MINERALS	0	0	0	0	0
U	-TOTAL	0	0	0	0	0
C	ACETALDEHYDE	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#0	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	LIGHT ENDS	0	0	0	0	0
#1	ETHANOL	0	0	0	0	0
	COMPONENT #8	0	0	0	0	0
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	0	0	0	0	0
	ACETIC ACID	0	0	0	0	0
	ISOAMYL ALCOHOL	0	0	0	0	0
	GLYCERINE	0	0	0	0	0
#0	COMPONENT #14	0	0	0	0	0
	LACTIC ACID	0	0	0	0	0
	SUCCINIC ACID	0	0	0	0	0
	COMPONENT #17	0	0	0	0	0
#0	COMPONENT #18	0	0	0	0	0
	COMPONENT #19	0	0	0	0	0
	BENZENE	0	0	0	0	0
	GLUCOSE	865,930	0	0	0	865,930
	AMMONIA	0	1,471	0	0	0
	PHOSPHORIC ACID	0	0	1,225	0	1,225
	POTASSIUM CHLORIDE	0	0	933	0	933
	MINOR NUTRIENTS	0	0	423	0	423
	WATER	1,298,896	0	0	2,354,188	3,653,083
	CARBON DIOXIDE	0	0	0	0	0
	OXYGEN	0	0	0	0	0
	NITROGEN	0	0	0	0	0
	HYDROGEN	0	0	0	0	0
	GRAND TOTAL	2,164,826	1,471	2,582	2,354,188	4,521,595
	CHECK ON TOTAL					
	TEMPERATURE, C	20	20	20	20	20
	PRESSURE, PSIA	14.7	14.7	14.7	20.8	25.0
	STATE	SOL'N	LIQUID	SOLIDS	LIQUID	SOL'N

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	6 HX SS EFFLUENT	7 STERILE MEDIUM	8 HX TS EFFLUENT	9 COOLER EFFLUENT	10 AIR TO FERM
P						
R	CELLS -CHO	0	0	0	0	0
O	-NH2	0	0	0	0	0
D	-MINERALS	0	0	0	0	0
U	-TOTAL	0	0	0	0	0
C	ACETALDEHYDE	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#0	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	LIGHT ENDS	0	0	0	0	0
#1	ETHANOL	0	0	0	0	0
	COMPONENT #8	0	0	0	0	0
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	0	0	0	0	0
	ACETIC ACID	0	0	0	0	0
	ISOAMYL ALCOHOL	0	0	0	0	0
	GLYCERINE	0	0	0	0	0
#0	COMPONENT #14	0	0	0	0	0
	LACTIC ACID	0	0	0	0	0
	SUCCINIC ACID	0	0	0	0	0
	COMPONENT #17	0	0	0	0	0
#0	COMPONENT #18	0	0	0	0	0
	COMPONENT #19	0	0	0	0	0
	BENZENE	0	0	0	0	0
	GLUCOSE	865,930	865,930	865,930	865,930	0
	AMMONIA	0	0	0	0	0
	PHOSPHORIC ACID	1,225	1,225	1,225	1,225	0
	POTASSIUM CHLORIDE	933	933	933	933	0
	MINOR NUTRIENTS	423	423	423	423	0
	WATER	3,653,083	3,822,678	3,822,678	3,822,678	0
	CARBON DIOXIDE	0	0	0	0	0
	OXYGEN	0	0	0	0	84,196
	NITROGEN	0	0	0	0	278,822
	HYDROGEN	0	0	0	0	0
	GRAND TOTAL	4,521,595	4,691,190	4,691,190	4,691,190	363,018
	CHECK ON TOTAL					
	TEMPERATURE, C	100	120	40	33	33
	PRESSURE, PSIA	25.0	25.0	25.0	25.0	60.0
	STATE	SOL'N	SOL'N	SOL'N	SOL'N	GAS

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	11 COMBINED FEED	12 BEER #1	13 BEER #2	14 VENT GROWTH	15 VENT PROD'N
P						
R	CELLS -CHO	0	15,146	233,206	0	0
O	-NH2	0	1,385	21,322	0	0
D	-MINERALS	0	423	6,513	0	0
U	-TOTAL	0	16,954	261,041	0	0
C	ACETALDEHYDE	0	0	0	0	576
T	COMPONENT #2	0	0	0	0	0
#0	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	LIGHT ENDS	0	0	443	0	0
#1	ETHANOL	0	0	443,045	0	0
	COMPONENT #8	0	0	0	0	0
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	0	0	0	0	0
	ACETIC ACID	0	0	4,967	0	0
	ISOAMYL ALCOHOL	0	0	2,215	0	0
	GLYCERINE	0	0	20,371	0	0
#0	COMPONENT #14	0	0	0	0	0
	LACTIC ACID	0	0	953	0	0
	SUCCINIC ACID	0	0	647	0	0
	COMPONENT #17	0	0	0	0	0
#0	COMPONENT #18	0	0	0	0	0
	COMPONENT #19	0	0	0	0	0
	BENZENE	0	0	0	0	0
	GLUCOSE	865,930	835,638	446	0	0
	AMMONIA	1,471	0	0	0	0
	PHOSPHORIC ACID	1,225	1,225	1,352	0	0
	POTASSIUM CHLORIDE	933	933	1,029	0	0
	MINOR NUTRIENTS	423	0	0	0	0
	WATER	3,822,678	3,821,251	4,185,555	11,288	16,663
	CARBON DIOXIDE	0	0	0	22,202	414,689
	OXYGEN	84,196	0	0	67,356	0
	NITROGEN	278,822	0	0	278,822	0
	HYDROGEN	0	0	0	0	2,175
	GRAND TOTAL	5,055,679	4,676,002	4,922,064	379,669	434,104
	CHECK ON TOTAL			4,922,064		
	TEMPERATURE, C	33	33	33	33	33
	PRESSURE, PSIA	--	44.7	44.7	14.7	14.7
	STATE	--	SLURRY	SLURRY	GAS	GAS

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	16 COMBINED VENT	17 CELL EFFLUENT	18 CELLS TO DISPOSAL	19 CELL RECYCLE	20 CRUDE FILTRATE
P						
R	CELLS -CHO	0	233,206	15,146	218,060	0
O	-NH2	0	21,322	1,385	19,937	0
D	-MINERALS	0	6,513	420	6,093	0
U	-TOTAL	0	261,041	16,950	244,090	0
C	ACETALDEHYDE	576	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#0	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	LIGHT ENDS	0	44	3	41	399
#1	ETHANOL	0	44,334	2,879	41,455	398,711
	COMPONENT #8	0	0	0	0	0
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	0	0	0	0	0
	ACETIC ACID	0	497	32	465	4,470
	ISOAMYL ALCOHOL	0	222	14	207	1,994
	GLYCERINE	0	2,038	132	1,906	18,332
#0	COMPONENT #14	0	0	0	0	0
	LACTIC ACID	0	95	6	89	858
	SUCCINIC ACID	0	65	4	61	583
	COMPONENT #17	0	0	0	0	0
#0	COMPONENT #18	0	0	0	0	0
	COMPONENT #19	0	0	0	0	0
	BENZENE	0	0	0	0	0
	GLUCOSE	0	45	45	0	402
	AMMONIA	0	0	0	0	0
	PHOSPHORIC ACID	0	135	9	126	1,217
	POTASSIUM CHLORIDE	0	103	7	96	926
	MINOR NUTRIENTS	0	0	0	0	0
	WATER	27,952	418,834	27,202	391,632	3,766,721
	CARBON DIOXIDE	436,891	0	0	0	0
	OXYGEN	67,356	0	0	0	0
	NITROGEN	278,822	0	0	0	0
	HYDROGEN	2,175	0	0	0	0
	GRAND TOTAL	813,773	727,453	47,284	680,211	4,194,611
	CHECK ON TOTAL		727,453		680,169	
	TEMPERATURE, C	33	33	33	33	33
	PRESSURE, PSIA	14.7	44.7	14.7	44.7	14.7
	STATE	GAS	SLURRY	SLURRY	SLURRY	SOL'N

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	21 BEER #1 FEED	22 BEER #1 MAKE	23 BEER #1 TAILS	24 BEER #2 MAKE
P					
R	CELLS -CHO	0	0	0	0
O	-NH2	0	0	0	0
D	-MINERALS	0	0	0	0
U	-TOTAL	0	0	0	0
C	ACETALDEHYDE	0	0	0	0
T	COMPONENT #2	0	0	0	0
#0	COMPONENT #3	0	0	0	0
	COMPONENT #4	0	0	0	0
	COMPONENT #5	0	0	0	0
	LIGHT ENDS	399	399	(0)	399
#1	ETHANOL	438,383	436,389	1,994	396,719
	COMPONENT #8	0	0	0	0
	COMPONENT #9	0	0	0	0
	COMPONENT #10	0	0	0	0
	ACETIC ACID	4,470	0	4,470	0
	ISOAMYL ALCOHOL	1,994	0	1,994	0
	GLYCERINE	18,332	0	18,332	0
#0	COMPONENT #14	0	0	0	0
	LACTIC ACID	858	0	858	0
	SUCCINIC ACID	583	0	583	0
	COMPONENT #17	0	0	0	0
#0	COMPONENT #18	0	0	0	0
	COMPONENT #19	0	0	0	0
	BENZENE	0	0	0	0
	GLUCOSE	402	0	402	0
	AMMONIA	0	0	0	0
	PHOSPHORIC ACID	1,217	0	1,217	0
	POTASSIUM CHLORIDE	926	0	926	0
	MINOR NUTRIENTS	0	0	0	0
	WATER	4,182,230	436,389	3,745,841	20,880
	CARBON DIOXIDE	0	0	0	0
	OXYGEN	0	0	0	0
	NITROGEN	0	0	0	0
	HYDROGEN	0	0	0	0
	GRAND TOTAL	4,649,792	873,177	3,776,615	417,998
	CHECK ON TOTAL				
	TEMPERATURE, C	--	109	120	99
	PRESSURE, PSIA	--	27.5	29.6	29.7
	STATE	SOL'N	SOL'N	SOL'N	SOL'N

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	25 BEER #2 TAILS	26 LBS #1 MAKE	27 LBS #1 TAILS	28 LBS #2 MAKE	29 LBS #2 TAILS
P						
R	CELLS -CHO	0	0	0	0	0
O	-NH2	0	0	0	0	0
D	-MINERALS	0	0	0	0	0
U	-TOTAL	0	0	0	0	0
C	ACETALDEHYDE	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#0	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	LIGHT ENDS	0	359	40	0	0
#1	ETHANOL	39,672	1,984	394,736	0	0
	COMPONENT #8	0	0	0	0	0
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	0	0	0	0	0
	ACETIC ACID	0	0	0	0	0
	ISOAMYL ALCOHOL	0	0	0	0	0
	GLYCERINE	0	0	0	0	0
#0	COMPONENT #14	0	0	0	0	0
	LACTIC ACID	0	0	0	0	0
	SUCCINIC ACID	0	0	0	0	0
	COMPONENT #17	0	0	0	0	0
#0	COMPONENT #18	0	0	0	0	0
	COMPONENT #19	0	0	0	0	0
	BENZENE	0	0	0	0	0
	GLUCOSE	0	0	0	0	0
	AMMONIA	0	0	0	0	0
	PHOSPHORIC ACID	0	0	0	0	0
	POTASSIUM CHLORIDE	0	0	0	0	0
	MINOR NUTRIENTS	0	0	0	0	0
	WATER	415,509	0	20,880	0	0
	CARBON DIOXIDE	0	0	0	0	0
	OXYGEN	0	0	0	0	0
	NITROGEN	0	0	0	0	0
	HYDROGEN	0	0	0	0	0
	GRAND TOTAL	455,181	2,342	415,656	0	0
	CHECK ON TOTAL					
	TEMPERATURE, C	120	111	120	(273)	120
	PRESSURE, PSIA	30.9	58.4	61.7	.0	.0
	STATE	SOL'N	SOL'N	SOL'N	SOL'N	SOL'N

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	30 LBS #3 MAKE	31 LBS #3 TAILS	32 HBS #1 MAKE	33 HBS #1 TAILS	34 HBS #2 MAKE
P						
R	CELLS -CHO	0	0	0	0	0
O	-NH2	0	0	0	0	0
D	-MINERALS	0	0	0	0	0
U	-TOTAL	0	0	0	0	0
C	ACETALDEHYDE	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#0	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	LIGHT ENDS	0	0	0	0	0
#1	ETHANOL	0	0	0	0	0
	COMPONENT #8	0	0	0	0	0
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	0	0	0	0	0
	ACETIC ACID	0	0	0	0	0
	ISOAMYL ALCOHOL	0	0	0	0	0
	GLYCERINE	0	0	0	0	0
#0	COMPONENT #14	0	0	0	0	0
	LACTIC ACID	0	0	0	0	0
	SUCCINIC ACID	0	0	0	583	0
	COMPONENT #17	0	0	0	0	0
#0	COMPONENT #18	0	0	0	0	0
	COMPONENT #19	0	0	0	0	0
	BENZENE	0	0	0	0	0
	GLUCOSE	0	0	0	402	0
	AMMONIA	0	0	0	0	0
	PHOSPHORIC ACID	0	0	0	1,217	0
	POTASSIUM CHLORIDE	0	0	0	926	0
	MINOR NUTRIENTS	0	0	0	0	0
	WATER	0	0	0	0	0
	CARBON DIOXIDE	0	0	0	0	0
	OXYGEN	0	0	0	0	0
	NITROGEN	0	0	0	0	0
	HYDROGEN	0	0	0	0	0
	GRAND TOTAL	0	0	0	3,127	0
	CHECK ON TOTAL					
	TEMPERATURE, C	(273)	120	(273)	150	(273)
	PRESSURE, PSIA	.0	.0	115.7	115.7	115.7
	STATE	SOL'N	SOL'N	SOL'N	SOL'N	SOL'N

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	35 HBS #2 TAILS	36 AZEO MAKE	37 AZEO TAILS	38 AZEO REFLUX	39 DECANTER FEED
P						
R	CELLS -CHO	0	0	0	0	0
O	-NH2	0	0	0	0	0
D	-MINERALS	0	0	0	0	0
U	-TOTAL	0	0	0	0	0
C	ACETALDEHYDE	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#0	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	LIGHT ENDS	0	0	0	0	0
#1	ETHANOL	0	258,681	394,632	258,577	316,966
	COMPONENT #8	0	0	0	0	0
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	0	0	0	0	0
	ACETIC ACID	0	0	0	0	0
	ISOAMYL ALCOHOL	0	0	0	0	0
	GLYCERINE	0	0	0	0	0
#0	COMPONENT #14	0	0	0	0	0
	LACTIC ACID	0	0	0	0	0
	SUCCINIC ACID	583	0	0	0	0
	COMPONENT #17	0	0	0	0	0
#0	COMPONENT #18	0	0	0	0	0
	COMPONENT #19	0	0	0	0	0
	BENZENE	0	1,751,011	2	1,751,013	1,756,388
	GLUCOSE	0	0	0	0	0
	AMMONIA	0	0	0	0	0
	PHOSPHORIC ACID	0	0	0	0	0
	POTASSIUM CHLORIDE	0	0	0	0	0
	MINOR NUTRIENTS	0	0	0	0	0
	WATER	0	47,272	79	26,470	74,769
	CARBON DIOXIDE	0	0	0	0	0
	OXYGEN	0	0	0	0	0
	NITROGEN	0	0	0	0	0
	HYDROGEN	0	0	0	0	0
	GRAND TOTAL	583	2,056,964	394,713	2,036,061	2,148,123
	CHECK ON TOTAL					
	TEMPERATURE, C	150				
	PRESSURE, PSIA	115.7				
	STATE	SOL'N	SOL'N	SOL'N	SOL'N	SOL'N

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	40 DECANTER UP LAYER	41 DECANTER LO LAYER	42 BENZENE MAKE	43 BENZENE TAILS	44 FUSEL OIL DRAW-OFF	45 REFINED PRODUCT
P							
R	CELLS -CHO	0	0	0	0	0	0
O	-NH2	0	0	0	0	0	0
D	-MINERALS	0	0	0	0	0	0
U	-TOTAL	0	0	0	0	0	0
C	ACETALDEHYDE	0	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0	0
#0	COMPONENT #3	0	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0	0
	LIGHT ENDS	0	0	0	0	0	0
#1	ETHANOL	258,577	58,388	58,284	104	0	394,632
	COMPONENT #8	0	0	0	0	0	0
	COMPONENT #9	0	0	0	0	0	0
	COMPONENT #10	0	0	0	0	0	0
	ACETIC ACID	0	0	0	0	0	0
	ISOAMYL ALCOHOL	0	0	0	0	0	0
	GLYCERINE	0	0	0	0	0	0
#0	COMPONENT #14	0	0	0	0	0	0
	LACTIC ACID	0	0	0	0	0	0
	SUCCINIC ACID	0	0	0	0	0	0
	COMPONENT #17	0	0	0	0	0	0
#0	COMPONENT #18	0	0	0	0	0	0
	COMPONENT #19	0	0	0	0	0	0
	BENZENE	1,751,015	5,377	5,377	0.21	0	2
	GLUCOSE	0	0	0	0	0	0
	AMMONIA	0	0	0	0	0	0
	PHOSPHORIC ACID	0	0	0	0	0	0
	POTASSIUM CHLORIDE	0	0	0	0	0	0
	MINOR NUTRIENTS	0	0	0	0	0	0
	WATER	26,470	48,299	27,498	20,801	0	79
	CARBON DIOXIDE	0	0	0	0	0	0
	OXYGEN	0	0	0	0	0	0
	NITROGEN	0	0	0	0	0	0
	HYDROGEN	0	0	0	0	0	0
	GRAND TOTAL	2,036,063	112,064	91,159	20,905	0	394,713
	CHECK ON TOTAL						
	TEMPERATURE, C						40
	PRESSURE, PSIA						14.7
	STATE	SOL'N	SOL'N	SOL'N	SOL'N	SOL'N	SOL'N

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	46 REFINED B.P.#1	47 REFINED B.P.#2	48 AQUEOUS WASTE	49 MAKE-UP WATER	50 MAKE-UP BENZENE
P						
R	CELLS -CHO	0	0	0	0	0
O	-NH2	0	0	0	0	0
D	-MINERALS	0	0	0	0	0
U	-TOTAL	0	0	0	0	0
C	ACETALDEHYDE	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#0	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	LIGHT ENDS	0	0	399	0	0
#1	ETHANOL	0	0	4,079	0	0
	COMPONENT #8	0	0	0	0	0
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	0	0	0	0	0
	ACETIC ACID	0	0	4,470	0	0
	ISOAMYL ALCOHOL	0	0	1,994	0	0
	GLYCERINE	0	0	18,332	0	0
#0	COMPONENT #14	0	0	0	0	0
	LACTIC ACID	0	0	858	0	0
	SUCCINIC ACID	0	0	583	0	0
	COMPONENT #17	0	0	0	0	0
#0	COMPONENT #18	0	0	0	0	0
	COMPONENT #19	0	0	0	0	0
	BENZENE	0	0	0	0	2
	GLUCOSE	0	0	402	0	0
	AMMONIA	0	0	0	0	0
	PHOSPHORIC ACID	0	0	1,217	0	0
	POTASSIUM CHLORIDE	0	0	926	0	0
	MINOR NUTRIENTS	0	0	0	0	0
	WATER	0	0	3,766,642	2,523,783	0
	CARBON DIOXIDE	0	0	0	0	0
	OXYGEN	0	0	0	0	0
	NITROGEN	0	0	0	0	0
	HYDROGEN	0	0	0	0	0
	GRAND TOTAL	0	0	3,799,900	2,523,783	2
	CHECK ON TOTAL					
	TEMPERATURE, C	40	40	40	20	20
	PRESSURE, PSIA	14.7	14.7	14.7	14.7	14.7
	STATE	SOL'N	SOL'N	SOL'N	LIQUID	LIQUID

