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Technoeconomic Evaluation of the Extractive Fermentation of Butanol as a Guide to Research in This Area of Biotechnology

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

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TECHNOECONOMIC EVALUATION OF THE EXTRACTIVE FERMENTATION OF BUTANOL AS A GUIDE TO RESEARCH IN THIS AREA OF BIOTECHNOLOGY

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EXECUTIVE SUMMARY

From World War I until the early 1930s, butanol was produced from corn by the Weizmann ABE process. Thereafter, however, the fermentation process was replaced by the cheaper Oxo process for producing synthetic butanol from propylene. The U.S. annual production is now close to 1 billion lb.

Synthetic butanol currently sells for $0.38/lb at a crude oil price of $17-$20/bbl. However, considering the increases expected again in crude oil prices in the 1990s, a doubling in the price for propylene-derived butanol is not inconceivable.

At the current state of the art, the ABE process would require butanol prices in excess of $1.20/lb to be competitive. Two major problems exist: (1) low product concentrations in the beer resulting from inhibition of the functioning of the organism by-product, which lead to high process investment charges; and (2) poor yields related to large losses of substrate to carbon dioxide and by-products, coupled with high prices for corn syrup compared with presently depressed oil prices.

To circumvent the inhibition problem, two scenarios have been developed for a new extractive fermentation process to remove the product from the field of fermentation "as rapidly as it forms." Both models rely on continuous fermentation instead of batch operation to effect significant cost reductions.

In the external multistage extraction model, the fermenter is operated with a large recycle of cells to increase volumetric productivity while maintaining product concentration in the beer that is fed to the extractor close to the threshold of inhibition at 13 g/L. As a result, it appears that fermenter volume and investment could be dramatically reduced. Raffinate is also recycled to improve the recovery of valuable by-products. Selling prices below $0.43/lb look feasible.

In the in situ single-stage extraction model, the fermentation is operated with simultaneous extraction at high ratios of solvent to aqueous feed so that, in fact, the product is removed into the solvent phase as rapidly as it forms. It appears that effective concentrations in the fermenter could reach ~200 g/L while maintaining product concentration at 13 g/L in the aqueous phase containing the organism. Since total plant investment decreases in direct proportion to increases in concentration, major cost

reductions could be expected. For this case, cell density and product cost would be about the same as in the external extraction case.

For either model, genetically engineering an organism that was less inhibited by product or substrate or that produced only butanol as the preferred product would lead to further cost reductions. If the goal case can be achieved, cost would be reduced to $0.35/lb butanol. However, the microbiological research program that would be required would have a lower probability of success than the engineering program required to develop the extraction processes based on the existing organism.

Certainly, these improvements would represent major breakthroughs in not only the Weizmann process, but, generically, in any fermentation process that suffers from product inhibition (which is most of them). Continuing research along these lines is highly recommended. Suggestions for fine-tuning the program are appended.

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 as part of the Energy Conversion and Utilization Technologies (ECUT) program of the Department of Energy, 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 butanol, acetone, ethanol, 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 bushels.

Furthermore, 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 bushels, or ~45% of the corn crop. In addition, the use of butanol for diesel blends or in jet fuel blends to enhance the range of military aircraft could further increase its market.

At the present state of the antiquated art for producing these products from corn by fermentation, product costs do not appear competitive compared with prices for incumbent petroleum-based chemicals. Industrial interest in fermentation chemicals had revived in the 1970s as a result of the oil crisis. However, the subsequent softening in oil prices in the 1980s removed the competitive edge of renewable materials compared with

fossil feedstocks and resulted in an almost complete loss of momentum in research in this area of biotechnology.

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, ~1%, product concentrations, as a result of which the recovery of product from dilute aqueous solution is accordingly expensive.

The problem resulting from the cost of raw materials will presumably rectify itself in a few years after increased demand for oil relative to Middle East production capacity and further Middle East turmoil again force oil prices to rise. Conoco predicts that this will happen in the 1990s (Fig. 1), at which 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.[2]

One possible solution to the inhibition problem would be to apply extraction or distillation as an integral part of the fermentation process so as to remove the product from the field of fermentation as rapidly as it forms. In the case of an external multistage extraction process, this is expected to permit a proportionate increase in cell density while maintaining product concentration in the fermenter near the threshold of inhibition. As a result, volumetric productivity increases and fermenter investment and cost decrease. Alternatively, in the case of an in situ single-stage fermenter/extractor, this is expected to increase productivity and effective product concentration while maintaining low concentrations in the beer.

In the current technoeconomic study of the butanol process, the state of the art for its fermentative manufacture was defined. From this, scenarios for an improved process were developed based on the expectations for adapting extractive fermentation to

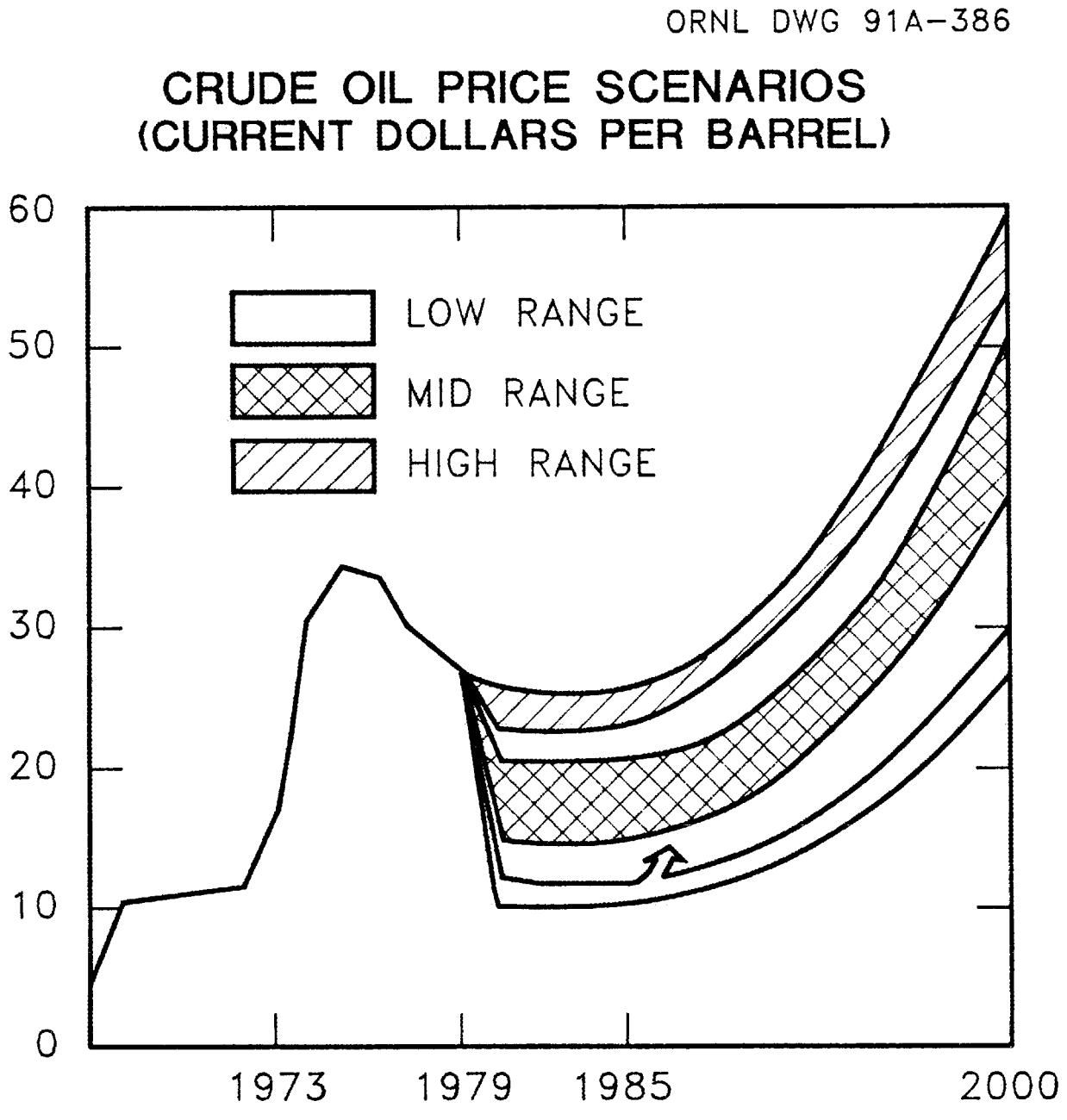

Fig. 1. Crude oil price scenarios.

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.

2. MARKET POSITION

The United States leads among world producers of butanol (Table 1).[3] Production has risen steadily at 5% annually since 1964 to a production level of ~918 million lb of *n*-butanol plus 190 million lb of isobutanol. European production is less and stagnant; Japanese production has declined to where Japan is now a net importer.

Almost all butanol is made from propylene by the Oxo process. Consumption favors *n*-butanol in all market areas, but especially in U.S. markets. As a result, newer plants are based on a rhodium catalyst system that enhances the production of *n*-butanol, the preferred isomer.

Table 1. Butanol production (10^6 lb)

Country	*n*-Butanol	Isobutanol	*n*/iso
United States	842	143	5.9
Europe	300	220	1.4
Japan	43	36	2.6

The major U.S. end uses for *n*-butanol in descending order are: butyl acrylates/methacrylates for latex paints, textile finishes, and floor polishes; glycol ethers as

solvents for surface coatings and adhesives; butyl acetate as a rapid drying solvent for varnishes; dibutylphthalate and other plasticizers for a variety of adhesives, packaging films, and surface coatings; amino acids; butylamines for use in pesticides and rubber processing; and uses in fire-resistant hydraulic fluids. Demand is expected to increase by 3.2-3.5% annually to reach 920 million lb in 1988.

Isobutanol has similar uses but favors direct solvent use. It also finds use in lube oil additives. It is generally inferior to *n*-butanol in properties and finds use only if price is sufficiently discounted -- historically 15%.

The use of *n*-butanol and isobutanol in blends with methanol as an octane enhancer for gasoline has been introduced but has faced environmental challenges and stiff competition from Oxinol *tert*-butanol blends and ethanol blends. The economics associated with butanol blends do not appear attractive when compared with methanol/ethanol blends. However, butanol might find better use as blends with diesel oil and with jet fuel for military aircraft.

Acetone, the primary by-product in butanol manufacture by fermentation, has actually a more important role than butanol in world markets. Demand in the United States over the decade of the 1980s has been relatively flat, at ~2.5 billion lb. Most of this total has been for producing methacrylates or acrylic resins (Fig. 2). It must be noted that the acetone supply is derived from two sources: (1) as a by-product in the conversion of cumene to phenol, or (2) by direct synthesis from isopropanol. U.S producers are listed in Table 2 on the basis of their raw material. By-product acetone tracks the demand for adhesives for plywood for the building trades and is always sold off first at a discount under the cost of isopropylene-derived product. Accordingly, acetone derived from fermentation must either compete with the latter or be discounted as the former. Recent producers of sugar-derived acetone are listed in Table 3. Of these, only the South African plant is significant.

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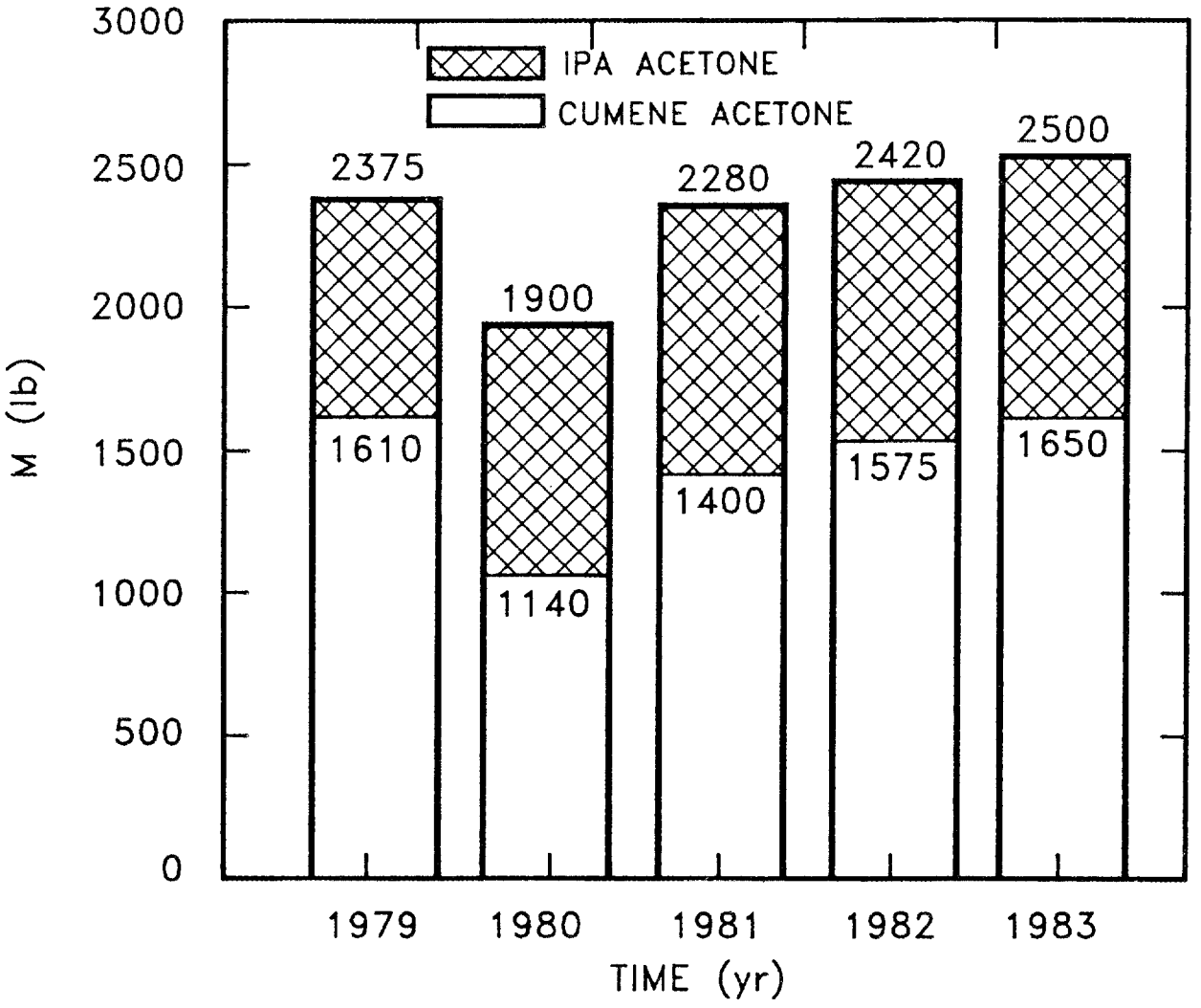

CUMENE ACETONE IN-PLACE CAP.	2053	2137	2368	2368	2368
IPA ACETONE IN-PLACE CAP.	990	1040	1190	1190	1190
TOTAL IN-PLACE CAPACITY	3043	3177	3558	3558	3558

Fig. 2. U.S. Acetone Industry supply/demand.

Table 2. U.S. acetone producers' "in-place" capacities

Producer	Output (10^6 lb)				
	1980	1981	1982	1983	1984
Cumene-based					
Allied	360	360	360	360	360
Chevron	33	33	33	33	33
Clark	54	54	54	54	54
Dow	284	284	284	284	284
General Electric	30	240	240	240	240
Georgia Pacific	177	198	198	198	198
Getty (Skelly)	57	57	57	57	57
Monsanto	300	300	300	300	300
Shell	300	300	300	300	300
U.C.C.	230	230	230	230	230
U.S. Steel	312	312	312	312	312
Subtotal	2137	2368	2368	2368	2368
Eastman	80	80	80	80	80
Exxon	140	140	140	140	140
Shell	650	800	800	800	800
U.C.C.	170	170	170	170	170
Subtotal	1040	1190	1190	1190	1190
GRAND TOTAL	3177	3558	3558	3558	3558

Table 3. Producers of sugar-derived acetone

Producer	Status
National Chemical Products Co. Transvaal, Union South Africa	Operating 12 x 25 M gal
Egyptian Sugar and Distillation Co. El-Hawamdia, Giza, A.R.E.	Operating
Soviet Union	Operating
Commercial Solvents Corp. Terre Haute, IN	Torn Down 50 M gal
Chase Chemical Puerto Rico	Torn Down 2 x 60 M gal
Publicker Industries Philadelphia, PA	Standby 140 Million PPY 5 x 2000 M gal (EtOH) 10 x 500 M gal 9 x 250 M gal 12 x 18 M gal 6 x 1 M gal

3. HISTORICAL DEVELOPMENT

The original Weizmann process for fermenting starch-containing grains to butanol and acetone was developed under the stimulus of the World War I demand for acetone for manufacturing "cordite," a double-based smokeless powder used for British naval guns. The process made a successful transition to civilian products but was finally supplanted in the 1950s by cheaper petrochemical processes. Interest in the fermentation process revived following the energy crisis of 1973 but was cooled again as a result of the softening in oil prices in the early 1980s.[4]

A few years prior to World War I, Weizmann had developed an organism, *C. acetobutylicum*, which successfully fermented starchy grains to produce a mixture of acetone, butanol, and ethanol (ABE). He applied for and received patents on the so-called ABE process.[5,6] With the outbreak of World War I, a plant was built at Kings Lynn, England, in 1914 to produce acetone by fermentation, but operation was a failure until Weizmann was placed in charge and installed his process. Because of the shortage of corn in England, the process was transferred to Canada in August 1916, where it operated until November 1918. To supplement this output, a butanol-acetone plant was built in Terre Haute, Indiana, which operated from May to November 1918 under the auspices of the War Production Board. While the Terre Haute Plant operated, there was no use for butanol and it was stored.

However, shortly after the end of the war, the Dupont Company developed Duco nitrocellulose lacquers for use in automobile finishes. It was found that *n*-butyl acetate was the solvent of choice for this coating system. In order to supply the *n*-butanol required for making the acetate, the Terre Haute plant was reactivated in 1920 as a private venture by Commercial Solvents Corporation, which had acquired an exclusive license under the Weizmann U.S. patent. Commercial Solvents used 50,000-gal fermenters to make the solvents. The plant is now owned by International Minerals and Chemical Corporation. It no longer operates the fermentation equipment but has maintained the historical cultures and has advised that the technology is available for licensing.

When the patents expired in 1936, new ABE plants were built in Philadelphia (Publicker), Baltimore, Puerto Rico, and Japan. A flow sheet for the process as practiced by Publicker in the late 1930s and 1940s is shown in Fig. 3. The Publicker plant was based on the use of 5000-gal Hortonspheres through 500,000-gal tanks for the batch fermenter train. Operation of this plant was described in detail by Beesch.[7] The plant was, since, shut down but was considered for reactivation in the late 1970s. The decision to proceed was deferred as a result of the oil glut of the 1980s.

At the present time, the only ABE plant operating in the free world is at Germiston in the Union of South Africa at National Chemical Products, Ltd., a division of Sentrachem Ltd. Started up in 1936, its operation was described by Spivey.[8]

4. TECHNICAL BACKGROUND

4.1 RAW MATERIAL DEMAND

Raw material economics has always been one of the most important parameters in the choice between fermentation processes for producing solvents. Until 1938, the ABE process operated solely on corn using *C. acetobutylicum*, with a solvents yield of ~26.5%, based on dry corn and comprising roughly 60% butanol, 30% acetone, and 10% ethanol.[9-11] After 1938, new organisms were developed which allowed the use of cheaper molasses.

Early in this study, it became apparent that the stoichiometry of the fermentation was very important to the economics. The metabolic pathway followed by *C. acetobutylicum* is outlined in Fig. 4. Electron balance must be maintained among the competing reactions. Yields to the various products are outlined in Table 4. Even though the organism operates near its biological maximum, carbon yields are poor because of the large losses to carbon dioxide. In general, the solvents are formed in the ratio 60% *n*-butanol, 30% acetone, and 10% ethanol, with the corresponding release of hydrogen and carbon dioxide.

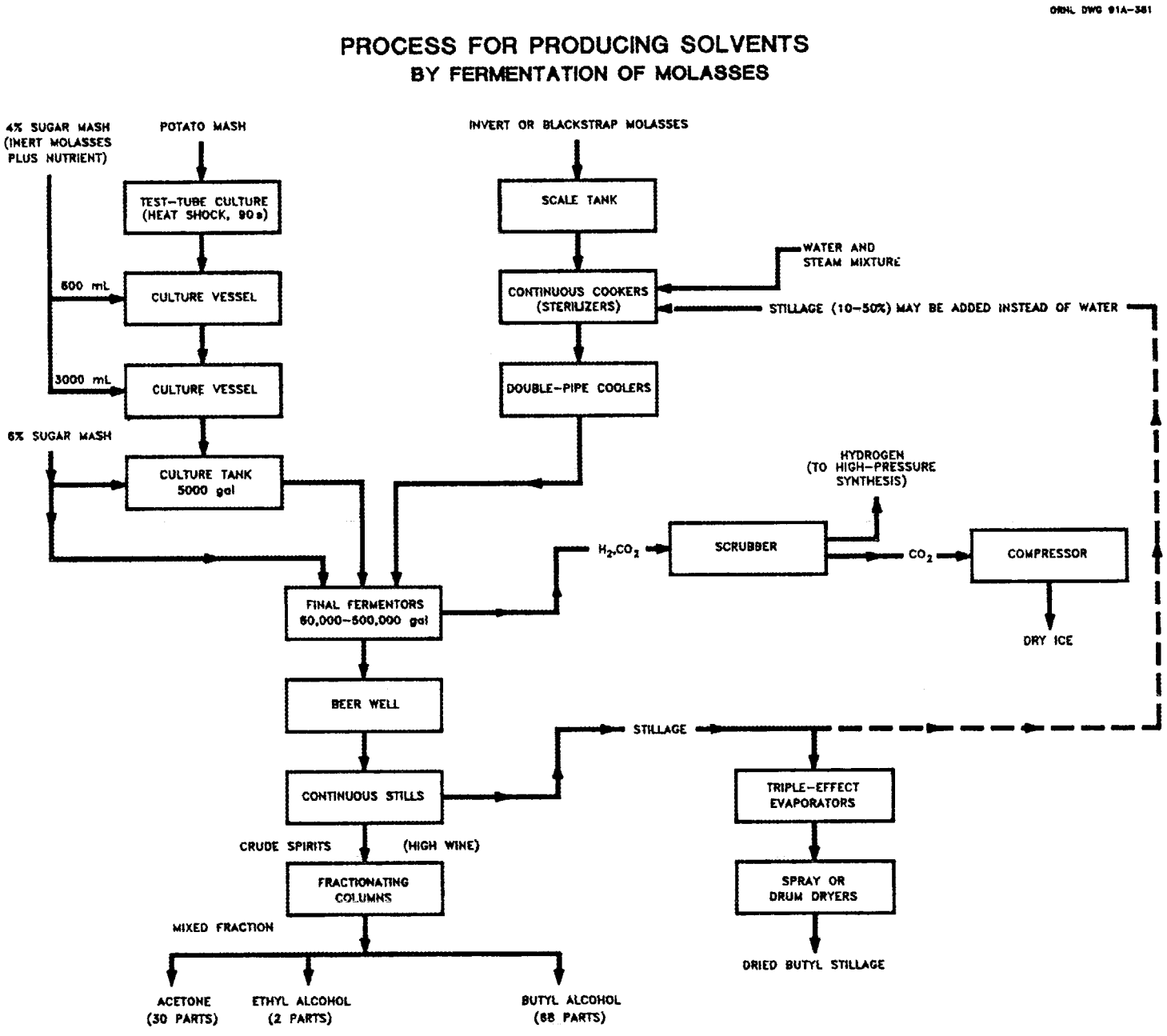

Fig. 3. Publicker Industries process for producing solvents by fermentation of molasses.

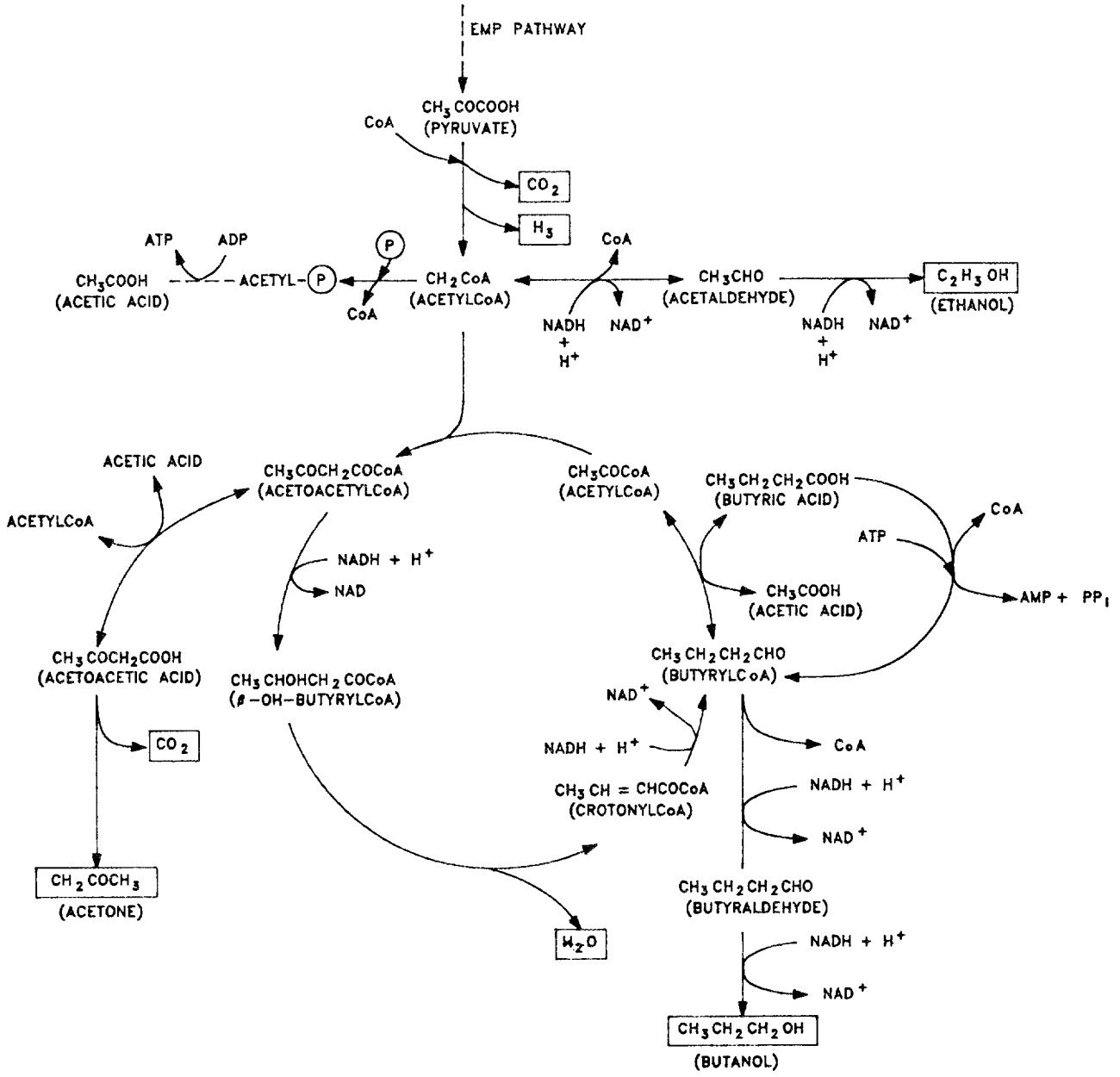

Fig. 4. Metabolic pathway for glucose utilization by clostridium bacteria.

Table 4. Fermentation stoichiometry
(per 100 mol butanol)

Basecase

Glucose -----> butanol + $2CO_2$ + H_2O
100.0 100.0 200.0 100.0

Glucose -----> acetone + $3CO_2$ + $4H_2$
40.0 40.0 120.0 159.8

Glucose + $2H_2O$ -----> 2 acetic acid + $2CO_2$ + $4H_2$
12.5 12.5 25.0 25.0 50.0

Glucose -----> 2 ethanol + $2CO_2$
8.3 16.6 16.6

Glucose -----> butyric acid + $2CO_2$ + $2H_2$
6.7 6.7 13.5 13.5

167.5 Glucose -----> 100.0 butanol + 40.0 acetone
+ 25.0 acetic acid + 16.6 ethanol
+ 6.7 butyric acid + 375.0 CO_2
+ 35.0 H_2O + 233.4 H_2

Goal case

100.0 glucose -----> 100.0 butanol + 200.0 CO_2 + 100.0 H_2O

Alternatively, Weimer has postulated that an organism could be developed that would produce only butanol according to the "goal" case of Table 3. This could theoretically be accomplished, although with great difficulty, by blocking the acetyl CoA to acetaldehyde (to ethanol) pathway and the acetoacetyl CoA to acetone pathway.[12] Small amounts of acetaldehyde might be added to the fermentation to inhibit the ethanol route, but since acetaldehyde is toxic in general, it might completely stop the fermentation.

4.2 PRODUCT INHIBITION

As with most fermentations, *C. acetobutylicum* is inhibited by its own substrate and products. Previous studies have shown that butanol is the most toxic of the products.[13,14] The fermentation is totally inhibited by butanol concentrations of 10-15 g/L.[4,15,16] Thus, in normal batch operation, productivity is limited to ~0.25 g/(L·h), or 13 g/L butanol after 40 batch hours plus 12 h of fermenter turnaround. Productivities in the range 0.16-0.58 g/(L·h) have been reported by various investigators.[12-17] This experience has suggested to many that the fermentation rate and product concentration could be raised to commercial levels by removing the butanol from the fermentation medium as fast as it forms. This assumption forms the basis for the scenarios developed for economic evaluation in this study.

Various methods for removing inhibitory products have been proposed. These include adsorption by activated carbon,[17-20] ion-exchange resins,[21-24] or polymeric resins;[25-28] extraction by aqueous solvents[29-35] or organic solvents;[36-42] or membrane separation.[43-44] The use of organic solvents is the subject of the butanol study.

As a preamble to extraction studies, a number of laboratories have tested the toxicity of various solvents toward the organism.[37,39,40,45-50] In many cases, it was found that good solvents for the products were also toxic to the organism.

In the early 1980s, Leung of MIT[45] studied at small scale the extraction of butanol with corn oil during fermentation to minimize inhibition.

Gill and Ratledge[51] suggested that the toxicity of hydrocarbons toward specific organisms might be related to the aqueous solubility of these compounds. They showed that toxicity was reduced by adding a nontoxic compound such as hexadecane to the organic phase.

Evans and Wang at Michigan[52] studied extractive fermentation at a 10-mL-test-tube scale with the aim of optimizing distribution coefficient versus toxicity by using mixtures of toxic solvents having good distribution coefficients with nontoxic hydrocarbons having low solubility in the aqueous fermentation medium. Oleyl alcohol was found to be a good solvent with low toxicity.

Japanese investigators also demonstrated the use of oleyl alcohol to extract butanol in batch experiments.[39]

Blanch and coworkers at the University of California at Berkeley[53] also showed in limited small-scale tests using oleyl alcohol as a solvent that the effect of butanol inhibition could be reduced and volumetric productivity increased by removing butanol in either batch[54] or fed-batch culture.[55] The feasibility of using continuous processing in extractive fermentation was also demonstrated at bench scale in experiments in which the fermenter broth was continuously recycled to an external extraction column.[56] In the fed-batch experiments using oleyl alcohol as a solvent, they were able to increase productivity to 1.5 g/(L·h). However, in these experiments, productivity can also be inhibited by the high concentrations of the sugar substrate required in batch culture to drive the fermentation to high butanol productivities. True continuous culture would circumvent this problem. Blanch's continuous runs were operated for over 55 h at double the productivity of batch or fed-batch culture.

In normal batch operation, productivity is limited to ~0.25 g/(L·h), or 13 g/L butanol after 40 batch h plus 12 h of fermenter turnaround. Productivities in the range of 0.16-0.58 g/(L·h) have been reported by various investigators.[33,39,41,42,56,57]

The extractive fermentation program at Battelle Memorial Institute picked up where these studies left off. Since early 1986, Battelle had been developing its "multi-phase fluidized-bed (MPFB) bioreactor" concept with the intent to enhance fermentation by removing product as fast as it forms using an in situ solvent (oleyl alcohol, etc.) that is not soluble in the aqueous fermentation medium and nontoxic to the organism. A schematic drawing of the bioreactor concept is shown in Fig. 5. This design was used to represent the fermenters in this study. The production of butanol/acetone/ethanol by *C. acetobutylicum* was chosen as the demonstration example for the generic process. More recently, this program has been transferred to the Oak Ridge National Laboratory. If

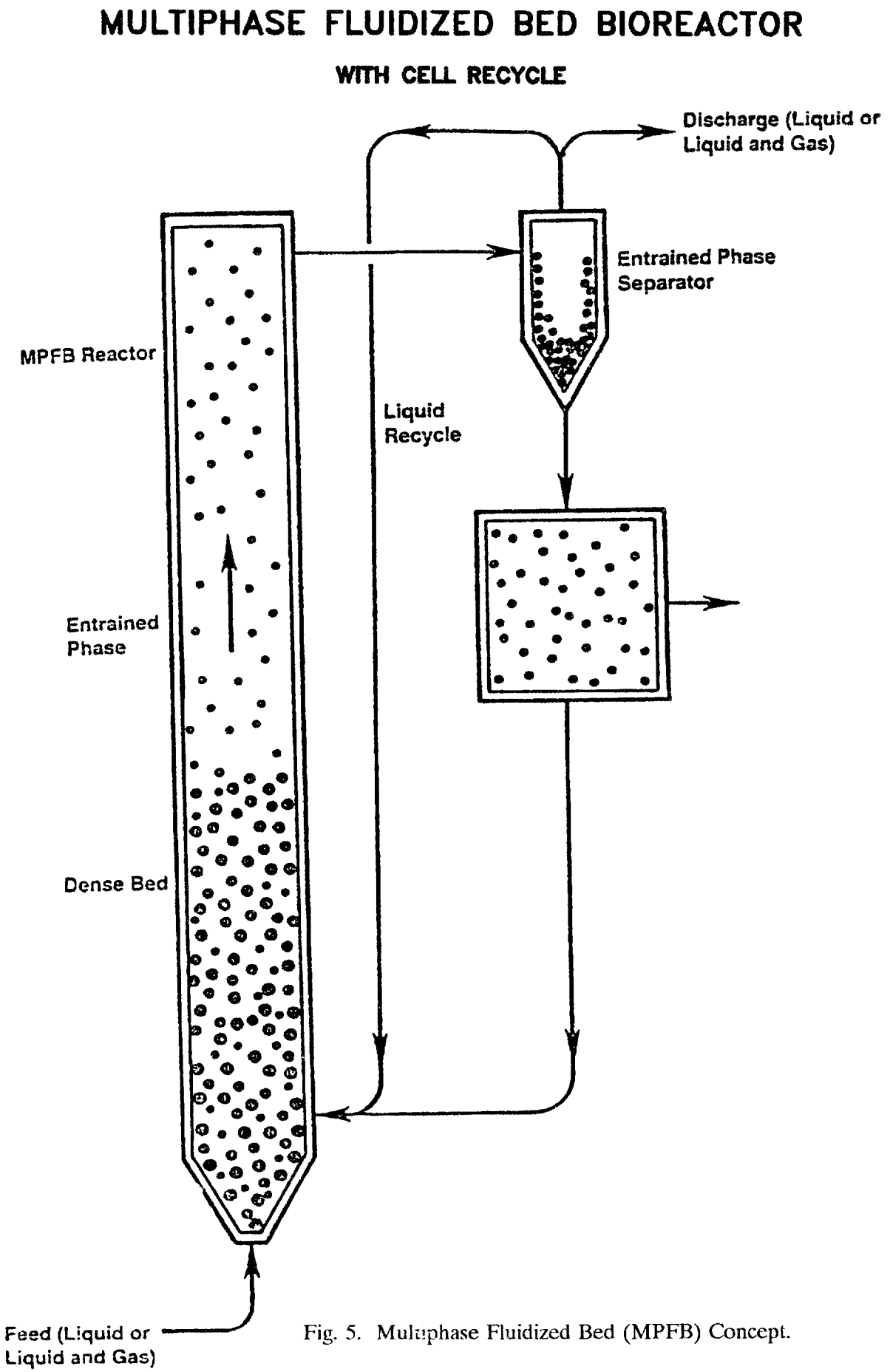

Fig. 5. Multiphase Fluidized Bed (MPFB) Concept.

successful with this system, the Oak Ridge program will be expanded to the acetic acid, ethanol, and other systems.

The goals of the Battelle program are to (1) demonstrate the feasibility of the MPFB bioreactor for producing bulk chemicals in a continuous mode and (2) provide a generic design basis which can be scaled up beyond the current prepilot scale to the commercial production of butanol as well as other major products.

The program to date has been aimed at developing a cell immobilization system; testing this in a fluidized-bed reactor; determining in separate tests the toxicity of the candidate solvents for butanol toward the immobilized organism; and in the course of all this, to design, build, and operate a process development unit (prepilot plant) to study operation. Progress has been reported in a number of papers.[58-62]

5. PROCESS DEVELOPMENT STRATEGY

5.1 BATCH MODE

In the operation of the conventional batch fermenter on *C. acetobutylicum*, 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.

5.2 CONTINUOUS MODE

It appears then that the development of a continuous fermentation system is a fundamental requirement for improving the economic viability of the butanol process. As noted earlier, Blanch has operated a small research unit in a continuous mode, as has Scott of Oak Ridge National Laboratory.[63] Scott incorporates lactic acid in an immobilized cell system to act as a mild hydrogen donor to scavenge oxygen so as to maintain a strict anaerobic environment and prevent cell deactivation. These results are encouraging, but it is imperative that continuous operation be demonstrated over an extended period at pilot scale.

This study was based on a continuous fermentation system in which product is removed from the broth either by an external, multistage extractor or by the in situ, single-stage extraction of product within the fermenter itself. The two approaches differ in that in the external case, the beer (at the maximum allowable, but low, product concentration) is the feed to a multistage extraction; whereas in the in situ case, the same beer is the raffinate leaving a single-stage extraction. In the latter case, the "effective concentration" in the fermenter (the"feed" to the in situ extraction) can be 10-15 times higher than in the aqueous beer phase, although the single-stage extraction is not as efficient as the multistage approach. Work is under way now to develop a model based on an in situ multistage extractor/fermenter design.

5.2.1 External Multistage Extractor

This study was based on a continuous fermentation system in which cells are maintained in the fermenter at a desired, maximum level. 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.

This result can be accomplished either by immobilizing the cells to prevent their loss from the fermenter or by filtering the cells from the beer and recycling them. The

immobilization approach would be preferred; it would avoid passing cells through a filter and, possibly, an extractor with possible deactivation of cells by mechanical attrition or exposure to solvent and with possible plugging of the trays of an extractor.

If for some reason the cells cannot be immobilized, then, two alternative recycle schemes can be considered: (1) a single recycle in which the cells are carried with the beer through an extractor and recycled with raffinate to the fermenter, or (2) a double recycle in which the cells are separated from the beer before the extractor and recycled, while cell-free raffinate from the extractor is recycled separately so as to assist in recovering by-products.

The economic consequences for any of the above options would be the same except for certain limiting situations.

5.2.2 External Extraction With Single Recycle

The single-recycle mode was used as the basis for this study as a "worse" case. It has the drawback that recycled cell density and recycled raffinate cannot be controlled separately. Thus, for this model, a point is reached at a recycle ratio of 15:1 beyond which recycle supplies all the need for makeup water in the fresh feed. To go higher would require that the 45% syrup feed to the fermenter be evaporated to maintain the water balance. This would greatly increase the cost of substrate and must be avoided.

This limitation may be moot, however, since at a 15:1 recycle, cell density has been increased from 1.4 g/L at zero recycle to 22.3 g/L, dilution rate from 0.03 h^{-1} to 0.48 h^{-1}, and volumetric productivity from 0.4 to 6.3 g/L·h. As a result, total plant investment has been reduced from $228 million to $41 million for a 160-million-pound-per-year production level and the cost-plus-return selling price from $1.08/lb butanol to $0.43/lb. Although cell density could presumably be increased above 22 g/L without adverse effect, further increases would lead to marginal improvements in cost.

5.2.3 External Extraction with Double Recycle

In the double-recycle case, cell density could reach higher levels than are possible with the water balance limitations of the single-recycle case. Likewise, cells would have

less exposure to solvent with concomitant possible toxic side effects. Process control would have to be more sophisticated, but this is not an insurmountable problem.

In either recycle case, the recycle of raffinate is mainly desirable to reduce product losses to the aqueous purge. It also reduces the fluid load on the first raffinate still, thereby reducing the cost of this large still and its attendant steam consumption and investment. Raffinate recycle is also ostensibly desirable to (1) enhance the extraction of less extractable by-products such as acetone and ethanol; (2) conserve process water; and (3) recycle cells in the single-recycle case. None of the latter arguments are critical to the process. For the basis of this study, the recovery of low-boiling chemicals by distillation of the raffinate is definitely economically justified. This prevents the loss at any recycle ratio of valuable byproducts that are not recovered by extraction. Conservation of process water is of minor importance compared with other cost elements. As noted, cell recycle can be accomplished by separate recycle or immobilization.

5.2.4 In Situ Extraction

In the in situ case, cells are either recycled, immobilized, or allowed to grow in a first-stage fermenter to the level required to produce the desired amount of product in a second stage, such that the raffinate (beer) leaving the fermenter does not exceed the threshold level of inhibition of product concentration. The effective concentration (i.e., amount produced divided by the aqueous flow) would be many times this since the bulk of the product leaves in the solvent extract. The multiplier would approximately equal the solvent/feed ratio times the distribution coefficient (~12X for the basis used).

In summary then, in external extraction, cell density is increased to reduce fermentation time and fermenter volume at the maximum allowable product concentration in the beer for a desired production level. In situ extraction cell density is increased to increase effective product concentration at the maximum allowable product concentration in the aqueous beer and constant fermentation time for the desired production level.

6. EXTRACTIVE FERMENTATION PROCESS SCENARIOS

6.1 PROCESS SCENARIO FOR EXTERNAL EXTRACTION

A flow sheet for the process model of external extraction is shown in Fig. 6. Beer leaving the fermenter train is passed to a multistage extractor (or first to a filter in the double-recycle model), whereupon substantially all of the product is removed by a selective solvent. Some of the by-product acetone and ethanol are removed also, as are the higher-boiling acids: acetic and butyric. Actually, as a worse case it was assumed, rather than known, that the acids would be, indeed, produced and that the pH of extraction would be low enough for the acids to exist as acids rather than as salts. In salt form, they could not be extracted and would stay with the raffinate.

The aqueous raffinate, containing cells in the single-recycle case, leaving the extractor is recycled to the desired, highest possible level to the fermenter. The balance is filtered to remove residual cells. The filtrate is sent to the raffinate still train to recover by-product acetone and ethanol. Residual salts either fed to or produced in the fermenters are purged as the tails from the first raffinate still.

Butanol, by-product acetone and ethanol, and solvent contained in the extract are separated in a low-boilers still train. Butanol and acetone are recovered in pure form in this train, whereas crude ethanol is sent to the raffinate train for purification. Solvent is separated from lower-boiling wastes in the high-boilers still and recycled to the extractor.

One potential problem with the use of a high-boiling solvent must be noted. If the solubility of solvent in water is high enough, the loss of solvent to the aqueous waste leaving the process as the tails from the first raffinate still might be unacceptable. A solubility of 20 ppm was assumed in this study, while Blanch assumed 100 ppm in his study. Either would be satisfactory.

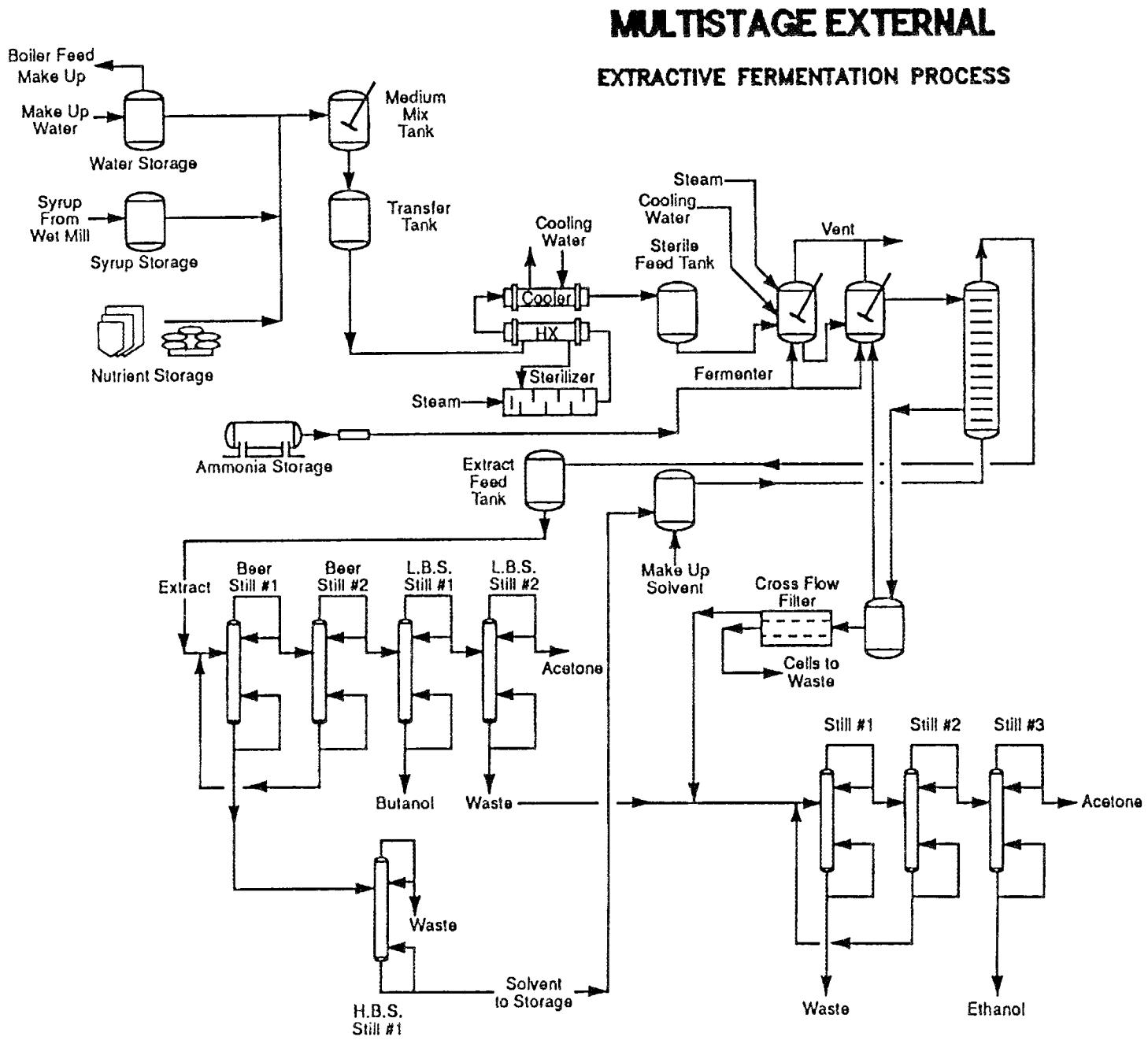

Fig. 6. Process model used in economic study.

6.2 PROCESS SCENARIO FOR IN SITU EXTRACTION

The flow sheet for the in situ case is substantially the same as for the external extractor case except that extraction is carried out in the fermenter and no additional extraction vessel is required. Also, aqueous raffinate containing cell debris and unextracted product and by-products is sent to waste disposal. The evaluation of this case did not include the recovery of chemicals in the raffinate. This would probably be justified; in which case the raffinate still train used for the external extractor case would be added. The process is shown in Fig. 7.

7. OPERATING CONDITIONS

It was assumed that the plant would be sited in the Midwest adjoining a wet corn mill, with dilute 45% syrup supplied over the fence by pipeline. Capacity was sized to a 180-million-pound-per-year butanol plant having a midpoint of construction in 1984 and operating in 1988 at a 160-million-pound-per-year production rate. Technical and financial data for the cases evaluated are provided in the appendixes.

Basic data for the external extraction process are outlined in Table 5 according to whether they are independent or dependent variables. Key equipment dimensions are shown to provide a feeling for scale of the operation. The basecase data for fermentation without cell recycle were obtained from the literature sources discussed earlier. Distribution coefficients were determined by Battelle.[62] A comparison with the basis used by Blanch is shown in Table 6.

The main differences among cases were whether or not raffinate with cells was recycled and whether raffinate chemicals were recovered. As can be noted from the selling prices required to provide an adequate return on investment, the recycle of cells

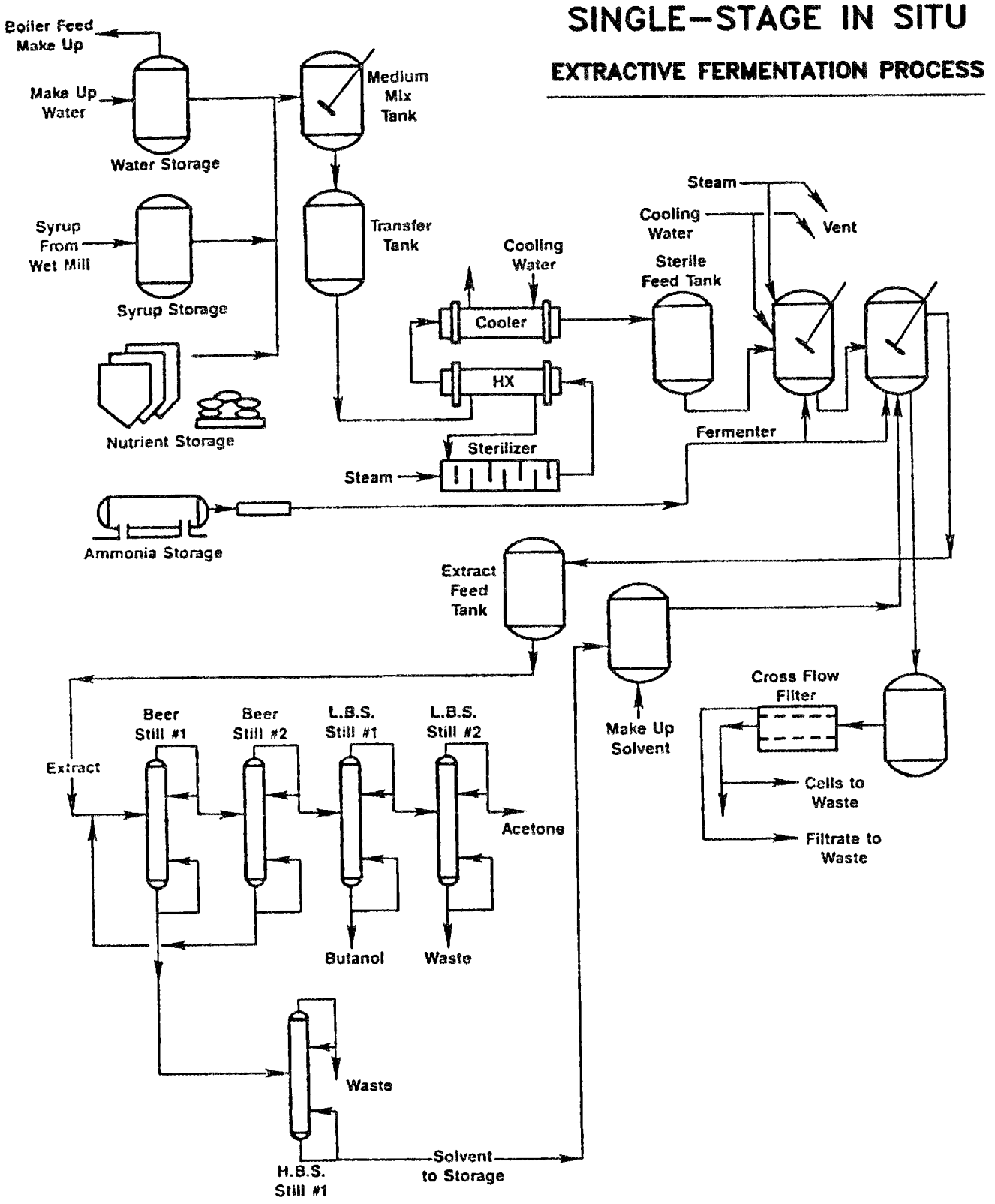

Fig. 7. Process model used in economic study.

Table 5. The external extraction process

Process basic data					
Model stoichiometry	Goal	Base	Base	Base	Base
With recycle of raffinate/cells	Yes	Yes	Yes	No	No
With recovery of raffinate chemials	N/A	Yes	No	Yes	No
Butanol cost+return selling price, $/lb	0.35	0.43	0.48	1.07	1.05
Specified operating parameters					
Annual capacity, 10^6 lb/year			180		
Butanol concentration in beer, g/L			13		
Specific productivity, g BuOH(g cells·h)			0.283		
Glucose to products, % of converted			95%		
Solvent-to-beer ratio			0.3		
Butanol yield to extract, lb/lb in beer	0.970	0.970	0.970	0.999	0.999
Raffinate & cell recycle ratio	27:1	15:1	15:1	-0-	-0-
Dependent variables					
Glucose demand, lb/lb butanol	2.56	4.29	4.29	4.29	4.29
Cell density, g/L	21.1	21.8	21.8	1.4	1.4
Dilution rate, L/h	0.46	0.48	0.48	0.03	0.03
Volumetric productivity, g BuOH(L·/h)	6.0	6.2	6.2	0.4	0.4
Butanol yield across refining, $ fed	99.4	98.8	98.8	98.9	98.9
Fermenter volume, 1000 gal (gross)	635	616	616	9654	9654
Extractors - Stages	9	9	9	20	20
- Height, ft	28	28	28	50	50
- Diameter, ft	11.5	11.5	11.5	11.1	11.1
- Number	4	4	4	4	4
Beer still #1 - Plates	11	10	10	10	10
- Height, ft	31	30	30	30	30
- Diameter, ft	5.4	6.4	6.4	5.8	5.8
Raffinate still #1 - Plates	N/A	32	--	42	--
- Height, ft	N/A	63	--	78	--
- Diameter, ft	N/A	4.9	--	18.9	--

Table 6. Blanch's basis comparison

	This study	Blanch's study
Product concentration, g/L	13.0	13.7
Fermentation time, h	33	30
Cell density, g/L	1.4	3.0
Specific productivity, g/g·h	0.28	--
Volumetric productivity, g/L·h	0.39	0.46-0.89
Distribution coefficient		
Butanol	4.3	2.6
Acetone	0.5	0.3
Ethanol	0.2	0.1
Acetic acid	0.2	n.a.
Butyric acid	0.2	n.a.

to the highest operable density is of utmost importance. Recovery of raffinate chemicals is also justified.

Data used for the in situ extraction case are the same as the above except that no recycle or raffinate recovery was involved.

8. EXTRACTION PERFORMANCE

In continuous, multistage, countercurrent extraction, a trade-off must be made between the required number of stages, which determines the cost of the extractor, and

the solvent-to-aqueous feed ratio, which determines the cost of recovering product from the solvent extract. The number of stages required for the separation approaches infinity as the product of the distribution coefficient times the solvent/feed ratio approaches unity. As a practical matter, this product should be controlled fairly close to unity for a proper balance. This effect can be seen from the data of Appendix G, which define the number of stages required for any given solvent/feed ratio and desired yield of product to extract.

For the external extractor basecase, a solvent/feed ratio of 0.3 at a distribution coefficient of 4.3 (0.3 x 4.3=1.29) called for 9 stages at a yield of 97%. As will be discussed later, this combination appeared to provide the lowest cost. The yields of acetone (15%) and ethanol (6%) are low because of their low distribution coefficients and low solvent/feed ratio.

For the in situ extraction case, the fermenter acts as a single stage of extraction. Consequently, the efficiency is lower than for the multistage case, but much higher effective concentrations of product in the fermenter can be realized.

Yields of product to extract for single-stage extraction for various distribution coefficients and solvent/beer ratios are shown in Table 7 and Fig. 8. At a distribution coefficient of 4.3, a solvent/beer ratio of 3.5 would lead to a distribution of 93.8% of the butanol solute in the fermenter to the extract. At its lower distribution coefficient, the yield of acetone to extract would be ~60%, and the yield of ethanol, 40%.

The improvement possible in effective concentration is shown in Table 8 and Fig. 9, in which "initial" concentration represents the amount of product produced relative to the aqueous flow. Thus, at a solvent/feed ratio of 3.5, the effective concentration of product in the fermenter can be increased to close to 200 g/L while maintaining the actual concentration in the aqueous raffinate (beer) at 13 g/L, the threshold of inhibition.

It should be noted that although oleyl alcohol was used as a model solvent in this study, as well as in many others reported in the literature, it could not be used in commercial practice since it boils too high to allow a practical separation of product from the extract. It was assumed in this study that the oleyl alcohol was either in a carrier of nonyl alcohol or that a new solvent was identified that had the solvent characteristics of oleyl alcohol and the distillation characteristics of nonyl alcohol.

