Cost Analysis of Farm and Cooperative ETHANOL PLANTS

IOWA CENTRAL
COMMUNITY COLLEGE

A COST ANALYSIS OF TWELVE SMALL SCALE FARM AND COOPERATIVE ETHANOL PRODUCTION PLANTS

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FARM ETHANOL RESEARCH PROJECT

Introduction

The feasibility of farm and farm cooperative stills continues to be a subject for speculation, principally because there are a number of unknowns which make it difficult to equate the advantages and disadvantages involved. The farmer has an abundance of renewable products which can be used to decrease the trend toward ever increasing motor fuel costs as well as decrease our dependence on foreign fuel. Both farmers and non-farmers are adversely affected by high energy costs. High fuel costs have become a major factor affecting the inflation spiral. Federal and State legislation, particularly the Federal Windfall Profit Tax Act and the Energy Security Act as well as State gasohol rebates, have been incentives for farmers to become involved in ethanol production. At the outset of farm ethanol production in 1979 and 1980, interest among farmers, farm related groups, and Federal and State governments was high. Meetings on farm stills were well attended. The Federal government responded by passing legislation favorable for the development of farm and commercial alcohol facilities. Some State governments also provided funds for various types of fuel developments.

During the latter part of 1981 there was a noticeable decrease in interest among farmers to build alcohol plants but there was a trend toward the development of cooperative facilities. The decrease in interest among farmers in ethanol production was due to a number of factors. One of the factors was that many farmers who wanted to build a farm plant did not have the technology and expertise to do the job at a reasonable cost. There were "turn-key" ethanol plants which could be purchased, but many farmers felt the cost was too high for the returns received. Another factor that has adversely affected the construction of farm ethanol plants relates to product utilization, particularly alcohol and stillage use. Engine modification for ethanol consumption has been slow to develop. United States car and tractor manufacturers have taken the attitude to "wait and see" before modifying tractors and cars for ethanol use. Consequently, it will be up to the ethanol producers and other innovators to make the necessary motor modifications for ethanol use. In some cases potential ethanol producers have not gone into production because of the limited outlets for distiller's grains. Since this is a by-product and can be successfully fed wet to livestock, a market close by is needed. Many of the producers have made plans to utilize this high protein feed in their own feedlot.

There is always uncertainty as to how long and to what extent either the Federal or State government will continue to financially support a given program. For this reason, a number of farmers and farm cooperative groups have hesitated to go through with plans for ethanol production. The trend is for Federal and State government to reduce their loan and grant programs.

Based on the above factors, farmers and other farm groups recognize the necessity of looking at the pros and cons of such a venture with particular emphasis on profitability. To make decisions about profitability, more specific data and information are needed. It is apparent that more information is needed on component parts, equipment sources and construction costs. More background is also needed on operational procedures and small plant techniques. The most important data needed is that on small plant operation profitability.

Because of the dearth of small plant performance data, a research project was initiated to begin a data bank as a basic reference point for ethanol producers. Areas of data collection include equipment used, operation costs, and revenues. Information includes a description of the plant, operational procedures, profitability data, and a summary.

Format

The general format for data collection and reporting will be as follows:

Size and type of operation

Normal procedures and techniques

Profitability statement

Summary

METHODOLOGY

The first step was to identify possible cooperators. Visits were made to the plant site, the program was explained and a potential schedule set up. In some cases, the operator did not wish to cooperate. Some cooperators, after starting the project, discontinued the survey because of difficulties in plant operation. At least three visits were made to cooperators who participated to obtain cost data and operational procedures. Cost data, description of the plant and a sketch of the operation are included with each survey report. Unusual or innovative procedures are pointed out in the summary statement. Contact was maintained with all the cooperators during the project period to determine any changes in operation or cost data. The expenses of the profitability statement were divided into variable and fixed costs. Items under variable costs include labor, fuel, electricity, water and supplies. The units for each item and the cost per unit were used to determine the total costs per gallon of alcohol produced. Generally, this was determined on a batch run or a daily production schedule. Labor costs were determined by the number of employees, hours per day, and the rate per hour paid. This cost was divided by the gallons produced during the given period. For farm units, the portion of time given for the ethanol production was used for the hours of labor. Corn prices at the time of the survey were used. The cost of fuel was determined by the amount of fuel used and the price per unit divided by the number of gallons produced during that period. In some cases, the cost of electricity was determined by the number of motors and lights used to determine the number of kilowatts used per production unit. This amount was then multiplied by the rate for that facility and divided by the number of gallons. Where separate meters were available, the kilowatt hours used for a given period of time and the number of gallons of alcohol produced for that period were used to determine the electricity cost. If the water was purchased the cost was included under that item otherwise about the only cost involved was the cost of electricity for pumping the water.

Fixed cost items include repair and maintenance, insurance, taxes, capital costs and miscellaneous items. Only those items applicable to the specific facility were utilized. The cost for most of these items was determined by using the yearly cost for the item and the yearly production.

Under revenue the average price for the ethanol, if sold, was used. If used on the farm, the existing price of the product was established by the market price. The selling of distillers grains was used if marketed. If the product was fed, a price was determined based on the price of soybean oil meal at that time. When distillers grains were fed to beef cattle, the price of distillers grains was determined in relationship to the feeding study conducted by Iowa State University.

When ethanol incentives were used, credit was shown on the profitability statement. A difference between the expenses and revenues determined the statement for profit or nonprofit.

Each of the cooperators is designated by survey number i.e., 1, 2, 3, 4, 5, etc. The general format was to give a brief description of normal procedures and techniques followed by the profitability statement and summary of the plant. In the summary statement, significant problem areas and innovative procedures and techniques were discussed. Following the individual survey reports, specific findings were listed and conclusions drawn from the overall project.

Major Plant Components

Land

Building

Storage bins

Grinding mill

Conveyors

Cookers

Fermenters

Distillation column

Storage tanks

Controllers

Pipes and valves

Metering controls

Micro-processors

Safety valves

Heat exchangers

Instrumentation

Insulation

Boiler

Fuel handling equipment

Feedstock handling equipment

Storage for stillage

Stillage treatment equipment

CO_2 handling equipment

Ethanol dehydration equipment

Extruder

Fuel

Water

Supplies

Motor(s)

Other

Profitability Statement

Expenses

- Operating labor
- Materials
  - corn
  - fuel
  - electricity
  - water
  - supplies
- Repairs and maintenance
- Insurance
- Taxes
- Depreciation
- Capital costs
- Other
- Transportation
- Total expenses

Revenue

- Ethanol
- Distillers grains
- Ethanol incentives

PROFITABILITY STATEMENT

	Units Used	Unit Cost	Cost/ Gal.
Expenses			
Operating Labor			
Materials			
Corn			
Fuel			
Electricity			
Water			
Supplies			
Sub Total			
Repairs & Maintenance			
Insurance			
Taxes			
Depreciation			
Capital costs			
Other			
Transportation			
Sub Total			
TOTAL EXPENSES			
Revenue			
Ethanol			
Distillers grains			
Ethanol incentives			
TOTAL REVENUE			
NET PROFIT			

Data from at least three runs per farm still were averaged. Since these plants were just starting up, the producer often had to change or modify some of his procedures and equipment. These changes and modifications necessitated additional contacts to obtain the most accurate data. An important part of this study involves the utilization of ethanol and stillage. The use or marketing of these products is of paramount importance to the profitability of the system.

The general summary points out some of the highlights as well as problems experienced in the specific still. More information about the plants may be obtained by contacting the project coordinator.

SURVEY 1

Size and Type of Operation

Plant S-1 is an atmospheric type distillation process. The column is 10 inches in diameter and 23 feet high. The bottom of the column has 10 plates with eight-inch spacing containing one-half inch holes in the plates. The top half of the column is packed with clay packing material. The beer enters the column at approximately the tenth plate from the bottom. Steam is injected through a sparge ring in the bottom of the column and a pressure of two to three pounds is maintained at the base of the column. To maximize the alcohol recovery the solids are put through the column. Besides the single column there are two 1,500 gallon cooking and fermentation tanks, six electric and hydraulic pumps, two heat exchangers and two condensers and the necessary plumbing and valves to accomplish the process. One of the 1500 gallon tanks is equipped with baffles and a hydraulically driven paddle. Steam nozzles are located in the bottom of this tank and cooking is accomplished by injecting live steam from a central power plant. An extensive monitoring system has been developed so that readings at critical points might be determined. Presently the plant is valued at approximately $50,000.

Normal Procedures and Techniques

For experimental purposes, forty bushels of finely ground corn are used for each batch. The normal procedure is as follows:

Add 440 gallons of water to the cooking tank. The steam is then turned on with the flow approximately 350 to 400 pounds per hour. The agitator is also turned on. To this, forty bushels of finely ground corn and 1000 ml of alpha-amylase are added. Cooking is continued until the temperature reaches 90 degrees centigrade. This is then held for one-half hour. Three hundred and fifty gallons of water are then added resulting in a temperature of approximately 70 degrees centigrade. The valves for cooling mash through the heat exchanger are opened to bring the temperature to approximately 60 degrees centigrade. At this time 1600 ml gluco-amylase is added. The mash is further cooled to approximately 30 degrees centigrade and five pounds of baker's yeast is added. The yeast is stirred until properly mixed with the mash and is left to ferment for approximately 72 hours minimum.

After proper fermentation, the beer is preheated by running it through the heat exchanger. When the beer in the heat exchanger reaches 50 to 64 degrees centigrade, the beer is then routed through the column instead of to the cooking tank. In the meantime, steam has been circulating through the column to bring the bottom of the column to approximately 100 to 105 degrees centigrade and the top to 78 to 80 degrees centigrade. At this point, the beer is allowed to pass through the column and the reflux pump is set into motion. For proper distillation, an attempt is made to maintain 78 to 79 degrees centigrade top temperature in the column with approximately 2 to 2.2 gpm beer flow with the bottom of the column being from 101 to 102 degrees centigrade. The beer preheat temperature should be approximately 54 to 64 degrees centigrade. The four factors which are brought into balance include beer preheat, beer feed rate, reflux rate and steam to the bottom of the column. If these factors are in balance and good beer is used, the column produces 185 to 190 proof alcohol. Some of the ethanol is used for experimental purposes, the rest is stored for future use. The stillage is also used for experimental feeding studies. No CO_2 is reclaimed.