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	51 STERILE STEAM	52 FERM'TR STEAM	53 DISTILL. STEAM	54 COND. MU P'WR H'SE	55 MEDIUM COOL WTR
P						
R	CELLS -CHO	0	0	0	0	0
O	-NH2	0	0	0	0	0
D	-MINERALS	0	0	0	0	0
U	-TOTAL	0	0	0	0	0
C	ACETALDEHYDE	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#0	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	LIGHT ENDS	0	0	0	0	0
#1	ETHANOL	0	0	0	0	0
	COMPONENT #8	0	0	0	0	0
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	0	0	0	0	0
	ACETIC ACID	0	0	0	0	0
	ISOAMYL ALCOHOL	0	0	0	0	0
	GLYCERINE	0	0	0	0	0
#0	COMPONENT #14	0	0	0	0	0
	LACTIC ACID	0	0	0	0	0
	SUCCINIC ACID	0	0	0	0	0
	COMPONENT #17	0	0	0	0	0
#0	COMPONENT #18	0	0	0	0	0
	COMPONENT #19	0	0	0	0	0
	BENZENE	0	0	0	0	0
	GLUCOSE	0	0	0	0	0
	AMMONIA	0	0	0	0	0
	PHOSPHORIC ACID	0	0	0	0	0
	POTASSIUM CHLORIDE	0	0	0	0	0
	MINOR NUTRIENTS	0	0	0	0	0
	WATER	169,595	0	2,709,900	169,595	2,189,222
	CARBON DIOXIDE	0	0	0	0	0
	OXYGEN	0	0	0	0	0
	NITROGEN	0	0	0	0	0
	HYDROGEN	0	0	0	0	0
	GRAND TOTAL	169,595	0	2,709,900	169,595	2,189,222
	CHECK ON TOTAL					
	TEMPERATURE, C	141	141	186	110	5
	PRESSURE, PSIA	64.7	64.7	164.7	20.8	14.7
	STATE	GAS	GAS	GAS	LIQUID	LIQUID

ETHANOL MANUFACTURE
GENERALIZED FERMENTATION ECONOMICS
EX S. CEREVISIAE - NO GLYCERINE RECOVERY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	56 FERM'TR COOL WTR	52 DISTILL. COOL WTR
P			
R	CELLS -CHO	0	0
O	-NH2	0	0
D	-MINERALS	0	0
U	-TOTAL	0	0
C	ACETALDEHYDE	0	0
T	COMPONENT #2	0	0
#0	COMPONENT #3	0	0
	COMPONENT #4	0	0
	COMPONENT #5	0	0
	LIGHT ENDS	0	0
#1	ETHANOL	0	0
	COMPONENT #8	0	0
	COMPONENT #9	0	0
	COMPONENT #10	0	0
	ACETIC ACID	0	0
	ISOAMYL ALCOHOL	0	0
	GLYCERINE	0	0
#0	COMPONENT #14	0	0
	LACTIC ACID	0	0
	SUCCINIC ACID	0	0
	COMPONENT #17	0	0
#0	COMPONENT #18	0	0
	COMPONENT #19	0	0
	BENZENE	0	0
	GLUCOSE	0	0
	AMMONIA	0	0
	PHOSPHORIC ACID	0	0
	POTASSIUM CHLORIDE	0	0
	MINOR NUTRIENTS	0	0
	WATER	20,298,918	72,533,938
	CARBON DIOXIDE	0	0
	OXYGEN	0	0
	NITROGEN	0	0
	HYDROGEN	0	0
	GRAND TOTAL	20,298,918	72,533,938
	CHECK ON TOTAL		
	TEMPERATURE, C	5	0
	PRESSURE, PSIA	14.7	14.7
	STATE	LIQUID	LIQUID

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	20 CRUDE FILTRATE	21 BEER #1 FEED	22 BEER #1 MAKE	23 BEER #1 TAILS	24 BEER #2 MAKE
ACETALDEHYDE	0	0	0	0	0
COMPONENT #2	0	0	0	0	0
COMPONENT #3	0	0	0	0	0
COMPONENT #4	0	0	0	0	0
COMPONENT #5	0	0	0	0	0
LIGHT ENDS	5	5	5	(0)	5
ETHANOL	8,655	9,516	9,473	43	8,612
COMPONENT #8	0	0	0	0	0
COMPONENT #9	0	0	0	0	0
COMPONENT #10	0	0	0	0	0
ACETIC ACID	74	74	0	74	0
ISOAMYL ALCOHOL	23	23	0	23	0
GLYCERINE	199	199	0	199	0
COMPONENT #14	0	0	0	0	0
LACTIC ACID	10	10	0	10	0
SUCCINIC ACID	5	5	0	5	0
COMPONENT #17	0	0	0	0	0
COMPONENT #18	0	0	0	0	0
COMPONENT #19	0	0	0	0	0
BENZENE	0	0	0	0	0
WATER	209,076	232,140	24,222	207,917	1,159
	218,046	241,971	33,700	208,271	9,775
(Storage)	1,194	1,308	1,265	44	1,150
VAPOR PRESS 40(g)	57.8	57.8	76.8	54.7	124.1
(Storage)	29,761	32,699	32,364	359	29,426
VAPOR PRESS 120(g)	1602.5	1601.9	2059.3	1528.0	3191.6
B(g) V.P. CONSTANT	-5107.2	-5107.7	-5057.2	-5119.0	-4992.6
A(g) V.P. CONSTANT	20.375	20.376	20.498	20.357	20.772
TEMPERATURE C	33.0	41.5	107.9	120.0	96.8
PRESSURE mmHg	760	760	1,368	1,528	1,438

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	25 BEER #2 TAILS	26 LBS #1 MAKE	27 LBS #1 TAILS	28 LBS #2 MAKE	29 LBS #2 TAILS	30 LBS #3 MAKE
ACETALDEHYDE	0	0	0	0	0	0
COMPONENT #2	0	0	0	0	0	0
COMPONENT #3	0	0	0	0	0	0
COMPONENT #4	0	0	0	0	0	0
COMPONENT #5	0	0	0	0	0	0
LIGHT ENDS	0	4	0	0	0	0
ETHANOL	861	43	8,569	0	0	0
COMPONENT #8	0	0	0	0	0	0
COMPONENT #9	0	0	0	0	0	0
COMPONENT #10	0	0	0	0	0	0
ACETIC ACID	0	0	0	0	0	0
ISOAMYL ALCOHOL	0	0	0	0	0	0
GLYCERINE	0	0	0	0	0	0
COMPONENT #14	0	0	0	0	0	0
LACTIC ACID	0	0	0	0	0	0
SUCCINIC ACID	0	0	0	0	0	0
COMPONENT #17	0	0	0	0	0	0
COMPONENT #18	0	0	0	0	0	0
COMPONENT #19	0	0	0	0	0	0
BENZENE	0	0	0	0	0	0
WATER	23,063	0	1,159	0	0	0
	23,924	47	9,728	0	0	0
(Storage)	115	7	1,143	0	0	0
VAPOR PRESS 40(q)	57.5	155.3	124.0	.0	.0	.0
(Storage)	2,962	191	29,259	24	24	24
VAPOR PRESS 120(q)	1597.7	4060.8	3189.9	.0	.0	.0
B(q) V.P. CONSTANT	-5113.0	-5018.8	-4993.6	0.0	0.0	0.0
A(q) V.P. CONSTANT	20.387	21.080	20.774	-4.605	-4.605	-4.605
TEMPERATURE C	120.0	111.2	120.0	ERR	120.0	ERR
PRESSURE mmHg	1,598	3,030	3,190	(160)	0	(160)

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	31 LBS #3 TAILS	32 HBS #1 MAKE	33 HBS #1 TAILS	34 HBS #2 MAKE	35 HBS #2 TAILS	36 AZEO MAKE
ACETALDEHYDE	0	0	0	0	0	0
COMPONENT #2	0	0	0	0	0	0
COMPONENT #3	0	0	0	0	0	0
COMPONENT #4	0	0	0	0	0	0
COMPONENT #5	0	0	0	0	0	0
LIGHT ENDS	0	0	0	0	0	0
ETHANOL	0	0	0	0	0	5,615
COMPONENT #8	0	0	0	0	0	0
COMPONENT #9	0	0	0	0	0	0
COMPONENT #10	0	0	0	0	0	0
ACETIC ACID	0	0	0	0	0	0
ISOAMYL ALCOHOL	0	0	0	0	0	0
GLYCERINE	0	0	0	0	0	0
COMPONENT #14	0	0	0	0	0	0
LACTIC ACID	0	0	0	0	0	0
SUCCINIC ACID	0	0	5	0	5	0
COMPONENT #17	0	0	0	0	0	0
COMPONENT #18	0	0	0	0	0	0
COMPONENT #19	0	0	0	0	0	0
BENZENE	0	0	0	0	0	22,209
WATER	0	0	0	0	0	2,624
	0	0	5	0	5	30,448
(Storage)	0	0	12	0	12	
VAPOR PRESS 40(g)	.0	.0	2422.2	.0	2422.2	
(Storage)	24	24	24	24	24	
VAPOR PRESS 120(g)	.0	.0	4915.4	.0	4915.4	
B(g) V.P. CONSTANT	0.0	0.0	-1088.2	0.0	-1088.2	
A(g) V.P. CONSTANT	-4.605	-4.605	11.269	-4.605	11.269	
TEMPERATURE C	120.0	-273.0	150.0	-273.0	150.0	
PRESSURE mmHg	0	5,822	5,982	5,822	5,982	

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	37 AZEO TAILS	38 AZEO REFLUX	39 DECANTER FEED	40 DECANTER UP LAYER	41 DECANTER LO LAYER	42 BENZENE MAKE
ACETALDEHYDE	0					0
COMPONENT #2	0					0
COMPONENT #3	0					0
COMPONENT #4	0					0
COMPONENT #5	0					0
LIGHT ENDS	0					0
ETHANOL	8,566					1,265
COMPONENT #8	0					0
COMPONENT #9	0					0
COMPONENT #10	0					0
ACETIC ACID	0					0
ISOAMYL ALCOHOL	0					0
GLYCERINE	0					0
COMPONENT #14	0					0
LACTIC ACID	0					0
SUCCINIC ACID	0					0
COMPONENT #17	0					0
COMPONENT #18	0					0
COMPONENT #19	0					0
BENZENE	0					68
WATER	4					1,526
	8,571					2,860

(Storage)
VAPOR PRESS 40(q)
(Storage)
VAPOR PRESS 120(q)
B(q) V.P. CONSTANT
A(q) V.P. CONSTANT
TEMPERATURE C
PRESSURE mmHg

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	43 BENZENE TAILS
ACETALDEHYDE	0
COMPONENT #2	0
COMPONENT #3	0
COMPONENT #4	0
COMPONENT #5	0
LIGHT ENDS	0
ETHANOL	2
COMPONENT #8	0
COMPONENT #9	0
COMPONENT #10	0
ACETIC ACID	0
ISOAMYL ALCOHOL	0
GLYCERINE	0
COMPONENT #14	0
LACTIC ACID	0
SUCCINIC ACID	0
COMPONENT #17	0
COMPONENT #18	0
COMPONENT #19	0
BENZENE	0
WATER	1,155
	1,157

(Storage)
VAPOR PRESS 40(g)
(Storage)
VAPOR PRESS 120(g)
B(g) V.P. CONSTANT
A(g) V.P. CONSTANT
TEMPERATURE C
PRESSURE mmHg

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	20 CRUDE FILTRATE	22 BEER #1 MAKE	23 BEER #1 TAILS	24 BEER #2 MAKE	25 BEER #2 TAILS
K1 (COMPONENT #)		7	7	7	7
K2 (COMPONENT #)		WATER	WATER	WATER	WATER
V.P.(K1)		2279.7	3411.6	1538.7	3411.6
V.P.(K2)		1010.3	1528.9	674.5	1528.9
GAMMA-K1 IN K2		1.822	1.822	1.822	1.822
GAMMA-K2 IN K1		1.822	1.822	1.822	1.822
ALPHA		2.934	4.065	1.443	3.894
AVG COLUMN ALPHA		3.500		2.669	
MOL FRACT. K1 (MAKE OR TAILS)		0.281	0.00021	0.881	0.03599
MOL FRACT. K1 (FEED)		0.039		0.281	
MOL FRACT. K2 (MAKE OR TAILS)		0.719	1.000	0.119	0.964
ADJ. GAMMA-K1 IN K2		1.364	1.822	1.008	1.746
ADJ. GAMMA-K2 IN K1		1.049	1.000	1.594	1.001
MINIMUM REFLUX RATIO (ADJUSTE		0.4		0.2	
ACTUAL REFLUX RATIO		0.5		0.3	
MINIMUM THEOR. PLATES (INFINI		6		5	
THEORETICAL PLATES		14		12	
PLATE EFFICIENCY -%		50%		80%	
ACTUAL PLATES		27		15	
PRESSURE mm Hg (REVISED)		1,420		1,537	
TEMPERATURE C (REVISED)		109		99	
AVERAGE MOLECULAR WEIGHT		25.91	18.13	42.76	19.03
GAS DENSITY - LB/CF		0.0964	0.0705	0.1770	0.0774
CROSS SECTIONAL AREA - SQ FT		123.3		37.9	
COLUMN HEIGHT - FT		55.6		37.7	
COLUMN DIAMETER		12.5		7.0	
K1 (MPPY)		436,389		396,719	
Hv (HEAT VAPORIZ.-Btu/Lb)		668.5	965.7	397.1	917.7
Cn (HEAT CAPACITY - Btu/Lb/F)		0.840	0.997	0.696	0.972
HEAT LOAD - MM Btu/Hr		121.584	195.405	30.125	31.346
CONDENSER COOLING WATER - GPM		9010		2232	
CALANDRIA STEAM - MPPH (150 PSIG)			228.01		36.58
COLUMN COST - $1000 3Q86 MPC - BARE EQUIPMENT					
- ALL CARBON STEEL		$216.6		$87.8	
- C.S w/304 S.S. TRAYS		$238.2		$96.6	
- ALL 304 STAINLESS STEEL		$343.2		$140.8	
- ALL 304L STAINLESS STEEL		$377.5		$154.9	
- ALL 316 STAINLESS STEEL		$463.3		$190.1	
CONDENSER OR CALANDRIA SURFAC		10,693	10,856	3,048	1,741
COND. OR CALAND. COST - $1000 3Q86 MPC - BARE EQUIPMENT					
-CARBON STEEL		$333.0	$338.3	$99.8	$62.7
-304 STAINLESS STEEL		$466.2	$473.6	$139.8	$87.8
-316 STAINLESS STEEL		$499.5	$507.5	$149.7	$94.0
-MONEL		$649.3	$659.7	$194.7	$122.2
SUBTOTAL			3,762,407		442,486
SUBTOTAL			3,746,659		415,509
SUBTOTAL			3,745,841		415,509
MINIMUM REFLUX RATIO		0.4		0.2	
Cn SUBTOTAL #1		296,932	1,356	269,957	26,977

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	20 CRUDE FILTRATE	22 BEER #1 MAKE	23 BEER #1 TAILS	24 BEER #2 MAKE	25 BEER #2 TAILS
Cn SUBTOTAL #2		0	14,392	0	0
Cn SUBTOTAL #3		436,389	3,746,659	20,880	415,509
Cn CHECK		0.750	0.996	0.525	0.956
Hv SUBTOTAL #1		160,312	732	145,746	14,568
Hv SUBTOTAL #2		0	8,433	0	0
Hv SUBTOTAL #3		423,428	3,635,284	20,260	403,168
Hv CHECK		592.5	964.7	252.7	904.5
MIN. PLATES(NORMAL)					
COL.COST-C/S NORMAL					
COL.COST-S/S NORMAL					
MIN.REFLUX(NORMAL)					
C.S. AREA(NORMAL)					
HEAT LOAD(NORMAL)					
CON/CAL COST(NORMAL)					
REFLUX FACTOR		0.275		0.878	

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	20 CRUDE FILTRATE	26 LBS #1 MAKE	27 LBS #1 TAILS	28 LBS #2 MAKE	29 LBS #2 TAILS	30 LBS #3 MAKE
K1 (COMPONENT #)		6,5,4,3	6,5,4,3	3	3	2
K2 (COMPONENT #)		7	7	4,5,6	4,5,6	3
V.P.(K1)		3954.0	4972.0	ERR	12121.9	ERR
V.P.(K2)		2550.5	3411.6	ERR	14554.7	ERR
GAMMA-K1 IN K2		1.105	1.105	1.000	1.000	1.000
GAMMA-K2 IN K1		1.000	1.000	1.105	1.105	1.000
ALPHA		1.685	1.611	ERR	ERR	ERR
AVG COLUMN ALPHA		1.648		ERR		ERR
MOL FRACT. K1 (MAKE OR TAILS)		0.086	.000	ERR	ERR	ERR
MOL FRACT. K1 (FEED)		0.001		0.000		ERR
MOL FRACT. K2 (MAKE OR TAILS)		0.914	1.000	ERR	ERR	ERR
ADJ. GAMMA-K1 IN K2		1.087	1.105	ERR	ERR	ERR
ADJ. GAMMA-K2 IN K1		1.000	1.000	ERR	ERR	ERR
MINIMUM REFLUX RATIO (ADJUSTE		20.1		ERR		ERR
ACTUAL REFLUX RATIO		25.1		ERR		ERR
MINIMUM THEOR. PLATES (INFINI		15)		0		0
THEORETICAL PLATES		34		0		0
PLATE EFFICIENCY -%		80%		80%		80%
ACTUAL PLATES		42		0		0
PRESSURE mm Hg (REVISED)		3,021		0		0
TEMPERATURE C (REVISED)		111		(273)		(273)
AVERAGE MOLECULAR WEIGHT		49.70	42.73	ERR	ERR	ERR
GAS DENSITY - LB/CF		0.3911	0.3470	ERR	ERR	ERR
CROSS SECTIONAL AREA - SQ FT		2.9		0.0		0.0
COLUMN HEIGHT - FT		78.3		0.0		15.0
COLUMN DIAMETER		1.9		0.0		0.0
K1 (MPPY)		359		0		0
Hv (HEAT VAPORIZ.-Btu/Lb)		338.0	397.5	ERR	ERR	ERR
Cn (HEAT CAPACITY - Btu/Lb/F)		0.648	0.696	ERR	ERR	ERR
HEAT LOAD - MM Btu/Hr		3.134	4.680	0.000	0.000	0.000
CONDENSER COOLING WATER - GPM		232)		0		0
CALANDRIA STEAM - MPPH (150 PSIG)			5.46		0.00	
COLUMN COST - $1000 3Q86 MPC - BARE EQUIPMENT						
- ALL CARBON STEEL		$54.3		$0.0		$0.0
- C.S w/304 S.S. TRAYS		$59.7		$0.0		$0.0
- ALL 304 STAINLESS STEEL		$88.1		$0.0		$0.0
- ALL 304L STAINLESS STEEL		$96.9		$0.0		$0.0
- ALL 316 STAINLESS STEEL		$119.0		$0.0		$0.0
CONDENSER OR CALANDRIA SURFAC		268	260	0	0	0
COND. OR CALAND. COST - $1000 3Q86 MPC - BARE EQUIPMENT						
-CARBON STEEL		$18.3	$18.0	$0.0	$0.0	$0.0
-304 STAINLESS STEEL		$25.6	$25.2	$0.0	$0.0	$0.0
-316 STAINLESS STEEL		$27.4	$27.0	$0.0	$0.0	$0.0
-MONEL		$35.7	$35.1	$0.0	$0.0	$0.0
SUBTOTAL			289,300		0	
SUBTOTAL			20,880		0	
SUBTOTAL			20,880		0	
MINIMUM REFLUX RATIO		20.1		ERR		ERR
Cn SUBTOTAL #1		1,518	268,439	0	0	0