Table 7. Yield of solute to extract
(% of solute produced)

Distribution coefficient, K	Solvent/beer ratio							
	0.25	0.50	0.75	1.00	2.00	3.00	4.00	5.00
0.25	0.059	0.111	0.158	0.200	0.333	0.429	0.500	0.556
0.50	0.111	0.200	0.273	0.333	0.500	0.600	0.667	0.714
0.75	0.158	0.273	0.360	0.429	0.600	0.692	0.750	0.789
1.00	0.200	0.333	0.429	0.500	0.667	0.750	0.800	0.833
1.25	0.238	0.385	0.484	0.556	0.714	0.789	0.833	0.862
1.50	0.273	0.429	0.529	0.600	0.750	0.818	0.857	0.882
1.75	0.304	0.467	0.568	0.636	0.778	0.840	0.875	0.897
2.00	0.333	0.500	0.600	0.667	0.800	0.857	0.889	0.909
2.25	0.360	0.529	0.628	0.692	0.818	0.871	0.900	0.918
2.50	0.385	0.556	0.652	0.714	0.833	0.882	0.909	0.926
2.75	0.407	0.579	0.673	0.733	0.846	0.892	0.917	0.932
3.00	0.429	0.600	0.692	0.750	0.857	0.900	0.923	0.938
3.25	0.448	0.619	0.709	0.765	0.867	0.907	0.929	0.942
3.50	0.467	0.636	0.724	0.778	0.875	0.913	0.933	0.946
3.75	0.484	0.652	0.738	0.789	0.882	0.918	0.938	0.949
4.00	0.500	0.667	0.750	0.800	0.889	0.923	0.941	0.952
4.25	0.515	0.680	0.761	0.810	0.895	0.927	0.944	0.955
4.50	0.529	0.692	0.771	0.818	0.900	0.931	0.947	0.957
4.75	0.543	0.704	0.781	0.826	0.905	0.934	0.950	0.960
5.00	0.556	0.714	0.789	0.833	0.909	0.938	0.952	0.962
10.00	0.714	0.833	0.882	0.909	0.952	0.968	0.976	0.980
15.00	0.789	0.882	0.918	0.938	0.968	0.978	0.984	0.987
20.00	0.833	0.909	0.937	0.952	0.976	0.984	0.988	0.990

Table 8. Basecase stoichiometry generalized fermentation economics
In situ extraction with distillation -- sensitivity of final beer
concentration (g/L) to solvent/beer ratio and initial concentration
(for K = 4.3)

Initial conc. (g/L)	Solvent/beer ratio						
	0.25	0.50	1.00	2.00	3.00	4.00	5.00
1.0	0.48	0.32	0.19	0.10	0.07	0.06	0.04
3.5	1.69	1.11	0.66	0.37	0.25	0.19	0.16
10	4.85	3.20	1.91	1.05	0.73	0.56	0.45
35	17.21	11.43	6.84	3.80	2.64	2.02	1.63
100	51.13	34.45	20.94	11.80	8.24	6.34	5.16
150	79.10	53.98	33.23	18.96	13.34	10.31	8.41
200	108.89	75.33	47.03	27.22	19.30	15.00	12.29
250	140.68	98.76	62.64	36.85	26.38	20.63	16.99
300	174.67	124.60	80.45	48.23	34.91	27.53	22.80
350	211.11	153.24	100.95	61.87	45.40	36.15	30.17
500	338.02	261.38	186.46	126.02	98.87	82.90	72.14

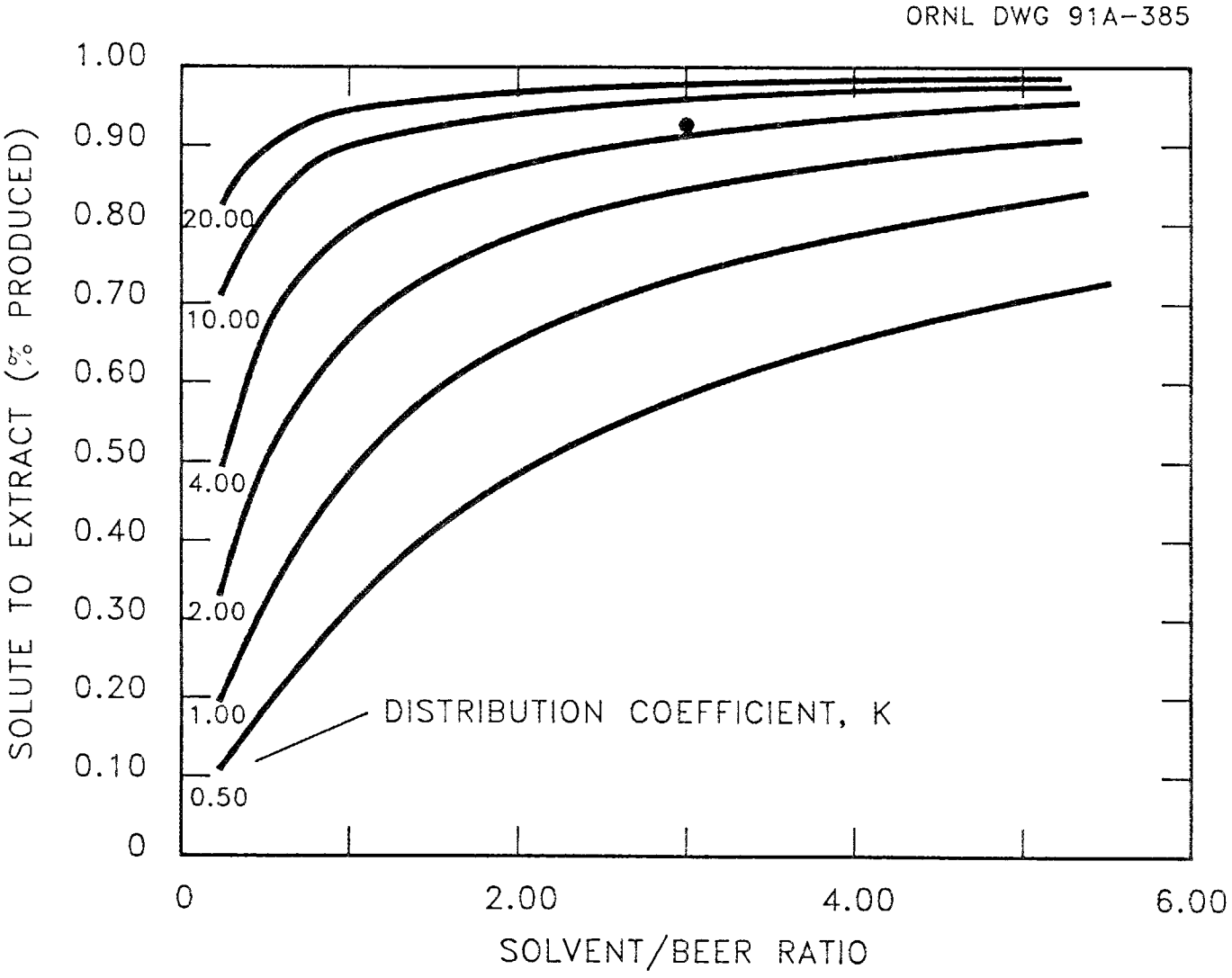

Fig. 8. Yield of solvent to extract as percent of solute produced.

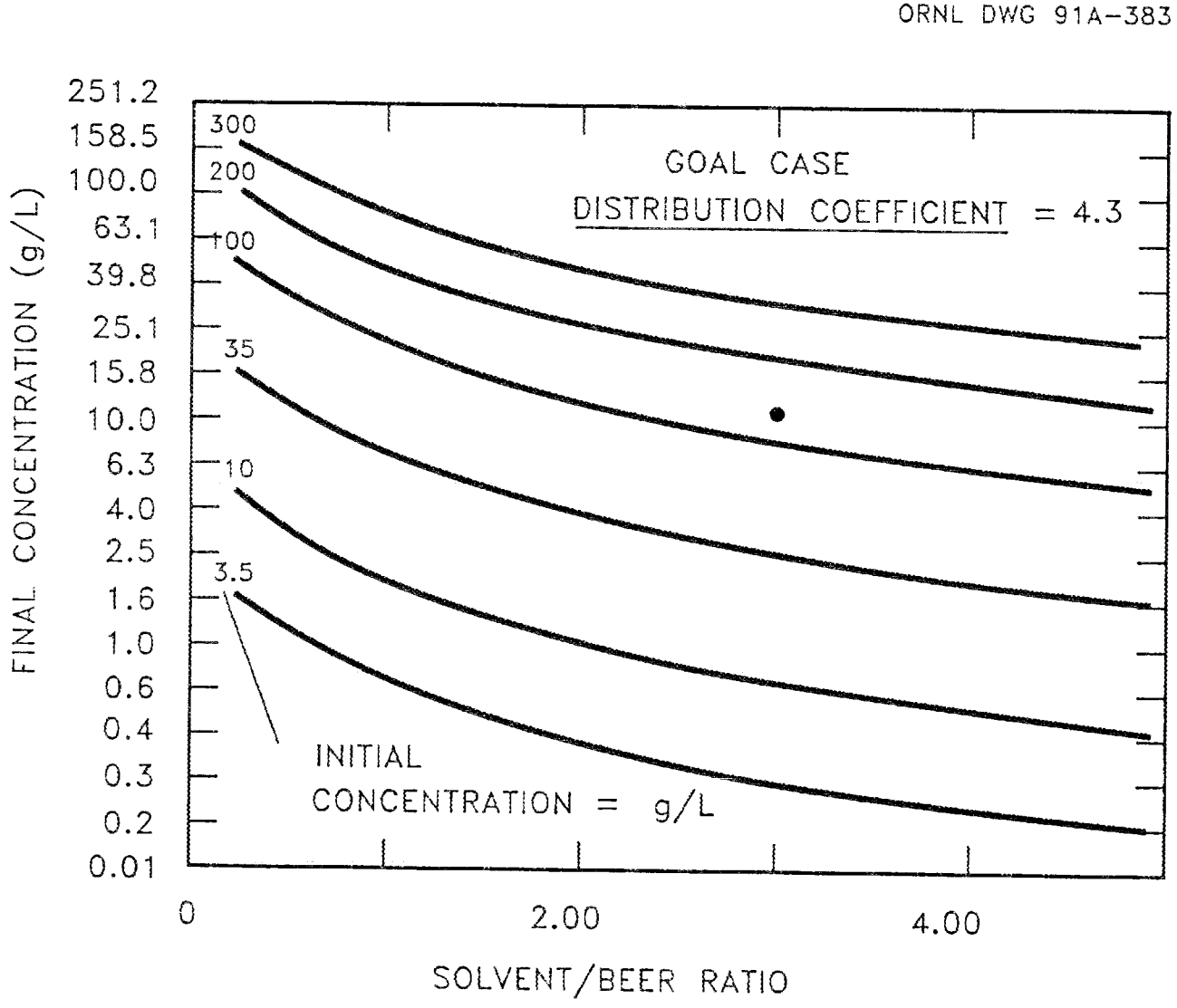

Fig. 9. Sensitivity of final concentration to solvent/beer ratio and initial conclusions.

9. PROJECTED ECONOMICS OF THE CONVENTIONAL WEIZMANN PROCESS

Butanol currently sells for $0.38/lb at a crude oil price of $15-$20/bbl. This price has been fairly stable since 1982. However, considering the increases expected again in crude oil prices in the 1990s, a doubling in the price for oil-based butanol is not inconceivable.

Lenz and Moreira analyzed the economics of the conventional Weizmann process utilizing a molasses substrate and found that the process would have to operate at a loss because of the combined effect of raw material costs and dilute concentrations.[64]

The current study also concluded that the Weizmann process would operate at a loss in the present economic environment. Butanol from a 170-million-pound-per-year plant based on the conventional process and operating at 150 million lb/year in 1987 would cost ~$1.19/lb for the fermentation operation alone (including raw materials cost but excluding recovery and purification costs).[65] This cost includes a 30% pretax return on investment.

The investment at the midpoint of construction of 1983 is comprised of $230 million in direct process equipment; $33 million in allocated power, services, and general facilities; and $30 million in working capital. Of the direct process investment, $200 million alone is for fermenters (16 million gal) and their ancillaries priced installed at $12.50/gross gal. A contingency factor of 30% was applied to the investment. Working capital is high because of the high value of the product inventory and accounts receivable.

This estimate assumes a butanol concentration of 13 g/L at a batch time of 40 h and a turnaround of 12 h. Of the glucose converted, 5% is used for cell growth and 95% for products according to the stoichiometry of Table 4. The product cost sheet is summarized in Table 9.

Table 9. Product cost sheet of the Weizmann Process

Factor	Cost ($)
Raw materials	0.30
Utilities	0.04
Labor-related	0.03
Depreciation	0.14
Other capital-related	0.05
Cost of manufacture	0.56
SE, R&D, administration	0.16
Cost of sales	0.72
Pretax earnings	0.58
By-product credit	(0.11)
Cost-plus-return price	1.19

Wang compared the economics of extractive batch fermenter designs with conventional batch designs and concluded that the extraction design appeared to be considerably more profitable than the conventional design.[66] Blanch made a similar conclusion with respect to a fed-batch extractive design.[67]

10. PROJECTED ECONOMICS OF THE EXTERNAL EXTRACTION PROCESS

External multistage extraction combined with raffinate/cell recycle and recovery of chemicals in the raffinate appears to have a dramatic effect on reducing product costs.

For the first time in over 30 years, it now seems that the fermentation process is within striking distance of competing with synthetic butanol at $0.38/lb. The economics of the five cases developed for the external extraction process are summarized in Table 10. These cases are also elaborated upon in Appendixes A through E. The mandatory prices are based on attaining a pretax return on an investment of 30%.

With a 15:1 recycle and recovery of raffinate chemicals, the cost-plus-return price appears to be reduced to $0.43/lb. With a double recycle and higher recycle ratio, further reductions appear possible, although these may be marginal.

The development of organisms that are less inhibited by product and/or have a selective stoichiometry favoring the production of butanol appears to reduce cost below the present price for synthetic butanol.

These conclusions will be discussed further in the following sections.

10.1 EFFECT OF RAFFINATE/CELL RECYCLE

Cost is primarily sensitive to the recycle of cells. As shown in Table 11, cost decreases with increases in recycle ratio over the entire range studied. This effect mainly results from a concomitant reduction in fermenter and total plant investment. For this model, recycle ratios over 15:1 would require evaporation of the syrup -- an undesirable requirement. However, this could be avoided by using a double recycle if cell concentrations above 22 g/L could be tolerated in the fermenter. Total flow through the fermenter remains constant irrespective of recycle ratio for a fixed, limiting product concentration and annual production rate. Cell density increases as cell recycle increases; thus, fermentation time and fermenter investment can be decreased correspondingly to balance production rate at a constant specific productivity.

10.2 EFFECT OF SOLVENT/BEER RATIO

The solvent-to-beer ratio should be minimized for optimum costs. The cost trade-off of operating parameters is shown in Table 12. For the conditions of this study, the best ratio appears to be 0.3. For a distribution coefficient of 4.3, the plates required in the extractor approach infinity at a ratio of 0.23, but drop sharply to reasonable levels

Table 10. Extractive fermentation of butanol multistage external extraction
(Production level - 160 million PPY)

Stoichiometry Raff/cell recycle Recover chemicals	Base 15:1 Yes	Base 15:1 No	Base 0 Yes	Base 0 No	Goal 26:1 N/A
Investment-$M MPC = 1984					
Direct permanent investment	$27.3	$25.8	$170.7	$159.3	$20.1
Allocated power, services, and general	12.9	10.6	60.0	34.9	8.2
Working capital	14.4	15.1	26.9	25.5	10.1
Total investment	$54.5	$51.6	$257.5	$219.7	$38.4
Cost - $/lb (1988)					
Raw materials	$ 0.29	$ 0.29	$ 0.29	$ 0.29	$ 0.17
Utilities	0.04	0.04	0.11	0.07	0.02
Labor-related	0.03	0.03	0.03	0.03	0.03
Capital-related	0.02	0.02	0.15	0.13	0.02
Cost of manufacture	0.38	0.38	0.57	0.52	0.24
SE, D, R&D, Adm, & IC	0.06	0.06	0.14	0.13	0.05
Cost of sales	0.44	0.44	0.71	0.65	0.28
Pretax earnings based on 30% pretax ROI	0.10	0.10	0.48	0.41	0.07
By-product credit	(0.11)	(0.06)	(0.11)	(0.01)	(0.00)
Selling price	$ 0.43	$ 0.48	$ 1.07	$ 1.05	$ 0.35

Table 11. Sensitivitiy analysis - effect of recycle ratio on fermentation performance
(For K = 4.3; solvent/feed ratio = 0.3; product concentration = 13 g/L;
specific productivity = 0.283 g/g·h)

Recycle ratio	Cost ($/lb)	TPI ($Million)	Fermenter ($Million)	Cells (g/L)	Dillution rate (1/h)	Vol. prod (g/L·h)
0.0	1.078	228	117	1.4	0.030	0.39
0.5	0.854	164	78	2.1	0.045	0.59
1.0	0.741	132	59	2.8	0.060	0.78
2.0	0.626	98	39	4.2	0.090	1.18
4.0	0.533	71	24	6.9	0.151	1.96
6.0	0.491	59	17	9.7	0.211	2.74
8.0	0.468	52	13	12.5	0.272	3.53
10.0	0.452	48	11	15.3	0.332	4.32
12.0	0.441	44	9	18.1	0.393	5.11
14.0	0.433	42	8	20.9	0.454	5.90
15.0	0.430	41	7	22.3	0.484	6.30

Table 12. Sensitivity analysis - effect of solvent/beer ratio on fermentation performance
(For K = 4.3; recycle ratio = 15; extract yield = 99.0%;
product concentration = 13 g/L; specific productivity = 0.283 g/g·h;
cell density = 22.3 g/L; volumetric productivity = 6.3 g/L·h)

Solvent/ water	Cost ($/lb)	TPI ($Million)	Stills ($Million)	Steam ($Million)	Extractors			
					($Million)	Stages	Diam (ft)	Number
0.30	0.430	41.0	5.5	8.1	5.5	13	11.5	4
0.40	0.434	41.5	5.9	9.7	3.9	7	11.9	4
0.50	0.444	43.8	6.3	11.2	4.0	6	11.0	5
0.75	0.468	48.8	7.2	15.2	3.7	4	11.8	5
1.00	0.492	54.3	8.2	19.1	3.8	3	11.4	6
1.50	0.544	66.0	10.1	26.9	4.6	3	11.8	7
2.00	0.597	77.9	12.1	34.6	5.7	3	11.3	9
2.50	0.647	88.9	14.1	42.4	5.7	2	11.6	10
3.00	0.700	100.7	16.2	50.2	6.5	2	11.8	11

at slightly higher ratios. As the solvent-to-beer ratio increases, the number of extractor stages that are required decreases but throughput and, hence, extractor diameter and/or number increase. These opposing effects modulate extractor investment. However, both distillation and steam investment increase in order to process the higher volume of fluid downstream.

10.3 EFFECT OF EXTRACTOR YIELD

A similar trade-off occurs in the choice of yield of product to extract. As yield increases, so does the number of stages required to effect the separation, in opposition to the improvement in process efficiency. As shown in Table 13 and Fig. 10, a cost optimum in reached at a yield of ~97%. Above this, cost rises sharply. If cells are not recycled, the optimum would occur at a higher yield.

10.4 EFFECT OF PRODUCT CONCENTRATION

The basecases of this study were developed using a 13-g/L product concentration -- supposedly close to the acceptable limit of feedback inhibition. Lower and higher concentrations were also explored. Higher concentrations would require developing an organism that is less sensitive to product inhibition. This appears to be a worthwhile research goal. The results are summarized in Table 14 and Fig. 11. Note that dilution rate is synonymous with raffinate/recycle ratio.

At any product concentration, it is clearly desirable to operate at as high a recycle ratio (dilution rate) as possible. At 13 g/L and a 15:1 ratio, cell density would reach 22 g/L. This level appears operable, but densities required for concentrations above, say, 50 g/L (even if attainable without inhibition) may produce unacceptable viscosities and adverse effects on the organism in the fermenter. As a practical matter, it does not appear that increasing concentration much above 25 g/L will have a significant effect on reducing further the cost of the product.

It can also be noted that at a 15:1 ratio (0.48 h^{-1} dilution rate) the cost curve is close to the "infinite " dilution rate curve, at which point further decreases in fermenter volume have an insignificant effect on cost and investment.

Table 13. Sensitivity of product cost to yield to extract and solvent/beer ratio

S/B Ratio:	15:1 Raffinate recycle 0.3	15:1 Raffinate recycle 0.4	No recycle 0.3	No recycle 0.4
Yield (lb/lb fed)				
0.85	$0.440	$0.450	$1.236	$1.250
0.90	0.434	0.443	1.172	1.183
0.93	0.430	0.440	1.137	1.148
0.95	0.429	0.438	1.116	1.126
0.96	0.428	0.437	1.105	1.115
0.97	0.428	0.435	1.095	1.104
0.98	0.428	0.434	1.085	1.094
0.99	0.430	0.434	1.078	1.085
0.999	0.436	0.438	1.075	1.080
0.9999	---	0.442	---	1.083

Table 14. Sensitivity of fermentation performance to product concentration (With recovery of raffinate chemicals)

Product conc. (g/L)	BuOH cost ($/lb)	TPI ($/lb)	Ferm inv $/lb	Ferm inv /TPI	Cells (g/L)	Dil rate (1/h)
			For no raffinate/cell recycle			
3	3.51	5.18	2.91	56%	0.3	0.03
6	1.94	2.66	1.46	55	0.6	0.03
13	1.10	1.30	0.67	52	1.4	0.03
18	0.89	0.97	0.49	50	1.9	0.03
25	0.74	0.73	0.35	48	2.7	0.03
50	0.55	0.41	0.17	42	5.4	0.03
100	0.45	0.25	0.09	35	10.7	0.03
			For 0.5:1 raffinate/cell recycle			
3	2.53	3.60	1.94	54	0.5	0.05
6	1.45	1.87	0.97	52	1.0	0.05
13	0.87	0.93	0.45	48	2.1	0.05
18	0.72	0.70	0.32	46	2.9	0.05
25	0.62	0.53	0.23	44	4.0	0.05
50	0.48	0.31	0.12	37	8.0	0.05
100	0.41	0.20	0.06	30	15.9	0.05
			For 2:1 raffinate/cell recycle			
3	1.56	2.02	0.97	48	0.9	0.09
6	0.96	1.07	0.49	45	1.9	0.09
13	0.63	0.55	0.22	41	4.1	0.09
18	0.55	0.42	0.16	38	5.7	0.09
25	0.49	0.33	0.12	35	7.9	0.09
50	0.42	0.21	0.06	28	15.8	0.09
100	0.38	0.14	0.03	21	31.8	0.09
			For 5:1 raffinate/cell recycle			
3	1.07	1.22	0.49	40	1.9	0.18
6	0.71	0.66	0.24	37	3.8	0.18
13	0.51	0.36	0.11	32	8.2	0.18
18	0.46	0.28	0.08	29	11.3	0.18
25	0.43	0.22	0.06	26	15.8	0.18
50	0.38	0.15	0.03	20	31.7	0.18
100	0.36	0.11	0.02	14	64.0	0.18

Table 14. (continued)

			For 10:1 raffinate/cell recycle			
3	0.84	0.85	0.26	31	3.4	0.32
6	0.59	0.47	0.13	28	6.9	0.33
13	0.45	0.26	0.06	24	15.0	0.33
18	0.42	0.21	0.04	21	20.8	0.33
25	0.40	0.17	0.03	19	29.0	0.33
50	0.37	0.12	0.02	13	58.6	0.33
100	0.36	0.09	0.009	9	119.6	0.34
			For 15:1 raffinate/cell recycle			
3	0.75	0.70	0.18	26	5.0	0.47
6	0.54	0.39	0.09	23	10.0	0.47
13	0.43	0.22	0.04	19	21.8	0.48
18	0.40	0.18	0.03	17	30.3	0.48
25	0.38	0.15	0.02	15	42.3	0.48
50	0.36	0.11	0.01	10	86.0	0.49
100	0.36	0.09	0.006	7	177.7	0.50

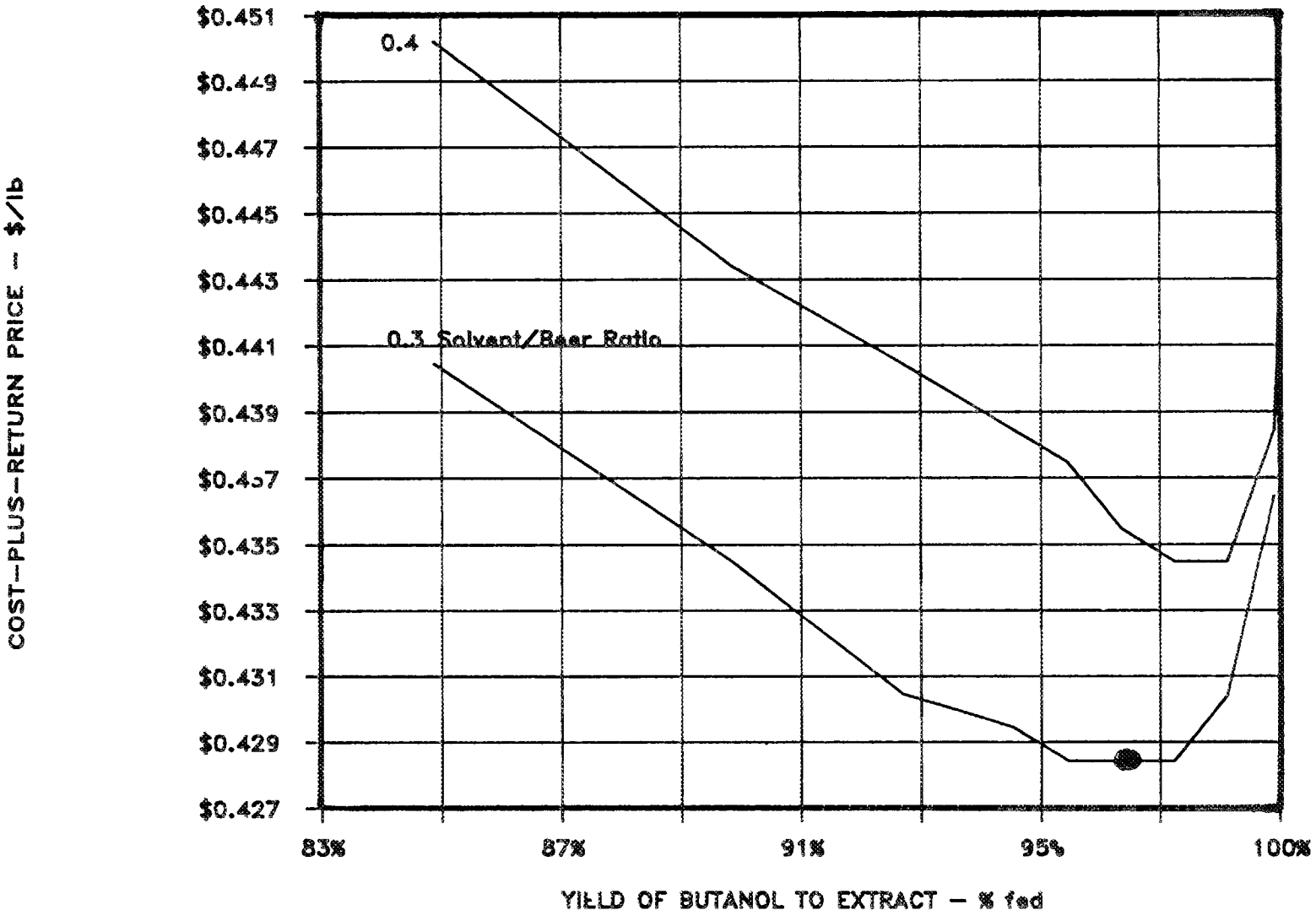

Fig. 10. Sensitivity of cost to yield to extract for 15:1 raffinate/cell recycle.

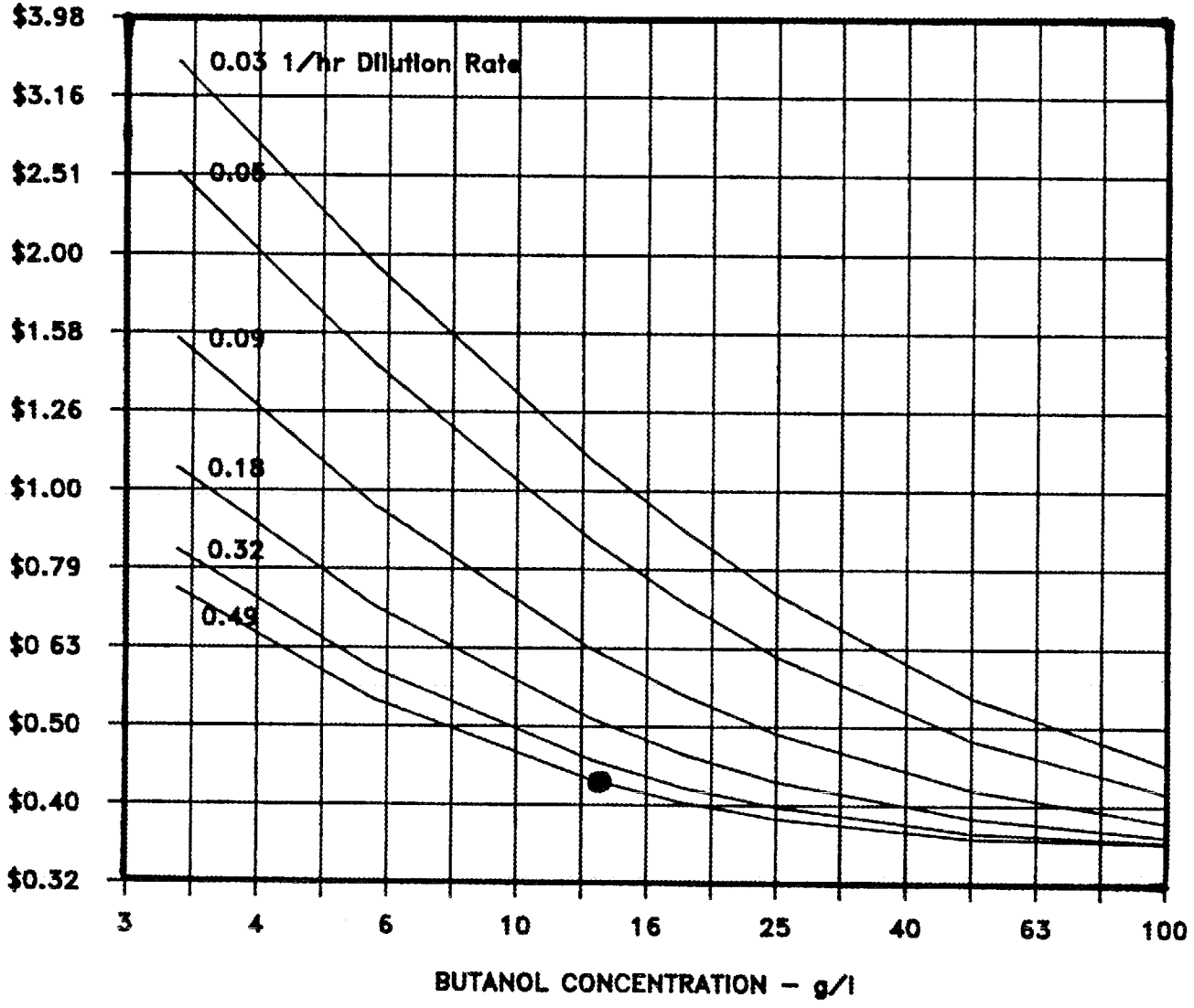

Fig. 11. Sensitivity of cost-plus-return to product concentration and dilution rate.

10.5 EFFECT OF SUGAR PRICE AND YIELD

The cost of the sugar substrate is a very important element of cost, particularly if the engineering improvements discussed in the previous section can be realized. For Basecase A, the cost of substrate amounts to 65% of the $0.43/lb selling price and 74% of the cost of manufacture. This cost combines the effects of sugar price and yield to product.

If an organism can be developed to provide the stoichiometry indicated as the goal case of Table 4, the cost-plus-return selling price could be reduced from $0.43/lb to $0.35/lb (i.e., below the current price for synthetic butanol). This case is summarized in Table 10 and Appendix E.

The 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. Unfortunately, such price information is considered proprietary by wet millers and is not forthcoming. However, a recent analysis of the feedstock costs for fermentation ethanol plants[68] showed that over the period 1Q81 - 2Q86 at an average price for #2 yellow corn ex Chicago of $2.86/bushel the average price for corn net of by-product credits was $0.039/lb of glucose. Similarly, over the period 2Q87 - 1Q88 the corresponding costs were $1.79/bushel and $0.009/lb of sugar.

A corn price of $2.60/bushel appears to correspond to a sugar cost of ~$0.081/lb of starch according to the correlation of published data shown in Fig. 12.

Finally, the following estimate was made by the author as an approximate, if not qualified, evaluation of substrate costs. The basis was for an early 1980 plant processing 60,000 daily bushels to produce 720 million annual pounds of syrup (dry basis). The wet mill yield was assumed to be 31.6 lb of starch/bushel. Investment in the wet mill was estimated to be $40 million (Table 15).

The sensitivity of butanol cost to sugar price is shown in Table 16 and Fig. 13. If sugar were free, cost-plus-return would drop to $0.09/lb.

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.

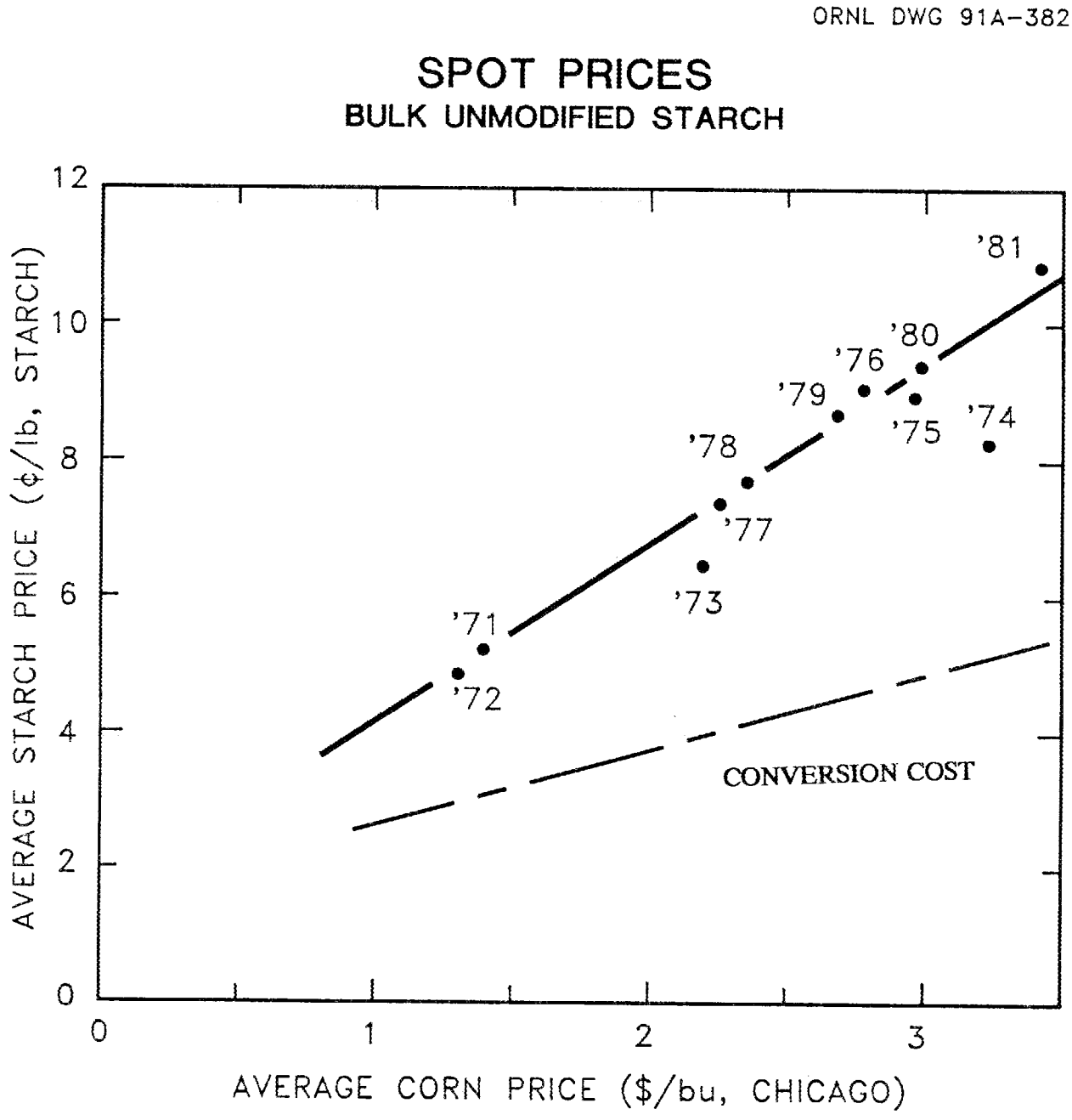

Fig. 12. CPC International, Inc. bulk unmodified starch spot prices.

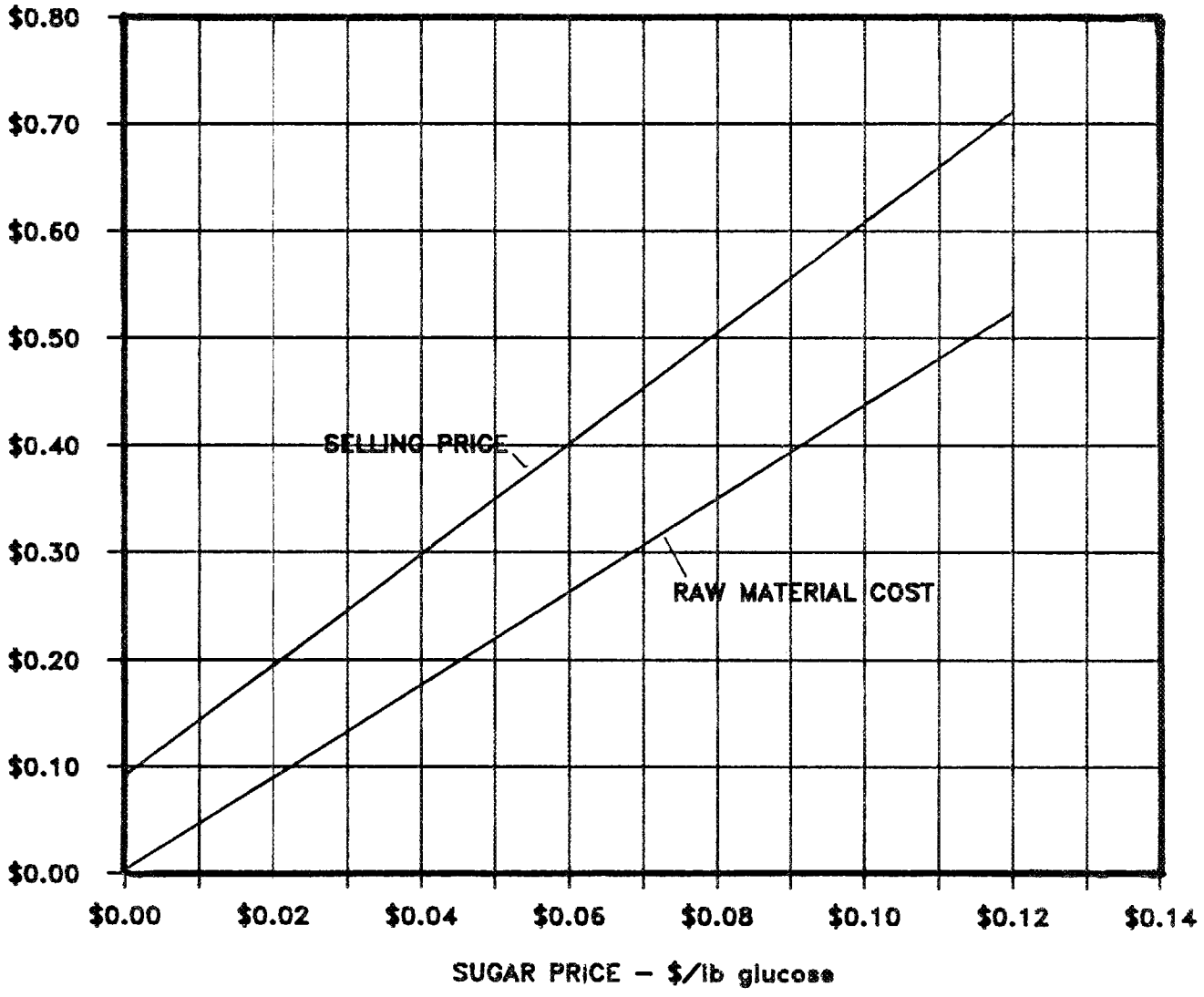

Fig. 13. Sensitivity of cost to sugar price for basecase conditions.

Table 15. Approximate evaluation of substrate costs

	$/lb glucose
Corn @ $2.60/bushel	$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, and 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 and depreciation	(0.001)
S, A, & R	(0.001)
Earnings	(0.007)
Adjusted contract price	$0.065

Table 16. Sensitivity analysis
Effect of sugar price on product cost

Sugar price ($/lb)	Cost of raw material ($/lb)	Cost of mfg. ($/lb)	Cost-plus-return ($/lb)
0.00	0.004	0.099	0.092
0.02	0.090	0.186	0.196
0.04	0.177	0.273	0.299
0.06	0.264	0.360	0.402
0.08	0.351	0.447	0.506
0.10	0.438	0.534	0.609
0.12	0.525	0.621	0.713

However, James McNabb of Conoco[2] 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. 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 per barrel by the year 2000. Thus, a doubling of the $0.38 price for butanol over the next decade is not out of the question.

10.6 EFFECT OF RECOVERY OF RAFFINATE CHEMICALS

Since butanol is the primary product of the ABE system, the process model was designed to extract substantially all of it with a reasonable number of extraction stages. However, since the major by-products acetone and ethanol have lower distribution coefficients, a considerable portion of that which is produced remains in the aqueous raffinate. For this system, it appears that the recovery of these by-products from the raffinate purge is economically justified provided that raffinate and cells are recycled at the level studied. Indeed, the return on the additional investment required amounts to 220%. The cases with and without recovery compare as follows (Table 17).

Table 17. Effect of recovery of raffinate chemicals

Expense, $/lb	No recovery	Recovery	Difference
Cost of sales	$0.444	$0.439	($0.005)
Acetone credit	(0.062)	(0.084)	(0.022)
Ethanol credit	--	(0.028)	(0.028)
	0.382	0.327	(0.055)
Investment, $/lb			
New stills	--	0.009	0.009
By-product storage	0.004	0.008	0.004
Steam	0.035	0.045	0.010
	0.039	0.062	0.023
Total plt. invest	0.203	0.228	0.025*

* $4.5 million for 180 MM PPY plant

Return on additional investment = $0.055/$0.025 = 220%

11. PROJECTED ECONOMICS OF THE IN SITU EXTRACTION PROCESS

The cost-plus-return for butanol as manufactured by the in situ extraction model would amount to $0.49/lb at the same 22-g/L cell density as for the external extraction case, for which the cost was $0.48/lb without recovery of raffinate chemicals. Both models would benefit further by recovery of the by-products, but that scheme was not included in the in situ model. As with the external extractor case, the minimum cost of the in situ case depends on the extent to which cell density can be increased. In the case of the in situ basecase, increasing the solvent to feed ratio at a fixed dilution rate is the main operating approach. A basecase ratio of 3.5 at a 0.03 h^{-1} dilution rate was used here. A summary of the economic picture is provided in Table 18 and Appendix F.

Table 18. Single-stage in situ extraction fermentation of butanol
(No recovery of raffinate chemicals)
Basecase stoichiometry
Summary

	Production level 163 Million PPY
Investment, $Million	
MPC = 1984	
Direct permanent investment	21.6
Allocated power, services, and general	9.5
Working capital	15.8
Total investment	47.0
Cost, $/lb (1988)	
Raw materials	0.30
Utilities	0.05
Labor-related	0.03
Capital-related	0.02
Cost of manufacture	0.40
SE, D, R&D, Adm, and IC	0.06
Cost of sales	0.46
Pretax earnings based on: 30% pretax ROI	0.09
By-product credit	(0.06)
Selling price	0.49
Financial Criteria	
Net ROI 3rd year (assumed)	16%
Investors rate of return (20 operating years)	17%
Years to break even - Annual cash	1987
- Cumulative cash	1991
- Cum. disc. cash (NPV)	1995
Net present value $Million (20 years @ 12%)	$16.4

11.1 EFFECT OF SOLVENT/FEED RATIO

Cost is reduced by raising the solvent/feed ratio to the highest level possible. As noted in Table 19, cost might be reduced to $0.39/lb at a 20:1 ratio if a cell density of 120 g/L were operable, but that seems doubtful. A large portion of the saving is related to the reduction in fermenter volume and investment that results from the trade-off with cell density at constant specific productivity. At high solvent/feed ratios, fermenter investment becomes insignificant compared with total plant investment, and, in effect, an "infinite" ratio is reached.

Distribution coefficient is an important adjunct to solvent/feed ratio. This effect is shown in Table 20 and Fig. 14. If a coefficient of 4.3 cannot be attained in commercial operation, the reduction in performance can be compensated for to some extent by raising the ratio.

11.2 EFFECT OF BUTANOL CONCENTRATION

For the in situ evaluation, butanol concentration was held constant at 13 g/L, the threshold of inhibition for the existing organism. However, cost performance could be improved if product inhibition could be reduced. The effect of increasing the allowable concentration in conjunction with changes in solvent/feed ratio is shown in Table 21 and Fig. 15.

Similarly, cost could be reduced by developing a more active organism with a higher specific productivity that could operate at a dilution rate higher than the 0.03 h^{-1} used in the in situ basecase. The combined effect of improvements in both dilution rate and product concentration is shown in Table 22 and Fig. 16. Data for an "infinite" dilution rate are included. That curve represents the limit to which the fermenter performance can be pushed.

Table 19. In situ extractive fermentation
Effect of solvent/feed ratio on fermentation performance
(For K = 4.3; product concentration = 13 g/L;
specific productivity = 0.283 g/g·h)

Solvent/ feed	Cost ($/lb)	TPI ($Million)	Fermenter ($Million)	Eff. prod. conc (g/L)	Cells (g/L)	Dilution rate (1/h)	Vol. prod. (g/L·h)
0.25	1.442	105	70	27	3	0.03	0.8
0.50	0.958	78	46	41	4	0.03	1.2
1.00	0.702	56	28	69	7	0.03	2.1
2.00	0.560	40	15	125	13	0.03	3.8
3.00	0.507	33	11	181	19	0.03	5.5
4.00	0.479	30	8	237	25	0.03	7.2
5.00	0.460	27	7	292	31	0.03	8.9
7.00	0.437	24	5	404	43	0.03	12.3
10.00	0.419	22	3	572	61	0.03	17.3
15.00	0.403	20	2	851	91	0.03	25.8
20.00	0.394	18	2	1131	121	0.03	34.3

Table 20. Single-stage in situ extractive fermentation of butanol
No recovery of raffinate chemicals
Basecase stoichiometry
(Sensitivity of cost-plus-return price to solvent/beer ratio
and distribution coefficient)

Distribution coefficient	Cost ($/lb) Solvent/beer ratio						
	0.25	0.50	1.00	3.00	5.00	10.00	20.00
0.25	16.48	8.67	4.78	2.17	1.65	1.24	1.03
0.50	8.54	4.62	2.64	1.30	1.02	0.81	0.69
1.00	4.55	2.57	1.56	0.86	0.71	0.59	0.52
2.00	2.54	1.53	1.00	0.63	0.55	0.48	0.43
3.00	1.86	1.17	0.82	0.55	0.49	0.44	0.41
4.30	1.44	0.96	0.70	0.51	0.46	0.42	0.39
5.00	1.31	0.89	0.66	0.49	0.45	0.41	0.39
10.00	0.89	0.67	0.55	0.44	0.42	0.39	0.37

Table 21. In situ extractive fermentation
Effect of product concentration and solvent/feed ratio
on butanol cost-plus-return

Butanol conc (g/L)	Cost ($/lb) Solvent/feed ratio						
	0.25	0.50	1.00	3.00	5.00	10.00	20.00
3	3.24	1.92	1.24	0.76	0.65	0.56	0.50
6	2.08	1.30	0.90	0.60	0.53	0.47	0.43
13	1.44	0.96	0.70	0.51	0.46	0.42	0.39
18	1.29	0.87	0.65	0.49	0.44	0.41	0.39
25	1.17	0.81	0.62	0.47	0.43	0.40	0.38
50	1.03	0.73	0.57	0.45	0.42	0.39	0.37
100	0.95	0.69	0.55	0.44	0.41	0.38	0.37
300	0.89	0.66	0.53	0.43	0.40	0.38	0.37

Table 22. Single-stage in situ extractive fermentation of butanol
No recovery of raffinate chemicals
Basecase stoichiometry
(Sensitivity of cost-plus-return price)

Raffinate concentration (g/L)	Cost ($/lb) Dilution rate (1/h)				
	0.01	0.03	0.10	0.30	1000000
1	2.25	1.40	1.10	1.02	0.97
3	1.05	0.76	0.66	0.63	0.62
10	0.62	0.53	0.50	0.49	0.49
30	0.49	0.46	0.45	0.45	0.45
100	0.44	0.44	0.43	0.43	0.43
300	0.43	0.43	0.43	0.43	0.43

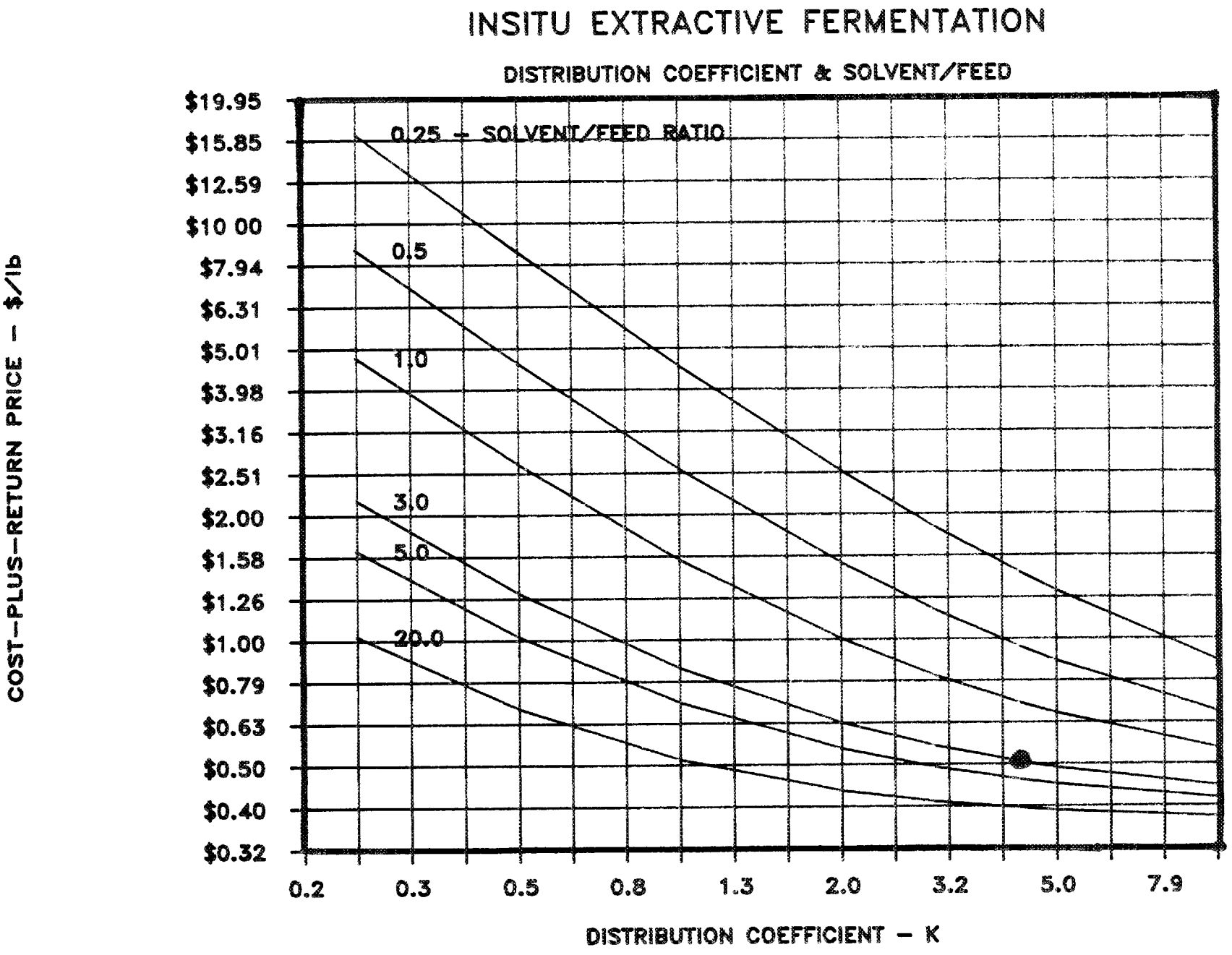

Fig. 14. In situ extractive fermentation distribution coefficient and solvent/feed.

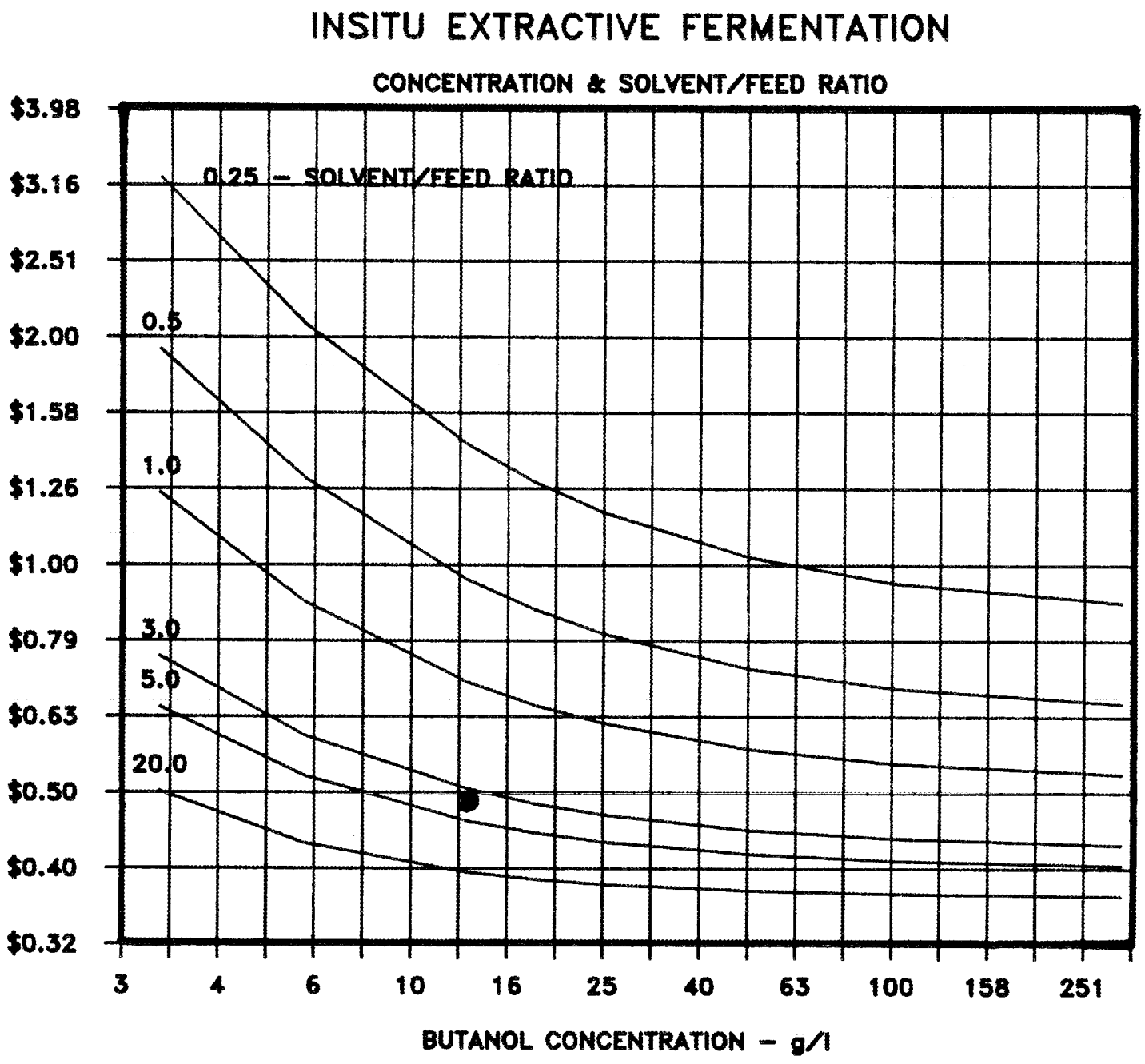

Fig. 15. In situ extractive fermentation concentration and solvent/feed ratio.