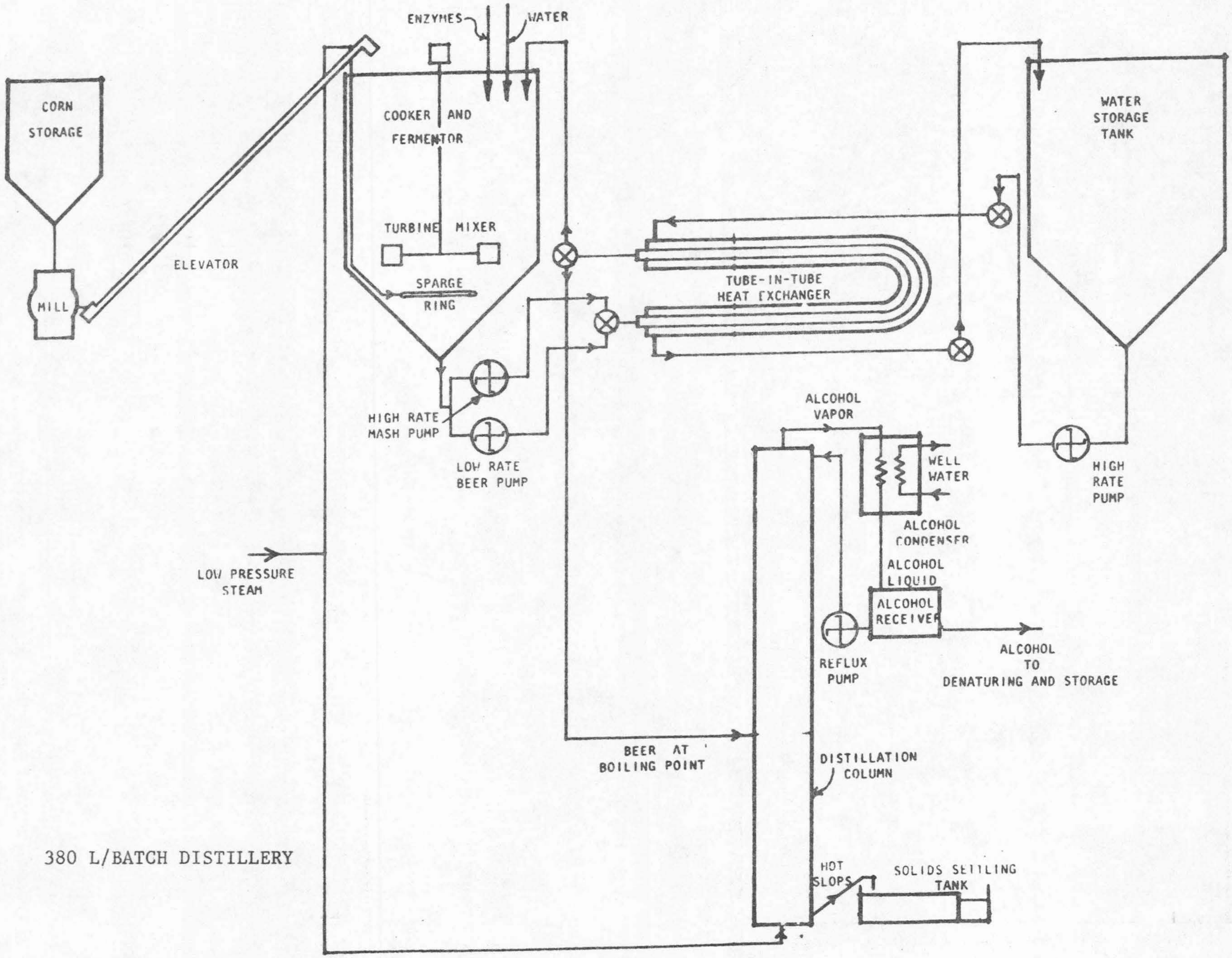
Statement of Profitability

The profitability statement is based on data obtained from the on-site operation and also from a *study by a faculty member in charge of the experiment. The ethanol plant was placed in an old dairy facility using city utilities. Hired manpower was used to operate and monitor the plant. The plant was not run continuously but was operated intermittently for experimental data on ethanol and also to provide stillage for feeding trials. Average data for the trials observed are shown on the profitability statement. The average yield of alcohol was 2.11 gallons per bushel whereas the yield of stillage was computed at 17.25 pounds per bushel on a dried basis.

*Chaplin, Jonathon, Performance Study of a Small Batch-Type Still. Ames, Iowa, Agricultural Engineering Department, Iowa State University, 1981.

PROFITABILITY STATEMENT

	Units Used	Unit Cost	Cost/ Gal.
Expenses			
Operating Labor	24 hrs/batch	$5.00/hr.	$1.42
Materials			
Corn	Batch-40 bu.	3.25/bu.	1.54
Fuel	2990 kg/batch	2.52/454 kg.	.22
Electricity	2.3 kwh.	.06	.14
Water (Under electricity-pumping)			
Supplies Alpha-acid, etc. Beta-yeast			.22
Sub Total			$3.54
Repairs & Maintenance	$50,000	.06	.71
Insurance			
Taxes			
Depreciation			
Capital costs	$50,000	0.1	1.18
Other (Yearly output) 50 batches or 4200 gal. Plant valuation	$50,000		
Transportation			
Sub Total			$1.89
TOTAL EXPENSES			$5.43
Revenue			
Ethanol	2.11 gal/bu.		1.70
Distillers grains	16 lb.	.128/lb.	.97
Ethanol incentives			2.67
TOTAL REVENUE			
NET PROFIT			-$2.76



380 L/BATCH DISTILLERY

Summary

It is obvious that a farm ethanol plant based on the costs involved at this facility is uneconomical. Because of low yearly production, high cost of labor, high utility costs, and high capital costs this is an unprofitable operation. This was an experimental farm ethanol unit from which cost data was obtained. The basic processes of producing alcohol were demonstrated. Data on operating costs under a specific set of conditions was reported. This data is available for comparative analysis with other farm ethanol plants. This plant is different from most "on the farm" plants. The heat source, water supply, capital costs and labor management represent the primary differences.

An important adjunct of this survey was the beef feeding trials conducted by the animal science department by utilizing the stillage from the college still. The results in this study are shown in Appendix A . Important data in this study was the distillers grains which were fed showed a higher value returned than the soybean oil meal fed. Therefore, based on the price of soybean meal which was $250 per ton at the time of the feeding trials, the value of distillers grains produced was approximately 97 cents per gallon of alcohol produced. This, of course, holds true only for the weight of cattle fed which was from 400 to 800 pounds.

SURVEY 2

Size and Type of Operation

This plant has an atmospheric type distillation column with a future capacity of approximately two million gallons per year. Presently, approximately 4,200 gallons of 200 proof alcohol are produced each week. Two 24 inch by 10 foot stripping columns with 1/2 inch holes that are spaced 9 1/2 inches apart giving eight percent open space. A rectifying unit with bubble type spacers are used in a 39 inch diameter by 18 foot high column. From the rectifying column the ethanol is passed through a drying sieve for 200 proof alcohol.

Normal Procedures and Techniques

A 1,000 bushel holding bin is used to store the grain. From this the corn is augered on to a scale and then through a 40 horsepower grinder using a 3/16 inch screen. From the grinder the corn is augered to the cookers. Presently two cookers averaging 2,800 gallons each supply two 11,000 gallon fermentation tanks. After proper fermentation, the whole mash is pumped into the distillation column. The ethanol is stored for later sale and the wet stillage is pumped into a holding tank and then through a rotating screen which divides the solids and solubles. The solids are further augered to a press leaving it about 60 percent moisture. The solubles part is sent to a holding tank and allowed to settle out. The sediment from this solution is sold to farmers as protein along with the solids. The distillers grains are put into a truck, weighed, and delivered to farmers. The specific steps for cooking, fermenting and distillation are as follows:

Add approximately 840 gallons of water to the cooker and start the agitators.

Heat the water to 140 degrees Fahrenheit.

Add 2,000 pounds of ground corn.

Add 20 ounces of Taka-Therm.

Add one scoop of caustic soda which is about two pints.

When heat gets up to 145 degrees, add another 2,000 pounds of ground corn.

Check pH - the range should be from 6 to 6.5.

Heat to 203 - 205 degrees Fahrenheit and hold for 15 minutes.

Turn on the cooling coil, drop the temperature to 195 degrees Fahrenheit.

Add 25 ounces of Taka-Therm, keeping the range from 6 to 6.5 pH.

Hold at 195 degrees for one hour.

Add cooling water to bring to 175 degrees Fahrenheit. This would take about 250 gallons.

Continue cooling to 140 degrees.

Drop pH to 4 - 4.5, adding three quarts of sulfuric acid.

Hold for 1 1/2 hours at 140 degrees Fahrenheit.

Add approximately six pints of diazyme, add cold water to bring temperature to approximately 90 degrees Fahrenheit.

Put in 15 pounds of baker's yeast in the fermenter.

Total yeast 60 pounds.

Takes four cooker batches to fill fermenter.

Continue to monitor the fermentation process to see if the yeast action is progressing properly. The batch is allowed to ferment two or three days depending on the rate of fermentation.

The distillation process follows the normal procedures. Steam is applied to the base of the stripper column to bring it to the proper temperature. This being 229 Fahrenheit or better at the base of the column and decreasing the temperature up the column till a reading of approximately 171 degrees is maintained at the final separation point. The beer fed to this column contains both the grain and water. Stripping of the grain and water is accomplished in the stripping columns. From the bubblecapped rectifying column, the alcohol goes through a molecular sieve to produce 200 proof alcohol. The final product is denatured and held for delivery for the local market. Gasoline at the rate of five gallons per 100 gallons of ethanol is used as a denaturant.

Profitability Statement

The cost of feedstuffs along with labor and fuel costs resulted in a small net profit for this plant. This plant also used gas furnaces which resulted in a fuel cost of approximately 25 cents per gallon. At the time of the survey the price of corn was also high, above the $3.00 level. Labor costs were held at a minimum.

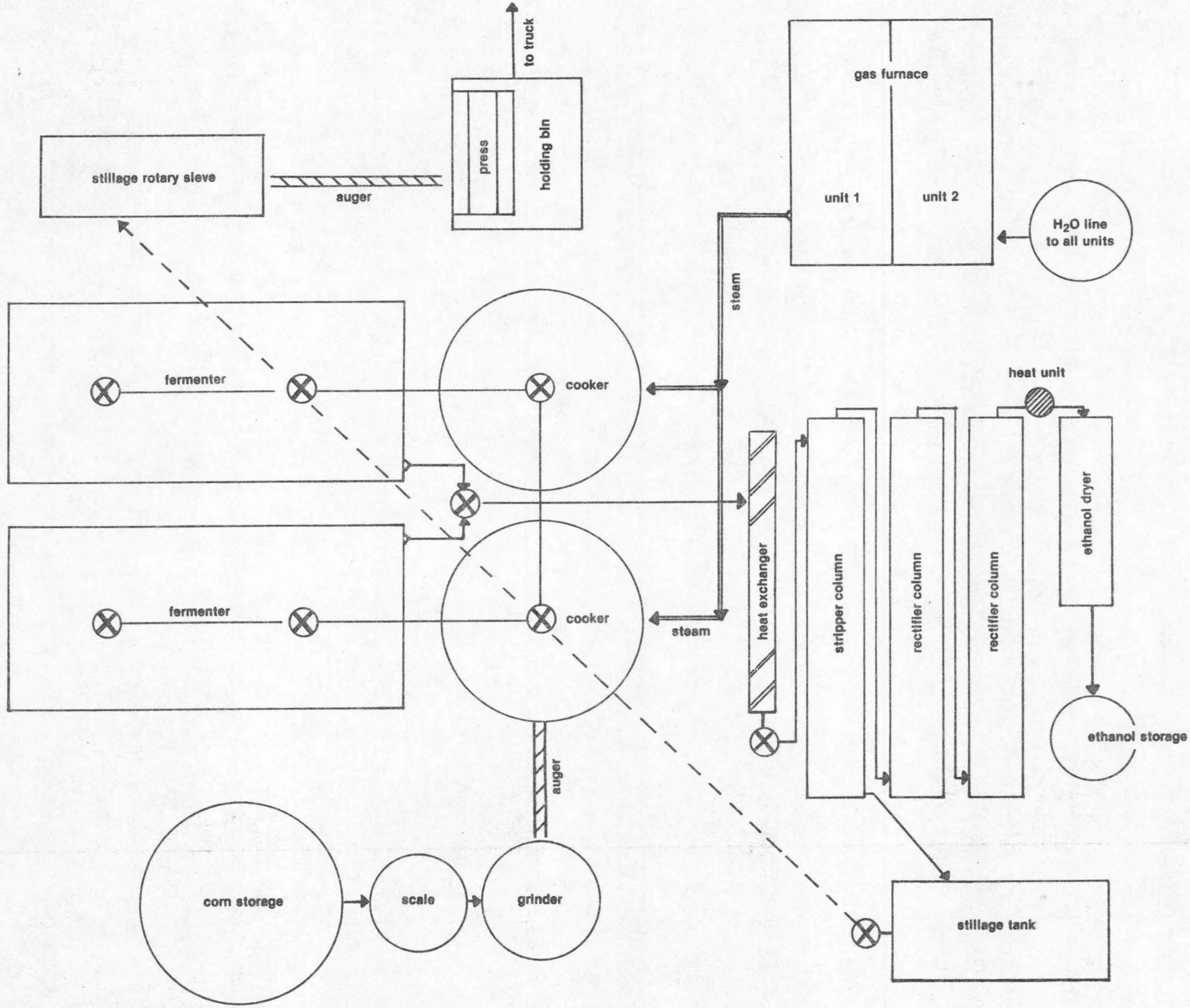
PROFITABILITY STATEMENT

	Units Used	Unit Cost	Cost/ Gal.
Expenses			
Operating Labor	5 hrs.	$5.00	$ .30
Materials			
Corn	35.7 bu.	3.25	1.41
Fuel (gas $4.19/1000 cu ft.)	65,000 Btu.	.0000038/Btu.	.25
Electricity	1.25 kwh/gal.	.04 kwh.	.05
Water	50 gal/bu.	1.20/1000	.03
Supplies			.15
Sub Total			$2.19
Repairs & Maintenance	$200,000	.02	.02
Insurance	$200,000	2.50/100	.02
Taxes	$200,000	3.80	.0038
Depreciation	$200,000	10 yr.	.10
Capital costs			
Other: Plant valuation	$200,000		
Other: Plant Output	$200,000 gal/yr.		
Transportation			.01
Sub Total			$ .15
TOTAL EXPENSES			$2.34
Revenue			
Ethanol		200 proof	1.80
Distillers grains	17 lb.	.08/lb.	.59
Ethanol incentives			
TOTAL REVENUE			$2.39
NET PROFIT			$ .05

Yield alcohol - 2.3 gal/bu.