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	20 CRUDE FILTRATE	26 LBS #1 MAKE	27 LBS #1 TAILS	28 LBS #2 MAKE	29 LBS #2 TAILS	30 LBS #3 MAKE
Cn SUBTOTAL #2		0	0	0	0	0
Cn SUBTOTAL #3		0	20,880	0	0	0
Cn CHECK		0.500	0.525	ERR	ERR	ERR
Hv SUBTOTAL #1		792	144,954	0	0	0
Hv SUBTOTAL #2		0	0	0	0	0
Hv SUBTOTAL #3		0	20,260	0	0	0
Hv CHECK		215.0	252.9	ERR	ERR	ERR
MIN. PLATES(NORMAL)						
COL.COST-C/S NORMAL		54				
COL.COST-S/S NORMAL		88				
MIN.REFLUX(NORMAL)						
C.S. AREA(NORMAL)		3				
HEAT LOAD(NORMAL)			5			
CON/CAL COST(NORMAL)		18	18			
REFLUX FACTOR		0.080		ERR		ERR

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	20 CRUDE FILTRATE	31 LBS #3 TAILS	32 HBS #1 MAKE	33 HBS #1 TAILS	34 HBS #2 MAKE	35 HBS #2 TAILS
K1 (COMPONENT #)		2	WATER	WATER	14	14
K2 (COMPONENT #)		3	14	14	15,16,17 &18	15,16,17 &18
V.P.(K1)		1.0	ERR	3853.9	ERR	18951.1
V.P.(K2)		12121.9	ERR	18951.1	ERR	1.0
GAMMA-K1 IN K2		1.000	1.822	1.822	1.000	1.000
GAMMA-K2 IN K1		1.000	1.822	1.822	1.000	1.000
ALPHA		ERR	ERR	ERR	ERR	*********
AVG COLUMN ALPHA			ERR		ERR	
MOL FRACT. K1 (MAKE OR TAILS)		ERR	ERR	ERR	ERR	0.000
MOL FRACT. K1 (FEED)			1.000		0.000	
MOL FRACT. K2 (MAKE OR TAILS)		ERR	ERR	ERR	ERR	1.000
ADJ. GAMMA-K1 IN K2		ERR	ERR	ERR	ERR	1.000
ADJ. GAMMA-K2 IN K1		ERR	ERR	ERR	ERR	1.000
MINIMUM REFLUX RATIO (ADJUSTED)			ERR		ERR	
ACTUAL REFLUX RATIO			ERR		ERR	
MINIMUM THEOR. PLATES (INFINITE REFLUX			0		0	
THEORETICAL PLATES			0		0	
PLATE EFFICIENCY -%			80%		80%	
ACTUAL PLATES			0		0	
PRESSURE mm Hg (REVISED)			5,982		5,982	
TEMPERATURE C (REVISED)			(273)		(273)	
AVERAGE MOLECULAR WEIGHT		ERR	ERR	633.85	ERR	118.09
GAS DENSITY - LB/CF		ERR	ERR	8.9690	ERR	1.6709
CROSS SECTIONAL AREA - SQ FT			0.0		0.0	
COLUMN HEIGHT - FT			0.0		0.0	
COLUMN DIAMETER			0.0		0.0	
K1 (MPPY)			0		0	
Hv (HEAT VAPORIZ.-Btu/Lb)		ERR	ERR	396.0	ERR	396.0
Cn (HEAT CAPACITY - Btu/Lb/F)		ERR	ERR	0.580	ERR	0.580
HEAT LOAD - MM Btu/Hr		0.000	0.000	0.000	0.000	0.000
CONDENSER COOLING WATER - GPM (15 C dT			0		0	
CALANDRIA STEAM - MPPH (150 P		0.00		0.00		0.00
COLUMN COST - $1000 3Q86 MPC - BARE EQUIPMENT						
- ALL CARBON STEEL			$0.0		$0.0	
- C.S w/304 S.S. TRAYS			$0.0		$0.0	
- ALL 304 STAINLESS STEEL			$0.0		$0.0	
- ALL 304L STAINLESS STEEL			$0.0		$0.0	
- ALL 316 STAINLESS STEEL			$0.0		$0.0	
CONDENSER OR CALANDRIA SURFAC		0	0	0	0	0
COND. OR CALAND. COST - $1000 3Q86 MPC - BARE EQUIPMENT						
-CARBON STEEL		$0.0	$0.0	$0.0	$0.0	$0.0
-304 STAINLESS STEEL		$0.0	$0.0	$0.0	$0.0	$0.0
-316 STAINLESS STEEL		$0.0	$0.0	$0.0	$0.0	$0.0
-MONEL		$0.0	$0.0	$0.0	$0.0	$0.0
SUBTOTAL		0		338		338
SUBTOTAL		0		338		338
SUBTOTAL		0		0		0
MINIMUM REFLUX RATIO			ERR		ERR	
Cn SUBTOTAL #1		0	0	0	0	0

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	20 CRUDE FILTRATE	31 LBS #3 TAILS	32 HBS #1 MAKE	33 HBS #1 TAILS	34 HBS #2 MAKE	35 HBS #2 TAILS
Cn SUBTOTAL #2		0	0	0	0	0
Cn SUBTOTAL #3		0	0	338	0	338
Cn CHECK		ERR	ERR	0.500	ERR	0.500
Hv SUBTOTAL #1		0	0	0	0	0
Hv SUBTOTAL #2		0	0	0	0	0
Hv SUBTOTAL #3		0	0	231	0	231
Hv CHECK		ERR	ERR	215.0	ERR	215.0
MIN. PLATES(NORMAL)					ERR	
COL.COST-C/S NORMAL					0	
COL.COST-S/S NORMAL					0	
MIN.REFLUX(NORMAL)						
C.S. AREA(NORMAL)						
HEAT LOAD(NORMAL)						
CON/CAL COST(NORMAL)						
REFLUX FACTOR			ERR		ERR	

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	20 CRUDE FILTRATE	36 AZEO MAKE	37 AZEO TAILS	38 AZEO REFLUX	39 DECANTER FEED
K1 (COMPONENT #)					
K2 (COMPONENT #)					
V.P.(K1)					
V.P.(K2)					
GAMMA-K1 IN K2					
GAMMA-K2 IN K1					
ALPHA					
AVG COLUMN ALPHA					
MOL FRACT. K1 (MAKE OR TAILS)					
MOL FRACT. K1 (FEED)					
MOL FRACT. K2 (MAKE OR TAILS)					
ADJ. GAMMA-K1 IN K2					
ADJ. GAMMA-K2 IN K1					
MINIMUM REFLUX RATIO (ADJUSTED)					
ACTUAL REFLUX RATIO					
MINIMUM THEOR. PLATES (INFINITE REFLUX)					
THEORETICAL PLATES					
PLATE EFFICIENCY -%		80%			
ACTUAL PLATES		50			
PRESSURE mm Hg (REVISED)					
TEMPERATURE C (REVISED)					
AVERAGE MOLECULAR WEIGHT					
GAS DENSITY - LB/CF					
CROSS SECTIONAL AREA - SQ FT		93.8			
COLUMN HEIGHT - FT		90.0			
COLUMN DIAMETER		10.9			
K1 (MPPY)					
Hv (HEAT VAPORIZ.-Btu/Lb)					
Cn (HEAT CAPACITY - Btu/Lb/F)					
HEAT LOAD - MM Btu/Hr		61.622	54.874		
CONDENSER COOLING WATER - GPM		6850	(10 C delta T)		
CALANDRIA STEAM - MPPH (150 PSIG)			64.03		
COLUMN COST - $1000 3Q86 MPC - BARE EQUIPMENT					
- ALL CARBON STEEL		$301.5			
- C.S w/304 S.S. TRAYS		$331.6			
- ALL 304 STAINLESS STEEL		$476.6			
- ALL 304L STAINLESS STEEL		$524.3			
- ALL 316 STAINLESS STEEL		$643.4			
CONDENSER OR CALANDRIA SURFAC		9,520	3,049		
COND. OR CALAND. COST - $1000 3Q86 MPC - BARE EQUIPMENT					
-CARBON STEEL		$295.1	$99.8		
-304 STAINLESS STEEL		$413.1	$139.8		
-316 STAINLESS STEEL		$442.6	$149.8		
-MONEL		$575.4	$194.7		
SUBTOTAL					
SUBTOTAL					
SUBTOTAL					
MINIMUM REFLUX RATIO					
Cn SUBTOTAL #1					

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	20 CRUDE FILTRATE	36 AZEO MAKE	37 AZEO TAILS	38 AZEO REFLUX	39 DECANTER FEED
Cn SUBTOTAL #2					
Cn SUBTOTAL #3					
Cn CHECK					
Hv SUBTOTAL #1					
Hv SUBTOTAL #2					
Hv SUBTOTAL #3					
Hv CHECK					
MIN. PLATES(NORMAL)					
COL.COST-C/S NORMAL					
COL.COST-S/S NORMAL					
MIN.REFLUX(NORMAL)					
C.S. AREA(NORMAL)					
HEAT LOAD(NORMAL)					
CON/CAL COST(NORMAL)					
REFLUX FACTOR					

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	20 CRUDE FILTRATE	40 DECANTER UP LAYER	41 DECANTER LO LAYER	42 BENZENE MAKE	43 BENZENE TAILS
K1 (COMPONENT #)					
K2 (COMPONENT #)					
V.P.(K1)					
V.P.(K2)					
GAMMA-K1 IN K2					
GAMMA-K2 IN K1					
ALPHA					
AVG COLUMN ALPHA					
MOL FRACT. K1 (MAKE OR TAILS)					
MOL FRACT. K1 (FEED)					
MOL FRACT. K2 (MAKE OR TAILS)					
ADJ. GAMMA-K1 IN K2					
ADJ. GAMMA-K2 IN K1					
MINIMUM REFLUX RATIO (ADJUSTED)					
ACTUAL REFLUX RATIO					
MINIMUM THEOR. PLATES (INFINITE REFLUX)					
THEORETICAL PLATES					
PLATE EFFICIENCY -%					
ACTUAL PLATES				30	
PRESSURE mm Hg (REVISED)					
TEMPERATURE C (REVISED)					
AVERAGE MOLECULAR WEIGHT					
GAS DENSITY - LB/CF					
CROSS SECTIONAL AREA - SQ FT				7.0	
COLUMN HEIGHT - FT				60.0	
COLUMN DIAMETER				3.0	
K1 (MPPY)					
Hv (HEAT VAPORIZ.-Btu/Lb)					
Cp (HEAT CAPACITY - Btu/Lb/F)					
HEAT LOAD - MM Btu/Hr					6.926
CONDENSER COOLING WATER - GPMDECANTER VOLUME - GAL.					
CALANDRIA STEAM - MPPH (150 P		9,866			8.08
COLUMN COST - $1000 3Q86 MPC - BARE EQUIPMENT					
- ALL CARBON STEEL				$63.0	
- C.S w/304 S.S. TRAYS				$69.3	
- ALL 304 STAINLESS STEEL				$81.0	
- ALL 304L STAINLESS STEEL				$89.1	
- ALL 316 STAINLESS STEEL				$109.4	
CONDENSER OR CALANDRIA SURFACE - SQ FT					385
COND. OR CALAND. COST - $1000 3Q86 MPC - BARE EQUIPMENT					
-CARBON STEEL					$22.3
-304 STAINLESS STEEL					$31.2
-316 STAINLESS STEEL					$33.5
-MONEL					$43.5
SUBTOTAL					
SUBTOTAL					
SUBTOTAL					
MINIMUM REFLUX RATIO					
Cp SUBTOTAL #1					

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	20 CRUDE FILTRATE	40 DECANTER UP LAYER	41 DECANTER LO LAYER	42 BENZENE MAKE	43 BENZENE TAILS
Cn SUBTOTAL #2					
Cn SUBTOTAL #3					
Cn CHECK					
Hv SUBTOTAL #1					
Hv SUBTOTAL #2					
Hv SUBTOTAL #3					
Hv CHECK					
MIN. PLATES(NORMAL)					
COL.COST-C/S NORMAL					
COL.COST-S/S NORMAL					
MIN.REFLUX(NORMAL)					
C.S. AREA(NORMAL)					
HEAT LOAD(NORMAL)					
CON/CAL COST(NORMAL)					
REFLUX FACTOR					

APPENDIX E. ADVANCED BACTERIUM CASE

ETHANOL MANUFACTURE
ZYMOMONAS MOBILIS
INHIBITED SYSTEM - PLUG FLOW - CELL RECYCLE
SUMMARY

	PRODUCTION LEVEL 54 MM GPY
INVESTMENT-$MILLION MPC = 1984	
Direct Permanent Investment	$29.3
Allocated Power, Services & General	$19.9
Working Capital	$17.1
Total Investment	$66.3
COST-$/GAL(1988)	
Raw Materials	$0.89
Utilities	$0.11
Labor-Related	$0.10
Capital-Related	$0.09
Cost of Manufacture	$1.19
SE, D, R&D, Adm, & I.C.	$0.26
Cost of Sales	$1.45
Pretax Earnings Based on: 30% Pretax ROI	$0.37
By-product Credits	$0.00
Selling Price	$1.81
FINANCIAL CRITERIA	
Net ROI 3rd Year (assumed)	16%
Investors Rate of Return (20 Operating Years)	25%
Year to Break Even - Annual Cash	1989
- Cumulative Cash	1991
- Cum. Disc. Cash (NPV)	1994
Net Present Value $MM (20 years @ 15%)	$28.3

ETHANOL MANUFACTURE
ZYMOMONAS MOBILIS
INHIBITED SYSTEM - PLUG FLOW - CELL RECYCLE

INVESTMENT

CONDITIONS

Sited in Iowa on the Mississippi River adjacent to a corn wet mill and a utility power house for over-the-fence supply of syrup and power.

	UNITS	THIS CASE
CAPACITY @ 8000 HRS	MM GPY	60.0
MID-POINT OF CONSTRUCTION	YEAR	1984
CONSTRUCTION COST INDEX	1980=100	128
INVESTMENT CONTINGENCY	% INSTALLED *	30%
FERMENTER UNIT INVESTMENT	$/GR.GAL.-GROWTH	$0.00
	$/GR.GAL.-PROD'N	$13.86

*40% Recommended for new processes

DIRECT PERMANENT INVESTMENT

	SCALE FACTOR		THIS CASE $MM	THIS CASE $/ANN.GAL.
FERMENTATION SECTION				
Receiving, Prep & Sterilization	0.60		$9.07	$0.151
Air Compression & Aeration	0.60		0.00	0.000
Fermentation	0.89-1.00		0.93	0.015
Product/Cell Separation	0.75		2.81	0.047
Fermentation Sub-total			$12.81	$0.213
DISTILLATION SECTION	STILLS	HX'S		
Beer Still #1	$0.94	$2.75	$3.69	$0.061
Beer Still #2	0.41	0.76	1.17	0.019
Low-Boilers Still #1	0.25	0.17	0.42	0.007
Low-Boilers Still #2	0.00	0.00	0.00	0.000
Low-Boilers Still #3	0.00	0.00	0.00	0.000
High-Boilers Still #1	0.00	0.00	0.00	0.000
High-Boilers Still #2	0.00	0.00	0.00	0.000
Azeotrope Still	1.41	1.84	3.25	0.054
Benzene Dehydrator	0.29	0.10	0.40	0.007
Decanter			0.03	0.001
Distillation Subtotal			$8.96	$0.149
STORAGE SECTION				
Storage - Product			$7.52	$0.125
Storage - Byproduct #1			$0.00	0.000
Storage - Byproduct #2			$0.00	0.000
			$7.52	$0.125
TOTAL DIRECT PLANT			$29.29	$0.488

ETHANOL MANUFACTURE
ZYMOMONAS MOBILIS
INHIBITED SYSTEM - PLUG FLOW - CELL RECYCLE

INVESTMENT

ALLOCATED PERMANENT INVESTMENT

	UNITS	API/UNIT BASECASE	API/UNIT THIS CASE	UNITS	$MM	$/ANN.GAL
ELECTRICITY	KW	$183	$183	641	$0.12	$0.002
STEAM	PPH	$45	$45	329,326	14.82	0.247
COOLING WATER	GPM	$52	$52	23,049	1.20	0.020
PROCESS WATER	GPM	$313	$313	484	0.15	0.003
WASTE DISPOSAL	MGPY	$3	$3	373,584	1.01	0.017
GEN'L & SERVICES	$MM	10%	10%	$26.3	2.63	0.044
TOTAL ALLOCATED PLANT					$19.93	$0.332
TOTAL PERMANENT INVESTMENT					$49.22	$0.820

WORKING CAPITAL

	BASIS	DAYS BASECASE	DAYS THIS CASE	$MM	$/ANN.GAL
RAW MAT'L INVENTORY	$RAW MATL	2	2	$0.28	$0.005
SEMI-FINISHED PRODUCT	$(R+M)/2	5	5	0.77	0.013
FINISHED PRODUCT	$COM	30	30	5.27	0.088
CASH	$(COS-D)	6	6	1.23	0.020
ACCOUNTS RCD.-TRADE	$SP	30	30	8.06	0.134
ACCOUNTS RCD.-MISC.	%COM	0.9%	0.9%	0.58	0.010
DEFERRED CHARGES	%COM	1.5%	1.5%	0.96	0.016
TOTAL WORKING CAPITAL				$17.13	$0.285

Note: R = raw materials; M or COM = cost of manufacture;
COS = cost of sales; SP = selling price; D = depreciation.

