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A Small-Scale Plant: Costs of Making Fuel Alcohol

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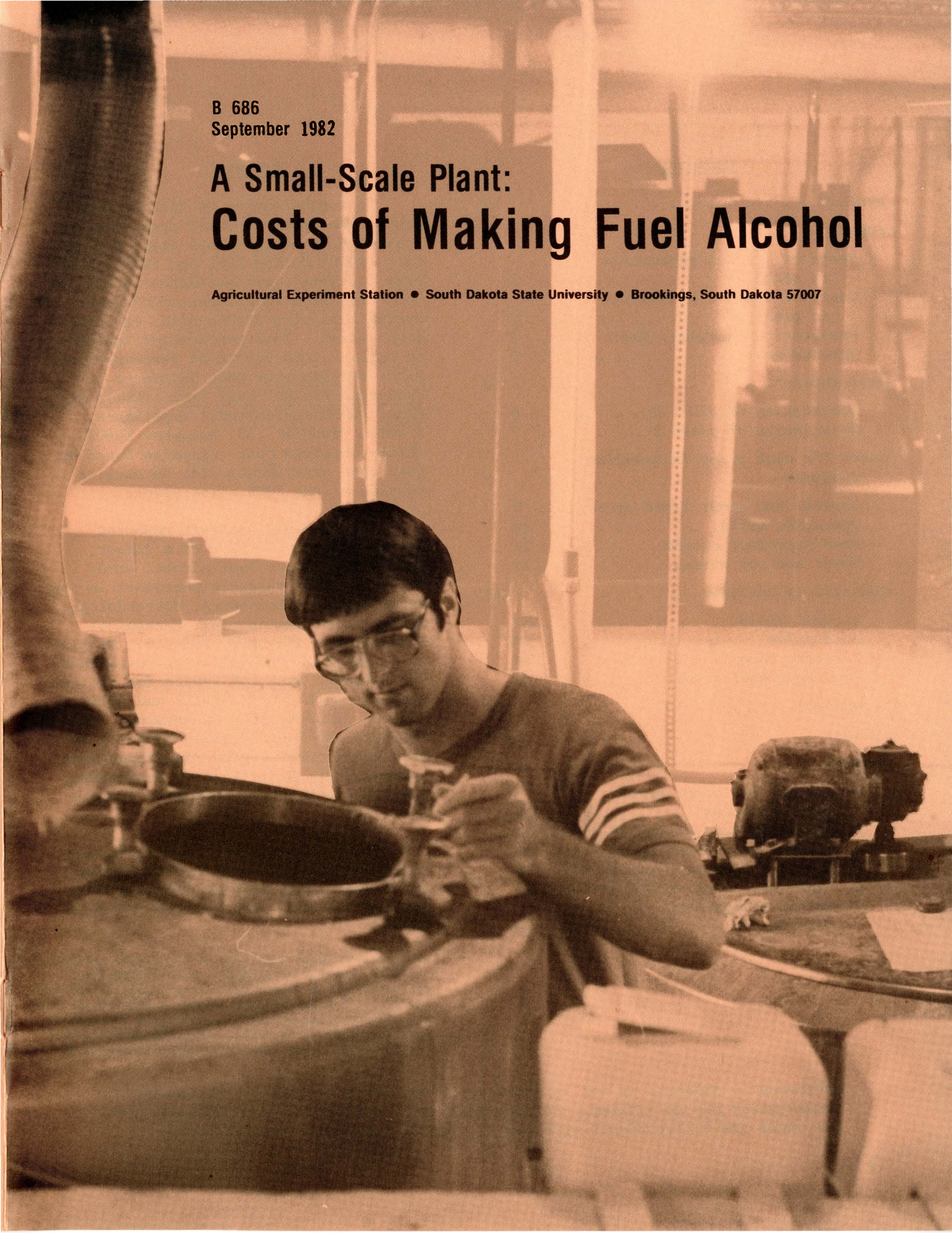

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Preface

This publication on fuel alcohol production costs is based upon research conducted at South Dakota State University (SDSU) during 1981 and 1982. Wherever possible, cost estimates were based upon data from experiments conducted during 1981 with SDSU's pilot fuel alcohol plant. This publication supplants an earlier SDSU report by Hutchinson and Dobbs (Preliminary Cost Estimates--Producing Alcohol Fuel from a Small Scale Plant, SDSU Agricultural Experiment Station Circular 233, December 1980), which contained cost estimates based in part upon experiments with an earlier version of the SDSU pilot plant.

The economic analysis reported herein constitutes part of a larger, interdisciplinary fuel alcohol study involving SDSU research personnel in the Departments of Economics, Microbiology, Agricultural Engineering, Mechanical Engineering, and Dairy Science. We wish to acknowledge the following researchers who provided data and advice for the cost analysis work: Carl Westby and Bill Gibbons, Microbiology Department; Tom Chisholm and Scott Stampe, formerly in the Agricultural Engineering Department; Andrew Clark, Dairy Science Department; and Ardelle Lundeen, Economics Department.

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A Small-Scale Plant:

Costs of Making Fuel Alcohol

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Summary

This bulletin constitutes a report on the costs of producing fuel alcohol in small- or community-scale alcohol plants. The basis for this analysis is a pilot fuel alcohol plant built on the South Dakota State University (SDSU) campus. Data taken and adapted from the operation of this pilot plant were used to estimate the capital and operating costs presented herein.

Costs were estimated for fuel alcohol plants of two different sizes. The first, called plant A, would be capable of producing 48,863 gallons of denatured 185 proof alcohol and 378 tons of distillers wet grain (DWG) as a feed byproduct annually. The other plant, plant B, could theoretically produce 175,074 gallons of denatured 185 proof alcohol and 1,356 tons of DWG per year.

Estimating costs of alcohol production in plants A and B required assumptions about four principal factors. The four factors are the following:

(1) alcohol yield per bushel of corn--assumed to be 2.6 gallons of alcohol per bushel of corn in the baseline case;

(2) the price of corn--set at $2.50 per bushel in the baseline case;

(3) the annual interest rate at which the cost of capital equipment is amortized--assumed to be 15% in the baseline case; and

(4) the value of the feed byproduct--for the baseline case, set at $39 per ton, the average value based on dairy heifer and cow feeding trials at SDSU.

The sensitivity of alcohol production costs to each of these assumptions was later analyzed by varying the level of each factor while holding the other three constant. Costs resulting from these changes were then compared to costs in the baseline case.

Costs of alcohol production in plant A

Plant A could theoretically produce about 49,000 gallons of denatured 185 proof alcohol annually. Construction of plant A requires an initial capital investment of $159,750. When the costs of capital items are amortized over their varied useful lives at 15% interest, annual capital and other fixed costs total $42,251, or approximately $.86 per gallon of denatured alcohol. (Hereafter, unless stated otherwise, costs per gallon figures will refer to denatured 185 proof alcohol.) Some of the more expensive fixed cost items are the centrifuge, property taxes, maintenance, the steam boiler, the distillation column, insurance, and the skid-steer loader.

Operating costs of plant A are $103,834 annually. This is equal to about $2.13 per gallon of 185 proof alcohol produced. Corn and labor costs account for $1.71 of that total.

Total annual costs for plant A alcohol production are $146,085, or about $2.99 per gallon. Subtracting the feed byproduct credit of $.30 per gallon leaves a net cost of $2.69 per gallon.

Costs of alcohol production in plant B

Plant B's theoretical alcohol production capacity, about 175,000 denatured gallons, is approximately three and one half times that of plant A. The greater production, relative to plant A, is made possible by expanding fermentation capacity and by making more intensive use of the other capital equipment.

The initial investment cost of capital equipment in plant B is $186,500. On an annual basis, fixed costs amount to $58,443, or approximately $.33 per gallon of alcohol. Some of the largest fixed cost items are insurance, maintenance, the centrifuge, property taxes, and the steam boiler.

Annual operating costs of plant B equal $306,730, or about $1.75 per gallon of alcohol produced. As with plant A, corn and labor costs make up a large proportion of total operating costs. Corn costs $.92 per gallon of alcohol, while labor costs equal $.45 per gallon.

Addition of operating and fixed costs results in annual total costs of $365,173 for plant B. This is equal to nearly $2.09 per gallon of alcohol produced. After subtracting a little more than $.30 for the feed byproduct value, the net per gallon cost of 185 proof alcohol from plant B is approximately $1.78.

Sensitivity analyses, plant B

The sensitivity of costs of alcohol production in plant B to varying alcohol yields, corn prices, interest rates, and feed byproduct values was analyzed.

The first analysis involved varying the alcohol yield while holding all other factors constant. In the baseline case, an alcohol yield of 2.6 gallons of 185 proof alcohol per bushel of corn was assumed. With that assumption, the net cost per gallon of alcohol was $1.78. When the alcohol yield was dropped to 2.3 gallons per bushel of corn, the net cost per denatured gallon rose to $2.01. With an even lower alcohol yield of only 2.0 gallons per bushel of corn, net costs rose to $2.30.

The baseline case involved an assumed corn price of $2.50 per bushel. At that price, the net cost per gallon of denatured alcohol in plant B was $1.78. If the price of corn were dropped to $2.00 per bushel, the result would be a lowering of net costs to $1.59 per gallon. On the other hand, if the price of corn were raised to $3.00 per bushel, plant B's per gallon costs would increase to $1.97.

Interest rates reflect the returns needed to cover annual charges on borrowed capital and a return on equity capital. Capital for both equipment and operating costs are included. In the baseline case, a 15% interest rate is used in amortizing equipment costs and "paying for" capital tied up for operating costs. In plant B, this results in a net total cost of $1.78 per gallon of alcohol, as already mentioned. By lowering the interest rate to 10%, this per gallon cost can be lowered to $1.72. Raising the interest rate to 20% and 30% causes the cost per gallon to rise to $1.85 and $1.98, respectively.

The final sensitivity analysis involved varying the value of the feed byproduct, based upon different assumed dairy ration uses. The baseline case involved a DWG value equal to the average value of DWG used in cow and heifer rations. This value was $39 per ton, which implies about a $.30 credit for each gallon of alcohol produced in plant B. If the DWG were used solely in dairy cow rations, its value would be equal to only $30 per ton, which converts to about a $.23 credit per gallon of alcohol produced. However, use of DWG in dairy heifer rations allows for a $48 per ton valuation or a $.37 credit per gallon of alcohol for DWG sales.

Conclusions

If an individual or a cooperative group possesses an alcohol plant similar in construction to plant A in this analysis, the necessary capital expansion should probably be undertaken to enable capacity to increase to at least that of plant B.

Even though this will cause an increase in total annual costs, the cost per gallon of alcohol produced can be expected to decrease. Assuming that there is a market for all of the 185 proof alcohol produced, the lower per gallon costs associated with plant B will enhance the possibility of such a plant being economically feasible.