200,000 gal/year

Each batch produced 82 gal/alcohol


to truck
gas furnace
stillage rotary sieve
auger
press
holding bin
unit 1
unit 2
H_2O line to all units
steam
fermenter
cooker
heat unit
fermenter
cooker
steam
heat exchanger
stripper column
rectifier column
rectifier column
ethanol dryer
ethanol storage
auger
corn storage
scale
grinder
stillage tank

Summary

At the time of the survey, the market outlet for both ethanol and distillers grains was irregular. The plant needed additional financing to support its operation until such time as a regular market could be established and the plant operation stabilized. The outlet for distillers grains was difficult to establish; however, the market for the 200 proof alcohol was quite easily disposed of. It was imperative for this plant to improve its market for distillers grains and ethanol to continue to operate.

SURVEY 3

Size and Type of Operation

This is an atmospheric type distillation facility. The stainless steel column is eight inches in diameter by 32 feet high and packed with ceramic saddles. The column has a capacity of approximately six gallons of ethanol per hour. A 1,500 stainless batch cooker and a fermenter of approximately the same size are used for cooking and fermentation. The solids and liquid are separated previous to distillation with a forty-eight inch basket centrifuge. A large used boiler with approximately 50 horsepower capacity is mounted on a cement base and supplied by a coal stoker. The ethanol is put into holding tanks and the stillage is augured into a wagon to be fed to hogs.

Normal Procedures and Techniques

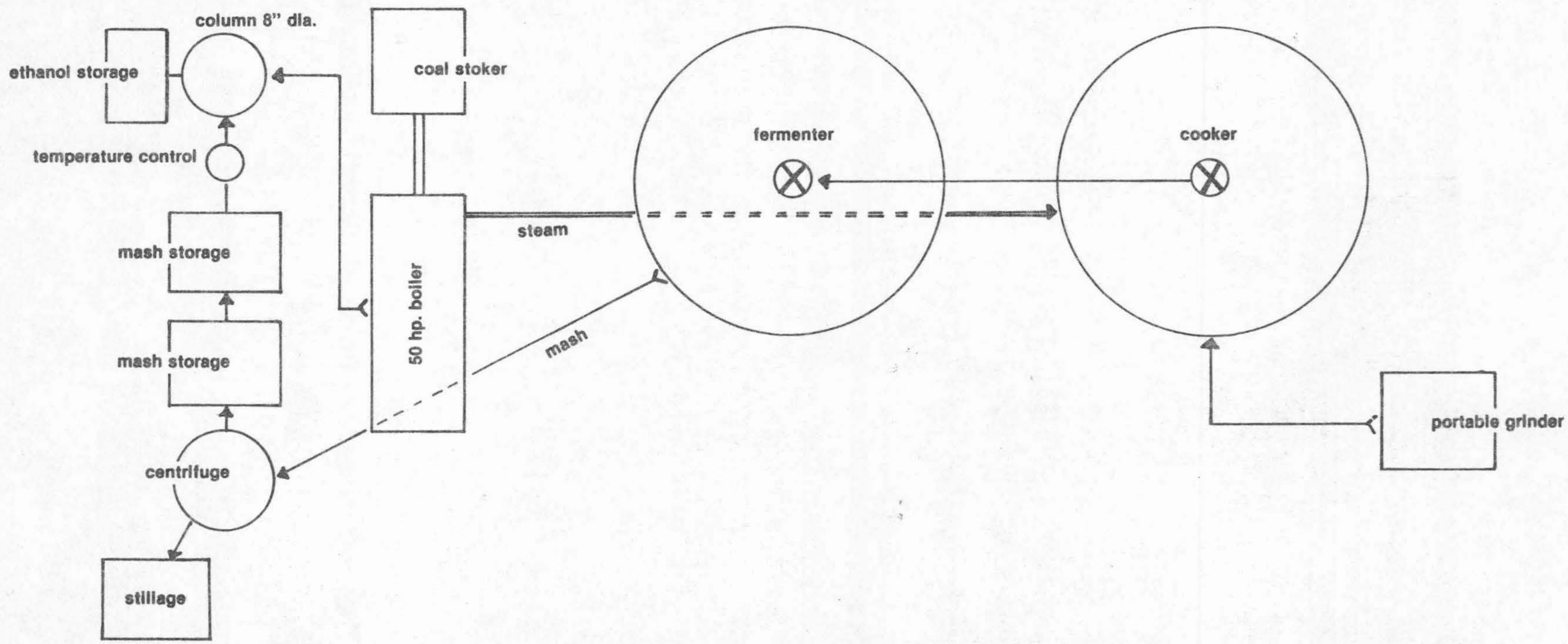
In the preparation process the grain is finely ground with a portable hammermill using a 3/16 inch screen. Approximately 30 gallons of water are used per bushel of corn. Two-thirds of the water is initially added to the corn and the initial enzyme. The mash is brought to approximately 180 degrees Fahrenheit with direct injected steam and held at this temperature for approximately three hours. The mash is then cooled to 140 degrees Fahrenheit by adding water and the second enzyme. This is then allowed to cool overnight to approximately 90 degrees Fahrenheit. Yeast is added and the batch is allowed to ferment for approximately three days.

To prepare for distillation the column is preheated. The column is allowed to establish its equilibrium by putting beer into the column, maintaining the steam pressure, and establishing the reflux temperature. Steam going into the column needs to be held to about 2.5 to 3 pounds pressure. The rate of beer flow is set at approximately 1 gallon per minute and the amount of water reflux is determined by the proof of the product. The beer is preheated in the column. The ethanol is placed in storage for tractor and vehicle use and the stillage is put in a wagon to be used later for hog feed.

PROFITABILITY STATEMENT

	Units Used	Unit Cost	Cost/ Gal.
Expenses			
Operating Labor	8	8	$ .78
Materials			
Corn	37.5/bu.	3.00	1.36
Fuel	4.7 lb/gal.	.0135/lb.	.06
Electricity	1.1 kwh/gal.	.06	.06
Water			
Supplies — Alpha A, acid; Beta A			.08
Sub Total			$2.34
Repairs & Maintenance	$30,000	.0025	.01
Insurance	$30,000	$2.50/1000	.01
Taxes	$30,000	1.5 mil.	.01
Depreciation	$30,000	30 yr.	.23
Capital costs			
Other — Plant Valuation; Production	$30,000; 4,200 gal/yr.		
Transportation		$75/yr.	.01
Sub Total			$ .27
TOTAL EXPENSES			$2.61
Revenue			
Ethanol	2.2 gal/bu.	190P	1.50
Distillers grains	20.5 lb/bu.	.10/lb.	1.00
Ethanol incentives			.30
TOTAL REVENUE			$2.80
NET PROFIT			$ .19

Each batch 82.5 gal. alcohol


column 8" dia.
ethanol storage
temperature control
mash storage
mash storage
centrifuge
stillage
coal stoker
50 hp. boiler
steam
mash
fermenter
cooker
portable grinder

Summary

This is an efficient farm ethanol operation. Beer processing and mash handling are noteworthy because of the use of a centrifuge and early separation of mash from the beer. Mash retrieval is at 20.5 pounds per bushel. The gallons of ethanol per bushel of corn averaged 2.2. The use of a coal stoker as a heat source is unique to the farm stills in this area. This has been a labor saving source of heat. At this point in time, the owner decided he would like to increase the size of the operation to increase labor productivity. However, additional financing is high and difficult to obtain presently. Since a market for the ethanol has not been established and the hog market has fallen drastically, the operation has been curtailed until funds are available.

SURVEY 4

Size and Type of Operation

This is an atmospheric type distillation facility with two 12 inch columns, twenty feet high with a condensor and preheater located between the two columns. The stripper column has plates with 1/2 inch holes and downcomers with cups. The rectifying column has plates with 3/16 inch holes, these plates being spaced 10 inches apart. The two columns are connected by a vapor column coming from the top of the stripper unit to the bottom of the rectifying unit. A reflux system is also used to control the flow and proof desired. Meters and sensors are also installed at the appropriate places to regulate the system. The heat is provided by a large used boiler with a capacity of approximately 40 horsepower. The source of heat is ground corn cobs which are automatically augured into the furnace. A large 4,000 gallon vertical tank is used for a fermenter. The corn is taken from an outside bin and ground by a portable unit using a 3/16 inch screen. The alcohol is stored in a 3,000 gallon tank. After distillation, the stillage is pumped into a large tank for feeding to livestock. Whole mash is put into the column. The column has a capacity to produce 20 gallons of alcohol per hour.

Normal Procedures and Techniques

Presently the facility is operated at minimum capacity for experience as well as determined data for the system.

The steps are as follows:

1. Put approximately 300 gallons of water in the cooker.
2. Adjust the pH to approximately 6.5.
3. Heat the water to approximately 208 degrees Fahrenheit.
4. Slowly add 20 bushels of finely ground corn.
5. Reduce temperature to 195 degrees.
6. Add 10 ounces of Taka-Therm.
7. Mix for an hour and a half.
8. Cool to 142 degrees Fahrenheit and add 2 1/2 pints of sulfuric acid to bring the ph to 4 to 4.5.
9. Add two pints of diazyme.
10. Mix for an hour and a half.
11. Cool to 95 degrees, add five pounds of yeast.
12. Adjust pH to 7 for distillation.
13. Distill.

In the distillation process the column is first heated with steam and the beer is added gradually. The alcohol reflux is added gradually to help establish equilibrium in the column. The temperature gauges are monitored to maintain the stripper columns bottom at 212 degrees, the middle of the column at about 195 degrees and the top of the rectifying column at about 174 degrees Fahrenheit. Ethanol is stored in the storage tanks and the stillage is stored in stillage tanks. The ethanol is used on the farm in cars and trucks and the stillage is fed to livestock.