TOTAL INVESTMENT FOR RETURN	$66.35	$1.105

ETHANOL MANUFACTURE
ZYMOMONAS MOBILIS
INHIBITED SYSTEM - PLUG FLOW - CELL RECYCLE

PRICES & COST FACTORS	BASECASE	INFLATION FACTOR	THIS CASE
Operating Year	1988	1988	1988
Raw Materials			
-Biosugar Syrup	$0.065 /lb. d.s.	1.00	$0.065 /lb. d.s.
-Anhyd. Ammonia	$0.046 /lb.	1.00	$0.046 /lb.
-Phosphoric Acid	$0.155 /lb.	1.00	$0.155 /lb.
-Potassium Chloride	$0.053 /lb.	1.00	$0.053 /lb.
-Minor Nutrients	$0.451 /lb.	1.00	$0.451 /lb.
Utilities			
-Electricity	$0.040 /KWH	1.00	$0.040 /KWH
-Steam	$2.20 /M lb.	1.00	$2.20 /M lb.
-Cooling Water	$0.04 /M gal.	1.00	$0.04 /M gal.
-Process Water	$0.50 /M gal.	1.00	$0.50 /M gal.
-Biodegradation	$0.04 /lb. d.s.	1.00	$0.04 /lb. d.s.
-Landfill	$0.05 /lb. d.s.	1.00	$0.05 /lb. d.s.
Labor-Related			
-Dir. Op. Wages & Ben.	$26.40 /man-hr.	1.00	$26.40 /man-hr.
-Dir. Salaries & Benefi	18 % DOW&B	--	18 % DOW&B
-Op. Supplies & Service	6 % DOW&B	--	6 % DOW&B
-GPOH on Operations	23 % DOWS&B	--	23 % DOWS&B
-Control Lab	$19.22 /man-hr.	1.00	$19.22 /man-hr.
-Tech. Assist. to Mfg.	$22.06 /man-hr.	1.00	$22.06 /man-hr.
Capital-Related			
-Maint. Wages & Ben.	1.7 % DPI	--	1.7 % DPI
-Maint. Salaries & Ben.	25 % MW&B	--	25 % MW&B
-Maint. Mat'l & Service	40 % MW&B	--	40 % MW&B
-Maint. Overhead	4 % MW&B	--	4 % MW&B
-GPOH on Maintenance	23 % MWS&B	--	23 % MWS&B
-Taxes & Insurance	0.3 % DPI	--	0.3 % DPI
-Depreciation - DPI	8 % DPI	--	8 % DPI
-Depreciation - APS&G	6 % APS&G	--	6 % APS&G
Cost of Manufacture			
-Selling Expense	3 % Sales	--	3 % Sales
-Distribution	$0.01 /lb.	--	$0.01 /lb.
-Research & Development	4.5 % Sales	--	4.5 % Sales
-Administrative Expense	2 % Sales	--	2 % Sales
-Incentive Compensation	6 % PTE	--	6 % PTE
Cost of Sales			
-Pretax Earnings	30 % TIFR	--	30 % TIFR
-Credit: Byproduct #1	$0.00 /lb.	1.00	$0.00 /lb.
-Credit: Byproduct #2	$0.00 /lb.	1.00	$0.00 /lb.
-Credit: Byproduct #3	$0.00 /lb.	1.00	$0.00 /lb.
-Product Selling Price	$0.00 /lb.	1.00	$0.00 /lb.

SALARIES & WAGES
CONTINUOUS FERMENTER CASE

		250 MM PPY DAY SHIFT	ROTATING SHIFTS
DIRECT OPERATORS			
SYRUP RECEIVING & TRANSFER		1	-
CHEMICALS RECEIVING & TRANSFER		3	-
INNOCULUM PREPARATION		1	-
MEDIUM PREPARATION		-	1
STERILIZATION		-	1
FERMENTATION			
-CONTROL ROOM		-	2
-PATROL		-	2
-AIR COMPRESSION & AMMONIA FEED		-	1
DISTILLATION		-	3
BEER FILTER & CELL RECYCLE		-	2
TOTAL DAY & 4.2-SHIFT OPERATORS		5	12
TOTAL OPERATORS		55	
CONTROL LABORATORY			
BIOLOGICAL ANALYSIS		-	1
CHEMICAL ANALYSIS		-	1
OTHER		-	-
TOTAL DAY & 4.2-SHIFT TECHNICIANS		0	8
TOTAL LAB FORCE INCL SUPERVISION @	20%	0.0	10.1
TOTAL LAB FORCE		10.1	
TECHNICAL ASSISTANCE TO MANUFACTURING			
PROCESS ENGINEERS		1	-

WAGES, SALARIES & BENEFITS SCHEDULE- 1988

OPERATING WAGES - $/HOUR	$20.14
TECHNICIANS - ANNUAL $	$30,500
PROCESS ENGINEERS - ANNUAL $	$35,000
PENSION - AS % OF COMPENSATION	8.1%
FICA	5.8%
UNEMPLOYMENT COMPENSATION	0.6%
GROUP LIFE INSURANCE	0.7%
MEDICAL INSURANCE	3.6%
DENTAL INSURANCE	0.8%
SAVINGS PLAN	2.5%
VACATION	7.4%
ILLNESS	1.4%
ABSENCE WITH PERMISSION	0.2%
TOTAL BENEFITS	31.1%

SALARIES & WAGES
CONTINUOUS FERMENTER CASE

DIRECT OPERATORS		MIN. FORCE DAY SHIFT	MIN. FORCE ROTATING SHIFTS
SYRUP RECEIVING & TRANSFER		1	-
CHEMICALS RECEIVING & TRANSFER			-
INNOCULUM PREPARATION		1	-
MEDIUM PREPARATION		1	-
STERILIZATION			-
FERMENTATION			
-CONTROL ROOM		-	1
-PATROL		-	1
-AIR COMPRESSION & AMMONIA FEED		-	1
DISTILLATION		-	1
BEER FILTER & CELL RECYCLE		-	1
TOTAL DAY & 4.2-SHIFT OPERATORS		3	5
TOTAL OPERATORS		24	
CONTROL LABORATORY			
BIOLOGICAL ANALYSIS		-	1
CHEMICAL ANALYSIS		-	1
OTHER		-	-
TOTAL DAY & 4.2-SHIFT TECHNICIANS		0	8
TOTAL LAB FORCE INCL SUPERVISION @	20%	0.0	10.1
TOTAL LAB FORCE		10.1	
TECHNICAL ASSISTANCE TO MANUFACTURING			
PROCESS ENGINEERS		1	-

WAGES, SALARIES & BENEFITS SCHEDULE- 1988

OPERATING WAGES - $/HOUR
TECHNICIANS - ANNUAL $
PROCESS ENGINEERS - ANNUAL $

PENSION - AS % OF COMPENSATION
FICA
UNEMPLOYMENT COMPENSATION
GROUP LIFE INSURANCE
MEDICAL INSURANCE
DENTAL INSURANCE
SAVINGS PLAN
VACATION
ILLNESS
ABSENCE WITH PERMISSION

TOTAL BENEFITS

ETHANOL MANUFACTURE
ZYMOMONAS MOBILIS
INHIBITED SYSTEM - PLUG FLOW - CELL RECYCLE

1988 COST SHEET	RATE /UNIT	MILLION UNITS	$MILLION	$/gal
Raw Materials				
-Biosugar Syrup	$0.065 /lb. d.s.	736.06	47.84	0.885
-Anhyd. Ammonia	$0.046 /lb.	1.07	0.05	0.001
-Phosphoric Acid	$0.155 /lb.	0.60	0.09	0.002
-Potassium Chloride	$0.053 /lb.	0.45	0.02	.000
-Minor Nutrients	$0.451 /lb.	0.21	0.09	0.002
Total Raw Materials			$48.10	$0.890
Utilities				
-Electricity	$0.040 /KWH	4.57	0.18	0.003
-Steam	$2.20 /M lb.	2.3474	5.16	0.096
-Cooling Water	$0.04 /M gal.	9.86	0.39	0.007
-Process Water	$0.50 /M gal.	0.21	0.10	0.002
-Biodegradation	$0.04 /lb. d.s.	2.47	0.10	0.002
-Landfill	$0.05 /lb. d.s.	0.00	0.00	0.000
Total Utilities			$5.95	$0.110
Labor-Related				
-Dir. Op. Wages & Ben.	$26.40 /man-hr.	0.125	3.29	0.061
-Dir. Salaries & Ben.	18 % DOW&B		0.59	0.011
-Op. Supplies & Service	6 % DOW&B		0.20	0.004
-GPOH on Operations	23 % DOWS&B		0.89	0.017
-Control Lab	$19.22 /man-hr.	0.020	0.39	0.007
-Tech. Assist. to Mfg.	$22.06 /man-hr.	0.002	0.04	0.001
Total Labor			$5.40	$0.100
Capital-Related				
-Maint. Wages & Ben.	1.7 % DPI	$29.3	0.50	0.009
-Maint. Salaries & Ben.	25 % MW&B		0.12	0.002
-Maint. Mat'l & Service	40 % MW&B		0.20	0.004
-Maint. Overhead	4 % MW&B		0.02	.000
-GPOH on Maintenance	23 % MWS&B		0.14	0.003
-Taxes & Insurance	0.3 % DPI	$29.3	0.09	0.002
-Depreciation - DPI	8 % DPI	$29.3	2.34	0.043
-Depreciation - APS&G	6 % APS&G	$19.9	1.20	0.022
Total Capital			$4.61	0.085
			-----	-----
Cost of Manufacture			$64.06	$1.186
-Selling Expense	3 % Sales	$98.0	2.94	0.054
-Distribution	$0.01 /lb.	355.6	3.56	0.066
-Research & Development	5 % Sales	$98.0	4.41	0.082
-Administrative Expense	2 % Sales	$98.0	1.96	0.036
-Incentive Compensation	6 % PTE	$19.9	1.19	0.022
			-----	-----
Cost of Sales			$78.12	$1.446
-Pretax Earnings	30.0 % TIFR	$66.3	19.90	0.368
-Credit: Byproduct #1	$0.00 /lb.	0.0	0.00	0.000
-Credit: Byproduct #2	$0.00 /lb.	0.0	0.00	0.000
-Credit: Byproduct #3	$0.00 /lb.	0.0	0.00	0.000
			-----	-----
Total Sales			$98.02	$1.814

ETHANOL MANUFACTURE
ZYMOMONAS MOBILIS
INHIBITED SYSTEM - PLUG FLOW - CELL RECYCLE

CASH FLOW (MILLION DOLLARS/YEAR)

Scenario:

1. Investment split evenly over three construction years.
2. Plant operates at 50% of full scale the first year.
3. " " 75% " " the second year.
4. " " 100% " " the third year.
5. " " 100% " " thereafter.
6. Five year depreciation rate; half-year convention; (20, 32, 19.2, 11.5, 11.5, 5.8 %); taxes: 34% fed, 3% state.

YEAR	INVESTMENT PI	WC	DEP.	COST EX D	SALES	NET EARN	ANN CASH
1983	$9.76						($9.76)
1984	$9.76						($9.76)
1985	$9.76						($9.76)
1986		$17.13	$5.86	$42.38	$49.01	$0.48	($10.79)
1987			$9.37	$61.69	$73.51	$1.55	$10.92
1988			$5.62	$74.58	$98.02	$11.22	$16.84
1989			$3.37	$74.58	$98.02	$12.64	$16.01
1990			$3.37	$74.58	$98.02	$12.64	$16.01
1991			$1.70	$74.58	$98.02	$13.69	$15.39
1992				$74.58	$98.02	$14.76	$14.76
1993				$74.58	$98.02	$14.76	$14.76
1994				$74.58	$98.02	$14.76	$14.76
1995				$74.58	$98.02	$14.76	$14.76
1996				$74.58	$98.02	$14.76	$14.76
1997				$74.58	$98.02	$14.76	$14.76
1998				$74.58	$98.02	$14.76	$14.76
1999				$74.58	$98.02	$14.76	$14.76
2000				$74.58	$98.02	$14.76	$14.76
2001				$74.58	$98.02	$14.76	$14.76
2002				$74.58	$98.02	$14.76	$14.76
2003				$74.58	$98.02	$14.76	$14.76
2004				$74.58	$98.02	$14.76	$14.76
2005		($17.13)		$74.58	$98.02	$14.76	$31.90

NET RETURN ON INVESTMENT-3RD OPERATING YEAR = 15.6%

ETHANOL MANUFACTURE
ZYMOMONAS MOBILIS
INHIBITED SYSTEM - PLUG FLOW - CELL RECYCLE

CASH FLOW (MILLION DOLLARS/YEAR)

Scenario:
1. Investment split evenly over three construction years.
2. Plant operates at 50% of full scale the first year.
3. " " 75% " " the second year.
4. " " 100% " " the third year.
5. " " 100% " " thereafter.
6. Five year depreciation rate; half-year convention; (20, 32, 19.2, 11.5, 11.5, 5.8 %); taxes: 34% fed, 3% state.

YEAR	CUM CASH	NPV @ 15%	%IRR
1983	($9.76)	($9.76)	--
1984	($19.53)	($18.25)	--
1985	($29.29)	($25.64)	--
1986	($40.08)	($32.73)	-205.0%
1987	($29.16)	($26.49)	-46.3%
1988	($12.32)	($18.11)	-11.5%
1989	$3.69	($11.19)	2.5%
1990	$19.70	($5.17)	10.3%
1991	$35.09	($0.14)	14.9%
1992	$49.86	$4.06	17.8%
1993	$64.62	$7.70	19.8%
1994	$79.38	$10.88	21.2%
1995	$94.15	$13.64	22.3%
1996	$108.91	$16.04	23.0%
1997	$123.67	$18.12	23.6%
1998	$138.44	$19.94	24.0%
1999	$153.20	$21.52	24.3%
2000	$167.97	$22.89	24.6%
2001	$182.73	$24.08	24.7%
2002	$197.49	$25.12	24.9%
2003	$212.26	$26.02	25.0%
2004	$227.02	$26.80	25.1%
2005	$258.91	$28.28	25.2%

ETHANOL MANUFACTURE
ZYMOMONAS MOBILIS
INHIBITED SYSTEM - PLUG FLOW - CELL RECYCLE

BASIC DATA

SCALE OF OPERATION

355.6	MM PPY	ANNUAL PRODUCTION LEVEL
54.0	MM GPY	" " "
395.1	MM PPY	ANNUAL CAPACITY
60.0	MM GPY	" "
90	%	OPERATING UTILITY
362.6	MM PPY	PRODUCT FORMED IN BEER
402.9	MM PPY	PRODUCT FORMED IN BEER AT CAPACITY
98.0	%	MOLAR YIELD-GLUC. TO PROD. IN BEER (E
2.03	lb/lb	GLUCOSE DEMAND/PROD (EXCL. SPILL)
46.07	MOL WT	PRODUCT MOLECULAR WEIGHT

PRODUCT STOICHIOMETRY

MOL. WT.	MOLES/MOL PRODUCT		COMPONENT
180.16	0.50842	/MOL PROD.	-GLUCOSE CONSUMED
32.00	0.00000	/MOL PROD.	-OXYGEN CONSUMED
17.02	0.00000	/MOL PROD.	-AMMONIA CONSUMED
44.05	0.00000	/MOL PROD.	-ACETALDEHYDE FORMED (#1)
.00		/MOL PROD.	-COMPONENT #2 FORMED
.00		/MOL PROD.	-COMPONENT #3 FORMED
.00		/MOL PROD.	-COMPONENT #4 FORMED
.00		/MOL PROD.	-COMPONENT #5 FORMED
88.10	0.00052	/MOL PROD.	-LIGHT ENDS FORMED (#6)
46.07	1.00000	/MOL PROD.	-ETHANOL FORMED (#7)
.00		/MOL PROD.	-COMPONENT #8 FORMED
.00		/MOL PROD.	-COMPONENT #9 FORMED
.00		/MOL PROD.	-COMPONENT #10 FORMED
18.02	-0.01649	/MOL PROD.	-WATER FORMED
60.05	0.00541	/MOL PROD.	-ACETIC ACID FORMED (#11)
88.15	0.00000	/MOL PROD.	-ISOAMYL ALCOHOL FORMED (#12)
92.09	0.00567	/MOL PROD.	-GLYCERINE FORMED (#13)
.00		/MOL PROD.	-COMPONENT #14 FORMED
90.08	0.00103	/MOL PROD.	-LACTIC ACID FORMED (#15)
118.09	0.00000	/MOL PROD.	-SUCCINIC ACID FORMED (#16)
.00		/MOL PROD.	-COMPONENT #17 FORMED
.00		/MOL PROD.	-COMPONENT #18 FORMED
.00		/MOL PROD.	-COMPONENT #19 FORMED
.00		/MOL PROD.	-COMPONENT #20 FORMED
44.01	1.01753	/MOL PROD.	-CARBON DIOXIDE FORMED
2.02	0.02835	/MOL PROD.	-HYDROGEN FORMED

ETHANOL MANUFACTURE
ZYMOMONAS MOBILIS
INHIBITED SYSTEM - PLUG FLOW - CELL RECYCLE

BASIC DATA

NUTRIENTS IN FERMENTER FEED

12	%	-N IN CELLS AS %CHO
80.9	mg/g cells	-H3PO4
61.6	mg/g cells	-KCl
27.9	mg/g cells	-MINOR NUTRIENTS
23.6	mg/g cells	-MgSO4.7H2O
0.01	mg/g cells	-VITAMIN B1
1.25	mg/g cells	-KI
0.89	mg/g cells	-NiCl2
0.72	mg/g cells	-FeCl3.6H2O
0.55	mg/g cells	-CaCl2.2H2O
0.54	mg/g cells	-H3BO3
0.22	mg/g cells	-ZnSO4.7H2O
0.15	mg/g cells	-MnSO4.H2O
7.7	ug/g cells	-CuSO4.5H2O
5.4	ug/g cells	-NaMoO4.2H2O
4.3	ug/g cells	-CoCl2.6H2O

FERMENTATION

TYPE	0	(0 OR 1)	-ANAEROBIC (0) OR AEROBIC (1)
STAGES	0	(0 OR 1)	-CONCUR'NT (0) OR SEQUENT'AL (1)
CULTURE MODE	1	(0 OR 1)	-BATCH (0) OR CONTINUOUS (1)
PROD INHIBITION	0	(0 OR 1)	-WITH (0) OR WITHOUT (1)

CONDITIONS

STAGE: GROWTH	PRODUCTION		
33	33	C	-TEMPERATURE
5.0	5.0		-pH
0	110	g/l **	-PRODUCT CONCENTRATION IN BEER
2.067	30.000	g/l	-CELL DENSITY (CHO ONLY)
0.00	1.147	1/hr	-DILUTION RATE * ERR
			-PRODUCT PRODUCTIVITY
	5.20	g/g*hr	-Max Specific, g/g cells*hr
	1		-Kinetics: CSTR (0) or Plug Flow
	80.9	%	-Activity Factor, % Max
	4.21	g/g*hr	-Specific, g/g cells*hr
0.00	126.21	g/l*hr	-Volumetric, g/l*hr *
2.37	0.00	g/l*hr	-CELL PRODUCTIVITY (CHO ONLY)
84	0	mM/l*hr	-OXYGEN TRANSFERRED
5	0	mM/mM	-OXYGEN FED / OXYGEN STOICH. DEMAND
--	0.1	g/l	-GLUCOSE SPILL
5	5	C	-COOLING WATER TEMPERATURE
--	19	kcal/gmol	-HEAT EVOLVED-PRODUCT FORMATION
105	767	Btu/hr*gal	-HEAT REMOVED BY COOLING COILS

* w/12 hrs batch mode turnaround

FERMENTERS

0	48,305	gallons	-ACTIVE VOLUME REQUIRED
15	15	% gross	-HEADSPACE
0	66,858	gallons	-GROSS VOLUME (incl. 15% spares)
0	35,000	gallons	-GROSS SIZE

ETHANOL MANUFACTURE
ZYMOMONAS MOBILIS
INHIBITED SYSTEM - PLUG FLOW - CELL RECYCLE

BASIC DATA

0.0	1.9 units	-NUMBER OF UNITS

PRODUCT SEPARATION

250 g/l	-CELL CONC. (CHO) EX FILTER
0.053 gal/min*sf	-FILTER THROUGHPUT
16,715 sq ft	-FILTER SIZE

PRODUCT RECOVERY & PURIFICATION

98.1%(wt)%	-YIELD ACROSS REFINING

MATERIALS OF CONSTRUCTION

	CHOICES	SELECTION
FERMENTERS	1,3	1
STILLS	1,2,3,4,5	1
HEAT EXCHANGERS	1,3,5,6	1
STORAGE TANKS	1,3	1

FOR WHICH:
1=CARBON STEEL
2=CARBON STEEL w/304 SS TRAYS
3=304 STAINLESS STEEL
4=304L STAINLESS STEEL
5=316 STAINLESS STEEL
6=MONEL

RETURN ON INVESTMENT

To Calculate Selling Price Required to Provide a Fixed Return,
Enter the Desired Return on Investment: 30 %
OR
To Calculate the ROI Resulting from a Fixed Market Price,
Enter the Market Price for: 1988 /lb.