If the assumptions stated for the baseline case in this analysis hold true, then the alcohol produced in plant B must be valued or sold at approximately $1.78 per gallon for the enterprise to break even economically. That price assumes that a $.30 per gallon credit for sale of the feed byproduct has already been built into net cost calculations for the plant.

The possibility of significantly lowering per gallon costs of alcohol from plant B by further expanding output is not good.

Approximately 84% of the total per gallon cost (before figuring in the byproduct credit) of alcohol produced in plant B is made up of operating costs. The ratio of variable inputs to alcohol output is roughly constant, with the exception of labor inputs. Hence, per gallon operating costs will not change greatly with changes in annual alcohol output--at least for so-called small- or community-scale plants. Also, to increase alcohol output above that of plant B would require a large investment in new capital equipment (e.g., a larger distillation unit) which might or might not reduce the fixed costs per gallon associated with small-scale fuel alcohol production. Even if per gallon fixed costs were reduced by this expansion, the reduction would probably not be greater than $.10 to $.15 per gallon, since the total fixed costs in plant B for the baseline case are only $.33 per gallon.

The costs of producing alcohol in plant B are sensitive to several factors, but seem to be most sensitive to the alcohol yield per bushel of corn and the price of corn. A drop in alcohol yield from 2.6 gallons of 185 proof to 2.0 gallons results in a $.52 per gallon increase in annual cost. A rise in the price of corn from $2.00 per bushel to $3.00 per bushel will cause a $.38 rise in the per gallon cost of producing alcohol in plant B.

Marketing of 185 proof alcohol and DWG may be a significant problem for small-scale plants. First of all, there will be costs for transportation, which were not included in this report. Second, it may be too optimistic to assume that a sufficient number of local farmers can be persuaded to use the 185 proof alcohol--given the limitations, costs, and inconveniences in converting existing farm vehicles and motorized equipment to utilize hydrous ("wet") alcohol.

Also, at the current prices of petroleum based fuels, the near-term profit prospects for 185 proof alcohol from small- or community-scale plants involving costs like those found in this study do not look good. A subsequent SDSU Agricultural Experiment Station bulletin (now being prepared) will contain an examination of potential fuel alcohol use. Costs contained in the present bulletin will be compared in that subsequent report with potential returns from both fuel and feed byproduct use, in an attempt to assess overall economic feasibility.

From a cost minimization standpoint, it makes sense for so-called "community-scale plants" to be as large as available technology, capital, and management capacity permit. With larger distillation units and greater fermentation capacity, community-scale plants might well be striving for an annual output of 500,000 to 1,000,000 gallons. However, the larger the plant, the more critical it becomes--from a fuel marketing standpoint--to achieve production of anhydrous (water free) alcohol. It must be kept in mind that procedures and costs presented in this report are for fuel alcohol that is only 185 proof, not for alcohol that is water free.

Introduction

The feasibility of producing fuel alcohol from grain has received much attention in the Midwest and Plains states over the last few years. As a result, several studies of the economic feasibility of large-scale fuel alcohol plants were conducted in the late 1970's. These studies have helped to fill information voids faced by university and government economists asked to provide feasibility and public policy information on fuel alcohol production.

Little research has been conducted, however, on the economic feasibility of "small- or community-scale" fuel alcohol plants where production machinery is actually available and in operation. This type of facility has been the center of multi-disciplinary research at South Dakota State University (SDSU) and has served as the "pilot plant" from which this report's cost analysis has been derived.

Two earlier cost studies[1] were based partially on data gathered from the SDSU fuel alcohol plant. Although the data were still very preliminary, those studies helped to provide a framework for the cost analysis presented here. The present cost analysis is more "final" in the sense that numerous experimental runs have been made subsequent to various plant expansions and modifications.

The economic analysis presented in this report deals only with the costs of producing fuel alcohol. An overall feasibility analysis--incorporating transportation costs for the marketing of outputs and revenue estimates from the sale of outputs--will be covered in a subsequent SDSU Agricultural Experiment Station bulletin, now in preparation. The present report covers costs for two plants which, for purposes of easy identification, are called (1) the pilot plant, plant A, and (2) the cooperative size plant, plant B.

Description of plant A

Plant A's physical facilities and operational structure are very similar to the experimental facility which presently exists at SDSU. The major physical components of this plant are (1) grain storage and handling system, (2) fermentation/cook tanks, (3) distillation column, (4) centrifuge, and (5) alcohol storage.

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[1] See the publications by Hutchinson and Dobbs and by Dobbs, Hoffman, and Lundeen in the list of "References".

The alcohol production system of this type at SDSU produced alcohol of approximately 185 proof in 1981. The amount of alcohol produced annually by plant A is dependent on two things; these are (1) the amount of alcohol extracted from each bushel of corn and (2) the physical limits of the plant in terms of fermentation and distillation capacity.

The bottleneck in physical production facilities in plant A is fermentation capacity. Plant A's fermentation tanks hold a total volume of 4,085 gallons of mash. Even with the fermentation tanks being continuously reloaded in staggered fashion, only 2.5 batches could be fermented in a week's time. This would not keep the distillation column running full time at its estimated capacity of 22 gallons of 185 proof alcohol per hour. Thus, there is underutilization of the distillation column.

The other factor limiting the amount of alcohol produced is the yield per bushel of corn. Data obtained from 1981 SDSU experimental operations and technical judgments of research personnel in charge of the SDSU plant were drawn on in establishing yield assumptions. It is assumed possible to obtain 2.6 gallons of 185 proof alcohol from each bushel of corn run through the production process. Given these limitations in fermentation capacity and alcohol yield, it was estimated that plant A could produce 48,863 gallons of denatured 185 proof alcohol on an annual basis.[2]

One of the byproducts of alcohol production is whole stillage. Whole stillage is about 92% water. When run through a centrifuge, the moisture content can be reduced to approximately 70%, resulting in a product called distillers wet grain (DWG). DWG, relatively high in crude protein content, is considered a potential replacement for soybean meal in many dairy and beef cattle rations.

Plant A is equipped with a centrifuge that enables the production of 70% moisture DWG. Data from 1981 experimental operations at SDSU were reviewed in establishing DWG yields. DWG output is estimated to be approximately 42.4 pounds for each bushel of corn used in the production of fuel alcohol. For plant A, this amounts to 378 tons of DWG produced annually.[3]

Even though plant A's alcohol output is relatively small, it is more than a "one man" operation. For purposes of this study, the following assumptions are made. Plant A is run as a cooperative, with the output being sold to either members or non-members. Management personnel and technical/processing labor are hired to perform all functions in plant A during its 45 weeks of annual operation. The plant does not operate for 7 weeks of the year, due to downtime for maintenance, repairs, holidays, etc.

Description of plant B

The principal difference between plant A and hypothetical plant B is that plant B has sufficient fermentation capacity to keep the distillation column constantly operating at full capacity. The following assumptions are made. Plant B's fermentation capacity is 20,900 gallons of mash, compared to only 4,085 gallons for plant A. There is some additional physical expansion in building size, grain storage, and alcohol storage--over and above that existing for plant A. Some other components of plant B, though not physically different from those in plant A, are utilized more intensively.

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[2] For more details concerning the assumptions used in estimating the annual alcohol output of plant A, see Annex C.

[3] For more details concerning the assumptions used in estimating the annual DWG output of plant A, see Annex D.

As in the case of plant A, plant B is assumed capable of producing 2.6 gallons of 185 proof alcohol per bushel of corn. Since fermentation capacity is greater, the limiting factor in annual alcohol production for plant B is the distillation column, which can distill at the rate of approximately 22 gallons of 185 proof alcohol per hour. Given that distillation rate and the assumption that plant B operates 45 weeks annually, total annual alcohol output capacity is estimated to be 166,320 gallons. When denaturant is added, annual alcohol fuel capacity of plant B totals 175,074 gallons.[4]

DWG is produced at the same rate in plant B as in plant A; for every bushel of corn used to produce alcohol, 42.4 pounds of 70% moisture DWG are also produced. This results in an annual DWG output of approximately 1,356 tons.[5]

More managerial and technical/processing labor is assumed necessary for operation of plant B than for plant A.[6] Like plant A, plant B is assumed to operate 45 weeks per year, leaving 7 weeks for downtime.

Costs for Each Plant in Baseline Analyses

Costs of producing 185 proof alcohol with plant A are shown in Table 1; those for plant B are shown in Table 2. Both tables are broken down into the following five parts: (1) capital and other fixed costs; (2) operating costs; (3) total costs; (4) credit for feed byproduct; and (5) net costs (i.e., costs net of the feed byproduct credit). Costs are shown on an annual basis and on a per gallon of denatured 185 proof alcohol basis.

See pages 16-19 for Tables 1 & 2

The baseline analysis for plants A and B involves four basic assumptions which can significantly affect cost estimates. The first assumption has already been alluded to--that the yield of 185 proof alcohol is 2.6 gallons per bushel of corn. Actual alcohol yield in cooperative plants may vary with the knowledge and abilities of the plant operator and with the nature of the equipment used.

A second assumption is that capital equipment can be amortized at a 15% interest rate. In practice, interest rates will vary with lending rates for borrowed capital and with opportunity costs for investor-owned capital.

The third assumption is that the cost of corn to the plant is $2.50 per bushel. During 1981, the study period, corn prices ranged from a little less than $3 to slightly more than $2 per bushel in South Dakota. The $2.50 price reflects a rough "mid-point".

Finally, the value of the feed byproduct is assumed to be an average value derived for DWG used in lactating dairy cow and dairy heifer feeding trials at SDSU. DWG will vary in value, depending on the type of ration in which it is fed and, hence, what feeds it substitutes for.

All four of these factors are considered in the cost sensitivity analyses.

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[4]For more details concerning the assumptions used in estimating the annual alcohol output of plant B, see Annex C.

[5]For more details concerning the assumptions used in estimating the annual DWG output of plant B, see Annex D.

[6]For a more detailed description of the labor requirements for plants A and B, see Annex B.

Capital and other fixed costs

Section I of Table 1 lists the fixed cost components of plant A, which are divided into the following three categories: (1) items not likely to be available; (2) items possibly already available among members of a cooperative group; and (3) other fixed costs.

"Items not likely to be available" are physical components of the plant that would probably have to be ordered from suppliers. "Items possibly already available among members of a cooperative group" could already be in the possession of cooperative members and, therefore, may be available for plant use at little cost. However, this report includes these items at full cost. "Other fixed costs" consist of charges for insurance, maintenance, and property taxes.[7]

As shown in Table 1, total capital and other fixed costs for plant A amount to $42,251 annually. When divided by plant A's annual output (48,863), this comes to $.86 per gallon of denatured alcohol.

For the physical components of plant A, annual cost is calculated by amortizing the original investment cost of each item at a rate of 15% over its useful life. In the case of "other fixed costs," a set amount must be paid yearly for insurance, maintenance, and property taxes.