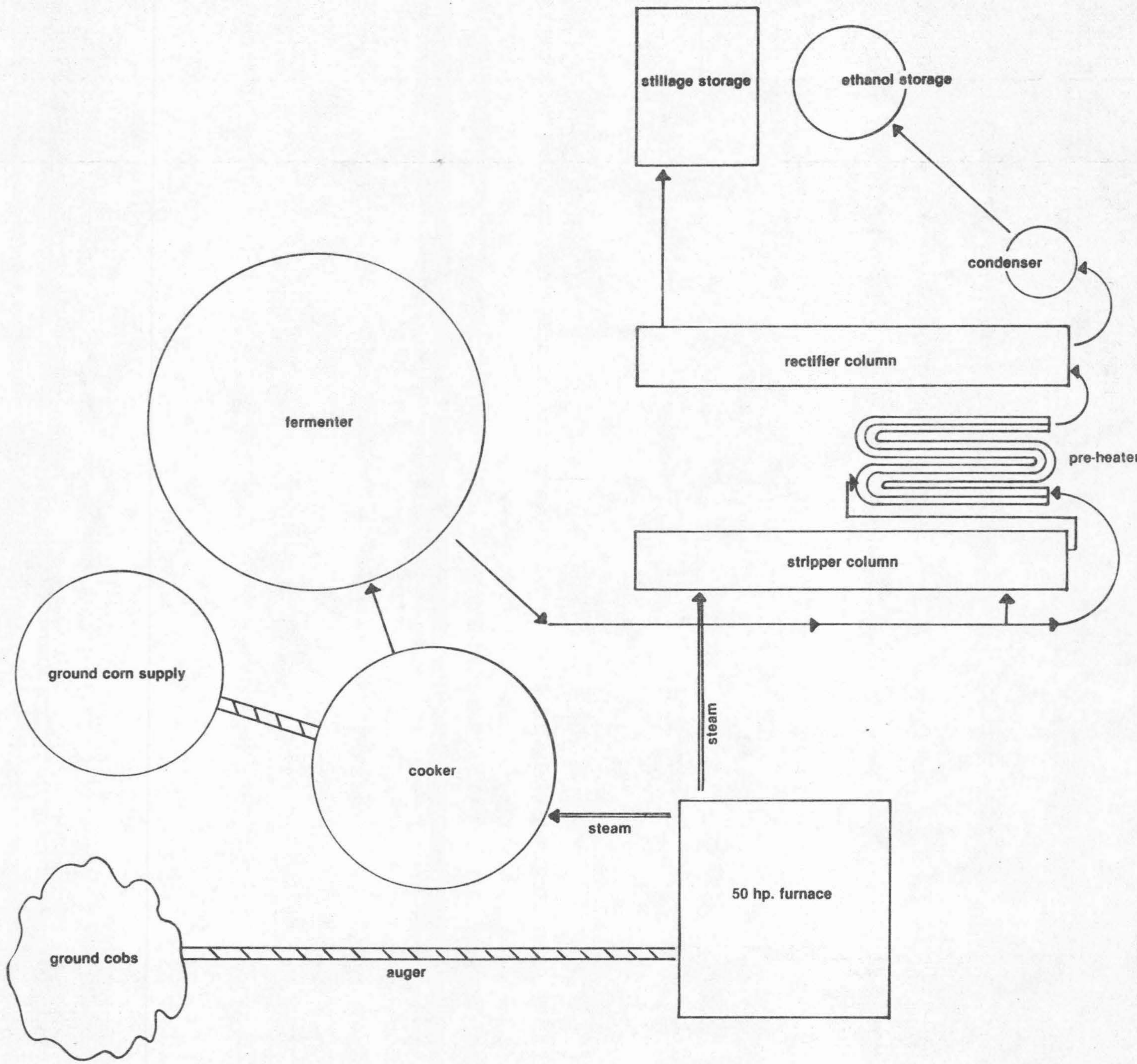
Profitability Statement

The enterprise showed a profit even though at the time of the survey corn was apparently high. Cost of supplies was also high compared to some other operations. Fuel costs were kept to a minimum by the use of corn cobs. An important factor in the costs in this plant was the fact that here we have a production capacity of 20 gallons per hour in a plant that was primarily developed and constructed by the owner, thereby cutting down on the initial cost. The ethanol is used on the farm and also sold for further upgrade. The distillers grains are used by the farmer and also sold to farmers in the vicinity.

PROFITABILITY STATEMENT

	Units Used	Unit Cost	Cost/ Gal.
Expenses			
Operating Labor	4	$4.00	$ .40
Materials			
Corn	20 bu.	2.55	1.27
Fuel	900 lb/batch	.000714	.02
Electricity	35 kwh/batch	.016 kwh	.05
Water	under electricity		
Supplies Alpha, Beta, yeast, chemicals			.15
Sub Total			$1.89
Repairs & Maintenance	50,000 gal.	$2,500	.05
Insurance	50,000 gal.	$500	.01
Taxes			
Depreciation	$20,000	$2,000/yr.	.04
Capital costs			
Other Plant Valuation	$20,000		
Transportation	50,000 gal.	$500	.01
Sub Total			$ .11
TOTAL EXPENSES			$2.00
Revenue			
Ethanol			1.30
Distillers grains			.64
Ethanol incentives			.30
TOTAL REVENUE			$2.24
NET PROFIT			$ .24

2 gal/bu $20,000 valuation
36 gal/batch 50,000 gal/yr.


stillage storage
ethanol storage
condenser
rectifier column
pre-heater
fermenter
stripper column
ground corn supply
steam
cooker
steam
50 hp. furnace
ground cobs
auger

Summary

This is a good example of vertical integration on the farm. The corn and cobs are both utilized in the production of ethanol which is both used on the farm and sold. The distillers grains are used on the farm and also marketed. An important factor in this operation is the capacity of the plant for production. With maximum of output, both the variable and fixed costs will be held to a minimum.

SURVEY 5

Size and Type of Operation

This is an atmospheric type ethanol plant. The column is an eight inch by 30 foot stainless steel structure with a capacity of seven to ten gallons of ethanol per hour. The column contains approximately 28 plates spaced seven inches apart. The plates have one inch bubble cap openings giving an eight percent open space. Each plate has a downcomer extending into a cup in the lower plate. The bottom four feet of the column has a steam jacket surrounding the tube. The live steam comes into the jacket for distillation but not into the column. The beer enters into the column at about the 20 foot level. A reflux as well as a heat exchange unit is included in the distillation system. Temperature gauges are placed at the top, center and bottom of the column. The temperature is maintained in the column by a thick insulation material. The beer is preheated before entering the column. For distillation, the bottom temperature is maintained at about 215 degrees Fahrenheit, the middle temperature about 195 degree Fahrenheit, and the top temperature about 174 degrees Fahrenheit. Steam is provided by a 20 horsepower high pressure steam furnace. Instead of a gas base a fire box was constructed to burn cobs, wood or coal. Presently cobs are used. The cobs are conveyed to the furnace from a supply outside the building. The cooker is a 750 gallon stainless steel dairy pasteurizing tank with a cooling and heating coil and a water agitation system. Two fifteen hundred gallon vertical fiberglass tanks are used for fermentation. One six hundred gallon stainless steel tank is used to hold the spent beer and a 1,800 gallon plastic tank is used to hold the stillage. The beer is run through a vibrating screen previous to distillation. The distillers grains are stored in the stillage tank and later fed to young cattle. The ethanol is stored for future use on the farm. The corn is prepared with a farm grinder using a 3/32 mesh screen.

Normal Procedures and Techniques

1. Heat 300 gallons of water to 190 degrees Fahrenheit.
2. Slowly add 20 bushels of ground corn, agitate vigorously while adding the corn.
3. Add Taka-Therm.
4. Hold at 190 degrees for approximately one hour.
5. Add 300 gallons of cold water cooling to 140 degrees.
6. Adjust pH to 4 to 4.5.
7. Add diazyme L-100.
8. Cool to 90 degrees Fahrenheit.
9. Adjust pH to 5 to 5.2.
10. Add Yeast.
11. Ferment for 36 to 72 hours.
12. Distill.

In the distillation the column is first brought up to the needed temperature and then the beer added to bring the process into equilibrium. The main controls to watch are the steam pressure and the column temperatures. The ethanol is tested for proof and regulated by the reflux rate and the rate of beer flow.

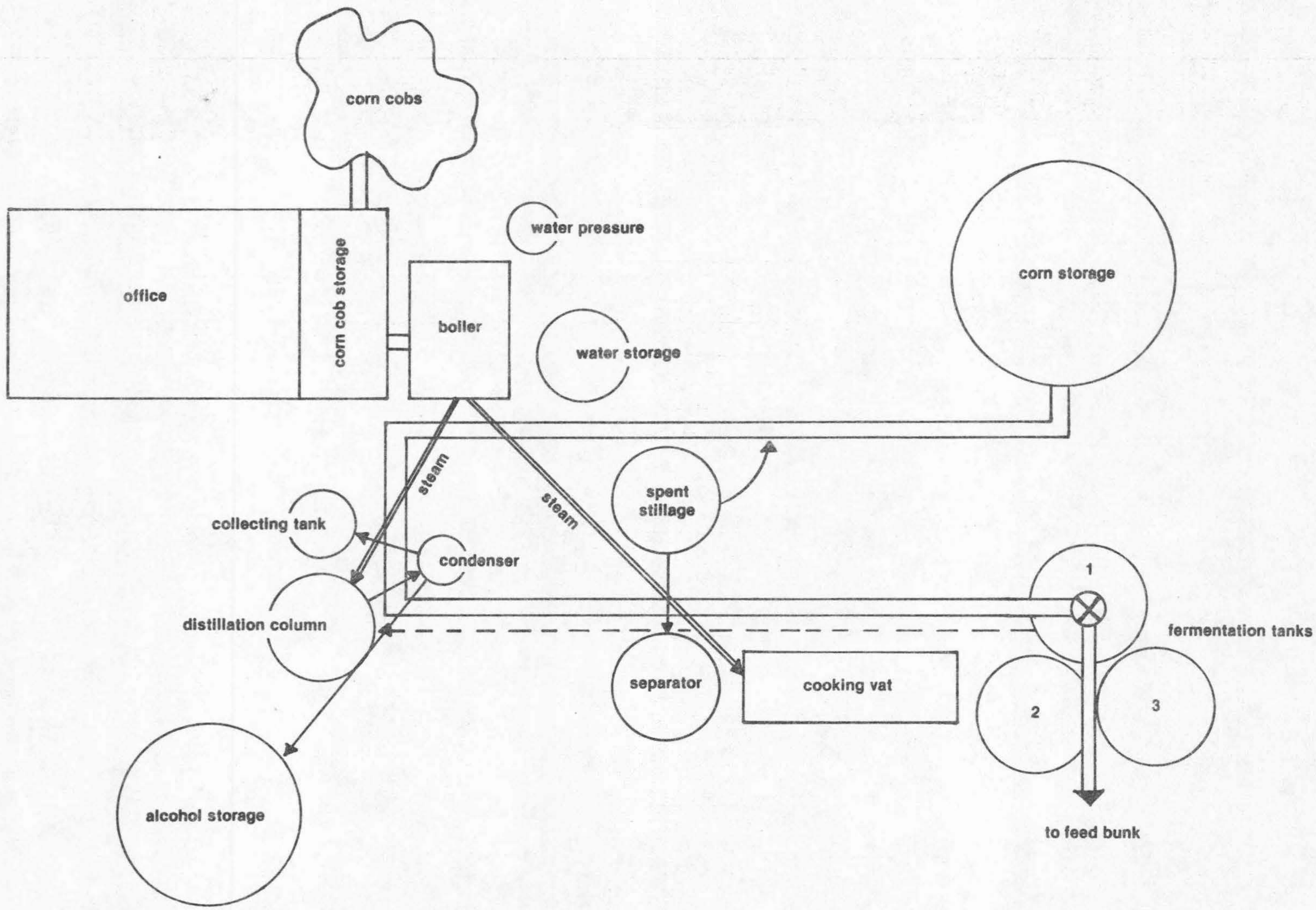
Profitability Statement

This is an efficient farm ethanol operation. The plant will consistently produce over 2.2 gallons of 180 proof alcohol per bushel of corn. Operation costs will decrease as more automation is used and the operators become more experienced in utilizing the proper techniques and procedures. The low price of corn is presently a plus factor for costs of production. Supply costs should be reduced as more proficiency is developed in plant operation. The use of corn cobs for energy has proven to work well in this type of furnace and is an economical source of energy. Taxes, insurance, and maintenance are at a minimum. At present prices, the operation shows a profit as shown on the following profitability statement.

PROFITABILITY STATEMENT

	Units Used	Unit Cost	Cost/ Gal.
Expenses			
Operating Labor	10 hrs.	$4.00/hr.	$ .40
Materials			
Corn	20 bu.	2.34/bu.	.93
Fuel	1500 lb/100 gal.	.000714.1b.	.01
Electricity	63.58/kwh	.07/kwh	.04
Water	37 gal/bu.	1.50	.02
Supplies Alph, Beta, yeast, chemicals			.12
Sub Total			$1.52
Repairs & Maintenance	$36,750	.025	.03
Insurance	$4.80/1000		.05
Taxes			
Depreciation	$36,750	12 yrs.	.07
Capital costs			
Other Plant Valuation	$36,750		
Transportation	36,000gal/yr.	$500	.01
Sub Total			$ .16
TOTAL EXPENSES			$1.68
Revenue			
Ethanol			1.26
Distillers grains			.68
Ethanol incentives			.30
TOTAL REVENUE			$2.24
NET PROFIT			$ .56

2.5 gal alcohol/bu. corn
36,000 gal/yr.


corn cobs
office
corn cob storage
boiler
water pressure
water storage
corn storage
steam
steam
spent stillage
collecting tank
condenser
distillation column
1
fermentation tanks
separator
cooking vat
2
3
alcohol storage
to feed bunk

Summary

The profitability of this operation is primarily related to three variables: the price of corn, the price of ethanol and the price of cattle. The low price of corn "$2.00 per bushel" is a big factor in the low cost of ethanol production. As the price of corn increases profitability will decrease, however, the value of the stillage will also increase which will, in part, compensate for the increase in corn prices. A noteworthy factor in this operation is the feeding of wet stillage to 400 pound feeder calves. The stillage is used as a primary source of protein in the ration.

The value of ethanol per gallon will determine from the current price of gasoline and subtracting that value by 1/6 will compensate for value as a fuel on the farm. As better carburetors are developed, more efficient ethanol utilization can be expected along with higher returns. While the cost of supplies are relatively high in this operation, a reduction of cost is expected as the procedure is refined.