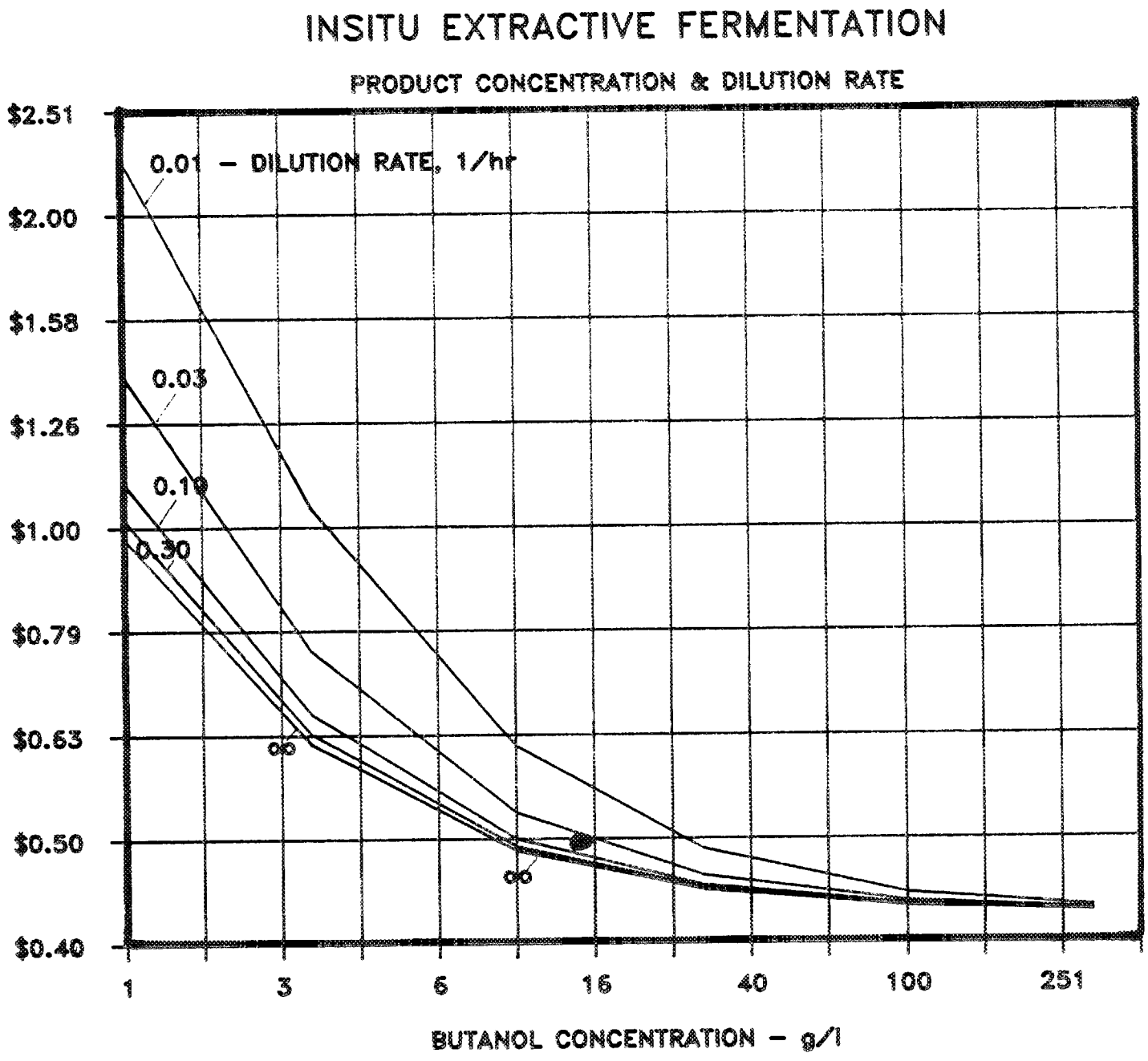

Fig. 16. In situ extractive fermentation product concentration and dilution rate.

11.3 EFFECT OF SUGAR PRICE

As might be expected, cost is highly sensitive to sugar price. This effect is shown in Table 23 and Fig. 17. It will be very important to the viability of either extraction mode to provide a cost-effective supply of syrup to the commercial venture.

12. RECOMMENDATIONS

It appeared from the results of the study that either the external or in situ extraction processes would be equally effective in reducing the cost of producing butanol to commercially acceptable levels. However, the external process would appear to be more easy to develop and operate on a commercial scale. Accordingly, the following recommendations are made as a guide to further research in this area:

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. In a separate system, test the continuous countercurrent extraction of butanol, acetone, and ethanol by oleyl alcohol or an improved solvent using a synthetic beer that mimics the expected impurity and salt levels of the fermentation beer (or use the actual beer if such is available at that time).

4. Concurrently, in a separate small-scale laboratory study, seek a solvent having better distillation characteristics than oleyl alcohol with at least the same

Table 23. Single-stage in situ extractive fermentation of butanol
No recovery of raffinate chemicals
Basecase stoichiometry
(Effect of sugar price on product cost)

Sugar price ($/lb)	Cost of raw mat. ($/lb)	Cost of mfg. ($/lb)	Cost plus return ($/lb)
0.00	0.00	0.10	0.15
0.04	0.19	0.29	0.37
0.06	0.28	0.38	0.48
0.08	0.38	0.48	0.59
0.10	0.47	0.57	0.70
0.12	0.56	0.66	0.81

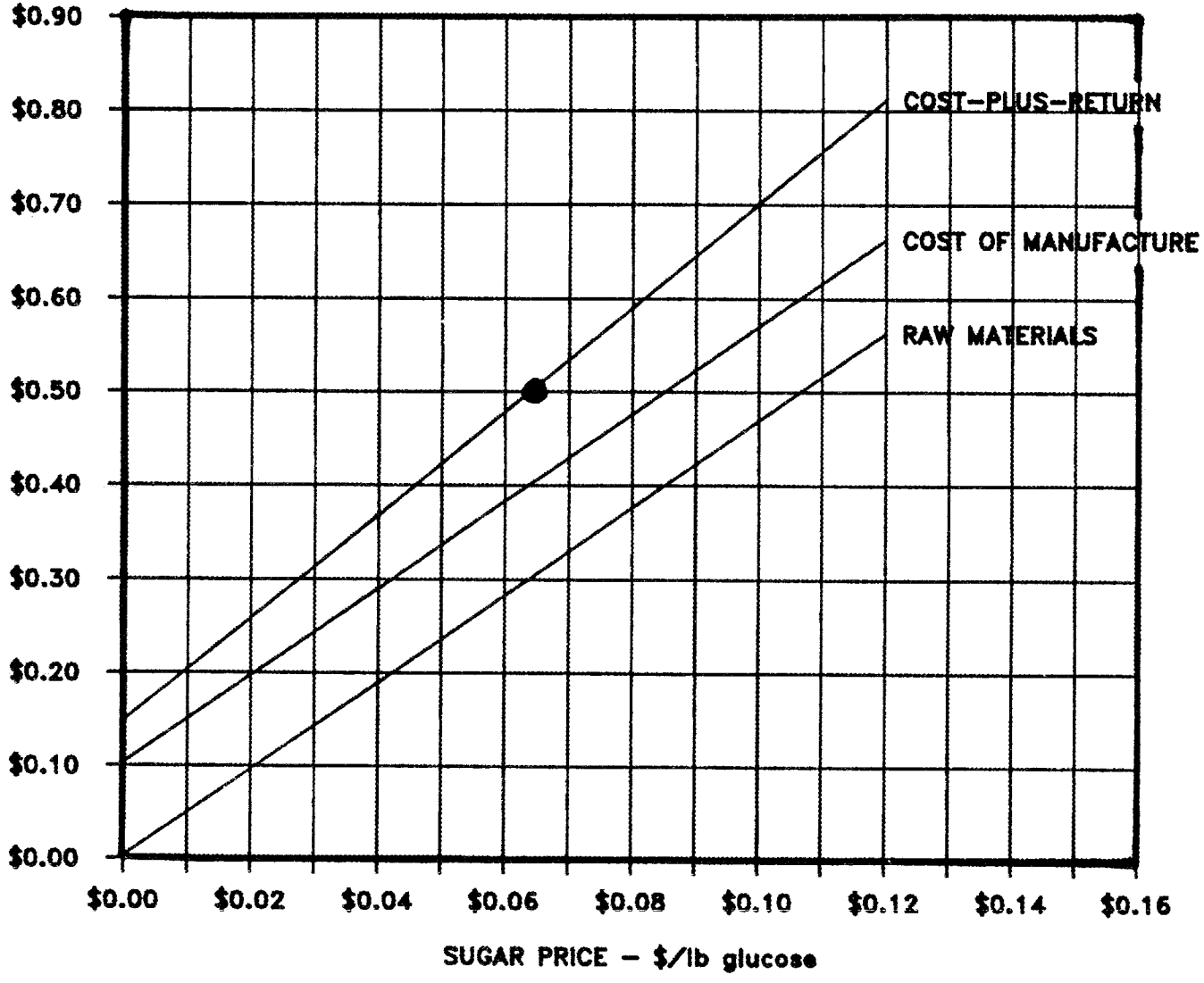

Fig. 17. Sensitivity of cost to sugar price in situ extractive fermentation.

distribution coefficient and low toxicity. A solvent boiling below water might be considered. Although this would require a different process scenario than the one used in this study for a high-boiling solvent, it might offer advantages over the high-boiling recovery process. In the selection of a new solvent, attention should be paid to the following potential problems: (1) separation of high-boiling acids, if any are present and at a sufficiently low pH to be extractable, might be difficult; (2) if the solubility of water in the solvent is much higher than the 20 ppm that was assumed, problems with azeotropes in the recovery still train involving acetone, butanol, and ethanol could arise; and (3) if the solubility of solvent in water is much higher than the 20 ppm that was assumed, additional investment would be required to recover and/or dispose of solvent in the waste raffinate.

5. Integrate the fermentation unit with the extraction unit and demonstrate operability without cell retention or recycle, then with cell buildup, and finally with raffinate recycle to assess possible adverse effects from the buildup of unextracted products or toxins.
6. Consider the concurrent development of a genetically revised organism that produces only butanol as its solvent slate and/or has an enhanced specific productivity.
7. Continue the comparative evaluation of the economics of both processes as new information is obtained from the research program. In the event a clear preference for the in situ process emerges, adapt the experimental program to the direct feed of solvent to the fermenter and demonstrate the in situ process.

13. CONCLUSIONS

Based on the economic analyses, it appears that the extractive fermentation system could substantially reduce the cost of butanol and other similar high-boiling fermentation products that are now produced at low product concentrations 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 an improved stoichiometry and/or specific productivity. The goal is sufficiently important, however, to warrant the laboratory effort.

Certainly, these improvements would represent major breakthroughs in not only the butanol process, but, generically, in any fermentation process that suffers from product inhibition (which is most of them), particularly where the product boils higher than water.

14. ACKNOWLEDGMENT

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APPENDIX A. BASECASE STOICHIOMETRY WITH 15:1 RAFFINATE/CELLS RECYCLE WITH RECOVERY OF RAFFINATE CHEMICALS

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY
SUMMARY

	PRODUCTION LEVEL 161 MM PPY
INVESTMENT-$MILLION	
MPC = 1984	
Direct Permanent Investment	$27.3
Allocated Power, Services & General	$12.9
Working Capital	$14.4
Total Investment	$54.5
COST-$/LB (1988)	
Raw Materials	$0.29
Utilities	$0.04
Labor-Related	$0.03
Capital-Related	$0.02
Cost of Manufacture	$0.38
SE, D, R&D, Adm, & I.C.	$0.06
Cost of Sales	$0.44
Pretax Earnings Based on: 30% Pretax ROI	$0.10
By-product Credit	($0.11)
Selling Price	$0.43
FINANCIAL CRITERIA	
Net ROI 3rd Year (assumed)	16%
Investors Rate of Return (20 Operating Years)	19%
Year to Break Even - Annual Cash	1987
- Cumulative Cash	1990
- Cum. Disc. Cash (NPV)	1994
Net Present Value $MM (20 years @ 12%)	$24.7

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL WITH RECOVERY OF RAFFINATE BASECASE STOICHIOMETRY

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 PPY	179.2
MID-POINT OF CONSTRUCTION	YEAR	1984
CONSTRUCTION COST INDEX	1980=100	128
INVESTMENT CONTINGENCY	% INSTALLED *	30%
FERMENTER UNIT INVESTMENT	$/GR.GAL.-GROWTH	$12.90
	$/GR.GAL.-PROD'N	$10.94

*40% Recommended for new processes

DIRECT PERMANENT INVESTMENT

	SCALE FACTOR		THIS CASE $MM	$/ANN.LB.
FERMENTATION SECTION				
Receiving, Prep & Sterilization	0.60		$3.82	$0.022
Air Compression & Aeration	0.60		0.00	0.000
Fermentation	0.80-1.00		7.60	0.042
Extraction			4.38	0.024
Product/Cell Separation	0.75		0.89	0.006
Fermentation Sub-total			$16.89	$0.094
DISTILLATION SECTION	STILLS	HX'S		
Beer Still #1	$0.31	$1.03	$1.34	$0.007
Beer Still #2	0.20	0.24	0.43	0.002
Low-Boilers Still #1	0.20	0.14	0.34	0.002
Low-Boilers Still #2	0.36	0.11	0.47	0.003
Low-Boilers Still #3	0.00	0.00	0.00	0.000
High-Boilers Still #1	0.77	0.31	1.08	0.006
Raffinate Still #1	0.48	0.51	0.99	0.006
Raffinate Still #2	0.28	0.14	0.42	0.002
Raffinate Still #3	0.32	0.10	0.42	0.002
Distillation Subtotal			$5.49	$0.03
STORAGE SECTION				
Storage - Butanol			$3.45	$0.019
Storage - Acetone			$1.05	0.006
Storage - Ethanol			$0.36	0.002
Storage Subtotal			$4.87	$0.03
TOTAL DIRECT PLANT			$27.26	$0.152

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL WITH RECOVERY OF RAFFINATE BASECASE STOICHIOMETRY

INVESTMENT

ALLOCATED PERMANENT INVESTMENT

	UNITS	API/UNIT BASECASE	API/UNIT THIS CASE	UNITS	$MM	$/ANN.LB.
ELECTRICITY	KW	$183	$183	1,965	$0.36	$0.002
STEAM	PPH	$45	$45	182,481	8.21	0.046
COOLING WATER	GPM	$52	$52	7,046	0.37	0.002
PROCESS WATER	GPM	$313	$313	31	0.01	.000
WASTE DISPOSAL	MGPY	$3	$3	118,431	0.32	0.002
GEN'L & SERVICES	$MM	10%	10%	$36.5	3.65	0.020
TOTAL ALLOCATED PLANT					$12.92	$0.072
TOTAL PERMANENT INVESTMENT					$40.18	$0.224

WORKING CAPITAL

	BASIS	DAYS BASECASE	DAYS THIS CASE	$MM	$/ANN. LB.
RAW MAT'L INVENTORY	$RAW MATL	2	2	$0.29	$0.002
SEMI-FINISHED PRODUCT	$(R+M)/2	5	5	0.74	0.004
FINISHED PRODUCT	$COM	30	30	5.06	0.028
CASH	$(COS-D)	6	6	1.12	0.006
ACCOUNTS RCD.-TRADE	$SP	30	30	5.68	0.032
ACCOUNTS RCD.-MISC.	%COM	0.9%	0.9%	0.55	0.003
DEFERRED CHARGES	%COM	1.5%	1.5%	0.92	0.005
TOTAL WORKING CAPITAL				$14.37	$0.080

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

TOTAL INVESTMENT FOR RETURN	$54.55	$0.304

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY

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	--	5 % Sales
-Administrative Expense	2 % Sales	--	2 % Sales
-Incentive Compensation	6 % PTE	--	6 % PTE
Cost of Sales			
-Pretax Earnings	30 % TIFR	--	30 % TIFR
-Credit: Acetone	$0.27 /lb.	1.00	$0.27 /lb.
-Credit: Ethanol	$0.29 /lb.	1.00	$0.29 /lb.
-Product Selling Price	$0.00 /lb.	1.00	$0.00 /lb.

SALARIES & WAGES

	250 MM PPY DAY SHIFT	250 MM PPY ROTATING SHIFTS	MIN. FORCE DAY SHIFT	MIN. FORCE ROTATING SHIFTS
DIRECT OPERATORS				
SYRUP RECEIVING & TRANSFER	1	-	1	-
CHEMICALS RECEIVING & TRANSFER	3	-		-
INNOCULUM PREPARATION	1	-	1	-
MEDIUM PREPARATION	-	1	1	-
STERILIZATION	-	1		-
FERMENTATION & EXTRACTION				
-CONTROL ROOM	-	2	-	1
-PATROL	-	2	-	1
-AIR COMPRESSION & AMMONIA FEED	-	1	-	1
-TURNAROUND	-	3	-	1
BEER FILTER & CELL RECYCLE	-	2	-	1
DISTILLATION	-	2	-	1
TOTAL DAY & 4.2-SHIFT OPS	5	14	3	5
TOTAL OPERATORS	64		28	
CONTROL LABORATORY				
BIOLOGICAL ANALYSIS	-	1	-	1
CHEMICAL ANALYSIS	-	1	-	1
OTHER	-	-	-	-
TOTAL DAY & 4.2-SHIFT TECHS	0	8	0	8
w/ SUPERVISION @ 20%	0.0	10.1	0.0	10.1
TOTAL LAB FORCE	10.1		10.1	
TECHNICAL ASSISTANCE TO MANUFACTURING				
PROCESS ENGINEERS	1	-	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%

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY

1988 COST SHEET	RATE /UNIT	MILLION UNITS	$MILLION	$/lb.
Raw Materials				
-Biosugar Syrup	$0.065 /lb. d.s.	701.02	45.57	0.282
-Anhyd. Ammonia	$0.046 /lb.	1.70	0.08	.000
-Phosphoric Acid	$0.155 /lb.	1.42	0.22	0.001
-Potassium Chloride	$0.053 /lb.	1.08	0.06	.000
-Minor Nutrients	$0.451 /lb.	0.49	0.22	0.001
Total Raw Materials			$46.14	$0.286
Utilities				
-Electricity	$0.040 /KWH	14.01	0.57	0.004
-Steam	$2.20 /M lb.	1.30	2.86	0.018
-Cooling Water	$0.04 /M gal.	3.01	0.12	0.001
-Process Water	$0.50 /M gal.	0.01	0.01	.000
-Biodegradation	$0.04 /lb. d.s.	71.93	2.88	0.018
-Landfill	$0.05 /lb. d.s.	0.00	0.00	0.000
Total Utilities			$6.43	$0.040
Labor-Related				
-Dir. Op. Wages & Ben.	$26.40 /man-hr.	0.117	3.08	0.019
-Dir. Salaries & Ben.	18 % DOW&B		0.55	0.003
-Op. Supplies & Service	6 % DOW&B		0.18	0.001
-GPOH on Operations	23 % DOWS&B		0.84	0.005
-Control Lab	$19.22 /man-hr.	0.020	0.39	0.002
-Tech. Assist. to Mfg.	$22.06 /man-hr.	0.002	0.04	.000
Total Labor			$5.09	$0.032
Capital-Related				
-Maint. Wages & Ben.	1.7 % DPI	$27.3	0.46	0.003
-Maint. Salaries & Ben.	25 % MW&B		0.12	0.001
-Maint. Mat'l & Service	40 % MW&B		0.19	0.001
-Maint. Overhead	4 % MW&B		0.02	.000
-GPOH on Maintenance	23 % MWS&B		0.13	0.001
-Taxes & Insurance	0.3 % DPI	$27.3	0.08	0.001
-Depreciation - DPI	8 % DPI	$27.3	2.18	0.014
-Depreciation - APS&G	6 % APS&G	$12.9	0.77	0.005
Total Capital			$3.95	$0.025
Cost of Manufacture			$61.62	$0.382
-Selling Expense	3 % Sales	$69.1	2.07	0.013
-Distribution	$0.01 /lb.	161.3	1.61	0.010
-Research & Development	5 % Sales	$69.1	3.11	0.019
-Administrative Expense	2 % Sales	$69.1	1.39	0.009
-Incentive Compensation	5 % PTE	$15.4	0.98	0.006
Cost of Sales			$70.83	$0.439
-Pretax Earnings	30.0 % TIFR	$54.5	16.37	0.101
-Credit: Acetone	$0.27 /lb.	50.0	(13.51)	(0.084)
-Credit: Ethanol	$0.29 /lb.	15.9	(4.55)	(0.028)
Total Sales			$69.15	$0.428

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL WITH RECOVERY OF RAFFINATE BASECASE STOICHIOMETRY

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%). Tax: 34% federal, 3% state.
7. Note that the cash flow analysis has meaning only if the product can be sold at the price indicated on the cost sheet.

YEAR	INVESTMENT PI	INVESTMENT WC	DEP.	COST EX D	SALES	NET EARN	ANN CASH
1983	$9.09						($9.09)
1984	$9.09						($9.09)
1985	$9.09	$14.37					($23.46)
1986			$5.45	$36.98	$43.60	$0.74	($8.18)
1987			$8.72	$53.70	$65.40	$1.88	$10.60
1988			$5.23	$67.88	$87.21	$8.88	$14.11
1989			$3.14	$67.88	$87.21	$10.20	$13.34
1990			$3.14	$67.88	$87.21	$10.20	$13.34
1991			$1.58	$67.88	$87.21	$11.18	$12.76
1992				$67.88	$87.21	$12.18	$12.18
1993				$67.88	$87.21	$12.18	$12.18
1994				$67.88	$87.21	$12.18	$12.18
1995				$67.88	$87.21	$12.18	$12.18
1996				$67.88	$87.21	$12.18	$12.18
1997				$67.88	$87.21	$12.18	$12.18
1998				$67.88	$87.21	$12.18	$12.18
1999				$67.88	$87.21	$12.18	$12.18
2000				$67.88	$87.21	$12.18	$12.18
2001				$67.88	$87.21	$12.18	$12.18
2002				$67.88	$87.21	$12.18	$12.18
2003				$67.88	$87.21	$12.18	$12.18
2004				$67.88	$87.21	$12.18	$12.18
2005		($14.37)		$67.88	$87.21	$12.18	$26.55

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

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY

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%). Tax: 34% federal, 3% state.
7. Note that the cash flow analysis has meaning only if the product can be sold at the price indicated on the cost sheet.

YEAR	CUM CASH	NPV @ 12%	%IRR
1983	($9.09)	($8.09)	---
1984	($18.17)	($17.20)	--
1985	($41.63)	($35.90)	--
1986	($40.81)	($41.73)	-138.4%
1987	($39.21)	($34.99)	-52.5%
1988	($25.10)	($26.98)	-21.6%
1989	($11.76)	($20.22)	-7.5%
1990	$1.57	($14.19)	0.8%
1991	$14.33	($9.04)	5.3%
1992	$26.51	($4.65)	9.2%
1993	$38.68	($0.72)	11.6%
1994	$50.86	$2.78	13.3%
1995	$63.04	$5.90	14.6%
1996	$75.22	$8.69	15.6%
1997	$87.39	$11.18	16.4%
1998	$99.57	$13.41	16.9%
1999	$111.74	$15.39	17.4%
2000	$123.92	$17.17	17.8%
2001	$136.10	$18.75	18.0%
2002	$148.27	$20.15	18.3%
2003	$160.45	$21.43	18.5%
2004	$172.63	$22.55	18.6%
2005	$199.17	$24.75	18.9%

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL WITH RECOVERY OF RAFFINATE BASECASE STOICHIOMETRY

BASIC DATA

SCALE OF OPERATION

161.32 MM PPY	ANNUAL PRODUCTION LEVEL
179.25 MM PPY	ANNUAL CAPACITY
90 %	OPERATING UTILITY
163.26 MM PPY	PRODUCT IN BEER
181.40 MM PPY	PRODUCT IN BEER AT CAPACITY
95.0 %	MOLAR YIELD-GLUC. TO PROD. IN BEER (E
4.29 lb/lb	GLUCOSE DEMAND/PROD (EXCL. SPILL)
74.12 MOL WT	PRODUCT MOLECULAR WEIGHT

PRODUCT STOICHIOMETRY

MOL. WT.	MOLES/MOL PRODUCT	COMPONENT
180.16	1.67525 /MOL PROD.	-GLUCOSE CONSUMED
32.00	0.00000 /MOL PROD.	-OXYGEN CONSUMED
17.02	0.00000 /MOL PROD.	-AMMONIA CONSUMED
.00	0.00000 /MOL PROD.	-COMPONENT #1 FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #2 FORMED
58.08	0.39985 /MOL PROD.	-COMPONENT #3 FORMED (ACETONE)
.00	0.00000 /MOL PROD.	-COMPONENT #4 FORMED
46.07	0.16600 /MOL PROD.	-COMPONENT #5 FORMED (ETHANOL)
.00	0.00000 /MOL PROD.	-COMPONENT #6 FORMED
74.12	1.00000 /MOL PROD.	-COMPONENT #7 FORMED (BUTANOL)
60.05	0.24982 /MOL PROD.	-COMPONENT #8 FORMED (ACETIC ACID)
.00	0.00000 /MOL PROD.	-COMPONENT #9 FORMED
88.10	0.06749 /MOL PROD.	-COMPONENT #10 FORMED (BUTYRIC ACID
18.02	0.35033 /MOL PROD.	-WATER FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #11 FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #12 FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #13 FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #14 FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #15 FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #16 FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #17 FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #18 FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #19 FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #20 FORMED
44.01	3.75035 /MOL PROD.	-CARBON DIOXIDE FORMED
2.02	2.23400 /MOL PROD.	-HYDROGEN FORMED

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

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL WITH RECOVERY OF RAFFINATE BASECASE STOICHIOMETRY

BASIC DATA

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		1 (0 OR 1)	-CONCUR'NT (0) OR SEQUENT'AL (1)
CONDITIONS			
STAGE:	GROWTH	PRODUCTION	
	33	33 C	-TEMPERATURE
	6.5	6.5	-pH
	0	13 g/l	-PRODUCT CONCENTRATION IN BEER
	21.6	21.8 g/l	-CELL DENSITY (CHO ONLY)
	0.280	0.475 1/hr	-DILUTION RATE
			-PRODUCT PRODUCTIVITY
	0.00	0.283 g/g*hr	*Specific Productivity
	0.00	6.18 g/l*hr	*Volumetric Productivity
	5.06	0.00 g/l*hr	-CELL PRODUCTIVITY (CHO ONLY)
	211	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
	264.13	23.32 Btu/hr*gal	-HEAT REMOVED BY COOLING COILS
FERMENTERS			
	48,564	444,878 gallons	-ACTIVE VOLUME REQUIRED
	15	15 % gross	-HEADSPACE
	67,217	615,748 gallons	-GROSS VOLUME (incl. 15% spares and
	100,000	250,000 gallons	-GROSS SIZE
	0.7	2.5 units	-NUMBER OF UNITS
PRODUCT SEPARATION			
		400 g/l	-CELL CONC. (CHO) EX FILTER
		0.053 gal/min*sf	-FILTER THROUGHPUT
		4,257 sq ft	-FILTER SIZE
PRODUCT RECOVERY & PURIFICATION			
		98.8%(wt)%	-YIELD ACROSS REFINING

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL WITH RECOVERY OF RAFFINATE BASECASE STOICHIOMETRY

BASIC DATA

MATERIALS OF CONSTRUCTION

	CHOICES	SELECTION
FERMENTERS & EXTRACTERS	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 Market Price for: 1988 (Year) /lb.

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

VENTURE TIMING

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

EXTRACTION

Solvent	Oleyl Alcohol CH3(CH2)7CH=CH(CH2)7CH2OH	
Solvent Molecular Weight	268.5	
Solvent Ratio, r	0.30	lb/lb water in feed
Mutual Solubilities		
Water in Solvent, w	0.000020	lb/lb solvent
Solvent in Water, s	0.000020	lb/lb water
(1+s)/(1+w)	1.00000	
Gamma	-0.70000	
Water in Solvent Feed, m	0.000000	lb./lb solvent
Solvent in Aqueous Feed	0.000019	lb/lb water in feed
Raffinate Recycle	15.0	lb raffinate water/lb water in fermenter feed

Solvent/Water Balances

Extract - Solvent	0.30000	lb/lb water in feed
- Water	0.00001	lb/lb water in feed
Raffinate - Water	0.99999	lb/lb water in feed
- Solvent	0.00002	lb/lb water in feed

Solute Distribution

	Phi	K	Extract	Raffinate

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY

BASIC DATA

Component #1	0.062	0.00	0.000	1.000 lb/lb in beer
Component #2	0.062	0.00	0.000	1.000 lb/lb in beer
Component #3	0.199	0.50	0.146	0.854 lb/lb in beer
Component #4	0.062	0.00	0.000	1.000 lb/lb in beer
Component #5	0.116	0.20	0.058	0.942 lb/lb in beer
Component #6	0.062	0.00	0.000	1.000 lb/lb in beer
Component #7P	0.972	4.30	0.9700	0.030 lb/lb in beer
Component #8	0.116	0.20	0.058	0.942 lb/lb in beer
Component #9	0.052	0.00	0.000	1.000 lb/lb in beer
Component #10	0.116	0.20	0.058	0.942 lb/lb in beer
Component #11	0.062	0.00	0.000	1.000 lb/lb in beer
Component #12	0.062	0.00	0.000	1.000 lb/lb in beer
Component #13	0.062	0.00	0.000	1.000 lb/lb in beer
Component #14	0.062	0.00	0.000	1.000 lb/lb in beer
Component #15	0.062	0.00	0.000	1.000 lb/lb in beer
Component #16	0.062	0.00	0.000	1.000 lb/lb in beer
Component #17	0.062	0.00	0.000	1.000 lb/lb in beer
Component #18	0.062	0.00	0.000	1.000 lb/lb in beer
Component #19	0.062	0.00	0.000	1.000 lb/lb in beer
Component #20	0.062	0.00	0.000	1.000 lb/lb in beer
Reactants	0.062	0.00	0.000	1.000 lb/lb in beer

	1	2
EXTRACTOR DESIGN		
Density - Raffinate, g/ml		0.9951
" - Extract, g,ml		0.0467
Capacity Factor		6000
CS Area/Extractor, sq ft		106
Number of Extractors		4
Extractor Diameter, ft		11.6
Theoretical Stages		9
Extractor Height, ft		28
Extractors Cost - $1000 3Q86 MPC - Bare Equipment		
-All Carbon Steel		$1,053.3
-All 304 Stainless Steel		$1,480.6

Stage to stage balances: Basis: lb/lb water in feed

Stage	Feed	0.03000 1	0.27806 2	0.47036 3	0.61942 4
Extract					
-Solvent		0.30000	0.30000	0.30000	0.30000
-Water		0.00001	0.00001	0.00001	0.00001
-Total		0.30000	0.30001	0.30001	0.30001
Raffinate					
-Solvent	0.00002	0.00002	0.00002	0.00002	0.00002
-Water	1.00000	1.00000	1.00000	1.00000	1.00000
-Total	1.00002	1.00002	1.00002	1.00002	1.00002

Product Partition: Basis: lb/lb solute in feed

Based on fixed yield =		97.00%			
Solvent/Feed Ratio, r =		0.30			
K = 4.30 ;stages=		9			
Extract		0.97000	0.72194	0.52964	0.38058
Raffinate	1.00000	0.75194	0.55964	0.41058	0.29502

0.73498	0.82456	0.88400	0.84783	0.98356	1.02180	1.04698	1.06642
5	6	7	8	9	10	11	12
0.30000	0.30000	0.30000	0.30000	0.30000	0.30000	0.30000	0.30000
0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
0.30001	0.30001	0.30001	0.30001	0.30001	0.30001	0.30001	0.30001
0.00002	0.00002	0.00002	0.00002	0.00002	0.00002	0.00002	0.00002
1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
1.00002	1.00002	1.00002	1.00002	1.00002	1.00002	1.00002	1.00002
0.26502	0.17544	0.10600	0.05217	0.01044	-0.02180	-0.04698	********
0.20544	0.13600	0.08217	0.04044	0.00810	-0.01698	-0.03642	********

1.08149	1.09317	1.10222	1.10924	1.11468	1.11890	1.12217	1.12471
13	14	15	16	17	18	19	20
0.30000	0.30000	0.30000	0.30000	0.30000	0.30000	0.30000	0.30000
0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
0.30001	0.30001	0.30001	0.30001	0.30001	0.30001	0.30001	0.30001
0.00002	0.00002	0.00002	0.00002	0.00002	0.00002	0.00002	0.00002
1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.99999
1.00002	1.00002	1.00002	1.00002	1.00002	1.00002	1.00002	1.00001

-0.08149	-0.09317	-0.10222	-0.10924	-0.11468	-0.11890	-0.12217	-0.12471
-0.06317	-0.07222	-0.07924	-0.08468	-0.08890	-0.09217	-0.09471	-0.09667

Solvent
0.30000
0.00000
0.30000

-0.12667

LOOK-UP TABLE: YIELD TO EXTRACT - % For K=0.2

		S/F Ratio:				
	Stages	0.25	0.30	0.35	0.40	0.45
	1	4.5%	5.4%	6.3%	7.2%	8.0%
	2	4.7%	5.7%	6.7%	7.7%	8.7%
	3	4.8%	5.8%	6.8%	7.8%	8.8%
	4	4.8%	5.8%	6.8%	7.8%	8.8%
	5	4.8%	5.8%	6.8%	7.8%	8.8%
	6	4.8%	5.8%	6.8%	7.8%	8.8%
	7	4.8%	5.8%	6.8%	7.8%	8.8%
	8	4.8%	5.8%	6.8%	7.8%	8.8%
	9	4.8%	5.8%	6.8%	7.8%	8.8%
	10	4.8%	5.8%	6.8%	7.8%	8.8%
	11	4.8%	5.8%	6.8%	7.8%	8.8%
	12	4.8%	5.8%	6.8%	7.8%	8.8%
	13	4.8%	5.8%	6.8%	7.8%	8.8%
Density, g	14	4.8%	5.8%	6.8%	7.8%	8.8%
	15	4.8%	5.8%	6.8%	7.8%	8.8%
	16	4.8%	5.8%	6.8%	7.8%	8.8%
0.7920	17	4.8%	5.8%	6.8%	7.8%	8.8%
	18	4.8%	5.8%	6.8%	7.8%	8.8%
0.7893	19	4.8%	5.8%	6.8%	7.8%	8.8%
	20	4.8%	5.8%	6.8%	7.8%	8.8%

0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00
8.9%	16.0%	22.0%	28.3%	33.1%	37.4%	41.1%	44.3%
9.7%	19.1%	27.0%	35.8%	42.7%	48.8%	54.2%	58.9%
9.8%	19.5%	27.0%	38.3%	46.6%	53.9%	60.4%	66.1%
9.8%	19.8%	29.6%	39.2%	48.2%	56.5%	63.8%	70.1%
9.8%	19.8%	29.8%	39.6%	49.1%	57.9%	65.9%	72.8%
9.8%	19.8%	29.8%	39.7%	49.5%	58.8%	67.2%	74.6%
9.8%	19.8%	29.9%	39.8%	49.7%	59.2%	68.1%	76.0%
9.8%	19.8%	29.9%	39.9%	49.8%	59.5%	68.6%	76.8%
9.8%	19.8%	29.9%	39.9%	49.8%	59.6%	69.1%	77.6%
9.8%	19.8%	29.9%	39.9%	49.8%	59.7%	69.3%	78.0%
9.8%	19.8%	29.9%	39.9%	49.8%	59.8%	69.5%	78.4%
9.8%	19.8%	29.9%	39.9%	49.8%	59.9%	69.6%	78.7%
9.8%	19.8%	29.9%	39.9%	49.8%	59.9%	69.7%	79.0%
9.8%	19.8%	29.9%	39.9%	49.8%	59.9%	69.8%	79.2%
9.8%	19.8%	29.9%	39.9%	49.8%	59.9%	69.8%	79.3%
9.8%	19.8%	29.9%	39.9%	49.8%	59.9%	69.9%	79.4%
9.8%	19.8%	29.9%	39.9%	49.8%	59.9%	69.9%	79.5%
9.8%	19.8%	29.9%	39.9%	49.8%	59.9%	69.9%	79.6%
9.8%	19.8%	29.9%	39.9%	49.8%	59.9%	69.9%	79.7%
9.8%	19.8%	29.9%	39.9%	49.8%	59.9%	69.9%	79.8%

4.50	5.00
47.3%	49.9%
63.1%	66.6%
70.8%	74.9%
75.6%	79.9%
78.6%	83.3%
80.7%	85.6%
82.4%	87.4%
83.6%	88.8%
84.6%	89.9%
85.3%	90.8%
86.0%	91.6%
86.5%	92.2%
87.0%	92.8%
87.3%	93.3%
87.7%	93.7%
87.9%	94.1%
88.2%	94.4%
88.4%	94.7%
88.5%	94.9%
88.5%	95.1%

LOOK-UP TABLE: YIELD TO EXTRACT - % For K=0.5

	S/F Ratio:						
Stages	0.25	0.30	0.35	0.40	0.45	0.50	1.00
1	10.0%	12.5%	14.6%	16.0%	18.0%	18.0%	33.0%
2	11.0%	14.0%	16.0%	18.0%	21.0%	24.0%	42.0%
3	12.0%	14.5%	17.0%	19.0%	22.0%	25.0%	43.0%
4	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	48.0%
5	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	48.5%
6	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.0%
7	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.5%
8	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.6%
9	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.7%
10	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.7%
11	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.7%
12	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.7%
13	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.7%
14	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.7%
15	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.7%
16	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.7%
17	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.7%
18	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.7%
19	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.7%
20	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.7%

1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00
42.0%	49.0%	55.3%	59.5%	63.0%	66.0%	69.0%	71.0%
56.0%	66.0%	73.0%	78.0%	82.0%	85.0%	87.0%	89.0%
65.0%	74.9%	82.0%	87.0%	91.0%	93.0%	94.0%	96.0%
67.0%	79.0%	87.5%	92.3%	95.1%	97.0%	97.7%	98.4%
69.0%	83.0%	91.0%	95.0%	97.0%	98.3%	99.1%	99.3%
71.0%	85.0%	93.2%	96.0%	98.4%	99.2%	99.5%	99.7%
71.5%	87.0%	94.9%	97.0%	99.0%	99.6%	99.8%	99.9%
72.5%	88.0%	96.0%	98.0%	99.5%	99.8%	99.9%	100.0%
73.0%	89.0%	96.5%	98.1%	99.7%	99.9%	100.0%	100.0%
73.5%	90.0%	97.0%	98.5%	99.8%	100.0%	100.0%	100.0%
74.0%	91.0%	98.0%	99.6%	99.9%	100.0%	100.0%	100.0%
74.2%	92.0%	98.5%	99.7%	99.9%	100.0%	100.0%	100.0%
74.3%	92.5%	98.7%	99.8%	100.0%	100.0%	100.0%	100.0%
74.5%	93.0%	99.0%	99.9%	100.0%	100.0%	100.0%	100.0%
74.6%	93.5%	99.2%	99.9%	100.0%	100.0%	100.0%	100.0%
74.6%	94.0%	99.4%	99.9%	100.0%	100.0%	100.0%	100.0%
74.7%	94.2%	99.5%	99.9%	100.0%	100.0%	100.0%	100.0%
74.7%	94.6%	99.6%	99.9%	100.0%	100.0%	100.0%	100.0%
74.7%	95.0%	99.7%	99.9%	100.0%	100.0%	100.0%	100.0%
74.8%	95.0%	99.8%	99.9%	100.0%	100.0%	100.0%	100.0%

DISTILLATION DATA MATRIX

ITEM	COMPONENT	DEFAULT VALUE	IMPURITY #1	IMPURITY #2	LOWER BOIL PRODUCT #3
1	NAME		NONE	NONE	ACETONE
2	PRIORITY AS REFINED PRODUCT	LIST	1-4		2
3					
4	NORMAL BOILING PT, C				56.5
5	LOSS/COLUMN, WT %	0.50			
6	LEVEL AS IMPURITY, WT%	0.20			
7	VAP PRESS TEMP, C	900			-9.4
8	VAPOR PRESS, mm Hg	800000			40.0
9	HT VAPORIZATION, Btu/lb	215.0			
10	SENSIBLE HT (LIQ), Btu/(lb)(F)	0.50			
11	MAX THERMAL STABILITY, C	225			
12	LN(ACTIVITY COEFFICIENTS)				
13	-COMP. #1 in:	*	xxxx		
14	-COMP. #2 in:	*		xxxx	
15	-COMP. #3 in:	*			xxxx
16	-COMP. #4 in:	*			
17	-COMP. #5 in:	*			0.400
18	-COMP. #6 in:	*			
19	-COMP. #7 in:	*			0.400
20	-COMP. #8 in:	*			0.700
21	-COMP. #9 in:	*			
22	-COMP. #10 in:	*			0.650
23	-SOLVENT in:	*			1.100
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:	*			
34	-WATER in:	*	0.600	0.600	0.600

* 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	-2476.10	-3880.77
35	A(n) VAPOR PRESSURE CONST.	15.703	15.703	18.411
36	VAPOR PRESSURE @40 C	2422.2	2422.2	408.5
37	VAPOR PRESSURE @120 C	12121.9	12121.9	5096.7

DISTILLATION DATA MATRIX

ITEM	COMPONENT	IMPURITY #4	IMPURITY #5	IMPURITY #6	LOW BOIL PRODUCT #7
1	NAME	NONE	ETHANOL	NONE	BUTANOL
2	PRIORITY AS REFINED PRODUCT				1
3					
4	NORMAL BOILING PT, C		78.4		117.5
5	LOSS/COLUMN, WT %				
6	LEVEL AS IMPURITY, WT%				
7	VAP PRESS TEMP, C		19.0		53.4
8	VAPOR PRESS, mm Hg		40.0		40.0
9	HT VAPORIZATION, Btu/lb				
10	SENSIBLE HT (LIQ), Btu/(lb)(F)				
11	MAX THERMAL STABILITY, C				
12	LN(ACTIVITY COEFFICIENTS)				
13	-COMP. #1 in:				
14	-COMP. #2 in:				
15	-COMP. #3 in:		0.400		0.400
16	-COMP. #4 in:	XXXX			
17	-COMP. #5 in:		XXXX		0.300
18	-COMP. #6 in:			XXXX	
19	-COMP. #7 in:		0.300		XXXX
20	-COMP. #8 in:		0.600		0.600
21	-COMP. #9 in:				
22	-COMP. #10 in:		0.500		0.400
23	-SOLVENT in:		1.050		0.700
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:				
34	-WATER in:	0.600	0.600	0.600	0.600

* 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	-5086.29	-2476.10	-5854.85
35	A(n) VAPOR PRESSURE CONST.	15.703	21.108	15.703	21.627
36	VAPOR PRESSURE @40 C	2422.2	128.7	2422.2	18.6
37	VAPOR PRESSURE @120 C	12121.9	3517.3	12121.9	836.1

DISTILLATION DATA MATRIX

ITEM	COMPONENT	IMPURITY #8	IMPURITY #9	IMPURITY #10	SOLVENT
1	NAME	ACETIC AC	NONE	BUTYRIC ACID	
2	PRIORITY AS REFINED PRODUCT				
3					
4	NORMAL BOILING PT, C	118.1		163.5	213.5
5	LOSS/COLUMN, WT %				
6	LEVEL AS IMPURITY, WT%				
7	VAP PRESS TEMP, C	43.0		88.0	118.0
8	VAPOR PRESS, mm Hg	40.0		40.0	15.0
9	HT VAPORIZATION, Btu/lb				215.0
10	SENSIBLE HT (LIQ), Btu/(lb)(F)				0.50
11	MAX THERMAL STABILITY, C				
12	LN(ACTIVITY COEFFICIENTS)				
13	-COMP. #1 in:				
14	-COMP. #2 in:				
15	-COMP. #3 in:	0.700		0.650	1.100
16	-COMP. #4 in:				
17	-COMP. #5 in:	0.600		0.500	1.050
18	-COMP. #6 in:				
19	-COMP. #7 in:	0.600		0.400	0.700
20	-COMP. #8 in:	xxxx		0.300	0.800
21	-COMP. #9 in:		xxxx		
22	-COMP. #10 in:	0.300		xxxx	0.750
23	-SOLVENT in:	0.800		0.750	xxxx
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:				
34	-WATER in:	0.600	0.600	0.600	0.600

* 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.	-4845.49	-2476.10	-6145.36	-7818.54
35	A(n) VAPOR PRESSURE CONST.	19.023	15.703	20.712	22.704
36	VAPOR PRESSURE @40 C	34.5	2422.2	2.9	0.1
37	VAPOR PRESSURE @120 C	806.9	12121.9	160.0	16.6

DISTILLATION DATA MATRIX

ITEM	COMPONENT	WATER
1	NAME	
2	PRIORITY AS REFINED PRODUCT	
3		
4	NORMAL BOILING PT, C	100.0
5	LOSS/COLUMN, WT %	
6	LEVEL AS IMPURITY, WT%	
7	VAP PRESS TEMP, C	30.0
8	VAPOR PRESS, mm Hg	31.8
9	HT VAPORIZATION, Btu/lb	970.3
10	SENSIBLE HT (LIQ), Btu/(lb)(F)	1.00
11	MAX THERMAL STABILITY, C	
12	LN(ACTIVITY COEFFICIENTS)	
13	-COMP. #1 in:	
14	-COMP. #2 in:	
15	-COMP. #3 in:	0.600
16	-COMP. #4 in:	
17	-COMP. #5 in:	0.600
18	-COMP. #6 in:	
19	-COMP. #7 in:	0.600
20	-COMP. #8 in:	0.600
21	-COMP. #9 in:	
22	-COMP. #10 in:	0.600
23	-SOLVENT 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:	
34	-WATER in:	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

34	B(n) VAPOR PRESSURE CONST.	-5124.37
35	A(n) VAPOR PRESSURE CONST.	20.372
36	VAPOR PRESSURE @40 C	54.6
37	VAPOR PRESSURE @120 C	1529.1

OFTEN USED PARAMETERS

(THOUSAND ANNUAL POUNDS)

181,401	PRODUCT FORMED
	FORMED WITH PRODUCT
0	-COMPONENT #1
0	-COMPONENT #2
56,835	-COMPONENT #3
0	-COMPONENT #4
18,716	-COMPONENT #5
0	-COMPONENT #6
181,401	-COMPONENT #7
36,717	-COMPONENT #8
0	-COMPONENT #9
14,553	-COMPONENT #10
15,447	-WATER
0	-COMPONENT #11
0	-COMPONENT #12
0	-COMPONENT #13
0	-COMPONENT #14
0	-COMPONENT #15
0	-COMPONENT #16
0	-COMPONENT #17
0	-COMPONENT #18
0	-COMPONENT #19
0	-COMPONENT #20
11,022	-HYDROGEN
403,951	-CARBON DIOXIDE
	CONSUMED FOR PRODUCT
738,842	-GLUCOSE
0	-AMMONIA
0	-OXYGEN
13,438	CELLS PRODUCED - CHO
1,777	CELLS PRODUCED - NH2
	FORMED WITH CELLS
11,656	-WATER-CHO
1,000	-WATER-NH2
12,656	-WATER-TOTAL
28,493	-CARBON DIOXIDE-CHO
	CONSUMED FOR CELLS
38,876	-GLUCOSE-CHO
1,888	-AMMONIA-NH2
20,722	-OXYGEN-CHO
889	-OXYGEN-NH2
21,611	-OXYGEN-TOTAL
108,054	OXYGEN FED-GROWTH
357,833	NITROGEN FED-GROWTH
86,444	OXYGEN VENT-GROWTH
357,833	NITROGEN VENT-GROWTH
28,493	CARBON DIOXIDE VENT-GROWTH
14,487	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
403,951	CARBON DIOXIDE VENT-PROD'N
23,238	WATER VENT-PROD'N
427,189	PHI

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL WITH RECOVERY OF RAFFINATE BASECASE STOICHIOMETRY

WATER BALANCE

WATER IN:	
MAKE UP WATER	120,779
BIOSUGAR SYRUP	778,913
STERILIZER STEAM	60,804
FORMED WITH CELLS	12,656
FORMED WITH PRODUCT	15,447
TOTAL IN	988,600
WATER OUT:	
AQUEOUS WASTE	841,353
CONDENSATE MAKEUP TO P.H	60,804
FERMENTER VENTS	37,725
PURGED WITH CELLS	48,595
MOISTURE IN PRODUCTS	121
TOTAL OUT	988,600

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

P	STREAM	1 CORN SYRUP	2 ANHYD AMMONIA	3 NUTRIENTS	4 MIX WATER	5 MIXED MEDIUM
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	COMPONENT #1	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#2	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	COMPONENT #6	0	0	0	0	0
#1	COMPONENT #7	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
	COMPONENT #11	0	0	0	0	0
	COMPONENT #12	0	0	0	0	0
	COMPONENT #13	0	0	0	0	0
#	COMPONENT #14	0	0	0	0	0
	COMPONENT #15	0	0	0	0	0
	COMPONENT #16	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
	COMPONENT #20	0	0	0	0	0
	GLUCOSE	778,913	0	0	0	778,913
	AMMONIA	0	1,888	0	0	0
	PHOSPHORIC ACID	0	0	1,573	0	1,573
	POTASSIUM CHLORIDE	0	0	1,197	0	1,197
	MINOR NUTRIENTS	0	0	543	0	543
	WATER	778,913	0	0	59,975	838,888
	SOLVENT	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	1,557,826	1,888	3,313	59,975	1,621,114
	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

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

P	STREAM	6 HX SS EFFLUENT	7 STERILE MEDIUM	8 HX TS EFFLUENT	9 COOLER EFFLUENT	10 AIR TO FERM
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	COMPONENT #1	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#2	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	COMPONENT #6	0	0	0	0	0
#1	COMPONENT #7	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
	COMPONENT #11	0	0	0	0	0
	COMPONENT #12	0	0	0	0	0
	COMPONENT #13	0	0	0	0	0
#	COMPONENT #14	0	0	0	0	0
	COMPONENT #15	0	0	0	0	0
	COMPONENT #16	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
	COMPONENT #20	0	0	0	0	0
	GLUCOSE	778,913	778,913	778,913	778,913	0
	AMMONIA	0	0	0	0	0
	PHOSPHORIC ACID	1,573	1,573	1,573	1,573	0
	POTASSIUM CHLORIDE	1,197	1,197	1,197	1,197	0
	MINOR NUTRIENTS	543	543	543	543	0
	WATER	838,888	899,692	899,692	899,692	0
	SOLVENT	0	0	0	0	0
	CARBON DIOXIDE	0	0	0	0	0
	OXYGEN	0	0	0	0	108,054
	NITROGEN	0	0	0	0	357,833
	HYDROGEN	0	0	0	0	0
	GRAND TOTAL	1,621,114	1,681,919	1,681,919	1,681,919	465,888
	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

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY

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	19,438	313,588	0	0
O	-NH2	0	1,777	28,671	0	0
D	-MINERALS	0	543	8,763	0	0
U	-TOTAL	0	21,758	351,021	0	0
C	COMPONENT #1	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#2	COMPONENT #3	0	0	286,098	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	160,661	0	0
	COMPONENT #6	0	0	0	0	0
#1	COMPONENT #7	0	0	186,654	0	0
	COMPONENT #8	0	0	315,184	0	0
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	0	0	124,924	0	0
	COMPONENT #11	0	0	0	0	0
	COMPONENT #12	0	0	0	0	0
	COMPONENT #13	0	0	0	0	0
#	COMPONENT #14	0	0	0	0	0
	COMPONENT #15	0	0	0	0	0
	COMPONENT #16	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
	COMPONENT #20	0	0	0	0	0
	GLUCOSE	778,913	740,037	22,512	0	0
	AMMONIA	1,888	0	0	0	0
	PHOSPHORIC ACID	1,573	1,573	25,369	0	0
	POTASSIUM CHLORIDE	1,197	1,197	19,317	0	0
	MINOR NUTRIENTS	543	0	0	0	0
	WATER	889,682	897,861	14,357,986	14,487	23,238
	SOLVENT	0	0	269	0	0
	CARBON DIOXIDE	0	0	0	28,493	403,951
	OXYGEN	108,054	0	0	86,444	0
	NITROGEN	357,833	0	0	357,833	0
	HYDROGEN	0	0	0	0	11,022
	GRAND TOTAL	2,149,694	1,662,426	15,849,985	487,257	438,212
	CHECK ON TOTAL					
	TEMPERATURE, C	33	33	33	33	33
	PRESSURE, PSIA	--	44.7	44.7	14.7	14.7
	STATE	--	SLURRY	SLURRY	GAS	GAS

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

P	STREAM	16 COMBINED VENT	17 SOLVENT FEED	18 RAFFINATE	19 RECYCLE	20 AQUEOUS PURGE
R	CELLS -CHO	0	0	313,588	294,150	19,438
O	-NH2	0	0	28,671	26,894	1,777
D	-MINERALS	0	0	8,763	8,220	543
U	-TOTAL	0	0	351,021	329,263	21,758
C	COMPONENT #1	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#2	COMPONENT #3	0	0	244,413	229,263	15,150
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	151,325	141,945	9,380
	COMPONENT #6	0	0	0	0	0
#1	COMPONENT #7	0	0	5,600	5,253	347
	COMPONENT #8	0	0	296,869	278,467	18,402
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	0	0	117,664	110,371	7,293
	COMPONENT #11	0	0	0	0	0
	COMPONENT #12	0	0	0	0	0
	COMPONENT #13	0	0	0	0	0
#	COMPONENT #14	0	0	0	0	0
	COMPONENT #15	0	0	0	0	0
	COMPONENT #16	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
	COMPONENT #20	0	0	0	0	0
	GLUCOSE	0	0	22,512	21,116	1,395
	AMMONIA	0	0	0	0	0
	PHOSPHORIC ACID	0	0	25,369	23,797	1,573
	POTASSIUM CHLORIDE	0	0	19,317	18,120	1,197
	MINOR NUTRIENTS	0	0	0	0	0
	WATER	37,725	0	14,357,900	13,467,916	889,984
	SOLVENT	0	4,307,396	287	269	18
	CARBON DIOXIDE	432,444	0	0	0	0
	OXYGEN	86,444	0	0	0	0
	NITROGEN	357,833	0	0	0	0
	HYDROGEN	11,022	0	0	0	0
	GRAND TOTAL	925,469	4,307,396	15,592,277	14,625,780	966,497
	CHECK ON TOTAL					
	TEMPERATURE, C	33	20			33
	PRESSURE, PSIA	14.7	15			15
	STATE	GAS	LIQUID	SLURRY	SLURRY	SLURRY

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	21 CELLS TO DISPOSAL	22 FILTRATE TO RAFF #1	23 EXTRACT	24 BEER #1 FEED	25 BEER #1 MAKE
P						
R	CELLS -CHO	19,438	0	0	0	0
O	-NH2	1,777	0	0	0	0
D	-MINERALS	543	0	0	0	0
U	-TOTAL	21,758	0	0	0	0
C	COMPONENT #1	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#2	COMPONENT #3	827	14,323	41,684	41,684	41,684
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	512	8,868	9,336	9,336	9,336
	COMPONENT #6	0	0	0	0	0
#1	COMPONENT #7	19	328	181,054	199,069	198,164
	COMPONENT #8	1,005	17,397	18,315	18,351	396
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	398	6,895	7,259	7,295	396
	COMPONENT #11	0	0	0	0	0
	COMPONENT #12	0	0	0	0	0
	COMPONENT #13	0	0	0	0	0
#	COMPONENT #14	0	0	0	0	0
	COMPONENT #15	0	0	0	0	0
	COMPONENT #16	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
	COMPONENT #20	0	0	0	0	0
	GLUCOSE	76	1,319	0	0	0
	AMMONIA	0	0	0	0	0
	PHOSPHORIC ACID	86	1,487	0	0	0
	POTASSIUM CHLORIDE	65	1,132	0	0	0
	MINOR NUTRIENTS	0	0	0	0	0
	WATER	48,595	841,389	86	86	86
	SOLVENT	1	17	4,307,378	4,505,182	198,164
	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	73,343	893,154	4,565,113	4,781,004	448,227
	CHECK ON TOTAL					
	TEMPERATURE, C	33	33	33	--	90
	PRESSURE, PSIA	14.7	14.7	14.7	--	11.5
	STATE	SLURRY	SOL'N	SOL'N	SOL'N	SOL'N

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

P	STREAM	26 BEER #1 TAILS	27 BEER #2 MAKE	28 BEER #2 TAILS	29 LBS #1 MAKE	30 LBS #1 TAILS
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	COMPONENT #1	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#2	COMPONENT #3	0	41,684	0	41,326	358
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	9,336	0	8,978	358
	COMPONENT #6	0	0	0	0	0
#1	COMPONENT #7	905	180,149	18,015	901	179,248
	COMPONENT #8	17,955	360	36	0	360
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	6,899	360	36	0	360
	COMPONENT #11	0	0	0	0	0
	COMPONENT #12	0	0	0	0	0
	COMPONENT #13	0	0	0	0	0
#	COMPONENT #14	0	0	0	0	0
	COMPONENT #15	0	0	0	0	0
	COMPONENT #16	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
	COMPONENT #20	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	0	86	0	0	86
	SOLVENT	4,307,018	360	197,804	0	360
	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	4,332,777	232,336	215,890	51,204	181,132
	CHECK ON TOTAL					
	TEMPERATURE, C	220	154	220	123	175
	PRESSURE, PSIA	12.3	89.3	90.2	98.3	100.5
	STATE	SOL'N	SOL'N	SOL'N	SOL'N	SOL'N