The most costly capital and other fixed cost items in plant A include the following: (1) the centrifuge used for reducing the moisture content of DWG--$.11/gallon; (2) property taxes--$.10/gallon; (3) maintenance--$.10/gallon; (4) boiler[8]--$.09/gallon; (5) distillation column--$.08/gallon; (6) insurance--$.07/gallon; and (7) a skid-steer loader for handling the DWG--$.06/gallon. These seven items comprise more than 70% of the per gallon fixed costs of producing 185 proof alcohol in plant A.

Section I of Table 2 lists the fixed cost components of plant B. An asterisk marks the items which differ in cost from those in plant A. The only new item shown is additional grain storage, included in "items possibly already available among members of a cooperative group." The other asterisked items have been altered from those in plant A to reflect either a higher initial cost (due to expansions or additions) or a shorter useful life (due to more intensive use).[9]

As in plant A, fixed costs per gallon of denatured alcohol in plant B were estimated by amortizing the initial investment cost of each capital item over its useful life at a rate of 15% and then dividing by the annual alcohol output (175,074 gallons).

Per gallon costs of insurance, maintenance, and property taxes were found by dividing yearly costs by annual output.

Total annual fixed costs for plant B were found by summing the annual costs for each item. The total equals $58,443, or $.33 per gallon of denatured alcohol. The major items comprising this cost total are the following: (1) insurance--$.05/gallon; (2) maintenance--$.04/gallon; (3) centrifuge--$.04/gallon; (4) property taxes--$.03/gallon; and (5) the

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[7] For more description of the capital and other fixed cost items listed in Table 1, see Annex A.

[8] The boiler is fueled by coal. Although initial investment costs for a coal-fired boiler are higher than for other types, this higher capital cost is more than offset by lower operating costs, assuming coal can be delivered to the plant by train or by transport of nearly equivalent cost.

[9] For more description of the capital and other fixed cost items listed in Table 2, see Annex A.

coal-fired boiler--$.03/gallon. These five items make up nearly 60% of the capital and other fixed costs in plant B.

There are obviously some economies of size involved in expanding annual alcohol output from plant A's 48,863 gallons to plant B's 175,074 gallons. Even though such an expansion requires an increase in total annual fixed costs, the cost increase is proportionately less than the increase in annual output. The large increase in annual alcohol output with a relatively small increase in annual fixed costs is made possible by more intense utilization of many of the capital items that would have been "under-utilized" in plant A. The result is a $.53 per gallon decrease in annual fixed costs as output is expanded from the level of plant A to that of plant B.

Operating costs

The variable inputs required for the operation of plant A are listed in Section II of Table 1. Column 2 shows the number of units of each input needed to produce each gallon of non-denatured 185 proof alcohol. These operating coefficients were estimated from experimental data taken during the summer and fall 1981 operation of the fuel alcohol plant at SDSU.[10]

Column 6 of this section shows the total operating cost of producing a gallon of denatured alcohol in plant A, as well as the per gallon cost for each individual input. The figures in column 6 were arrived at by multiplying the number of units of each input needed to produce a gallon of non-denatured alcohol (column 2) by the cost per unit of each input (column 3), resulting in the cost of each input per non-denatured gallon of alcohol (column 4). The cost per gallon of non-denatured alcohol for each input was then multiplied by the annual non-denatured alcohol output of plant A (46,420 gallons) to find the annual cost of each input (column 5). The annual cost per gallon of denatured alcohol for each variable input was found by dividing the figures in column 5 by the annual denatured output of plant A (48,863 gallons).

Annual operating costs shown in column 5 total $103,834 for plant A, or $2.12 per gallon of denatured alcohol. Two input items account for the vast majority of total operating costs; these are corn and labor.

At a price of $2.50/bushel, the cost of corn equals $.92 per gallon of denatured alcohol. Varying the price of corn significantly affects total operating costs, as is shown later in this report.

Labor costs add nearly $.80 per gallon to the cost of producing fuel alcohol in plant A. The SDSU alcohol research team agreed that the amount of labor assumed to run the plant in this analysis is the minimum amount that could handle the operation effectively. Therefore, labor costs for a plant of this type probably can not be expected to be less than the amount shown in the table.

Corn and labor costs total $1.71 per gallon of denatured alcohol, leaving only $.41 for all other operating costs. Of the others, interest on operating capital, diazyme-100, and denaturant are the largest, from a cost standpoint. Their respective per gallon costs are $.08, $.07, and $.07.

The variable input quantities and costs for plant B are shown in Table 2, Section II. The inputs themselves are exactly the same as those listed for plant A. However, there are a few price and unit/per gallon differences for some inputs. In the case of labor, the units per gallon of denatured alcohol are lower. Also, for electricity and water,

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[10] For more description of the operating inputs listed in Table 1, see Annex B.

the average cost per unit differs between plant B and plant A.[11]

Total annual operating costs in plant B are $306,730, compared to $103,834 in plant A. The annual operating cost per gallon of denatured alcohol for plant B is $1.75, compared to $2.12 for plant A--a difference of $.37.

Corn and labor costs are a large part of total operating costs in plant B, as they were in plant A. However, labor is only $.45 per gallon of denatured alcohol in plant B, compared to $.80 per gallon in plant A. The per gallon cost of corn ($.92) is the same in the two plants.

Besides labor, there are other per gallon variable input costs that are lower in plant B than in plant A. These are electricity (plant A = $.028/gallon and plant B = $.025/gallon), water (plant A = $.017/gallon and plant B = $.010/gallon), and interest on operating capital (plant A = $.077/gallon and plant B = $.063/gallon).

The decreases in costs of electricity and water per gallon of alcohol occur because of a declining block rate charge structure for those items. This means that, over a certain range, the more electricity and water used per month, the cheaper each successive unit becomes.

Interest on operating capital is lower for plant B than for plant A, on a per gallon of alcohol produced basis, because the increase in total annual operating costs (on which interest is charged) is proportionately less than the increase in annual alcohol output as production is expanded from that of plant A to that of plant B.

Feed byproduct credit

The sale of the feed byproduct is an important source of revenue for alcohol plants. Indeed, many fuel alcohol proponents now claim that the difference between profit and loss in the fuel alcohol business depends upon the successful marketing and utilization of the DWG. Although this report deals primarily with costs involved in fuel alcohol production, rather than revenues, a credit for the sale of DWG has been estimated and applied to the cost calculations.

An estimate of the amount of DWG produced per bushel of corn used in fuel alcohol production was made, using experimental data gathered during 1981 operations of the fuel alcohol plant at SDSU. The same amount of DWG per bushel of corn was assumed for both plants. Based on the bushels of corn that would be used in each plant, the yearly amount of DWG production was estimated to be (1) approximately 378 tons in plant A and (2) approximately 1,356 tons in plant B.[12]

Values of DWG were estimated, using data collected from feeding trials at SDSU with dairy heifers and cows. The DWG was used in experimental rations, mainly to replace soybean meal in the control rations; however, the DWG did also replace small amounts of some other ingredients used in both experimental and control rations. There was no significant difference between the performance of the DWG-fed animals and the animals fed control rations. Thus, values for the DWG were estimated by determining the differences in costs of control and experimental rations, with the difference in each case considered to be the value of DWG. In the dairy cow trials, this

[11] For more description of the operating inputs listed in Table 2, see Annex B.

[12] For more details concerning the estimation of annual DWG production in plants A and B, see Annex D.

value was estimated to be $33.55/ton of DWG, while the value of DWG in dairy heifer feeding trials was $53.25/ton.[13]

For the baseline cases in this report, the DWG value is assumed to be the average of the above two values, or $43.40/ton of DWG. However, the DWG produced in plants A and B has a very high moisture content--about 70%. Because of some anticipated difficulties in handling and transporting high moisture DWG, a discount of 10% is assumed to apply to its market value. The calculated market value is therefore $39.06, or approximately $39/ton. When this is converted to a credit per gallon of denatured alcohol, it amounts to $.30/gallon for both plant A and plant B.[14]

Total and net costs

Total and net costs for producing alcohol in plant A are shown in Sections III and V of Table 1. Total annual costs shown in Section III are found by adding annual fixed costs to annual operating costs. The total comes to $146,085, or $2.99 per gallon of alcohol.

From this amount, the credit for the feed byproduct is subtracted. The feed byproduct credit shown in Section IV equals $14,742 per year, $.30 per gallon. Thus, the total cost of producing 185 proof alcohol in plant A--net of the feed byproduct credit--equals $131,343 annually, or $2.69 per gallon.

Total and net costs for plant B are presented in a similar fashion in Table 2. In that table, total annual costs are shown to be $365,173, which comes to $2.09 per gallon. The annual credit for the feed byproduct is $52,884, or $.30 per gallon. Hence, the total cost of producing 185 proof alcohol in plant B--net of the feed byproduct credit--is $312,289 annually, or $1.78 per gallon.

A comparison of Tables 1 and 2 reveals that an expansion from plant size A to plant size B, increasing annual production from 48,863 to 175,074 gallons, would result in a per gallon decrease in net costs of more than $.90 per gallon. This decrease in per gallon costs is due largely to the relatively small increases in capital equipment costs associated with "sizing up" some parts of the plant (e.g., fermentation capacity) to more fully utilize other parts (e.g., the distillation unit).

Sensitivity Analyses

A change in certain assumptions made in the baseline analyses could significantly change per gallon costs associated with production of fuel alcohol in plants A and B. This section of the report contains sensitivity analyses of four factors that could substantially affect final cost outcomes. These factors are the following:

(1) the alcohol yield per bushel of corn;

(2) the price of corn;

(3) the interest rate at which the cost of capital equipment is amortized, and at which operating capital is made available; and

(4) the value of the feed byproduct.

The sensitivity of costs to changes in these factors is analyzed only for plant B. Due to the lower per gallon costs associated with plant B, it is henceforth assumed that a cooperative group would "size-up" its production capacity to at least that of plant B.

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[13] For more details concerning the estimation of DWG value, see Annex E.

[14] For more details concerning the estimation of this credit, see Annex E.

Alcohol yield

Alcohol yield in the baseline analysis was 2.6 gallons of 185 proof product per bushel of corn. This figure was arrived at through fuel alcohol experimentation by and consultation with SDSU agricultural engineers and microbiologists. In an alcohol plant similar to plant B, it is unlikely that alcohol yield will be greater than 2.6 gallons per bushel.

However, a lower alcohol yield may well exist in some cases. This is most likely to happen if plant operators lack sufficient skills in either microbiology (for cooking and fermentation) or engineering (for distillation and total system operation).

Table 3 shows the effect on per gallon costs of reducing the alcohol yield from 2.6 to 2.3 and to 2.0 gallons per bushel of corn. Annual capital costs are assumed to remain constant for all three yields. Annual operating costs are also assumed to remain constant, except for small decreases in denaturant costs and costs of interest on operating capital caused by the decrease in annual alcohol output.