The biggest innovation of this plant is the furnace using corn cobs. The cost of fuel is low and will become lower as production becomes more continuous. This ethanol plant is an excellent example of a good family farm ethanol operation. Some of the ethanol is sold to another alcohol producer and some is used in trucks and tractors on the farm.

SURVEY 6

Size and Type of Operation

This is an atmospheric type ethanol plant. The column is a 12 inch by 24 foot steel distillation structure with a capacity of 15 to 20 gallons of ethanol per hour. The 24-foot column contains 33 plates. The bottom nine provides an eight percent opening with half-inch holes and measure nine inches between plates. Each plate has a downcomer and a cup. The downcomers are two inches in diameter and raised three-quarters inch above the surface of the plate and descend within three-quarters inch of the lower plate. The downcomer extends downward to a liquid seal cup with a 2 1/2 inch diameter. The bottom unit is the stripper part of the column. The upper one-half is a rectifying portion. It contains 20 plates at six-inch centers from top to bottom. These plates contain eight percent open space. The holes are three-eighths in diameter Three temperature gauges are placed at the top, middle and bottom of the column. The ethanol vapor is collected in a condenser for further reflux or storage. The mash enters just at the top of the stripper plates after passing through a copper pipe coiled around the upper part of the column for preheating the beer.

The steam is provided by a 24 horsepower furnace mounted on a fire box that can utilize used motor oil to minimize the cost of fuel. The cooker is a used 750 gallon stainless steel dairy pasteurizing tank. Two fermenting tanks are used. One a 600 gallon stainless steel tank and the other a 500 gallon steel barrel placed vertically on steel supports. The ethanol is stored in steel tanks. The stillage is stored in a concrete area after passing through a rotating screen separator. The solids go to stillage and the liquid is stored in auxiliary tanks for distillation. The corn is ground with a portable farm grinder using a 3/16 mesh screen. In the distillation process, the column is first heated with live steam and then the beer slowly added to bring the column into equilibrium. The beer is added at the rate of approximately four gallons per minute. The bottom temperature of the column is maintained at about 210 degrees, the middle at about 195 and the top at about 174 degrees Fahrenheit. The pressure of the steam is maintained at about five pounds. The proof of the alcohol is maintained by the reflux rate as well as the beer flow rate.

Normal Procedures and Techniques

1. Heat 300 gallons of water to 190 degrees Fahrenheit.
2. Add 20 bushels of ground corn slowly to the water, agitate vigorously.
3. Add Taka-Therm.
4. Add 300 gallons of water and heat for one hour. Hold at 190 degrees Fahrenheit.
5. Cool to 140 degrees Fahrenheit. Adjust pH to 4 - 4.5.
6. Add diazyme L-100.
7. Cool to 90 degrees Fahrenheit.
8. Adjust pH to 5 - 5.2.
9. Add yeast at the rate of 2 to 4 pounds per thousand gallons of mash.
10. Allow to ferment from 24 to 36 hours.
11. Distill

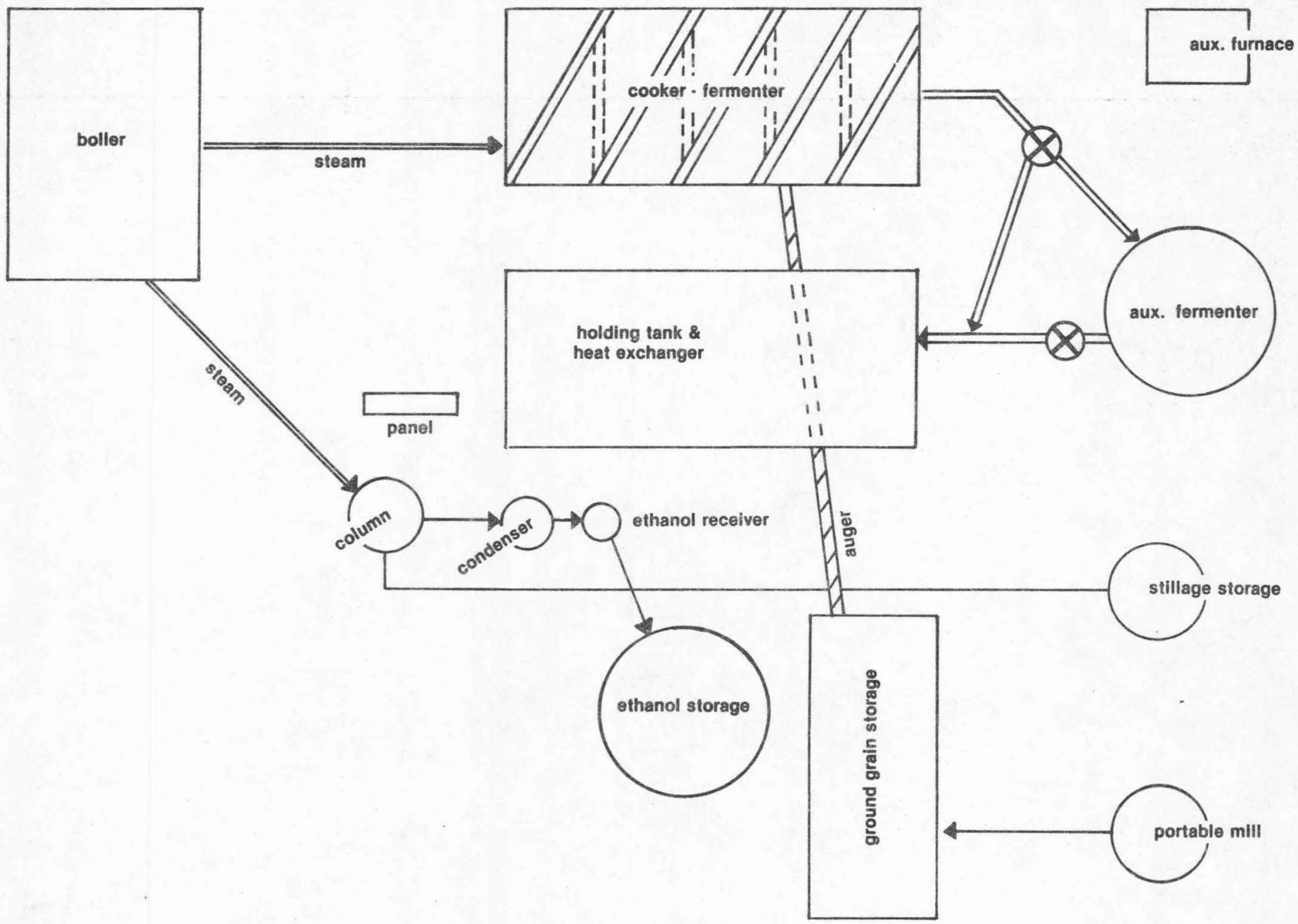
Profitability Statement

The low cost of corn and the favorable distillers grains return show a profitable statement. This could easily be affected adversely by an increase in grain prices. Fuel costs were held down by the use of used motor oil. Supply costs are high because of buying the enzymes in small quantities. This can be helped by cooperative purchasing among farmers producing alcohol. Fixed costs of insurance, taxes, and repairs are low because plant capitalization is low.

PROFITABILITY STATEMENT

	Units Used	Unit Cost	Cost/ Gal.
Expenses			
Operating Labor	8	$4.00	$ .88
Materials			
Corn	20	$2.25	1.25
Fuel	30 gal.	.05 gal.	.04
Electricity	1 kwh/gal.	.05 kwh	.05
Water			
Supplies			.12
Sub Total			$ 2.34
Repairs & Maintenance	$20,000	.025	.05
Insurance	2.50/1000		.005
Taxes (taxed on farm)			
Depreciation	$20,000	20 yrs.	.10
Capital costs			
Other Plant Valuation	$20,000		
Transportation		$100	.01
Sub Total			.16
TOTAL EXPENSES			$ 2.50
Revenue			
Ethanol	1.8 gal/bu.	180 proof	1.30
Distillers grains	16 lb/bu.	.12/lb.	.96
Ethanol incentives			.30
TOTAL REVENUE			$ 2.56
NET PROFIT			$ .06

36 gal/batch
10,000 gal./yr.


boiler
steam
cooker · fermenter
aux. furnace
holding tank &
heat exchanger
aux. fermenter
steam
panel
column
condenser
ethanol receiver
auger
stillage storage
ethanol storage
ground grain storage
portable mill

Summary

One of the problems encountered with this plant was the erratic proof of ethanol produced by the column. This was due in part to the height of the column and the fluctuation in steam pressure. Better automatic controls on the column would help to stabilize the proof content. One of the innovations of this plant was the conversion of the 24 horsepower gas furnace to a used motor oil furnace. This adaptation worked well because there were sufficient controls to start and stop the fire. Most of the oil was obtained free by picking it up.

By using the ethanol on the farm in trucks and tractors and also feeding distillers grains to livestock, the highest going price was realized for the products produced. This plant can become more efficient as more automation is utilized and the price of the feedstuffs held at a minimum. Doubling the output per year would increase the margin of profit.

SURVEY 7

Size and Type of Operation

This is a farmer-owned atmospheric type ethanol plant. A number of the 40 farm-owners helped build the plant to keep construction costs down. The facility is housed in a building approximately 50 by 35 feet. Presently there are nine employees used to operate the plant on a 24-hour basis. The plant has been enlarged by adding more cooking and fermenting capacity since it was started two years ago.

Presently the corn is ground using a 1/8 inch screen and then delivered to the plant by a local elevator. In time, the corn will be stored and ground at the plantsite. The ground corn is augured into one of the two 9,000 gallon cookers. After cooking, the material is pumped into one of the four 30,000 gallon fermenting tanks. After fermenting, the mash is pumped through heat exchangers to the stripping column which is 24 inches by 17 feet. The stripper column has plates spaced about a foot apart and containing half inch holes and downcomers. From the stripper column, the liquid goes through two rectifying columns which are 20 inches by 17 feet. These columns contain plates with smaller holes and downcomers with cups. The temperature at the base of the stripper column is held at about 217 degrees Fahrenheit and the top of the rectifying column at 173 degrees Fahrenheit. The ethanol vapor is passed through a condensor and on to the dehydration column to produce 200 proof ethanol.

The steam is provided by two gas burning boilers, one a 35 horsepower and the other a 125 horsepower unit. The stillage from the stripper column is run through a sieve and then elevated to trucks for distribution. Presently, the CO_2 is not processed. The 200 proof ethanol is put in storage tanks having a capacity of 45,000 gallons.

Normal Procedures and Techniques

Since Miles enzymes were used the following procedure as recommended by Miles was used:

1. Heat 22 gallons of water per cwt. (15.0% moisture) of milled grain (16 mesh) to $190^{\circ}F$.
2. Add 1.46 ounces of lime per cwt. of milled grain. This will supply the necessary calcium in order to stablize the enzyme at high temperatures. The pH will also be raised.
3. With good agitation, add one-fourth to one-third of the milled grain. Be sure to maintain a temperature of $190^{\circ}F$. $+^{\circ}F$. The amount of grain which you will be able to add at this point will depend directly on the rate of agitation and the rate of grain addition. If large dough balls appear, slow the grain addition until at least one-fourth of the grain is in the cooker.
4. Adjust the grain mash to pH 6.2-6.4 using sulfuric acid, or hydrochloric acid to lower and lime or caustic soda to raise.

5. Add Taka-Therm at 0.1% based on the dry starch content (DSB) of the milled grain. For each 100 lb. corn use .065 to .07 lb. Taka-Therm.
6. With continuous agitation, add the remainder of the milled grain. Maintain a temperature of 190°F.±5°F.
7. Hold for 30 minutes at 190°F.±F.
8. Heat to 210-212°F. and hold for 30 minutes.
9. Cool to 190°F.±5°F. by the use of cooling coils, a heat exchanger, vacuum, or the addition of cold water. If cold water is used, do not add more than 14.5 gallons of water per cwt. of milled grain.
10. Check the pH and adjust to 6.0-6.5 if necessary.
11. Add Taka-Therm at 0.1% based on the dry starch content (DSB) of the milled grain.
12. Hold for another 30 minutes or until you get a negative starch iodine test (12-16DE).
13. Cool to 140°F. by the use of cooling coils, a heat exchanger, vacuum, or by the addition of cold water. If cold water is used, make sure the total amount of cold water added in Step 9 and at this step does not exceed 14.5 gallons per cwt.
14. Adjust to pH 4.0-4.5 using sulfuric, hydrochloric or phosphoric acid.
15. Add Diazyme at a level of 100 Diazyme Units per cwt. starch.
16. Hold for two hours at 140°F.