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

P	STREAM	31 LBS #2 MAKE	32 LBS #2 TAILS	33 LBS #3 MAKE	34 LBS #3 TAILS	35 HBS #1 MAKE
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	COMPONENT #1	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#2	COMPONENT #3	41,119	207	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	82	8,895	0	0	0
	COMPONENT #6	0	0	0	0	0
#1	COMPONENT #7	0	901	0	0	905
	COMPONENT #8	0	0	0	0	17,865
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	0	0	0	0	6,865
	COMPONENT #11	0	0	0	0	0
	COMPONENT #12	0	0	0	0	0
	COMPONENT #13	0	0	0	0	0
#	COMPONENT #14	0	0	0	0	0
	COMPONENT #15	0	0	0	0	0
	COMPONENT #16	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
	COMPONENT #20	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	0	0	0	0	0
	SOLVENT	0	0	0	0	14
	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	41,202	10,003	0	0	25,649
	CHECK ON TOTAL					
	TEMPERATURE, C	100	120	(273)	120	122
	PRESSURE, PSIA	58.4	65.5	.0	.0	14.2
	STATE	SOL'N	SOL'N	SOL'N	SOL'N	SOL'N

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

P	STREAM	36 HBS #1 TAILS	37 BYPRODUCT FEED	38 RAFF #1 FEED	39 RAFF #1 MAKE	40 RAFF #1 TAILS
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	COMPONENT #1	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#2	COMPONENT #3	0	14,530	14,530	14,530	(0)
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	17,763	19,530	19,442	89
	COMPONENT #6	0	0	0	0	0
#1	COMPONENT #7	0	1,229	1,232	39	1,194
	COMPONENT #8	90	17,397	17,397	0	17,397
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	34	6,895	6,895	0	6,895
	COMPONENT #11	0	0	0	0	0
	COMPONENT #12	0	0	0	0	0
	COMPONENT #13	0	0	0	0	0
#	COMPONENT #14	0	0	0	0	0
	COMPONENT #15	0	0	0	0	0
	COMPONENT #16	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
	COMPONENT #20	0	0	0	0	0
	GLUCOSE	0	1,319	1,319	0	1,319
	AMMONIA	0	0	0	0	0
	PHOSPHORIC ACID	0	1,487	1,487	0	1,487
	POTASSIUM CHLORIDE	0	1,132	1,132	0	1,132
	MINOR NUTRIENTS	0	0	0	0	0
	WATER	0	841,389	860,795	19,442	841,353
	SOLVENT	4,307,004	17	17	0	17
	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	4,307,128	903,157	924,334	53,452	870,882
	CHECK ON TOTAL					
	TEMPERATURE, C	220	34	33	85	105
	PRESSURE, PSIA	17.7	14.7	--	15.1	17.6
	STATE	SOL'N	SOL'N	SOL'N	SOL'N	SOL'N

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

P	STREAM	41 RAFF #2 MAKE	42 RAFF #2 TAILS	43 RAFF #3 MAKE	44 RAFF #3 TAILS	45 REFINED BUTANOL	46 REFINED ACETONE
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	COMPONENT #1	0	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0	0
#2	COMPONENT #3	14,530	0	14,457	73	358	55,575
	COMPONENT #4	0	0	0	0	0	0
	COMPONENT #5	17,674	1,767	29	17,645	358	111
	COMPONENT #6	0	0	0	0	0	0
#1	COMPONENT #7	35	4	0	35	179,248	0
	COMPONENT #8	0	0	0	0	360	0
	COMPONENT #9	0	0	0	0	0	0
	COMPONENT #10	0	0	0	0	360	0
	COMPONENT #11	0	0	0	0	0	0
	COMPONENT #12	0	0	0	0	0	0
	COMPONENT #13	0	0	0	0	0	0
#	COMPONENT #14	0	0	0	0	0	0
	COMPONENT #15	0	0	0	0	0	0
	COMPONENT #16	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
	COMPONENT #20	0	0	0	0	0	0
	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	35	19,406	0	35	86	0
	SOLVENT	0	0	0	0	360	0
	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	32,274	21,177	14,486	17,789	181,132	55,687
	CHECK ON TOTAL					0	0
	TEMPERATURE, C	64	100	82	105	175	100
	PRESSURE, PSIA	12.3	15.4	34.2	40.6	101	58
	STATE	SOL'N	SOL'N	SOL'N	SOL'N	0	0

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

P	STREAM	47 REFINED ETHANOL	48 ORGANIC WASTE	49 MAKE-UP SOLVENT	50 MAKE-UP WATER	51 STERILE STEAM
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	COMPONENT #1	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#2	COMPONENT #3	73	(0)	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	17,645	89	0	0	0
	COMPONENT #6	0	0	0	0	0
#1	COMPONENT #7	35	2,099	0	0	0
	COMPONENT #8	0	35,262	0	0	0
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	0	13,760	0	0	0
	COMPONENT #11	0	0	0	0	0
	COMPONENT #12	0	0	0	0	0
	COMPONENT #13	0	0	0	0	0
#	COMPONENT #14	0	0	0	0	0
	COMPONENT #15	0	0	0	0	0
	COMPONENT #16	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
	COMPONENT #20	0	0	0	0	0
	GLUCOSE	0	1,319	0	0	0
	AMMONIA	0	0	0	0	0
	PHOSPHORIC ACID	0	1,487	0	0	0
	POTASSIUM CHLORIDE	0	1,132	0	0	0
	MINOR NUTRIENTS	0	0	0	0	0
	WATER	35	841,353	0	120,779	60,804
	SOLVENT	0	31	374	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	17,789	896,531	374	120,779	60,804
	CHECK ON TOTAL			374		
	TEMPERATURE, C	105	40	20	20	141
	PRESSURE, PSIA	40.6	14.7	14.7	14.7	64.7
	STATE	SOL'N	SOL'N	LIQUID	LIQUID	GAS

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

P	STREAM	52 FERM'TR STEAM	53 DISTILL. STEAM	54 COND. MU P'WR H'SE	55 MEDIUM COOL WTR	56 FERM'TR COOL WTR
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	COMPONENT #1	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#2	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	COMPONENT #6	0	0	0	0	0
#1	COMPONENT #7	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
	COMPONENT #11	0	0	0	0	0
	COMPONENT #12	0	0	0	0	0
	COMPONENT #13	0	0	0	0	0
#	COMPONENT #14	0	0	0	0	0
	COMPONENT #15	0	0	0	0	0
	COMPONENT #16	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
	COMPONENT #20	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	0	1,384,445	60,804	784,895	12,760,550
	SOLVENT	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	1,384,445	60,804	784,895	12,760,550
	CHECK ON TOTAL					
	TEMPERATURE, C	141	186	110	5	5
	PRESSURE, PSIA	64.7	164.7	20.8	14.7	14.7
	STATE	GAS	GAS	LIQUID	LIQUID	LIQUID

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	57 DISTILL. COOL WTR
P		
R	CELLS -CHO	0
O	-NH2	0
D	-MINERALS	0
U	-TOTAL	0
C	COMPONENT #1	0
T	COMPONENT #2	0
#2	COMPONENT #3	0
	COMPONENT #4	0
	COMPONENT #5	0
	COMPONENT #6	0
#1	COMPONENT #7	0
	COMPONENT #8	0
	COMPONENT #9	0
	COMPONENT #10	0
	COMPONENT #11	0
	COMPONENT #12	0
	COMPONENT #13	0
#	COMPONENT #14	0
	COMPONENT #15	0
	COMPONENT #16	0
	COMPONENT #17	0
#	COMPONENT #18	0
	COMPONENT #19	0
	COMPONENT #20	0
	GLUCOSE	0
	AMMONIA	0
	PHOSPHORIC ACID	0
	POTASSIUM CHLORIDE	0
	MINOR NUTRIENTS	0
	WATER	14,346,709
	SOLVENT	0
	CARBON DIOXIDE	0
	OXYGEN	0
	NITROGEN	0
	HYDROGEN	0
	GRAND TOTAL	14,346,709
	CHECK ON TOTAL	
	TEMPERATURE, C	0
	PRESSURE, PSIA	14.7
	STATE	LIQUID

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	23 EXTRACT	24 BEER #1 FEED	25 BEER #1 MAKE	26 BEER #1 TAILS
COMPONENT #1	0	0	0	0
COMPONENT #2	0	0	0	0
COMPONENT #3	718	718	718	0
COMPONENT #4	0	0	0	0
COMPONENT #5	203	203	203	0
COMPONENT #6	0	0	0	0
COMPONENT #7	2,443	2,686	2,674	12
COMPONENT #8	305	306	7	299
COMPONENT #9	0	0	0	0
COMPONENT #10	82	83	4	78
COMPONENT #11	0	0	0	0
COMPONENT #12	0	0	0	0
COMPONENT #13	0	0	0	0
COMPONENT #14	0	0	0	0
COMPONENT #15	0	0	0	0
COMPONENT #16	0	0	0	0
COMPONENT #17	0	0	0	0
COMPONENT #18	0	0	0	0
COMPONENT #19	0	0	0	0
COMPONENT #20	0	0	0	0
WATER	5	5	5	0
SOLVENT	16,044	16,781	738	16,043
TOTAL (q)	19,800	20,780	4,348	16,432
(Storage)	375	380	369	11
VAPOR PRESS 40(q)	18.1	18.4	85.0	0.8
(Storage)	6,672	6,876	6,612	264
VAPOR PRESS 120(q)	350.8	344.7	1525.2	32.3
B(q) V.P. CONSTANT	-4479.0	-4507.4	-4440.0	-5771.4
A(q) V.P. CONSTANT	17.257	17.312	18.628	18.160
TEMPERATURE C	33.0	69.4	83.2	220.0
PRESSURE mmHg	760	760	475	635
K1 (COMPONENT #)			7	7
K2 (COMPONENT #)			SOLVENT	SOLVENT
V.P.(K1)			179.4	17164.0
V.P.(K2)			2.1	939.4
GAMMA-K1 IN K2			2.014	2.014
GAMMA-K2 IN K1			2.014	2.014
ALPHA			56.712	36.756
AVG COLUMN ALPHA			46.734	
MOL FRACT. K1 (MAKE OR TAILS)			0.784	0.001
MOL FRACT. K1 (FEED)			0.138	
MOL FRACT. K2 (MAKE OR TAILS)			0.216	0.999
ADJ. GAMMA-K1 IN K2			1.033	2.012
ADJ. GAMMA-K2 IN K1			1.537	1.000
MINIMUM REFLUX RATIO (ADJUSTED)			0.0	
ACTUAL REFLUX RATIO			0.0	
MINIMUM PLATES			2	

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	23 EXTRACT	24 BEER #1 FEED	25 BEER #1 MAKE	26 BEER #1 TAILS
ACTUAL PLATES			10	
PRESSURE mm Hg (REVISED)			595	
TEMPERATURE C (REVISED)			90	
AVERAGE MOLECULAR WEIGHT			103.09	263.67
GAS DENSITY - LB/CF			0.1682	0.3397
CROSS SECTIONAL AREA - SQ FT			31.8	
COLUMN HEIGHT - FT			29.9	
COLUMN DIAMETER			6.4	
K1 (MPPY)			198,164	
Hv (HEAT VAPORIZ.-Btu/Lb)			215.1	215.0
Cn (HEAT CAPACITY - Btu/LB/F)			0.500	0.500
HEAT LOAD - MM Btu/Hr			13.384	94.957
CONDENSER COOLING WATER - GPM (15 C dT)			993	
CALANDRIA STEAM - MPPH (150 PSIG)				110.80
COLUMN COST - $1000 3Q86 MPC - BARE EQUIPMENT				
- ALL CARBON STEEL			$66.4	
- C.S w/304 S.S. TRAYS			$73.0	
- ALL 304 STAINLESS STEEL			$107.2	
- ALL 304L STAINLESS STEEL			$117.9	
- ALL 316 STAINLESS STEEL			$144.7	
CONDENSER OR CALANDRIA SURFACE - SQ FT			1,556	5,275
COND. OR CALAND. COST - $1000 3Q86 MPC - BARE EQUIPMENT				
-CARBON STEEL			$57.4	$164.4
-304 STAINLESS STEEL			$80.4	$230.2
-316 STAINLESS STEEL			$86.1	$246.6
-MONEL			$111.9	$320.6
SUBTOTAL				2,166,389
SUBTOTAL				2,153,509
SUBTOTAL				2,153,509
MINIMUM REFLUX RATIO			(0.4)	
Cn SUBTOTAL #1			124,592	453
Cn SUBTOTAL #2			396	12,427
Cn SUBTOTAL #3			99,168	2,153,509
Cn CHECK			0.500	0.500
Hv SUBTOTAL #1			53,575	195
Hv SUBTOTAL #2			170	5,344
Hv SUBTOTAL #3			42,689	926,009
Hv CHECK			215.1	215.0
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)				

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	27 BEER #2 MAKE	28 BEER #2 TAILS	29 LBS #1 MAKE	30 LBS #1 TAILS
COMPONENT #1	0	0	0	0
COMPONENT #2	0	0	0	0
COMPONENT #3	718	0	712	6
COMPONENT #4	0	0	0	0
COMPONENT #5	203	0	195	8
COMPONENT #6	0	0	0	0
COMPONENT #7	2,431	243	12	2,418
COMPONENT #8	6	1	0	5
COMPONENT #9	0	0	0	0
COMPONENT #10	4	0	0	4
COMPONENT #11	0	0	0	0
COMPONENT #12	0	0	0	0
COMPONENT #13	0	0	0	0
COMPONENT #14	0	0	0	0
COMPONENT #15	0	0	0	0
COMPONENT #16	0	0	0	0
COMPONENT #17	0	0	0	0
COMPONENT #18	0	0	0	0
COMPONENT #19	0	0	0	0
COMPONENT #20	0	0	0	0
WATER	5	0	0	5
SOLVENT	1	737	0	1
TOTAL (q)	3,367	981	919	2,449
(Storage)	365	5	316	49
VAPOR PRESS 40(q)	108.4	4.7	344.0	20.0
(Storage)	6,408	204	4,322	2,086
VAPOR PRESS 120(q)	1905.4	220.2	4705.2	855.0
B(q) V.P. CONSTANT	-4408.4	-5815.7	-4022.2	-5777.0
A(q) V.P. CONSTANT	18.770	20.447	18.691	21.451
TEMPERATURE C	152.7	220.0	122.6	175.0
PRESSURE mmHg	4,505	4,665	5,037	5,187
K1 (COMPONENT #)	7	7	6,5,4,3	6,5,4,3
K2 (COMPONENT #)	SOLVENT	SOLVENT	7	7
V.P.(K1)	2621.7	17164.0	3833.6	17229.0
V.P.(K2)	76.4	939.4	923.2	5206.5
GAMMA-K1 IN K2	2.014	2.014	1.350	1.350
GAMMA-K2 IN K1	2.014	2.014	1.350	1.350
ALPHA	17.053	26.000	3.187	4.458
AVG COLUMN ALPHA	21.527		3.822	
MOL FRACT. K1 (MAKE OR TAILS)	0.999	0.248	0.941	0.003
MOL FRACT. K1 (FEED)	0.784		0.077	
MOL FRACT. K2 (MAKE OR TAILS)	0.001	0.752	0.059	0.997
ADJ. GAMMA-K1 IN K2	1.000	1.486	1.001	1.347
ADJ. GAMMA-K2 IN K1	2.012	1.044	1.304	1.000
MINIMUM REFLUX RATIO (ADJUSTED)	0.0		0.5	
ACTUAL REFLUX RATIO	0.0		0.7	
MINIMUM PLATES	3		6	

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	27 BEER #2 MAKE	28 BEER #2 TAILS	29 LBS #1 MAKE	30 LBS #1 TAILS
ACTUAL PLATES	13		29	
PRESSURE mm Hg (REVISED)	4,615		5,082	
TEMPERATURE C (REVISED)	154		123	
AVERAGE MOLECULAR WEIGHT	69.00	220.11	55.74	73.98
GAS DENSITY - LB/CF	0.7468	2.0840	0.7159	0.8586
CROSS SECTIONAL AREA - SQ FT	7.9		2.9	
COLUMN HEIGHT - FT	33.9		57.9	
COLUMN DIAMETER	3.2		1.9	
K1 (MPPY)	180,149		8,978	
Hv (HEAT VAPORIZ.-Btu/Lb)	215.3	215.0	215.0	215.4
Cn (HEAT CAPACITY - Btu/Lb/F)	0.500	0.500	0.500	0.500
HEAT LOAD - MM Btu/Hr	6.947	10.461	2.527	3.011
CONDENSER COOLING WATER - GPM (1	515		187	
CALANDRIA STEAM - MPPH (150 PSIG)		12.21		3.51
COLUMN COST - $1000 3Q86 MPC - BARE EQUIPMENT				
- ALL CARBON STEEL	$41.8		$43.1	
- C.S w/304 S.S. TRAYS	$46.0		$47.4	
- ALL 304 STAINLESS STEEL	$68.6		$70.6	
- ALL 304L STAINLESS STEEL	$75.4		$77.6	
- ALL 316 STAINLESS STEEL	$92.6		$95.3	
CONDENSER OR CALANDRIA SURFACE -	390	581	189	167
COND. OR CALAND. COST - $1000 3Q86 MPC - BARE EQUIPMENT				
-CARBON STEEL	$22.5	$28.7	$15.3	$14.5
-304 STAINLESS STEEL	$31.5	$40.1	$21.5	$20.3
-316 STAINLESS STEEL	$33.7	$43.0	$23.0	$21.7
-MONEL	$43.9	$55.9	$29.9	$28.3
SUBTOTAL		107,945		90,251
SUBTOTAL		98,902		266
SUBTOTAL		98,902		266
MINIMUM REFLUX RATIO	(0.8)		0.5	
Cn SUBTOTAL #1	115,585	9,007	25,602	89,983
Cn SUBTOTAL #2	360	36	0	360
Cn SUBTOTAL #3	266	98,902	0	266
Cn CHECK	0.500	0.500	0.500	0.500
Hv SUBTOTAL #1	49,701	3,873	11,009	38,693
Hv SUBTOTAL #2	155	15	0	155
Hv SUBTOTAL #3	161	42,528	0	161
Hv CHECK	215.3	215.0	215.0	215.4
MIN. PLATES(NORMAL)				
COL.COST-C/S NORMAL			43	
COL.COST-S/S NORMAL			71	
MIN.REFLUX(NORMAL)				
C.S. AREA(NORMAL)			3	
HEAT LOAD(NORMAL)				3.01
CON/CAL COST(NORMAL)			15	14

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	31 LBS #2 MAKE	32 LBS #2 TAILS	33 LBS #3 MAKE	34 LBS #3 TAILS
COMPONENT #1	0	0	0	0
COMPONENT #2	0	0	0	0
COMPONENT #3	708	4	0	0
COMPONENT #4	0	0	0	0
COMPONENT #5	2	193	0	0
COMPONENT #6	0	0	0	0
COMPONENT #7	0	12	0	0
COMPONENT #8	0	0	0	0
COMPONENT #9	0	0	0	0
COMPONENT #10	0	0	0	0
COMPONENT #11	0	0	0	0
COMPONENT #12	0	0	0	0
COMPONENT #13	0	0	0	0
COMPONENT #14	0	0	0	0
COMPONENT #15	0	0	0	0
COMPONENT #16	0	0	0	0
COMPONENT #17	0	0	0	0
COMPONENT #18	0	0	0	0
COMPONENT #19	0	0	0	0
COMPONENT #20	0	0	0	0
WATER	0	0	0	0
SOLVENT	0	0	0	0
TOTAL (q)	710	209	0	0
(Storage)	288	27	0	0
VAPOR PRESS 40(q)	407.8	127.1	.0	.0
(Storage)	3,615	707	0	0
VAPOR PRESS 120(q)	5092.7	3388.2	.0	.0
B(q) V.P. CONSTANT	-3882.2	-5048.5	0.0	0.0
A(q) V.P. CONSTANT	18.414	20.974	-4.605	-4.605
TEMPERATURE C	102.7	120.0	ERR	120.0
PRESSURE mmHg	3,228	3,388	(160)	0
K1 (COMPONENT #)	3	3	2,1	2,1
K2 (COMPONENT #)	4,5,6	4,5,6	3	3
V.P.(K1)	3231.3	5096.7	ERR	1.0
V.P.(K2)	1935.6	3517.3	ERR	5096.7
GAMMA-K1 IN K2	1.492	1.492	1.000	1.000
GAMMA-K2 IN K1	1.492	1.492	1.000	1.000
ALPHA	1.121	2.131	ERR	ERR
AVG COLUMN ALPHA	1.626		ERR	
MOL FRACT. K1 (MAKE OR TAILS)	0.997	0.018	ERR	ERR
MOL FRACT. K1 (FEED)	0.785		0.000	
MOL FRACT. K2 (MAKE OR TAILS)	0.003	0.982	ERR	ERR
ADJ. GAMMA-K1 IN K2	1.000	1.471	ERR	ERR
ADJ. GAMMA-K2 IN K1	1.489	1.000	ERR	ERR
MINIMUM REFLUX RATIO (ADJUSTED)	0.0		0.0	
ACTUAL REFLUX RATIO	0.0		0.0	
MINIMUM PLATES	21		0	

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	31 LBS #2 MAKE	32 LBS #2 TAILS	33 LBS #3 MAKE	34 LBS #3 TAILS
ACTUAL PLATES	92		0	
PRESSURE mm Hg (REVISED)	3,019		0	
TEMPERATURE C (REVISED)	100		(273)	
AVERAGE MOLECULAR WEIGHT	58.05	47.91	ERR	ERR
GAS DENSITY - LB/CF	0.4698	0.4133	ERR	ERR
CROSS SECTIONAL AREA - SQ FT	1.8		0.0	
COLUMN HEIGHT - FT	153.5		0.0	
COLUMN DIAMETER	1.5		0.0	
K1 (MPPY)	41,119		0	
Hv (HEAT VAPORIZ.-Btu/Lb)	215.0	215.0	ERR	ERR
Cn (HEAT CAPACITY - Btu/Lb/F)	0.500	0.500	ERR	ERR
HEAT LOAD - MM Btu/Hr	1.230	1.227	0.000	0.000
CONDENSER COOLING WATER - GPM (1	91		0	
CALANDRIA STEAM - MPPH (150 PSIG)		1.43		0.00
COLUMN COST - $1000 3Q86 MPC - BARE EQUIPMENT				
- ALL CARBON STEEL	$78.1		$0.0	
- C.S w/304 S.S. TRAYS	$85.9		$0.0	
- ALL 304 STAINLESS STEEL	$125.5		$0.0	
- ALL 304L STAINLESS STEEL	$138.1		$0.0	
- ALL 316 STAINLESS STEEL	$169.5		$0.0	
CONDENSER OR CALANDRIA SURFACE -	122	58	0	0
COND. OR CALAND. COST - $1000 3Q86 MPC - BARE EQUIPMENT				
-CARBON STEEL	$12.6	$10.2	$0.0	$0.0
-304 STAINLESS STEEL	$17.7	$14.2	$0.0	$0.0
-316 STAINLESS STEEL	$18.9	$15.2	$0.0	$0.0
-MONEL	$24.6	$19.8	$0.0	$0.0
SUBTOTAL		450		0
SUBTOTAL		0		0
SUBTOTAL		0		0
MINIMUM REFLUX RATIO	(0.6)		0.0	
Cn SUBTOTAL #1	20,601	5,001	0	0
Cn SUBTOTAL #2	0	0	0	0
Cn SUBTOTAL #3	0	0	0	0
Cn CHECK	0.500	0.500	ERR	ERR
Hv SUBTOTAL #1	8,858	2,151	0	0
Hv SUBTOTAL #2	0	0	0	0
Hv SUBTOTAL #3	0	0	0	0
Hv CHECK	215.0	215.0	ERR	ERR
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)				

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	35 HBS #1 MAKE	36 HBS #1 TAILS	37 BYPRODUCT FEED	38 RAFF #1 FEED
COMPONENT #1	0	0	0	0
COMPONENT #2	0	0	0	0
COMPONENT #3	0	0	250	250
COMPONENT #4	0	0	0	0
COMPONENT #5	0	0	386	424
COMPONENT #6	0	0	0	0
COMPONENT #7	12	0	17	17
COMPONENT #8	297	1	290	290
COMPONENT #9	0	0	0	0
COMPONENT #10	78	0	78	78
COMPONENT #11	0	0	0	0
COMPONENT #12	0	0	0	0
COMPONENT #13	0	0	0	0
COMPONENT #14	0	0	0	0
COMPONENT #15	0	0	0	0
COMPONENT #16	0	0	0	0
COMPONENT #17	0	0	0	0
COMPONENT #18	0	0	0	0
COMPONENT #19	0	0	0	0
COMPONENT #20	0	0	0	0
WATER	0	1	46,702	47,779
SOLVENT	0	16,043	0	0
TOTAL (q)	388	16,046	47,723	48,838
(Storage)	11	0	162	167
VAPOR PRESS 40(q)	27.7	0.1	56.8	56.8
(Storage)	263	1	2,831	3,026
VAPOR PRESS 120(q)	677.7	16.8	1557.0	1558.0
B(q) V.P. CONSTANT	-4817.5	-7747.0	-5090.5	-5091.2
A(q) V.P. CONSTANT	19.032	22.531	20.303	20.306
TEMPERATURE C	123.4	220.0	34.0	33.5
PRESSURE mmHg	753	913	760	760
K1 (COMPONENT #)	10,9,8	10,9,8		
K2 (COMPONENT #)	SOLVENT	SOLVENT		
V.P.(K1)	182.6	3815.4		
V.P.(K2)	19.7	939.4		
GAMMA-K1 IN K2	2.117	2.117		
GAMMA-K2 IN K1	2.858	2.858		
ALPHA	3.256	8.598		
AVG COLUMN ALPHA	5.927			
MOL FRACT. K1 (MAKE OR TAILS)	0.998	.000		
MOL FRACT. K1 (FEED)	0.005			
MOL FRACT. K2 (MAKE OR TAILS)	0.001	1.000		
ADJ. GAMMA-K1 IN K2	1.000	2.117		
ADJ. GAMMA-K2 IN K1	2.854	1.000		
MINIMUM REFLUX RATIO (ADJUSTED)	10.9			
ACTUAL REFLUX RATIO	13.6			
MINIMUM PLATES	10			

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	35 HBS #1 MAKE	36 HBS #1 TAILS	37 BYPRODUCT FEED	38 RAFF #1 FEED
ACTUAL PLATES	45			
PRESSURE mm Hg (REVISED)	732			
TEMPERATURE C (REVISED)	122			
AVERAGE MOLECULAR WEIGHT	66.16	268.43		
GAS DENSITY - LB/CF	0.1225	0.4976		
CROSS SECTIONAL AREA - SQ FT	31.2			
COLUMN HEIGHT - FT	83.1			
COLUMN DIAMETER	6.3			
KI (MPPY)	0			
Hv (HEAT VAPORIZ.-Btu/LB)	215.0	215.0		
Cn (HEAT CAPACITY - Btu/LB/F)	0.500	0.500		
HEAT LOAD - MM Btu/Hr	11.157	11.157		
CONDENSER COOLING WATER - GPM (1	827			
CALANDRIA STEAM - MPPH (150 PSIG)		13.02		
COLUMN COST - $1000 3Q86 MPC - BARE EQUIPMENT				
- ALL CARBON STEEL	$165.2			
- C.S w/304 S.S. TRAYS	$181.7			
- ALL 304 STAINLESS STEEL	$262.5			
- ALL 304L STAINLESS STEEL	$288.7			
- ALL 316 STAINLESS STEEL	$354.3			
CONDENSER OR CALANDRIA SURFACE -	838	620		
COND. OR CALAND. COST - $1000 3Q86 MPC - BARE EQUIPMENT				
-CARBON STEEL	$36.5	$29.8		
-304 STAINLESS STEEL	$51.1	$41.8		
-316 STAINLESS STEEL	$54.8	$44.8		
-MONEL	$71.2	$58.2		
SUBTOTAL		2,153,564		
SUBTOTAL		2,153,502		
SUBTOTAL		2,153,502		
MINIMUM REFLUX RATIO	10.9			
Cn SUBTOTAL #1	453	0		
Cn SUBTOTAL #2	12,365	62		
Cn SUBTOTAL #3	7	2,153,502		
Cn CHECK	0.500	0.500		
Hv SUBTOTAL #1	185	0		
Hv SUBTOTAL #2	5,317	27		
Hv SUBTOTAL #3	3	926,006		
Hv CHECK	215.0	215.0		
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)				

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	39 RAFF #1 MAKE	40 RAFF #1 TAILS	41 RAFF #2 MAKE	42 RAFF #2 TAILS
COMPONENT #1	0	0	0	0
COMPONENT #2	0	0	0	0
COMPONENT #3	250	(0)	250	0
COMPONENT #4	0	0	0	0
COMPONENT #5	422	2	384	38
COMPONENT #6	0	0	0	0
COMPONENT #7	1	16	0	0
COMPONENT #8	0	290	0	0
COMPONENT #9	0	0	0	0
COMPONENT #10	0	78	0	0
COMPONENT #11	0	0	0	0
COMPONENT #12	0	0	0	0
COMPONENT #13	0	0	0	0
COMPONENT #14	0	0	0	0
COMPONENT #15	0	0	0	0
COMPONENT #16	0	0	0	0
COMPONENT #17	0	0	0	0
COMPONENT #18	0	0	0	0
COMPONENT #19	0	0	0	0
COMPONENT #20	0	0	0	0
WATER	1,079	46,700	2	1,077
SOLVENT	0	0	0	0
TOTAL (q)	1,752	47,086	636	1,116
(Storage)	157	11	152	5
VAPOR PRESS 40(q)	123.0	54.4	238.4	57.1
(Storage)	2,760	267	2,625	135
VAPOR PRESS 120(q)	2517.4	1522.3	4130.2	1597.5
B(q) V.P. CONSTANT	-4642.1	-5123.6	-4385.5	-5121.5
A(q) V.P. CONSTANT	19.643	20.365	19.485	20.408
TEMPERATURE C	83.4	105.0	63.5	100.0
PRESSURE mmHg	747	907	634	794
K1 (COMPONENT #)	5	5	5	5
K2 (COMPONENT #)	WATER	WATER	WATER	WATER
V.P.(K1)	928.8	2104.6	400.4	1757.3
V.P.(K2)	400.2	911.5	171.3	760.0
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	3.021	4.207	1.291	4.043
AVG COLUMN ALPHA	3.614		2.667	
MOL FRACT. K1 (MAKE OR TAILS)	0.281	.000	0.995	0.034
MOL FRACT. K1 (FEED)	0.009		0.281	
MOL FRACT. K2 (MAKE OR TAILS)	0.719	1.000	0.005	0.966
ADJ. GAMMA-K1 IN K2	1.364	1.822	1.000	1.750
ADJ. GAMMA-K2 IN K1	1.049	1.000	1.811	1.001
MINIMUM REFLUX RATIO (ADJUSTED)	1.7		0.3	
ACTUAL REFLUX RATIO	2.2		0.4	
MINIMUM PLATES	7		9	

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	39 RAFF #1 MAKE	40 RAFF #1 TAILS	41 RAFF #2 MAKE	42 RAFF #2 TAILS
ACTUAL PLATES	32		40	
PRESSURE mm Hg (REVISED)	779		636	
TEMPERATURE C (REVISED)	85		64	
AVERAGE MOLECULAR WEIGHT	30.51	18.50	50.72	18.98
GAS DENSITY - LB/CF	0.0665	0.0444	0.0359	0.0404
CROSS SECTIONAL AREA - SQ FT	19.2		4.1	
COLUMN HEIGHT - FT	63.1		74.3	
COLUMN DIAMETER	4.9		2.3	
K1 (MPPY)	13,442		17,674	
Hv (HEAT VAPORIZ.-Btu/Lb)	489.7	948.0	215.8	907.1
Cn (HEAT CAPACITY - Btu/Lb/F)	0.682	0.985	0.501	0.958
HEAT LOAD - MM Btu/Hr	11.506	26.675	1.313	1.391
CONDENSER COOLING WATER - GPM (1	853		97	
CALANDRIA STEAM - MPPH (150 PSIG)		31.13		1.62
COLUMN COST - $1000 3Q86 MPC - BARE EQUIPMENT				
- ALL CARBON STEEL	$102.4		$60.5	
- C.S w/304 S.S. TRAYS	$112.6		$66.5	
- ALL 304 STAINLESS STEEL	$163.8		$97.9	
- ALL 304L STAINLESS STEEL	$180.2		$107.7	
- ALL 316 STAINLESS STEEL	$221.1		$132.2	
CONDENSER OR CALANDRIA SURFACE -	1,466	1,482	271	77
COND. OR CALAND. COST - $1000 3Q86 MPC - BARE EQUIPMENT				
-CARBON STEEL	$54.8	$55.3	$18.4	$10.6
-304 STAINLESS STEEL	$76.7	$77.4	$25.8	$14.9
-316 STAINLESS STEEL	$82.2	$82.9	$27.6	$15.9
-MONEL	$106.9	$107.8	$35.9	$20.7
SUBTOTAL		854,105		19,408
SUBTOTAL		841,362		19,406
SUBTOTAL		841,362		19,406
MINIMUM REFLUX RATIO	1.7		0.3	
Cn SUBTOTAL #1	17,005	641	16,120	885
Cn SUBTOTAL #2	0	12,146	0	0
Cn SUBTOTAL #3	13,442	841,362	35	19,406
Cn CHECK	0.682	0.985	0.501	0.958
Hv SUBTOTAL #1	7,312	276	6,931	381
Hv SUBTOTAL #2	0	5,223	0	0
Hv SUBTOTAL #3	18,884	816,369	34	18,830
Hv CHECK	489.7	948.0	215.8	907.1
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)				

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	43 RAFF #3 MAKE	44 RAFF #3 TAILS
COMPONENT #1	0	0
COMPONENT #2	0	0
COMPONENT #3	249	1
COMPONENT #4	0	0
COMPONENT #5	1	383
COMPONENT #6	0	0
COMPONENT #7	0	0
COMPONENT #8	0	0
COMPONENT #9	0	0
COMPONENT #10	0	0
COMPONENT #11	0	0
COMPONENT #12	0	0
COMPONENT #13	0	0
COMPONENT #14	0	0
COMPONENT #15	0	0
COMPONENT #16	0	0
COMPONENT #17	0	0
COMPONENT #18	0	0
COMPONENT #19	0	0
COMPONENT #20	0	0
WATER	0	2
SOLVENT	0	0
TOTAL (q)	250	387
(Storage)	102	50
VAPOR PRESS 40(q)	407.8	129.1
(Storage)	1,271	1,354
VAPOR PRESS 120(q)	5082.7	3509.1
B(q) V.P. CONSTANT	-3882.2	-5078.0
A(q) V.P. CONSTANT	18.414	21.084
TEMPERATURE C	85.0	105.0
PRESSURE mmHg	1,941	2,101
K1 (COMPONENT #)	3	3
K2 (COMPONENT #)	5	5
V.P.(K1)	1943.6	3444.3
V.P.(K2)	994.2	2104.6
GAMMA-K1 IN K2	1.492	1.492
GAMMA-K2 IN K1	1.492	1.492
ALPHA	1.313	2.435
AVG COLUMN ALPHA	1.874	
MOL FRACT. K1 (MAKE OR TAILS)	0.997	0.003
MOL FRACT. K1 (FEED)	0.395	
MOL FRACT. K2 (MAKE OR TAILS)	0.003	0.997
ADJ. GAMMA-K1 IN K2	1.000	1.488
ADJ. GAMMA-K2 IN K1	1.489	1.000
MINIMUM REFLUX RATIO (ADJUSTED)	0.7	
ACTUAL REFLUX RATIO	0.9	
MINIMUM PLATES	19	

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	43 RAFF #3 MAKE	44 RAFF #3 TAILS
ACTUAL PLATES	84	
PRESSURE mm Hg (REVISED)	1,766	
TEMPERATURE C (REVISED)	82	
AVERAGE MOLECULAR WEIGHT	58.05	46.00
GAS DENSITY - LB/CF	0.2890	0.2558
CROSS SECTIONAL AREA - SQ FT	1.5	
COLUMN HEIGHT - FT	140.8	
COLUMN DIAMETER	1.4	
K1 (MPPY)	14,457	
Hv (HEAT VAPORIZ.-Btu/Lb)	215.0	216.5
Cn (HEAT CAPACITY - Btu/Lb/F)	0.500	0.501
HEAT LOAD - MM Btu/Hr	0.836	0.928
CONDENSER COOLING WATER - GPM (1	52	
CALANDRIA STEAM - MPPH (150 PSIG)		1.08
COLUMN COST - $1000 3Q86 MPC - BARE EQUIPMENT		
- ALL CARBON STEEL	$68.1	
- C.S w/304 S.S. TRAYS	$74.9	
- ALL 304 STAINLESS STEEL	$109.9	
- ALL 304L STAINLESS STEEL	$120.9	
- ALL 316 STAINLESS STEEL	$148.3	
CONDENSER OR CALANDRIA SURFACE -	112	52
COND. OR CALAND. COST - $1000 3Q86 MPC - BARE EQUIPMENT		
-CARBON STEEL	$12.2	$9.3
-304 STAINLESS STEEL	$17.1	$13.0
-316 STAINLESS STEEL	$18.3	$14.0
-MONEL	$23.8	$18.2
SUBTOTAL		53
SUBTOTAL		35
SUBTOTAL		35
MINIMUM REFLUX RATIO	0.7	
Cn SUBTOTAL #1	7,243	8,877
Cn SUBTOTAL #2	0	0
Cn SUBTOTAL #3	0	35
Cn CHECK	0.500	0.501
Hv SUBTOTAL #1	3,114	3,817
Hv SUBTOTAL #2	0	0
Hv SUBTOTAL #3	0	34
Hv CHECK	215.0	216.5
MIN. PLATES(NORMAL)		
COL.COST-C/S NORMAL	68	
COL.COST-S/S NORMAL	110	
MIN.REFLUX(NORMAL)		
C.S. AREA(NORMAL)	2	
HEAT LOAD(NORMAL)		1
CON/CAL COST(NORMAL)	12	9

APPENDIX B. BASECASE STOICHIOMETRY WITH 15:1 RAFFINATE/CELLS RECYCLE NO RECOVERY OF RAFFINATE CHEMICALS

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
NO RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY
SUMMARY

	PRODUCTION LEVEL 151.53 MM PPY
INVESTMENT-$MILLION	
MPC = 1984	
Direct Permanent Investment	$25.8
Allocated Power, Services & General	$10.6
Working Capital	$15.1
Total Investment	$51.5
COST-$/LB (1988)	
Raw Materials	$0.29
Utilities	$0.04
Labor-Related	$0.03
Capital-Related	$0.02
Cost of Manufacture	$0.38
SE, D, R&D, Adm, & I.C.	$0.06
Cost of Sales	$0.44
Pretax Earnings Based on: 30% Pretax ROI	$0.10
By-product Credit	($0.06)
Selling Price	$0.48
FINANCIAL CRITERIA	
Net ROI 3rd Year (assumed)	16%
Investors Rate of Return (20 Operating Years)	18%
Year to Break Even - Annual Cash	1987
- Cumulative Cash	1991
- Cum. Disc. Cash (NPV)	1995
Net Present Value $MM (20 years @ 12%)	$20.7

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
NO RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY

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 PPY	179.5
MID-POINT OF CONSTRUCTION	YEAR	1984
CONSTRUCTION COST INDEX	1980=100	128
INVESTMENT CONTINGENCY	% INSTALLED *	30%
FERMENTER UNIT INVESTMENT	$/GR.GAL.-GROWTH	$12.92
	$/GR.GAL.-PROD'N	$10.94

*40% Recommended for new processes

DIRECT PERMANENT INVESTMENT

	SCALE FACTOR		THIS CASE $MM	$/ANN.LB.
FERMENTATION SECTION				
Receiving, Prep & Sterilization	0.60		$3.88	$0.022
Air Compression & Aeration	0.60		0.00	0.000
Fermentation	0.89-1.00		7.46	0.042
Extraction			5.62	0.031
Product/Cell Separation	0.75		0.97	0.005
Fermentation Sub-total			$17.94	$0.100
DISTILLATION SECTION	STILLS	HX'S		
Beer Still #1	$0.31	$1.02	$1.33	$0.007
Beer Still #2	0.20	0.21	0.41	0.002
Low-Boilers Still #1	0.23	0.17	0.40	0.002
Low-Boilers Still #2	0.36	0.11	0.47	0.003
Low-Boilers Still #3	0.00	0.00	0.00	0.000
High-Boilers Still #1	0.76	0.31	1.07	0.006
Distillation Subtotal			$3.68	$0.02
STORAGE SECTION				
Storage - Product			$3.45	$0.019
Storage - Byproduct #1			$0.78	0.004
Storage Subtotal			$4.24	$0.02
TOTAL DIRECT PLANT			$25.85	$0.144

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
NO RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY

INVESTMENT

ALLOCATED PERMANENT INVESTMENT

	UNITS	API/UNIT BASECASE	API/UNIT THIS CASE	UNITS	$MM	$/ANN.LB.
ELECTRICITY	KW	$183	$183	1,956	$0.36	$0.002
STEAM	PPH	$45	$45	140,561	6.33	0.035
COOLING WATER	GPM	$52	$52	5,987	0.31	0.002
PROCESS WATER	GPM	$313	$313	26	0.01	.000
WASTE DISPOSAL	MGPY	$3	$3	118,238	0.32	0.002
GEN'L & SERVICES	$MM	10%	10%	$33.2	3.32	0.018
TOTAL ALLOCATED PLANT					$10.64	$0.059
TOTAL PERMANENT INVESTMENT					$36.49	$0.203

WORKING CAPITAL

	BASIS	DAYS BASECASE	DAYS THIS CASE	$MM	$/ANN. LB.
RAW MAT'L INVENTORY	$RAW MATL	2	2	$0.29	$0.002
SEMI-FINISHED PRODUCT	$(R+M)/2	5	5	0.74	0.004
FINISHED PRODUCT	$COM	30	30	5.08	0.028
CASH	$(COS-D)	6	6	1.13	0.006
ACCOUNTS RCD.-TRADE	$SP	30	30	6.34	0.035
ACCOUNTS RCD.-MISC.	%COM	0.9%	0.9%	0.56	0.003
DEFERRED CHARGES	%COM	1.5%	1.5%	0.93	0.005
TOTAL WORKING CAPITAL				$15.07	$0.084

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

TOTAL INVESTMENT FOR RETURN	$51.56	$0.287

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
NO RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY

1988 COST SHEET	RATE	/UNIT	MILLION UNITS	$MILLION	$/lb.
Raw Materials					
-Biosugar Syrup	$0.065	/lb. d.s.	701.02	45.57	0.282
-Anhyd. Ammonia	$0.046	/lb.	1.70	0.08	.000
-Phosphoric Acid	$0.155	/lb.	1.42	0.22	0.001
-Potassium Chloride	$0.053	/lb.	1.08	0.06	.000
-Minor Nutrients	$0.451	/lb.	0.49	0.22	0.001
Total Raw Materials				$46.14	$0.286
Utilities					
-Electricity	$0.040	/KWH	13.94	0.56	0.003
-Steam	$2.20	/M lb.	1.0019	2.20	0.014
-Cooling Water	$0.04	/M gal.	2.56	0.10	0.001
-Process Water	$0.50	/M gal.	0.01	0.01	.000
-Biodegradation	$0.04	/lb. d.s.	100.74	4.03	0.025
-Landfill	$0.05	/lb. d.s.	0.00	0.00	0.000
Total Utilities				$6.91	$0.043
Labor-Related					
-Dir. Op. Wages & Ben.	$26.40	/man-hr.	0.117	3.08	0.019
-Dir. Salaries & Ben.	18	% DOW&B		0.56	0.003
-Op. Supplies & Service	6	% DOW&B		0.19	0.001
-GPOH on Operations	23	% DOWS&B		0.84	0.005
-Control Lab	$19.22	/man-hr.	0.020	0.39	0.002
-Tech. Assist. to Mfg.	$22.06	/man-hr.	0.002	0.04	.000
Total Labor				$5.09	$0.032
Capital-Related					
-Maint. Wages & Ben.	1.7	% DPI	$25.8	0.44	0.003
-Maint. Salaries & Ben.	25	% MW&B		0.11	0.001
-Maint. Mat'l & Service	40	% MW&B		0.18	0.001
-Maint. Overhead	4	% MW&B		0.02	.000
-GPOH on Maintenance	23	% MWS&B		0.13	0.001
-Taxes & Insurance	0.3	% DPI	$25.8	0.08	.000
-Depreciation - DPI	8	% DPI	$25.8	2.07	0.013
-Depreciation - APS&G	6	% APS&G	$10.6	0.64	0.004
Total Capital				$3.65	$0.023
Cost of Manufacture				$61.79	$0.383
-Selling Expense	3	% Sales	$77.1	2.31	0.014
-Distribution	$0.01	/lb.	161.5	1.62	0.010
-Research & Development	5	% Sales	$77.1	3.47	0.021
-Administrative Expense	2	% Sales	$77.1	1.54	0.010
-Incentive Compensation	6	% PTE	$15.5	0.93	0.006
Cost of Sales				$71.66	$0.444
-Pretax Earnings	30.0	% TIFR	$51.6	15.47	0.096
-Credit: Byproduct #1	$0.27	/lb.	37.0	(9.99)	(0.062)
Total Sales				$77.14	$0.478

APPENDIX C. BASECASE STOICHIOMETRY
NO RAFFINATE/CELLS RECYCLE
WITH RECOVERY OF RAFFINATE CHEMICALS

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY
SUMMARY

	PRODUCTION LEVEL 161 MM PPY
INVESTMENT-$MILLION	
MPC = 1984	
Direct Permanent Investment	$170.7
Allocated Power, Services & General	$60.0
Working Capital	$26.9
Total Investment	$257.5
COST-$/LB (1988)	
Raw Materials	$0.29
Utilities	$0.11
Labor-Related	$0.03
Capital-Related	$0.15
Cost of Manufacture	$0.57
SE, D, R&D, Adm, & I.C.	$0.14
Cost of Sales	$0.71
Pretax Earnings Based on: 30% Pretax ROI	$0.48
By-product Credit	($0.11)
Selling Price	$1.07
FINANCIAL CRITERIA	
Net ROI 3rd Year (assumed)	16%
Investors Rate of Return (20 Operating Years)	22%
Year to Break Even - Annual Cash	1986
- Cumulative Cash	1989
- Cum. Disc. Cash (NPV)	1991
Net Present Value $MM (20 years @ 12%)	$167.0

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY

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 PPY	179.4
MID-POINT OF CONSTRUCTION	YEAR	1984
CONSTRUCTION COST INDEX	1980=100	128
INVESTMENT CONTINGENCY	% INSTALLED *	30%
FERMENTER UNIT INVESTMENT	$/GR.GAL.-GROWTH	$10.94
	$/GR.GAL.-PROD'N	$10.94

*40% Recommended for new processes

DIRECT PERMANENT INVESTMENT

	SCALE FACTOR		THIS CASE $MM	$/ANN.LB.
FERMENTATION SECTION				
Receiving, Prep & Sterilization	0.60		$20.35	$0.113
Air Compression & Aeration	0.60		0.00	0.000
Fermentation	0.89-1.00		117.07	0.652
Extraction			7.16	0.040
Product/Cell Separation	0.75		7.74	0.043
Fermentation Sub-total			$152.32	$0.849
DISTILLATION SECTION	STILLS	HX'S		
Beer Still #1	$0.29	$1.07	$1.36	$0.008
Beer Still #2	0.18	0.21	0.39	0.002
Low-Boilers Still #1	0.11	0.09	0.20	0.001
Low-Boilers Still #2	0.18	0.07	0.25	0.001
Low-Boilers Still #3	0.00	0.00	0.00	0.000
High-Boilers Still #1	0.82	0.30	1.12	0.006
Raffinate Still #1	2.08	7.04	9.12	0.051
Raffinate Still #2	0.36	0.20	0.55	0.003
Raffinate Still #3	0.37	0.12	0.49	0.003
Distillation Subtotal			$13.47	$0.08
STORAGE SECTION				
Storage - Butanol			$3.45	$0.019
Storage - Acetone			$1.07	0.006
Storage - Ethanol			$0.37	0.002
Storage Subtotal			$4.89	$0.03
TOTAL DIRECT PLANT			$170.69	$0.951

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL WITH RECOVERY OF RAFFINATE BASECASE STOICHIOMETRY

INVESTMENT

ALLOCATED PERMANENT INVESTMENT

	UNITS	API/UNIT BASECASE	API/UNIT THIS CASE	UNITS	$MM	$/ANN.LB.
ELECTRICITY	KW	$183	$183	8,815	$1.61	$0.009
STEAM	PPH	$45	$45	684,813	30.82	0.172
COOLING WATER	GPM	$52	$52	18,215	0.95	0.005
PROCESS WATER	GPM	$313	$313	3331	1.04	0.006
WASTE DISPOSAL	MGPY	$3	$3	1,684,615	4.57	0.025
GEN'L & SERVICES	$MM	10%	10%	$209.7	20.97	0.117
TOTAL ALLOCATED PLANT					$59.95	$0.334
TOTAL PERMANENT INVESTMENT					$230.64	$1.286

WORKING CAPITAL

	BASIS	DAYS BASECASE	DAYS THIS CASE	$MM	$/ANN. LB.
RAW MAT'L INVENTORY	$RAW MATL	2	2	$0.29	$0.002
SEMI-FINISHED PRODUCT	$(R+M)/2	5	5	0.95	0.005
FINISHED PRODUCT	$COM	30	30	7.55	0.042
CASH	$(COS-D)	6	6	1.50	0.009
ACCOUNTS RCD.-TRADE	$SP	30	30	14.26	0.079
ACCOUNTS RCD.-MISC.	%COM	0.9%	0.9%	0.83	0.005
DEFERRED CHARGES	%COM	1.5%	1.5%	1.38	0.008
TOTAL WORKING CAPITAL				$26.85	$0.150

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

TOTAL INVESTMENT FOR RETURN	$257.50	$1.435

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY

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	--	5 % Sales
-Administrative Expense	2 % Sales	--	2 % Sales
-Incentive Compensation	6 % PTE	--	6 % PTE
Cost of Sales			
-Pretax Earnings	30 % TIFR	--	30 % TIFR
-Credit: Acetone	$0.27 /lb.	1.00	$0.27 /lb.
-Credit: Ethanol	$0.29 /lb.	1.00	$0.29 /lb.
-Product Selling Price	$0.00 /lb.	1.00	$0.00 /lb.

SALARIES & WAGES

	250 MM PPY DAY SHIFT	250 MM PPY ROTATING SHIFTS	MIN. FORCE DAY SHIFT	MIN. FORCE ROTATING SHIFTS
DIRECT OPERATORS				
SYRUP RECEIVING & TRANSFER	1	-	1	-
CHEMICALS RECEIVING & TRANSFER	3	-		-
INNOCULUM PREPARATION	1	-	1	-
MEDIUM PREPARATION	-	1	1	-
STERILIZATION	-	1		-
FERMENTATION & EXTRACTION				
-CONTROL ROOM	-	2	-	1
-PATROL	-	2	-	1
-AIR COMPRESSION & AMMONIA FEED	-	1	-	1
-TURNAROUND	-	3	-	1
BEER FILTER & CELL RECYCLE	-	2	-	1
DISTILLATION	-	2	-	1
TOTAL DAY & 4.2-SHIFT OPS	5	14	3	8
TOTAL OPERATORS	64		28	
CONTROL LABORATORY				
BIOLOGICAL ANALYSIS	-	1	-	1
CHEMICAL ANALYSIS	-	1	-	1
OTHER	-	-	-	-
TOTAL DAY & 4.2-SHIFT TECHS	0	8	0	8
w/ SUPERVISION @ 20%	0.0	10.1	0.0	10.1
TOTAL LAB FORCE	10.1		10.1	
TECHNICAL ASSISTANCE TO MANUFACTURING				
PROCESS ENGINEERS	1	-	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	3.5%
DENTAL INSURANCE	0.8%
SAVINGS PLAN	2.5%
VACATION	7.4%
ILLNESS	1.4%
ABSENCE WITH PERMISSION	0.2%
TOTAL BENEFITS	31.1%

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY

1988 COST SHEET	RATE /UNIT	MILLION UNITS	$MILLION	$/lb.
Raw Materials				
-Biosugar Syrup	$0.065 /lb. d.s.	701.02	45.57	0.282
-Anhyd. Ammonia	$0.046 /lb.	1.70	0.08	.000
-Phosphoric Acid	$0.155 /lb.	1.42	0.22	0.001
-Potassium Chloride	$0.053 /lb.	1.08	0.06	.000
-Minor Nutrients	$0.451 /lb.	0.49	0.22	0.001
Total Raw Materials			$46.14	$0.286
Utilities				
-Electricity	$0.040 /KWH	52.83	2.54	0.016
-Steam	$2.20 /M lb.	4.88	10.74	0.067
-Cooling Water	$0.04 /M gal.	7.79	0.31	0.002
-Process Water	$0.50 /M gal.	1.42	0.71	0.004
-Biodegradation	$0.04 /lb. d.s.	71.11	2.84	0.018
-Landfill	$0.05 /lb. d.s.	0.00	0.00	0.000
Total Utilities			$17.15	$0.106
Labor-Related				
-Dir. Op. Wages & Ben.	$26.40 /man-hr.	0.117	3.08	0.019
-Dir. Salaries & Ben.	18 % DOW&B		0.56	0.003
-Op. Supplies & Service	6 % DOW&B		0.19	0.001
-GPOH on Operations	23 % DOWS&B		0.84	0.005
-Control Lab	$19.22 /man-hr.	0.020	0.38	0.002
-Tech. Assist. to Mfg.	$22.06 /man-hr.	0.002	0.04	.000
Total Labor			$5.09	$0.032
Capital-Related				
-Maint. Wages & Ben.	1.7 % DPI	$170.7	2.90	0.018
-Maint. Salaries & Ben.	25 % MW&B		0.73	0.004
-Maint. Mat'l & Service	40 % MW&B		1.16	0.007
-Maint. Overhead	4 % MW&B		0.12	0.001
-GPOH on Maintenance	23 % MWS&B		0.83	0.005
-Taxes & Insurance	0.3 % DPI	$170.7	0.51	0.003
-Depreciation - DPI	8 % DPI	$170.7	13.66	0.085
-Depreciation - APS&G	6 % APS&G	$60.0	3.60	0.022
Total Capital			$23.50	$0.146
Cost of Manufacture			$91.88	$0.569
-Selling Expense	3 % Sales	$173.5	5.21	0.032
-Distribution	$0.01 /lb.	161.5	1.61	0.010
-Research & Development	5 % Sales	$173.5	7.81	0.048
-Administrative Expense	2 % Sales	$173.5	3.46	0.021
-Incentive Compensation	6 % PTE	$77.2	4.63	0.029
Cost of Sales			$114.55	$0.710
-Pretax Earnings	30.0 % TIFR	$257.5	77.24	0.478
-Credit: Acetone	$0.27 /lb.	50.5	(13.62)	(0.084)
-Credit: Ethanol	$0.29 /lb.	16.3	(4.67)	(0.029)
Total Sales			$173.50	$1.075

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY

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%). Tax: 34% federal, 3% state.
7. Note that the cash flow analysis has meaning only if the product can be sold at the price indicated on the cost sheet.

YEAR	INVESTMENT PI	INVESTMENT WC	DEP.	COST EX D	SALES	NET EARN	ANN CASH
1983	$56.90						($56.90)
1984	$56.90						($56.90)
1985	$56.90	$26.85					($83.75)
1986			$34.14	$52.81	$95.90	$5.64	$12.92
1987			$54.62	$74.82	$143.84	$9.08	$63.70
1988			$32.77	$97.30	$191.79	$38.88	$71.66
1989			$19.63	$97.30	$191.79	$47.16	$68.79
1990			$19.63	$97.30	$191.79	$47.16	$68.79
1991			$9.90	$97.30	$191.79	$53.29	$63.19
1992				$97.30	$191.79	$59.53	$59.53
1993				$97.30	$191.79	$59.53	$59.53
1994				$97.30	$191.79	$59.53	$59.53
1995				$97.30	$191.79	$59.53	$59.53
1996				$97.30	$191.79	$59.53	$59.53
1997				$97.30	$191.79	$59.53	$59.53
1998				$97.30	$191.79	$59.53	$59.53
1999				$97.30	$191.79	$59.53	$59.53
2000				$97.30	$191.79	$59.53	$59.53
2001				$97.30	$191.79	$59.53	$59.53
2002				$97.30	$191.79	$59.53	$59.53
2003				$97.30	$191.79	$59.53	$59.53
2004				$97.30	$191.79	$59.53	$59.53
2005		($26.85)		$97.30	$191.79	$59.53	$86.38

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

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY

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%). Tax: 34% federal, 3% state.
7. Note that the cash flow analysis has meaning only if the product can be sold at the price indicated on the cost sheet.