Enter an Investment Contingency to Represent
the Risk Level of the Basic Data 30 %

VENTURE TIMING

Midpoint of Construction (i.e. 19XX)	1984	-4
Operating Year (i.e. 19XX)	1988	

DISTILLATION DATA MATRIX

ITEM	COMPONENT	DEFAULT VALUE	IMPURITY #1	IMPURITY #2	LOWER BOIL PRODUCT #3
1	NAME				
2	PRIORITY AS REFINED PRODUCT	LIST 1-4			
3					
4	NORMAL BOILING PT, C				
5	LOSS/COLUMN, WT %	0.50			
6	LEVEL AS IMPURITY, WT%	0.20			
7	VAP PRESS TEMP, C	900			
8	VAPOR PRESS, mm Hg	800000			
9	HT VAPORIZATION, Btu/lb	215.0			
10	SENSIBLE HT (LIQ), Btu/(lb)	0.50			
11	MAX THERMAL STABILITY, C	150			
12	LN(ACTIVITY COEFFICIENTS)				
13	-COMP. #1 in:	*	xxxx	0.100	0.100
14	-COMP. #2 in:	*	0.100	xxxx	0.100
15	-COMP. #3 in:	*	0.100	0.100	xxxx
16	-COMP. #4 in:	*	0.100	0.100	0.100
17	-COMP. #5 in:	*	0.100	0.100	0.100
18	-COMP. #6 in:	*	0.100	0.100	0.100
19	-COMP. #7 in:	*	0.100	0.100	0.100
20	-COMP. #8 in:	*	0.100	0.100	0.100
21	-COMP. #9 in:	*	0.100	0.100	0.100
22	-COMP. #10 in:	*	0.100	0.100	0.100
23	-WATER in:	*	0.600	0.600	0.600
24	-COMP. #11 in:	*	0.100	0.100	0.100
25	-COMP. #12 in:	*	0.100	0.100	0.100
26	-COMP. #13 in:	*	0.100	0.100	0.100
27	-COMP. #14 in:	*	0.100	0.100	0.100
28	-COMP. #15 in:	*	0.100	0.100	0.100
29	-COMP. #16 in:	*	0.100	0.100	0.100
30	-COMP. #17 in:	*	0.100	0.100	0.100
31	-COMP. #18 in:	*	0.100	0.100	0.100
32	-COMP. #19 in:	*	0.100	0.100	0.100
33	-COMP. #20 in:	*	0.100	0.100	0.100

* The following values can be used in lieu of actual activity coefficients; however, the uncertainty of the calculation is raised significantly:

alcohol/alcohol; ketone/ketone; aldehyde/aldehyde = 0.1
aldehyde/ketone = 0.3
other organic/other organic = 0.5
alcohol/water = 0.6
other organic/water = 1.0

ITEM	COMPONENT	DEFAULT VALUE	IMPURITY #1	IMPURITY #2	LOWER BOIL PRODUCT #3
34	B(n) VAPOR PRESSURE CONST.		-2476.10	-2476.10	-2476.10
35	A(n) VAPOR PRESSURE CONST.		15.703	15.703	15.703
36	VAPOR PRESSURE @40 C		2422.2	2422.2	2422.2
37	VAPOR PRESSURE @120 C		12121.9	12121.9	12121.9

DISTILLATION DATA MATRIX

ITEM	COMPONENT	DEFAULT VALUE	IMPURITY #4	IMPURITY #5	IMPURITY #6
1	NAME			ACETALHD	LITE ENDS
2	PRIORITY AS REFINED PRODUCT	LIST			
3					
4	NORMAL BOILING PT, C			20.2	57.8
5	LOSS/COLUMN, WT %	0.50			
6	LEVEL AS IMPURITY, WT%	0.20		0.00	.00
7	VAP PRESS TEMP, C	900		-10.0	-0.5
8	VAPOR PRESS, mm Hg	800000		200.0	60.0
9	HT VAPORIZATION, Btu/lb	215.0		244.8	176.4
10	SENSIBLE HT (LIQ), Btu/(lb)	0.50		0.50	0.47
11	MAX THERMAL STABILITY, C	150			
12	LN(ACTIVITY COEFFICIENTS)				
13	-COMP. #1 in:	*			
14	-COMP. #2 in:	*			
15	-COMP. #3 in:	*			
16	-COMP. #4 in:	*	xxxx		
17	-COMP. #5 in:	*		xxxx	
18	-COMP. #6 in:	*			xxxx
19	-COMP. #7 in:	*			
20	-COMP. #8 in:	*			
21	-COMP. #9 in:	*			
22	-COMP. #10 in:	*			
23	-WATER in:	*			
24	-COMP. #11 in:	*			
25	-COMP. #12 in:	*			
26	-COMP. #13 in:	*			
27	-COMP. #14 in:	*			
28	-COMP. #15 in:	*			
29	-COMP. #16 in:	*			
30	-COMP. #17 in:	*			
31	-COMP. #18 in:	*			
32	-COMP. #19 in:	*			
33	-COMP. #20 in:	*			

* The following values can be used in lieu of actual activity coefficients; however, the uncertainty of the calculation is raised significantly:

alcohol/alcohol; ketone/ketone; aldehyde/aldehyde = 0.1
aldehyde/ketone = 0.3
other organic/other organic = 0.5
alcohol/water = 0.6
other organic/water = 1.0

ITEM	COMPONENT	DEFAULT VALUE	IMPURITY #4	IMPURITY #5	IMPURITY #6
34	B(n) VAPOR PRESSURE CONST.		-2476.10	-3408.74	-3925.74
35	A(n) VAPOR PRESSURE CONST.		15.703	18.259	18.501
36	VAPOR PRESSURE @40 C		2422.2	1585.7	387.0
37	VAPOR PRESSURE @120 C		12121.9	14554.7	4972.0

DISTILLATION DATA MATRIX

ITEM	COMPONENT	DEFAULT VALUE	LOW BOIL PRODUCT #7	IMPURITY #8	IMPURITY #9
1	NAME		ETHANOL		
2	PRIORITY AS REFINED PRODUCT	LIST	1		
3					
4	NORMAL BOILING PT, C		78.4		
5	LOSS/COLUMN, WT %	0.50			
6	LEVEL AS IMPURITY, WT%	0.20			
7	VAP PRESS TEMP, C	900	18.0		
8	VAPOR PRESS, mm Hg	800000	40.0		
9	HT VAPORIZATION, Btu/lb	215.0	367.2		
10	SENSIBLE HT (LIQ), Btu/(lb)	0.50	0.68		
11	MAX THERMAL STABILITY, C	150			
12	LN(ACTIVITY COEFFICIENTS)				
13	-COMP. #1 in:	*	0.100	0.100	0.100
14	-COMP. #2 in:	*	0.100	0.100	0.100
15	-COMP. #3 in:	*	0.100	0.100	0.100
16	-COMP. #4 in:	*	0.100	0.100	0.100
17	-COMP. #5 in:	*	0.100	0.100	0.100
18	-COMP. #6 in:	*	0.100	0.100	0.100
19	-COMP. #7 in:	*	xxxx	0.100	0.100
20	-COMP. #8 in:	*	0.100	xxxx	0.100
21	-COMP. #9 in:	*	0.100	0.100	xxxx
22	-COMP. #10 in:	*	0.100	0.100	0.100
23	-WATER in:	*	0.600	0.600	0.600
24	-COMP. #11 in:	*	0.100	0.100	0.100
25	-COMP. #12 in:	*	0.100	0.100	0.100
26	-COMP. #13 in:	*	0.100	0.100	0.100
27	-COMP. #14 in:	*	0.100	0.100	0.100
28	-COMP. #15 in:	*	0.100	0.100	0.100
29	-COMP. #16 in:	*	0.100	0.100	0.100
30	-COMP. #17 in:	*	0.100	0.100	0.100
31	-COMP. #18 in:	*	0.100	0.100	0.100
32	-COMP. #19 in:	*	0.100	0.100	0.100
33	-COMP. #20 in:	*	0.100	0.100	0.100

* The following values can be used in lieu of actual activity coefficients; however, the uncertainty of the calculation is raised significantly:

alcohol/alcohol; ketone/ketone; aldehyde/aldehyde = 0.1
aldehyde/ketone = 0.3
other organic/other organic = 0.5
alcohol/water = 0.6
other organic/water = 1.0

ITEM	COMPONENT	DEFAULT VALUE	LOW BOIL PRODUCT #7	IMPURITY #8	IMPURITY #9
34	B(n) VAPOR PRESSURE CONST.		-4984.94	-2476.10	-2476.10
35	A(n) VAPOR PRESSURE CONST.		20.819	15.703	15.703
36	VAPOR PRESSURE @40 C		133.3	2422.2	2422.2
37	VAPOR PRESSURE @120 C		3411.6	12121.9	12121.9

DISTILLATION DATA MATRIX

ITEM	COMPONENT	DEFAULT VALUE	IMPURITY #10	WATER	IMPURITY #11
1	NAME				ACET ACD
2	PRIORITY AS REFINED PRODUCT	LIST			
3					
4	NORMAL BOILING PT, C			100.0	118.1
5	LOSS/COLUMN, WT %	0.50			
6	LEVEL AS IMPURITY, WT%	0.20			
7	VAP PRESS TEMP, C	900		30.0	20.0
8	VAPOR PRESS, mm Hg	800000		31.8	11.7
9	HT VAPORIZATION, Btu/lb	215.0		970.3	174.2
10	SENSIBLE HT (LIQ), Btu/(lb)	0.50		1.00	0.52
11	MAX THERMAL STABILITY, C	150			
12	LN(ACTIVITY COEFFICIENTS)				
13	-COMP. #1 in:	*	0.100	0.600	0.100
14	-COMP. #2 in:	*	0.100	0.600	0.100
15	-COMP. #3 in:	*	0.100	0.600	0.100
16	-COMP. #4 in:	*	0.100	0.600	0.100
17	-COMP. #5 in:	*	0.100	0.600	0.100
18	-COMP. #6 in:	*	0.100	0.600	0.100
19	-COMP. #7 in:	*	0.100	0.600	0.100
20	-COMP. #8 in:	*	0.100	0.600	0.100
21	-COMP. #9 in:	*	0.100	0.600	0.100
22	-COMP. #10 in:	*	xxxx	0.600	0.100
23	-WATER in:	*	0.600	xxxx	0.600
24	-COMP. #11 in:	*	0.100	0.600	xxxx
25	-COMP. #12 in:	*	0.100	0.600	0.100
26	-COMP. #13 in:	*	0.100	0.600	0.100
27	-COMP. #14 in:	*	0.100	0.600	0.100
28	-COMP. #15 in:	*	0.100	0.600	0.100
29	-COMP. #16 in:	*	0.100	0.600	0.100
30	-COMP. #17 in:	*	0.100	0.600	0.100
31	-COMP. #18 in:	*	0.100	0.600	0.100
32	-COMP. #19 in:	*	0.100	0.600	0.100
33	-COMP. #20 in:	*	0.100	0.600	0.100

* The following values can be used in lieu of actual activity coefficients; however, the uncertainty of the calculation is raised significantly:

alcohol/alcohol; ketone/ketone; aldehyde/aldehyde = 0.1
aldehyde/ketone = 0.3
other organic/other organic = 0.5
alcohol/water = 0.6
other organic/water = 1.0

ITEM	COMPONENT	DEFAULT VALUE	IMPURITY #10	WATER	IMPURITY #11
34	B(n) VAPOR PRESSURE CONST.		-2476.10	-5123.15	-4875.41
35	A(n) VAPOR PRESSURE CONST.		15.703	20.368	19.099
36	VAPOR PRESSURE @40 C		2422.2	54.6	33.9
37	VAPOR PRESSURE @120 C		12121.9	1528.9	807.2

DISTILLATION DATA MATRIX

ITEM	COMPONENT	DEFAULT VALUE	IMPURITY #12	IMPURITY #13	HIGH BOIL PRODUCT #14
1	NAME		I-AM ALK	GLYCERINE	
2	PRIORITY AS REFINED PRODUCT	LIST			
3					
4	NORMAL BOILING PT, C		130.5	290.0	
5	LOSS/COLUMN, WT %	0.50			
6	LEVEL AS IMPURITY, WT%	0.20			
7	VAP PRESS TEMP, C	900	40.8	153.8	
8	VAPOR PRESS, mm Hg	800000	10.0	5.0	
9	HT VAPORIZATION, Btu/lb	215.0	198.0	396.0	
10	SENSIBLE HT (LIQ), Btu/(lb)	0.50	0.72	0.58	
11	MAX THERMAL STABILITY, C	150			
12	LN(ACTIVITY COEFFICIENTS)				
13	-COMP. #1 in:	*	0.100	0.100	0.100
14	-COMP. #2 in:	*	0.100	0.100	0.100
15	-COMP. #3 in:	*	0.100	0.100	0.100
16	-COMP. #4 in:	*	0.100	0.100	0.100
17	-COMP. #5 in:	*	0.100	0.100	0.100
18	-COMP. #6 in:	*	0.100	0.100	0.100
19	-COMP. #7 in:	*	0.100	0.100	0.100
20	-COMP. #8 in:	*	0.100	0.100	0.100
21	-COMP. #9 in:	*	0.100	0.100	0.100
22	-COMP. #10 in:	*	0.100	0.100	0.100
23	-WATER in:	*	0.600	0.600	0.600
24	-COMP. #11 in:	*	0.100	0.100	0.100
25	-COMP. #12 in:	*	xxxx	0.100	0.100
26	-COMP. #13 in:	*	0.100	xxxx	0.100
27	-COMP. #14 in:	*	0.100	0.100	xxxx
28	-COMP. #15 in:	*	0.100	0.100	0.100
29	-COMP. #16 in:	*	0.100	0.100	0.100
30	-COMP. #17 in:	*	0.100	0.100	0.100
31	-COMP. #18 in:	*	0.100	0.100	0.100
32	-COMP. #19 in:	*	0.100	0.100	0.100
33	-COMP. #20 in:	*	0.100	0.100	0.100

* The following values can be used in lieu of actual activity coefficients; however, the uncertainty of the calculation is raised significantly:

alcohol/alcohol; ketone/ketone; aldehyde/aldehyde = 0.1
aldehyde/ketone = 0.3
other organic/other organic = 0.5
alcohol/water = 0.6
other organic/water = 1.0

ITEM	COMPONENT	DEFAULT VALUE	IMPURITY #12	IMPURITY #13	HIGH BOIL PRODUCT #14
34	B(n) VAPOR PRESSURE CONST.		-6113.16	-8863.29	-2476.10
35	A(n) VAPOR PRESSURE CONST.		21.784	22.376	15.703
36	VAPOR PRESSURE @40 C		9.5	.0	2422.2
37	VAPOR PRESSURE @120 C		507.0	0.8	12121.9

DISTILLATION DATA MATRIX

ITEM	COMPONENT	DEFAULT VALUE	IMPURITY #15	IMPURITY #16	IMPURITY #17
1	NAME		LAC ACD	SUC ACD	
2	PRIORITY AS REFINED PRODUCT	LIST			
3					
4	NORMAL BOILING PT, C				
5	LOSS/COLUMN, WT %	0.50			
6	LEVEL AS IMPURITY, WT%	0.20			
7	VAP PRESS TEMP, C	900			
8	VAPOR PRESS, mm Hg	800000			
9	HT VAPORIZATION, Btu/lb	215.0	540.0	396.0	
10	SENSIBLE HT (LIQ), Btu/(lb)	0.50	0.56	0.58	
11	MAX THERMAL STABILITY, C	150			
12	LN(ACTIVITY COEFFICIENTS)				
13	-COMP. #1 in:	*			
14	-COMP. #2 in:	*			
15	-COMP. #3 in:	*			
16	-COMP. #4 in:	*			
17	-COMP. #5 in:	*			
18	-COMP. #6 in:	*			
19	-COMP. #7 in:	*			
20	-COMP. #8 in:	*			
21	-COMP. #9 in:	*			
22	-COMP. #10 in:	*			
23	-WATER in:	*			
24	-COMP. #11 in:	*			
25	-COMP. #12 in:	*			
26	-COMP. #13 in:	*			
27	-COMP. #14 in:	*			
28	-COMP. #15 in:	*	xxxx		
29	-COMP. #16 in:	*		xxxx	
30	-COMP. #17 in:	*			xxxx
31	-COMP. #18 in:	*			
32	-COMP. #19 in:	*			
33	-COMP. #20 in:	*			

* The following values can be used in lieu of actual activity coefficients; however, the uncertainty of the calculation is raised significantly:

alcohol/alcohol; ketone/ketone; aldehyde/aldehyde = 0.1
aldehyde/ketone = 0.3
other organic/other organic = 0.5
alcohol/water = 0.6
other organic/water = 1.0

ITEM	COMPONENT	DEFAULT VALUE	IMPURITY #15	IMPURITY #16	IMPURITY #17
34	B(n) VAPOR PRESSURE CONST.		-2476.10	-2476.10	-2476.10
35	A(n) VAPOR PRESSURE CONST.		15.703	15.703	15.703
36	VAPOR PRESSURE @40 C		2422.2	2422.2	2422.2
37	VAPOR PRESSURE @120 C		12121.9	12121.9	12121.9