17. Cool the mash to 82-86°F. and add yeast for fermentation.

18. Add dry yeast at rate of 2.4 lb/1000 gallon mash.

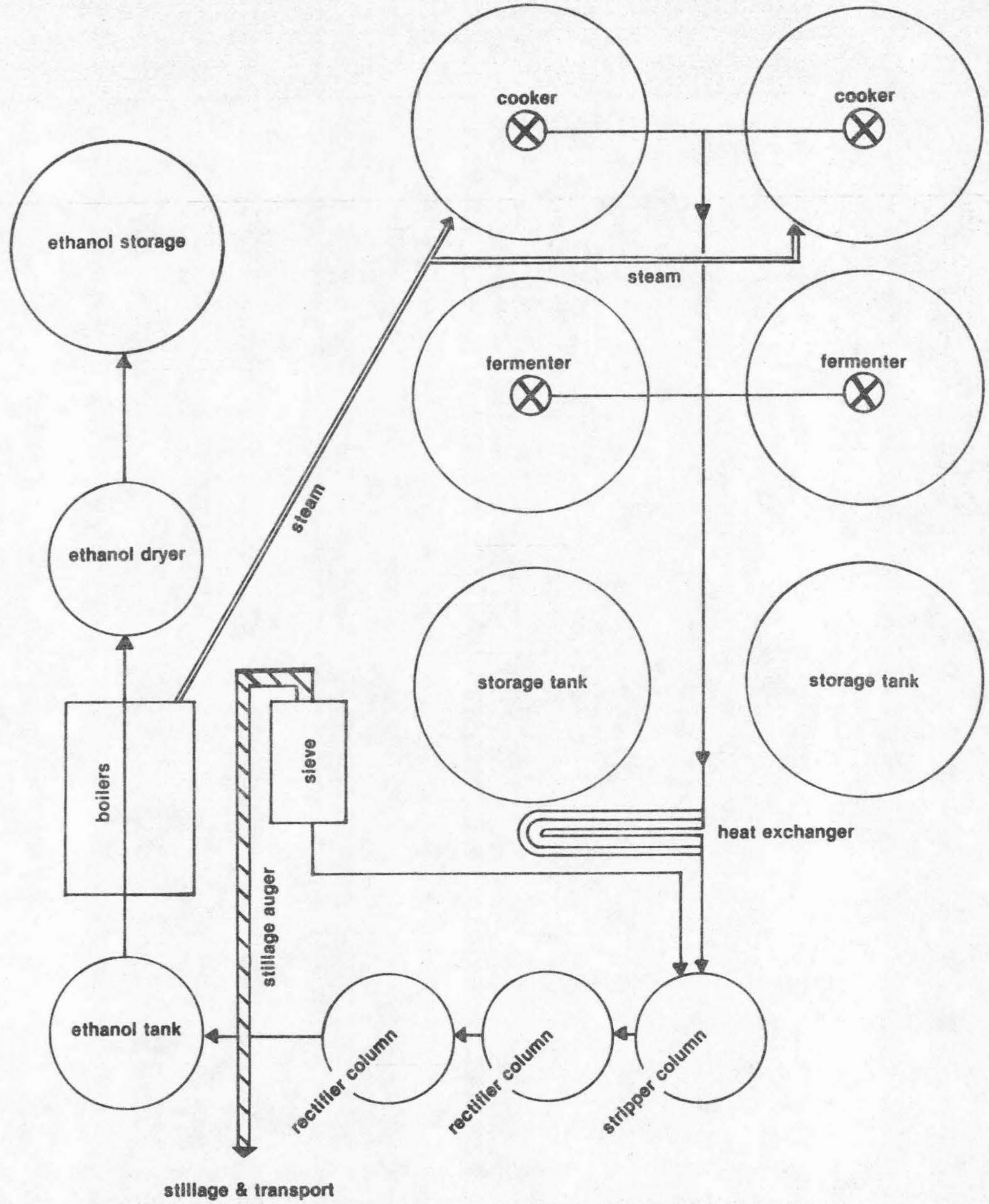
Profitability Statement

The low cost of corn, labor efficiency and the volumne of ethanol produced are major factors resulting in a favorable profit statement. As the price of corn increases the net profit will tend to decrease. This, however, will be partially offset by the increased value of distillers grains. The use of natural gas resulted in relatively higher costs for heat.

PROFITABILITY STATEMENT

		Units Used	Unit Cost	Cost/ Gal.
Expenses				
Operating Labor		24 hrs.	$5.00/hr.	$ .24
Materials				
Corn	1500 bu./day	2.35 gal/bu.	2.25	.95
Fuel		45,000 gal/mo.	$4504/mo.	.10
Electricity		1,502/gal.	.04 kwh	.04
Water		11,000 gal.	.85/1000 gal.	.006
Supplies		See procedure		.065
Sub Total				$1.40
Repairs & Maintenance		$650,000	.02	.03
Insurance		450,000 gal.	$9,000/yr.	.02
Taxes			$ 692	.0015
Depreciation		$650,000	10 yr.	.14
Capital costs				
Other (Loan)	Plant Valuation	$650,000 $ 8,500/mo.		.19
Transportation				
Sub Total				.38
TOTAL EXPENSES				$1.78
Revenue				
Ethanol				1.70
Distillers grains				.56
Ethanol incentives				
TOTAL REVENUE				$2.26
NET PROFIT				$ .48

$2.35 gal/bu.
1,500 gal/day
450,000/yr.


cooker
cooker
ethanol storage
steam
fermenter
fermenter
steam
ethanol dryer
storage tank
storage tank
boilers
sieve
heat exchanger
stillage auger
ethanol tank
rectifier column
rectifier column
stripper column
stillage & transport

Summary

This is a good example of a profitable farmer-owned plant. By initially helping to construct the plant, the owners are aware of how and what such an operation can and should do. With continuing good management, the plant can become even more efficient. Presently, there is a greater demand for the 200 proof ethanol than can be locally produced. The market for distillers grains has not become well established, however, a number of options for feed utilization are being considered. This plant is an excellent example of what a cooperative effort can do in the production and utilization of ethanol in the middle-west.

SURVEY 8

Size and Type of Operation

This is an atmospheric type ethanol facility. The corp- eration is financed by farmers utilizing four employees, two of which manage the plant. The low initial cost of the invest- ment as well as the low cost of operation is due primarily to the technical and innovative skills of the managers. The 104 by 50 foot building housing the equipment is situated on a five acre plot of ground next to a good hard surfaced highway.

Corn is temporarily stored in an 800 bushel steel bin. For processing, the corn is ground using 1/8 inch screen, weighed and augured to one of four 6,000 gallon cooker-fermenters. Each tank is provided with the necessary stirring, hearing controls and instrumentation to monitor and produce the mash. After the batch has been properly fermented, the mash is pumped from the cooker-fermenter to one of two distillation units. In one unit, each of the three columns is 14 inches in diameter by 17 feet high and in the other unit the columns are 10 inches in diameter by 13 feet high. In each of the units, the first column is a stripper column having 1/2 inch openings to accommodate better stillage passage. The ethanol vapor is condensed and pumped into various tanks totaling 7,000 gallons. The plant presently has the cap- ability of producing 1,200 gallons of 185 proof alcohol per day. No CO_2 is processed.

The stillage is augured through a pressure sieve and then through a dehydration drum. The dry distillers grains are sacked and stored for distribution.

The plant is powered by electric motors ranging from 3/4 to 10 horsepower. Metering controls, safety valves, exchangers, pipe, instrumentation and insulation are used as needed. Steam heat is produced by 30 horsepower high pressure biomass and waste boiler and an auxiliary biomass-waste furnace for stillage dehydration. Used oil and other wastes such as corn cobs and corn stocks are used in the furnace. Cooling water is provided by a 12 million gallon reservoir.

Normal Procedures and Techniques

Presently ALLTECH enzymes and yeast are used. The fermentation process is that recommended by ALLTECH.

1. The corn is weighed and ground using a 1/8 inch screen. Each batch is about 250 bushel.
2. Water is put into the cooker-fermenter and heated to 140 degrees Fahrenheit using about 18 gallons per bushel of corn.
3. Check pH, keep between 6.5-7.
4. Add corn slowly to water which is 140 degrees Fahrenheit.
5. Add alpha-enzyme at the rate of approximately six-tenths pounds per thousand gallons of mash.
6. Bring to 212 degrees Fahrenheit and cook for one hour.

7. Add additional water to bring temperature down to 165 - 175 degrees Fahrenheit to a total of water per bushel of corn.
8. Put in four-tenths pounds of alpha-enzyme per thousand gallons of mash.
9. Cool to 97 degrees Fahrenheit and add the beta-enzyme at approximately six pounds per thousand gallons.
10. Cool to 88 - 90 degrees Fahrenheit then add yeast at the rate of 10 pounds per batch.
11. Ferment for approximately 48 hours.

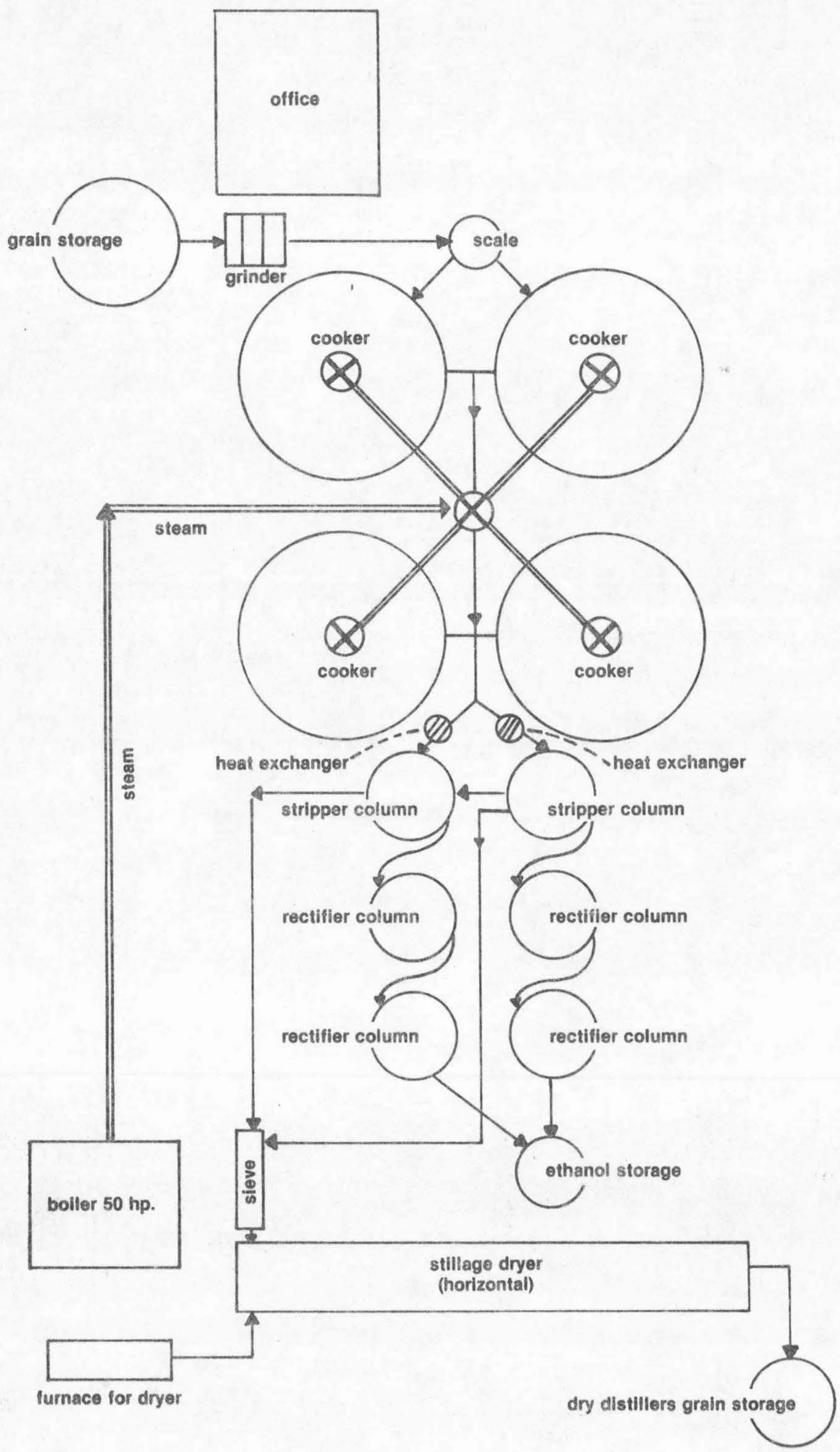
Profitability Statement

Low grain prices, low labor costs, low fuel costs, and high production per day were the primary factors accounting for the favorable profitability statement. The cost of supplies per gallon should decrease as the operation becomes more stabilized. The loan costs can also be decreased as the loan is paid off. As the market becomes better established the margins for ethanol and distillers grains should increase. Drying ethanol could prove to be a means of increasing the selling price of ethanol at this time. The drying of distillers grains produces a product which is easier to handle than wet, does not spoil, and is a marketable product.