YEAR	CUM CASH	NPV @ 12%	%IRR
1983	($56.90)	($56.90)	--
1984	($113.79)	($107.70)	--
1985	($197.54)	($174.45)	--
1986	($184.82)	($155.26)	-86.1%
1987	($120.82)	($124.78)	-30.6%
1988	($48.27)	($84.12)	-8.5%
1989	$17.52	($50.29)	2.3%
1990	$84.32	($20.07)	8.8%
1991	$147.51	$5.45	12.8%
1992	$207.04	$26.92	15.3%
1993	$266.57	$46.09	17.2%
1994	$326.10	$63.20	18.5%
1995	$385.63	$78.48	19.5%
1996	$445.16	$92.12	20.2%
1997	$504.69	$104.30	20.8%
1998	$564.22	$115.18	21.2%
1999	$623.75	$124.89	21.5%
2000	$683.28	$133.56	21.8%
2001	$742.81	$141.30	22.0%
2002	$802.34	$148.21	22.1%
2003	$861.87	$154.38	22.3%
2004	$921.40	$159.89	22.4%
2005	$1,007.79	$167.03	22.5%

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY

BASIC DATA

SCALE OF OPERATION

161.47 MM PPY	ANNUAL PRODUCTION LEVEL
179.41 MM PPY	ANNUAL CAPACITY
90 %	OPERATING UTILITY
163.26 MM PPY	PRODUCT IN BEER
181.40 MM PPY	PRODUCT IN BEER AT CAPACITY
95.0 %	MOLAR YIELD-GLUC. TO PROD. IN BEER (E
4.29 lb/lb	GLUCOSE DEMAND/PROD (EXCL. SPILL)
74.12 MOL WT	PRODUCT MOLECULAR WEIGHT

PRODUCT STOICHIOMETRY

MOL. WT.	MOLES/MOL PRODUCT	COMPONENT
180.16	1.67525 /MOL PROD.	-GLUCOSE CONSUMED
32.00	0.00000 /MOL PROD.	-OXYGEN CONSUMED
17.02	0.00000 /MOL PROD.	-AMMONIA CONSUMED
.00	0.00000 /MOL PROD.	-COMPONENT #1 FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #2 FORMED
58.08	0.39385 /MOL PROD.	-COMPONENT #3 FORMED (ACETONE)
.00	0.00000 /MOL PROD.	-COMPONENT #4 FORMED
46.07	0.16600 /MOL PROD.	-COMPONENT #5 FORMED (ETHANOL)
.00	0.00000 /MOL PROD.	-COMPONENT #6 FORMED
74.12	1.00000 /MOL PROD.	-COMPONENT #7 FORMED (BUTANOL)
60.05	0.24982 /MOL PROD.	-COMPONENT #8 FORMED (ACETIC ACID)
.00	0.00000 /MOL PROD.	-COMPONENT #9 FORMED
88.10	0.06749 /MOL PROD.	-COMPONENT #10 FORMED (BUTYRIC ACID
18.02	0.35033 /MOL PROD.	-WATER FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #11 FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #12 FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #13 FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #14 FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #15 FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #16 FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #17 FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #18 FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #19 FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #20 FORMED
44.01	3.75036 /MOL PROD.	-CARBON DIOXIDE FORMED
2.02	2.23400 /MOL PROD.	-HYDROGEN FORMED

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

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY

BASIC DATA

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
0.88 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	1	(0 OR 1)	-CONCUR'NT (0) OR SEQUENT'AL (1)
CONDITIONS			
STAGE: GROWTH	PRODUCTION		
33	33	C	-TEMPERATURE
6.5	6.5		-pH
0	13	g/l	-PRODUCT CONCENTRATION IN BEER
1.4	1.4	g/l	-CELL DENSITY (CHO ONLY)
0.280	0.030	1/hr	-DILUTION RATE
			-PRODUCT PRODUCTIVITY
0.00	0.283	g/g*hr	*Specific Productivity
0.00	0.39	g/l*hr	*Volumetric Productivity
0.39	0.00	g/l*hr	-CELL PRODUCTIVITY (CHO ONLY)
14	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
16.99	1.49	Btu/hr*gal	-HEAT REMOVED BY COOLING COILS
FERMENTERS			
755,173	6,975,148	gallons	-ACTIVE VOLUME REQUIRED
15	15	% gross	-HEADSPACE
1,045,222	9,654,184	gallons	-GROSS VOLUME (incl. 15% spares and
100,000	250,000	gallons	-GROSS SIZE
10.5	38.6	units	-NUMBER OF UNITS
PRODUCT SEPARATION			
	400	g/l	-CELL CONC. (CHO) EX FILTER
	0.053	gal/min*sf	-FILTER THROUGHPUT
	66,846	sq ft	-FILTER SIZE
PRODUCT RECOVERY & PURIFICATION			
	98.8%(wt)%		-YIELD ACROSS REFINING

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL WITH RECOVERY OF RAFFINATE BASECASE STOICHIOMETRY

BASIC DATA

MATERIALS OF CONSTRUCTION

	CHOICES	SELECTION
FERMENTERS & EXTRACTERS	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 Market Price for: 1988 (Year) /lb.

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

VENTURE TIMING

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

EXTRACTION

Solvent	Oleyl Alcohol CH3(CH2)7CH=CH(CH2)7CH2OH	
Solvent Molecular Weight	268.5	
Solvent Ratio, r	0.30	lb/lb water in feed
Mutual Solubilities		
Water in Solvent, w	0.000020	lb/lb solvent
Solvent in Water, s	0.000020	lb/lb water
(1+s)/(1+w)	1.00000	
Gamma	-0.70000	
Water in Solvent Feed, m	0.000000	lb./lb solvent
Solvent in Aqueous Feed	0.000000	lb/lb water in feed
Raffinate Recycle	0.0	lb raffinate water/lb water in fermenter feed
Solvent/Water Balances		
Extract - Solvent	0.29998	lb/lb water in feed
- Water	0.00001	lb/lb water in feed
Raffinate - Water	0.99999	lb/lb water in feed
- Solvent	0.00002	lb/lb water in feed

Solute Distribution

	Phi	K	Extract	Raffinate

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY

BASIC DATA

Component #1	1.000	0.00	0.000	1.000 lb/lb in beer
Component #2	1.000	0.00	0.000	1.000 lb/lb in beer
Component #3	1.000	0.50	0.146	0.854 lb/lb in beer
Component #4	1.000	0.00	0.000	1.000 lb/lb in beer
Component #5	1.000	0.20	0.058	0.942 lb/lb in beer
Component #6	1.000	0.00	0.000	1.000 lb/lb in beer
Component #7P	1.000	4.30	0.9990	0.001 lb/lb in beer
Component #8	1.000	0.20	0.058	0.942 lb/lb in beer
Component #9	1.000	0.00	0.000	1.000 lb/lb in beer
Component #10	1.000	0.20	0.058	0.942 lb/lb in beer
Component #11	1.000	0.00	0.000	1.000 lb/lb in beer
Component #12	1.000	0.00	0.000	1.000 lb/lb in beer
Component #13	1.000	0.00	0.000	1.000 lb/lb in beer
Component #14	1.000	0.00	0.000	1.000 lb/lb in beer
Component #15	1.000	0.00	0.000	1.000 lb/lb in beer
Component #16	1.000	0.00	0.000	1.000 lb/lb in beer
Component #17	1.000	0.00	0.000	1.000 lb/lb in beer
Component #18	1.000	0.00	0.000	1.000 lb/lb in beer
Component #19	1.000	0.00	0.000	1.000 lb/lb in beer
Component #20	1.000	0.00	0.000	1.000 lb/lb in beer
Reactants	1.000	0.00	0.000	1.000 lb/lb in beer

	1	2
EXTRACTOR DESIGN		
Density - Raffinate, g/ml		0.9991
" - Extract, g,ml		0.0359
Capacity Factor		6000
CS Area/Extractor, sq ft		97
Number of Extractors		4
Extractor Diameter, ft		11.1
Theoretical Stages		20
Extractor Height, ft		50
Extractors Cost - $1000 3Q86 MPC - Bare Equipment		
-All Carbon Steel		$1,722.3
-All 304 Stainless Steel		$2,417.2

Stage to stage balances: Basis: lb/lb water in feed

Stage	Feed	0.00100 1	0.22653 2	0.40141 3	0.53698 4
Extract					
-Solvent		0.29998	0.30000	0.30000	0.30000
-Water		0.00001	0.00001	0.00001	0.00001
-Total		0.29999	0.30001	0.30001	0.30001
Raffinate					
-Solvent	0.00000	0.00002	0.00002	0.00002	0.00002
-Water	1.00000	1.00000	1.00000	1.00000	1.00000
-Total	1.00000	1.00002	1.00002	1.00002	1.00002

Product Partition: Basis: lb/lb solute in feed

Based on fixed yield =		99.90%			
Solvent/Feed Ratio, r =		0.30			
K = 4.30 ;stages=		20			
Extract		0.99800	0.77347	0.59859	0.46302
Raffinate	1.00000	0.77447	0.59959	0.46402	0.35893

0.64207	0.72353	0.78668	0.83564	0.87359	0.90301	0.92581	0.94349
5	6	7	8	9	10	11	12
0.30000	0.30000	0.30000	0.30000	0.30000	0.30000	0.30000	0.30000
0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
0.30001	0.30001	0.30001	0.30001	0.30001	0.30001	0.30001	0.30001
0.00002	0.00002	0.00002	0.00002	0.00002	0.00002	0.00002	0.00002
1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
1.00002	1.00002	1.00002	1.00002	1.00002	1.00002	1.00002	1.00002
0.35783	0.27647	0.21332	0.16436	0.12641	0.09699	0.07419	0.05651
0.27747	0.21432	0.16536	0.12741	0.09799	0.07519	0.05751	0.04381

0.95719	0.96782	0.97605	0.98244	0.98738	0.99122	0.99419	0.99650
13	14	15	16	17	18	19	20
0.30000	0.30000	0.30000	0.30000	0.30000	0.30000	0.30000	0.30000
0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
0.30001	0.30001	0.30001	0.30001	0.30001	0.30001	0.30001	0.30001
0.00002	0.00002	0.00002	0.00002	0.00002	0.00002	0.00002	0.00002
1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.99999
1.00002	1.00002	1.00002	1.00002	1.00002	1.00002	1.00002	1.00001
0.04281	0.03218	0.02385	0.01756	0.01262	0.00878	0.00581	0.00350
0.03318	0.02495	0.01856	0.01362	0.00978	0.00681	0.00450	0.00271

Solvent
0.30000
0.00000
0.30000

0.00171

LOOK-UP TABLE: YIELD TO EXTRACT - % For K=0.2

		S/F Ratio:				
	Stages	0.25	0.30	0.35	0.40	0.45
	1	4.5%	5.4%	6.3%	7.2%	8.0%
	2	4.7%	5.7%	6.7%	7.7%	8.7%
	3	4.8%	5.8%	6.8%	7.8%	8.8%
	4	4.8%	5.8%	6.8%	7.8%	8.8%
	5	4.8%	5.8%	6.8%	7.8%	8.8%
	6	4.8%	5.8%	6.8%	7.8%	8.8%
	7	4.8%	5.8%	6.8%	7.8%	8.8%
	8	4.8%	5.8%	6.8%	7.8%	8.8%
	9	4.8%	5.8%	6.8%	7.8%	8.8%
	10	4.8%	5.8%	6.8%	7.8%	8.8%
	11	4.8%	5.8%	6.8%	7.8%	8.8%
	12	4.8%	5.8%	6.8%	7.8%	8.8%
	13	4.8%	5.8%	6.8%	7.8%	8.8%
Density, g	14	4.8%	5.8%	6.8%	7.8%	8.8%
	15	4.8%	5.8%	6.8%	7.8%	8.8%
	16	4.8%	5.8%	6.8%	7.8%	8.8%
0.7920	17	4.8%	5.8%	6.8%	7.8%	8.8%
	18	4.8%	5.8%	6.8%	7.8%	8.8%
0.7893	19	4.8%	5.8%	6.8%	7.8%	8.8%
	20	4.8%	5.8%	6.8%	7.8%	8.8%

0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00
8.8%	16.0%	22.0%	28.3%	33.1%	37.4%	41.1%	44.3%
9.7%	18.1%	27.0%	35.8%	42.7%	48.8%	54.2%	58.9%
9.8%	19.5%	27.0%	38.3%	46.6%	53.9%	60.4%	66.1%
9.8%	19.8%	29.6%	39.2%	48.2%	56.5%	63.8%	70.1%
9.8%	19.8%	29.8%	39.6%	49.1%	57.9%	65.9%	72.8%
9.8%	19.8%	29.8%	39.7%	49.5%	58.8%	67.2%	74.5%
9.8%	19.8%	29.9%	39.8%	49.7%	59.2%	68.1%	76.0%
9.8%	19.8%	29.9%	39.9%	49.8%	59.5%	68.6%	76.8%
9.8%	19.8%	29.9%	39.9%	49.8%	59.6%	69.1%	77.6%
9.8%	19.8%	29.9%	39.9%	49.8%	59.7%	69.3%	78.0%
9.8%	19.8%	29.9%	39.9%	49.8%	59.8%	69.5%	78.4%
9.8%	19.8%	29.9%	39.9%	49.8%	59.9%	69.6%	78.7%
9.8%	19.8%	29.9%	39.9%	49.8%	59.9%	69.7%	79.0%
9.8%	19.8%	29.9%	39.9%	49.8%	59.9%	69.8%	79.2%
9.8%	19.8%	29.9%	39.9%	49.8%	59.9%	69.8%	79.3%
9.8%	19.8%	29.9%	39.9%	49.8%	59.9%	69.9%	79.4%
9.8%	19.8%	29.9%	39.9%	49.8%	59.9%	69.9%	79.5%
9.8%	19.8%	29.9%	39.9%	49.8%	59.9%	69.9%	79.6%
9.8%	19.8%	29.9%	39.9%	49.8%	59.9%	69.9%	79.7%
9.8%	19.8%	29.9%	39.9%	49.8%	59.9%	69.9%	79.8%

4.50	5.00
47.3%	49.9%
63.1%	66.6%
70.8%	74.9%
75.6%	79.9%
78.6%	83.3%
80.7%	85.6%
82.4%	87.4%
83.6%	88.8%
84.6%	89.9%
85.3%	90.8%
86.0%	91.6%
86.5%	92.2%
87.0%	92.8%
87.3%	93.3%
87.7%	93.7%
87.9%	94.1%
88.2%	94.4%
88.4%	94.7%
88.5%	94.9%
88.5%	95.1%

LOOK-UP TABLE: YIELD TO EXTRACT - % For K=0.5

	S/F Ratio:						
Stages	0.25	0.30	0.35	0.40	0.45	0.50	1.00
1	10.0%	12.5%	14.6%	16.0%	18.0%	19.0%	33.0%
2	11.0%	14.0%	16.0%	18.0%	21.0%	24.0%	42.0%
3	12.0%	14.5%	17.0%	19.0%	22.0%	25.0%	43.0%
4	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	48.0%
5	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	48.5%
6	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.0%
7	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.5%
8	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.6%
9	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.7%
10	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.7%
11	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.7%
12	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.7%
13	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.7%
14	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.7%
15	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.7%
16	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.7%
17	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.7%
18	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.7%
19	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.7%
20	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.7%

1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00
42.0%	49.0%	55.3%	59.5%	63.0%	66.0%	69.0%	71.0%
56.0%	66.0%	73.0%	78.0%	82.0%	85.0%	87.0%	89.0%
65.0%	74.9%	82.0%	87.0%	91.0%	93.0%	94.0%	96.0%
67.0%	79.0%	87.5%	92.3%	95.1%	97.0%	97.7%	98.4%
69.0%	83.0%	91.0%	95.0%	97.0%	98.3%	99.1%	99.3%
71.0%	85.0%	93.2%	96.0%	98.4%	99.2%	99.5%	99.7%
71.5%	87.0%	94.9%	97.0%	99.0%	99.6%	99.8%	99.9%
72.5%	88.0%	96.0%	98.0%	99.5%	99.8%	99.9%	100.0%
73.0%	89.0%	96.5%	99.1%	99.7%	99.9%	100.0%	100.0%
73.5%	90.0%	97.0%	99.5%	99.8%	100.0%	100.0%	100.0%
74.0%	91.0%	98.0%	99.6%	99.9%	100.0%	100.0%	100.0%
74.2%	92.0%	98.5%	99.7%	99.9%	100.0%	100.0%	100.0%
74.3%	92.5%	98.7%	99.8%	100.0%	100.0%	100.0%	100.0%
74.5%	93.0%	99.0%	99.8%	100.0%	100.0%	100.0%	100.0%
74.6%	93.5%	99.2%	99.9%	100.0%	100.0%	100.0%	100.0%
74.6%	94.0%	99.4%	99.9%	100.0%	100.0%	100.0%	100.0%
74.7%	94.2%	99.5%	99.9%	100.0%	100.0%	100.0%	100.0%
74.7%	94.6%	99.6%	99.9%	100.0%	100.0%	100.0%	100.0%
74.7%	95.0%	99.7%	99.9%	100.0%	100.0%	100.0%	100.0%
74.8%	95.0%	99.8%	99.9%	100.0%	100.0%	100.0%	100.0%

DISTILLATION DATA MATRIX

ITEM	COMPONENT	DEFAULT VALUE	IMPURITY #1	IMPURITY #2	LOWER BOIL PRODUCT #3
1	NAME		NONE	NONE	ACETONE
2	PRIORITY AS REFINED PRODUCT	LIST 1-4			2
3					
4	NORMAL BOILING PT, C				56.5
5	LOSS/COLUMN, WT %	0.50			
6	LEVEL AS IMPURITY, WT%	0.20			
7	VAP PRESS TEMP, C	900			-9.4
8	VAPOR PRESS, mm Hg	800000			40.0
9	HT VAPORIZATION, Btu/lb	215.0			
10	SENSIBLE HT (LIQ), Btu/(lb)(F)	0.50			
11	MAX THERMAL STABILITY, C	225			
12	LN(ACTIVITY COEFFICIENTS)				
13	-COMP. #1 in:	*	xxxx		
14	-COMP. #2 in:	*		xxxx	
15	-COMP. #3 in:	*			xxxx
16	-COMP. #4 in:	*			
17	-COMP. #5 in:	*			0.400
18	-COMP. #6 in:	*			
19	-COMP. #7 in:	*			0.400
20	-COMP. #8 in:	*			0.700
21	-COMP. #9 in:	*			
22	-COMP. #10 in:	*			0.650
23	-SOLVENT in:	*			1.100
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:	*			
34	-WATER in:	*	0.600	0.600	0.600

* 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	-2476.10	-3880.77
35	A(n) VAPOR PRESSURE CONST.	15.703	15.703	18.411
36	VAPOR PRESSURE @40 C	2422.2	2422.2	408.5
37	VAPOR PRESSURE @120 C	12121.9	12121.9	5096.7

DISTILLATION DATA MATRIX

ITEM	COMPONENT	IMPURITY #4	IMPURITY #5	IMPURITY #6	LOW BOIL PRODUCT #7
1	NAME	NONE	ETHANOL	NONE	BUTANOL
2	PRIORITY AS REFINED PRODUCT				1
3					
4	NORMAL BOILING PT, C		78.4		117.5
5	LOSS/COLUMN, WT %				
6	LEVEL AS IMPURITY, WT%				
7	VAP PRESS TEMP, C		19.0		53.4
8	VAPOR PRESS, mm Hg		40.0		40.0
9	HT VAPORIZATION, Btu/lb				
10	SENSIBLE HT (LIQ), Btu/(lb)(F)				
11	MAX THERMAL STABILITY, C				
12	LN(ACTIVITY COEFFICIENTS)				
13	-COMP. #1 in:				
14	-COMP. #2 in:				
15	-COMP. #3 in:		0.400		0.400
16	-COMP. #4 in:	XXXX			
17	-COMP. #5 in:		XXXX		0.300
18	-COMP. #6 in:			XXXX	
19	-COMP. #7 in:		0.300		XXXX
20	-COMP. #8 in:		0.600		0.600
21	-COMP. #9 in:				
22	-COMP. #10 in:		0.500		0.400
23	-SOLVENT in:		1.050		0.700
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:				
34	-WATER in:	0.600	0.600	0.600	0.600

* 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	-5086.29	-2476.10	-5854.85
35	A(n) VAPOR PRESSURE CONST.	15.703	21.108	15.703	21.627
36	VAPOR PRESSURE @40 C	2422.2	128.7	2422.2	18.6
37	VAPOR PRESSURE @120 C	12121.9	3517.3	12121.9	836.1

DISTILLATION DATA MATRIX

ITEM	COMPONENT	IMPURITY #8	IMPURITY #9	IMPURITY #10	SOLVENT
1	NAME	ACETIC AC	NONE	BUTYRIC ACID	
2	PRIORITY AS REFINED PRODUCT				
3					
4	NORMAL BOILING PT, C	118.1		163.5	213.5
5	LOSS/COLUMN, WT %				
6	LEVEL AS IMPURITY, WT%				
7	VAP PRESS TEMP, C	43.0		88.0	118.0
8	VAPOR PRESS, mm Hg	40.0		40.0	15.0
9	HT VAPORIZATION, Btu/lb				215.0
10	SENSIBLE HT (LIQ), Btu/(lb)(F)				0.50
11	MAX THERMAL STABILITY, C				
12	LN(ACTIVITY COEFFICIENTS)				
13	-COMP. #1 in:				
14	-COMP. #2 in:				
15	-COMP. #3 in:	0.700		0.650	1.100
16	-COMP. #4 in:				
17	-COMP. #5 in:	0.600		0.500	1.050
18	-COMP. #6 in:				
19	-COMP. #7 in:	0.600		0.400	0.700
20	-COMP. #8 in:	xxxx		0.300	0.800
21	-COMP. #9 in:		xxxx		
22	-COMP. #10 in:	0.300		xxxx	0.750
23	-SOLVENT in:	0.800		0.750	xxxx
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:				
34	-WATER in:	0.600	0.600	0.600	0.600

* 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.	-4845.43	-2476.10	-6145.36	-7818.54
35	A(n) VAPOR PRESSURE CONST.	19.023	15.703	20.712	22.704
36	VAPOR PRESSURE @40 C	34.5	2422.2	2.9	0.1
37	VAPOR PRESSURE @120 C	806.9	12121.9	160.0	16.6

DISTILLATION DATA MATRIX

ITEM	COMPONENT	WATER
1	NAME	
2	PRIORITY AS REFINED PRODUCT	
3		
4	NORMAL BOILING PT, C	100.0
5	LOSS/COLUMN, WT %	
6	LEVEL AS IMPURITY, WT%	
7	VAP PRESS TEMP, C	30.0
8	VAPOR PRESS, mm Hg	31.8
9	HT VAPORIZATION, Btu/lb	970.3
10	SENSIBLE HT (LIQ), Btu/(lb)(F)	1.00
11	MAX THERMAL STABILITY, C	
12	LN(ACTIVITY COEFFICIENTS)	
13	-COMP. #1 in:	
14	-COMP. #2 in:	
15	-COMP. #3 in:	0.600
16	-COMP. #4 in:	
17	-COMP. #5 in:	0.600
18	-COMP. #6 in:	
19	-COMP. #7 in:	0.600
20	-COMP. #8 in:	0.600
21	-COMP. #9 in:	
22	-COMP. #10 in:	0.600
23	-SOLVENT 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:	
34	-WATER in:	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

34	B(n) VAPOR PRESSURE CONST.	-5124.37
35	A(n) VAPOR PRESSURE CONST.	20.372
36	VAPOR PRESSURE @40 C	54.6
37	VAPOR PRESSURE @120 C	1529.1

OFTEN USED PARAMETERS

(THOUSAND ANNUAL POUNDS)

181,401	PRODUCT FORMED
	FORMED WITH PRODUCT
0	-COMPONENT #1
0	-COMPONENT #2
56,835	-COMPONENT #3
0	-COMPONENT #4
18,716	-COMPONENT #5
0	-COMPONENT #6
181,401	-COMPONENT #7
36,717	-COMPONENT #8
0	-COMPONENT #9
14,553	-COMPONENT #10
15,447	-WATER
0	-COMPONENT #11
0	-COMPONENT #12
0	-COMPONENT #13
0	-COMPONENT #14
0	-COMPONENT #15
0	-COMPONENT #16
0	-COMPONENT #17
0	-COMPONENT #18
0	-COMPONENT #19
0	-COMPONENT #20
11,022	-HYDROGEN
403,951	-CARBON DIOXIDE
	CONSUMED FOR PRODUCT
738,642	-GLUCOSE
0	-AMMONIA
0	-OXYGEN
19,438	CELLS PRODUCED - CHO
1,777	CELLS PRODUCED - NH2
	FORMED WITH CELLS
11,656	-WATER-CHO
1,000	-WATER-NH2
12,656	-WATER-TOTAL
28,493	-CARBON DIOXIDE-CHO
	CONSUMED FOR CELLS
38,876	-GLUCOSE-CHO
1,888	-AMMONIA-NH2
20,722	-OXYGEN-CHO
889	-OXYGEN-NH2
21,611	-OXYGEN-TOTAL
108,054	OXYGEN FED-GROWTH
357,833	NITROGEN FED-GROWTH
86,444	OXYGEN VENT-GROWTH
357,833	NITROGEN VENT-GROWTH
28,493	CARBON DIOXIDE VENT-GROWTH
14,487	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
403,951	CARBON DIOXIDE VENT-PROD'N
23,238	WATER VENT-PROD'N
427,189	PHI

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY

WATER BALANCE

WATER IN:	
MAKE UP WATER	13,184,656
BIOSUGAR SYRUP	778,913
STERILIZER STEAM	533,088
FORMED WITH CELLS	12,656
FORMED WITH PRODUCT	15,447
TOTAL IN	14,524,759
WATER OUT:	
AQUEOUS WASTE	13,905,231
CONDENSATE MAKEUP TO P.H	533,088
FERMENTER VENTS	37,725
PURGED WITH CELLS	48,595
MOISTURE IN PRODUCTS	120
TOTAL OUT	14,524,759

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

P	STREAM	1 CORN SYRUP	2 ANHYD AMMONIA	3 NUTRIENTS	4 MIX WATER	5 MIXED MEDIUM
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	COMPONENT #1	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#2	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	COMPONENT #6	0	0	0	0	0
#1	COMPONENT #7	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
	COMPONENT #11	0	0	0	0	0
	COMPONENT #12	0	0	0	0	0
	COMPONENT #13	0	0	0	0	0
#	COMPONENT #14	0	0	0	0	0
	COMPONENT #15	0	0	0	0	0
	COMPONENT #16	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
	COMPONENT #20	0	0	0	0	0
	GLUCOSE	778,913	0	0	0	778,913
	AMMONIA	0	1,888	0	0	0
	PHOSPHORIC ACID	0	0	1,573	0	1,573
	POTASSIUM CHLORIDE	0	0	1,197	0	1,197
	MINOR NUTRIENTS	0	0	543	0	543
	WATER	778,913	0	0	12,651,568	13,430,481
	SOLVENT	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	1,557,826	1,888	3,313	12,651,568	14,212,707
	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

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

P	STREAM	6 HX SS EFFLUENT	7 STERILE MEDIUM	8 HX TS EFFLUENT	9 COOLER EFFLUENT	10 AIR TO FERM
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	COMPONENT #1	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#2	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	COMPONENT #6	0	0	0	0	0
#1	COMPONENT #7	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
	COMPONENT #11	0	0	0	0	0
	COMPONENT #12	0	0	0	0	0
	COMPONENT #13	0	0	0	0	0
#	COMPONENT #14	0	0	0	0	0
	COMPONENT #15	0	0	0	0	0
	COMPONENT #16	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
	COMPONENT #20	0	0	0	0	0
	GLUCOSE	778,913	778,913	778,913	778,913	0
	AMMONIA	0	0	0	0	0
	PHOSPHORIC ACID	1,573	1,573	1,573	1,573	0
	POTASSIUM CHLORIDE	1,197	1,197	1,197	1,197	0
	MINOR NUTRIENTS	543	543	543	543	0
	WATER	13,430,481	13,963,569	13,963,569	13,963,569	0
	SOLVENT	0	0	0	0	0
	CARBON DIOXIDE	0	0	0	0	0
	OXYGEN	0	0	0	0	108,054
	NITROGEN	0	0	0	0	357,833
	HYDROGEN	0	0	0	0	0
	GRAND TOTAL	14,212,707	14,745,795	14,745,795	14,745,795	465,888
	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

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY

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	19,438	19,438	0	0
O	-NH2	0	1,777	1,777	0	0
D	-MINERALS	0	543	543	0	0
U	-TOTAL	0	21,758	21,758	0	0
C	COMPONENT #1	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#2	COMPONENT #3	0	0	56,835	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	18,716	0	0
	COMPONENT #6	0	0	0	0	0
#1	COMPONENT #7	0	0	181,401	0	0
	COMPONENT #8	0	0	36,717	0	0
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	0	0	14,553	0	0
	COMPONENT #11	0	0	0	0	0
	COMPONENT #12	0	0	0	0	0
	COMPONENT #13	0	0	0	0	0
#	COMPONENT #14	0	0	0	0	0
	COMPONENT #15	0	0	0	0	0
	COMPONENT #16	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
	COMPONENT #20	0	0	0	0	0
	GLUCOSE	778,913	740,037	1,395	0	0
	AMMONIA	1,888	0	0	0	0
	PHOSPHORIC ACID	1,573	1,573	1,573	0	0
	POTASSIUM CHLORIDE	1,197	1,197	1,197	0	0
	MINOR NUTRIENTS	543	0	0	0	0
	WATER	13,963,569	13,961,738	13,953,346	14,487	23,238
	SOLVENT	0	0	0	0	0
	CARBON DIOXIDE	0	0	0	28,493	403,951
	OXYGEN	108,054	0	0	86,444	0
	NITROGEN	357,833	0	0	357,833	0
	HYDROGEN	0	0	0	0	11,022
	GRAND TOTAL	15,213,571	14,726,303	14,288,091	487,257	438,212
	CHECK ON TOTAL					
	TEMPERATURE, C	33	33	33	33	33
	PRESSURE, PSIA	--	44.7	44.7	14.7	14.7
	STATE	--	SLURRY	SLURRY	GAS	GAS

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	16 COMBINED VENT	17 SOLVENT FEED	18 RAFFINATE	19 RECYCLE	20 AQUEOUS PURGE
P						
R	CELLS -CHO	0	0	19,438	0	19,438
O	-NH2	0	0	1,777	0	1,777
D	-MINERALS	0	0	543	0	543
U	-TOTAL	0	0	21,758	0	21,758
C	COMPONENT #1	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#2	COMPONENT #3	0	0	48,554	0	48,554
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	17,628	0	17,628
	COMPONENT #6	0	0	0	0	0
#1	COMPONENT #7	0	0	181	0	181
	COMPONENT #8	0	0	34,583	0	34,583
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	0	0	13,707	0	13,707
	COMPONENT #11	0	0	0	0	0
	COMPONENT #12	0	0	0	0	0
	COMPONENT #13	0	0	0	0	0
#	COMPONENT #14	0	0	0	0	0
	COMPONENT #15	0	0	0	0	0
	COMPONENT #16	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
	COMPONENT #20	0	0	0	0	0
	GLUCOSE	0	0	1,395	0	1,395
	AMMONIA	0	0	0	0	0
	PHOSPHORIC ACID	0	0	1,573	0	1,573
	POTASSIUM CHLORIDE	0	0	1,197	0	1,197
	MINOR NUTRIENTS	0	0	0	0	0
	WATER	37,725	0	13,953,862	0	13,953,862
	SOLVENT	0	4,186,184	279	0	279
	CARBON DIOXIDE	432,444	0	0	0	0
	OXYGEN	86,444	0	0	0	0
	NITROGEN	357,833	0	0	0	0
	HYDROGEN	11,022	0	0	0	0
	GRAND TOTAL	925,469	4,186,184	14,094,719	0	14,094,719
	CHECK ON TOTAL					
	TEMPERATURE, C	33	20			33
	PRESSURE, PSIA	14.7	15			15
	STATE	GAS	LIQUID	SLURRY	SLURRY	SLURRY

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	21 CELLS TO DISPOSAL	22 FILTRATE TO RAFF #1	23 EXTRACT	24 BEER #1 FEED	25 BEER #1 MAKE
P						
R	CELLS -CHO	19,438	0	0	0	0
O	-NH2	1,777	0	0	0	0
D	-MINERALS	543	0	0	0	0
U	-TOTAL	21,758	0	0	0	0
C	COMPONENT #1	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#2	COMPONENT #3	169	48,385	8,281	8,281	8,281
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	61	17,567	1,088	1,088	1,088
	COMPONENT #6	0	0	0	0	0
#1	COMPONENT #7	1	181	181,220	199,251	198,345
	COMPONENT #8	120	34,463	2,134	2,170	397
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	48	13,658	846	882	397
	COMPONENT #11	0	0	0	0	0
	COMPONENT #12	0	0	0	0	0
	COMPONENT #13	0	0	0	0	0
#	COMPONENT #14	0	0	0	0	0
	COMPONENT #15	0	0	0	0	0
	COMPONENT #16	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
	COMPONENT #20	0	0	0	0	0
	GLUCOSE	5	1,391	0	0	0
	AMMONIA	0	0	0	0	0
	PHOSPHORIC ACID	5	1,567	0	0	0
	POTASSIUM CHLORIDE	4	1,193	0	0	0
	MINOR NUTRIENTS	0	0	0	0	0
	WATER	48,595	13,905,268	84	84	84
	SOLVENT	1	278	4,185,905	4,383,889	198,345
	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	70,768	14,023,951	4,379,556	4,595,644	406,936
	CHECK ON TOTAL					
	TEMPERATURE, C	33	33	33	--	114
	PRESSURE, PSIA	14.7	14.7	14.7	--	13.5
	STATE	SLURRY	SOL'N	SOL'N	SOL'N	SOL'N

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

P	STREAM	26 BEER #1 TAILS	27 BEER #2 MAKE	28 BEER #2 TAILS	29 LBS #1 MAKE	30 LBS #1 TAILS
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	COMPONENT #1	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#2	COMPONENT #3	0	8,281	0	7,922	359
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	1,088	0	729	359
	COMPONENT #6	0	0	0	0	0
#1	COMPONENT #7	906	180,314	18,031	902	178,412
	COMPONENT #8	1,773	361	36	0	361
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	485	361	36	0	361
	COMPONENT #11	0	0	0	0	0
	COMPONENT #12	0	0	0	0	0
	COMPONENT #13	0	0	0	0	0
#	COMPONENT #14	0	0	0	0	0
	COMPONENT #15	0	0	0	0	0
	COMPONENT #16	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
	COMPONENT #20	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	0	84	0	0	84
	SOLVENT	4,185,544	361	197,385	0	361
	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	4,188,708	190,848	215,088	9,552	181,295
	CHECK ON TOTAL					
	TEMPERATURE, C	220	170	220	124	175
	PRESSURE, PSIA	14.3	88.2	80.2	88.1	100.5
	STATE	SOL'N	SOL'N	SOL'N	SOL'N	SOL'N

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

P	STREAM	31 LBS #2 MAKE	32 LBS #2 TAILS	33 LBS #3 MAKE	34 LBS #3 TAILS	35 HBS #1 MAKE
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	COMPONENT #1	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#2	COMPONENT #3	7,882	40	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	16	713	0	0	0
	COMPONENT #6	0	0	0	0	0
#1	COMPONENT #7	0	902	0	0	906
	COMPONENT #8	0	0	0	0	1,764
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	0	0	0	0	483
	COMPONENT #11	0	0	0	0	0
	COMPONENT #12	0	0	0	0	0
	COMPONENT #13	0	0	0	0	0
#	COMPONENT #14	0	0	0	0	0
	COMPONENT #15	0	0	0	0	0
	COMPONENT #16	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
	COMPONENT #20	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	0	0	0	0	0
	SOLVENT	0	0	0	0	1
	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	7,898	1,654	0	0	3,154
	CHECK ON TOTAL					
	TEMPERATURE, C	87	120	(273)	120	120
	PRESSURE, PSIA	40.3	46.5	.0	.0	14.1
	STATE	SOL'N	SOL'N	SOL'N	SOL'N	SOL'N

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

P	STREAM	36 HBS #1 TAILS	37 BYPRODUCT FEED	38 RAFF #1 FEED	39 RAFF #1 MAKE	40 RAFF #1 TAILS
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	COMPONENT #1	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#2	COMPONENT #3	0	48,424	48,424	48,424	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	18,280	20,099	20,007	91
	COMPONENT #6	0	0	0	0	0
#1	COMPONENT #7	0	1,082	1,086	40	1,046
	COMPONENT #8	9	34,463	34,463	0	34,463
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	2	13,659	13,659	0	13,659
	COMPONENT #11	0	0	0	0	0
	COMPONENT #12	0	0	0	0	0
	COMPONENT #13	0	0	0	0	0
#	COMPONENT #14	0	0	0	0	0
	COMPONENT #15	0	0	0	0	0
	COMPONENT #16	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
	COMPONENT #20	0	0	0	0	0
	GLUCOSE	0	1,391	1,391	0	1,391
	AMMONIA	0	0	0	0	0
	PHOSPHORIC ACID	0	1,567	1,567	0	1,567
	POTASSIUM CHLORIDE	0	1,193	1,193	0	1,193
	MINOR NUTRIENTS	0	0	0	0	0
	WATER	0	13,905,268	13,925,239	20,007	13,905,231
	SOLVENT	4,185,543	278	278	0	278
	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	4,185,554	14,025,605	14,047,399	88,479	13,958,920
	CHECK ON TOTAL					
	TEMPERATURE, C	220	33	33	74	105
	PRESSURE, PSIA	18.1	14.7	--	14.4	17.6
	STATE	SOL'N	SOL'N	SOL'N	SOL'N	SOL'N

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

P	STREAM	41 RAFF #2 MAKE	42 RAFF #2 TAILS	43 RAFF #3 MAKE	44 RAFF #3 TAILS	45 REFINED BUTANOL	46 REFINED ACETONE
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	COMPONENT #1	0	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0	0
#2	COMPONENT #3	48,424	0	48,182	242	359	56,065
	COMPONENT #4	0	0	0	0	0	0
	COMPONENT #5	18,189	1,819	96	18,092	359	112
	COMPONENT #6	0	0	0	0	0	0
#1	COMPONENT #7	36	4	0	36	179,412	0
	COMPONENT #8	0	0	0	0	361	0
	COMPONENT #9	0	0	0	0	0	0
	COMPONENT #10	0	0	0	0	361	0
	COMPONENT #11	0	0	0	0	0	0
	COMPONENT #12	0	0	0	0	0	0
	COMPONENT #13	0	0	0	0	0	0
#	COMPONENT #14	0	0	0	0	0	0
	COMPONENT #15	0	0	0	0	0	0
	COMPONENT #16	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
	COMPONENT #20	0	0	0	0	0	0
	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	36	19,971	0	36	84	0
	SOLVENT	0	0	0	0	361	0
	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	66,686	21,794	48,279	18,407	181,295	56,177
	CHECK ON TOTAL					0	0
	TEMPERATURE, C	57	100	83	105	175	87
	PRESSURE, PSIA	12.3	15.4	35.0	40.9	101	40
	STATE	SOL'N	SOL'N	SOL'N	SOL'N	0	0

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

P	STREAM	47 REFINED ETHANOL	48 ORGANIC WASTE	49 MAKE-UP SOLVENT	50 MAKE-UP WATER	51 STERILE STEAM
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	COMPONENT #1	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#2	COMPONENT #3	242	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	18,092	91	0	0	0
	COMPONENT #6	0	0	0	0	0
#1	COMPONENT #7	36	1,952	0	0	0
	COMPONENT #8	0	35,227	0	0	0
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	0	14,142	0	0	0
	COMPONENT #11	0	0	0	0	0
	COMPONENT #12	0	0	0	0	0
	COMPONENT #13	0	0	0	0	0
#	COMPONENT #14	0	0	0	0	0
	COMPONENT #15	0	0	0	0	0
	COMPONENT #16	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
	COMPONENT #20	0	0	0	0	0
	GLUCOSE	0	1,391	0	0	0
	AMMONIA	0	0	0	0	0
	PHOSPHORIC ACID	0	1,567	0	0	0
	POTASSIUM CHLORIDE	0	1,193	0	0	0
	MINOR NUTRIENTS	0	0	0	0	0
	WATER	36	**********	0	13,184,656	533,088
	SOLVENT	0	279	362	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	18,407	**********	362	13,184,656	533,088
	CHECK ON TOTAL			362		
	TEMPERATURE, C	105	40	20	20	141
	PRESSURE, PSIA	40.9	14.7	14.7	14.7	64.7
	STATE	SOL'N	SOL'N	LIQUID	LIQUID	GAS

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	52 FERM'TR STEAM	53 DISTILL. STEAM	54 COND. MU P'WR H'SE	55 MEDIUM COOL WTR	56 FERM'TR 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	COMPONENT #1	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#2	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	COMPONENT #6	0	0	0	0	0
#1	COMPONENT #7	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
	COMPONENT #11	0	0	0	0	0
	COMPONENT #12	0	0	0	0	0
	COMPONENT #13	0	0	0	0	0
#	COMPONENT #14	0	0	0	0	0
	COMPONENT #15	0	0	0	0	0
	COMPONENT #16	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
	COMPONENT #20	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	0	4,890,633	533,088	6,881,371	12,760,550
	SOLVENT	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	4,890,633	533,088	6,881,371	12,760,550
	CHECK ON TOTAL					
	TEMPERATURE, C	141	186	110	5	5
	PRESSURE, PSIA	64.7	164.7	20.8	14.7	14.7
	STATE	GAS	GAS	LIQUID	LIQUID	LIQUID

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	57 DISTILL. COOL WTR
P		
R	CELLS -CHO	0
O	-NH2	0
D	-MINERALS	0
U	-TOTAL	0
C	COMPONENT #1	0
T	COMPONENT #2	0
#2	COMPONENT #3	0
	COMPONENT #4	0
	COMPONENT #5	0
	COMPONENT #6	0
#1	COMPONENT #7	0
	COMPONENT #8	0
	COMPONENT #9	0
	COMPONENT #10	0
	COMPONENT #11	0
	COMPONENT #12	0
	COMPONENT #13	0
#	COMPONENT #14	0
	COMPONENT #15	0
	COMPONENT #16	0
	COMPONENT #17	0
#	COMPONENT #18	0
	COMPONENT #19	0
	COMPONENT #20	0
	GLUCOSE	0
	AMMONIA	0
	PHOSPHORIC ACID	0
	POTASSIUM CHLORIDE	0
	MINOR NUTRIENTS	0
	WATER	52,460,844
	SOLVENT	0
	CARBON DIOXIDE	0
	OXYGEN	0
	NITROGEN	0
	HYDROGEN	0
	GRAND TOTAL	52,460,844
	CHECK ON TOTAL	
	TEMPERATURE, C	0
	PRESSURE, PSIA	14.7
	STATE	LIQUID

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	23 EXTRACT	24 BEER #1 FEED	25 BEER #1 MAKE	26 BEER #1 TAILS
COMPONENT #1	0	0	0	0
COMPONENT #2	0	0	0	0
COMPONENT #3	143	143	143	0
COMPONENT #4	0	0	0	0
COMPONENT #5	24	24	24	0
COMPONENT #6	0	0	0	0
COMPONENT #7	2,445	2,688	2,676	12
COMPONENT #8	36	36	7	30
COMPONENT #9	0	0	0	0
COMPONENT #10	10	10	5	5
COMPONENT #11	0	0	0	0
COMPONENT #12	0	0	0	0
COMPONENT #13	0	0	0	0
COMPONENT #14	0	0	0	0
COMPONENT #15	0	0	0	0
COMPONENT #16	0	0	0	0
COMPONENT #17	0	0	0	0
COMPONENT #18	0	0	0	0
COMPONENT #19	0	0	0	0
COMPONENT #20	0	0	0	0
WATER	5	5	5	0
SOLVENT	15,592	16,329	739	15,590
TOTAL (q)	18,253	19,234	3,597	15,638
(Storage)	108	112	111	1
VAPOR PRESS 40(q)	6.0	5.9	31.0	0.2
(Storage)	2,884	3,088	3,053	35
VAPOR PRESS 120(q)	172.6	175.0	854.2	18.8
B(q) V.P. CONSTANT	-5161.5	-5200.3	-5098.8	-7119.7
A(q) V.P. CONSTANT	18.284	18.397	19.724	21.050
TEMPERATURE C	33.0	35.8	108.7	220.0
PRESSURE mmHg	760	760	581	741
K1 (COMPONENT #)			7	7
K2 (COMPONENT #)			SOLVENT	SOLVENT
V.P.(K1)			537.1	17164.0
V.P.(K2)			9.2	939.4
GAMMA-K1 IN K2			2.014	2.014
GAMMA-K2 IN K1			2.014	2.014
ALPHA			39.260	36.755
AVG COLUMN ALPHA			38.007	
MOL FRACT. K1 (MAKE OR TAILS)			0.784	0.001
MOL FRACT. K1 (FEED)			0.141	
MOL FRACT. K2 (MAKE OR TAILS)			0.216	0.999
ADJ. GAMMA-K1 IN K2			1.033	2.012
ADJ. GAMMA-K2 IN K1			1.537	1.000
MINIMUM REFLUX RATIO (ADJUSTED)			0.0	
ACTUAL REFLUX RATIO			0.0	
MINIMUM PLATES			2	

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	23 EXTRACT	24 BEER #1 FEED	25 BEER #1 MAKE	26 BEER #1 TAILS
ACTUAL PLATES			10	
PRESSURE mm Hg (REVISED)			699	
TEMPERATURE C (REVISED)			114	
AVERAGE MOLECULAR WEIGHT			113.14	267.86
GAS DENSITY - LB/CF			0.2045	0.4029
CROSS SECTIONAL AREA - SQ FT			25.3	
COLUMN HEIGHT - FT			30.7	
COLUMN DIAMETER			5.8	
K1 (MPPY)			198,345	
Hv (HEAT VAPORIZ.-Btu/LB)			215.2	215.0
Cn (HEAT CAPACITY - Btu/LB/F)			0.500	0.500
HEAT LOAD - MM Btu/Hr			12.160	108.586
CONDENSER COOLING WATER - GPM (15 C dT)			801	
CALANDRIA STEAM - MPPH (150 PSIG)				126.70
COLUMN COST - $1000 3Q86 MPC - BARE EQUIPMENT				
- ALL CARBON STEEL			$62.6	
- C.S w/304 S.S. TRAYS			$68.8	
- ALL 304 STAINLESS STEEL			$101.2	
- ALL 304L STAINLESS STEEL			$111.3	
- ALL 316 STAINLESS STEEL			$136.6	
CONDENSER OR CALANDRIA SURFACE - SQ FT			1,005	6,033
COND. OR CALAND. COST - $1000 3Q86 MPC - BARE EQUIPMENT				
-CARBON STEEL			$41.5	$187.0
-304 STAINLESS STEEL			$58.0	$261.7
-316 STAINLESS STEEL			$62.2	$280.4
-MONEL			$80.8	$364.6
SUBTOTAL				2,094,354
SUBTOTAL				2,092,772
SUBTOTAL				2,092,772
MINIMUM REFLUX RATIO			(0.4)	
Cn SUBTOTAL #1			103,857	453
Cn SUBTOTAL #2			397	1,129
Cn SUBTOTAL #3			99,256	2,092,772
Cn CHECK			0.500	0.500
Hv SUBTOTAL #1			44,658	195
Hv SUBTOTAL #2			171	485
Hv SUBTOTAL #3			42,725	899,892
Hv CHECK			215.2	215.0
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)				

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	27 BEER #2 MAKE	28 BEER #2 TAILS	29 LBS #1 MAKE	30 LBS #1 TAILS
COMPONENT #1	0	0	0	0
COMPONENT #2	0	0	0	0
COMPONENT #3	143	0	136	6
COMPONENT #4	0	0	0	0
COMPONENT #5	24	0	16	8
COMPONENT #6	0	0	0	0
COMPONENT #7	2,433	243	12	2,421
COMPONENT #8	6	1	0	6
COMPONENT #9	0	0	0	0
COMPONENT #10	4	0	0	4
COMPONENT #11	0	0	0	0
COMPONENT #12	0	0	0	0
COMPONENT #13	0	0	0	0
COMPONENT #14	0	0	0	0
COMPONENT #15	0	0	0	0
COMPONENT #16	0	0	0	0
COMPONENT #17	0	0	0	0
COMPONENT #18	0	0	0	0
COMPONENT #19	0	0	0	0
COMPONENT #20	0	0	0	0
WATER	5	0	0	5
SOLVENT	1	737	0	1
TOTAL (q)	2,615	982	164	2,451
(Storage)	107	5	58	49
VAPOR PRESS 40(q)	40.9	4.7	352.7	20.0
(Storage)	2,849	204	761	2,088
VAPOR PRESS 120(q)	1092.3	220.2	4629.4	855.0
B(q) V.P. CONSTANT	-5051.6	-5815.7	-3958.7	-5777.1
A(q) V.P. CONSTANT	19.850	20.447	18.513	21.451
TEMPERATURE C	168.7	220.0	123.3	175.0
PRESSURE mmHg	4,505	4,665	5,037	5,197
K1 (COMPONENT #)	7	7	6,5,4,3	6,5,4,3
K2 (COMPONENT #)	SOLVENT	SOLVENT	7	7
V.P.(K1)	4319.8	17164.0	3818.8	17229.0
V.P.(K2)	148.8	938.4	947.1	5206.5
GAMMA-K1 IN K2	2.014	2.014	1.350	1.350
GAMMA-K2 IN K1	2.014	2.014	1.350	1.350
ALPHA	14.423	26.000	3.880	4.458
AVG COLUMN ALPHA	20.212		4.219	
MOL FRACT. K1 (MAKE OR TAILS)	0.999	0.248	0.565	0.003
MOL FRACT. K1 (FEED)	0.784		0.010	
MOL FRACT. K2 (MAKE OR TAILS)	0.001	0.752	0.435	0.997
ADJ. GAMMA-K1 IN K2	1.000	1.486	1.058	1.347
ADJ. GAMMA-K2 IN K1	2.012	1.044	1.101	1.000
MINIMUM REFLUX RATIO (ADJUSTED)	0.0		1.3	
ACTUAL REFLUX RATIO	0.0		1.6	
MINIMUM PLATES	3		4	

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	27 BEER #2 MAKE	28 BEER #2 TAILS	29 LBS #1 MAKE	30 LBS #1 TAILS
ACTUAL PLATES	13		18	
PRESSURE mm Hg (REVISED)	4,614		5,122	
TEMPERATURE C (REVISED)	170		124	
AVERAGE MOLECULAR WEIGHT	72.98	220.11	58.11	73.98
GAS DENSITY - LB/CF	0.7612	2.0840	0.7501	0.8586
CROSS SECTIONAL AREA - SQ FT	6.4		0.8	
COLUMN HEIGHT - FT	34.3		43.1	
COLUMN DIAMETER	2.9		1.0	
K1 (MPPY)	180,314		729	
Hv (HEAT VAPORIZ.-Btu/Lb)	215.3	215.0	215.0	215.3
Cn (HEAT CAPACITY - Btu/Lb/F)	0.500	0.500	0.500	0.500
HEAT LOAD - MM Btu/Hr	5.708	8.570	0.747	0.869
CONDENSER COOLING WATER - GPM (1	423		55	
CALANDRIA STEAM - MPPH (150 PSIG)		10.00		1.01
COLUMN COST - $1000 3Q86 MPC - BARE EQUIPMENT				
- ALL CARBON STEEL	$39.0		$23.3	
- C.S w/304 S.S. TRAYS	$42.9		$25.6	
- ALL 304 STAINLESS STEEL	$64.2		$39.4	
- ALL 304L STAINLESS STEEL	$70.6		$43.3	
- ALL 316 STAINLESS STEEL	$86.7		$53.2	
CONDENSER OR CALANDRIA SURFACE -	284	476	55	48
COND. OR CALAND. COST - $1000 3Q86 MPC - BARE EQUIPMENT				
-CARBON STEEL	$18.8	$25.3	$9.5	$9.1
-304 STAINLESS STEEL	$26.4	$35.4	$13.3	$12.8
-316 STAINLESS STEEL	$28.3	$38.0	$14.3	$13.7
-MONEL	$36.8	$49.4	$18.5	$17.8
SUBTOTAL		108,044		90,331
SUBTOTAL		98,992		264
SUBTOTAL		98,992		264
MINIMUM REFLUX RATIO	(0.9)		1.3	
Cn SUBTOTAL #1	94,841	9,016	4,776	90,065
Cn SUBTOTAL #2	361	36	0	361
Cn SUBTOTAL #3	264	98,992	0	264
Cn CHECK	0.500	0.500	0.500	0.500
Hv SUBTOTAL #1	40,782	3,877	2,054	38,728
Hv SUBTOTAL #2	155	16	0	155
Hv SUBTOTAL #3	159	42,567	0	159
Hv CHECK	215.3	215.0	215.0	215.3
MIN. PLATES(NORMAL)				
COL.COST-C/S NORMAL			23	
COL.COST-S/S NORMAL			39	
MIN.REFLUX(NORMAL)				
C.S. AREA(NORMAL)			1	
HEAT LOAD(NORMAL)				0.87
CON/CAL COST(NORMAL)			10	9

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	31 LBS #2 MAKE	32 LBS #2 TAILS	33 LBS #3 MAKE	34 LBS #3 TAILS
COMPONENT #1	0	0	0	0
COMPONENT #2	0	0	0	0
COMPONENT #3	136	1	0	0
COMPONENT #4	0	0	0	0
COMPONENT #5	0	15	0	0
COMPONENT #6	0	0	0	0
COMPONENT #7	0	12	0	0
COMPONENT #8	0	0	0	0
COMPONENT #9	0	0	0	0
COMPONENT #10	0	0	0	0
COMPONENT #11	0	0	0	0
COMPONENT #12	0	0	0	0
COMPONENT #13	0	0	0	0
COMPONENT #14	0	0	0	0
COMPONENT #15	0	0	0	0
COMPONENT #16	0	0	0	0
COMPONENT #17	0	0	0	0
COMPONENT #18	0	0	0	0
COMPONENT #19	0	0	0	0
COMPONENT #20	0	0	0	0
WATER	0	0	0	0
SOLVENT	0	0	0	0
TOTAL (q)	136	28	0	0
(Storage)	55	2	0	0
VAPOR PRESS 40(q)	407.8	88.1	.0	.0
(Storage)	693	68	0	0
VAPOR PRESS 120(q)	5092.7	2403.9	.0	.0
B(q) V.P. CONSTANT	-3882.2	-5083.2	0.0	0.0
A(q) V.P. CONSTANT	18.414	20.719	-4.605	-4.605
TEMPERATURE C	89.9	120.0	ERR	120.0
PRESSURE mmHg	2,244	2,404	(160)	0
K1 (COMPONENT #)	3	3	2,1	2,1
K2 (COMPONENT #)	4,5,6	4,5,6	3	3
V.P.(K1)	2246.3	5086.7	ERR	1.0
V.P.(K2)	1201.9	3517.3	ERR	5086.7
GAMMA-K1 IN K2	1.492	1.492	1.000	1.000
GAMMA-K2 IN K1	1.492	1.492	1.000	1.000
ALPHA	1.255	2.090	ERR	ERR
AVG COLUMN ALPHA	1.673		ERR	
MOL FRACT. K1 (MAKE OR TAILS)	0.997	0.042	ERR	ERR
MOL FRACT. K1 (FEED)	0.896		0.000	
MOL FRACT. K2 (MAKE OR TAILS)	0.003	0.958	ERR	ERR
ADJ. GAMMA-K1 IN K2	1.000	1.443	ERR	ERR
ADJ. GAMMA-K2 IN K1	1.489	1.001	ERR	ERR
MINIMUM REFLUX RATIO (ADJUSTED)	0.0		0.0	
ACTUAL REFLUX RATIO	0.0		0.0	
MINIMUM PLATES	18		0	

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	31 LBS #2 MAKE	32 LBS #2 TAILS	33 LBS #3 MAKE	34 LBS #3 TAILS
ACTUAL PLATES	80		0	
PRESSURE mm Hg (REVISED)	2,085		0	
TEMPERATURE C (REVISED)	87		(273)	
AVERAGE MOLECULAR WEIGHT	58.05	58.40	ERR	ERR
GAS DENSITY - LB/CF	0.3360	0.3575	ERR	ERR
CROSS SECTIONAL AREA - SQ FT	0.4		0.0	
COLUMN HEIGHT - FT	134.5		0.0	
COLUMN DIAMETER	0.7		0.0	
K1 (MPPY)	7,882		0	
Hv (HEAT VAPORIZ.-Btu/Lb)	215.0	215.0	ERR	ERR
Cn (HEAT CAPACITY - Btu/Lb/F)	0.500	0.500	ERR	ERR
HEAT LOAD - MM Btu/Hr	0.236	0.235	0.000	0.000
CONDENSER COOLING WATER - GPM (1	17		0	
CALANDRIA STEAM - MPPH (150 PSIG)		0.27		0.00
COLUMN COST - $1000 3Q86 MPC - BARE EQUIPMENT				
- ALL CARBON STEEL	$38.4		$0.0	
- C.S w/304 S.S. TRAYS	$42.2		$0.0	
- ALL 304 STAINLESS STEEL	$63.2		$0.0	
- ALL 304L STAINLESS STEEL	$68.5		$0.0	
- ALL 316 STAINLESS STEEL	$85.3		$0.0	
CONDENSER OR CALANDRIA SURFACE -	29	13	0	0
COND. OR CALAND. COST - $1000 3Q86 MPC - BARE EQUIPMENT				
-CARBON STEEL	$8.0	$7.1	$0.0	$0.0
-304 STAINLESS STEEL	$11.3	$10.0	$0.0	$0.0
-316 STAINLESS STEEL	$12.1	$10.7	$0.0	$0.0
-MONEL	$15.7	$13.9	$0.0	$0.0
SUBTOTAL		451		0
SUBTOTAL		0		0
SUBTOTAL		0		0
MINIMUM REFLUX RATIO	(0.8)		0.0	
Cn SUBTOTAL #1	3,948	827	0	0
Cn SUBTOTAL #2	0	0	0	0
Cn SUBTOTAL #3	0	0	0	0
Cn CHECK	0.500	0.500	ERR	ERR
Hv SUBTOTAL #1	1,698	356	0	0
Hv SUBTOTAL #2	0	0	0	0
Hv SUBTOTAL #3	0	0	0	0
Hv CHECK	215.0	215.0	ERR	ERR
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)				