DISTILLATION DATA MATRIX

ITEM	COMPONENT	DEFAULT VALUE	--------------------HIGHER BOIL PRODUCT #18	IMPURITY #19	IMPURITY #20
1	NAME				
2	PRIORITY AS REFINED PRODUCT	LIST			
3					
4	NORMAL BOILING PT, C				
5	LOSS/COLUMN, WT %	0.50			
6	LEVEL AS IMPURITY, WT%	0.20			
7	VAP PRESS TEMP, C	900			
8	VAPOR PRESS, mm Hg	800000			
9	HT VAPORIZATION, Btu/lb	215.0			
10	SENSIBLE HT (LIQ), Btu/(lb)	0.50			
11	MAX THERMAL STABILITY, C	150			
12	LN(ACTIVITY COEFFICIENTS)				
13	-COMP. #1 in:	*	0.100	0.100	0.100
14	-COMP. #2 in:	*	0.100	0.100	0.100
15	-COMP. #3 in:	*	0.100	0.100	0.100
16	-COMP. #4 in:	*	0.100	0.100	0.100
17	-COMP. #5 in:	*	0.100	0.100	0.100
18	-COMP. #6 in:	*	0.100	0.100	0.100
19	-COMP. #7 in:	*	0.100	0.100	0.100
20	-COMP. #8 in:	*	0.100	0.100	0.100
21	-COMP. #9 in:	*	0.100	0.100	0.100
22	-COMP. #10 in:	*	0.100	0.100	0.100
23	-WATER in:	*	0.600	0.600	0.600
24	-COMP. #11 in:	*	0.100	0.100	0.100
25	-COMP. #12 in:	*	0.100	0.100	0.100
26	-COMP. #13 in:	*	0.100	0.100	0.100
27	-COMP. #14 in:	*	0.100	0.100	0.100
28	-COMP. #15 in:	*	0.100	0.100	0.100
29	-COMP. #16 in:	*	0.100	0.100	0.100
30	-COMP. #17 in:	*	0.100	0.100	0.100
31	-COMP. #18 in:	*	xxxx	0.100	0.100
32	-COMP. #19 in:	*	0.100	xxxx	0.100
33	-COMP. #20 in:	*	0.100	0.100	xxxx

* The following values can be used in lieu of actual activity coefficients; however, the uncertainty of the calculation is raised significantly:

alcohol/alcohol; ketone/ketone; aldehyde/aldehyde = 0.1
aldehyde/ketone = 0.3
other organic/other organic = 0.5
alcohol/water = 0.6
other organic/water = 1.0

ITEM	COMPONENT	DEFAULT VALUE	PRODUCT #18	IMPURITY #19	IMPURITY #20
34	B(n) VAPOR PRESSURE CONST.		-2476.10	-2476.10	-2476.10
35	A(n) VAPOR PRESSURE CONST.		15.703	15.703	15.703
36	VAPOR PRESSURE @40 C		2422.2	2422.2	2422.2
37	VAPOR PRESSURE @120 C		12121.9	12121.9	12121.9

OFTEN USED PARAMETERS

(THOUSAND ANNUAL POUNDS)

402,933	PRODUCT FORMED
	FORMED WITH PRODUCT
0	-ACETALDEHYDE
0	-COMPONENT #2
0	-COMPONENT #3
0	-COMPONENT #4
0	-COMPONENT #5
403	-LIGHT ENDS
402,933	-ETHANOL (PRODUCT)
0	-COMPONENT #8
0	-COMPONENT #9
0	-COMPONENT #10
(2,598)	-WATER
2,842	-ACETIC ACID
0	-ISOAMYL ALCOHOL
4,567	-GLYCERINE
0	-COMPONENT #14
812	-LACTIC ACID
0	-SUCCINIC ACID
0	-COMPONENT #17
0	-COMPONENT #18
0	-COMPONENT #19
0	-COMPONENT #20
500	-HYDROGEN
391,681	-CARBON DIOXIDE
	CONSUMED FOR PRODUCT
801,133	-GLUCOSE
0	-AMMONIA
0	-OXYGEN
8,175	CELLS PRODUCED - CHO
1,121	CELLS PRODUCED - NH2
	FORMED WITH CELLS
4,902	-WATER-CHO
631	-WATER-NH2
5,533	-WATER-TOTAL
11,983	-CARBON DIOXIDE-CHO
	CONSUMED FOR CELLS
16,350	-GLUCOSE-CHO
1,191	-AMMONIA-NH2
8,715	-OXYGEN-CHO
561	-OXYGEN-NH2
9,276	-OXYGEN-TOTAL
46,378	OXYGEN FED-GROWTH
153,584	NITROGEN FED-GROWTH
37,102	OXYGEN VENT-GROWTH
153,584	NITROGEN VENT-GROWTH
11,983	CARBON DIOXIDE VENT-GROWTH
6,213	WATER VENT GROWTH

OFTEN USED PARAMETERS

(THOUSAND ANNUAL POUNDS)

0	OXYGEN FED-PROD'N
0	NITROGEN FED-PROD'N
0	OXYGEN VENT-PROD'N
0	NITROGEN VENT-PROD'N
391,681	CARBON DIOXIDE VENT-PROD'N
14,515	WATER VENT-PROD'N
406,196	PHI

WATER BALANCE

WATER IN:

MAKE UP WATER	1,917,318
BIOSUGAR SYRUP	1,226,774
STERILIZER STEAM	143,282
FORMED WITH CELLS	5,533
FORMED WITH PRODUCT	(2,598)
TOTAL IN	3,290,308

WATER OUT:

AQUEOUS WASTE	3,097,336
CONDENSATE MAKEUP TO P.H	143,282
FERMENTER VENTS	20,728
PURGED WITH CELLS	28,883
MOISTURE IN PRODUCTS	79
TOTAL OUT	3,290,308

ETHANOL MANUFACTURE
ZYMOMONAS MOBILIS
INHIBITED SYSTEM - PLUG FLOW - CELL RECYCLE

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	1 CORN SYRUP	2 ANHYD AMMONIA	3 NUTRIENTS	4 MIX WATER	5 MIXED MEDIUM
P						
R	CELLS -CHO	0	0	0	0	0
O	-NH2	0	0	0	0	0
D	-MINERALS	0	0	0	0	0
U	-TOTAL	0	0	0	0	0
C	ACETALDEHYDE	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#0	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	LIGHT ENDS	0	0	0	0	0
#1	ETHANOL	0	0	0	0	0
	COMPONENT #8	0	0	0	0	0
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	0	0	0	0	0
	ACETIC ACID	0	0	0	0	0
	ISOAMYL ALCOHOL	0	0	0	0	0
	GLYCERINE	0	0	0	0	0
#0	COMPONENT #14	0	0	0	0	0
	LACTIC ACID	0	0	0	0	0
	SUCCINIC ACID	0	0	0	0	0
	COMPONENT #17	0	0	0	0	0
#0	COMPONENT #18	0	0	0	0	0
	COMPONENT #19	0	0	0	0	0
	BENZENE	0	0	0	0	0
	GLUCOSE	817,849	0	0	0	817,849
	AMMONIA	0	1,191	0	0	0
	PHOSPHORIC ACID	0	0	661	0	661
	POTASSIUM CHLORIDE	0	0	504	0	504
	MINOR NUTRIENTS	0	0	228	0	228
	WATER	1,226,774	0	0	1,774,036	3,000,810
	CARBON DIOXIDE	0	0	0	0	0
	OXYGEN	0	0	0	0	0
	NITROGEN	0	0	0	0	0
	HYDROGEN	0	0	0	0	0
	GRAND TOTAL	2,044,623	1,191	1,393	1,774,036	3,820,053
	CHECK ON TOTAL					
	TEMPERATURE, C	20	20	20	20	20
	PRESSURE, PSIA	14.7	14.7	14.7	20.8	25.0
	STATE	SOL'N	LIQUID	SOLIDS	LIQUID	SOL'N

ETHANOL MANUFACTURE
ZYMOMONAS MOBILIS
INHIBITED SYSTEM - PLUG FLOW - CELL RECYCLE

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	6 HX SS EFFLUENT	7 STERILE MEDIUM	8 HX TS EFFLUENT	9 COOLER EFFLUENT	10 AIR TO FERM
P						
R	CELLS -CHO	0	0	0	0	0
O	-NH2	0	0	0	0	0
D	-MINERALS	0	0	0	0	0
U	-TOTAL	0	0	0	0	0
C	ACETALDEHYDE	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#0	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	LIGHT ENDS	0	0	0	0	0
#1	ETHANOL	0	0	0	0	0
	COMPONENT #8	0	0	0	0	0
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	0	0	0	0	0
	ACETIC ACID	0	0	0	0	0
	ISOAMYL ALCOHOL	0	0	0	0	0
	GLYCERINE	0	0	0	0	0
#0	COMPONENT #14	0	0	0	0	0
	LACTIC ACID	0	0	0	0	0
	SUCCINIC ACID	0	0	0	0	0
	COMPONENT #17	0	0	0	0	0
#0	COMPONENT #18	0	0	0	0	0
	COMPONENT #19	0	0	0	0	0
	BENZENE	0	0	0	0	0
	GLUCOSE	817,849	817,849	817,849	817,849	0
	AMMONIA	0	0	0	0	0
	PHOSPHORIC ACID	661	661	661	661	0
	POTASSIUM CHLORIDE	504	504	504	504	0
	MINOR NUTRIENTS	228	228	228	228	0
	WATER	3,000,810	3,144,092	3,144,092	3,144,092	0
	CARBON DIOXIDE	0	0	0	0	0
	OXYGEN	0	0	0	0	46,378
	NITROGEN	0	0	0	0	153,584
	HYDROGEN	0	0	0	0	0
	GRAND TOTAL	3,820,053	3,963,334	3,963,334	3,963,334	199,962
	CHECK ON TOTAL					
	TEMPERATURE, C	100	120	40	33	33
	PRESSURE, PSIA	25.0	25.0	25.0	25.0	60.0
	STATE	SOL'N	SOL'N	SOL'N	SOL'N	GAS

ETHANOL MANUFACTURE
ZYMOMONAS MOBILIS
INHIBITED SYSTEM - PLUG FLOW - CELL RECYCLE

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	11 COMBINED FEED	12 BEER #1	13 BEER #2	14 VENT GROWTH	15 VENT PROD'N
P						
R	CELLS -CHO	0	8,175	119,542	0	0
O	-NH2	0	1,121	16,394	0	0
D	-MINERALS	0	228	3,341	0	0
U	-TOTAL	0	9,524	139,277	0	0
C	ACETALDEHYDE	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#0	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	LIGHT ENDS	0	0	454	0	0
#1	ETHANOL	0	0	453,647	0	0
	COMPONENT #8	0	0	0	0	0
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	0	0	0	0	0
	ACETIC ACID	0	0	3,199	0	0
	ISOAMYL ALCOHOL	0	0	0	0	0
	GLYCERINE	0	0	5,142	0	0
#0	COMPONENT #14	0	0	0	0	0
	LACTIC ACID	0	0	914	0	0
	SUCCINIC ACID	0	0	0	0	0
	COMPONENT #17	0	0	0	0	0
#0	COMPONENT #18	0	0	0	0	0
	COMPONENT #19	0	0	0	0	0
	BENZENE	0	0	0	0	0
	GLUCOSE	817,849	801,500	366	0	0
	AMMONIA	1,191	0	0	0	0
	PHOSPHORIC ACID	661	661	745	0	0
	POTASSIUM CHLORIDE	504	504	567	0	0
	MINOR NUTRIENTS	228	0	0	0	0
	WATER	3,144,092	3,143,412	3,519,781	6,213	14,515
	CARBON DIOXIDE	0	0	0	11,983	391,681
	OXYGEN	46,378	0	0	37,102	0
	NITROGEN	153,584	0	0	153,584	0
	HYDROGEN	0	0	0	0	500
	GRAND TOTAL	4,164,488	3,955,601	4,124,091	208,882	406,696
	CHECK ON TOTAL			4,124,091		
	TEMPERATURE, C	33	33	33	33	33
	PRESSURE, PSIA	--	44.7	44.7	14.7	14.7
	STATE	--	SLURRY	SLURRY	GAS	GAS

ETHANOL MANUFACTURE
ZYMOMONAS MOBILIS
INHIBITED SYSTEM - PLUG FLOW - CELL RECYCLE

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	16 COMBINED VENT	17 CELL EFFLUENT	18 CELLS TO DISPOSAL	19 CELL RECYCLE	20 CRUDE FILTRATE
P						
R	CELLS -CHO	0	119,542	8,175	111,367	0
O	-NH2	0	16,394	1,121	15,273	0
D	-MINERALS	0	3,341	229	3,112	0
U	-TOTAL	0	139,277	9,524	129,753	0
C	ACETALDEHYDE	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#0	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	LIGHT ENDS	0	54	4	51	399
#1	ETHANOL	0	54,437	3,723	50,714	399,210
	COMPONENT #8	0	0	0	0	0
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	0	0	0	0	0
	ACETIC ACID	0	384	26	358	2,815
	ISOAMYL ALCOHOL	0	0	0	0	0
	GLYCERINE	0	617	42	575	4,525
#0	COMPONENT #14	0	0	0	0	0
	LACTIC ACID	0	110	7	102	804
	SUCCINIC ACID	0	0	0	0	0
	COMPONENT #17	0	0	0	0	0
#0	COMPONENT #18	0	0	0	0	0
	COMPONENT #19	0	0	0	0	0
	BENZENE	0	0	0	0	0
	GLUCOSE	0	44	44	(0)	322
	AMMONIA	0	0	0	0	0
	PHOSPHORIC ACID	0	89	6	83	655
	POTASSIUM CHLORIDE	0	68	5	63	499
	MINOR NUTRIENTS	0	0	0	0	0
	WATER	20,728	422,366	28,883	393,483	3,097,415
	CARBON DIOXIDE	403,664	0	0	0	0
	OXYGEN	37,102	0	0	0	0
	NITROGEN	153,584	0	0	0	0
	HYDROGEN	500	0	0	0	0
	GRAND TOTAL	615,578	617,446	42,265	575,223	3,506,645
	CHECK ON TOTAL		617,446		575,182	
	TEMPERATURE, C	33	33	33	33	33
	PRESSURE, PSIA	14.7	44.7	14.7	44.7	14.7
	STATE	GAS	SLURRY	SLURRY	SLURRY	SOL'N

ETHANOL MANUFACTURE
ZYMOMONAS MOBILIS
INHIBITED SYSTEM - PLUG FLOW - CELL RECYCLE

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	21 BEER #1 FEED	22 BEER #1 MAKE	23 BEER #1 TAILS	24 BEER #2 MAKE
P					
R	CELLS -CHO	0	0	0	0
O	-NH2	0	0	0	0
D	-MINERALS	0	0	0	0
U	-TOTAL	0	0	0	0
C	ACETALDEHYDE	0	0	0	0
T	COMPONENT #2	0	0	0	0
#0	COMPONENT #3	0	0	0	0
	COMPONENT #4	0	0	0	0
	COMPONENT #5	0	0	0	0
	LIGHT ENDS	399	399	0	399
#1	ETHANOL	438,932	436,936	1,996	397,214
	COMPONENT #8	0	0	0	0
	COMPONENT #9	0	0	0	0
	COMPONENT #10	0	0	0	0
	ACETIC ACID	2,815	0	2,815	0
	ISOAMYL ALCOHOL	0	0	0	0
	GLYCERINE	4,525	0	4,525	0
#0	COMPONENT #14	0	0	0	0
	LACTIC ACID	804	0	804	0
	SUCCINIC ACID	0	0	0	0
	COMPONENT #17	0	0	0	0
#0	COMPONENT #18	0	0	0	0
	COMPONENT #19	0	0	0	0
	BENZENE	0	0	0	0
	GLUCOSE	322	0	322	0
	AMMONIA	0	0	0	0
	PHOSPHORIC ACID	655	0	655	0
	POTASSIUM CHLORIDE	499	0	499	0
	MINOR NUTRIENTS	0	0	0	0
	WATER	3,513,444	436,936	3,076,509	20,906
	CARBON DIOXIDE	0	0	0	0
	OXYGEN	0	0	0	0
	NITROGEN	0	0	0	0
	HYDROGEN	0	0	0	0
	GRAND TOTAL	3,962,396	874,271	3,088,125	418,519
	CHECK ON TOTAL				
	TEMPERATURE, C	--	109	120	99
	PRESSURE, PSIA	--	27.5	29.6	29.7
	STATE	SOL'N	SOL'N	SOL'N	SOL'N

ETHANOL MANUFACTURE
ZYMOMONAS MOBILIS
INHIBITED SYSTEM - PLUG FLOW - CELL RECYCLE

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

		25	26	27	28	29
		BEER #2	LBS #1	LBS #1	LBS #2	LBS #2
	STREAM	TAILS	MAKE	TAILS	MAKE	TAILS
P						
R	CELLS -CHO	0	0	0	0	0
O	-NH2	0	0	0	0	0
D	-MINERALS	0	0	0	0	0
U	-TOTAL	0	0	0	0	0
C	ACETALDEHYDE	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#0	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	LIGHT ENDS	0	359	40	0	0
#1	ETHANOL	39,721	1,986	395,228	0	0
	COMPONENT #8	0	0	0	0	0
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	0	0	0	0	0
	ACETIC ACID	0	0	0	0	0
	ISOAMYL ALCOHOL	0	0	0	0	0
	GLYCERINE	0	0	0	0	0
#0	COMPONENT #14	0	0	0	0	0
	LACTIC ACID	0	0	0	0	0
	SUCCINIC ACID	0	0	0	0	0
	COMPONENT #17	0	0	0	0	0
#0	COMPONENT #18	0	0	0	0	0
	COMPONENT #19	0	0	0	0	0
	BENZENE	0	0	0	0	0
	GLUCOSE	0	0	0	0	0
	AMMONIA	0	0	0	0	0
	PHOSPHORIC ACID	0	0	0	0	0
	POTASSIUM CHLORIDE	0	0	0	0	0
	MINOR NUTRIENTS	0	0	0	0	0
	WATER	416,030	0	20,906	0	0
	CARBON DIOXIDE	0	0	0	0	0
	OXYGEN	0	0	0	0	0
	NITROGEN	0	0	0	0	0
	HYDROGEN	0	0	0	0	0
	GRAND TOTAL	455,751	2,345	416,174	0	0
	CHECK ON TOTAL					
	TEMPERATURE, C	120	111	120	(273)	120
	PRESSURE, PSIA	30.9	58.4	61.7	.0	.0
	STATE	SOL'N	SOL'N	SOL'N	SOL'N	SOL'N

ETHANOL MANUFACTURE
ZYMOMONAS MOBILIS
INHIBITED SYSTEM - PLUG FLOW - CELL RECYCLE

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	30 LBS #3 MAKE	31 LBS #3 TAILS	32 HBS #1 MAKE	33 HBS #1 TAILS	34 HBS #2 MAKE
P						
R	CELLS -CHO	0	0	0	0	0
O	-NH2	0	0	0	0	0
D	-MINERALS	0	0	0	0	0
U	-TOTAL	0	0	0	0	0
C	ACETALDEHYDE	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#0	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	LIGHT ENDS	0	0	0	0	0
#1	ETHANOL	0	0	0	0	0
	COMPONENT #8	0	0	0	0	0
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	0	0	0	0	0
	ACETIC ACID	0	0	0	0	0
	ISOAMYL ALCOHOL	0	0	0	0	0
	GLYCERINE	0	0	0	0	0
#0	COMPONENT #14	0	0	0	0	0
	LACTIC ACID	0	0	0	0	0
	SUCCINIC ACID	0	0	0	0	0
	COMPONENT #17	0	0	0	0	0
#0	COMPONENT #18	0	0	0	0	0
	COMPONENT #19	0	0	0	0	0
	BENZENE	0	0	0	0	0
	GLUCOSE	0	0	0	322	0
	AMMONIA	0	0	0	0	0
	PHOSPHORIC ACID	0	0	0	655	0
	POTASSIUM CHLORIDE	0	0	0	499	0
	MINOR NUTRIENTS	0	0	0	0	0
	WATER	0	0	0	0	0
	CARBON DIOXIDE	0	0	0	0	0
	OXYGEN	0	0	0	0	0
	NITROGEN	0	0	0	0	0
	HYDROGEN	0	0	0	0	0
	GRAND TOTAL	0	0	0	1,476	0
	CHECK ON TOTAL					
	TEMPERATURE, C	(273)	120	(273)	150	(273)
	PRESSURE, PSIA	.0	.0	.0	.0	.0
	STATE	SOL'N	SOL'N	SOL'N	SOL'N	SOL'N