PROFITABILITY STATEMENT

	Units Used	Unit Cost	Cost/ Gal.
Expenses			
Operating Labor	48 hrs.	$3.60	$ .14
Materials			
Corn	2.3 gal alcohol/bu.	2.35	1.02
Fuel	waste lumber and paper		.01
Electricity	1 kwh/gal.	.05	.05
Water		$70/mo.	.002
Supplies	All tech		.135
Sub Total			$1.36
Repairs & Maintenance	36,000 gal. alcohol	$300/mo.	.01
Insurance	438,000 gal/yr.	$5,000	.01
Taxes	$250,000	1.5 M.	.0008
Depreciation	$250,000	10 yrs.	.057
Capital costs			
Other Plant Valuation (Loan)	$250,000 36,000 gal.	$2,600/mo.	.07
Transportation	36,000 gal.	$ 600	.02
Sub Total			.17
TOTAL EXPENSES			$1.53
Revenue			
Ethanol			1.33
Distillers grains	121b/bu.	.075	.45
Ethanol incentives			1.78
TOTAL REVENUE			$ .25
NET PROFIT			

2.7 gal/bu.
Based on 1,200gal/day or
36,000 gal/mo.


office
grain storage
grinder
scale
cooker
cooker
steam
cooker
cooker
steam
heat exchanger
heat exchanger
stripper column
stripper column
rectifier column
rectifier column
rectifier column
rectifier column
ethanol storage
sieve
boiler 50 hp.
stillage dryer
(horizontal)
furnace for dryer
dry distillers grain storage

Summary

This plant is an excellent example of what initiative, innovation, and perseverance can do to accomplish a goal. Much of the construction was done by the plant managers. Heat costs were kept to a minimum through the utilization of the waste and biomass materials. The development of a stillage pressure sieve and a stillage dryer have produced a dry stillage product that is a quality protein. The addition of a low cost ethanol dryer could initially provide better market for ethanol. Since the survey the company has developed other products to market such as an ethanol burner and ethanol cartridges for burners. The company is also using waste solvents for fuel. This was developed through the assistance of the Iowa Department of Environmental Quality.

SURVEY 9

Size and Type of Operation

This is an atmospheric type distillation facility. The stainless steel packed column is eight inches in diameter by 32 feet high. The column has a capacity of approximately five gallons of ethanol per hour. The cooker is a 750 gallon stainless steel tank which has both heating and cooling coils. The cooker is also used for fermenting. The stillage is stored in the holding tank and later used for feeding. The ethanol is stored in steel tanks. Corn is ground with a portable farm grinder using a 3/16 mesh screen. In the distillation process the column is first heated with live steam and then the spent beer slowly added to bring the column into equilibrium. The bottom temperature is maintained at about 214 degrees, the middle at 195 and the top at 173 degrees Fahrenheit. The proof of the alcohol is maintained by a reflux system as well as a controlled beer flow.

Normal Procedures and Techniques

1. Heat 300 gallons of water to 190 degrees Fahrenheit.
2. Add 20 bushels of corn slowly to the water agitate vigorously.
3. Add Taka-Therm
4. Add 300 gallons of water and heat for one hour, hold at 190 degrees Fahrenheit.
5. Cool to 140 degrees Fahrenheit, adjust pH to 4-4.5.
6. Add diazyme L-100.

7. Cool to 90 degrees Fahrenheit, adjust pH to 5-5.2.
8. Adjust pH to 5-5.2.
9. Add yeast at the rate of two to four pounds per thousand gallons of mash.
10. Allow to ferment from 24 to 48 hours.
11. Distill

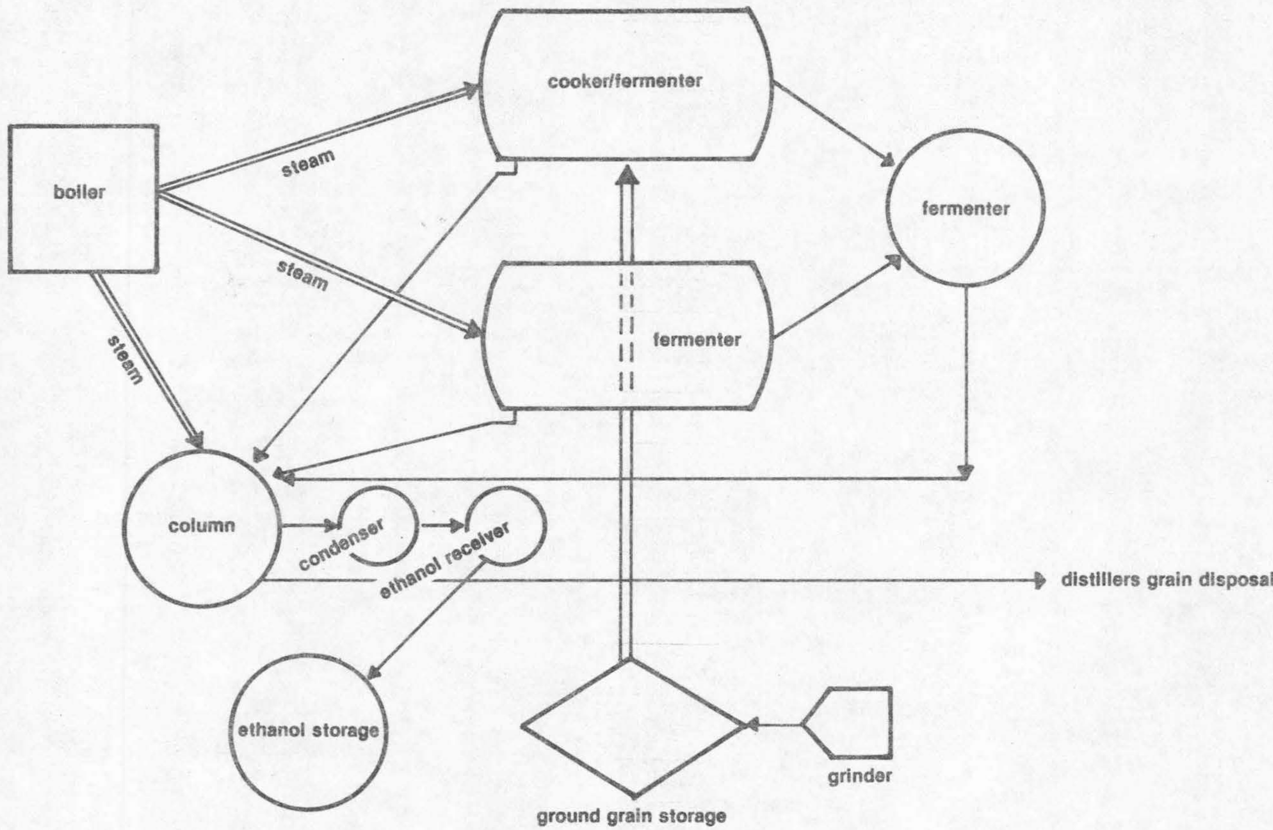
Profitability Statement

The low cost of corn and the favorable distillers grains return show a profitable statement. Fuel costs were held to a minimum by the use of used motor oil. This facility anticipates the use of other waste material to further reduce its heat energy cost. This particular unit has favorable returns statement; however, because of the small size of the column quantities of ethanol cannot be produced.

PROFITABILITY STATEMENT

	Units Used	Unit Cost	Cost/ Gal.
Expenses			
Operating Labor	8	$3.50	$ .66
Materials			
Corn	20	$2.25	1.02
Fuel	50	.01 gal.	.01
Electricity	1 kwh/gal.	.05 kwh	.05
Water			
Supplies			.11
Sub Total			$1.85
Repairs & Maintenance	$20,000	.025	.04
Insurance	$20,000	2.50/1000	.04
Taxes			
Depreciation			.15
Capital costs			
Other Plant valuation	$20,000		
Transportation		$150	.01
Sub Total			.24
TOTAL EXPENSES			$2.09
Revenue			
Ethanol	2.2 gal/bu.	(180 proof)	1.30
Distillers grains	16 1b/bu.	.08/1b.	.64
Ethanol incentives			.30
TOTAL REVENUE			$2.24
NET PROFIT			$ .15

44 gal/batch
13,000 gal/yr.


boiler
steam
steam
steam
cooker/fermenter
fermenter
fermenter
column
condenser
ethanol receiver
distillers grain disposal
ethanol storage
ground grain storage
grinder

Summary

As mentioned previously, one of the problems of this plant was the small size of the column which limits the capacity of the plant. The utilization of waste motor oil as well as other waste material should help maintain profitability. The utilization of distillers grains and ethanol on the farm facility is also a plus factor for the operation.

SURVEY 10

Size and Type of Operation

This is a vacuum type distillation unit used for demonstration purposes. The system was developed as a home and farm unit with the idea of utilizing solar energy as a part of the energy supply. The distillation column is approximately three inches in diameter and five feet high. It is attached to a tank which provides the base for heating and also supports the distillation column. A small condenser is connected to the distillation unit by tubing and disposes the ethanol to a vacuum tank. The tank houses a hydrometer for direct reading. An aspirator is connected to the vacuum line and to the water line to create the vacuum in the holding tank. A separate electric motor driven vacuum could also be attached to the vacuum line. The cooking and fermenting process is done in a 50 gallon barrel and utilizes a kerosene space heater for cooking. Corn is ground in a portable grinder using a 3/16 inch mesh screen. The stillage is fed wet to farm animals. In this particular unit a water heater is used as the base of the distillation unit. The water heater has a heating element in it with a cycling thermostat to maintain the temperature at approximately 120 to 130 degrees Fahrenheit. The vacuum in the unit should be maintained within a range of 20 to 28 inches of mercury averaging 26 inches. The alcohol is taken from the supply tank and stored in larger containers for future farm use.

Normal Procedures and Techniques

1. Grind a bushel of corn with a 3/16 inch mesh screen.
2. Add approximately 20 gallons of water per bushel.
3. Add the proper amounts of Canalpha enzymes and mix well.
4. Heat to 200 to 212 degrees Fahrenheit with constant mixing.
5. Hold 15 minutes at this temperature.
6. Cool mash to 150 to 170 degrees Fahrenheit by adding approximately 10 gallons of water.
7. Add additional Canalpha enzyme.
8. Hold 30 minutes with constant mixing.
9. Cool mash to 90 degrees Fahrenheit.
10. Add Gasolase enzymes.
11. Add distillers yeast.
12. Mix well.
13. Ferment for three to five days in area where temperature will not go over 90 degrees Fahrenheit.