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	35 HBS #1 MAKE	36 HBS #1 TAILS	37 BYPRODUCT FEED	38 RAFF #1 FEED
COMPONENT #1	0	0	0	0
COMPONENT #2	0	0	0	0
COMPONENT #3	0	0	834	834
COMPONENT #4	0	0	0	0
COMPONENT #5	0	0	397	436
COMPONENT #6	0	0	0	0
COMPONENT #7	12	0	15	15
COMPONENT #8	29	0	574	574
COMPONENT #9	0	0	0	0
COMPONENT #10	5	0	155	155
COMPONENT #11	0	0	0	0
COMPONENT #12	0	0	0	0
COMPONENT #13	0	0	0	0
COMPONENT #14	0	0	0	0
COMPONENT #15	0	0	0	0
COMPONENT #16	0	0	0	0
COMPONENT #17	0	0	0	0
COMPONENT #18	0	0	0	0
COMPONENT #19	0	0	0	0
COMPONENT #20	0	0	0	0
WATER	0	0	771,829	772,937
SOLVENT	0	15,590	1	1
TOTAL (g)	47	15,591	773,804	774,952
(Storage)	1	0	412	417
VAPOR PRESS 40(g)	26.7	0.1	55.0	55.0
(Storage)	35	0	6,145	6,284
VAPOR PRESS 120(g)	739.2	16.6	1533.2	1533.3
B(g) V.P. CONSTANT	-5105.8	-7812.0	-5117.4	-5117.4
A(g) V.P. CONSTANT	19.587	22.688	20.356	20.357
TEMPERATURE C	121.5	220.0	33.0	33.0
PRESSURE mmHg	777	937	760	760
K1 (COMPONENT #)	10,9,8	10,9,8		
K2 (COMPONENT #)	SOLVENT	SOLVENT		
V.P.(K1)	169.9	3815.4		
V.P.(K2)	17.9	939.4		
GAMMA-K1 IN K2	2.117	2.117		
GAMMA-K2 IN K1	2.858	2.858		
ALPHA	3.321	8.598		
AVG COLUMN ALPHA	5.960			
MOL FRACT. K1 (MAKE OR TAILS)	0.998	.000		
MOL FRACT. K1 (FEED)	.000			
MOL FRACT. K2 (MAKE OR TAILS)	0.001	1.000		
ADJ. GAMMA-K1 IN K2	1.000	2.117		
ADJ. GAMMA-K2 IN K1	2.854	1.000		
MINIMUM REFLUX RATIO (ADJUSTED)	87.2			
ACTUAL REFLUX RATIO	109.0			
MINIMUM PLATES	12			

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	35 HBS #1 MAKE	36 HBS #1 TAILS	37 BYPRODUCT FEED	38 RAFF #1 FEED
ACTUAL PLATES	52			
PRESSURE mm Hg (REVISED)	729			
TEMPERATURE C (REVISED)	120			
AVERAGE MOLECULAR WEIGHT	66.98	268.46		
GAS DENSITY - LB/CF	0.1245	0.5105		
CROSS SECTIONAL AREA - SQ FT	28.7			
COLUMN HEIGHT - FT	92.8			
COLUMN DIAMETER	6.0			
K1 (MPPY)	0			
Hv (HEAT VAPORIZ.-Btu/Lb)	215.0	215.0		
Cn (HEAT CAPACITY - Btu/Lb/F)	0.500	0.500		
HEAT LOAD - MM Btu/Hr	10.355	10.355		
CONDENSER COOLING WATER - GPM (1	767			
CALANDRIA STEAM - MPPH (150 PSIG)		12.08		
COLUMN COST - $1000 3Q86 MPC - BARE EQUIPMENT				
- ALL CARBON STEEL	$176.4			
- C.S w/304 S.S. TRAYS	$194.0			
- ALL 304 STAINLESS STEEL	$280.0			
- ALL 304L STAINLESS STEEL	$308.0			
- ALL 316 STAINLESS STEEL	$378.0			
CONDENSER OR CALANDRIA SURFACE -	803	575		
COND. OR CALAND. COST - $1000 3Q86 MPC - BARE EQUIPMENT				
-CARBON STEEL	$35.4	$28.5		
-304 STAINLESS STEEL	$48.6	$39.9		
-316 STAINLESS STEEL	$53.2	$42.7		
-MONEL	$69.1	$55.5		
SUBTOTAL		2,092,777		
SUBTOTAL		2,092,772		
SUBTOTAL		2,092,772		
MINIMUM REFLUX RATIO	87.2			
Cn SUBTOTAL #1	453	0		
Cn SUBTOTAL #2	1,123	6		
Cn SUBTOTAL #3	0	2,092,772		
Cn CHECK	0.500	0.500		
Hv SUBTOTAL #1	195	0		
Hv SUBTOTAL #2	483	2		
Hv SUBTOTAL #3	0	899,882		
Hv CHECK	215.0	215.0		
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)				

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	39 RAFF #1 MAKE	40 RAFF #1 TAILS	41 RAFF #2 MAKE	42 RAFF #2 TAILS
COMPONENT #1	0	0	0	0
COMPONENT #2	0	0	0	0
COMPONENT #3	834	0	834	0
COMPONENT #4	0	0	0	0
COMPONENT #5	434	2	395	39
COMPONENT #6	0	0	0	0
COMPONENT #7	1	14	0	0
COMPONENT #8	0	574	0	0
COMPONENT #9	0	0	0	0
COMPONENT #10	0	155	0	0
COMPONENT #11	0	0	0	0
COMPONENT #12	0	0	0	0
COMPONENT #13	0	0	0	0
COMPONENT #14	0	0	0	0
COMPONENT #15	0	0	0	0
COMPONENT #16	0	0	0	0
COMPONENT #17	0	0	0	0
COMPONENT #18	0	0	0	0
COMPONENT #19	0	0	0	0
COMPONENT #20	0	0	0	0
WATER	1,111	771,827	2	1,109
SOLVENT	0	1	0	0
TOTAL (q)	2,379	772,573	1,231	1,148
(Storage)	396	21	391	5
VAPOR PRESS 40(q)	192.1	54.6	318.0	57.1
(Storage)	5,778	507	5,639	139
VAPOR PRESS 120(q)	3142.2	1528.3	4582.6	1597.5
B(q) V.P. CONSTANT	-4296.8	-5124.3	-4102.2	-5121.5
A(q) V.P. CONSTANT	18.986	20.371	18.868	20.408
TEMPERATURE C	74.5	105.0	57.4	100.0
PRESSURE mmHg	751	911	634	794
K1 (COMPONENT #)	5	5	5	5
K2 (COMPONENT #)	WATER	WATER	WATER	WATER
V.P.(K1)	646.3	2104.6	302.9	1757.3
V.P.(K2)	277.4	911.5	129.3	760.0
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	3.029	4.207	1.294	4.043
AVG COLUMN ALPHA	3.618		2.668	
MOL FRACT. K1 (MAKE OR TAILS)	0.281	.000	0.995	0.034
MOL FRACT. K1 (FEED)	0.001		0.281	
MOL FRACT. K2 (MAKE OR TAILS)	0.719	1.000	0.005	0.966
ADJ. GAMMA-K1 IN K2	1.364	1.822	1.000	1.750
ADJ. GAMMA-K2 IN K1	1.049	1.000	1.811	1.001
MINIMUM REFLUX RATIO (ADJUSTED)	23.8		0.1	
ACTUAL REFLUX RATIO	29.8		0.2	
MINIMUM PLATES	9		9	

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	39 RAFF #1 MAKE	40 RAFF #1 TAILS	41 RAFF #2 MAKE	42 RAFF #2 TAILS
ACTUAL PLATES	42		39	
PRESSURE mm Hg (REVISED)	744		636	
TEMPERATURE C (REVISED)	74		57	
AVERAGE MOLECULAR WEIGHT	37.13	18.07	54.17	18.98
GAS DENSITY - LB/CF	0.0797	0.0436	0.1044	0.0404
CROSS SECTIONAL AREA - SQ FT	281.8		7.1	
COLUMN HEIGHT - FT	77.6		74.2	
COLUMN DIAMETER	18.9		3.0	
K1 (MPPY)	20,007		18,189	
Hv (HEAT VAPORIZ.-Btu/Lb)	385.8	967.6	215.4	907.1
Cn (HEAT CAPACITY - Btu/Lb/F)	0.613	0.998	0.500	0.958
HEAT LOAD - MM Btu/Hr	145.847	336.551	2.350	2.484
CONDENSER COOLING WATER - GPM (1	10808		174	
CALANDRIA STEAM - MPPH (150 PSIG)		462.72		2.90
COLUMN COST - $1000 3Q86 MPC - BARE EQUIPMENT				
- ALL CARBON STEEL	$445.9		$76.2	
- C.S w/304 S.S. TRAYS	$490.4		$83.8	
- ALL 304 STAINLESS STEEL	$703.5		$122.6	
- ALL 304L STAINLESS STEEL	$773.8		$134.8	
- ALL 316 STAINLESS STEEL	$949.7		$165.5	
CONDENSER OR CALANDRIA SURFACE -	22,892	22,031	594	138
COND. OR CALAND. COST - $1000 3Q86 MPC - BARE EQUIPMENT				
-CARBON STEEL	$771.0	$737.6	$29.0	$13.3
-304 STAINLESS STEEL	$1,079.3	$1,032.6	$40.7	$18.6
-316 STAINLESS STEEL	$1,156.4	$1,106.4	$43.6	$20.0
-MONEL	$1,503.4	$1,438.3	$56.6	$25.9
SUBTOTAL		13,929,954		19,973
SUBTOTAL		13,905,370		19,971
SUBTOTAL		13,905,370		19,971
MINIMUM REFLUX RATIO	23.8		0.1	
Cn SUBTOTAL #1	34,236	569	33,325	911
Cn SUBTOTAL #2	0	24,061	0	0
Cn SUBTOTAL #3	20,007	13,905,370	36	19,971
Cn CHECK	0.613	0.998	0.500	0.958
Hv SUBTOTAL #1	14,721	245	14,330	392
Hv SUBTOTAL #2	0	10,346	0	0
Hv SUBTOTAL #3	19,413	13,492,306	35	19,378
Hv CHECK	385.8	967.6	215.4	907.1
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)				

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	43 RAFF #3 MAKE	44 RAFF #3 TAILS
COMPONENT #1	0	0
COMPONENT #2	0	0
COMPONENT #3	830	4
COMPONENT #4	0	0
COMPONENT #5	2	393
COMPONENT #6	0	0
COMPONENT #7	0	0
COMPONENT #8	0	0
COMPONENT #9	0	0
COMPONENT #10	0	0
COMPONENT #11	0	0
COMPONENT #12	0	0
COMPONENT #13	0	0
COMPONENT #14	0	0
COMPONENT #15	0	0
COMPONENT #16	0	0
COMPONENT #17	0	0
COMPONENT #18	0	0
COMPONENT #19	0	0
COMPONENT #20	0	0
WATER	0	2
SOLVENT	0	0
TOTAL (q)	832	399
(Storage)	339	52
VAPOR PRESS 40(q)	407.8	131.1
(Storage)	4,236	1,403
VAPOR PRESS 120(q)	5082.7	3520.5
B(q) V.P. CONSTANT	-3882.2	-5059.1
A(q) V.P. CONSTANT	18.414	21.039
TEMPERATURE C	85.2	105.0
PRESSURE mmHg	1,952	2,112
K1 (COMPONENT #)	3	3
K2 (COMPONENT #)	5	5
V.P.(K1)	1954.5	3444.3
V.P.(K2)	1001.5	2104.6
GAMMA-K1 IN K2	1.492	1.492
GAMMA-K2 IN K1	1.492	1.492
ALPHA	1.311	2.421
AVG COLUMN ALPHA	1.866	
MOL FRACT. K1 (MAKE OR TAILS)	0.997	0.011
MOL FRACT. K1 (FEED)	0.679	
MOL FRACT. K2 (MAKE OR TAILS)	0.003	0.989
ADJ. GAMMA-K1 IN K2	1.000	1.478
ADJ. GAMMA-K2 IN K1	1.489	1.000
MINIMUM REFLUX RATIO (ADJUSTED)	0.0	
ACTUAL REFLUX RATIO	0.0	
MINIMUM PLATES	17	

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	43 RAFF #3 MAKE	44 RAFF #3 TAILS
ACTUAL PLATES	76	
PRESSURE mm Hg (REVISED)	1,808	
TEMPERATURE C (REVISED)	83	
AVERAGE MOLECULAR WEIGHT	58.05	46.09
GAS DENSITY - LB/CF	0.2353	0.2577
CROSS SECTIONAL AREA - SQ FT	2.6	
COLUMN HEIGHT - FT	128.9	
COLUMN DIAMETER	1.8	
K1 (MPPY)	48,182	
Hv (HEAT VAPORIZ.-Btu/Lb)	215.0	216.5
Cn (HEAT CAPACITY - Btu/LB/F)	0.500	0.501
HEAT LOAD - MM Btu/Hr	1.442	1.551
CONDENSER COOLING WATER - GPM (1	107	
CALANDRIA STEAM - MPPH (150 PSIG)		1.81
COLUMN COST - $1000 3Q86 MPC - BARE EQUIPMENT		
- ALL CARBON STEEL	$79.5	
- C.S w/304 S.S. TRAYS	$87.4	
- ALL 304 STAINLESS STEEL	$127.8	
- ALL 304L STAINLESS STEEL	$140.5	
- ALL 316 STAINLESS STEEL	$172.5	
CONDENSER OR CALANDRIA SURFACE -	130	86
COND. OR CALAND. COST - $1000 3Q86 MPC - BARE EQUIPMENT		
-CARBON STEEL	$15.4	$11.0
-304 STAINLESS STEEL	$21.5	$15.4
-316 STAINLESS STEEL	$23.1	$16.5
-MONEL	$30.0	$21.5
SUBTOTAL		55
SUBTOTAL		36
SUBTOTAL		36
MINIMUM REFLUX RATIO	(0.5)	
Cn SUBTOTAL #1	24,139	9,185
Cn SUBTOTAL #2	0	0
Cn SUBTOTAL #3	0	36
Cn CHECK	0.500	0.501
Hv SUBTOTAL #1	10,380	3,950
Hv SUBTOTAL #2	0	0
Hv SUBTOTAL #3	0	35
Hv CHECK	215.0	216.5
MIN. PLATES(NORMAL)		
COL.COST-C/S NORMAL	79	
COL.COST-S/S NORMAL	128	
MIN.REFLUX(NORMAL)		
C.S. AREA(NORMAL)	3	
HEAT LOAD(NORMAL)		1
CON/CAL COST(NORMAL)	15	11

APPENDIX D. BASECASE STOICHIOMETRY
NO RAFFINATE/CELLS RECYCLE
NO RECOVERY OF RAFFINATE CHEMICALS

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
NO RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY
SUMMARY

	PRODUCTION LEVEL 161.47 MM PPY
INVESTMENT-$MILLION	
MPC = 1984	
Direct Permanent Investment	$159.3
Allocated Power, Services & General	$34.9
Working Capital	$25.5
Total Investment	$219.7
COST-$/LB (1988)	
Raw Materials	$0.29
Utilities	$0.07
Labor-Related	$0.03
Capital-Related	$0.13
Cost of Manufacture	$0.52
SE, D, R&D, Adm, & I.C.	$0.13
Cost of Sales	$0.65
Pretax Earnings Based on: 30% Pretax ROI	$0.41
By-product Credit	($0.01)
Selling Price	$1.05
FINANCIAL CRITERIA	
Net ROI 3rd Year (assumed)	16%
Investors Rate of Return (20 Operating Years)	21%
Year to Break Even - Annual Cash	1986
- Cumulative Cash	1990
- Cum. Disc. Cash (NPV)	1992
Net Present Value $MM (20 years @ 12%)	$129.3

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
NO RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY

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 PPY	179.4
MID-POINT OF CONSTRUCTION	YEAR	1984
CONSTRUCTION COST INDEX	1980=100	128
INVESTMENT CONTINGENCY	% INSTALLED *	30%
FERMENTER UNIT INVESTMENT	$/GR.GAL.-GROWTH	$10.94
	$/GR.GAL.-PROD'N	$10.94

*40% Recommended for new processes

DIRECT PERMANENT INVESTMENT

	SCALE FACTOR		THIS CASE $MM	$/ANN.LB.
FERMENTATION SECTION				
Receiving, Prep & Sterilization	0.60		$20.35	$0.113
Air Compression & Aeration	0.60		0.00	0.000
Fermentation	0.89-1.00		117.07	0.652
Extraction			7.16	0.040
Product/Cell Separation	0.75		7.74	0.043
Fermentation Sub-total			$152.32	$0.849
DISTILLATION SECTION	STILLS	HX'S		
Beer Still #1	$0.29	$1.07	$1.36	$0.008
Beer Still #2	0.18	0.18	0.37	0.002
Low-Boilers Still #1	0.11	0.09	0.20	0.001
Low-Boilers Still #2	0.18	0.07	0.25	0.001
Low-Boilers Still #3	0.00	0.00	0.00	0.000
High-Boilers Still #1	0.82	0.30	1.12	0.006
Distillation Subtotal			$3.29	$0.02
STORAGE SECTION				
Storage - Product			$3.45	$0.019
Storage - Byproduct #1			$0.21	0.001
Storage Subtotal			$3.66	$0.02
TOTAL DIRECT PLANT			$159.27	$0.888

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
NO RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY

INVESTMENT

ALLOCATED PERMANENT INVESTMENT

	UNITS	API/UNIT BASECASE	API/UNIT THIS CASE	UNITS	$MM	$/ANN.LB.
ELECTRICITY	KW	$183	$183	8,815	$1.61	$0.009
STEAM	PPH	$45	$45	214,445	9.65	0.054
COOLING WATER	GPM	$52	$52	7,126	0.37	0.002
PROCESS WATER	GPM	$313	$313	3331	1.04	0.006
WASTE DISPOSAL	MGPY	$3	$3	*********	4.59	0.026
GEN'L & SERVICES	$MM	10%	10%	$176.5	17.65	0.098
TOTAL ALLOCATED PLANT					$34.92	$0.195

TOTAL PERMANENT INVESTMENT $194.19 $1.082

WORKING CAPITAL

	BASIS	DAYS BASECASE	DAYS THIS CASE	$MM	$/ANN. LB.
RAW MAT'L INVENTORY	$RAW MATL	2	2	$0.29	$0.002
SEMI-FINISHED PRODUCT	$(R+M)/2	5	5	0.89	0.005
FINISHED PRODUCT	$COM	30	30	6.89	0.038
CASH	$(COS-D)	6	6	1.49	0.008
ACCOUNTS RCD.-TRADE	$SP	30	30	13.93	0.078
ACCOUNTS RCD.-MISC.	%COM	0.9%	0.9%	0.75	0.004
DEFERRED CHARGES	%COM	1.5%	1.5%	1.26	0.007
TOTAL WORKING CAPITAL				$25.51	$0.142

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

TOTAL INVESTMENT FOR RETURN $219.69 $1.225

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
NO RECOVERY OF RAFFINATE
BASECASE STOICHIOMETRY

1988 COST SHEET	RATE	/UNIT	MILLION UNITS	$MILLION	$/lb.
Raw Materials					
-Biosugar Syrup	$0.065	/lb. d.s.	701.02	45.57	0.282
-Anhyd. Ammonia	$0.046	/lb.	1.70	0.08	.000
-Phosphoric Acid	$0.155	/lb.	1.42	0.22	0.001
-Potassium Chloride	$0.053	/lb.	1.08	0.06	.000
-Minor Nutrients	$0.451	/lb.	0.49	0.22	0.001
Total Raw Materials				$46.14	$0.286
Utilities					
-Electricity	$0.040	/KWH	62.83	2.54	0.016
-Steam	$2.20	/M lb.	1.5286	3.36	0.021
-Cooling Water	$0.04	/M gal.	3.05	0.12	0.001
-Process Water	$0.50	/M gal.	1.42	0.71	0.004
-Biodegradation	$0.04	/lb. d.s.	131.10	5.24	0.032
-Landfill	$0.05	/lb. d.s.	0.00	0.00	0.000
Total Utilities				$11.98	$0.074
Labor-Related					
-Dir. Op. Wages & Ben.	$26.40	/man-hr.	0.117	3.08	0.019
-Dir. Salaries & Ben.	18	% DOW&B		0.56	0.003
-Op. Supplies & Service	6	% DOW&B		0.19	0.001
-GPOH on Operations	23	% DOWS&B		0.84	0.005
-Control Lab	$19.22	/man-hr.	0.020	0.39	0.002
-Tech. Assist. to Mfg.	$22.06	/man-hr.	0.002	0.04	.000
Total Labor				$5.09	$0.032
Capital-Related					
-Maint. Wages & Ben.	1.7	% DPI	$159.3	2.71	0.017
-Maint. Salaries & Ben.	25	% MW&B		0.68	0.004
-Maint. Mat'l & Service	40	% MW&B		1.08	0.007
-Maint. Overhead	4	% MW&B		0.11	0.001
-GPOH on Maintenance	23	% MWS&B		0.78	0.005
-Taxes & Insurance	0.3	% DPI	$159.3	0.48	0.003
-Depreciation - DPI	8	% DPI	$159.3	12.74	0.079
-Depreciation - APS&G	6	% APS&G	$34.8	2.09	0.013
Total Capital				$20.67	$0.128
Cost of Manufacture				$83.88	$0.519
-Selling Expense	3	% Sales	$169.5	5.08	0.031
-Distribution	$0.01	/lb.	161.5	1.61	0.010
-Research & Development	5	% Sales	$169.5	7.63	0.047
-Administrative Expense	2	% Sales	$169.5	3.38	0.021
-Incentive Compensation	6	% PTE	$65.9	3.95	0.024
Cost of Sales				$105.48	$0.654
-Pretax Earnings	30.0	% TIFR	$219.7	65.90	0.408
-Credit: Byproduct #1	$0.27	/lb.	7.1	(1.92)	(0.012)
Total Sales				$169.46	$1.050

APPENDIX E. GOAL STOICHIOMETRY WITH 27:1 RAFFINATE/CELLS RECYCLE

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
GOAL STOICHIOMETRY
SUMMARY

	PRODUCTION LEVEL 162 MM PPY
INVESTMENT-$MILLION	
MPC = 1984	
Direct Permanent Investment	$20.1
Allocated Power, Services & General	$8.2
Working Capital	$10.1
Total Investment	$38.4
COST-$/LB (1988)	
Raw Materials	$0.17
Utilities	$0.02
Labor-Related	$0.03
Capital-Related	$0.02
Cost of Manufacture	$0.24
SE, D, R&D, Adm, & I.C.	$0.05
Cost of Sales	$0.28
Pretax Earnings Based on: 30% Pretax ROI	$0.07
By-product Credit	($.00)
Selling Price	$0.35
FINANCIAL CRITERIA	
Net ROI 3rd Year (assumed)	16%
Investors Rate of Return (20 Operating Years)	18%
Year to Break Even - Annual Cash	1987
- Cumulative Cash	1991
- Cum. Disc. Cash (NPV)	1994
Net Present Value $MM (20 years @ 12%)	$16.0

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL WITH RECOVERY OF RAFFINATE GOAL STOICHIOMETRY

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 PPY	180.3
MID-POINT OF CONSTRUCTION	YEAR	1984
CONSTRUCTION COST INDEX	1980=100	128
INVESTMENT CONTINGENCY	% INSTALLED *	30%
FERMENTER UNIT INVESTMENT	$/GR.GAL.-GROWTH	$13.72
	$/GR.GAL.-PROD'N	$10.94

*40% Recommended for new processes

DIRECT PERMANENT INVESTMENT

	SCALE FACTOR		THIS CASE $MM	$/ANN.LB.
FERMENTATION SECTION				
Receiving, Prep & Sterilization	0.60		$2.81	$0.016
Air Compression & Aeration	0.60		0.00	0.000
Fermentation	0.80-1.00		7.48	0.041
Extraction			4.24	0.024
Product/Cell Separation	0.75		0.65	0.004
Fermentation Sub-total			$15.18	$0.084
DISTILLATION SECTION	STILLS	HX'S		
Beer Still #1	$0.28	$0.85	$1.13	$0.006
Beer Still #2	0.18	0.20	0.38	0.002
Low-Boilers Still #1	0.00	0.00	0.00	0.000
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
Raffinate Still #1	0.00	0.00	0.00	0.000
Raffinate Still #2	0.00	0.00	0.00	0.000
Raffinate Still #3	0.00	0.00	0.00	0.000
Distillation Subtotal			$1.50	$0.01
STORAGE SECTION				
Storage - Butanol			$3.44	$0.019
Storage - Acetone			$0.00	0.000
Storage - Ethanol			$.00	.000
Storage Subtotal			$3.44	$0.02
TOTAL DIRECT PLANT			$20.12	$0.112

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL WITH RECOVERY OF RAFFINATE GOAL STOICHIOMETRY

INVESTMENT

ALLOCATED PERMANENT INVESTMENT

	UNITS	API/UNIT BASECASE	API/UNIT THIS CASE	UNITS	$MM	$/ANN.LB.
ELECTRICITY	KW	$183	$183	1,160	$0.21	$0.001
STEAM	PPH	$45	$45	110,722	4.98	0.028
COOLING WATER	GPM	$52	$52	3,900	0.20	0.001
PROCESS WATER	GPM	$313	$313	12	.00	.000
WASTE DISPOSAL	MGPY	$3	$3	67,751	0.18	0.001
GEN'L & SERVICES	$MM	10%	10%	$25.7	2.57	0.014
TOTAL ALLOCATED PLANT					$8.16	$0.045
TOTAL PERMANENT INVESTMENT					$28.28	$0.157

WORKING CAPITAL

	BASIS	DAYS BASECASE	DAYS THIS CASE	$MM	$/ANN. LB.
RAW MAT'L INVENTORY	$RAW MATL	2	2	$0.17	$0.001
SEMI-FINISHED PRODUCT	$(R+M)/2	5	5	0.45	0.003
FINISHED PRODUCT	$COM	30	30	3.14	0.017
CASH	$(COS-D)	6	6	0.72	0.004
ACCOUNTS RCD.-TRADE	$SP	30	30	4.73	0.026
ACCOUNTS RCD.-MISC.	%COM	0.9%	0.9%	0.34	0.002
DEFERRED CHARGES	%COM	1.5%	1.5%	0.57	0.003
TOTAL WORKING CAPITAL				$10.13	$0.056

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

TOTAL INVESTMENT FOR RETURN	$38.41	$0.213

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
GOAL STOICHIOMETRY

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	--	5 % Sales
-Administrative Expense	2 % Sales	--	2 % Sales
-Incentive Compensation	6 % PTE	--	6 % PTE
Cost of Sales			
-Pretax Earnings	30 % TIFR	--	30 % TIFR
-Credit: Acetone	$0.27 /lb.	1.00	$0.27 /lb.
-Credit: Ethanol	$0.29 /lb.	1.00	$0.29 /lb.
-Product Selling Price	$0.00 /lb.	1.00	$0.00 /lb.

SALARIES & WAGES

	250 MM PPY DAY SHIFT	250 MM PPY ROTATING SHIFTS	MIN. FORCE DAY SHIFT	MIN. FORCE ROTATING SHIFTS
DIRECT OPERATORS				
SYRUP RECEIVING & TRANSFER	1	-	1	-
CHEMICALS RECEIVING & TRANSFER	3	-		-
INNOCULUM PREPARATION	1	-	1	-
MEDIUM PREPARATION	-	1	1	-
STERILIZATION	-	1		-
FERMENTATION & EXTRACTION				
-CONTROL ROOM	-	2	-	1
-PATROL	-	2	-	1
-AIR COMPRESSION & AMMONIA FEED	-	1	-	1
-TURNAROUND	-	3	-	1
BEER FILTER & CELL RECYCLE	-	2	-	1
DISTILLATION	-	2	-	1
TOTAL DAY & 4.2-SHIFT OPS	5	14	3	6
TOTAL OPERATORS	84		28	
CONTROL LABORATORY				
BIOLOGICAL ANALYSIS	-	1	-	1
CHEMICAL ANALYSIS	-	1	-	1
OTHER	-	-	-	-
TOTAL DAY & 4.2-SHIFT TECHS	0	8	0	8
w/ SUPERVISION @ 20%	0.0	10.1	0.0	10.1
TOTAL LAB FORCE	10.1		10.1	
TECHNICAL ASSISTANCE TO MANUFACTURING				
PROCESS ENGINEERS	1	-	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%

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
GOAL STOICHIOMETRY

1988 COST SHEET	RATE	/UNIT	MILLION UNITS	$MILLION	$/lb.
Raw Materials					
-Biosugar Syrup	$0.065	/lb. d.s.	418.96	27.23	0.168
-Anhyd. Ammonia	$0.046	/lb.	1.01	0.05	.000
-Phosphoric Acid	$0.155	/lb.	0.84	0.13	0.001
-Potassium Chloride	$0.053	/lb.	0.64	0.03	.000
-Minor Nutrients	$0.451	/lb.	0.29	0.13	0.001
Total Raw Materials				$27.58	$0.170
Utilities					
-Electricity	$0.040	/KWH	8.27	0.33	0.002
-Steam	$2.20	/M lb.	0.79	1.74	0.011
-Cooling Water	$0.04	/M gal.	1.67	0.07	.000
-Process Water	$0.50	/M gal.	0.01	.00	.000
-Biodegradation	$0.04	/lb. d.s.	14.64	0.59	0.004
-Landfill	$0.05	/lb. d.s.	0.00	0.00	0.000
Total Utilities				$2.73	$0.017
Labor-Related					
-Dir. Op. Wages & Ben.	$26.40	/man-hr.	0.117	3.09	0.019
-Dir. Salaries & Ben.	18	% DOW&B		0.56	0.003
-Op. Supplies & Service	6	% DOW&B		0.19	0.001
-GPOH on Operations	23	% DOWS&B		0.84	0.005
-Control Lab	$18.22	/man-hr.	0.020	0.38	0.002
-Tech. Assist. to Mfg.	$22.06	/man-hr.	0.002	0.04	.000
Total Labor				$5.10	$0.031
Capital-Related					
-Maint. Wages & Ben.	1.7	% DPI	$20.1	0.34	0.002
-Maint. Salaries & Ben.	25	% MW&B		0.09	0.001
-Maint. Mat'l & Service	40	% MW&B		0.14	0.001
-Maint. Overhead	4	% MW&B		0.01	.000
-GPOH on Maintenance	23	% MWS&B		0.10	0.001
-Taxes & Insurance	0.3	% DPI	$20.1	0.06	.000
-Depreciation - DPI	8	% DPI	$20.1	1.61	0.010
-Depreciation - APS&G	6	% APS&G	$8.2	0.49	0.003
Total Capital				$2.84	$0.017
Cost of Manufacture				$38.24	$0.236
-Selling Expense	3	% Sales	$57.5	1.73	0.011
-Distribution	$0.01	/lb.	162.3	1.62	0.010
-Research & Development	5	% Sales	$57.5	2.59	0.016
-Administrative Expense	2	% Sales	$57.5	1.15	0.007
-Incentive Compensation	6	% PTE	$11.5	0.69	0.004
Cost of Sales				$46.01	$0.284
-Pretax Earnings	30.0	% TIFR	$38.4	11.51	0.071
-Credit: Acetone	$0.27	/lb.	0.0	0.00	0.000
-Credit: Ethanol	$0.29	/lb.	.0	(.00)	(.000)
Total Sales				$57.52	$0.355

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL WITH RECOVERY OF RAFFINATE GOAL STOICHIOMETRY

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%). Tax: 34% federal, 3% state.
7. Note that the cash flow analysis has meaning only if the product can be sold at the price indicated on the cost sheet.

YEAR	INVESTMENT PI	INVESTMENT WC	DEP.	COST EX D	SALES	NET EARN	ANN CASH
1983	$6.71						($6.71)
1984	$6.71						($6.71)
1985	$6.71	$10.13					($16.84)
1986			$4.02	$25.02	$28.76	($0.18)	($6.29)
1987			$6.44	$35.89	$43.14	$0.51	$6.35
1988			$3.86	$43.91	$57.52	$6.14	$10.00
1989			$2.31	$43.91	$57.52	$7.11	$9.43
1990			$2.31	$43.91	$57.52	$7.11	$9.43
1991			$1.17	$43.91	$57.52	$7.84	$9.00
1992				$43.91	$57.52	$8.57	$8.57
1993				$43.91	$57.52	$8.57	$8.57
1994				$43.91	$57.52	$8.57	$8.57
1995				$43.91	$57.52	$8.57	$8.57
1996				$43.91	$57.52	$8.57	$8.57
1997				$43.91	$57.52	$8.57	$8.57
1998				$43.91	$57.52	$8.57	$8.57
1999				$43.91	$57.52	$8.57	$8.57
2000				$43.91	$57.52	$8.57	$8.57
2001				$43.91	$57.52	$8.57	$8.57
2002				$43.91	$57.52	$8.57	$8.57
2003				$43.91	$57.52	$8.57	$8.57
2004				$43.91	$57.52	$8.57	$8.57
2005		($10.13)		$43.91	$57.52	$8.57	$18.70

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

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
GOAL STOICHIOMETRY

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%). Tax: 34% federal, 3% state.
7. Note that the cash flow analysis has meaning only if the
product can be sold at the price indicated on the cost sheet.

YEAR	CUM CASH	NPV @ 12%	%IRR
1983	($6.71)	($6.71)	--
1984	($13.42)	($12.70)	--
1985	($30.25)	($26.12)	--
1986	($36.54)	($30.60)	-141.3%
1987	($29.59)	($25.18)	-55.6%
1988	($19.59)	($20.50)	-23.4%
1989	($10.16)	($15.73)	-9.0%
1990	($0.74)	($11.46)	-0.5%
1991	$8.27	($7.83)	4.7%
1992	$16.84	($4.74)	8.1%
1993	$25.41	($1.98)	10.5%
1994	$33.98	$0.48	12.3%
1995	$42.55	$2.69	13.7%
1996	$51.12	$4.65	14.7%
1997	$59.69	$6.41	15.4%
1998	$68.27	$7.97	16.0%
1999	$76.84	$9.37	16.5%
2000	$85.41	$10.62	16.9%
2001	$93.98	$11.73	17.2%
2002	$102.55	$12.73	17.5%
2003	$111.12	$13.62	17.7%
2004	$119.69	$14.41	17.8%
2005	$138.39	$15.36	18.1%

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL WITH RECOVERY OF RAFFINATE GOAL STOICHIOMETRY

BASIC DATA

SCALE OF OPERATION

162.25	MM PPY	ANNUAL PRODUCTION LEVEL
180.28	MM PPY	ANNUAL CAPACITY
90	%	OPERATING UTILITY
163.26	MM PPY	PRODUCT IN BEER
181.40	MM PPY	PRODUCT IN BEER AT CAPACITY
95.0	%	MOLAR YIELD-GLUC. TO PROD. IN BEER (E
2.56	lb/lb	GLUCOSE DEMAND/PROD (EXCL. SPILL)
74.12	MOL WT	PRODUCT MOLECULAR WEIGHT

PRODUCT STOICHIOMETRY

MOL. WT.	MOLES/MOL PRODUCT	COMPONENT
180.16	1.00000 /MOL PROD.	-GLUCOSE CONSUMED
32.00	0.00000 /MOL PROD.	-OXYGEN CONSUMED
17.02	0.00000 /MOL PROD.	-AMMONIA CONSUMED
.00	0.00000 /MOL PROD.	-COMPONENT #1 FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #2 FORMED
58.08	0.00000 /MOL PROD.	-COMPONENT #3 FORMED (ACETONE)
.00	0.00000 /MOL PROD.	-COMPONENT #4 FORMED
46.07	0.00000 /MOL PROD.	-COMPONENT #5 FORMED (ETHANOL)
.00	0.00000 /MOL PROD.	-COMPONENT #6 FORMED
74.12	1.00000 /MOL PROD.	-COMPONENT #7 FORMED (BUTANOL)
60.05	0.00000 /MOL PROD.	-COMPONENT #8 FORMED (ACETIC ACID)
.00	0.00000 /MOL PROD.	-COMPONENT #9 FORMED
88.10	0.00000 /MOL PROD.	-COMPONENT #10 FORMED (BUTYRIC ACID
18.02	1.00000 /MOL PROD.	-WATER FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #11 FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #12 FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #13 FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #14 FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #15 FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #16 FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #17 FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #18 FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #19 FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #20 FORMED
44.01	2.00000 /MOL PROD.	-CARBON DIOXIDE FORMED
2.02	0.00000 /MOL PROD.	-HYDROGEN FORMED

NUTRIENTS IN FERMENTER FEED

8	%	-N IN CELLS AS %CHO
80.9	mg/g cells	-H3PO4
61.6	mg/g cells	-KCl
27.8	mg/g cells	-MINOR NUTRIENTS

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
GOAL STOICHIOMETRY

BASIC DATA

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	1 (0 OR 1)	-CONCUR'NT (0) OR SEQUENT'AL (1)
CONDITIONS		

STAGE: GROWTH	PRODUCTION		
33	33	C	-TEMPERATURE
6.5	6.5		-pH
0	13	g/l	-PRODUCT CONCENTRATION IN BEER
22.7	21.2	g/l	-CELL DENSITY (CHO ONLY)
0.280	0.461	1/hr	-DILUTION RATE
			-PRODUCT PRODUCTIVITY
0.00	0.283	g/g*hr	*Specific Productivity
0.00	5.99	g/l*hr	*Volumetric Productivity
6.35	0.00	g/l*hr	-CELL PRODUCTIVITY (CHO ONLY)
221	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
276.56	22.60	Btu/hr*gal	-HEAT REMOVED BY COOLING COILS

FERMENTERS

27,686	458,989	gallons	-ACTIVE VOLUME REQUIRED
15	15	% gross	-HEADSPACE
38,320	635,279	gallons	-GROSS VOLUME (incl. 15% spares and
100,000	250,000	gallons	-GROSS SIZE
0.4	2.5	units	-NUMBER OF UNITS

PRODUCT SEPARATION

400	g/l	-CELL CONC. (CHO) EX FILTER
0.053	gal/min*sf	-FILTER THROUGHPUT
2,489	sq ft	-FILTER SIZE

PRODUCT RECOVERY & PURIFICATION

98.4%(wt)%	-YIELD ACROSS REFINING

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL WITH RECOVERY OF RAFFINATE GOAL STOICHIOMETRY

BASIC DATA

MATERIALS OF CONSTRUCTION

	CHOICES	SELECTION
FERMENTERS & EXTRACTERS	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 Market Price for: 1988 (Year) /lb.

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

VENTURE TIMING

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

EXTRACTION

Solvent	Oleyl Alcohol CH3(CH2)7CH=CH(CH2)7CH2OH	
Solvent Molecular Weight	268.5	
Solvent Ratio, r	0.30	lb/lb water in feed
Mutual Solubilities		
Water in Solvent, w	0.000020	lb/lb solvent
Solvent in Water, s	0.000020	lb/lb water
(1+s)/(1+w)	1.00000	
Gamma	-0.70000	
Water in Solvent Feed, m	0.000000	lb./lb solvent
Solvent in Aqueous Feed	0.000019	lb/lb water in feed
Raffinate Recycle	27.0	lb raffinate water/lb water in fermenter feed
Solvent/Water Balances		
Extract - Solvent	0.30000	lb/lb water in feed
- Water	0.00001	lb/lb water in feed
Raffinate - Water	0.99999	lb/lb water in feed
- Solvent	0.00002	lb/lb water in feed

Solute Distribution

	Phi	K	Extract	Raffinate

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL WITH RECOVERY OF RAFFINATE GOAL STOICHIOMETRY

BASIC DATA

Component #1	0.038	0.00	0.000	1.000 lb/lb in beer
Component #2	0.038	0.00	0.000	1.000 lb/lb in beer
Component #3	0.178	0.50	0.146	0.854 lb/lb in beer
Component #4	0.038	0.00	0.000	1.000 lb/lb in beer
Component #5	0.094	0.20	0.058	0.942 lb/lb in beer
Component #6	0.038	0.00	0.000	1.000 lb/lb in beer
Component #7P	0.971	4.30	0.9700	0.030 lb/lb in beer
Component #8	0.094	0.20	0.058	0.942 lb/lb in beer
Component #9	0.038	0.00	0.000	1.000 lb/lb in beer
Component #10	0.094	0.20	0.058	0.942 lb/lb in beer
Component #11	0.038	0.00	0.000	1.000 lb/lb in beer
Component #12	0.038	0.00	0.000	1.000 lb/lb in beer
Component #13	0.038	0.00	0.000	1.000 lb/lb in beer
Component #14	0.038	0.00	0.000	1.000 lb/lb in beer
Component #15	0.038	0.00	0.000	1.000 lb/lb in beer
Component #16	0.038	0.00	0.000	1.000 lb/lb in beer
Component #17	0.038	0.00	0.000	1.000 lb/lb in beer
Component #18	0.038	0.00	0.000	1.000 lb/lb in beer
Component #19	0.038	0.00	0.000	1.000 lb/lb in beer
Component #20	0.038	0.00	0.000	1.000 lb/lb in beer
Reactants	0.038	0.00	0.000	1.000 lb/lb in beer

	1	2
EXTRACTOR DESIGN		
Density - Raffinate, g/ml		0.9993
" - Extract, g,ml		0.0327
Capacity Factor		6000
CS Area/Extractor, sq ft		101
Number of Extractors		4
Extractor Diameter, ft		11.4
Theoretical Stages		9
Extractor Height, ft		27
Extractors Cost - $1000 3Q86 MPC - Bare Equipment		
-All Carbon Steel		$1,020.3
-All 304 Stainless Steel		$1,434.4

Stage to stage balances: Basis: lb/lb water in feed

Stage	Feed	0.03000 1	0.27806 2	0.47036 3	0.61342 4
Extract					
-Solvent		0.30000	0.30000	0.30000	0.30000
-Water		0.00001	0.00001	0.00001	0.00001
-Total		0.30001	0.30001	0.30001	0.30001
Raffinate					
-Solvent	0.00002	0.00002	0.00002	0.00002	0.00002
-Water	1.00000	1.00000	1.00000	1.00000	1.00000
-Total	1.00002	1.00002	1.00002	1.00002	1.00002

Product Partition: Basis: lb/lb solute in feed

Based on fixed yield = 97.00%

Solvent/Feed Ratio, r = 0.30

K = 4.30 ;stages= 9

Extract		0.97000	0.72194	0.52964	0.38058
Raffinate	1.00000	0.75194	0.55964	0.41058	0.29502

0.73498	0.82456	0.88400	0.94783	0.98956	1.02190	1.04698	1.06642
5	6	7	8	9	10	11	12
0.30000	0.30000	0.30000	0.30000	0.30000	0.30000	0.30000	0.30000
0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
0.30001	0.30001	0.30001	0.30001	0.30001	0.30001	0.30001	0.30001
0.00002	0.00002	0.00002	0.00002	0.00002	0.00002	0.00002	0.00002
1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
1.00002	1.00002	1.00002	1.00002	1.00002	1.00002	1.00002	1.00002
0.26502	0.17544	0.10600	0.05217	0.01044	-0.02190	-0.04698	********
0.20544	0.13600	0.08217	0.04044	0.00810	-0.01698	-0.03642	********

1.08149	1.09317	1.10222	1.10924	1.11468	1.11890	1.12217	1.12471
13	14	15	16	17	18	19	20
0.30000	0.30000	0.30000	0.30000	0.30000	0.30000	0.30000	0.30000
0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
0.30001	0.30001	0.30001	0.30001	0.30001	0.30001	0.30001	0.30001
0.00002	0.00002	0.00002	0.00002	0.00002	0.00002	0.00002	0.00002
1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.99999
1.00002	1.00002	1.00002	1.00002	1.00002	1.00002	1.00002	1.00001

-0.08149	-0.09317	-0.10222	-0.10924	-0.11468	-0.11890	-0.12217	-0.12471
-0.06317	-0.07222	-0.07924	-0.08468	-0.08890	-0.09217	-0.09471	-0.09667

Solvent
0.30000
0.00000
0.30000

-0.12667

LOOK-UP TABLE: YIELD TO EXTRACT - % For K=0.2

		S/F Ratio:				
	Stages	0.25	0.30	0.35	0.40	0.45
	1	4.5%	5.4%	6.3%	7.2%	8.0%
	2	4.7%	5.7%	6.7%	7.7%	8.7%
	3	4.8%	5.8%	6.8%	7.8%	8.8%
	4	4.8%	5.8%	6.8%	7.8%	8.8%
	5	4.8%	5.8%	6.8%	7.8%	8.8%
	6	4.8%	5.8%	6.8%	7.8%	8.8%
	7	4.8%	5.8%	6.8%	7.8%	8.8%
	8	4.8%	5.8%	6.8%	7.8%	8.8%
	9	4.8%	5.8%	6.8%	7.8%	8.8%
	10	4.8%	5.8%	6.8%	7.8%	8.8%
	11	4.8%	5.8%	6.8%	7.8%	8.8%
	12	4.8%	5.8%	6.8%	7.8%	8.8%
	13	4.8%	5.8%	6.8%	7.8%	8.8%
Density, g	14	4.8%	5.8%	6.8%	7.8%	8.8%
	15	4.8%	5.8%	6.8%	7.8%	8.8%
	16	4.8%	5.8%	6.8%	7.8%	8.8%
0.7920	17	4.8%	5.8%	6.8%	7.8%	8.8%
	18	4.8%	5.8%	6.8%	7.8%	8.8%
0.7893	19	4.8%	5.8%	6.8%	7.8%	8.8%
	20	4.8%	5.8%	6.8%	7.8%	8.8%

0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00
8.9%	16.0%	22.0%	28.3%	33.1%	37.4%	41.1%	44.3%
9.7%	19.1%	27.0%	35.8%	42.7%	48.8%	54.2%	58.9%
9.8%	19.5%	27.0%	38.3%	46.6%	53.9%	60.4%	66.1%
9.8%	19.8%	29.6%	38.2%	48.2%	56.5%	63.8%	70.1%
9.8%	19.8%	29.8%	39.6%	49.1%	57.9%	65.9%	72.8%
9.8%	19.8%	29.8%	39.7%	49.5%	58.8%	67.2%	74.6%
9.8%	19.8%	29.9%	39.8%	49.7%	59.2%	68.1%	76.0%
9.8%	19.8%	29.8%	39.9%	49.8%	59.5%	68.6%	76.8%
9.8%	19.8%	29.9%	39.9%	49.8%	59.6%	69.1%	77.6%
9.8%	19.8%	29.8%	39.9%	49.8%	59.7%	69.3%	78.0%
9.8%	19.8%	29.9%	39.9%	49.8%	59.8%	69.5%	78.4%
9.8%	19.8%	29.8%	39.9%	49.8%	59.9%	69.6%	78.7%
9.8%	19.8%	29.9%	39.9%	49.8%	59.9%	69.7%	79.0%
9.8%	19.8%	29.9%	39.9%	49.8%	59.9%	69.8%	79.2%
9.8%	19.8%	29.9%	39.9%	49.8%	59.9%	69.8%	79.3%
9.8%	19.8%	29.9%	39.9%	49.8%	59.9%	69.9%	79.4%
9.8%	19.8%	29.8%	39.9%	49.8%	59.9%	69.9%	79.5%
9.8%	19.8%	29.9%	39.9%	49.8%	59.9%	69.9%	79.6%
9.8%	19.8%	29.9%	39.9%	49.8%	59.9%	69.9%	79.7%
9.8%	19.8%	29.9%	39.9%	49.8%	59.9%	69.9%	79.8%

4.50	5.00
47.3%	49.9%
63.1%	66.6%
70.8%	74.9%
75.6%	79.9%
78.6%	83.3%
80.7%	85.6%
82.4%	87.4%
83.6%	88.8%
84.6%	89.9%
85.3%	90.8%
86.0%	91.6%
86.5%	92.2%
87.0%	92.8%
87.3%	93.3%
87.7%	93.7%
87.9%	94.1%
88.2%	94.4%
88.4%	94.7%
88.5%	94.9%
88.5%	95.1%

LOOK-UP TABLE: YIELD TO EXTRACT - % For K=0.5

Stages	S/F Ratio: 0.25	0.30	0.35	0.40	0.45	0.50	1.00
1	10.0%	12.5%	14.5%	16.0%	18.0%	19.0%	33.0%
2	11.0%	14.0%	16.0%	18.0%	21.0%	24.0%	42.0%
3	12.0%	14.5%	17.0%	19.0%	22.0%	25.0%	43.0%
4	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	48.0%
5	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	48.5%
6	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.0%
7	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.5%
8	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.6%
9	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.7%
10	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.7%
11	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.7%
12	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.7%
13	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.7%
14	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.7%
15	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.7%
16	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.7%
17	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.7%
18	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.7%
19	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.7%
20	12.0%	14.6%	17.1%	20.0%	23.0%	25.0%	49.7%

1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00
42.0%	49.0%	55.3%	59.5%	63.0%	66.0%	69.0%	71.0%
56.0%	66.0%	73.0%	78.0%	82.0%	85.0%	87.0%	89.0%
65.0%	74.9%	82.0%	87.0%	91.0%	93.0%	94.0%	96.0%
67.0%	78.0%	87.5%	92.3%	95.1%	97.0%	97.7%	98.4%
69.0%	83.0%	91.0%	95.0%	97.0%	98.3%	99.1%	99.3%
71.0%	85.0%	93.2%	96.0%	98.4%	99.2%	99.5%	99.7%
71.5%	87.0%	94.9%	97.0%	99.0%	99.6%	99.8%	99.9%
72.5%	88.0%	96.0%	98.0%	99.5%	99.8%	99.9%	100.0%
73.0%	89.0%	96.5%	99.1%	99.7%	99.9%	100.0%	100.0%
73.5%	90.0%	97.0%	99.5%	99.8%	100.0%	100.0%	100.0%
74.0%	91.0%	98.0%	99.6%	99.9%	100.0%	100.0%	100.0%
74.2%	92.0%	98.5%	99.7%	99.9%	100.0%	100.0%	100.0%
74.3%	92.5%	98.7%	99.8%	100.0%	100.0%	100.0%	100.0%
74.5%	93.0%	99.0%	99.9%	100.0%	100.0%	100.0%	100.0%
74.6%	93.5%	99.2%	99.9%	100.0%	100.0%	100.0%	100.0%
74.6%	94.0%	99.4%	99.9%	100.0%	100.0%	100.0%	100.0%
74.7%	94.2%	99.5%	99.9%	100.0%	100.0%	100.0%	100.0%
74.7%	94.5%	99.6%	99.9%	100.0%	100.0%	100.0%	100.0%
74.7%	95.0%	99.7%	99.9%	100.0%	100.0%	100.0%	100.0%
74.8%	95.0%	99.8%	99.9%	100.0%	100.0%	100.0%	100.0%

DISTILLATION DATA MATRIX

ITEM	COMPONENT	DEFAULT VALUE	IMPURITY #1	IMPURITY #2	LOWER BOIL PRODUCT #3
1	NAME		NONE	NONE	ACETONE
2	PRIORITY AS REFINED PRODUCT	LIST 1-4			2
3					
4	NORMAL BOILING PT, C				56.5
5	LOSS/COLUMN, WT %	0.50			
6	LEVEL AS IMPURITY, WT%	0.20			
7	VAP PRESS TEMP, C	900			-9.4
8	VAPOR PRESS, mm Hg	800000			40.0
9	HT VAPORIZATION, Btu/lb	215.0			
10	SENSIBLE HT (LIQ), Btu/(lb)(F)	0.50			
11	MAX THERMAL STABILITY, C	225			
12	LN(ACTIVITY COEFFICIENTS)				
13	-COMP. #1 in:	*	XXXX		
14	-COMP. #2 in:	*		XXXX	
15	-COMP. #3 in:	*			XXXX
16	-COMP. #4 in:	*			
17	-COMP. #5 in:	*			0.400
18	-COMP. #6 in:	*			
19	-COMP. #7 in:	*			0.400
20	-COMP. #8 in:	*			0.700
21	-COMP. #9 in:	*			
22	-COMP. #10 in:	*			0.650
23	-SOLVENT in:	*			1.100
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:	*			
34	-WATER in:	*	0.600	0.600	0.600

* 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	-2476.10	-3880.77
35	A(n) VAPOR PRESSURE CONST.	15.703	15.703	18.411
36	VAPOR PRESSURE @40 C	2422.2	2422.2	408.5
37	VAPOR PRESSURE @120 C	12121.9	12121.9	5096.7

DISTILLATION DATA MATRIX

ITEM	COMPONENT	IMPURITY #4	IMPURITY #5	IMPURITY #6	LOW BOIL PRODUCT #7
1	NAME	NONE	ETHANOL	NONE	BUTANOL
2	PRIORITY AS REFINED PRODUCT				1
3					
4	NORMAL BOILING PT, C		78.4		117.5
5	LOSS/COLUMN, WT %				
6	LEVEL AS IMPURITY, WT%				
7	VAP PRESS TEMP, C		19.0		53.4
8	VAPOR PRESS, mm Hg		40.0		40.0
9	HT VAPORIZATION, Btu/lb				
10	SENSIBLE HT (LIQ), Btu/(lb)(F)				
11	MAX THERMAL STABILITY, C				
12	LN(ACTIVITY COEFFICIENTS)				
13	-COMP. #1 in:				
14	-COMP. #2 in:				
15	-COMP. #3 in:		0.400		0.400
16	-COMP. #4 in:	XXXX			
17	-COMP. #5 in:		XXXX		0.300
18	-COMP. #6 in:			XXXX	
19	-COMP. #7 in:		0.300		XXXX
20	-COMP. #8 in:		0.600		0.600
21	-COMP. #9 in:				
22	-COMP. #10 in:		0.500		0.400
23	-SOLVENT in:		1.050		0.700
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:				
34	-WATER in:	0.600	0.600	0.600	0.600

* 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 = 0.5
other organic/water = 1.0

34	B(n) VAPOR PRESSURE CONST.	-2476.10	-5086.29	-2476.10	-5854.85
35	A(n) VAPOR PRESSURE CONST.	15.703	21.108	15.703	21.627
36	VAPOR PRESSURE @40 C	2422.2	128.7	2422.2	18.6
37	VAPOR PRESSURE @120 C	12121.9	3517.3	12121.9	836.1

DISTILLATION DATA MATRIX

ITEM	COMPONENT	IMPURITY #8	IMPURITY #9	IMPURITY #10	SOLVENT
1	NAME	ACETIC AC	NONE	BUTYRIC ACID	
2	PRIORITY AS REFINED PRODUCT				
3					
4	NORMAL BOILING PT, C	118.1		163.5	213.5
5	LOSS/COLUMN, WT %				
6	LEVEL AS IMPURITY, WT%				
7	VAP PRESS TEMP, C	43.0		88.0	118.0
8	VAPOR PRESS, mm Hg	40.0		40.0	15.0
9	HT VAPORIZATION, Btu/lb				215.0
10	SENSIBLE HT (LIQ), Btu/(lb)(F)				0.50
11	MAX THERMAL STABILITY, C				
12	LN(ACTIVITY COEFFICIENTS)				
13	-COMP. #1 in:				
14	-COMP. #2 in:				
15	-COMP. #3 in:	0.700		0.650	1.100
16	-COMP. #4 in:				
17	-COMP. #5 in:	0.600		0.500	1.050
18	-COMP. #6 in:				
19	-COMP. #7 in:	0.600		0.400	0.700
20	-COMP. #8 in:	xxxx		0.300	0.800
21	-COMP. #9 in:		xxxx		
22	-COMP. #10 in:	0.300		xxxx	0.750
23	-SOLVENT in:	0.800		0.750	xxxx
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:				
34	-WATER in:	0.600	0.600	0.600	0.600

* 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.	-4845.49	-2476.10	-6145.36	-7818.54
35	A(n) VAPOR PRESSURE CONST.	19.023	15.703	20.712	22.704
36	VAPOR PRESSURE @40 C	34.5	2422.2	2.8	0.1
37	VAPOR PRESSURE @120 C	806.9	12121.9	160.0	16.6

DISTILLATION DATA MATRIX

ITEM	COMPONENT	WATER
1	NAME	
2	PRIORITY AS REFINED PRODUCT	
3		
4	NORMAL BOILING PT, C	100.0
5	LOSS/COLUMN, WT %	
6	LEVEL AS IMPURITY, WT%	
7	VAP PRESS TEMP, C	30.0
8	VAPOR PRESS, mm Hg	31.8
9	HT VAPORIZATION, Btu/lb	970.3
10	SENSIBLE HT (LIQ), Btu/(lb)(F)	1.00
11	MAX THERMAL STABILITY, C	
12	LN(ACTIVITY COEFFICIENTS)	
13	-COMP. #1 in:	
14	-COMP. #2 in:	
15	-COMP. #3 in:	0.600
16	-COMP. #4 in:	
17	-COMP. #5 in:	0.600
18	-COMP. #6 in:	
19	-COMP. #7 in:	0.600
20	-COMP. #8 in:	0.600
21	-COMP. #9 in:	
22	-COMP. #10 in:	0.600
23	-SOLVENT 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:	
34	-WATER in:	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

34	B(n) VAPOR PRESSURE CONST.	-5124.37
35	A(n) VAPOR PRESSURE CONST.	20.372
36	VAPOR PRESSURE @40 C	54.6
37	VAPOR PRESSURE @120 C	1529.1