See page 20 for Table 3

The annual cost per gallon of denatured alcohol (net of the feed byproduct credit) is $1.78 when the alcohol yield is 2.6 gallons; this is the baseline case. If alcohol yield were to fall to 2.3 gallons per bushel, annual alcohol production would fall to 154,891 denatured gallons. The lowered production results in a net annual per gallon cost of $2.01, an increase of $.23 over that of the baseline case.

If alcohol yield were to fall to only 2.0 gallons per bushel, the per gallon cost rises another $.29, to $2.30. A high alcohol yield is extremely important, even if it requires greater investment in trained operators than some entrepreneurs might originally have thought.

Corn price

In the baseline case, the price of corn was assumed to be $2.50 per bushel. At that price, the cost of corn per gallon of alcohol is $.92, representing over 50% of the net per gallon cost of producing alcohol in plant B. Obviously, a change in the price of corn will have a large impact on per gallon costs. In one of the sensitivity analyses, only the price of corn is changed, while other inputs and prices are held constant.

Table 4 shows the effect on operating and total costs of varying the price of corn. The cost of corn per gallon of 185 proof denatured alcohol is $.73 when corn is $2.00 per bushel, compared to $.92 in the baseline case with $2.50 corn. This causes a reduction in net costs per gallon of $.19.[15]

See page 21 for Table 4

Table 4 also shows the effect on annual operating and total costs if the price of corn should rise to $3.00 per bushel. In this case, the per gallon cost of corn increases to $1.10. This results in a net cost per gallon of $1.97.

A comparison of cases shows that a change in corn price from $2 per bushel to $3 per bushel results in almost a $.40 increase in the per gallon cost of alcohol.

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[15] There is a slightly greater drop in net per gallon costs than in corn costs per gallon. This is because of a small decrease in interest on operating capital. Whenever operating costs are reduced, this will occur.

Interest rate

Another factor affecting costs of alcohol production is the interest rate at which the original purchase price of capital items is amortized and at which operating capital is borrowed or otherwise made available. The interest rate used in the baseline analysis is 15%. Table 5 shows the effect of varying the interest rate on net costs per gallon of alcohol produced in plant B (all other factors held constant).

See page 21 for Table 5

The lowest interest rate assumed is 10%. In this case, the effect of lowering the interest rate from the baseline case (15%) is to reduce net per gallon costs from $1.78 to $1.72.

Costs were also calculated at 20% interest. This calculation results in about a $.06 rise in net per gallon costs, compared to the baseline case. Should investors demand a return on capital as high as 30%--to offset the potentially high risks associated with fuel alcohol investments--then total annual per gallon costs would be pushed to $1.98. Thus, over the range of 10% to 30% interest rates, there is a difference in annual per gallon costs of $.26.

Although per gallon costs are less sensitive to varying interest rates than they are to varying alcohol yields and corn prices, the interest rate is still an important determinant of alcohol production profitability.

Feed byproduct credit

The baseline case calculations were based on the average value of DWG used in dairy cow rations and dairy heifer rations in experiments at SDSU. The value of DWG in dairy heifer rations, however, is much higher than its value in dairy cow rations. The type of ration in which the DWG is fed can thus make a large difference in the byproduct value, which, in turn, affects the net cost of producing fuel alcohol.

Table 6 shows the effect on alcohol production costs of using different values for the DWG credit. DWG used in dairy heifer rations is valued at almost $.14 per gallon of alcohol more than DWG used in dairy cow rations. It is evident that the type of feeding operation available to make use of the DWG can strongly influence its market value and, hence, the net costs of fuel alcohol production.

See page 21 for Table 6

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Table 1. Fuel alcohol production costs: plant A (48,863 gallons of 185 proof alcohol, including denaturant, and 378 tons of DWG), 15% interest rate, $2.50/bu corn, alcohol yield of 2.6 gal/bu of corn

I. Capital and other fixed costs

(1) Item	(2) Capital Cost	(3) Useful Life (Years)	(4) Annual Amortized Cost (at 15% Interest)	(5) Cost Per Gal of Denatured Alcohol (Col. 4 ÷ 48,863 Gal)
A. Items not likely to be available				
Coal-fired boiler	$ 26,450	15	$ 4,523	$.093
Fermentation tanks	11,750	10	2,338	.048
Grain handling system	12,800	10	2,547	.052
Alcohol storage	4,050	10	806	.016
Auger	500	10	100	.002
Heat exchanger	1,750	10	348	.007
Feed byproduct storage	1,200	20	191	.004
Water softeners (2)	1,000	10	199	.004
Building	16,000	20	2,544	.052
Distillation column	19,000	10	3,781	.077
Temperature meter	300	10	60	.001
Pressure gauges (2)	50	10	10	.000[1/]
Pumps and motors	2,350	10	468	.010
Pipes and accessories	850	5	253	.005
Centrifuge	32,000	15	5,472	.112
Flow meters (2)	150	10	30	.001
Differential pressure cell	250	10	50	.001
Cooling tower	3,900	10	776	.016
Laboratory	3,000	10	597	.012
Subtotal A =	$137,340		$25,093	$.513
B. Items possibly already available among members of a cooperative group				
Vertical auger	$ 2,400	10	$ 478	$.010
Skid-steer loader (or tractor loader of some kind)	20,000	20	3,180	.065
Subtotal B =	$ 22,400		$ 3,658	$.075
C. Other fixed costs			Annual Cost	
Insurance			$ 3,600	$.074
Maintenance			4,800	.098
Property taxes			5,100	.104
Subtotal C =			$13,500	$.276
Total capital and other fixed costs (A + B + C)	$159,750		$42,251	$.864

(Table 1, continued)

II. Operating costs

(1) Item	(2) Units/ Gal of Non-denatured Alcohol	(3) Cost/ Unit	(4) Cost/Gal of Non-denatured Alcohol (Col. 2 x Col. 3)	(5) Annual Cost (Col. 4 x 46,420)	(6) Cost Per Gal of Denatured Alcohol (Col. 5 ÷ 48,863)
Corn (2.6 gal/bu)	.385 bu	$2.50/bu	$.963	$ 44,702	$.915
Diazyme L-100	.63 oz	.12/oz	.076	3,528	.072
Taka-Therm	.18 oz	.14/oz	.025	1,161	.024
Sulfuric acid	1.00 oz	.01/fl oz	.010	464	.009
Ammonium hydroxide	.49 oz	.05/fl oz	.025	1,161	.024
Yeast	.02 lbs	1.20/lb	.024	1,114	.023
Electricity	.89 kwh	.033/kwh[2]	.029	1,346	.028
Fuel (10,000 btu/lb coal)	2.60 lbs	47.00/ton	.061	2,832	.058
Water	11.0 gal	1.61/1000 gal[3]	.018	836	.017
Labor	--[4]	--[4]	--[4]	39,060	.799
Laboratory tests	--[5]	--[5]	--[5]	675	.013
Denaturant (gasoline)	.053 gal	1.30/gal	.069	3,202	.066
Interest on operating capital (15% interest/yr for 3 months/yr)	--	--	--	3,753	.077
Total operating costs				$103,834	$2.125
III. Total costs (I + II)				$146,085	$2.989
IV. Credit for feed byproduct				$ 14,742	$ .302
V. Net cost of denatured alcohol (III - IV)				$131,343	$2.687 ($2.69, rounded)

[1] The annual cost per gallon of denatured alcohol is so small for these items that it rounds to 0 at three decimal places.

[2] The cost per unit of electricity is the <u>average</u> cost per kwh, given the declining block rate structure of an electric utility on a monthly basis and the estimated electrical usage for a full month of plant operation.

[3] The cost per unit of water is the <u>average</u> cost per 1,000 gallons, given the declining block rate structure of a water utility on a monthly basis and the estimated water usage for a full month of plant operation.

[4] Labor costs are estimated on an annual basis for different types of labor. For more details explaining the type, amount, and the cost of labor, see Annex B.

[5] Laboratory tests are estimated on a weekly basis for different types of samples. For more details explaining the type, amount, and cost of outside laboratory testing, see Annex B.

Table 2. Fuel alcohol production costs: plant B (175,074 gallons of 185 proof alcohol, including denaturant, and 1,356 tons of DWG), 15% interest rate, $2.50/bu corn, alcohol yield of 2.6 gal/bu of corn

I. Capital and other fixed costs

(1) Item	(2) Capital Cost	(3) Useful Life (Years)	(4) Annual Amortized Cost (at 15% Interest)	(5) Cost Per Gal of Denatured Alcohol (Col. 4 ÷ 175,074 Gal
A. Items not likely to be available				
Coal-fired boiler*	$ 26,450	10	$ 5,264	$.030
Fermentation tanks*	23,300	10	4,637	.026
Grain handling system	12,800	10	2,547	.015
Alcohol storage*	5,000	10	995	.006
Auger*	500	5	149	.001
Heat exchanger	1,750	10	348	.002
Feed byproduct storage	1,200	20	191	.001
Water softeners (2)*	1,000	5	298	.002
Building*	26,000	20	4,134	.024
Distillation column	19,000	10	3,781	.022
Temperature meter	300	10	60	.000 1/
Pressure gauges (2)	50	10	10	.000 1/
Pumps and motors*	2,350	5	700	.004
Pipes and accessories*	1,000	5	298	.002
Centrifuge*	32,000	10	6,368	.036
Flow meters (2)	150	10	30	.000 1/
Differential pressure cell	250	10	50	.000 1/
Cooling tower	3,900	10	776	.004
Laboratory	3,000	10	597	.003
Subtotal A =	$160,000		$31,233	$.178
B. Items possibly already available among members of a cooperative group				
Vertical auger	$ 2,400	10	$ 478	$.003
Skid-steer loader (or tractor loader of some kind)	20,000	20	3,180	.018
Steel grain bin*	4,100	20	652	.004
Subtotal B =	$26,500		$ 4,310	$.025
C. Other fixed costs			Annual cost	
Insurance*			$ 9,500	$.054
Maintenance*			7,450	.043
Property taxes*			5,950	.034
Subtotal C =			$22,900	$.131
Total capital and other fixed costs (A + B + C)	$186,500		$58,443	$.334

(Table 2, continued)

II. Operating costs

(1) Item	(2) Units/ Gal of Non-denatured Alcohol	(3) Cost/ Unit	(4) Cost/Gal of Non-denatured Alcohol (Col. 2 x Col. 3)	(5) Annual Cost (Col. 4 x 166,320)	(6) Cost Per Gal of Denatured Alcohol (Col. 5 ÷ 175,074)
Corn (2.6 gal/bu)	.385 bu	$2.50/bu	$.963	$160,166	$.915
Diazyme L-100	.63 oz	.12/oz	.076	12,640	.072
Taka-Therm	.18 oz	.14/oz	.025	4,158	.024
Sulfuric acid	1.00 oz	.01/fl oz	.010	1,663	.009
Ammonium hydroxide	.49 oz	.05/fl oz	.025	4,158	.024
Yeast	.02 lbs	1.20/lb	.024	3,992	.023
Electricity*	.89 kwh	.029/kwh 2/	.026	4,324	.025
Fuel (10,000 btu/lb coal)	2.60 lbs	47.00/ton	.061	10,146	.058
Water*	11.0 gal	.99/1000 gal 3/	.011	1,830	.010
Labor*	-- 4/	-- 4/	-- 4/	78,840	.450
Laboratory tests	-- 5/	-- 5/	-- 5/	2,250	.013
Denaturant (gasoline)	.053 gal	1.30/gal	.069	11,476	.066
Interest on operating capital (15% interest/yr for 3 months/yr)	--	--	--	11,089	.063
Total operating costs				$306,730	$1.752
III. Total costs (I + II)				$365,173	$2.086
IV. Credit for feed byproduct				$ 52,884	$ .302
V. Net cost of denatured alcohol (III - IV)				$312,289	$1.784 ($1.78, rounded)

*Denotes items which have been changed in plant B from what they were in plant A. The changes may occur in quantity, useful life, or input cost per unit.