ETHANOL MANUFACTURE
ZYMOMONAS MOBILIS
INHIBITED SYSTEM - PLUG FLOW - CELL RECYCLE

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	35 HBS #2 TAILS	36 AZEO MAKE	37 AZEO TAILS	38 AZEO REFLUX	39 DECANTER FEED
P						
R	CELLS -CHO	0	0	0	0	0
O	-NH2	0	0	0	0	0
D	-MINERALS	0	0	0	0	0
U	-TOTAL	0	0	0	0	0
C	ACETALDEHYDE	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#0	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	LIGHT ENDS	0	0	0	0	0
#1	ETHANOL	0	259,004	395,124	258,900	317,361
	COMPONENT #8	0	0	0	0	0
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	0	0	0	0	0
	ACETIC ACID	0	0	0	0	0
	ISOAMYL ALCOHOL	0	0	0	0	0
	GLYCERINE	0	0	0	0	0
#0	COMPONENT #14	0	0	0	0	0
	LACTIC ACID	0	0	0	0	0
	SUCCINIC ACID	0	0	0	0	0
	COMPONENT #17	0	0	0	0	0
#0	COMPONENT #18	0	0	0	0	0
	COMPONENT #19	0	0	0	0	0
	BENZENE	0	1,753,195	2	1,753,197	1,758,579
	GLUCOSE	0	0	0	0	0
	AMMONIA	0	0	0	0	0
	PHOSPHORIC ACID	0	0	0	0	0
	POTASSIUM CHLORIDE	0	0	0	0	0
	MINOR NUTRIENTS	0	0	0	0	0
	WATER	0	47,330	79	26,503	74,862
	CARBON DIOXIDE	0	0	0	0	0
	OXYGEN	0	0	0	0	0
	NITROGEN	0	0	0	0	0
	HYDROGEN	0	0	0	0	0
	GRAND TOTAL	0	2,059,530	395,205	2,038,600	2,150,802
	CHECK ON TOTAL					
	TEMPERATURE, C	150				
	PRESSURE, PSIA	.0				
	STATE	SOL'N	SOL'N	SOL'N	SOL'N	SOL'N

ETHANOL MANUFACTURE
ZYMOMONAS MOBILIS
INHIBITED SYSTEM - PLUG FLOW - CELL RECYCLE

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	40 DECANTER UP LAYER	41 DECANTER LO LAYER	42 BENZENE MAKE	43 BENZENE TAILS	44 FUSEL OIL DRAW-OFF	45 REFINED PRODUCT
P							
R	CELLS -CHO	0	0	0	0	0	0
O	-NH2	0	0	0	0	0	0
D	-MINERALS	0	0	0	0	0	0
U	-TOTAL	0	0	0	0	0	0
C	ACETALDEHYDE	0	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0	0
#0	COMPONENT #3	0	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0	0
	LIGHT ENDS	0	0	0	0	0	0
#1	ETHANOL	258,900	58,461	58,357	104	0	395,124
	COMPONENT #8	0	0	0	0	0	0
	COMPONENT #9	0	0	0	0	0	0
	COMPONENT #10	0	0	0	0	0	0
	ACETIC ACID	0	0	0	0	0	0
	ISOAMYL ALCOHOL	0	0	0	0	0	0
	GLYCERINE	0	0	0	0	0	0
#0	COMPONENT #14	0	0	0	0	0	0
	LACTIC ACID	0	0	0	0	0	0
	SUCCINIC ACID	0	0	0	0	0	0
	COMPONENT #17	0	0	0	0	0	0
#0	COMPONENT #18	0	0	0	0	0	0
	COMPONENT #19	0	0	0	0	0	0
	BENZENE	1,753,199	5,384	5,384	0.21	0	2
	GLUCOSE	0	0	0	0	0	0
	AMMONIA	0	0	0	0	0	0
	PHOSPHORIC ACID	0	0	0	0	0	0
	POTASSIUM CHLORIDE	0	0	0	0	0	0
	MINOR NUTRIENTS	0	0	0	0	0	0
	WATER	26,503	48,359	27,532	20,827	0	79
	CARBON DIOXIDE	0	0	0	0	0	0
	OXYGEN	0	0	0	0	0	0
	NITROGEN	0	0	0	0	0	0
	HYDROGEN	0	0	0	0	0	0
	GRAND TOTAL	2,038,603	112,204	91,273	20,931	0	395,205
	CHECK ON TOTAL						
	TEMPERATURE, C						40
	PRESSURE, PSIA						14.7
	STATE	SOL'N	SOL'N	SOL'N	SOL'N	SOL'N	SOL'N

ETHANOL MANUFACTURE
ZYMOMONAS MOBILIS
INHIBITED SYSTEM - PLUG FLOW - CELL RECYCLE

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	46 REFINED B.P.#1	47 REFINED B.P.#2	48 AQUEOUS WASTE	49 MAKE-UP WATER	50 MAKE-UP BENZENE
P						
R	CELLS -CHO	0	0	0	0	0
O	-NH2	0	0	0	0	0
D	-MINERALS	0	0	0	0	0
U	-TOTAL	0	0	0	0	0
C	ACETALDEHYDE	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#0	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	LIGHT ENDS	0	0	399	0	0
#1	ETHANOL	0	0	4,086	0	0
	COMPONENT #8	0	0	0	0	0
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	0	0	0	0	0
	ACETIC ACID	0	0	2,815	0	0
	ISOAMYL ALCOHOL	0	0	0	0	0
	GLYCERINE	0	0	4,525	0	0
#0	COMPONENT #14	0	0	0	0	0
	LACTIC ACID	0	0	804	0	0
	SUCCINIC ACID	0	0	0	0	0
	COMPONENT #17	0	0	0	0	0
#0	COMPONENT #18	0	0	0	0	0
	COMPONENT #19	0	0	0	0	0
	BENZENE	0	0	0	0	2
	GLUCOSE	0	0	322	0	0
	AMMONIA	0	0	0	0	0
	PHOSPHORIC ACID	0	0	655	0	0
	POTASSIUM CHLORIDE	0	0	499	0	0
	MINOR NUTRIENTS	0	0	0	0	0
	WATER	0	0	3,097,336	1,917,318	0
	CARBON DIOXIDE	0	0	0	0	0
	OXYGEN	0	0	0	0	0
	NITROGEN	0	0	0	0	0
	HYDROGEN	0	0	0	0	0
	GRAND TOTAL	0	0	3,111,442	1,917,318	2
	CHECK ON TOTAL					
	TEMPERATURE, C	40	40	40	20	20
	PRESSURE, PSIA	14.7	14.7	14.7	14.7	14.7
	STATE	SOL'N	SOL'N	SOL'N	LIQUID	LIQUID

ETHANOL MANUFACTURE
ZYMOMONAS MOBILIS
INHIBITED SYSTEM - PLUG FLOW - CELL RECYCLE

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	51 STERILE STEAM	52 FERM'TR STEAM	53 DISTILL. STEAM	54 COND. MU P'WR H'SE	55 MEDIUM COOL WTR
P						
R	CELLS -CHO	0	0	0	0	0
O	-NH2	0	0	0	0	0
D	-MINERALS	0	0	0	0	0
U	-TOTAL	0	0	0	0	0
C	ACETALDEHYDE	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#0	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	LIGHT ENDS	0	0	0	0	0
#1	ETHANOL	0	0	0	0	0
	COMPONENT #8	0	0	0	0	0
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	0	0	0	0	0
	ACETIC ACID	0	0	0	0	0
	ISOAMYL ALCOHOL	0	0	0	0	0
	GLYCERINE	0	0	0	0	0
#0	COMPONENT #14	0	0	0	0	0
	LACTIC ACID	0	0	0	0	0
	SUCCINIC ACID	0	0	0	0	0
	COMPONENT #17	0	0	0	0	0
#0	COMPONENT #18	0	0	0	0	0
	COMPONENT #19	0	0	0	0	0
	BENZENE	0	0	0	0	0
	GLUCOSE	0	0	0	0	0
	AMMONIA	0	0	0	0	0
	PHOSPHORIC ACID	0	0	0	0	0
	POTASSIUM CHLORIDE	0	0	0	0	0
	MINOR NUTRIENTS	0	0	0	0	0
	WATER	143,282	0	2,464,780	143,282	1,849,556
	CARBON DIOXIDE	0	0	0	0	0
	OXYGEN	0	0	0	0	0
	NITROGEN	0	0	0	0	0
	HYDROGEN	0	0	0	0	0
	GRAND TOTAL	143,282	0	2,464,780	143,282	1,849,556
	CHECK ON TOTAL					
	TEMPERATURE, C	141	141	186	110	5
	PRESSURE, PSIA	64.7	64.7	164.7	20.8	14.7
	STATE	GAS	GAS	GAS	LIQUID	LIQUID

ETHANOL MANUFACTURE
ZYMOMONAS MOBILIS
INHIBITED SYSTEM - PLUG FLOW - CELL RECYCLE

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	56 FERM'TR COOL WTR	52 DISTILL. COOL WTR
P			
R	CELLS -CHO	0	0
O	-NH2	0	0
D	-MINERALS	0	0
U	-TOTAL	0	0
C	ACETALDEHYDE	0	0
T	COMPONENT #2	0	0
#0	COMPONENT #3	0	0
	COMPONENT #4	0	0
	COMPONENT #5	0	0
	LIGHT ENDS	0	0
#1	ETHANOL	0	0
	COMPONENT #8	0	0
	COMPONENT #9	0	0
	COMPONENT #10	0	0
	ACETIC ACID	0	0
	ISOAMYL ALCOHOL	0	0
	GLYCERINE	0	0
#0	COMPONENT #14	0	0
	LACTIC ACID	0	0
	SUCCINIC ACID	0	0
	COMPONENT #17	0	0
#0	COMPONENT #18	0	0
	COMPONENT #19	0	0
	BENZENE	0	0
	GLUCOSE	0	0
	AMMONIA	0	0
	PHOSPHORIC ACID	0	0
	POTASSIUM CHLORIDE	0	0
	MINOR NUTRIENTS	0	0
	WATER	20,366,802	69,017,179
	CARBON DIOXIDE	0	0
	OXYGEN	0	0
	NITROGEN	0	0
	HYDROGEN	0	0
	GRAND TOTAL	20,366,802	69,017,179
	CHECK ON TOTAL		
	TEMPERATURE, C	5	0
	PRESSURE, PSIA	14.7	14.7
	STATE	LIQUID	LIQUID

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	20 CRUDE FILTRATE	21 BEER #1 FEED	22 BEER #1 MAKE	23 BEER #1 TAILS	24 BEER #2 MAKE
ACETALDEHYDE	0	0	0	0	0
COMPONENT #2	0	0	0	0	0
COMPONENT #3	0	0	0	0	0
COMPONENT #4	0	0	0	0	0
COMPONENT #5	0	0	0	0	0
LIGHT ENDS	5	5	5	0	5
ETHANOL	8,666	9,528	9,485	43	8,622
COMPONENT #8	0	0	0	0	0
COMPONENT #9	0	0	0	0	0
COMPONENT #10	0	0	0	0	0
ACETIC ACID	47	47	0	47	0
ISOAMYL ALCOHOL	0	0	0	0	0
GLYCERINE	49	49	0	49	0
COMPONENT #14	0	0	0	0	0
LACTIC ACID	9	9	0	9	0
SUCCINIC ACID	0	0	0	0	0
COMPONENT #17	0	0	0	0	0
COMPONENT #18	0	0	0	0	0
COMPONENT #19	0	0	0	0	0
BENZENE	0	0	0	0	0
WATER	171,926	195,018	24,253	170,765	1,160
	180,701	204,655	33,742	170,914	9,787
(Storage)	1,180	1,295	1,266	29	1,151
VAPOR PRESS 40(q)	58.5	58.4	76.8	54.7	124.1
(Storage)	29,757	32,698	32,404	318	29,463
VAPOR PRESS 120(q)	1619.3	1616.7	2059.3	1529.4	3191.6
B(q) V.P. CONSTANT	-5106.0	-5106.7	-5057.2	-5120.2	-4992.6
A(q) V.P. CONSTANT	20.382	20.382	20.498	20.361	20.772
TEMPERATURE C	33.0	43.0	107.9	120.0	96.8
PRESSURE mmHg	760	760	1,369	1,529	1,438

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	25 BEER #2 TAILS	26 LBS #1 MAKE	27 LBS #1 TAILS	28 LBS #2 MAKE	29 LBS #2 TAILS	30 LBS #3 MAKE
ACETALDEHYDE	0	0	0	0	0	0
COMPONENT #2	0	0	0	0	0	0
COMPONENT #3	0	0	0	0	0	0
COMPONENT #4	0	0	0	0	0	0
COMPONENT #5	0	0	0	0	0	0
LIGHT ENDS	0	4	0	0	0	0
ETHANOL	862	43	8,579	0	0	0
COMPONENT #8	0	0	0	0	0	0
COMPONENT #9	0	0	0	0	0	0
COMPONENT #10	0	0	0	0	0	0
ACETIC ACID	0	0	0	0	0	0
ISOAMYL ALCOHOL	0	0	0	0	0	0
GLYCERINE	0	0	0	0	0	0
COMPONENT #14	0	0	0	0	0	0
LACTIC ACID	0	0	0	0	0	0
SUCCINIC ACID	0	0	0	0	0	0
COMPONENT #17	0	0	0	0	0	0
COMPONENT #18	0	0	0	0	0	0
COMPONENT #19	0	0	0	0	0	0
BENZENE	0	0	0	0	0	0
WATER	23,092	0	1,160	0	0	0
	23,954	47	9,740	0	0	0
(Storage)	115	7	1,144	0	0	0
VAPOR PRESS 40(q)	57.5	155.3	124.0	.0	.0	.0
(Storage)	2,966	192	29,295	24	24	24
VAPOR PRESS 120(q)	1597.7	4060.2	3189.9	.0	.0	.0
B(q) V.P. CONSTANT	-5113.0	-5018.5	-4993.6	0.0	0.0	0.0
A(q) V.P. CONSTANT	20.387	21.079	20.774	-4.605	-4.605	-4.605
TEMPERATURE C	120.0	111.2	120.0	ERR	120.0	ERR
PRESSURE mmHg	1,598	3,030	3,190	(160)	0	(160)

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	31 LBS #3 TAILS	32 HBS #1 MAKE	33 HBS #1 TAILS	34 HBS #2 MAKE	35 HBS #2 TAILS	36 AZEO MAKE
ACETALDEHYDE	0	0	0	0	0	0
COMPONENT #2	0	0	0	0	0	0
COMPONENT #3	0	0	0	0	0	0
COMPONENT #4	0	0	0	0	0	0
COMPONENT #5	0	0	0	0	0	0
LIGHT ENDS	0	0	0	0	0	0
ETHANOL	0	0	0	0	0	5,622
COMPONENT #8	0	0	0	0	0	0
COMPONENT #9	0	0	0	0	0	0
COMPONENT #10	0	0	0	0	0	0
ACETIC ACID	0	0	0	0	0	0
ISOAMYL ALCOHOL	0	0	0	0	0	0
GLYCERINE	0	0	0	0	0	0
COMPONENT #14	0	0	0	0	0	0
LACTIC ACID	0	0	0	0	0	0
SUCCINIC ACID	0	0	0	0	0	0
COMPONENT #17	0	0	0	0	0	0
COMPONENT #18	0	0	0	0	0	0
COMPONENT #19	0	0	0	0	0	0
BENZENE	0	0	0	0	0	22,237
WATER	0	0	0	0	0	2,627
	0	0	0	0	0	30,486
(Storage)	0	0	0	0	0	
VAPOR PRESS 40(q)	.0	.0	.0	.0	.0	
(Storage)	24	24	24	24	24	
VAPOR PRESS 120(q)	.0	.0	.0	.0	.0	
B(q) V.P. CONSTANT	0.0	0.0	0.0	0.0	0.0	
A(q) V.P. CONSTANT	-4.605	-4.605	-4.605	-4.605	-4.605	
TEMPERATURE C	120.0	ERR	150.0	ERR	150.0	
PRESSURE mmHg	0	(160)	0	(160)	0	

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	37 AZEO TAILS	38 AZEO REFLUX	39 DECANTER FEED	40 DECANTER UP LAYER	41 DECANTER LO LAYER	42 BENZENE MAKE
ACETALDEHYDE	0					0
COMPONENT #2	0					0
COMPONENT #3	0					0
COMPONENT #4	0					0
COMPONENT #5	0					0
LIGHT ENDS	0					0
ETHANOL	8,577					1,267
COMPONENT #8	0					0
COMPONENT #9	0					0
COMPONENT #10	0					0
ACETIC ACID	0					0
ISOAMYL ALCOHOL	0					0
GLYCERINE	0					0
COMPONENT #14	0					0
LACTIC ACID	0					0
SUCCINIC ACID	0					0
COMPONENT #17	0					0
COMPONENT #18	0					0
COMPONENT #19	0					0
BENZENE	0					68
WATER	4					1,528
	8,581					2,863

(Storage)
VAPOR PRESS 40(q)
(Storage)
VAPOR PRESS 120(q)
B(q) V.P. CONSTANT
A(q) V.P. CONSTANT
TEMPERATURE C
PRESSURE mmHg

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	43 BENZENE TAILS
ACETALDEHYDE	0
COMPONENT #2	0
COMPONENT #3	0
COMPONENT #4	0
COMPONENT #5	0
LIGHT ENDS	0
ETHANOL	2
COMPONENT #8	0
COMPONENT #9	0
COMPONENT #10	0
ACETIC ACID	0
ISOAMYL ALCOHOL	0
GLYCERINE	0
COMPONENT #14	0
LACTIC ACID	0
SUCCINIC ACID	0
COMPONENT #17	0
COMPONENT #18	0
COMPONENT #19	0
BENZENE	0
WATER	1,156
	1,158

(Storage)
VAPOR PRESS 40(q)
(Storage)
VAPOR PRESS 120(q)
B(q) V.P. CONSTANT
A(q) V.P. CONSTANT
TEMPERATURE C
PRESSURE mmHg