OFTEN USED PARAMETERS

(THOUSAND ANNUAL POUNDS)

181,401	PRODUCT FORMED
	FORMED WITH PRODUCT
0	-COMPONENT #1
0	-COMPONENT #2
0	-COMPONENT #3
0	-COMPONENT #4
0	-COMPONENT #5
0	-COMPONENT #6
181,401	-COMPONENT #7
0	-COMPONENT #8
0	-COMPONENT #9
0	-COMPONENT #10
44,092	-WATER
0	-COMPONENT #11
0	-COMPONENT #12
0	-COMPONENT #13
0	-COMPONENT #14
0	-COMPONENT #15
0	-COMPONENT #16
0	-COMPONENT #17
0	-COMPONENT #18
0	-COMPONENT #19
0	-COMPONENT #20
0	-HYDROGEN
215,420	-CARBON DIOXIDE
	CONSUMED FOR PRODUCT
440,914	-GLUCOSE
0	-AMMONIA
0	-OXYGEN
11,603	CELLS PRODUCED - CHO
1,061	CELLS PRODUCED - NH2
	FORMED WITH CELLS
6,958	-WATER-CHO
597	-WATER-NH2
7,555	-WATER-TOTAL
17,008	-CARBON DIOXIDE-CHO
	CONSUMED FOR CELLS
23,206	-GLUCOSE-CHO
1,127	-AMMONIA-NH2
12,370	-OXYGEN-CHO
530	-OXYGEN-NH2
12,900	-OXYGEN-TOTAL
64,500	OXYGEN FED-GROWTH
213,600	NITROGEN FED-GROWTH
51,600	OXYGEN VENT-GROWTH
213,600	NITROGEN VENT-GROWTH
17,008	CARBON DIOXIDE VENT-GROWTH
8,648	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
215,420	CARBON DIOXIDE VENT-PROD'N
7,767	WATER VENT-PROD'N
223,187	PHI

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL WITH RECOVERY OF RAFFINATE GOAL STOICHIOMETRY

WATER BALANCE

WATER IN:	
MAKE UP WATER	47,443
BIOSUGAR SYRUP	465,515
STERILIZER STEAM	35,445
FORMED WITH CELLS	7,555
FORMED WITH PRODUCT	44,092
TOTAL IN	600,051
WATER OUT:	
AQUEOUS WASTE	519,037
CONDENSATE MAKEUP TO P.H	35,445
FERMENTER VENTS	16,415
PURGED WITH CELLS	29,007
MOISTURE IN PRODUCTS	86
TOTAL OUT	600,051

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
GOAL STOICHIOMETRY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

P	STREAM	1 CORN SYRUP	2 ANHYD AMMONIA	3 NUTRIENTS	4 MIX WATER	5 MIXED MEDIUM
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	COMPONENT #1	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#2	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	COMPONENT #6	0	0	0	0	0
#1	COMPONENT #7	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
	COMPONENT #11	0	0	0	0	0
	COMPONENT #12	0	0	0	0	0
	COMPONENT #13	0	0	0	0	0
#	COMPONENT #14	0	0	0	0	0
	COMPONENT #15	0	0	0	0	0
	COMPONENT #16	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
	COMPONENT #20	0	0	0	0	0
	GLUCOSE	465,515	0	0	0	465,515
	AMMONIA	0	1,127	0	0	0
	PHOSPHORIC ACID	0	0	939	0	939
	POTASSIUM CHLORIDE	0	0	715	0	715
	MINOR NUTRIENTS	0	0	324	0	324
	WATER	465,515	0	0	11,998	477,514
	SOLVENT	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	931,030	1,127	1,978	11,998	945,006
	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

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
GOAL STOICHIOMETRY

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	COMPONENT #1	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#2	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	COMPONENT #6	0	0	0	0	0
#1	COMPONENT #7	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
	COMPONENT #11	0	0	0	0	0
	COMPONENT #12	0	0	0	0	0
	COMPONENT #13	0	0	0	0	0
#	COMPONENT #14	0	0	0	0	0
	COMPONENT #15	0	0	0	0	0
	COMPONENT #16	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
	COMPONENT #20	0	0	0	0	0
	GLUCOSE	465,515	465,515	465,515	465,515	0
	AMMONIA	0	0	0	0	0
	PHOSPHORIC ACID	939	939	939	939	0
	POTASSIUM CHLORIDE	715	715	715	715	0
	MINOR NUTRIENTS	324	324	324	324	0
	WATER	477,514	512,959	512,959	512,959	0
	SOLVENT	0	0	0	0	0
	CARBON DIOXIDE	0	0	0	0	0
	OXYGEN	0	0	0	0	64,500
	NITROGEN	0	0	0	0	213,600
	HYDROGEN	0	0	0	0	0
	GRAND TOTAL	945,006	980,452	980,452	980,452	278,100
	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

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
GOAL STOICHIOMETRY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

P	STREAM	11 COMBINED FEED	12 BEER #1	13 BEER #2	14 VENT GROWTH	15 VENT PROD'N
R	CELLS -CHO	0	11,603	304,171	0	0
O	-NH2	0	1,061	27,810	0	0
D	-MINERALS	0	324	8,500	0	0
U	-TOTAL	0	12,988	340,480	0	0
C	COMPONENT #1	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#2	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	COMPONENT #6	0	0	0	0	0
#1	COMPONENT #7	0	0	186,781	0	0
	COMPONENT #8	0	0	0	0	0
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	0	0	0	0	0
	COMPONENT #11	0	0	0	0	0
	COMPONENT #12	0	0	0	0	0
	COMPONENT #13	0	0	0	0	0
#	COMPONENT #14	0	0	0	0	0
	COMPONENT #15	0	0	0	0	0
	COMPONENT #16	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
	COMPONENT #20	0	0	0	0	0
	GLUCOSE	465,515	442,309	36,580	0	0
	AMMONIA	1,127	0	0	0	0
	PHOSPHORIC ACID	939	939	24,607	0	0
	POTASSIUM CHLORIDE	715	715	18,737	0	0
	MINOR NUTRIENTS	324	0	0	0	0
	WATER	512,959	511,866	14,368,560	8,648	7,767
	SOLVENT	0	0	276	0	0
	CARBON DIOXIDE	0	0	0	17,008	215,420
	OXYGEN	84,500	0	0	51,600	0
	NITROGEN	213,600	0	0	213,600	0
	HYDROGEN	0	0	0	0	0
	GRAND TOTAL	1,259,679	968,816	14,976,032	290,856	223,187
	CHECK ON TOTAL					
	TEMPERATURE, C	33	33	33	33	33
	PRESSURE, PSIA	--	44.7	44.7	14.7	14.7
	STATE	--	SLURRY	SLURRY	GAS	GAS

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
GOAL STOICHIOMETRY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

P	STREAM	16 COMBINED VENT	17 SOLVENT FEED	18 RAFFINATE	19 RECYCLE	20 AQUEOUS PURGE
R	CELLS -CHO	0	0	304,171	292,568	11,603
O	-NH2	0	0	27,810	26,748	1,061
D	-MINERALS	0	0	8,500	8,175	324
U	-TOTAL	0	0	340,480	327,492	12,988
C	COMPONENT #1	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#2	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	COMPONENT #6	0	0	0	0	0
#1	COMPONENT #7	0	0	5,604	5,390	214
	COMPONENT #8	0	0	0	0	0
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	0	0	0	0	0
	COMPONENT #11	0	0	0	0	0
	COMPONENT #12	0	0	0	0	0
	COMPONENT #13	0	0	0	0	0
#	COMPONENT #14	0	0	0	0	0
	COMPONENT #15	0	0	0	0	0
	COMPONENT #16	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
	COMPONENT #20	0	0	0	0	0
	GLUCOSE	0	0	36,580	35,185	1,395
	AMMONIA	0	0	0	0	0
	PHOSPHORIC ACID	0	0	24,607	23,669	939
	POTASSIUM CHLORIDE	0	0	18,737	18,022	715
	MINOR NUTRIENTS	0	0	0	0	0
	WATER	16,415	0	14,368,473	13,820,368	548,105
	SOLVENT	0	4,310,568	287	276	11
	CARBON DIOXIDE	232,428	0	0	0	0
	OXYGEN	51,600	0	0	0	0
	NITROGEN	213,600	0	0	0	0
	HYDROGEN	0	0	0	0	0
	GRAND TOTAL	514,043	4,310,568	14,794,769	14,230,403	564,366
	CHECK ON TOTAL					
	TEMPERATURE, C	33	20			33
	PRESSURE, PSIA	14.7	15			15
	STATE	GAS	LIQUID	SLURRY	SLURRY	SLURRY

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
GOAL STOICHIOMETRY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	21 CELLS TO DISPOSAL	22 FILTRATE TO WASTE	23 EXTRACT	24 BEER #1 FEED	25 BEER #1 MAKE
P						
R	CELLS -CHO	11,503	0	0	0	0
O	-NH2	1,061	0	0	0	0
D	-MINERALS	324	0	0	0	0
U	-TOTAL	12,388	0	0	0	0
C	COMPONENT #1	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#2	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	COMPONENT #6	0	0	0	0	0
#1	COMPONENT #7	11	202	181,188	199,216	198,310
	COMPONENT #8	0	0	0	0	0
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	0	0	0	0	0
	COMPONENT #11	0	0	0	0	0
	COMPONENT #12	0	0	0	0	0
	COMPONENT #13	0	0	0	0	0
#	COMPONENT #14	0	0	0	0	0
	COMPONENT #15	0	0	0	0	0
	COMPONENT #16	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
	COMPONENT #20	0	0	0	0	0
	GLUCOSE	74	1,322	0	0	0
	AMMONIA	0	0	0	0	0
	PHOSPHORIC ACID	50	889	0	0	0
	POTASSIUM CHLORIDE	38	677	0	0	0
	MINOR NUTRIENTS	0	0	0	0	0
	WATER	29,007	519,087	86	86	86
	SOLVENT	1	10	4,310,557	4,508,506	198,310
	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	42,169	522,198	4,491,831	4,707,808	396,706
	CHECK ON TOTAL					
	TEMPERATURE, C	33	33	33	--	127
	PRESSURE, PSIA	14.7	14.7	14.7	--	16.7
	STATE	SLURRY	SOL'N	SOL'N	SOL'N	SOL'N

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
GOAL STOICHIOMETRY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

P	STREAM	26 BEER #1 TAILS	27 BEER #2 MAKE	28 BEER #2 TAILS	29 LBS #1 MAKE	30 LBS #1 TAILS
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	COMPONENT #1	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#2	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	COMPONENT #6	0	0	0	0	0
#1	COMPONENT #7	906	180,282	18,028	0	180,282
	COMPONENT #8	0	0	0	0	0
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	0	0	0	0	0
	COMPONENT #11	0	0	0	0	0
	COMPONENT #12	0	0	0	0	0
	COMPONENT #13	0	0	0	0	0
#	COMPONENT #14	0	0	0	0	0
	COMPONENT #15	0	0	0	0	0
	COMPONENT #16	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
	COMPONENT #20	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	0	86	0	0	86
	SOLVENT	4,310,196	361	197,949	0	361
	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	4,311,102	180,728	215,977	0	180,728
	CHECK ON TOTAL					
	TEMPERATURE, C	220	171	220	(273)	175
	PRESSURE, PSIA	17.5	89.3	80.3	100.7	100.7
	STATE	SOL'N	SOL'N	SOL'N	SOL'N	SOL'N

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
GOAL STOICHIOMETRY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

P	STREAM	31 LBS #2 MAKE	32 LBS #2 TAILS	33 LBS #3 MAKE	34 LBS #3 TAILS	35 HBS #1 MAKE
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	COMPONENT #1	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#2	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	COMPONENT #6	0	0	0	0	0
#1	COMPONENT #7	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
	COMPONENT #11	0	0	0	0	0
	COMPONENT #12	0	0	0	0	0
	COMPONENT #13	0	0	0	0	0
#	COMPONENT #14	0	0	0	0	0
	COMPONENT #15	0	0	0	0	0
	COMPONENT #16	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
	COMPONENT #20	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	0	0	0	0	0
	SOLVENT	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	0	0
	CHECK ON TOTAL					
	TEMPERATURE, C	(273)	120	(273)	120	(273)
	PRESSURE, PSIA	.0	.0	.0	.0	.0
	STATE	SOL'N	SOL'N	SOL'N	SOL'N	SOL'N

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
GOAL STOICHIOMETRY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

P	STREAM	35 HBS #1 TAILS	37 BYPRODUCT FEED	38 RAFF #1 FEED	39 RAFF #1 MAKE	40 RAFF #1 TAILS
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	COMPONENT #1	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#2	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	COMPONENT #6	0	0	0	0	0
#1	COMPONENT #7	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
	COMPONENT #11	0	0	0	0	0
	COMPONENT #12	0	0	0	0	0
	COMPONENT #13	0	0	0	0	0
#	COMPONENT #14	0	0	0	0	0
	COMPONENT #15	0	0	0	0	0
	COMPONENT #16	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
	COMPONENT #20	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	0	0	0	0	0
	SOLVENT	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	0	0
	CHECK ON TOTAL					
	TEMPERATURE, C	220	33	0	0	0
	PRESSURE, PSIA	.0	14.7	--	0.0	0.0
	STATE	SOL'N	SOL'N	SOL'N	SOL'N	SOL'N

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
GOAL STOICHIOMETRY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

P	STREAM	41 RAFF #2 MAKE	42 RAFF #2 TAILS	43 RAFF #3 MAKE	44 RAFF #3 TAILS	45 REFINED BUTANOL	46 REFINED ACETONE
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	COMPONENT #1	0	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0	0
#2	COMPONENT #3	0	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0	0
	COMPONENT #6	0	0	0	0	0	0
#1	COMPONENT #7	0	0	0	0	180,282	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
	COMPONENT #11	0	0	0	0	0	0
	COMPONENT #12	0	0	0	0	0	0
	COMPONENT #13	0	0	0	0	0	0
#	COMPONENT #14	0	0	0	0	0	0
	COMPONENT #15	0	0	0	0	0	0
	COMPONENT #16	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
	COMPONENT #20	0	0	0	0	0	0
	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	0	0	0	0	86	0
	SOLVENT	0	0	0	0	361	0
	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	0	0	0	0	180,728	0
	CHECK ON TOTAL					0	0
	TEMPERATURE, C	0	0	0	0	175	(273)
	PRESSURE, PSIA	0.0	0.0	0.0	0.0	101	0
	STATE	SOL'N	SOL'N	SOL'N	SOL'N	0	0

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
GOAL STOICHIOMETRY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	47 REFINED ETHANOL	48 ORGANIC WASTE	49 MAKE-UP SOLVENT	50 MAKE-UP WATER	51 STERILE STEAM
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	COMPONENT #1	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#2	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	(0)	0	0	0
	COMPONENT #6	0	0	0	0	0
#1	COMPONENT #7	0	202	0	0	0
	COMPONENT #8	0	0	0	0	0
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	0	0	0	0	0
	COMPONENT #11	0	0	0	0	0
	COMPONENT #12	0	0	0	0	0
	COMPONENT #13	0	0	0	0	0
#	COMPONENT #14	0	0	0	0	0
	COMPONENT #15	0	0	0	0	0
	COMPONENT #16	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
	COMPONENT #20	0	0	0	0	0
	GLUCOSE	0	1,322	0	0	0
	AMMONIA	0	0	0	0	0
	PHOSPHORIC ACID	0	889	0	0	0
	POTASSIUM CHLORIDE	0	677	0	0	0
	MINOR NUTRIENTS	0	0	0	0	0
	WATER	0	518,087	0	47,443	35,445
	SOLVENT	0	10	361	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	522,197	361	47,443	35,445
	CHECK ON TOTAL			361		
	TEMPERATURE, C	0	40	20	20	141
	PRESSURE, PSIA	0.0	14.7	14.7	14.7	64.7
	STATE	SOL'N	SOL'N	LIQUID	LIQUID	GAS

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
GOAL STOICHIOMETRY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

P	STREAM	52 FERM'TR STEAM	53 DISTILL. STEAM	54 COND. MU P'WR H'SE	55 MEDIUM COOL WTR	56 FERM'TR COOL WTR
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	COMPONENT #1	0	0	0	0	0
T	COMPONENT #2	0	0	0	0	0
#2	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	COMPONENT #6	0	0	0	0	0
#1	COMPONENT #7	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
	COMPONENT #11	0	0	0	0	0
	COMPONENT #12	0	0	0	0	0
	COMPONENT #13	0	0	0	0	0
#	COMPONENT #14	0	0	0	0	0
	COMPONENT #15	0	0	0	0	0
	COMPONENT #16	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
	COMPONENT #20	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	0	841,475	35,445	457,544	9,916,825
	SOLVENT	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	841,475	35,445	457,544	9,916,825
	CHECK ON TOTAL					
	TEMPERATURE, C	141	186	110	5	5
	PRESSURE, PSIA	64.7	154.7	20.8	14.7	14.7
	STATE	GAS	GAS	LIQUID	LIQUID	LIQUID

MULTISTAGE EXTRACTIVE FERMENTATION OF BUTANOL
WITH RECOVERY OF RAFFINATE
GOAL STOICHIOMETRY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	57 DISTILL. COOL WTR
P		
R	CELLS -CHO	0
O	-NH2	0
D	-MINERALS	0
U	-TOTAL	0
C	COMPONENT #1	0
T	COMPONENT #2	0
#2	COMPONENT #3	0
	COMPONENT #4	0
	COMPONENT #5	0
	COMPONENT #6	0
#1	COMPONENT #7	0
	COMPONENT #8	0
	COMPONENT #9	0
	COMPONENT #10	0
	COMPONENT #11	0
	COMPONENT #12	0
	COMPONENT #13	0
#	COMPONENT #14	0
	COMPONENT #15	0
	COMPONENT #16	0
	COMPONENT #17	0
#	COMPONENT #18	0
	COMPONENT #19	0
	COMPONENT #20	0
	GLUCOSE	0
	AMMONIA	0
	PHOSPHORIC ACID	0
	POTASSIUM CHLORIDE	0
	MINOR NUTRIENTS	0
	WATER	5,063,201
	SOLVENT	0
	CARBON DIOXIDE	0
	OXYGEN	0
	NITROGEN	0
	HYDROGEN	0
	GRAND TOTAL	5,063,201
	CHECK ON TOTAL	
	TEMPERATURE, C	0
	PRESSURE, PSIA	14.7
	STATE	LIQUID

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	23 EXTRACT	24 BEER #1 FEED	25 BEER #1 MAKE	26 BEER #1 TAILS
COMPONENT #1	0	0	0	0
COMPONENT #2	0	0	0	0
COMPONENT #3	0	0	0	0
COMPONENT #4	0	0	0	0
COMPONENT #5	0	0	0	0
COMPONENT #6	0	0	0	0
COMPONENT #7	2,445	2,688	2,676	12
COMPONENT #8	0	0	0	0
COMPONENT #9	0	0	0	0
COMPONENT #10	0	0	0	0
COMPONENT #11	0	0	0	0
COMPONENT #12	0	0	0	0
COMPONENT #13	0	0	0	0
COMPONENT #14	0	0	0	0
COMPONENT #15	0	0	0	0
COMPONENT #16	0	0	0	0
COMPONENT #17	0	0	0	0
COMPONENT #18	0	0	0	0
COMPONENT #19	0	0	0	0
COMPONENT #20	0	0	0	0
WATER	5	5	5	0
SOLVENT	16,056	16,793	739	16,055
TOTAL (q)	18,505	19,486	3,419	16,067
(Storage)	45	50	50	0
VAPOR PRESS 40(q)	2.6	2.7	14.6	0.1
(Storage)	2,044	2,247	2,237	10
VAPOR PRESS 120(q)	125.2	130.0	660.0	17.2
B(q) V.P. CONSTANT	-5984.8	-5979.1	-5857.8	-7678.3
A(q) V.P. CONSTANT	20.059	20.082	21.398	22.384
TEMPERATURE C	33.0	87.7	123.3	220.0
PRESSURE mmHg	760	760	747	907
K1 (COMPONENT #)			7	7
K2 (COMPONENT #)			SOLVENT	SOLVENT
V.P.(K1)			945.7	17164.0
V.P.(K2)			19.6	939.4
GAMMA-K1 IN K2			2.014	2.014
GAMMA-K2 IN K1			2.014	2.014
ALPHA			32.474	36.756
AVG COLUMN ALPHA			34.615	
MOL FRACT. K1 (MAKE OR TAILS)			0.784	0.001
MOL FRACT. K1 (FEED)			0.138	
MOL FRACT. K2 (MAKE OR TAILS)			0.216	0.999
ADJ. GAMMA-K1 IN K2			1.033	2.012
ADJ. GAMMA-K2 IN K1			1.537	1.000
MINIMUM REFLUX RATIO (ADJUSTED)			0.0	
ACTUAL REFLUX RATIO			0.0	
MINIMUM PLATES			2	

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	23 EXTRACT	24 BEER #1 FEED	25 BEER #1 MAKE	26 BEER #1 TAILS
ACTUAL PLATES			11	
PRESSURE mm Hg (REVISED)			864	
TEMPERATURE C (REVISED)			127	
AVERAGE MOLECULAR WEIGHT			116.03	268.32
GAS DENSITY - LB/CF			0.2505	0.4837
CROSS SECTIONAL AREA - SQ FT			23.2	
COLUMN HEIGHT - FT			31.1	
COLUMN DIAMETER			5.4	
K1 (MPPY)			138,310	
Hv (HEAT VAPORIZ.-Btu/Lb)			215.2	215.0
Cn (HEAT CAPACITY - Btu/Lb/F)			0.500	0.500
HEAT LOAD - MM Btu/Hr			11.855	83.143
CONDENSER COOLING WATER - GPM (15 C dT)			879	
CALANDRIA STEAM - MPPH (150 PSIG)				97.02
COLUMN COST - $1000 3Q86 MPC - BARE EQUIPMENT				
- ALL CARBON STEEL			$60.1	
- C.S w/304 S.S. TRAYS			$66.1	
- ALL 304 STAINLESS STEEL			$97.3	
- ALL 304L STAINLESS STEEL			$107.0	
- ALL 316 STAINLESS STEEL			$131.4	
CONDENSER OR CALANDRIA SURFACE - SQ FT			847	4,619
COND. OR CALAND. COST - $1000 3Q86 MPC - BARE EQUIPMENT				
-CARBON STEEL			$36.8	$145.1
-304 STAINLESS STEEL			$51.5	$203.2
-316 STAINLESS STEEL			$55.1	$217.7
-MONEL			$71.7	$283.0
SUBTOTAL				2,155,551
SUBTOTAL				2,155,098
SUBTOTAL				2,155,088
MINIMUM REFLUX RATIO			(0.4)	
Cn SUBTOTAL #1			99,155	453
Cn SUBTOTAL #2			0	0
Cn SUBTOTAL #3			99,241	2,155,098
Cn CHECK			0.500	0.500
Hv SUBTOTAL #1			42,637	195
Hv SUBTOTAL #2			0	0
Hv SUBTOTAL #3			42,720	926,692
Hv CHECK			215.2	215.0
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)				

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	27 BEER #2 MAKE	28 BEER #2 TAILS	29 LBS #1 MAKE	30 LBS #1 TAILS
COMPONENT #1	0	0	0	0
COMPONENT #2	0	0	0	0
COMPONENT #3	0	0	0	0
COMPONENT #4	0	0	0	0
COMPONENT #5	0	0	0	0
COMPONENT #6	0	0	0	0
COMPONENT #7	2,432	243	0	2,432
COMPONENT #8	0	0	0	0
COMPONENT #9	0	0	0	0
COMPONENT #10	0	0	0	0
COMPONENT #11	0	0	0	0
COMPONENT #12	0	0	0	0
COMPONENT #13	0	0	0	0
COMPONENT #14	0	0	0	0
COMPONENT #15	0	0	0	0
COMPONENT #16	0	0	0	0
COMPONENT #17	0	0	0	0
COMPONENT #18	0	0	0	0
COMPONENT #19	0	0	0	0
COMPONENT #20	0	0	0	0
WATER	5	0	0	5
SOLVENT	1	737	0	1
TOTAL (g)	2,438	981	0	2,438
(Storage)	45	5	0	45
VAPOR PRESS 40(g)	18.6	4.7	.0	18.6
(Storage)	2,034	203	0	2,034
VAPOR PRESS 120(g)	837.0	219.9	.0	837.0
B(g) V.P. CONSTANT	-5851.5	-5919.2	0.0	-5851.5
A(g) V.P. CONSTANT	21.619	20.455	-4.605	21.619
TEMPERATURE C	170.1	220.0	-273.0	175.0
PRESSURE mmHg	4,506	4,666	5,047	5,207
K1 (COMPONENT #)	7	7	6,5,4,3	6,5,4,3
K2 (COMPONENT #)	SOLVENT	SOLVENT	7	7
V.P.(K1)	4505.7	17164.0	ERR	17229.0
V.P.(K2)	157.5	939.4	ERR	5206.5
GAMMA-K1 IN K2	2.014	2.014	1.350	1.350
GAMMA-K2 IN K1	2.014	2.014	1.350	1.350
ALPHA	14.221	26.000	ERR	4.467
AVG COLUMN ALPHA	20.110		ERR	
MOL FRACT. K1 (MAKE OR TAILS)	0.999	0.248	ERR	0.000
MOL FRACT. K1 (FEED)	0.784		0.000	
MOL FRACT. K2 (MAKE OR TAILS)	0.001	0.752	ERR	1.000
ADJ. GAMMA-K1 IN K2	1.000	1.486	ERR	1.350
ADJ. GAMMA-K2 IN K1	2.012	1.044	ERR	1.000
MINIMUM REFLUX RATIO (ADJUSTED	0.0		0.0	
ACTUAL REFLUX RATIO	0.0		0.0	
MINIMUM PLATES	3		0	

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	27 BEER #2 MAKE	28 BEER #2 TAILS	29 LBS #1 MAKE	30 LBS #1 TAILS
ACTUAL PLATES	13		0	
PRESSURE mm Hg (REVISED)	4,615		5,207	
TEMPERATURE C (REVISED)	171		(273)	
AVERAGE MOLECULAR WEIGHT	74.12	220.26	ERR	74.12
GAS DENSITY - LB/CF	0.7709	2.0860	ERR	0.8619
CROSS SECTIONAL AREA - SQ FT	6.0		0.0	
COLUMN HEIGHT - FT	34.4		0.0	
COLUMN DIAMETER	2.8		0.0	
K1 (MPPY)	180,282		0	
Hv (HEAT VAPORIZ.-Btu/Lb)	215.4	215.0	ERR	215.4
Cn (HEAT CAPACITY - Btu/Lb/F)	0.500	0.500	ERR	0.500
HEAT LOAD - MM Btu/Hr	5.406	7.911	0.000	0.000
CONDENSER COOLING WATER - GPM	401		0	
CALANDRIA STEAM - MPPH (150 PSIG)		9.23		0.00
COLUMN COST - $1000 3Q86 MPC - BARE EQUIPMENT				
- ALL CARBON STEEL	$38.2		$0.0	
- C.S w/304 S.S. TRAYS	$42.0		$0.0	
- ALL 304 STAINLESS STEEL	$62.8		$0.0	
- ALL 304L STAINLESS STEEL	$69.2		$0.0	
- ALL 316 STAINLESS STEEL	$84.8		$0.0	
CONDENSER OR CALANDRIA SURFACE	266	439	0	0
COND. OR CALAND. COST - $1000 3Q86 MPC - BARE EQUIPMENT				
-CARBON STEEL	$18.2	$24.1	$0.0	$0.0
-304 STAINLESS STEEL	$25.5	$33.8	$0.0	$0.0
-316 STAINLESS STEEL	$27.3	$36.2	$0.0	$0.0
-MONEL	$35.5	$47.0	$0.0	$0.0
SUBTOTAL		107,989		90,407
SUBTOTAL		98,975		266
SUBTOTAL		98,975		266
MINIMUM REFLUX RATIO	(1.0)		0.0	
Cn SUBTOTAL #1	90,141	9,014	0	90,141
Cn SUBTOTAL #2	0	0	0	0
Cn SUBTOTAL #3	266	98,975	0	266
Cn CHECK	0.500	0.500	ERR	0.500
Hv SUBTOTAL #1	38,761	3,876	0	38,761
Hv SUBTOTAL #2	0	0	0	0
Hv SUBTOTAL #3	161	42,553	0	161
Hv CHECK	215.4	215.0	ERR	215.4
MIN. PLATES(NORMAL)				
COL.COST-C/S NORMAL			0	
COL.COST-S/S NORMAL			0	
MIN.REFLUX(NORMAL)				
C.S. AREA(NORMAL)			ERR	
HEAT LOAD(NORMAL)				0.09
CON/CAL COST(NORMAL)			ERR	ERR

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	31 LBS #2 MAKE	32 LBS #2 TAILS	33 LBS #3 MAKE	34 LBS #3 TAILS
COMPONENT #1	0	0	0	0
COMPONENT #2	0	0	0	0
COMPONENT #3	0	0	0	0
COMPONENT #4	0	0	0	0
COMPONENT #5	0	0	0	0
COMPONENT #6	0	0	0	0
COMPONENT #7	0	0	0	0
COMPONENT #8	0	0	0	0
COMPONENT #9	0	0	0	0
COMPONENT #10	0	0	0	0
COMPONENT #11	0	0	0	0
COMPONENT #12	0	0	0	0
COMPONENT #13	0	0	0	0
COMPONENT #14	0	0	0	0
COMPONENT #15	0	0	0	0
COMPONENT #16	0	0	0	0
COMPONENT #17	0	0	0	0
COMPONENT #18	0	0	0	0
COMPONENT #19	0	0	0	0
COMPONENT #20	0	0	0	0
WATER	0	0	0	0
SOLVENT	0	0	0	0
TOTAL (q)	0	0	0	0
(Storage)	0	0	0	0
VAPOR PRESS 40(q)	.0	.0	.0	.0
(Storage)	0	0	0	0
VAPOR PRESS 120(q)	.0	.0	.0	.0
B(q) V.P. CONSTANT	0.0	0.0	0.0	0.0
A(q) V.P. CONSTANT	-4.605	-4.605	-4.605	-4.605
TEMPERATURE C	ERR	120.0	ERR	120.0
PRESSURE mmHg	(160)	0	(160)	0
K1 (COMPONENT #)	3	3	2,1	2,1
K2 (COMPONENT #)	4,5,6	4,5,6	3	3
V.P.(K1)	ERR	5096.7	ERR	1.0
V.P.(K2)	ERR	3517.3	ERR	5096.7
GAMMA-K1 IN K2	1.492	1.492	1.000	1.000
GAMMA-K2 IN K1	1.492	1.492	1.000	1.000
ALPHA	ERR	ERR	ERR	ERR
AVG COLUMN ALPHA	ERR		ERR	
MOL FRACT. K1 (MAKE OR TAILS)	ERR	ERR	ERR	ERR
MOL FRACT. K1 (FEED)	ERR		ERR	
MOL FRACT. K2 (MAKE OR TAILS)	ERR	ERR	ERR	ERR
ADJ. GAMMA-K1 IN K2	ERR	ERR	ERR	ERR
ADJ. GAMMA-K2 IN K1	ERR	ERR	ERR	ERR
MINIMUM REFLUX RATIO (ADJUSTED	0.0		0.0	
ACTUAL REFLUX RATIO	0.0		0.0	
MINIMUM PLATES	0		0	

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	31 LBS #2 MAKE	32 LBS #2 TAILS	33 LBS #3 MAKE	34 LBS #3 TAILS
ACTUAL PLATES	0		0	
PRESSURE mm Hg (REVISED)	0		0	
TEMPERATURE C (REVISED)	(273)		(273)	
AVERAGE MOLECULAR WEIGHT	ERR	ERR	ERR	ERR
GAS DENSITY - LB/CF	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
Cn (HEAT CAPACITY - Btu/Lb/F)	ERR	ERR	ERR	ERR
HEAT LOAD - MM Btu/Hr	0.000	0.000	0.000	0.000
CONDENSER COOLING WATER - GPM	0		0	
CALANDRIA STEAM - MPPH (150 PSIG)		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 SURFACE	0	0	0	0
COND. OR CALAND. COST - $1000 3Q86 MPC - BARE EQUIPMENT				
-CARBON STEEL	$0.0	$0.0	$0.0	$0.0
-304 STAINLESS STEEL	$0.0	$0.0	$0.0	$0.0
-316 STAINLESS STEEL	$0.0	$0.0	$0.0	$0.0
-MONEL	$0.0	$0.0	$0.0	$0.0
SUBTOTAL		0		0
SUBTOTAL		0		0
SUBTOTAL		0		0
MINIMUM REFLUX RATIO	0.0		0.0	
Cn SUBTOTAL #1	0	0	0	0
Cn SUBTOTAL #2	0	0	0	0
Cn SUBTOTAL #3	0	0	0	0
Cn CHECK	ERR	ERR	ERR	ERR
Hv SUBTOTAL #1	0	0	0	0
Hv SUBTOTAL #2	0	0	0	0
Hv SUBTOTAL #3	0	0	0	0
Hv CHECK	ERR	ERR	ERR	ERR
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)				

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	35 HBS #1 MAKE	36 HBS #1 TAILS	37 BYPRODUCT FEED	38 RAFF #1 FEED
COMPONENT #1	0	0	0	0
COMPONENT #2	0	0	0	0
COMPONENT #3	0	0	0	0
COMPONENT #4	0	0	0	0
COMPONENT #5	0	0	0	0
COMPONENT #6	0	0	0	0
COMPONENT #7	0	0	0	0
COMPONENT #8	0	0	0	0
COMPONENT #9	0	0	0	0
COMPONENT #10	0	0	0	0
COMPONENT #11	0	0	0	0
COMPONENT #12	0	0	0	0
COMPONENT #13	0	0	0	0
COMPONENT #14	0	0	0	0
COMPONENT #15	0	0	0	0
COMPONENT #16	0	0	0	0
COMPONENT #17	0	0	0	0
COMPONENT #18	0	0	0	0
COMPONENT #19	0	0	0	0
COMPONENT #20	0	0	0	0
WATER	0	0	0	0
SOLVENT	0	0	0	0
TOTAL (q)	0	0	0	0
(Storage)	0	0		
VAPOR PRESS 40(q)	.0	.0		
(Storage)	0	0		
VAPOR PRESS 120(q)	.0	.0		
B(q) V.P. CONSTANT	0.0	0.0		
A(q) V.P. CONSTANT	-4.605	-4.605		
TEMPERATURE C	ERR	220.0		
PRESSURE mmHg	(160)	0		
K1 (COMPONENT #)	10,9,8	10,9,8		
K2 (COMPONENT #)	SOLVENT	SOLVENT		
V.P.(K1)	ERR	3815.4		
V.P.(K2)	ERR	939.4		
GAMMA-K1 IN K2	2.117	2.117		
GAMMA-K2 IN K1	2.858	2.858		
ALPHA	ERR	ERR		
AVG COLUMN ALPHA	ERR			
MOL FRACT. K1 (MAKE OR TAILS)	ERR	ERR		
MOL FRACT. K1 (FEED)	0.000			
MOL FRACT. K2 (MAKE OR TAILS)	ERR	ERR		
ADJ. GAMMA-K1 IN K2	ERR	ERR		
ADJ. GAMMA-K2 IN K1	ERR	ERR		
MINIMUM REFLUX RATIO (ADJUSTED	0.0			
ACTUAL REFLUX RATIO	0.0			
MINIMUM PLATES	0			

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	35 HBS #1 MAKE	36 HBS #1 TAILS	37 BYPRODUCT FEED	38 RAFF #1 FEED
ACTUAL PLATES	0			
PRESSURE mm Hg (REVISED)	0			
TEMPERATURE C (REVISED)	(273)			
AVERAGE MOLECULAR WEIGHT	ERR	ERR		
GAS DENSITY - LB/CF	ERR	ERR		
CROSS SECTIONAL AREA - SQ FT	0.0			
COLUMN HEIGHT - FT	0.0			
COLUMN DIAMETER	0.0			
K1 (MPPY)	0			
Hv (HEAT VAPORIZ.-Btu/Lb)	ERR	ERR		
Cn (HEAT CAPACITY - Btu/Lb/F)	ERR	ERR		
HEAT LOAD - MM Btu/Hr	0.000	0.000		
CONDENSER COOLING WATER - GPM	0			
CALANDRIA STEAM - MPPH (150 PSIG)		0.00		
COLUMN COST - $1000 3Q86 MPC - BARE EQUIPMENT				
- ALL CARBON STEEL	$0.0			
- C.S w/304 S.S. TRAYS	$0.0			
- ALL 304 STAINLESS STEEL	$0.0			
- ALL 304L STAINLESS STEEL	$0.0			
- ALL 316 STAINLESS STEEL	$0.0			
CONDENSER OR CALANDRIA SURFACE	0	0		
COND. OR CALAND. COST - $1000 3Q86 MPC - BARE EQUIPMENT				
-CARBON STEEL	$0.0	$0.0		
-304 STAINLESS STEEL	$0.0	$0.0		
-316 STAINLESS STEEL	$0.0	$0.0		
-MONEL	$0.0	$0.0		
SUBTOTAL		0		
SUBTOTAL		0		
SUBTOTAL		0		
MINIMUM REFLUX RATIO	0.0			
Cn SUBTOTAL #1	0	0		
Cn SUBTOTAL #2	0	0		
Cn SUBTOTAL #3	0	0		
Cn CHECK	ERR	ERR		
Hv SUBTOTAL #1	0	0		
Hv SUBTOTAL #2	0	0		
Hv SUBTOTAL #3	0	0		
Hv CHECK	ERR	ERR		
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)				

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	39 RAFF #1 MAKE	40 RAFF #1 TAILS	41 RAFF #2 MAKE	42 RAFF #2 TAILS
COMPONENT #1	0	0	0	0
COMPONENT #2	0	0	0	0
COMPONENT #3	0	0	0	0
COMPONENT #4	0	0	0	0
COMPONENT #5	0	0	0	0
COMPONENT #6	0	0	0	0
COMPONENT #7	0	0	0	0
COMPONENT #8	0	0	0	0
COMPONENT #9	0	0	0	0
COMPONENT #10	0	0	0	0
COMPONENT #11	0	0	0	0
COMPONENT #12	0	0	0	0
COMPONENT #13	0	0	0	0
COMPONENT #14	0	0	0	0
COMPONENT #15	0	0	0	0
COMPONENT #16	0	0	0	0
COMPONENT #17	0	0	0	0
COMPONENT #18	0	0	0	0
COMPONENT #19	0	0	0	0
COMPONENT #20	0	0	0	0
WATER	0	0	0	0
SOLVENT	0	0	0	0
TOTAL (q)	0	0	0	0

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

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 PLATES

	DISTILLATION CALCULATIONS			
M LB. MOLES/YEAR	39 RAFF #1 MAKE	40 RAFF #1 TAILS	41 RAFF #2 MAKE	42 RAFF #2 TAILS
ACTUAL PLATES				
PRESSURE mm Hg (REVISED)				
TEMPERATURE C (REVISED)				
AVERAGE MOLECULAR WEIGHT				
GAS DENSITY - LB/CF				
CROSS SECTIONAL AREA - SQ FT				
COLUMN HEIGHT - FT				
COLUMN DIAMETER				
K1 (MPPY)				
Hv (HEAT VAPORIZ.-Btu/Lb)				
Cn (HEAT CAPACITY - Btu/Lb/F)				
HEAT LOAD - MM Btu/Hr				
CONDENSER COOLING WATER - GPM (15 C dT)				
CALANDRIA STEAM - MPPH (150 PSIG)				
COLUMN COST - $1000 3Q86 MPC - BARE EQUIPMENT				
- ALL CARBON STEEL				
- C.S w/304 S.S. TRAYS				
- ALL 304 STAINLESS STEEL				
- ALL 304L STAINLESS STEEL				
- ALL 316 STAINLESS STEEL				
CONDENSER OR CALANDRIA SURFACE - SQ FT				
COND. OR CALAND. COST - $1000 3Q86 MPC - BARE EQUIPMENT				
-CARBON STEEL				
-304 STAINLESS STEEL				
-316 STAINLESS STEEL				
-MONEL				
SUBTOTAL				
SUBTOTAL				
SUBTOTAL				
MINIMUM REFLUX RATIO				
Cn SUBTOTAL #1				
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)				

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	43 RAFF #3 MAKE	44 RAFF #3 TAILS
COMPONENT #1	0	0
COMPONENT #2	0	0
COMPONENT #3	0	0
COMPONENT #4	0	0
COMPONENT #5	0	0
COMPONENT #6	0	0
COMPONENT #7	0	0
COMPONENT #8	0	0
COMPONENT #9	0	0
COMPONENT #10	0	0
COMPONENT #11	0	0
COMPONENT #12	0	0
COMPONENT #13	0	0
COMPONENT #14	0	0
COMPONENT #15	0	0
COMPONENT #16	0	0
COMPONENT #17	0	0
COMPONENT #18	0	0
COMPONENT #19	0	0
COMPONENT #20	0	0
WATER	0	0
SOLVENT	0	0
TOTAL (q)	0	0

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

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 PLATES

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	43 RAFF #3 MAKE	44 RAFF #3 TAILS
ACTUAL PLATES		
PRESSURE mm Hg (REVISED)		
TEMPERATURE C (REVISED)		
AVERAGE MOLECULAR WEIGHT		
GAS DENSITY - LB/CF		
CROSS SECTIONAL AREA - SQ FT		
COLUMN HEIGHT - FT		
COLUMN DIAMETER		
K1 (MPPY)		
Hv (HEAT VAPORIZ.-Btu/Lb)		
Cn (HEAT CAPACITY - Btu/Lb/F)		
HEAT LOAD - MM Btu/Hr		
CONDENSER COOLING WATER - GPM (15 C dT)		
CALANDRIA STEAM - MPPH (150 PSIG)		
COLUMN COST - $1000 3Q86 MPC - BARE EQUIPMENT		
- ALL CARBON STEEL		
- C.S w/304 S.S. TRAYS		
- ALL 304 STAINLESS STEEL		
- ALL 304L STAINLESS STEEL		
- ALL 316 STAINLESS STEEL		
CONDENSER OR CALANDRIA SURFACE - SQ FT		
COND. OR CALAND. COST - $1000 3Q86 MPC - BARE EQUIPMENT		
-CARBON STEEL		
-304 STAINLESS STEEL		
-316 STAINLESS STEEL		
-MONEL		
SUBTOTAL		
SUBTOTAL		
SUBTOTAL		
MINIMUM REFLUX RATIO		
Cn SUBTOTAL #1		
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)		

APPENDIX F. IN SITU EXTRACTION NO RECOVERY OF RAFFINATE RECYCLE

SINGLE-STAGE INSITU EXTRACTIVE FERMENTATION OF BUTANOL
NO RECOVERY OF RAFFINATE CHEMICALS
BASECASE STOICHIOMETRY
SUMMARY

	PRODUCTION LEVEL 163 MM PPY
INVESTMENT-$MILLION	
MPC = 1984	
Direct Permanent Investment	$21.6
Allocated Power, Services & General	$9.5
Working Capital	$15.8
Total Investment	$47.0
COST-$/LB (1988)	
Raw Materials	$0.30
Utilities	$0.05
Labor-Related	$0.03
Capital-Related	$0.02
Cost of Manufacture	$0.40
SE, D, R&D, Adm, & I.C.	$0.06
Cost of Sales	$0.46
Pretax Earnings Based on: 30% Pretax ROI	$0.09
By-product Credit	($0.06)
Selling Price	$0.49
FINANCIAL CRITERIA	
Net ROI 3rd Year (assumed)	16%
Investors Rate of Return (20 Operating Years)	17%
Year to Break Even - Annual Cash	1987
- Cumulative Cash	1991
- Cum. Disc. Cash (NPV)	1995
Net Present Value $MM (20 years @ 12%)	$16.4

SINGLE-STAGE INSITU EXTRACTIVE FERMENTATION OF BUTANOL
NO RECOVERY OF RAFFINATE CHEMICALS
BASECASE STOICHIOMETRY

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 PPY	181.1
MID-POINT OF CONSTRUCTION	YEAR	1984
CONSTRUCTION COST INDEX	1980=100	128
INVESTMENT CONTINGENCY	% INSTALLED *	30%
FERMENTER UNIT INVESTMENT	$/GR.GAL.-GROWTH	$12.84
	$/GR.GAL.-PROD'N	$10.94

*40% Recommended for new processes

DIRECT PERMANENT INVESTMENT

	SCALE FACTOR		THIS CASE $MM	$/ANN.LB.
FERMENTATION SECTION				
Receiving, Prep & Sterilization	0.60		$3.87	$0.021
Air Compression & Aeration	0.60		0.00	0.000
Fermentation	0.89-1.00		9.21	0.051
Product/Cell Separation	0.75		0.97	0.005
Fermentation Sub-total			$14.05	$0.078
DISTILLATION SECTION	STILLS	HX'S		
Beer Still #1	$0.31	$0.90	$1.21	$0.007
Beer Still #2	0.19	0.24	0.43	0.002
Low-Boilers Still #1	0.20	0.14	0.34	0.002
Low-Boilers Still #2	0.36	0.10	0.46	0.003
Low-Boilers Still #3	0.00	0.00	0.00	0.000
High-Boilers Still #1	0.67	0.26	0.93	0.005
Distillation Subtotal			$3.37	$0.019
STORAGE SECTION				
Storage - Product			$3.48	$0.019
Storage - Byproduct #1			$0.74	0.004
Storage Subtotal			$4.22	$0.023
TOTAL DIRECT PLANT			$21.65	$0.120

SINGLE-STAGE INSITU EXTRACTIVE FERMENTATION OF BUTANOL
NO RECOVERY OF RAFFINATE CHEMICALS
BASECASE STOICHIOMETRY

INVESTMENT

ALLOCATED PERMANENT INVESTMENT

	UNITS	API/UNIT BASECASE	THIS CASE	UNITS	$MM	$/ANN.LB.
ELECTRICITY	KW	$183	$183	2,097	$0.38	$0.002
STEAM	PPH	$45	$45	124,940	5.62	0.031
COOLING WATER	GPM	$52	$52	6,119	0.32	0.002
PROCESS WATER	GPM	$313	$313	28	0.01	.000
WASTE DISPOSAL	MGPY	$3	$3	128,606	0.35	0.002
GEN'L & SERVICES	$MM	10%	10%	$28.3	2.83	0.016
TOTAL ALLOCATED PLANT					$9.51	$0.053
TOTAL PERMANENT INVESTMENT					$31.16	$0.172

WORKING CAPITAL

	BASIS	DAYS BASECASE	DAYS THIS CASE	$MM	$/ANN. LB.
RAW MAT'L INVENTORY	$RAW MATL	2	2	$0.31	$0.002
SEMI-FINISHED PRODUCT	$(R+M)/2	5	5	0.79	0.004
FINISHED PRODUCT	$COM	30	30	5.37	0.030
CASH	$(COS-D)	6	6	1.20	0.007
ACCOUNTS RCD.-TRADE	$SP	30	30	6.58	0.036
ACCOUNTS RCD.-MISC.	%COM	0.9%	0.9%	0.59	0.003
DEFERRED CHARGES	%COM	1.5%	1.5%	0.98	0.005
TOTAL WORKING CAPITAL				$15.82	$0.087

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

TOTAL INVESTMENT FOR RETURN	$46.98	$0.259

SINGLE-STAGE INSITU EXTRACTIVE FERMENTATION OF BUTANOL
NO RECOVERY OF RAFFINATE CHEMICALS
BASECASE STOICHIOMETRY

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	--	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	$0.27 /lb.	1.00	$0.27 /lb.
-Product Selling Price	$0.00 /lb.	1.00	$0.00 /lb.

SALARIES & WAGES

	250 MM PPY DAY SHIFT	250 MM PPY ROTATING SHIFTS	MIN. FORCE DAY SHIFT	MIN. FORCE ROTATING SHIFTS
DIRECT OPERATORS				
SYRUP RECEIVING & TRANSFER	1	-	1	-
CHEMICALS RECEIVING & TRANSFER	3	-		-
INNOCULUM PREPARATION	1	-	1	-
MEDIUM PREPARATION	-	1	1	-
STERILIZATION	-	1		-
FERMENTATION				
-CONTROL ROOM	-	2	-	1
-PATROL	-	2	-	1
-AIR COMPRESSION & AMMONIA FEED	-	1	-	1
-TURNAROUND	-	3	-	1
BEER FILTER & CELL RECYCLE	-	2	-	1
DISTILLATION	-	2	-	1
TOTAL DAY & 4.2-SHIFT OPS	5	14	3	6
TOTAL OPERATORS	64		28	
CONTROL LABORATORY				
BIOLOGICAL ANALYSIS	-	1	-	1
CHEMICAL ANALYSIS	-	1	-	1
OTHER	-	-	-	-
TOTAL DAY & 4.2-SHIFT TECHS	0	8	0	8
w/ SUPERVISION @ 20%	0.0	10.1	0.0	10.1
TOTAL LAB FORCE	10.1		10.1	
TECHNICAL ASSISTANCE TO MANUFACTURING				
PROCESS ENGINEERS	1	-	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%

SINGLE-STAGE INSITU EXTRACTIVE FERMENTATION OF BUTANOL
NO RECOVERY OF RAFFINATE CHEMICALS
BASECASE STOICHIOMETRY

1988 COST SHEET	RATE	/UNIT	MILLION UNITS	$MILLION	$/lb.
Raw Materials					
-Biosugar Syrup	$0.065	/lb. d.s.	752.65	48.92	0.300
-Anhyd. Ammonia	$0.046	/lb.	1.83	0.08	0.001
-Phosphoric Acid	$0.155	/lb.	1.52	0.24	0.001
-Potassium Chloride	$0.053	/lb.	1.16	0.06	.000
-Minor Nutrients	$0.451	/lb.	0.53	0.24	0.001
Total Raw Materials				$49.54	$0.304
Utilities					
-Electricity	$0.040	/KWH	14.95	0.60	0.004
-Steam	$2.20	/M lb.	0.8906	1.96	0.012
-Cooling Water	$0.04	/M gal.	2.62	0.10	0.001
-Process Water	$0.50	/M gal.	0.01	0.01	.000
-Biodegradation	$0.04	/lb. d.s.	122.70	4.91	0.030
-Landfill	$0.05	/lb. d.s.	0.00	0.00	0.000
Total Utilities				$7.58	$0.047
Labor-Related					
-Dir. Op. Wages & Ben.	$25.40	/man-hr.	0.117	3.09	0.019
-Dir. Salaries & Ben.	18	% DOW&B		0.56	0.003
-Op. Supplies & Service	6	% DOW&B		0.19	0.001
-GPOH on Operations	23	% DOWS&B		0.84	0.005
-Control Lab	$19.22	/man-hr.	0.020	0.39	0.002
-Tech. Assist. to Mfg.	$22.06	/man-hr.	0.002	0.04	.000
Total Labor				$5.10	$0.031
Capital-Related					
-Maint. Wages & Ben.	1.7	% DPI	$21.6	0.37	0.002
-Maint. Salaries & Ben.	25	% MW&B		0.09	0.001
-Maint. Mat'l & Service	40	% MW&B		0.15	0.001
-Maint. Overhead	4	% MW&B		0.01	.000
-GPOH on Maintenance	23	% MWS&B		0.11	0.001
-Taxes & Insurance	0.3	% DPI	$21.6	0.06	.000
-Depreciation - DPI	8	% DPI	$21.6	1.73	0.011
-Depreciation - APS&G	6	% APS&G	$9.5	0.57	0.004
Total Capital				$3.10	$0.019
Cost of Manufacture				$65.32	$0.401
-Selling Expense	3	% Sales	$80.0	2.40	0.015
-Distribution	$0.01	/lb.	163.0	1.63	0.010
-Research & Development	5	% Sales	$80.0	3.60	0.022
-Administrative Expense	2	% Sales	$80.0	1.60	0.010
-Incentive Compensation	6	% PTE	$14.1	0.85	0.005
Cost of Sales				$75.40	$0.463
-Pretax Earnings	30.0	% TIFR	$47.0	14.09	0.086
-Credit: Byproduct #1	$0.27	/lb.	35.0	(9.45)	(0.058)
Total Sales				$80.04	$0.491

SINGLE-STAGE INSITU EXTRACTIVE FERMENTATION OF BUTANOL
NO RECOVERY OF RAFFINATE CHEMICALS
BASECASE STOICHIOMETRY

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%). Tax: 34% federal, 3% state.

	INVESTMENT		DEP.	COST EX D	SALES	NET EARN	ANN CASH
YEAR	PI	WC					
1983	$7.22						($7.22)
1984	$7.22						($7.22)
1985	$7.22	$15.82					($23.03)
1986			$4.33	$39.63	$44.75	$0.50	($10.99)
1987			$6.93	$57.77	$67.12	$1.53	$8.45
1988			$4.16	$73.10	$89.49	$7.71	$11.87
1989			$2.49	$73.10	$89.49	$8.76	$11.25
1990			$2.49	$73.10	$89.49	$8.76	$11.25
1991			$1.26	$73.10	$89.49	$9.54	$10.79
1992				$73.10	$89.49	$10.33	$10.33
1993				$73.10	$89.49	$10.33	$10.33
1994				$73.10	$89.49	$10.33	$10.33
1995				$73.10	$89.49	$10.33	$10.33
1996				$73.10	$89.49	$10.33	$10.33
1997				$73.10	$89.49	$10.33	$10.33
1998				$73.10	$89.49	$10.33	$10.33
1999				$73.10	$89.49	$10.33	$10.33
2000				$73.10	$89.49	$10.33	$10.33
2001				$73.10	$89.49	$10.33	$10.33
2002				$73.10	$89.49	$10.33	$10.33
2003				$73.10	$89.49	$10.33	$10.33
2004				$73.10	$89.49	$10.33	$10.33
2005		($15.82)		$73.10	$89.49	$10.33	$26.15

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

SINGLE-STAGE INSITU EXTRACTIVE FERMENTATION OF BUTANOL
NO RECOVERY OF RAFFINATE CHEMICALS
BASECASE STOICHIOMETRY

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%). Tax: 34% federal, 3% state.

YEAR	CUM CASH	NPV @ 12%	%IRR
1983	($7.22)	($7.22)	--
1984	($14.43)	($13.66)	--
1985	($37.46)	($32.02)	--
1986	($48.45)	($39.84)	-151.8%
1987	($40.00)	($34.47)	-60.8%
1988	($28.13)	($27.74)	-27.5%
1989	($16.88)	($22.04)	-12.2%
1990	($5.63)	($16.95)	-3.2%
1991	$5.16	($12.59)	2.4%
1992	$15.49	($8.86)	6.1%
1993	$25.82	($5.54)	8.7%
1994	$36.15	($2.57)	10.6%
1995	$46.48	$0.08	12.0%
1996	$56.81	$2.45	13.1%
1997	$67.14	$4.57	14.0%
1998	$77.47	$6.45	14.6%
1999	$87.80	$8.14	15.2%
2000	$98.13	$9.64	15.6%
2001	$108.46	$10.99	15.9%
2002	$118.79	$12.19	16.2%
2003	$129.12	$13.26	16.4%
2004	$139.45	$14.21	16.6%
2005	$165.59	$16.37	17.0%

SINGLE-STAGE INSITU EXTRACTIVE FERMENTATION OF BUTANOL
NO RECOVERY OF RAFFINATE CHEMICALS
BASECASE STOICHIOMETRY

BASIC DATA

SCALE OF OPERATION

163.00	MM PPY	ANNUAL PRODUCTION LEVEL
181.11	MM PPY	ANNUAL CAPACITY
90	%	OPERATING UTILITY
175.58	MM PPY	PRODUCT IN BEER
195.09	MM PPY	PRODUCT IN BEER AT CAPACITY
85.0	%	MOLAR YIELD-GLUC. TO PROD. IN BEER (E
4.29	lb/lb	GLUCOSE DEMAND/PROD (EXCL. SPILL)
74.12	MOL WT	PRODUCT MOLECULAR WEIGHT

PRODUCT STOICHIOMETRY

MOL. WT.	MOLES/MOL PRODUCT	COMPONENT
180.16	1.67525 /MOL PROD.	-GLUCOSE CONSUMED
32.00	0.00000 /MOL PROD.	-OXYGEN CONSUMED
17.02	0.00000 /MOL PROD.	-AMMONIA CONSUMED
.00	0.00000 /MOL PROD.	-COMPONENT #1 FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #2 FORMED
58.08	0.39985 /MOL PROD.	-COMPONENT #3 FORMED (ACETONE)
.00	0.00000 /MOL PROD.	-COMPONENT #4 FORMED
46.07	0.16600 /MOL PROD.	-COMPONENT #5 FORMED (ETHANOL)
.00	0.00000 /MOL PROD.	-COMPONENT #6 FORMED
74.12	1.00000 /MOL PROD.	-COMPONENT #7 FORMED (BUTANOL)
60.05	0.24982 /MOL PROD.	-COMPONENT #8 FORMED (ACETIC ACID)
.00	0.00000 /MOL PROD.	-COMPONENT #9 FORMED
88.10	0.06749 /MOL PROD.	-COMPONENT #10 FORMED (BUTYRIC ACID
18.02	0.35033 /MOL PROD.	-WATER FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #11 FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #12 FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #13 FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #14 FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #15 FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #16 FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #17 FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #18 FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #19 FORMED
.00	0.00000 /MOL PROD.	-COMPONENT #20 FORMED
44.01	3.75036 /MOL PROD.	-CARBON DIOXIDE FORMED
2.02	2.23400 /MOL PROD.	-HYDROGEN FORMED

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

SINGLE-STAGE INSITU EXTRACTIVE FERMENTATION OF BUTANOL
NO RECOVERY OF RAFFINATE CHEMICALS
BASECASE STOICHIOMETRY

BASIC DATA

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	1	(0 OR 1)	-CONCUR'NT (0) OR SEQUENT'AL (1)
CONDITIONS			

STAGE: GROWTH	PRODUCTION		
33	33	C	-TEMPERATURE
6.5	6.5		-pH
			-PRODUCT CONCENTRATION IN BEER
0	208.6	g/l **	*Before Extraction
0	13.0		*After extraction
22.2	22.4	g/l	-CELL DENSITY (CHO ONLY)
0.28	0.030	1/hr	-DILUTION RATE
0.00	6.33	g/l*hr	-PRODUCT PRODUCTIVITY
6.20	0.00	g/l*hr	-CELL PRODUCTIVITY (CHO ONLY)
216	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
270	24	Btu/hr*gal	-HEAT REMOVED BY COOLING COILS

FERMENTERS

50,574	466,523	gallons	-ACTIVE VOLUME REQUIRED
15	15	% gross	-HEADSPACE
69,999	759,655	gallons	-GROSS VOLUME (incl. 15% spares and
100,000	250,000	gallons	-GROSS SIZE
0.7	3.0	units	-NUMBER OF UNITS

log(g/l)
0.0000
0.4771
1.0000
1.4771
2.0000
2.4771
ERR

PRODUCT SEPARATION

400	g/l	-CELL CONC. (CHO)
0.053	gal/min*sf	-FILTER THROUGHPU
4,698	sq ft	-FILTER SIZE

PRODUCT RECOVERY & PURIFICATION

92.8%(wt)%		-YIELD ACROSS REFINING

MATERIALS OF CONSTRUCTION

SINGLE-STAGE INSITU EXTRACTIVE FERMENTATION OF BUTANOL
NO RECOVERY OF RAFFINATE CHEMICALS
BASECASE STOICHIOMETRY

BASIC DATA

	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 1985: /lb.