1/ The annual cost per gallon of denatured alcohol is so small for these items that it rounds to 0 at three decimal places.

2/ The cost per unit of electricity is the average cost per kwh, given the declining block rate structure of an electric utility on a monthly basis and the estimated electrical usage for a full month of plant operation.

3/ The cost per unit of water is the average cost per 1,000 gallons, given the declining block rate structure of a water utility on a monthly basis and the estimated water usage for a full month of plant operation.

4/ Labor costs are estimated on an annual basis for different types of labor. For more details explaining the type, amount, and the cost of labor, see Annex B.

5/ Laboratory tests are estimated on a weekly basis for different types of samples. For more details explaining the type, amount, and cost of outside laboratory testing, see Annex B.

Table 3. Sensitivity of per gallon costs of 185 proof alcohol to changes in alcohol yield per bushel of corn

Alcohol Yield/Bushel of Corn	Annual Capital Cost	Annual Operating Cost	Annual Denatured Production	Total Cost/Gal of Denatured Alcohol	Cost Per Gal of Denatured Alcohol Net of Feed Byproduct Credit
(Gallons)			(Gallons)		
2.6 (baseline case)	$58,443	$306,730	175,074	$2.09	$1.78
2.3*	$58,443	$305,357 1/	154,891	$2.35	$2.01
2.0*	$58,443	$303,983 2/	134,687	$2.69	$2.30

*Annual operating costs are lower for the operations yielding 2.3 and 2.0 gallons of 185 proof alcohol per bushel of corn. This is because less gasoline input is required yearly to denature the lower annual alcohol output. In turn, the annual cost of interest on operating capital is also somewhat lower because of the decreased total annual operating costs resulting from reduced denaturant input.

1/ Annual denaturant cost for plant B when the alcohol yield is 2.3 gal/bu of corn equals $10,153. Annual interest on operating capital equals $11,037.

2/ Annual denaturant cost for plant B when the alcohol yield is 2.0 gal/bu of corn equals $8,829. Annual interest on operating capital equals $10,987.

Table 4. Sensitivity of per gallon costs of 185 proof alcohol to changes in corn price

Cost of Corn	Annual Capital Cost	Annual Operating Cost	Cost Per Gal of Denatured Alcohol Net of Feed Byproduct Credit
$2.00/bu	$58,443	$273,426	$1.59
$2.50/bu (baseline case)	$58,443	$306,730	$1.78
$3.00/bu	$58,443	$339,861	$1.97

Table 5. Sensitivity of per gallon costs of 185 proof alcohol to changes in interest rates

Interest Charge (Annual %)	Cost Per Gal of Denatured Alcohol Net of Feed Byproduct Credit
10%	$1.72
15% (baseline case)	1.78
20%	1.85
30%	1.98

Table 6. Sensitivity of the feed byproduct credit and per gal cost of alcohol to the type of ration in which DWG is fed*

Ration on Which DWG Value is Based	DWG Value	DWG Credit/Denatured Gal of Alcohol	Cost Per Gal of Denatured Alcohol Net of Feed Byproduct Credit
Dairy heifer ration	$48/ton	$.37	$1.72
Average of dairy cow and heifer rations (baseline case)	$39/ton	$.30	$1.78
Dairy cow ration	$30/ton	$.23	$1.85

*Alcohol yield, corn price, and interest rate are all equal to those in the baseline case.

ANNEX A

Explanation of Capital and Other Fixed Cost Estimates

This annex contains a description of the capital and other fixed cost items necessary for the operation of plants A and B. Included in this description are the sources of the cost estimates. The annex is divided into the following three sections: (a) items not likely to be already available; (b) items possibly already available among members of a cooperative group; and (c) other fixed costs. The following items are listed in the order in which they appear in Tables 1 and 2.

Items not likely to be already available

(1) Coal-fired steam boiler: The cost listed is for a 750,000 btu/hr output boiler built to use 10,000 btu/lb coal. This unit includes hopper-stoker, electronic control panel, and automatic ash removal. The cost includes installation and freight. Because of the boiler's relatively more intensive use in plant B, it is assumed that the useful life is 10 years instead of 15 years, as in the case of plant A. Cost estimates were provided by Risager Plumbing and Heating, Aberdeen, SD, and Prill Brothers, Sheridan, WY.

(2) Fermentation tanks: Plant A has three fermentation/cook tanks. Two of the tanks hold a volume of 1,500 gal and the third holds a volume of 1,300, for a total of 4,300 gal.

Plant B has four fermentation/cook tanks. Each of these holds 5,500 gal, for a total of 22,000 gal.

Costs for each of the fermentation tanks in both plants A and B include (a) fabrication of the plain steel tanks with heating coils; (b) manufacture and installation of an agitator system in each tank; (c) non-corrosive paint; (d) an electric motor to run each agitator system; and (e) freight and installation. The cost estimates were provided by Fabricators, Inc., Sioux City, IA; the SDSU Physical Plant; Wheeldon's, Brookings, SD; and American Freight, Brookings, SD.

(3) Grain handling system: Costs for the grain handling system include (a) a 3,000-bu steel grain bin; (b) two u-troughs, one 8- and one 32-ft, with necessary connections and accessories; (c) 20-ft auger; (d) 5-hp hammermill; and (e) installation and freight. All cost estimates were provided by Berreau Industries, Round Lake, MN.

(4) Alcohol storage: Plant A has an alcohol storage capacity of 5,000 gal, while plant B's storage capacity is 10,000 gal. Costs for alcohol storage include (a) fiberglass tank with fittings; (b) fireplug pump; and (c) installation and freight. Cost estimates were provided by Fiberglass Unlimited, Inc., Watertown, SD; O'Day Equipment Inc., Sioux Falls, SD; and the SDSU Physical Plant.

(5) Auger: This cost is for a 5-inch diameter auger, 16 ft long, that is to be used in transferring DWG from the centrifuge to the storage bunker. The cost includes a 1-hp electric motor. Cost estimates were provided by Midwest Implement, Inc., Brookings, SD, and Wheeldon's, Brookings, SD.

(6) Heat exchanger: The cost is for a 25-square ft tube and shell heat exchanger made of carbon steel. The cost estimate was provided by Scott Stampe, SDSU agricultural engineering graduate research assistant.

(7) Feed byproduct storage: The cost listed is for a 25 long x 10 wide x 5 high (in ft) open-ended cement feed bunker. The walls and floor of the bunker are 4 inches thick, with the floor containing 6 x 6 ten gauge welded wire mesh. The cost estimate was provided by Louis Lubinus, SDSU Extension agricultural engineer.

(8) Water softener: This cost included two water softeners, each capable of handling 55 gal/hr of water of 20-30 grains hardness. (One handles the water softening needs while the other is recharging.) The softening is for boiler water only. The cost estimate was provided by Culligan, Brookings, SD.

(9) Building: Plant A has a building containing 800 square ft. Because of the larger fermentation tanks in plant B, its building contains 1,300 square ft.

Both buildings are insulated, wired metal buildings with concrete floors and steel supports. The roof serves as the ceiling. The cost estimate was provided by Louis Lubinus, SDSU Extension agricultural engineer.

(10) Distillation column: The cost is for a stainless steel, 12-inch diameter, insulated column with a 20-25-gal/hr distillation capacity. This cost is assumed to include the condenser. The cost estimate was provided by Arlon Industries, Sheldon, IA.

(11) Temperature meter: The cost estimate was provided by Scott Stampe, SDSU agricultural engineering graduate research assistant.

(12) Pressure gauges: The cost estimate for two pressure gauges was provided by Scott Stampe, SDSU agricultural engineering graduate research assistant.

(13) Pumps and motors: The number and size of pumps and motors used to transfer the beer and alcohol are assumed to be no different in plant B than they are in plant A. However, plant B will be using the pumps and motors more intensively; therefore, the assumed useful life of pumps and motors in plant B is 5 years, as compared to 10 years for those in plant A. The cost listed for pumps and motors includes (a) two Roper brand positive displacement progressive cavity pumps; (b) two Viking brand positive displacement gear pumps; and (c) four Char-Lynn brand hydraulic motors. Cost estimates were provided by Arlon Industries, Sheldon, IA.

(14) Pipes and accessories: The cost of pipes and accessories for plant A is based on what currently exists at the SDSU experimental plant. Although the size of pipes and accessories used in plant B is not expected to differ from those of plant A, it is assumed that there would be a 20% increase in cost due to an increase in the length of pipe needed and an increase in the number of accessory fittings that would be required.

The cost estimates include 1¼-inch black iron steam line, 3/4-inch rigid copper line, 3/4-inch ball valves, 3/4-inch gate valves, 1¼-inch pneumatic valves, 1-inch rubber hose, and 5/8-inch rubber hose. Cost estimates were provided by Thill Plumbing & Heating, Brookings, SD, and Running's, Brookings, SD.

(15) Centrifuge: The cost estimate is for a P-600 Sharples centrifuge. The estimate was provided by Pennwalt Corporation - Sharples Division, Oak Brook, IL. Due to heavier usage in plant B, the assumed useful life of the centrifuge is only 10 years, as compared to 15 years in plant A.

(16) Flow meters: The cost estimate for two flow meters was provided by Scott Stampe, SDSU agricultural engineering graduate research assistant.

(17) Differential pressure cell: The cost estimate was provided by Scott Stampe, SDSU agricultural engineering graduate research assistant.

(18) Cooling tower: The cost estimate is for the delivery and installation of a 65-ton open pit tower. The purpose of the cooling tower is to reduce the temperature of water that has been used to cool mash in the cook and fermentation process. A cool water holding tank will initially be filled with water to be used for this cooling. Scott Stampe, SDSU agricultural engineering graduate research assistant, estimates that 1.1 gal of the initial cooling water will be lost to evaporation for every gallon of 185 proof alcohol that is produced. Therefore, the cooling water must be replaced at that rate.