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	20 CRUDE FILTRATE	22 BEER #1 MAKE	23 BEER #1 TAILS	24 BEER #2 MAKE	25 BEER #2 TAILS
K1 (COMPONENT #)		7	7	7	7
K2 (COMPONENT #)		WATER	WATER	WATER	WATER
V.P.(K1)		2282.0	3411.6	1538.7	3411.6
V.P.(K2)		1011.3	1528.9	674.5	1528.9
GAMMA-K1 IN K2		1.822	1.822	1.822	1.822
GAMMA-K2 IN K1		1.822	1.822	1.822	1.822
ALPHA		2.934	4.065	1.443	3.894
AVG COLUMN ALPHA		3.499		2.669	
MOL FRACT. K1 (MAKE OR TAILS)		0.281	0.00025	0.881	0.03599
MOL FRACT. K1 (FEED)		0.047		0.281	
MOL FRACT. K2 (MAKE OR TAILS)		0.719	1.000	0.119	0.964
ADJ. GAMMA-K1 IN K2		1.364	1.822	1.008	1.746
ADJ. GAMMA-K2 IN K1		1.049	1.000	1.594	1.001
MINIMUM REFLUX RATIO (ADJUSTE		0.3		0.2	
ACTUAL REFLUX RATIO		0.3		0.3	
MINIMUM THEOR. PLATES (INFINI		6		5	
THEORETICAL PLATES		13		12	
PLATE EFFICIENCY -%		50%		80%	
ACTUAL PLATES		26		15	
PRESSURE mm Hg (REVISED)		1,424		1,537	
TEMPERATURE C (REVISED)		109		99	
AVERAGE MOLECULAR WEIGHT		25.91	18.07	42.76	19.03
GAS DENSITY - LB/CF		0.0966	0.0704	0.1770	0.0774
CROSS SECTIONAL AREA - SQ FT		110.8		38.0	
COLUMN HEIGHT - FT		54.6		37.7	
COLUMN DIAMETER		11.9		7.0	
K1 (MPPY)		436,936		397,214	
Hv (HEAT VAPORIZ.-Btu/Lb)		668.5	968.2	397.1	917.7
Cn (HEAT CAPACITY - Btu/Lb/F)		0.840	0.999	0.696	0.972
HEAT LOAD - MM Btu/Hr		109.438	168.769	30.162	31.375
CONDENSER COOLING WATER - GPM		8110		2235	
CALANDRIA STEAM - MPPH (150 PSIG)			196.93		36.61
COLUMN COST - $1000 3Q86 MPC - BARE EQUIPMENT					
- ALL CARBON STEEL		$202.1		$87.8	
- C.S w/304 S.S. TRAYS		$222.3		$96.6	
- ALL 304 STAINLESS STEEL		$320.4		$140.9	
- ALL 304L STAINLESS STEEL		$352.5		$155.0	
- ALL 316 STAINLESS STEEL		$432.6		$190.2	
CONDENSER OR CALANDRIA SURFAC		9,614	9,376	3,052	1,743
COND. OR CALAND. COST - $1000 3Q86 MPC - BARE EQUIPMENT					
-CARBON STEEL		$298.1	$290.5	$99.9	$62.7
-304 STAINLESS STEEL		$417.3	$406.6	$139.9	$87.8
-316 STAINLESS STEEL		$447.1	$435.7	$149.9	$94.1
-MONEL		$581.3	$566.4	$194.9	$122.3
SUBTOTAL			3,082,405		443,040
SUBTOTAL			3,076,959		416,030
SUBTOTAL			3,076,509		416,030
MINIMUM REFLUX RATIO		0.3		0.2	
Cn SUBTOTAL #1		297,304	1,357	270,293	27,011

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	20 CRUDE FILTRATE	22 BEER #1 MAKE	23 BEER #1 TAILS	24 BEER #2 MAKE	25 BEER #2 TAILS
Cn SUBTOTAL #2		0	4,088	0	0
Cn SUBTOTAL #3		436,936	3,076,959	20,906	416,030
Cn CHECK		0.750	0.998	0.525	0.956
Hv SUBTOTAL #1		160,513	733	145,927	14,586
Hv SUBTOTAL #2		0	2,282	0	0
Hv SUBTOTAL #3		423,959	2,985,571	20,285	403,674
Hv CHECK		592.5	967.8	252.7	904.5
MIN. PLATES(NORMAL)					
COL.COST-C/S NORMAL					
COL.COST-S/S NORMAL					
MIN.REFLUX(NORMAL)					
C.S. AREA(NORMAL)					
HEAT LOAD(NORMAL)					
CON/CAL COST(NORMAL)					
REFLUX FACTOR		0.275		0.878	

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	20 CRUDE FILTRATE	26 LBS #1 MAKE	27 LBS #1 TAILS	28 LBS #2 MAKE	29 LBS #2 TAILS	30 LBS #3 MAKE
K1 (COMPONENT #)		6,5,4,3	6,5,4,3	3	3	2
K2 (COMPONENT #)		7	7	4,5,6	4,5,6	3
V.P.(K1)		3954.4	4972.0	ERR	12121.9	ERR
V.P.(K2)		2550.8	3411.6	ERR	14554.7	ERR
GAMMA-K1 IN K2		1.105	1.105	1.000	1.000	1.000
GAMMA-K2 IN K1		1.000	1.000	1.105	1.105	1.000
ALPHA		1.685	1.611	ERR	ERR	ERR
AVG COLUMN ALPHA		1.648		ERR		ERR
MOL FRACT. K1 (MAKE OR TAILS)		0.086	.000	ERR	ERR	ERR
MOL FRACT. K1 (FEED)		0.001		0.000		ERR
MOL FRACT. K2 (MAKE OR TAILS)		0.914	1.000	ERR	ERR	ERR
ADJ. GAMMA-K1 IN K2		1.087	1.105	ERR	ERR	ERR
ADJ. GAMMA-K2 IN K1		1.000	1.000	ERR	ERR	ERR
MINIMUM REFLUX RATIO (ADJUSTE		20.1		ERR		ERR
ACTUAL REFLUX RATIO		25.1		ERR		ERR
MINIMUM THEOR. PLATES (INFINI		15)		0		0
THEORETICAL PLATES		34		0		0
PLATE EFFICIENCY -%		80%		80%		80%
ACTUAL PLATES		42		0		0
PRESSURE mm Hg (REVISED)		3,021		0		0
TEMPERATURE C (REVISED)		111		(273)		(273)
AVERAGE MOLECULAR WEIGHT		49.70	42.73	ERR	ERR	ERR
GAS DENSITY - LB/CF		0.3911	0.3470	ERR	ERR	ERR
CROSS SECTIONAL AREA - SQ FT		2.9		0.0		0.0
COLUMN HEIGHT - FT		78.3		0.0		0.0
COLUMN DIAMETER		1.9		0.0		0.0
K1 (MPPY)		359		0		0
Hv (HEAT VAPORIZ.-Btu/Lb)		338.0	397.5	ERR	ERR	ERR
Cp (HEAT CAPACITY - Btu/Lb/F)		0.648	0.696	ERR	ERR	ERR
HEAT LOAD - MM Btu/Hr		3.138	4.686	0.000	0.000	0.000
CONDENSER COOLING WATER - GPM		233)		0		0
CALANDRIA STEAM - MPPH (150 PSIG)			5.47		0.00	
COLUMN COST - $1000 3Q86 MPC - BARE EQUIPMENT						
- ALL CARBON STEEL		$54.3		$0.0		$0.0
- C.S w/304 S.S. TRAYS		$59.7		$0.0		$0.0
- ALL 304 STAINLESS STEEL		$88.2		$0.0		$0.0
- ALL 304L STAINLESS STEEL		$97.0		$0.0		$0.0
- ALL 316 STAINLESS STEEL		$119.0		$0.0		$0.0
CONDENSER OR CALANDRIA SURFAC		269	260	0	0	0
COND. OR CALAND. COST - $1000 3Q86 MPC - BARE EQUIPMENT						
-CARBON STEEL		$18.3	$18.0	$0.0	$0.0	$0.0
-304 STAINLESS STEEL		$25.6	$25.2	$0.0	$0.0	$0.0
-316 STAINLESS STEEL		$27.5	$27.0	$0.0	$0.0	$0.0
-MONEL		$35.7	$35.1	$0.0	$0.0	$0.0
SUBTOTAL			289,661		0	
SUBTOTAL			20,906		0	
SUBTOTAL			20,906		0	
MINIMUM REFLUX RATIO		20.1		ERR		ERR
Cp SUBTOTAL #1		1,519	268,774	0	0	0

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	20 CRUDE FILTRATE	26 LBS #1 MAKE	27 LBS #1 TAILS	28 LBS #2 MAKE	29 LBS #2 TAILS	30 LBS #3 MAKE
Cn SUBTOTAL #2		0	0	0	0	0
Cn SUBTOTAL #3		0	20,906	0	0	0
Cn CHECK		0.500	0.525	ERR	ERR	ERR
Hv SUBTOTAL #1		793	145,135	0	0	0
Hv SUBTOTAL #2		0	0	0	0	0
Hv SUBTOTAL #3		0	20,285	0	0	0
Hv CHECK		215.0	252.9	ERR	ERR	ERR
MIN. PLATES(NORMAL)						
COL.COST-C/S NORMAL		54				
COL.COST-S/S NORMAL		88				
MIN.REFLUX(NORMAL)						
C.S. AREA(NORMAL)		3				
HEAT LOAD(NORMAL)			5			
CON/CAL COST(NORMAL)		18	18			
REFLUX FACTOR		0.080		ERR		ERR

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	20 CRUDE FILTRATE	31 LBS #3 TAILS	32 HBS #1 MAKE	33 HBS #1 TAILS	34 HBS #2 MAKE	35 HBS #2 TAILS
K1 (COMPONENT #)		2	WATER	WATER	14	14
K2 (COMPONENT #)		3	14	14	15,16,17 &18	15,16,17 &18
V.P.(K1)		1.0	ERR	3853.9	ERR	18951.1
V.P.(K2)		12121.9	ERR	18951.1	ERR	1.0
GAMMA-K1 IN K2		1.000	1.822	1.822	1.000	1.000
GAMMA-K2 IN K1		1.000	1.822	1.822	1.000	1.000
ALPHA		ERR	ERR	ERR	ERR	ERR
AVG COLUMN ALPHA			ERR		ERR	
MOL FRACT. K1 (MAKE OR TAILS)		ERR	ERR	ERR	ERR	ERR
MOL FRACT. K1 (FEED)			1.000		ERR	
MOL FRACT. K2 (MAKE OR TAILS)		ERR	ERR	ERR	ERR	ERR
ADJ. GAMMA-K1 IN K2		ERR	ERR	ERR	ERR	ERR
ADJ. GAMMA-K2 IN K1		ERR	ERR	ERR	ERR	ERR
MINIMUM REFLUX RATIO (ADJUSTED)			ERR		ERR	
ACTUAL REFLUX RATIO			ERR		ERR	
MINIMUM THEOR. PLATES (INFINITE REFLUX			0		0	
THEORETICAL PLATES			0		0	
PLATE EFFICIENCY -%			80%		80%	
ACTUAL PLATES			0		0	
PRESSURE mm Hg (REVISED)			0		0	
TEMPERATURE C (REVISED)			(273)		(273)	
AVERAGE MOLECULAR WEIGHT		ERR	ERR	ERR	ERR	ERR
GAS DENSITY - LB/CF		ERR	ERR	ERR	ERR	ERR
CROSS SECTIONAL AREA - SQ FT			0.0		0.0	
COLUMN HEIGHT - FT			0.0		0.0	
COLUMN DIAMETER			0.0		0.0	
K1 (MPPY)			0		0	
Hv (HEAT VAPORIZ.-Btu/Lb)		ERR	ERR	ERR	ERR	ERR
Cn (HEAT CAPACITY - Btu/Lb/F)		ERR	ERR	ERR	ERR	ERR
HEAT LOAD - MM Btu/Hr		0.000	0.000	0.000	0.000	0.000
CONDENSER COOLING WATER - GPM (15 C dT			0		0	
CALANDRIA STEAM - MPPH (150 P		0.00		0.00		0.00
COLUMN COST - $1000 3Q86 MPC - BARE EQUIPMENT						
- ALL CARBON STEEL			$0.0		$0.0	
- C.S w/304 S.S. TRAYS			$0.0		$0.0	
- ALL 304 STAINLESS STEEL			$0.0		$0.0	
- ALL 304L STAINLESS STEEL			$0.0		$0.0	
- ALL 316 STAINLESS STEEL			$0.0		$0.0	
CONDENSER OR CALANDRIA SURFAC		0	0	0	0	0
COND. OR CALAND. COST - $1000 3Q86 MPC - BARE EQUIPMENT						
-CARBON STEEL		$0.0	$0.0	$0.0	$0.0	$0.0
-304 STAINLESS STEEL		$0.0	$0.0	$0.0	$0.0	$0.0
-316 STAINLESS STEEL		$0.0	$0.0	$0.0	$0.0	$0.0
-MONEL		$0.0	$0.0	$0.0	$0.0	$0.0
SUBTOTAL		0		0		0
SUBTOTAL		0		0		0
SUBTOTAL		0		0		0
MINIMUM REFLUX RATIO			ERR		ERR	
Cn SUBTOTAL #1		0	0	0	0	0

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	20 CRUDE FILTRATE	31 LBS #3 TAILS	32 HBS #1 MAKE	33 HBS #1 TAILS	34 HBS #2 MAKE	35 HBS #2 TAILS
Cn SUBTOTAL #2		0	0	0	0	0
Cn SUBTOTAL #3		0	0	0	0	0
Cn CHECK		ERR	ERR	ERR	ERR	ERR
Hv SUBTOTAL #1		0	0	0	0	0
Hv SUBTOTAL #2		0	0	0	0	0
Hv SUBTOTAL #3		0	0	0	0	0
Hv CHECK		ERR	ERR	ERR	ERR	ERR
MIN. PLATES(NORMAL)					ERR	
COL.COST-C/S NORMAL					0	
COL.COST-S/S NORMAL					0	
MIN.REFLUX(NORMAL)						
C.S. AREA(NORMAL)						
HEAT LOAD(NORMAL)						
CON/CAL COST(NORMAL)						
REFLUX FACTOR			ERR		ERR	

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	20 CRUDE FILTRATE	36 AZEO MAKE	37 AZEO TAILS	38 AZEO REFLUX	39 DECANTER FEED
K1 (COMPONENT #)					
K2 (COMPONENT #)					
V.P.(K1)					
V.P.(K2)					
GAMMA-K1 IN K2					
GAMMA-K2 IN K1					
ALPHA					
AVG COLUMN ALPHA					
MOL FRACT. K1 (MAKE OR TAILS)					
MOL FRACT. K1 (FEED)					
MOL FRACT. K2 (MAKE OR TAILS)					
ADJ. GAMMA-K1 IN K2					
ADJ. GAMMA-K2 IN K1					
MINIMUM REFLUX RATIO (ADJUSTED)					
ACTUAL REFLUX RATIO					
MINIMUM THEOR. PLATES (INFINITE REFLUX)					
THEORETICAL PLATES					
PLATE EFFICIENCY -%		80%			
ACTUAL PLATES		50			
PRESSURE mm Hg (REVISED)					
TEMPERATURE C (REVISED)					
AVERAGE MOLECULAR WEIGHT					
GAS DENSITY - LB/CF					
CROSS SECTIONAL AREA - SQ FT		93.9			
COLUMN HEIGHT - FT		90.0			
COLUMN DIAMETER		10.9			
K1 (MPPY)					
Hv (HEAT VAPORIZ.-Btu/Lb)					
Cn (HEAT CAPACITY - Btu/Lb/F)					
HEAT LOAD - MM Btu/Hr		61.699	54.942		
CONDENSER COOLING WATER - GPM		6858 (10 C delta T)			
CALANDRIA STEAM - MPPH (150 PSIG)			64.11		
COLUMN COST - $1000 3Q86 MPC - BARE EQUIPMENT					
- ALL CARBON STEEL		$301.7			
- C.S w/304 S.S. TRAYS		$331.8			
- ALL 304 STAINLESS STEEL		$476.9			
- ALL 304L STAINLESS STEEL		$524.6			
- ALL 316 STAINLESS STEEL		$643.8			
CONDENSER OR CALANDRIA SURFAC		9,532	3,052		
COND. OR CALAND. COST - $1000 3Q86 MPC - BARE EQUIPMENT					
-CARBON STEEL		$295.5	$99.9		
-304 STAINLESS STEEL		$413.6	$139.9		
-316 STAINLESS STEEL		$443.2	$149.9		
-MONEL		$576.1	$194.9		
SUBTOTAL					
SUBTOTAL					
SUBTOTAL					
MINIMUM REFLUX RATIO					
Cn SUBTOTAL #1					

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	20 CRUDE FILTRATE	36 AZEO MAKE	37 AZEO TAILS	38 AZEO REFLUX	39 DECANTER FEED
Cn SUBTOTAL #2					
Cn SUBTOTAL #3					
Cn CHECK					
Hv SUBTOTAL #1					
Hv SUBTOTAL #2					
Hv SUBTOTAL #3					
Hv CHECK					
MIN. PLATES(NORMAL)					
COL.COST-C/S NORMAL					
COL.COST-S/S NORMAL					
MIN.REFLUX(NORMAL)					
C.S. AREA(NORMAL)					
HEAT LOAD(NORMAL)					
CON/CAL COST(NORMAL)					
REFLUX FACTOR					

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	20 CRUDE FILTRATE	40 DECANTER UP LAYER	41 DECANTER LO LAYER	42 BENZENE MAKE	43 BENZENE TAILS
K1 (COMPONENT #)					
K2 (COMPONENT #)					
V.P.(K1)					
V.P.(K2)					
GAMMA-K1 IN K2					
GAMMA-K2 IN K1					
ALPHA					
AVG COLUMN ALPHA					
MOL FRACT. K1 (MAKE OR TAILS)					
MOL FRACT. K1 (FEED)					
MOL FRACT. K2 (MAKE OR TAILS)					
ADJ. GAMMA-K1 IN K2					
ADJ. GAMMA-K2 IN K1					
MINIMUM REFLUX RATIO (ADJUSTED)					
ACTUAL REFLUX RATIO					
MINIMUM THEOR. PLATES (INFINITE REFLUX)					
THEORETICAL PLATES					
PLATE EFFICIENCY -%					
ACTUAL PLATES				30	
PRESSURE mm Hg (REVISED)					
TEMPERATURE C (REVISED)					
AVERAGE MOLECULAR WEIGHT					
GAS DENSITY - LB/CF					
CROSS SECTIONAL AREA - SQ FT				7.0	
COLUMN HEIGHT - FT				60.0	
COLUMN DIAMETER				3.0	
K1 (MPPY)					
Hv (HEAT VAPORIZ.-Btu/Lb)					
Cn (HEAT CAPACITY - Btu/Lb/F)					
HEAT LOAD - MM Btu/Hr					6.934
CONDENSER COOLING WATER - GPMDECANTER VOLUME - GAL.					
CALANDRIA STEAM - MPPH (150 P		9,878			8.09
COLUMN COST - $1000 3Q86 MPC - BARE EQUIPMENT					
- ALL CARBON STEEL				$63.0	
- C.S w/304 S.S. TRAYS				$69.3	
- ALL 304 STAINLESS STEEL				$81.1	
- ALL 304L STAINLESS STEEL				$89.2	
- ALL 316 STAINLESS STEEL				$109.4	
CONDENSER OR CALANDRIA SURFACE - SQ FT					385
COND. OR CALAND. COST - $1000 3Q86 MPC - BARE EQUIPMENT					
-CARBON STEEL					$22.3
-304 STAINLESS STEEL					$31.3
-316 STAINLESS STEEL					$33.5
-MONEL					$43.5
SUBTOTAL					
SUBTOTAL					
SUBTOTAL					
MINIMUM REFLUX RATIO					
Cn SUBTOTAL #1					

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