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

VENTURE TIMING

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

EXTRACTION

Solvent	Oleyl Alcohol CH3(CH2)7CH=CH(CH2)7CH2OH	
Solvent Molecular Weight	268.5	
Solvent Ratio	3.50	lb/lb water in beer before extraction
Mutual Solubilities		
Water in Solvent	0.020	lb/M lb
Solvent in Water	0.020	lb/M lb
Balances		
Extract - Solvent	3.49998	lb/lb water in beer before extraction
- Water	0.00007	lb/lb water in beer before extraction
Raffinate - Water	0.99993	lb/lb water in beer before extraction
- Solvent	0.00002	lb/lb water in beer before extraction

Solute Distribution

Solute	K	Extract	Raffinate
Component #1	0.00	0.000	1.000 lb/lb in beer
Component #2	0.00	0.000	1.000 lb/lb in beer
Component #3	0.52	0.645	0.355 lb/lb in beer
Component #4	0.00	0.000	1.000 lb/lb in beer
Component #5	0.22	0.435	0.565 lb/lb in beer
Component #6	0.00	0.000	1.000 lb/lb in beer
Component #7	4.30	0.938	0.062 lb/lb in beer
Component #8	0.22	0.435	0.565 lb/lb in beer

SINGLE-STAGE INSITU EXTRACTIVE FERMENTATION OF BUTANOL
NO RECOVERY OF RAFFINATE CHEMICALS
BASECASE STOICHIOMETRY

BASIC DATA

Component #9	0.00	0.000	1.000 lb/lb in beer
Component #10	0.22	0.435	0.565 lb/lb in beer
Component #11	0.00	0.000	1.000 lb/lb in beer
Component #12	0.00	0.000	1.000 lb/lb in beer
Component #13	0.00	0.000	1.000 lb/lb in beer
Component #14	0.00	0.000	1.000 lb/lb in beer
Component #15	0.00	0.000	1.000 lb/lb in beer
Component #16	0.00	0.000	1.000 lb/lb in beer
Component #17	0.00	0.000	1.000 lb/lb in beer
Component #18	0.00	0.000	1.000 lb/lb in beer
Component #19	0.00	0.000	1.000 lb/lb in beer

DISTILLATION DATA MATRIX

ITEM	COMPONENT	DEFAULT VALUE	IMPURITY #1	IMPURITY #2	LOWER BOIL PRODUCT #3
1	NAME		NONE	NONE	ACETONE
2	PRIORITY AS REFINED PRODUCT	LIST 1-4			2
3					
4	NORMAL BOILING PT, C				56.5
5	LOSS/COLUMN, WT %	0.50			
6	LEVEL AS IMPURITY, WT%	0.20			
7	VAP PRESS TEMP, C	900			-9.4
8	VAPOR PRESS, mm Hg	800000			40.0
9	HT VAPORIZATION, Btu/lb	215.0			
10	SENSIBLE HT (LIQ), Btu/(lb)	0.50			
11	MAX THERMAL STABILITY, C	225			
12	LN(ACTIVITY COEFFICIENTS)				
13	-COMP. #1 in:	*	xxxx		
14	-COMP. #2 in:	*		xxxx	
15	-COMP. #3 in:	*			xxxx
16	-COMP. #4 in:	*			
17	-COMP. #5 in:	*			0.400
18	-COMP. #6 in:	*			
19	-COMP. #7 in:	*			0.400
20	-COMP. #8 in:	*			0.700
21	-COMP. #9 in:	*			
22	-COMP. #10 in:	*			0.650
23	-SOLVENT in:	*			1.100
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

34	B(n) VAPOR PRESSURE CONST.	-2476.10	-2476.10	-3880.77
35	A(n) VAPOR PRESSURE CONST.	15.703	15.703	18.411
36	VAPOR PRESSURE @40 C	2422.2	2422.2	408.5
37	VAPOR PRESSURE @120 C	12121.9	12121.9	5096.7

DISTILLATION DATA MATRIX

ITEM	COMPONENT	IMPURITY #4	IMPURITY #5	IMPURITY #6	LOW BOIL PRODUCT #7
1	NAME	NONE	ETHANOL	NONE	BUTANOL
2	PRIORITY AS REFINED PRODUCT				1
3					
4	NORMAL BOILING PT, C		78.4		117.5
5	LOSS/COLUMN, WT %				
6	LEVEL AS IMPURITY, WT%				
7	VAP PRESS TEMP, C		19.0		53.4
8	VAPOR PRESS, mm Hg		40.0		40.0
9	HT VAPORIZATION, Btu/lb				
10	SENSIBLE HT (LIQ), Btu/(lb)(F)				
11	MAX THERMAL STABILITY, C				
12	LN(ACTIVITY COEFFICIENTS)				
13	-COMP. #1 in:				
14	-COMP. #2 in:				
15	-COMP. #3 in:		0.400		0.400
16	-COMP. #4 in:	xxxx			
17	-COMP. #5 in:		xxxx		0.300
18	-COMP. #6 in:			xxxx	
19	-COMP. #7 in:		0.300		xxxx
20	-COMP. #8 in:		0.600		0.600
21	-COMP. #9 in:				
22	-COMP. #10 in:		0.500		0.400
23	-SOLVENT in:		1.050		0.700
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

34	B(n) VAPOR PRESSURE CONST.	-2476.10	-5086.29	-2476.10	-5854.85
35	A(n) VAPOR PRESSURE CONST.	15.703	21.108	15.703	21.627
36	VAPOR PRESSURE @40 C	2422.2	128.7	2422.2	18.6
37	VAPOR PRESSURE @120 C	12121.9	3517.3	12121.9	836.1

DISTILLATION DATA MATRIX

ITEM	COMPONENT	IMPURITY #8	IMPURITY #9	IMPURITY #10	SOLVENT
1	NAME	ACETIC AC	NONE	BUTYRIC ACID	
2	PRIORITY AS REFINED PRODUCT				
3					
4	NORMAL BOILING PT, C	118.1		163.5	213.5
5	LOSS/COLUMN, WT %				
6	LEVEL AS IMPURITY, WT%				
7	VAP PRESS TEMP, C	43.0		88.0	118.0
8	VAPOR PRESS, mm Hg	40.0		40.0	15.0
9	HT VAPORIZATION, Btu/lb				215.0
10	SENSIBLE HT (LIQ), Btu/(lb)(F)				0.50
11	MAX THERMAL STABILITY, C				
12	LN(ACTIVITY COEFFICIENTS)				
13	-COMP. #1 in:				
14	-COMP. #2 in:				
15	-COMP. #3 in:	0.700		0.650	1.100
16	-COMP. #4 in:				
17	-COMP. #5 in:	0.600		0.500	1.050
18	-COMP. #6 in:				
19	-COMP. #7 in:	0.600		0.400	0.700
20	-COMP. #8 in:	xxxx		0.300	0.800
21	-COMP. #9 in:		xxxx		
22	-COMP. #10 in:	0.300		xxxx	0.750
23	-SOLVENT in:	0.800		0.750	xxxx
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

34	B(n) VAPOR PRESSURE CONST.	-4845.49	-2476.10	-6145.36	-7818.54
35	A(n) VAPOR PRESSURE CONST.	19.023	15.703	20.712	22.704
36	VAPOR PRESSURE @40 C	34.5	2422.2	2.9	0.1
37	VAPOR PRESSURE @120 C	806.9	12121.9	160.0	16.6

OFTEN USED PARAMETERS

(THOUSAND ANNUAL POUNDS)

195,090	PRODUCT FORMED
	FORMED WITH PRODUCT
0	-COMPONENT #1
0	-COMPONENT #2
61,123	-COMPONENT #3
0	-COMPONENT #4
20,128	-COMPONENT #5
0	-COMPONENT #6
195,090	-COMPONENT #7
39,488	-COMPONENT #8
0	-COMPONENT #9
15,651	-COMPONENT #10
16,612	-WATER
0	-COMPONENT #11
0	-COMPONENT #12
0	-COMPONENT #13
0	-COMPONENT #14
0	-COMPONENT #15
0	-COMPONENT #16
0	-COMPONENT #17
0	-COMPONENT #18
0	-COMPONENT #19
0	-COMPONENT #20
11,854	-HYDROGEN
434,434	-CARBON DIOXIDE
	CONSUMED FOR PRODUCT
794,380	-GLUCOSE
0	-AMMONIA
0	-OXYGEN
20,905	CELLS PRODUCED - CHO
1,911	CELLS PRODUCED - NH2
	FORMED WITH CELLS
12,536	-WATER-CHO
1,075	-WATER-NH2
13,611	-WATER-TOTAL
30,643	-CARBON DIOXIDE-CHO
	CONSUMED FOR CELLS
41,809	-GLUCOSE-CHO
2,031	-AMMONIA-NH2
22,286	-OXYGEN-CHO
956	-OXYGEN-NH2
23,242	-OXYGEN-TOTAL
116,208	OXYGEN FED-GROWTH
384,836	NITROGEN FED-GROWTH
92,967	OXYGEN VENT-GROWTH
384,836	NITROGEN VENT-GROWTH
30,643	CARBON DIOXIDE VENT-GROWTH
15,580	WATER VENT GROWTH

OFTEN USED PARAMETERS

0	OXYGEN FED-PROD'N
0	NITROGEN FED-PROD'N
0	OXYGEN VENT-PROD'N
0	NITROGEN VENT-PROD'N
434,434	CARBON DIOXIDE VENT-PROD'N
24,992	WATER VENT-PROD'N
459,425	PHI

WATER BALANCE

WATER IN:	
MAKE UP WATER	109,085
BIOSUGAR SYRUP	836,283
STERILIZER STEAM	64,539
FORMED WITH CELLS	13,611
FORMED WITH PRODUCT	16,612
TOTAL IN	1,040,131
WATER OUT:	
AQUEOUS WASTE	908,353
CONDENSATE MAKEUP TO P.H	64,539
FERMENTER VENTS	40,572
PURGED WITH CELLS	26,601
MOISTURE IN PRODUCTS	65
TOTAL OUT	1,040,131

SINGLE-STAGE INSITU EXTRACTIVE FERMENTATION OF BUTANOL
NO RECOVERY OF RAFFINATE CHEMICALS
BASECASE STOICHIOMETRY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	1 CORN SYRUP	2 ANHYD AMMONIA	3 NUTRIENTS	4 MIX WATER	5 MIXED MEDIUM
	CELLS -CHO	0	0	0	0	0
	-NH2	0	0	0	0	0
	-MINERALS	0	0	0	0	0
	-TOTAL	0	0	0	0	0
	COMPONENT #1	0	0	0	0	0
	COMPONENT #2	0	0	0	0	0
2	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	COMPONENT #6	0	0	0	0	0
1	COMPONENT #7	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
	COMPONENT #11	0	0	0	0	0
	COMPONENT #12	0	0	0	0	0
	COMPONENT #13	0	0	0	0	0
	COMPONENT #14	0	0	0	0	0
	COMPONENT #15	0	0	0	0	0
	COMPONENT #16	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
	COMPONENT #20	0	0	0	0	0
	GLUCOSE	836,283	0	0	0	836,283
	AMMONIA	0	2,031	0	0	0
	PHOSPHORIC ACID	0	0	1,691	0	1,691
	POTASSIUM CHLORIDE	0	0	1,288	0	1,288
	MINOR NUTRIENTS	0	0	584	0	584
	WATER	836,283	0	0	44,547	880,830
	SOLVENT	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	1,672,567	2,031	3,563	44,547	1,720,676
	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

SINGLE-STAGE INSITU EXTRACTIVE FERMENTATION OF BUTANOL
NO RECOVERY OF RAFFINATE CHEMICALS
BASECASE STOICHIOMETRY

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
	CELLS -CHO	0	0	0	0	0
	-NH2	0	0	0	0	0
	-MINERALS	0	0	0	0	0
	-TOTAL	0	0	0	0	0
	COMPONENT #1	0	0	0	0	0
	COMPONENT #2	0	0	0	0	0
2	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	COMPONENT #6	0	0	0	0	0
1	COMPONENT #7	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
	COMPONENT #11	0	0	0	0	0
	COMPONENT #12	0	0	0	0	0
	COMPONENT #13	0	0	0	0	0
	COMPONENT #14	0	0	0	0	0
	COMPONENT #15	0	0	0	0	0
	COMPONENT #16	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
	COMPONENT #20	0	0	0	0	0
	GLUCOSE	836,283	836,283	836,283	836,283	0
	AMMONIA	0	0	0	0	0
	PHOSPHORIC ACID	1,691	1,691	1,691	1,691	0
	POTASSIUM CHLORIDE	1,288	1,288	1,288	1,288	0
	MINOR NUTRIENTS	584	584	584	584	0
	WATER	880,830	945,369	945,369	945,369	0
	SOLVENT	0	0	0	0	0
	CARBON DIOXIDE	0	0	0	0	0
	OXYGEN	0	0	0	0	116,208
	NITROGEN	0	0	0	0	384,836
	HYDROGEN	0	0	0	0	0
	GRAND TOTAL	1,720,676	1,785,215	1,785,215	1,785,215	501,044
	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

SINGLE-STAGE INSITU EXTRACTIVE FERMENTATION OF BUTANOL
NO RECOVERY OF RAFFINATE CHEMICALS
BASECASE STOICHIOMETRY

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
	CELLS -CHO	0	20,905	20,905	0	0
	-NH2	0	1,911	1,911	0	0
	-MINERALS	0	584	584	0	0
	-TOTAL	0	23,400	23,400	0	0
	COMPONENT #1	0	0	0	0	0
	COMPONENT #2	0	0	0	0	0
2	COMPONENT #3	0	0	61,123	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	20,128	0	0
	COMPONENT #6	0	0	0	0	0
1	COMPONENT #7	0	0	195,090	0	0
	COMPONENT #8	0	0	39,488	0	0
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	0	0	15,651	0	0
	COMPONENT #11	0	0	0	0	0
	COMPONENT #12	0	0	0	0	0
	COMPONENT #13	0	0	0	0	0
	COMPONENT #14	0	0	0	0	0
	COMPONENT #15	0	0	0	0	0
	COMPONENT #16	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
	COMPONENT #20	0	0	0	0	0
	GLUCOSE	836,283	794,474	94	0	0
	AMMONIA	2,031	0	0	0	0
	PHOSPHORIC ACID	1,691	1,691	1,691	0	0
	POTASSIUM CHLORIDE	1,288	1,288	1,288	0	0
	MINOR NUTRIENTS	584	0	0	0	0
	WATER	945,369	943,399	935,020	15,580	24,992
	SOLVENT	0	0	0	0	0
	CARBON DIOXIDE	0	0	0	30,643	434,434
	OXYGEN	116,208	0	0	92,967	0
	NITROGEN	384,836	0	0	384,836	0
	HYDROGEN	0	0	0	0	11,854
	GRAND TOTAL	2,288,290	1,764,252	1,292,973	524,026	471,280
	CHECK ON TOTAL					
	TEMPERATURE, C	33	33	33	33	33
	PRESSURE, PSIA	--	44.7	44.7	14.7	14.7
	STATE	--	SLURRY	SLURRY	GAS	GAS

SINGLE-STAGE INSITU EXTRACTIVE FERMENTATION OF BUTANOL
NO RECOVERY OF RAFFINATE CHEMICALS
BASECASE STOICHIOMETRY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	16 COMBINED VENT	17 SOLVENT FEED	18 RAFFINATE	19 CELL EFFLUENT	20 CELLS TO DISPOSAL
	CELLS -CHO	0	0	20,905	20,905	20,905
	-NH2	0	0	1,911	1,911	1,911
	-MINERALS	0	0	584	584	584
	-TOTAL	0	0	23,400	23,400	23,400
	COMPONENT #1	0	0	0	0	0
	COMPONENT #2	0	0	0	0	0
2	COMPONENT #3	0	0	21,674	617	617
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	11,372	324	324
	COMPONENT #6	0	0	0	0	0
1	COMPONENT #7	0	0	12,154	346	346
	COMPONENT #8	0	0	22,309	635	635
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	0	0	8,842	252	252
	COMPONENT #11	0	0	0	0	0
	COMPONENT #12	0	0	0	0	0
	COMPONENT #13	0	0	0	0	0
	COMPONENT #14	0	0	0	0	0
	COMPONENT #15	0	0	0	0	0
	COMPONENT #16	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
	COMPONENT #20	0	0	0	0	0
	GLUCOSE	0	0	94	3	3
	AMMONIA	0	0	0	0	0
	PHOSPHORIC ACID	0	0	1,691	48	48
	POTASSIUM CHLORIDE	0	0	1,288	37	37
	MINOR NUTRIENTS	0	0	0	0	0
	WATER	40,572	0	934,954	26,601	26,601
	SOLVENT	0	3,272,570	19	1	1
	CARBON DIOXIDE	465,077	0	0	0	0
	OXYGEN	92,967	0	0	0	0
	NITROGEN	384,836	0	0	0	0
	HYDROGEN	11,854	0	0	0	0
	GRAND TOTAL	995,306	3,272,570	1,037,797	52,262	52,262
	CHECK ON TOTAL				52,262	
	TEMPERATURE, C	33	20	33	33	33
	PRESSURE, PSIA	14.7	15	15	44.7	14.7
	STATE	GAS	LIQUID	SOL'N	SLURRY	SLURRY

SINGLE-STAGE INSITU EXTRACTIVE FERMENTATION OF BUTANOL
NO RECOVERY OF RAFFINATE CHEMICALS
BASECASE STOICHIOMETRY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	21 FILTRATE TO WASTE	22 EXTRACT	23 BEER #1 FEED	24 BEER #1 MAKE	25 BEER #1 TAILS
	CELLS -CHO	0	0	0	0	0
	-NH2	0	0	0	0	0
	-MINERALS	0	0	0	0	0
	-TOTAL	0	0	0	0	0
	COMPONENT #1	0	0	0	0	0
	COMPONENT #2	0	0	0	0	0
2	COMPONENT #3	21,057	39,449	39,449	39,449	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	11,048	8,757	8,757	8,757	0
	COMPONENT #6	0	0	0	0	0
1	COMPONENT #7	11,809	182,936	201,138	200,223	915
	COMPONENT #8	21,674	17,179	17,215	17,129	16,815
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	8,591	6,809	6,845	6,811	6,445
	COMPONENT #11	0	0	0	0	0
	COMPONENT #12	0	0	0	0	0
	COMPONENT #13	0	0	0	0	0
	COMPONENT #14	0	0	0	0	0
	COMPONENT #15	0	0	0	0	0
	COMPONENT #16	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
	COMPONENT #20	0	0	0	0	0
	GLUCOSE	91	0	0	0	0
	AMMONIA	0	0	0	0	0
	PHOSPHORIC ACID	1,643	0	0	0	0
	POTASSIUM CHLORIDE	1,251	0	0	0	0
	MINOR NUTRIENTS	0	0	0	0	0
	WATER	908,353	65	65	65	0
	SOLVENT	18	3,272,551	3,472,410	200,223	3,272,187
	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	985,535	3,527,746	3,745,879	472,658	3,296,361
	CHECK ON TOTAL					
	TEMPERATURE, C	33	33	--	94	220
	PRESSURE, PSIA	14.7	14.7	--	12.1	12.9
	STATE	SOL'N	SOL'N	SOL'N	SOL'N	SOL'N

SINGLE-STAGE INSITU EXTRACTIVE FERMENTATION OF BUTANOL
NO RECOVERY OF RAFFINATE CHEMICALS
BASECASE STOICHIOMETRY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	26 BEER #2 MAKE	27 BEER #2 TAILS	28 LBS #1 MAKE	29 LBS #1 TAILS	30 LBS #2 MAKE
	CELLS -CHO	0	0	0	0	0
	-NH2	0	0	0	0	0
	-MINERALS	0	0	0	0	0
	-TOTAL	0	0	0	0	0
	COMPONENT #1	0	0	0	0	0
	COMPONENT #2	0	0	0	0	0
2	COMPONENT #3	39,449	0	39,087	362	38,892
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	8,757	0	8,394	362	78
	COMPONENT #6	0	0	0	0	0
1	COMPONENT #7	182,021	18,202	910	181,111	0
	COMPONENT #8	364	36	0	364	0
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	364	36	0	364	0
	COMPONENT #11	0	0	0	0	0
	COMPONENT #12	0	0	0	0	0
	COMPONENT #13	0	0	0	0	0
	COMPONENT #14	0	0	0	0	0
	COMPONENT #15	0	0	0	0	0
	COMPONENT #16	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
	COMPONENT #20	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	65	0	0	65	0
	SOLVENT	364	199,859	0	364	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	231,385	218,134	48,392	182,993	38,969
	CHECK ON TOTAL					
	TEMPERATURE, C	155	220	117	170	100
	PRESSURE, PSIA	89.3	90.2	84.6	86.7	58.2
	STATE	SOL'N	SOL'N	SOL'N	SOL'N	SOL'N

SINGLE-STAGE INSITU EXTRACTIVE FERMENTATION OF BUTANOL
NO RECOVERY OF RAFFINATE CHEMICALS
BASECASE STOICHIOMETRY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	31 LBS #2 TAILS	32 LBS #3 MAKE	33 LBS #3 TAILS	34 HBS #1 MAKE	35 HBS #1 TAILS
	CELLS -CHO	0	0	0	0	0
	-NH2	0	0	0	0	0
	-MINERALS	0	0	0	0	0
	-TOTAL	0	0	0	0	0
	COMPONENT #1	0	0	0	0	0
	COMPONENT #2	0	0	0	0	0
2	COMPONENT #3	195	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	8,317	0	0	0	0
	COMPONENT #6	0	0	0	0	0
1	COMPONENT #7	910	0	0	915	0
	COMPONENT #8	0	0	0	16,731	84
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	0	0	0	6,413	32
	COMPONENT #11	0	0	0	0	0
	COMPONENT #12	0	0	0	0	0
	COMPONENT #13	0	0	0	0	0
	COMPONENT #14	0	0	0	0	0
	COMPONENT #15	0	0	0	0	0
	COMPONENT #16	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
	COMPONENT #20	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	0	0	0	0	0
	SOLVENT	0	0	0	13	3,272,174
	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	9,422	0	0	24,071	3,272,290
	CHECK ON TOTAL					
	TEMPERATURE, C	120	(273)	120	123	220
	PRESSURE, PSIA	65.3	.0	.0	14.3	17.8
	STATE	SOL'N	SOL'N	SOL'N	SOL'N	SOL'N

SINGLE-STAGE INSITU EXTRACTIVE FERMENTATION OF BUTANOL
NO RECOVERY OF RAFFINATE CHEMICALS
BASECASE STOICHIOMETRY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	36 REFINED PRODUCT	37 REFINED B.P.#1	38 ORGANIC WASTE	39 MAKE-UP SOLVENT	40 MAKE-UP WATER
	CELLS -CHO	0	0	0	0	0
	-NH2	0	0	0	0	0
	-MINERALS	0	0	0	0	0
	-TOTAL	0	0	0	0	0
	COMPONENT #1	0	0	0	0	0
	COMPONENT #2	0	0	0	0	0
2	COMPONENT #3	362	38,892	195	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	362	78	8,317	0	0
	COMPONENT #6	0	0	0	0	0
1	COMPONENT #7	181,111	0	1,825	0	0
	COMPONENT #8	364	0	16,731	0	0
	COMPONENT #9	0	0	0	0	0
	COMPONENT #10	364	0	6,413	0	0
	COMPONENT #11	0	0	0	0	0
	COMPONENT #12	0	0	0	0	0
	COMPONENT #13	0	0	0	0	0
	COMPONENT #14	0	0	0	0	0
	COMPONENT #15	0	0	0	0	0
	COMPONENT #16	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
	COMPONENT #20	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	65	0	0	0	109,085
	SOLVENT	364	0	13	377	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
		0	0			
	GRAND TOTAL	182,993	38,969	33,493	377	109,085
	CHECK ON TOTAL	0	0		377	
	TEMPERATURE, C	170	100	40	20	20
	PRESSURE, PSIA	87	58	14.7	14.7	14.7
	STATE	0	0	SOL'N	LIQUID	LIQUID

SINGLE-STAGE INSITU EXTRACTIVE FERMENTATION OF BUTANOL
NO RECOVERY OF RAFFINATE CHEMICALS
BASECASE STOICHIOMETRY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	41 STERILE STEAM	42 FERM'TR STEAM	43 DISTILL. STEAM	44 COND. MU P'WR H'SE	45 MEDIUM COOL WTR
	CELLS -CHO	0	0	0	0	0
	-NH2	0	0	0	0	0
	-MINERALS	0	0	0	0	0
	-TOTAL	0	0	0	0	0
	COMPONENT #1	0	0	0	0	0
	COMPONENT #2	0	0	0	0	0
2	COMPONENT #3	0	0	0	0	0
	COMPONENT #4	0	0	0	0	0
	COMPONENT #5	0	0	0	0	0
	COMPONENT #6	0	0	0	0	0
1	COMPONENT #7	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
	COMPONENT #11	0	0	0	0	0
	COMPONENT #12	0	0	0	0	0
	COMPONENT #13	0	0	0	0	0
	COMPONENT #14	0	0	0	0	0
	COMPONENT #15	0	0	0	0	0
	COMPONENT #16	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
	COMPONENT #20	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	64,539	0	924,984	64,539	833,100
	SOLVENT	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	64,539	0	924,984	64,539	833,100
	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

SINGLE-STAGE INSITU EXTRACTIVE FERMENTATION OF BUTANOL
NO RECOVERY OF RAFFINATE CHEMICALS
BASECASE STOICHIOMETRY

MATERIAL BALANCE FLOWSHEET

THOUSAND ANNUAL POUNDS (330 DAYS) @ CAPACITY

	STREAM	46 FERM'TR COOL WTR	47 DISTILL. COOL WTR
	CELLS -CHO	0	0
	-NH2	0	0
	-MINERALS	0	0
	-TOTAL	0	0
	COMPONENT #1	0	0
	COMPONENT #2	0	0
2	COMPONENT #3	0	0
	COMPONENT #4	0	0
	COMPONENT #5	0	0
	COMPONENT #6	0	0
1	COMPONENT #7	0	0
	COMPONENT #8	0	0
	COMPONENT #9	0	0
	COMPONENT #10	0	0
	COMPONENT #11	0	0
	COMPONENT #12	0	0
	COMPONENT #13	0	0
	COMPONENT #14	0	0
	COMPONENT #15	0	0
	COMPONENT #16	0	0
	COMPONENT #17	0	0
	COMPONENT #18	0	0
	COMPONENT #19	0	0
	COMPONENT #20	0	0
	GLUCOSE	0	0
	AMMONIA	0	0
	PHOSPHORIC ACID	0	0
	POTASSIUM CHLORIDE	0	0
	MINOR NUTRIENTS	0	0
	WATER	13,649,059	9,739,168
	SOLVENT	0	0
	CARBON DIOXIDE	0	0
	OXYGEN	0	0
	NITROGEN	0	0
	HYDROGEN	0	0
	GRAND TOTAL	13,649,059	9,739,168
	CHECK ON TOTAL		
	TEMPERATURE, C	5	0
	PRESSURE, PSIA	14.7	14.7
	STATE	LIQUID	LIQUID

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	22 EXTRACT	23 BEER #1 FEED	24 BEER #1 MAKE	25 BEER #1 TAILS
COMPONENT #1	0	0	0	0
COMPONENT #2	0	0	0	0
COMPONENT #3	679	679	679	0
COMPONENT #4	0	0	0	0
COMPONENT #5	190	190	190	0
COMPONENT #6	0	0	0	0
COMPONENT #7	2,468	2,714	2,701	12
COMPONENT #8	286	287	285	280
COMPONENT #9	0	0	0	0
COMPONENT #10	77	78	77	73
COMPONENT #11	0	0	0	0
COMPONENT #12	0	0	0	0
COMPONENT #13	0	0	0	0
COMPONENT #14	0	0	0	0
COMPONENT #15	0	0	0	0
COMPONENT #16	0	0	0	0
COMPONENT #17	0	0	0	0
COMPONENT #18	0	0	0	0
COMPONENT #19	0	0	0	0
COMPONENT #20	0	0	0	0
WATER	4	4	4	0
SOLVENT	12,190	12,934	746	12,188
TOTAL (q)	15,894	16,885	4,683	12,554
(Storage)	358	362	362	10
VAPOR PRESS 40(q)	22.6	21.5	77.4	0.9
(Storage)	6,437	6,643	6,631	248
VAPOR PRESS 120(q)	417.7	406.1	1418.8	35.9
B(q) V.P. CONSTANT	-4485.6	-4515.5	-4473.2	-5657.5
A(q) V.P. CONSTANT	17.449	17.497	18.640	17.976
TEMPERATURE C	33.0	66.9	87.3	220.0
PRESSURE mmHg	760	760	505	665
K1 (COMPONENT #)			7	7
K2 (COMPONENT #)			SOLVENT	SOLVENT
V.P.(K1)			216.4	17164.0
V.P.(K2)			2.7	939.4
GAMMA-K1 IN K2			2.014	2.014
GAMMA-K2 IN K1			2.014	2.014
ALPHA			53.256	36.743
AVG COLUMN ALPHA			44.999	
MOL FRACT. K1 (MAKE OR TAILS)			0.784	0.001
MOL FRACT. K1 (FEED)			0.173	

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	22 EXTRACT	23 BEER #1 FEED	24 BEER #1 MAKE	25 BEER #1 TAILS
MOL FRACT. K2 (MAKE OR TAILS)			0.216	0.999
ADJ. GAMMA-K1 IN K2			1.033	2.011
ADJ. GAMMA-K2 IN K1			1.537	1.000
MINIMUM REFLUX RATIO (ADJUSTED)			0.0	
ACTUAL REFLUX RATIO			0.0	
MINIMUM PLATES			2	
ACTUAL PLATES			10	
PRESSURE mm Hg (REVISED)			626	
TEMPERATURE C (REVISED)			94	
AVERAGE MOLECULAR WEIGHT			100.94	262.58
GAS DENSITY - LB/CF			0.1726	0.3545
CROSS SECTIONAL AREA - SQ FT			33.3	
COLUMN HEIGHT - FT			29.5	
COLUMN DIAMETER			6.5	
K1 (MPPY)			200,223	
Hv (HEAT VAPORIZ.-Btu/Lb)			215.1	215.0
Cn (HEAT CAPACITY - Btu/Lb/F)			0.500	0.500
HEAT LOAD - MM Btu/Hr			14.121	77.210
CONDENSER COOLING WATER - GPM (15 C dT)			1046	
CALANDRIA STEAM - MPPH (150 PSIG)				90.09
COLUMN COST - $1000 3Q85 MPC - BARE EQUIPMENT				
- ALL CARBON STEEL			$66.9	
- C.S w/304 S.S. TRAYS			$73.6	
- ALL 304 STAINLESS STEEL			$108.0	
- ALL 304L STAINLESS STEEL			$118.8	
- ALL 316 STAINLESS STEEL			$145.8	
CONDENSER OR CALANDRIA SURFACE - SQ FT			1,540	4,289
COND. OR CALAND. COST - $1000 3Q86 MPC - BARE EQUIPMENT				
-CARBON STEEL			$56.9	$135.5
-304 STAINLESS STEEL			$79.7	$189.7
-316 STAINLESS STEEL			$85.4	$203.3
-MONEL			$111.0	$264.3
SUBTOTAL				12,087
SUBTOTAL				0
SUBTOTAL				0
MINIMUM REFLUX RATIO			(0.4)	
Cn SUBTOTAL #1			124,215	457
Cn SUBTOTAL #2			11,970	11,630
Cn SUBTOTAL #3			100,177	1,636,093
Cn CHECK			0.500	0.500
Hv SUBTOTAL #1			53,412	197
Hv SUBTOTAL #2			5,147	5,001
Hv SUBTOTAL #3			43,111	703,520
Hv CHECK			215.2	215.0
MIN. PLATES(NORMAL)				
COL.COST-C/S NORMAL				
COL.COST-S/S NORMAL				
MIN.REFLUX(NORMAL)				
C.S. AREA(NORMAL)				
HEAT LOAD(NORMAL)				

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	22 EXTRACT	23 BEER #1 FEED	24 BEER #1 MAKE	25 BEER #1 TAILS
CON/CAL COST(NORMAL)				

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	26 BEER #2 MAKE	27 BEER #2 TAILS	28 LBS #1 MAKE	29 LBS #1 TAILS
COMPONENT #1	0	0	0	0
COMPONENT #2	0	0	0	0
COMPONENT #3	679	0	673	6
COMPONENT #4	0	0	0	0
COMPONENT #5	190	0	182	8
COMPONENT #6	0	0	0	0
COMPONENT #7	2,456	246	12	2,443
COMPONENT #8	6	1	0	6
COMPONENT #9	0	0	0	0
COMPONENT #10	4	0	0	4
COMPONENT #11	0	0	0	0
COMPONENT #12	0	0	0	0
COMPONENT #13	0	0	0	0
COMPONENT #14	0	0	0	0
COMPONENT #15	0	0	0	0
COMPONENT #16	0	0	0	0
COMPONENT #17	0	0	0	0
COMPONENT #18	0	0	0	0
COMPONENT #19	0	0	0	0
COMPONENT #20	0	0	0	0
WATER	4	0	0	4
SOLVENT	1	744	0	1
TOTAL (q)	3,340	991	868	2,473
(Storage)	348	5	299	49
VAPOR PRESS 40(q)	104.1	4.7	344.2	19.9
(Storage)	6,189	206	4,081	2,108
VAPOR PRESS 120(q)	1852.9	220.2	4704.6	852.4
B(q) V.P. CONSTANT	-4427.0	-5915.7	-4021.0	-5779.9
A(q) V.P. CONSTANT	18.789	20.447	18.688	21.455
TEMPERATURE C	153.7	220.0	116.8	170.0
PRESSURE mmHg	4,505	4,665	4,323	4,483
K1 (COMPONENT #)	7	7	6,5,4,3	6,5,4,3
K2 (COMPONENT #)	SOLVENT	SOLVENT	7	7
V.P.(K1)	2707.3	17164.0	3160.4	15156.9
V.P.(K2)	79.8	939.4	739.2	4492.5
GAMMA-K1 IN K2	2.014	2.014	1.350	1.350
GAMMA-K2 IN K1	2.014	2.014	1.350	1.350
ALPHA	16.870	26.000	3.290	4.545
AVG COLUMN ALPHA	21.435		3.918	
MOL FRACT. K1 (MAKE OR TAILS)	0.999	0.248	0.937	0.003
MOL FRACT. K1 (FEED)	0.784		0.072	

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	26 BEER #2 MAKE	27 BEER #2 TAILS	28 LBS #1 MAKE	29 LBS #1 TAILS
MOL FRACT. K2 (MAKE OR TAILS)	0.001	0.752	0.063	0.997
ADJ. GAMMA-K1 IN K2	1.000	1.486	1.001	1.347
ADJ. GAMMA-K2 IN K1	2.012	1.044	1.301	1.000
MINIMUM REFLUX RATIO (ADJUSTED	0.0		0.5	
ACTUAL REFLUX RATIO	0.0		0.7	
MINIMUM PLATES	3		6	
ACTUAL PLATES	13		28	
PRESSURE mm Hg (REVISED)	4,615		4,372	
TEMPERATURE C (REVISED)	155		117	
AVERAGE MOLECULAR WEIGHT	69.27	220.11	55.78	74.00
GAS DENSITY - LB/CF	0.7479	2.0840	0.6254	0.7493
CROSS SECTIONAL AREA - SQ FT	7.8		3.0	
COLUMN HEIGHT - FT	34.0		56.7	
COLUMN DIAMETER	3.2		2.0	
K1 (MPPY)	182,021		8,394	
Hv (HEAT VAPORIZ.-Btu/Lb)	215.2	215.0	215.0	215.3
Cn (HEAT CAPACITY - Btu/Lb/F)	0.500	0.500	0.500	0.500
HEAT LOAD - MM Btu/Hr	6.916	10.361	2.425	2.776
CONDENSER COOLING WATER - GPM	513		180	
CALANDRIA STEAM - MPPH (150 PSIG)		12.09		3.24
COLUMN COST - $1000 3Q85 MPC - BARE EQUIPMENT				
- ALL CARBON STEEL	$41.8		$42.9	
- C.S w/304 S.S. TRAYS	$45.9		$47.1	
- ALL 304 STAINLESS STEEL	$68.5		$70.2	
- ALL 304L STAINLESS STEEL	$75.3		$77.2	
- ALL 316 STAINLESS STEEL	$92.5		$94.8	
CONDENSER OR CALANDRIA SURFACE	385	576	193	154
COND. OR CALAND. COST - $1000 3Q86 MPC - BARE EQUIPMENT				
-CARBON STEEL	$22.3	$28.5	$15.5	$14.0
-304 STAINLESS STEEL	$31.3	$39.9	$21.7	$19.6
-316 STAINLESS STEEL	$33.5	$42.7	$23.3	$21.0
-MONEL	$43.5	$55.5	$30.2	$27.2
SUBTOTAL		9,137		90,952
SUBTOTAL		0		33
SUBTOTAL		0		33
MINIMUM REFLUX RATIO	(0.8)		0.5	
Cn SUBTOTAL #1	115,113	9,101	24,196	90,918
Cn SUBTOTAL #2	364	36	0	364
Cn SUBTOTAL #3	247	99,929	0	247
Cn CHECK	0.500	0.500	0.500	0.500
Hv SUBTOTAL #1	49,499	3,913	10,404	39,095
Hv SUBTOTAL #2	157	16	0	157
Hv SUBTOTAL #3	142	42,970	0	142
Hv CHECK	215.2	215.0	215.0	215.3
MIN. PLATES(NORMAL)				
COL.COST-C/S NORMAL			43	
COL.COST-S/S NORMAL			70	
MIN.REFLUX(NORMAL)				
C.S. AREA(NORMAL)			3	
HEAT LOAD(NORMAL)				3

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	26 BEER #2 MAKE	27 BEER #2 TAILS	28 LBS #1 MAKE	29 LBS #1 TAILS
CON/CAL COST(NORMAL)			16	14

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	30 LBS #2 MAKE	31 LBS #2 TAILS	32 LBS #3 MAKE	33 LBS #3 TAILS
COMPONENT #1	0	0	0	0
COMPONENT #2	0	0	0	0
COMPONENT #3	670	3	0	0
COMPONENT #4	0	0	0	0
COMPONENT #5	2	181	0	0
COMPONENT #6	0	0	0	0
COMPONENT #7	0	12	0	0
COMPONENT #8	0	0	0	0
COMPONENT #9	0	0	0	0
COMPONENT #10	0	0	0	0
COMPONENT #11	0	0	0	0
COMPONENT #12	0	0	0	0
COMPONENT #13	0	0	0	0
COMPONENT #14	0	0	0	0
COMPONENT #15	0	0	0	0
COMPONENT #16	0	0	0	0
COMPONENT #17	0	0	0	0
COMPONENT #18	0	0	0	0
COMPONENT #19	0	0	0	0
COMPONENT #20	0	0	0	0
WATER	0	0	0	0
SOLVENT	0	0	0	0
TOTAL (g)	671	196	0	0
(Storage)	274	25	0	0
VAPOR PRESS 40(g)	407.8	126.6	.0	.0
(Storage)	3,419	662	0	0
VAPOR PRESS 120(g)	5092.7	3376.6	.0	.0
B(g) V.P. CONSTANT	-3882.2	-5048.7	0.0	0.0
A(g) V.P. CONSTANT	18.414	20.971	-4.605	-4.605
TEMPERATURE C	102.5	120.0	ERR	120.0
PRESSURE mmHg	3,217	3,377	(160)	0
K1 (COMPONENT #)	3	3	2,1	2,1
K2 (COMPONENT #)	4,5,6	4,5,6	3	3
V.P.(K1)	3219.7	5096.7	ERR	1.0
V.P.(K2)	1926.5	3517.3	ERR	5096.7
GAMMA-K1 IN K2	1.492	1.492	1.000	1.000
GAMMA-K2 IN K1	1.492	1.492	1.000	1.000
ALPHA	1.123	2.130	ERR	ERR
AVG COLUMN ALPHA	1.626		ERR	
MOL FRACT. K1 (MAKE OR TAILS)	0.997	0.018	ERR	ERR
MOL FRACT. K1 (FEED)	0.787		0.000	

DISTILLATION CALCULATIONS

| M LB. MOLES/YEAR | 30 LBS #2 MAKE | 31 LBS #2 TAILS | 32 LBS #3 MAKE | 33 LBS #3 TAILS |

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	30 LBS #2 MAKE	31 LBS #2 TAILS	32 LBS #3 MAKE	33 LBS #3 TAILS
MOL FRACT. K2 (MAKE OR TAILS)	0.003	0.982	ERR	ERR
ADJ. GAMMA-K1 IN K2	1.000	1.470	ERR	ERR
ADJ. GAMMA-K2 IN K1	1.489	1.000	ERR	ERR
MINIMUM REFLUX RATIO (ADJUSTED	0.0		ERR	
ACTUAL REFLUX RATIO	0.0		ERR	
MINIMUM PLATES	20		0	
ACTUAL PLATES	92		0	
PRESSURE mm Hg (REVISED)	3,008		0	
TEMPERATURE C (REVISED)	100		(273)	
AVERAGE MOLECULAR WEIGHT	58.05	48.03	ERR	ERR
GAS DENSITY - LB/CF	0.4682	0.4129	ERR	ERR
CROSS SECTIONAL AREA - SQ FT	1.7		0.0	
COLUMN HEIGHT - FT	153.3		0.0	
COLUMN DIAMETER	1.5		0.0	
K1 (MPPY)	38,892		0	
Hv (HEAT VAPORIZ.-Btu/Lb)	215.0	215.0	ERR	ERR
Cp (HEAT CAPACITY - Btu/Lb/F)	0.500	0.500	ERR	ERR
HEAT LOAD - MM Btu/Hr	1.164	1.167	0.000	0.000
CONDENSER COOLING WATER - GPM	86		0	
CALANDRIA STEAM - MPPH (150 PSIG)		1.36		0.00
COLUMN COST - $1000 3Q85 MPC - BARE EQUIPMENT				
- ALL CARBON STEEL	$76.2		$0.0	
- C.S w/304 S.S. TRAYS	$83.8		$0.0	
- ALL 304 STAINLESS STEEL	$122.5		$0.0	
- ALL 304L STAINLESS STEEL	$134.8		$0.0	
- ALL 316 STAINLESS STEEL	$165.4		$0.0	
CONDENSER OR CALANDRIA SURFACE	115	65	0	0
COND. OR CALAND. COST - $1000 3Q86 MPC - BARE EQUIPMENT				
-CARBON STEEL	$12.3	$10.0	$0.0	$0.0
-304 STAINLESS STEEL	$17.3	$14.0	$0.0	$0.0
-316 STAINLESS STEEL	$18.5	$15.0	$0.0	$0.0
-MONEL	$24.1	$19.5	$0.0	$0.0
SUBTOTAL		455		0
SUBTOTAL		0		0
SUBTOTAL		0		0
MINIMUM REFLUX RATIO	(0.6)		ERR	
Cp SUBTOTAL #1	19,485	4,711	0	0
Cp SUBTOTAL #2	0	0	0	0
Cp SUBTOTAL #3	0	0	0	0
Cp CHECK	0.500	0.500	ERR	ERR
Hv SUBTOTAL #1	8,378	2,026	0	0
Hv SUBTOTAL #2	0	0	0	0
Hv SUBTOTAL #3	0	0	0	0
Hv CHECK	215.0	215.0	ERR	ERR
MIN. PLATES(NORMAL)				
COL.COST-C/S NORMAL				
COL.COST-S/S NORMAL				
MIN.REFLUX(NORMAL)				
C.S. AREA(NORMAL)				
HEAT LOAD(NORMAL)				

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	30 LBS #2 MAKE	31 LBS #2 TAILS	32 LBS #3 MAKE	33 LBS #3 TAILS
CON/CAL COST(NORMAL)				

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	34 HBS #1 MAKE	35 HBS #1 TAILS
COMPONENT #1	0	0
COMPONENT #2	0	0
COMPONENT #3	0	0
COMPONENT #4	0	0
COMPONENT #5	0	0
COMPONENT #6	0	0
COMPONENT #7	12	0
COMPONENT #8	279	1
COMPONENT #9	0	0
COMPONENT #10	73	0
COMPONENT #11	0	0
COMPONENT #12	0	0
COMPONENT #13	0	0
COMPONENT #14	0	0
COMPONENT #15	0	0
COMPONENT #16	0	0
COMPONENT #17	0	0
COMPONENT #18	0	0
COMPONENT #19	0	0
COMPONENT #20	0	0
WATER	0	1
SOLVENT	0	12,188
TOTAL (q)	364	12,191
(Storage)	10	0
VAPOR PRESS 40(q)	27.7	0.1
(Storage)	247	1
VAPOR PRESS 120(q)	678.4	16.7
B(q) V.P. CONSTANT	-4919.6	-7768.0
A(q) V.P. CONSTANT	19.038	22.581
TEMPERATURE C	123.6	220.0
PRESSURE mmHg	760	920
K1 (COMPONENT #)	10,9,8	10,9,8
K2 (COMPONENT #)	SOLVENT	SOLVENT
V.P.(K1)	184.5	3815.4
V.P.(K2)	19.9	939.4
GAMMA-K1 IN K2	2.117	2.117
GAMMA-K2 IN K1	2.858	2.858
ALPHA	3.247	8.598
AVG COLUMN ALPHA	5.923	
MOL FRACT. K1 (MAKE OR TAILS)	0.999	.000
MOL FRACT. K1 (FEED)	0.006	

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	34 HBS #1 MAKE	35 HBS #1 TAILS
MOL FRACT. K2 (MAKE OR TAILS)	0.001	1.000
ADJ. GAMMA-K1 IN K2	1.000	2.117
ADJ. GAMMA-K2 IN K1	2.854	1.000
MINIMUM REFLUX RATIO (ADJUSTED	8.7	
ACTUAL REFLUX RATIO	10.9	
MINIMUM PLATES	10	
ACTUAL PLATES	45	
PRESSURE mm Hg (REVISED)	741	
TEMPERATURE C (REVISED)	123	
AVERAGE MOLECULAR WEIGHT	66.17	268.42
GAS DENSITY - LB/CF	0.1239	0.5014
CROSS SECTIONAL AREA - SQ FT	23.8	
COLUMN HEIGHT - FT	82.3	
COLUMN DIAMETER	5.5	
K1 (MPPY)	0	
Hv (HEAT VAPORIZ.-Btu/Lb)	215.0	215.0
Cn (HEAT CAPACITY - Btu/Lb/F)	0.500	0.500
HEAT LOAD - MM Btu/Hr	8.576	8.576
CONDENSER COOLING WATER - GPM	636	
CALANDRIA STEAM - MPPH (150 PSIG)		10.01
COLUMN COST - $1000 3Q85 MPC - BARE EQUIPMENT		
- ALL CARBON STEEL	$144.5	
- C.S w/304 S.S. TRAYS	$158.9	
- ALL 304 STAINLESS STEEL	$229.9	
- ALL 304L STAINLESS STEEL	$252.9	
- ALL 316 STAINLESS STEEL	$310.3	
CONDENSER OR CALANDRIA SURFACE	642	476
COND. OR CALAND. COST - $1000 3Q86 MPC - BARE EQUIPMENT		
-CARBON STEEL	$30.5	$25.3
-304 STAINLESS STEEL	$42.8	$35.5
-316 STAINLESS STEEL	$45.8	$38.0
-MONEL	$59.6	$49.4
SUBTOTAL		65
SUBTOTAL		6
SUBTOTAL		6
MINIMUM REFLUX RATIO	8.7	
Cn SUBTOTAL #1	457	0
Cn SUBTOTAL #2	11,572	58
Cn SUBTOTAL #3	6	1,636,087
Cn CHECK	0.500	0.550
Hv SUBTOTAL #1	197	0
Hv SUBTOTAL #2	4,976	25
Hv SUBTOTAL #3	3	703,517
Hv CHECK	215.0	290.0
MIN. PLATES(NORMAL)		
COL.COST-C/S NORMAL		
COL.COST-S/S NORMAL		
MIN.REFLUX(NORMAL)		
C.S. AREA(NORMAL)		
HEAT LOAD(NORMAL)		

DISTILLATION CALCULATIONS

M LB. MOLES/YEAR	34 HBS #1 MAKE	35 HBS #1 TAILS
CON/CAL COST(NORMAL)		

APPENDIX G. EXTERNAL EXTRACTOR MODE NUMBER OF EXTRACTOR STAGES REQUIRED FOR VARIOUS SOLVENT/FEED RATIOS AND YIELD TO EXTRACT

SENSITIVITY ANALYSIS
NUMBER OF STAGES
FOR K= 10

Solvent/ Water Ratio	Solute Yield (as % of solute in feed)							
	70.00%	80.00%	90.00%	95.00%	98.00%	99.00%	99.90%	99.99%
0.11	3	3	5	9	17	≥ 20	> 20	> 20
0.15	2	3	4	5	8	9	15	≥ 20
0.20	2	2	3	4	5	6	10	13
0.30	1	2	2	3	4	4	6	9
0.40	1	2	2	2	3	4	5	7
0.50	1	1	2	2	3	3	5	6
1.00	1	1	1	2	2	2	3	4
1.50	1	1	1	2	2	2	3	4
2.00	1	1	1	1	2	2	3	4
2.50	1	1	1	1	2	2	3	3
3.00	1	1	1	1	2	2	3	3
3.50	1	1	1	1	2	2	2	3

SENSITIVITY ANALYSIS
NUMBER OF STAGES
FOR K= 6

Solvent/ Water Ratio	Solute Yield (as % of solute in feed)							
	70.00%	80.00%	90.00%	95.00%	98.00%	99.00%	99.90%	99.99%
0.18	3	3	6	10	19	≥ 20	> 20	> 20
0.20	2	3	6	8	13	16	≥ 20	> 20
0.30	2	2	3	4	6	7	11	15
0.40	1	2	3	3	4	5	8	10
0.50	1	2	2	3	4	4	6	9
1.00	1	1	2	2	3	3	4	6
1.50	1	1	1	2	2	3	4	5
2.00	1	1	1	2	2	2	3	4
2.50	1	1	1	2	2	2	3	4
3.00	1	1	1	2	2	2	3	4
3.50	1	1	1	1	2	2	3	4
4.00	1	1	1	1	2	2	3	3

SENSITIVITY ANALYSIS
NUMBER OF STAGES
FOR K= 4.3

Solvent/ Water Ratio	Solute Yield (as % of solute in feed)							
	70.00%	80.00%	90.00%	95.00%	98.00%	99.00%	99.90%	99.99%
0.24	3	3	6	11	≥ 20	> 20	> 20	> 20
0.30	2	3	5	7	10	13	≥ 20	> 20
0.40	2	2	3	5	6	7	12	16
0.50	2	2	3	4	5	6	9	12
1.00	1	1	2	2	3	3	5	7
1.50	1	1	2	2	3	3	4	5
2.00	1	1	2	2	2	3	4	5
2.50	1	1	1	2	2	2	3	4
3.00	1	1	1	2	2	2	3	4
3.50	1	1	1	2	2	2	3	4
4.00	1	1	1	2	2	2	3	4
4.50	1	1	1	1	2	2	3	4

SENSITIVITY ANALYSIS
NUMBER OF STAGES
FOR K= 2

Solvent/ Water Ratio	Solute Yield (as % of solute in feed)							
	70.00%	80.00%	90.00%	95.00%	98.00%	99.00%	99.90%	99.99%
0.53	3	4	7	13	>20	>20	>20	>20
1.00	2	2	3	4	5	6	9	13
1.50	1	2	2	3	4	4	6	9
2.00	1	1	2	2	3	4	5	7
2.50	1	1	2	2	3	3	5	6
3.00	1	1	2	2	3	3	4	6
3.50	1	1	2	2	2	3	4	5
4.00	1	1	2	2	2	3	4	5
4.50	1	1	1	2	2	3	4	5
5.00	1	1	1	2	2	2	3	4
5.50	1	1	1	2	2	2	3	4
6.00	1	1	1	2	2	2	3	4

SENSITIVITY ANALYSIS
NUMBER OF STAGES
FOR K= 1

Solvent/ Water Ratio	Solute Yield (as % of solute in feed)							
	70.00%	80.00%	90.00%	95.00%	98.00%	99.00%	99.90%	99.99%
1.05	3	4	8	14	>20	>20	>20	>20
1.50	2	3	4	5	8	9	15	20
2.00	2	2	3	4	5	6	9	13
2.50	1	2	3	3	4	5	7	10
3.00	1	2	2	3	4	4	6	9
3.50	1	2	2	3	3	4	6	8
4.00	1	1	2	2	3	4	5	7
4.50	1	1	2	2	3	3	5	6
5.00	1	1	2	2	3	3	5	6
5.50	1	1	2	2	3	3	4	6
6.00	1	1	2	2	3	3	4	6
6.50	1	1	2	2	2	3	4	5

SENSITIVITY ANALYSIS
NUMBER OF STAGES
FOR K= 0.75

Solvent/ Water Ratio	Solute Yield (as % of solute in feed)							
	70.00%	80.00%	90.00%	95.00%	98.00%	99.00%	99.90%	99.99%
1.40	3	4	8	14	>20	>20	>20	>20
1.50	2	4	6	10	16	>20	>20	>20
2.00	2	3	4	5	8	9	15	20
2.50	2	2	3	4	6	7	10	14
3.00	2	2	3	3	5	5	8	11
3.50	1	2	2	3	4	5	7	10
4.00	1	2	2	3	4	4	6	8
4.50	1	2	2	3	3	4	6	8
5.00	1	2	2	3	3	4	5	7
5.50	1	1	2	2	3	4	5	7
6.00	1	1	2	2	3	3	5	6
6.50	1	1	2	2	3	3	5	6

SENSITIVITY ANALYSIS
NUMBER OF STAGES
FOR K= 0.5

Solvent/ Water Ratio	Solute Yield (as % of solute in feed)							
	70.00%	80.00%	90.00%	95.00%	98.00%	99.00%	99.90%	99.9
2.10	3	5	9	15	>20	>20	>20	>2
2.50	2	3	5	8	11	14	>20	>2
3.00	2	3	4	5	8	9	15	2
3.50	2	2	3	4	6	7	11	1
4.00	2	2	3	4	5	6	9	1
4.50	2	2	3	3	5	5	8	1
5.00	1	2	3	3	4	5	7	1
5.50	1	2	2	3	4	5	7	
6.00	1	2	2	3	4	4	6	
6.50	1	2	2	3	3	4	6	
7.00	1	2	2	3	3	4	6	
7.50	1	2	2	3	3	4	5	

SENSITIVITY ANALYSIS
NUMBER OF STAGES
FOR K= 0.25

Solvent/ Water Ratio	Solute Yield (as % of solute in feed)							
	70.00%	80.00%	90.00%	95.00%	98.00%	99.00%	99.90%	99.99%
4.20	2	5	9	16	>20	>20	>20	>20
4.50	2	4	6	10	16	>20	>20	>20
5.00	2	3	5	7	11	14	>20	>20
5.50	2	3	4	6	9	11	18	>20
6.00	2	3	4	5	7	9	15	>20
6.50	2	2	4	5	7	8	13	17
7.00	2	2	3	4	6	7	11	15
7.50	2	2	3	4	6	7	10	14
8.00	2	2	3	4	5	6	9	13
8.50	2	2	3	4	5	6	9	12
9.00	2	2	3	3	5	5	8	11
9.50	1	2	3	3	4	5	8	10

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