The cost estimate for the cooling tower was provided by the Gorgen Co., Minneapolis, MN.

(19) Laboratory: The cost estimate for a small, basic laboratory and equipment (to test alcohol content, etc.) was provided by Bill Gibbons, SDSU microbiology graduate research assistant.

Items possibly already available among members of a cooperative group

(1) Vertical auger: The cost is for a 43-ft, 7-inch auger with a 16-hp motor. This auger is used to auger corn from an unloading truck to the top of the bin. The cost estimate was provided by Midwest Implement, Inc., Brookings, SD.

(2) Skid-steer loader: The cost is for a new (1981) Case model 1845 with 45 hp. The cost estimate was provided by Case Power and Equipment, Brookings, SD.

(3) Steel grain bin: This grain storage (an addition to that described earlier as part of the grain handling system) is included only for plant B. The bin has a capacity of 3,200 bu of corn. The cost includes assembly on the site. The cost estimate was provided by Opland Agri-service, Brookings, SD.

Other fixed costs

(1) Insurance: The cost of insurance was calculated from the following schedule:

	Insurance type	Rate
(a)	General liability - $500,000 coverage	$.65/$100 payroll
(b)	Product liability	$1.00/$100 sales
(c)	Workmen's compensation	$4.95/$100 payroll
(d)	Fire and extended coverage	$.80/$100 sales

For purposes of calculations here, only rough estimates of alcohol and DWG revenues were used. For calculating insurance costs, the 185 proof alcohol was assumed to sell for $1.30/gal and the DWG was assumed to sell for $40/ton.

The insurance schedule was taken from Small-Scale Fuel Alcohol Production, USDA, March 1980. Actual cost will vary from state to state and insurer to insurer.

(2) Maintenance: Maintenance for plant A was calculated as 3% of equipment investment. Guidelines for estimating this maintenance cost were drawn from Small-Scale Fuel Alcohol Production, USDA, March 1980--with modifications deemed appropriate for the SDSU-type plant.

Maintenance for plant B was calculated as 4% of equipment investment. Even though shorter useful lives were assumed for some capital components of plant B (than in the case of plant A), it was felt that the much more intensive use of all capital equipment in plant B would necessitate at least this much of an increase in the cost allowance for maintenance.

(3) Property taxes: Property tax information was taken from the Annual Statistical Report, FY 1980 of the SD Department of Revenue. The tax rate is for a permanent site in Moody County.

The formula for computing annual property taxes is as follows: Initial capital cost x ratio of assessed value to market value x taxable value percent x mill levy = amount of annual property tax owed.

In Moody County, the city of Egan has the following data for 1980:

(1)	ratio of assessed value to market value	= .911
(2)	taxable value	= .45
(3)	mill levy	= .078

There is a possibility of reducing property taxes through the tax assessment credit made available for the installation of renewable resource energy systems by the South Dakota Legislature in 1980. The assessment credit is determined in one of two ways--the assessed value of the property with the system installed minus the assessed value without the system or the actual cost of the system, whichever amount is greater.

Both residential and commercial structures qualify for the assessment credit. Residential dwellings qualify for a 100% and commercial structures for a 50% credit. The credit may be applied for 3 continuous years for both residential and commercial applications, followed by 3 years of diminishing credit of 75%, 50%, and 25% of the base year credit.

However, the assessment credit does not apply when (1) the energy produced is to be sold or (2) the title to the property is transferred. It was assumed in this analysis that at least some of the alcohol would have to be sold to non-cooperative customers. Therefore, the assessment credit was not applied.

ANNEX B

Explanation of Operating Cost Estimates

This annex contains an explanation of considerations entering into estimation of costs of each variable input. Also noted are the sources of cost information. Units of each input are listed on a per gallon of 185 proof non-denatured alcohol basis. The inputs are listed in the order in which they appear in Tables 1 and 2.

(1) Corn: The cost of corn for both plants A and B is assumed to be that offered for corn at local grain elevators. In the base cases, this cost is assumed to be $2.50/bushel. The assumed amount of corn required per gallon of 185 proof alcohol is based on data from 1981 experiments by and judgements of SDSU microbiologists and agricultural engineers on the fuel alcohol research team. Those individuals felt that 2.6 gallons of 185 proof alcohol per bushel of corn could be obtained by a commercial or cooperative plant patterned after SDSU's if proper equipment and management were used.

(2) Diazyme L-100: Diazyme L-100 is purchased in a standard concentration, the cost estimate of which was taken from invoices received by SDSU from Miles Laboratories, Inc. of Elkhart, IN. The cost estimate includes freight.

(3) Taka-Therm: Taka-Therm also is purchased in a standard concentration. The cost estimate was taken from invoices received by SDSU from Miles Laboratories, Inc. of Elkhart, IN. The cost estimate includes freight.

(4) Sulfuric acid: The cost for sulfuric acid was taken from invoices received by SDSU from Dakota Chemical Co. of Sioux Falls, SD. The acid is 98-100% concentrated H_2SO_4, 36 N. The cost includes freight.

(5) Ammonium hydroxide: The cost of the ammonium hydroxide solution was taken from invoices received by SDSU from Dakota Chemical Co. of Sioux Falls, SD. The trade name is Aqua Ammonia ($NH_4OH + H_2O$) and it is 29% concentrated by weight. The cost includes freight.

(6) Yeast: The yeast used for alcohol production experiments at SDSU was made by SDSU microbiologists. If one were to purchase such yeast, the cost would be $1.20/lb, including freight. Bill Gibbons, SDSU microbiology graduate research assistant, recommended using about 2 lb of yeast per 1,000 gal of mash.

The cost estimate was provided by Universal Foods of Milwaukee, WI, for Red Star Distillers Active Dry Yeast.

(7) Electricity: Electrical rates for 1981 were provided by Sioux Valley Electric, Colman, SD. Electrical use per gallon of 185 proof alcohol is based on 1981 experimental data.

(8) Fuel: The fuel assumed to be used in both plants A and B for steam production is 10,000 btu/lb coal. The boiler using the coal is assumed to operate at 70% efficiency.

The amount of steam used per gallon of 185 proof alcohol, based on 1981 experimental data, was 20,507 btu's. However, this measurement was taken without a heat exchanger in place. Scott Stampe, SDSU agricultural engineering graduate research assistant, estimates a 10% savings in steam requirement if a heat exchanger were to be installed. Since this analysis assumes the use of a heat exchanger, the amount of steam needed per gallon of 185 proof alcohol was reduced 10%, to 18,457 btu's.

The cost estimate for the 10,000 btu/lb coal was provided by Schultz Coal Brokers, Sheridan, WY; it includes freight.

(9) Water: The amount of water used per gallon of 185 proof alcohol produced is based on (a) 1981 fuel alcohol plant experimental data concerning water use for cooking, cooling, clean-up, etc. and (b) water-to-steam conversion estimates provided by Scott Stampe, SDSU agricultural engineering graduate research assistant. This analysis assumes that 75% of the water required for the total process can be recycled through a cooling tower and used again.

The cost of water is based on 1981 rates provided by the Big Sioux Rural Water System, headquartered in Brookings, SD.

(10) Water Softener Salt: The water softeners are assumed to soften only water going to the boiler. They can soften water of 20-30 grains hardness at a rate of around 54 gal/hr.

For plant B, this requires approximately 480 lb of softener salt, which costs $4.25/80-lb bag.

For plant A, about 160 lb of softener salt are required, at $4.25/80-lb bag.

Estimates of the amount of softener salt needed and costs for water softener salt were provided by Culligan Water, Brookings, SD.

(11) Denaturant: Bureau of Alcohol, Tobacco, and Firearms regulations (see Distilled Spirits for Fuel Use, July 1980, in list of References) require addition of a denaturant to alcohol, to render it unfit for beverage use, if it is to be free of beverage alcohol taxes and used for fuel alcohol. One way of satisfying the regulations is by adding 5 gal or more of gasoline to each 100 gal of alcohol. See Annex C for the denaturant assumption used in the analyses for this report.

(12) Labor: In plant A, the following assumptions apply to labor requirements. Two types of labor are required. They are (1) managerial and (2) technical/processing labor. The equivalent of one person of managerial capability is required at the plant for 8 hr per day, 7 days per week, for 45 weeks of operation. This managerial capability may be represented by more than one person, such as two partners.

The manager(s) is responsible for the purchase of inputs and the marketing of outputs. He is also responsible for the operation of the plant during his work shift. In addition to managing, this person(s) must have some knowledge of microbiology or engineering or related fields. The hourly wage for managerial labor is $8/hr. Therefore, total annual managerial labor cost for plant A is computed as follows: ($8/hr)(8 hr/day)(7 days/week)(45 weeks/yr) = $20,160 annual managerial labor cost.

Even though the fermentation process takes much of the time required to process each alcohol batch and requires little monitoring, a person with technical/processing training must be at the alcohol plant for 12 hr per day--in addition to the manager's 8-hr shift. In other words, someone is at the plant 20 hr per day. There are two reasons for this. First, the cook/fermentation tanks are loaded in a staggered fashion, to produce the maximum amount of beer possible in a week's time. Therefore, each tank will begin and end fermenting at different times. Second, the plant is powered by a coal-fired boiler, which requires a great deal of monitoring.

The technical/processing personnel are paid $5/hour. Therefore, total annual technical/processing labor cost for plant A equals: ($5/hr)(12 hr/day)(7 days/week)(45 weeks/yr) = $18,900 annual technical/processing labor cost.

Total annual labor cost for plant A would then equal: $20,160/yr managerial labor cost + $18,900/yr technical/processing labor cost = $39,060/yr. The total annual labor cost of $39,060/yr does <u>not</u> include labor for truck drivers delivering the alcohol or DWG to consuming farms. That labor cost is to be included in the marketing analysis in a separate report.

In plant B, the three types of labor required are (1) overall manager; (2) plant manager/engineer; and (3) technical/processing labor. In plant B, the manager is fully occupied in planning, oversight, purchasing inputs, selling outputs, and so forth for 8 hr per day, 6 days per week, 45 weeks of the year. As in plant A, he has some training in microbiology or engineering or a related field. His hourly wage is $10/hour, so that, on an annual basis, he is paid as follows: ($10/hr)(8 hr/day)(6 days/week)(45 weeks/yr) = $21,600/yr.

Because plant B is assumed to be in operation 24 hr/day and the manager is likely to be fully occupied with managing activities, the SDSU fuel alcohol research team felt there is a need for a person with professional training in microbiology or engineering to aid the manager in physical operation of the plant. He or she works 8 hr per day, 6 days per week, 45 weeks per year at an hourly wage of $9 per hour. The total annual wage of this "plant engineer" is equal to: ($9/hr)(8 hr/day)(6 days/week)(45 weeks/yr) = $19,440/yr.

As in plant A, the technical/processsing personnel are paid $5/hr. There will need to be someone to monitor operations 24 hr per day. Therefore, total annual technical/processing labor cost for plant B equals: ($5/hr)(24 hrs/day)(7 days/week)(45 weeks/yr) = $37,800/yr.

Total annual labor cost for plant B therefore equals: $21,600 managerial labor + $19,440 "plant engineer" labor + $37,800 technical/processing labor = $78,840.

Members of the SDSU fuel alcohol research team agreed that the labor requirements and costs assumed for plants A and B are the minimum at which those plants could operate. Also recognized was the likely difficulty in obtaining personnel with the necessary combinations of skills and training needed to fill the positions described.

(13) Laboratory tests: Both plants A and B are equipped with what is called a "small" laboratory. With this laboratory, one could test alcohol levels in the beer, test glucose concentrations in the mash and in the beer, and make rough estimates of starch concentrations in the corn.

Bill Gibbons, SDSU microbiology graduate research assistant, suggests that managers of both plants would want to have samples of wet solids sent to more sophisticated laboratories to test for protein, fat, and other nutrient composition. They may also want to send periodic corn samples to outside laboratories for more accurate measurements of starch concentrations. Occasional samples of mash and beer might be sent to better-equipped laboratories to check the accuracy of a plant's own sampling procedures.

Gibbons estimates the cost of testing samples from plant B at an outside laboratory would be approximately $50/week. Because plant A produces less than one-third as much alcohol and DWG as does plant B, it is assumed that the cost of outside lab tests for plant A would be only about 30% of those for plant B, or about $15/week.

ANNEX C

Explanation of Alcohol Production Estimates

Estimation of annual output of 185 proof alcohol was done for two plant sizes. Plant A was assumed to produce approximately 49,000 denatured gallons of 185 proof alcohol yearly, while plant B was assumed to produce around 175,000 gallons. The factors and assumptions used in determining these production figures are explained in this annex.

I. Plant A Estimates of 185 Proof Alcohol Production

To calculate the alcohol producing capacity of plant A, several factors were considered:

(1) Fermentation capacity: Fermentation capacity is the limiting factor determining the amount of 185 proof alcohol that can be produced yearly in plant A. Plant A contains three fermentation/cook tanks with a total volume of 4,300 gal. If filled to the 95% level, total fermentation capacity is 4,085 gal of mash.

(2) Alcohol content of beer: The goal of the plant is to make beer with a 10% alcohol content.

(3) Length of time for the production process: Each fermentation tank holds an average of 1,362 gal of mash. It is assumed that each tank requires 68 hr to complete the production process; this includes 12 hr for loading and cooking, 48 hr for fermentation, and 8 hr for distillation and cleanup. Production of alcohol within these time constraints allows for approximately 7.5 tanks full of mash to be processed per week of operation. This assumes that the tanks are loaded, fermented, and distilled in a staggered fashion.

(4) Amount of corn used per tank: In order to achieve an alcohol content of 10% in the beer, the following ratio of corn to mash is needed:

$$\frac{12.89 \text{ bu of corn}}{331.6 \text{ gal of mash}}$$

Thus, for each 1,362-gal tank of mash, the amount of corn required equals:

$$\frac{12.89 \text{ bu of corn}}{331.6 \text{ gal of mash}} = \frac{X}{1{,}362 \text{ gal of mash}}$$

X = 52.9 bu of corn

(5) Days of operation: Plant A is assumed to operate 24 hr per day for 45 weeks of the year. Seven weeks are allowed for downtime, due to maintenance and repair, vacation time for personnel, etc.

(6) Annual output of 185 proof alcohol: SDSU experimental data gathered during 1981 showed that each bushel of corn produced an average of 2.36

gallons of 185 proof alcohol. However, consultation with the agricultural engineering and microbiology researchers running the plant indicated that approximately 9% of the alcohol yield was lost due to interruptions and variations in the production process required for experimental purposes. Therefore, 2.36 gal of 185 proof alcohol per bushel of corn represents, in the judgment of the engineering and microbiology researchers at SDSU, only approximately 91% of the actual alcohol yield. The actual per bushel yield is therefore estimated to be approximately 2.6 gal of 185 proof non-denatured alcohol. Thus, the total annual non-denatured alcohol production of plant A is calculated as follows: (52.9 bu of corn/fermentation tank)(7.5 tanks processed/week) (2.6 gallons of 185 proof alcohol/bu of corn)(45 weeks/yr) = 46,420 gal.

(7) Denaturant: Reference was made in Annex B to a Bureau of Alcohol, Tobacco, and Firearms requirement that at least 5 gal of gasoline be added to each 100 gal of alcohol (if gasoline is used as the denaturant). This minimum amount of gasoline would represent 4.76% of plant fuel output (5 ÷ 105). The analysis in this bulletin was based on the assumption that 5% of the fuel output is made up of gasoline, i.e., that 5 gal of gasoline denaturant are added to each 95 gal of alcohol. Thus, the amount of denaturant added to the alcohol produced in plant A is calculated as follows--

(a) $.95\ X = 46{,}420$ gal of 185 proof alcohol produced annually

(b) $X = \frac{46{,}420}{.95} = 48{,}863$ gal of 185 proof alcohol plus denaturant produced annually

(c) 48,863 gal of fuel - 46,420 gal of 185 proof alcohol = 2,443 gal of gasoline added yearly as denaturant.

(8) Total annual denatured 185 proof alcohol fuel output: Total annual output of denatured 185 proof alcohol equals: 46,420 gal of 185 proof alcohol + 2,443 gal of gasoline = 48,863 gal of fuel.

II. Plant B Estimates of 185 Proof Alcohol Production

As in the case of plant A, there were several assumptions that needed to be made about plant B concerning factors affecting annual alcohol production.

(1) Fermentation capacity: The limiting factor in the annual production of 185 proof alcohol in plant B is distillation capacity. The distillation column is capable of distilling 22 gal of 185 proof alcohol per hour. In order for the distillation column to operate at full capacity, four fermentation/cook tanks are needed, with each tank holding a volume of 5,500 gal--for a total of 22,000 gal. These tanks are assumed filled to the 95% level, thus allowing for a fermentation capacity of 5,225 gal of mash in each tank. Total fermentation capacity for all four tanks is therefore 20,900 gal of mash.

(2) Alcohol content of beer: The goal of the plant is to make beer with a 10% alcohol content.

(3) Length of time for the production process: Each tank in plant B is assumed to take 4 days to complete the production process; this includes 15 hr for loading and cooking, 57 hr for fermentation, and 24 hr for distillation. Starting the four tanks through the 4-day production process in a staggered fashion would allow one tank to begin distillation just as another is finishing, in a continuous cycle.

There are some differences from plant A in time allowed for each component of the production process in plant B. Because the fermentation tanks in plant B are larger than those in plant A, it is assumed that it requires 3 more hours per tank for loading and cooking the mash.

The mash in plant B's tanks is assumed to ferment 57 hr (compared to 48 hr in plant A), even though 48 hr of fermentation would be sufficient. The reason for this is that as each tank is started through the 4-day production process in a staggered fashion, the distillation column will be kept running at full capacity. However, in the 3 days before each tank begins distillation, there are 9 hr in which the fermentation tank could be left idle. Instead of leaving the tank sit empty, 9 extra hr of fermentation time have been assumed.

The 4-day production process also allows for a regular schedule for starting and stopping operations for each tank. This makes it easier to schedule work shifts and to handle the flow of inputs and outputs in general.

In plant A, there was some time allowed for clean-up duties; none was allowed in plant B. The assumption is that the continuous batch process of plant B requires less time in the distillation stage because the column is not periodically shut down and started up again, as in plant A. It is assumed that there is no needed cleaning before the next batch. Also, no time is required to adjust the distillation column to its optimum operating level in plant B.

(4) Amount of corn used per tank: In order to achieve an alcohol content of 10% in the beer, the following ratio of corn to mash is needed:

$$\frac{12.89 \text{ bu of corn}}{331.6 \text{ gal of mash}}$$

Thus, for each 5,225-gal tank of mash, the amount of corn required equals:

$$\frac{12.89 \text{ bu of corn}}{331.6 \text{ gal of mash}} = \frac{X}{5{,}225 \text{ gal of mash}}$$

X = 203.1 bu of corn

(5) Days of operation: Plant B is assumed to operate 24 hr per day for 45 weeks of the year. Seven weeks are allowed for downtime, due to maintenance and repair, vacation time for personnel, etc.

(6) Annual output of 185 proof alcohol: Plant B is structured to allow the distillation column to run 24 hr per day at the rate of 22 gal of 185 proof alcohol per hour, for 45 weeks of the year. Therefore, annual output is calculated as follows: (22 gal of 185 proof alcohol/hr)(24 hr/day)(7 days/week) (45 weeks/year) = 166,320 gallons of undenatured 185 proof alcohol.

(7) Denaturant: The denaturant requirement is computed for plant B in the same way as for plant A. For plant B, the calculation is as follows--

(a) .95 X = 166,320 gal of 185 proof alcohol produced annually

(b) $X = \frac{166,320}{.95}$ = 175,074 gal of 185 proof alcohol plus denaturant produced annually

(c) 175,074 gal of fuel - 166,320 gal of 185 proof alcohol = 8,754 gal of gasoline added yearly as denaturant.

(8) Total annual denatured 185 proof alcohol fuel output: Total annual output of denatured 185 proof alcohol equals: 166,320 gal of 185 proof alcohol + 8,754 gal of gasoline = 175,074 gal of fuel.

ANNEX D

Explanation of Byproduct Quantity Estimates

Estimates of byproduct (distillers wet grains) quantities produced in plants A and B were first estimated from 1981 SDSU experimental data. The data showed that for every bushel of corn used in the production of 185 proof alcohol, 38.5 lb of 70% moisture distillers wet grains (DWG)[1] was produced. However, researchers operating the SDSU alcohol plant indicated that approximately 9% of the DWG was lost due to interruptions in the production process required for experimental purposes. Therefore, 38.5 lb of DWG per bushel of corn is assumed to represent only 91% of the actual output of DWG. The actual amount of DWG produced per bushel of corn is therefore approximately 42.4 lb.

Estimates of annual production of DWG for plants A and B are thus based on the corn used in each plant. For plant A, the annual production of DWG is calculated as follows: (42.4 lb of DWG/bu of corn)(52.9 bu of corn/1,362-gal tank full of mash)(7.5 tank fulls/week)(45 weeks of operation/year) = 756,999 lb of DWG/yr, or about 378 tons of DWG.

For plant B, the annual production of DWG is calculated as follows: (42.4 lb of DWG/bu of corn)(203.1 bu/corn/5,225-gal tank full of mash)(4 tank fulls/4 days) $\left(\frac{\text{315 operating days}}{\text{4-day production cycle}}\right)$ = 2,712,604 lb of DWG/yr,

or about 1,356 tons of DWG.

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[1]The DWG produced in the 1981 experiments contained 70% moisture after being run through a centrifuge.

ANNEX E

Explanation of Byproduct Value Estimates

The prices of feeds used in dairy trial rations were drawn from a number of different sources. This annex lists the feeds and explains the process through which the distillers wet grain (DWG) was assigned a value.

(1) Ground corn: The price of corn was assumed to be the same as the price paid by the alcohol plant for corn used in alcohol production. That price was $2.50/bu. An additional charge of $.09/bu was added to the corn price for grinding and mixing. The cost of mixing and grinding was taken from Rates Paid for Custom Work in South Dakota, by Ron Thaden and Wallace G. Aanderud, SDSU Extension Circular 663, 1980.

(2) Ground oats: The price of oats was assumed to be the local price in mid-1981. This amounted to $1.85/bu, plus $.05/bu for grinding and mixing. The price quote for oats was from Sexauer's in Brookings, SD, and the cost of mixing and grinding was from Rates Paid for Custom Work in South Dakota, by Ron Thaden and Wallace G. Aanderud.

(3) Soybean meal: The price of soybean meal is for bulk, 47% protein meal, delivered. Price quotations were from several local grain elevators for 44% protein soybean meal in mid-1981. These price estimates ranged from $215/ton to $250/ton, depending on the quantity purchased and the time of year. A price of $235/ton was subjectively selected as a "mid-range" price. Since the ration used 47% protein soybean meal, the price was raised to $240/ton to make some allowance for a higher price on the higher protein soybean meal.

(4) Oats straw: The price of oats straw was arrived at through consultation with personnel in dairy science, animal science, and Extension economics at SDSU. It was generally agreed that the price of oats straw is between 30% and 40% of the price of alfalfa hay. Oats straw was thus priced at $30/ton, which is 37½% of the assumed 1981 price of alfalfa.

(5) Limestone: The price of limestone is $4.50/cwt. This price quotation was received from the Farmer's Coop in Brookings, SD.

(6) Water: The price of water is assumed to be the same as water used for alcohol production in plant A; that is $1.60/1,000 gal. That water price is based on water rates from the Big Sioux Rural Water System, Brookings, SD.

(7) Dicalcium phosphate: The price of dicalcium phosphate is $9.50/50 lb. This price quotation was received from the Farmer's Coop in Brookings, SD.

(8) Trace mineral salt: The price of trace mineral salt is $7.00/cwt. This price quotation was received from the Farmer's Coop in Brookings, SD.

(9) Corn Silage: The price of corn silage was assumed to be the average between that used for 1980 and 1981 year-end inventories. This is equal to $17.50/ton, on a wet basis. The prices for inventories were provided by Herb Allen, SDSU economics professor. The average of these year-end prices is intended to represent a "mid-1981" price.

(10) Alfalfa Hay: The price of alfalfa hay was determined through consultation with farm management economists and from price data listed for 1980 and 1981 year-end inventories. The result was an assumed "mid-1981" price of $80/ton.

(11) DWG: The value of DWG was determined by subtracting the cost of the experimental rations, exclusive of DWG, from the cost of the control rations in both dairy heifer and dairy cow trials run by SDSU Dairy Science Department researchers. The difference was the value assigned to the DWG.

In the dairy heifer trials, the substitution value of the DWG was found to be $65.85/ton. The DWG was substituted for soybean meal and some corn and oats.

From the $65.85/ton, $12.60/ton was subtracted to account for the cost of propionic acid, which is added to DWG to extend the time it can be stored without spoilage and mold growth. This reduced the value of the DWG in dairy heifer rations to $53.25/ton.

In the lactating dairy cow trials, the substitution value of the DWG was found to be only $46.15/ton. Here, the DWG substituted for soybean meal and some corn, oats, and corn silage. Again, the $12.60/ton cost for propionic acid was subtracted, reducing the value of DWG in lactating dairy cow rations to $33.55/ton.

The average of those two values--43.40/ton--was used to establish the value for DWG in this study. From the $43.40, a discount for handling and transportation was applied. This discount was assumed to be 10%, which is the same as the discount applied in Preliminary Cost Estimates--Producing Alcohol Fuel From A Small Scale Plant, by Hutchinson and Dobbs, SDSU Agricultural Experiment Station Circular 233, 1980. It is felt that this discount might even be too little, given the inconvenience of handling high moisture DWG, compared to dried feeds, and given the possibility of substantial transportation costs.[1]

The net value of the DWG thus arrived at was as follows:

$43.40/ton - 10% (43.40) = approximately $39/ton

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[1]For preliminary estimates of feed byproduct transportation costs, see Framework for Examining the Economic Feasibility of Small Scale Alcohol Plants, by Dobbs, Hoffman, and Lundeen, SDSU Economics Department Staff Paper No. 81-3, August 1981.

The net value of the DWG on a per gallon of denatured 185 proof alcohol basis is equal to:

(1) <u>for plant A</u>

$$\frac{(378 \text{ tons of DWG})(\$39/\text{ton})}{48{,}863 \text{ gal of denatured 185 proof alcohol}} = \$.302/\text{gal}$$

(2) <u>for plant B</u>

$$\frac{(1{,}356 \text{ tons of DWG})(\$39/\text{ton})}{175{,}074 \text{ gal of denatured 185 proof alcohol}} = \$.302/\text{gal}$$

More details on ration compositions and costs of feeds will be found in a Master's thesis being written by Daryl Brehm, a graduate research assistant in economics at South Dakota State University.

(12) <u>Propionic acid</u>: A propionic acid-based preservative is assumed added to the DWG to extend the time which DWG can be stored without spoilage and mold growth. The product is made up of 70% propionic acid and 30% acetic acid. It is mixed with the DWG in undiluted form at a ratio of .7% preservative to 99.3% DWG, weight-to-weight. It is here assumed that this allows for safe storage of DWG for about 2 weeks.

This particular preservative has been used by SDSU Dairy Science Department researchers to preserve DWG used in feeding trials. The ratio of preservative to DWG cited above represents the smallest amount of propionic acid that has been added to DWG; it resulted in DWG that was preserved in quality for a reasonable length of time. However, it is <u>possible</u> that smaller amounts of propionic acid could be added to the DWG that would also prevent spoilage for a reasonable length of time.

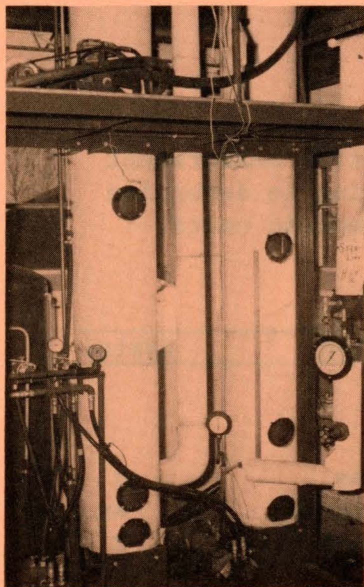
The cost of this preservative is estimated to be $.90/lb, including freight. This estimate was provided by Kemin Industries of Des Moines, IA.

ANNEX F

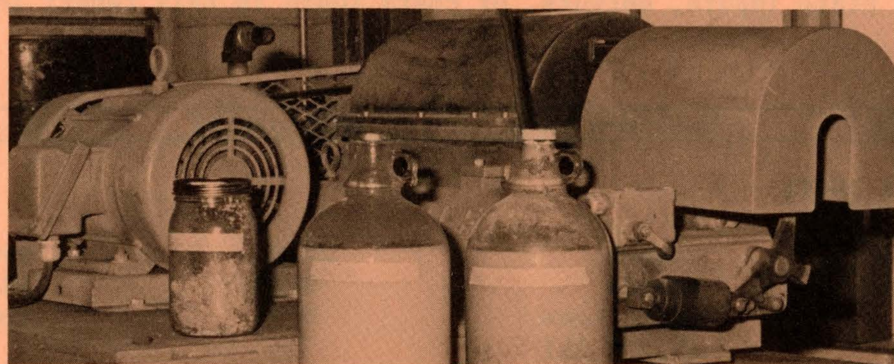
Metric Measurement Conversions

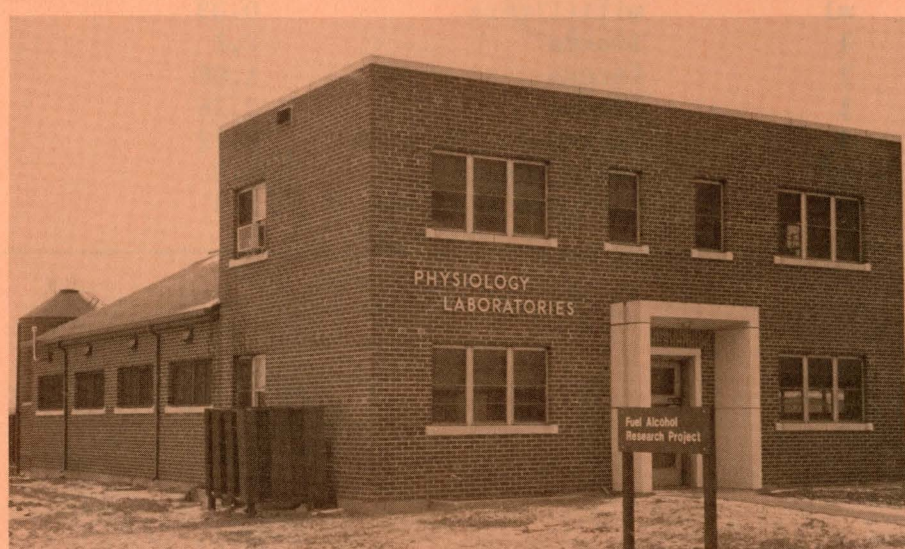
Contained here are certain conversions of English to metric measurement units. These conversions will be of use to individuals wishing to determine and state inputs, outputs, or costs found in this report in metric units.

Symbol	When You Know	Multiply By	To Find	Symbol
MASS (WGT)				
oz	ounces	28.0	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2,000 lb)	0.9	tonnes	t
	long tons (2,240 lb)	1.01	tonnes	t
g	grams	0.035	ounce	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1,000 kg)	1.1	short tons	
t	tonnes (1,000 kg)	0.98	long tons	
VOLUME				
tsp	teaspoons	5.0	milliliters	ml
tbsp	tablespoons	15.0	milliliters	ml
fl oz	fluid ounces	30.0	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons (U.S.)	3.8	liters	l
gal	gallons (Imp)	4.5	liters	l
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons (U.S.)	gal (U.S.)
l	liters	0.22	gallons (Imp)	gal (Imp)
m^3	cubic meters	35.0	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3



The SDSU Fuel Alcohol Research Plant





Cover photo: Bill Gibbons, research assistant in microbiology, checks the temperature in an experimental vat. This page: distilling columns, centrifuge, fermentation vats, and other equipment are in a building north of SDSU outdoor track; grain handling system is behind.