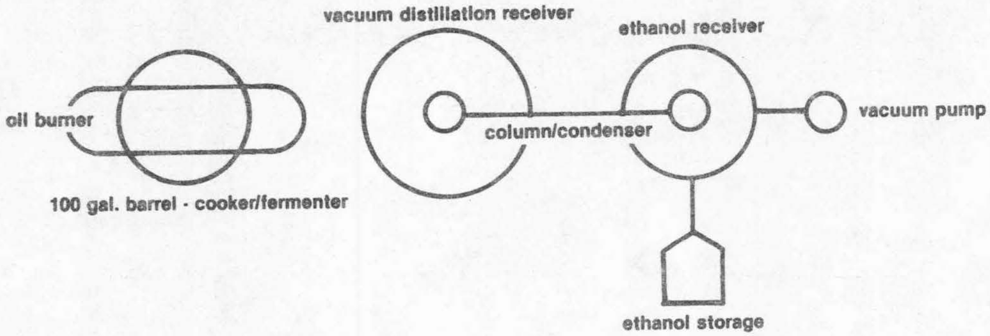
Profitability Statement

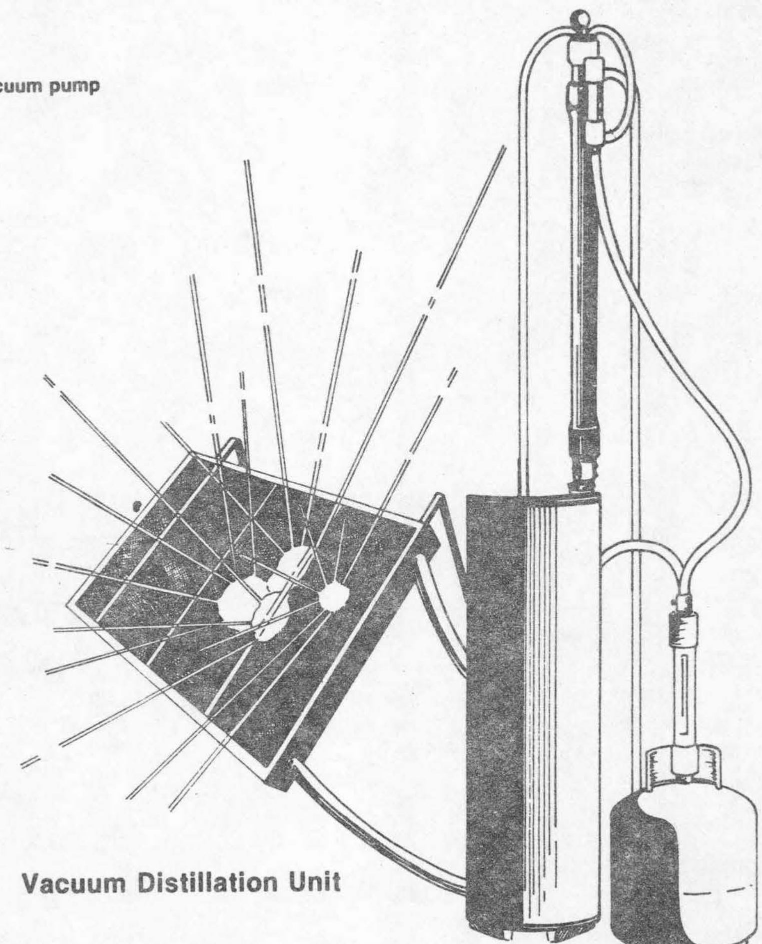
Even though the equipment costs are minimal, low production results in costs that are unprofitable to the operation.

PROFITABILITY STATEMENT

	Units Used	Unit Cost	Cost/ Gal.
Expenses			
Operating Labor	1	4.00	$2.22
Materials			
Corn	1 bu.	2.35	1.30
Fuel	1 gal.	1.40	.77
Electricity	1 kmh/gal.	.05 kmh	.05
Water			
Supplies			.12
Sub Total			$4.46
Repairs & Maintenance			
Insurance			
Taxes			
Depreciation	$1,000	10 yrs.	.06
Capital costs			
Other Plant valuation	$1,000		
Transportation			
Sub Total			.06
TOTAL EXPENSES			$4.52
Revenue			
Ethanol	1.8 gal/bu.	170 proof	1.00
Distillers grains	16 lb/bu.	.9/lb.	.75
Ethanol incentives			.30
TOTAL REVENUE			$2.05
NET PROFIT			-$2.47

5 gal./day
1500/year





Vacuum Distillation Unit

Summary

Since this type of operation is not profitable the only reason for maintaining this type of system is for educational purposes or a hobby. The cost items could be reduced by increasing the size of operation.

SURVEY 11

Size and Type of Operation

This is an atmospheric type ethanol plant. The facility is housed in a rennovated crib approximately 40' by 28'. The corn is stored in the regular steel bin on the farm and is then ground using a portable grinder with a 3/16 inch screen. Two cooker-fermenters are used each with a capacity of 1,500 gallons. Each tank has a heating-cooling coil and also agitators. An extra 750 gallon tank is used to store warm water. The distillation unit is made up of two 12-inch diameter steel columns 20 feet high. The stripper column has sieve plates with larger holes for stripping the whole grain along with the downcomers and cups. The rectifying column has smaller holes in the sieve plates but also has the downcomers and cups. The boiler is a 15 horsepower gas burner with a capacity of 625,000 BTU's per hour. A tube in the tube heat exchanger about 15 feet high is used to preheat the mash. The bottom of the stripper column is maintained at approximately 215 degrees Fahrenheit, the middle about 195 degrees and the top approximately 185 degrees Fahrenheit. Proof is regulated by controlling the temperature in the column, the rate of flow of mash into the column, and the reflux from the rectifying column. The spent beer level in the stripping column is also maintained at a given height by regulating the spent beer pump. The alcohol vapor is run through a cooling condensor and then through a holding barrel and later pumped into a storage tank. The whole distillers grains are put into large holding tanks and fed wet to beef cattle and cows.

Normal Procedures and Techniques

1. Seventeen gallons of water per bushel of corn is used initially.
2. Heat to 160 degrees Fahrenheit.
3. Add 1/4 oz. Canalpha per bushel of corn.
4. Add corn and stir.
5. Heat mash to 212 degrees Fahrenheit for one-half hour.
6. Cool to 175 degrees Fahrenheit.
7. Add .37 oz. Canalpha per bushel of corn.
8. Add 10 gallons of water per bushel of corn and cool to 90 degrees Fahrenheit.
9. Add 1/4 oz. of Gasolase per bushel of corn.
10. Add 3/4 oz. of dry yeast.
11. Wait 72 hours until crust is off the top.

Profitability Statement

At present prices this is a profitable unit. Fuel costs are high. This plant uses natural gas for fuel which makes the energy cost high. In time an alternate fuel might be utilized in this plant. One hundred ninety proof alcohol is consistently produced. The plant is conveniently arranged and is well operated. An important element in cost reduction of this plant is the fact the owner has purchased equipment at a fair price and did much of the construction himself. Water costs are a part of the electricity costs. The producer has been able to cut his costs of enzymes by using about half the recommended initial amount.

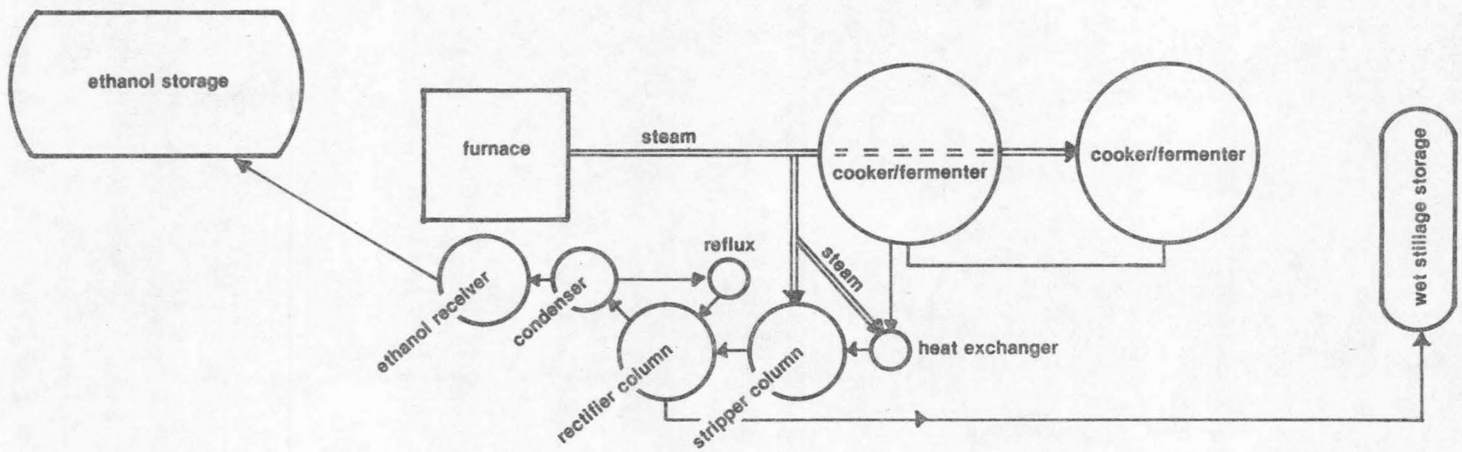
Fixed expenses are based on the yearly production which is approximately 5,000 gallons per year at the present time. Taxes are not assessed against the still. Depreciation is at the rate of \$.05 per gallon. Transportation costs for still operation are estimated at \$.01 per gallon.

PROFITABILITY STATEMENT

	Units Used	Unit Cost	Cost/ Gal.
Expenses			
Operating Labor	8 hr.	$4.00	$ .31
Materials			
Corn	46.3	2.30	1.04
Fuel	64.07 gal.	.53 gal.	.33
Electricity	1 kwh/gal.	.04	.04
Water	Under electricity		
Supplies			.10
Sub Total			$ 1.82
Repairs & Maintenance	5,000 gal.	$250/yr.	.05
Insurance	$15,000 value	3.50/1000	.01
Taxes			
Depreciation	5,000 gal.	$250.00	.05
Capital costs			
Other Plant valuation	$15,000		
Transportation	$50.00	5,000 gal.	.01
Sub Total			.12
TOTAL EXPENSES			$ 1.94
Revenue			
Ethanol	$1.30/gal.		1.30
Distillers grains	17 lb/bu.	.075/lb.	.57
Ethanol incentives	per gal.		.30
TOTAL REVENUE			$ 2.17
NET PROFIT			$ .23

Gal/year - 5,000 gal.
Value of still - $15,000
102 gal/batch

yield alcohol = 2.2 gal/bu.
5,000 gal/yr.


ethanol storage
furnace
steam
cooker/fermenter
cooker/fermenter
wet stillage storage
reflux
steam
ethanol receiver
condenser
rectifier column
stripper column
heat exchanger

Summary

This plant is a good example of a workable farm ethanol facility. An old corn crib has been converted to house the ethanol equipment. The two 1,500 gallon cooker-fermenter tanks provide ample supply for a day's run; however, it did not allow for continuous operation. Total mash was fed into the column in order to get maximum alcohol returns as well as provide less handling time and cost. The total spent beer was collected in the large tanks and used directly in the cattle feeding operation. A large steel tank is buried in the ground for ethanol storage. The ethanol is used in three tractors and two cars on the farm. One hundred ninety proof alcohol is used in a 10-90 mix in one car and two tractors and 190 proof alcohol burned straight in a truck and a tractor. Modifications were made in the equipment to accommodate ethanol use. On the 190 proof mix, the ethanol and gasoline is premixed at a rate of 40 gallons of gasoline to 4 gallons 190 proof alcohol and allowed to set overnight to allow the ingredients to reach an even temperature before mixing with the rest of the gasoline. In time, this operation will provide the ethanol and most of the protein feed for the farm operation.

SURVEY 12

Size and Type of Operation

A large specialty manufacturing firm based in the midwest made a major effort to develop a farm-scale ethanol plant which would produce ethanol according to given specifications. To further support stated specifications, the company submitted the basic plan to the American Society for Testing Materials (ESTM). Management of this company wanted to insure that the parent plant had been fully field-tested to meet established parameters. These parameters are: 1) efficiency of feedstock conversion; 2) energy spent in conversion; 3) production rate; and, 4) mass balance which considers the production of distillers grains along with the alcohol. The proposed method for testing is included in the appendix under "Methods for Performance Evaluation of Fermentation Fuel Manufacturing Facilities."

The general specifications of these atmospheric type distillation plants are an annual production of 41,000 gallons of 190 proof 2.3 gallons per bushel alcohol per year, producing 285 tons of distillers grains 60 percent moisture content. The facility is housed in a steel building 40' by 14' by 14'. Fifty bushels of corn and 900 hundred gallons of water are used each day. The plant utilizes maximum automation to minimize labor requirements and provide quality control.

The spent grains are separated from the beer before distillation. The grains are dewatered through a separator and a squeezer. The stainless steel distillation column is a single column 10 inches in diameter and 29 feet high. The column follows the basic atmospheric column design utilizing 24 stripper plates and 20 rectifier plates. The top of the column has a control unit with monitors going to a central panel. The column is insulated and placed outside the building. At the present time, the system utilizes a five horsepower 350,000 Btu gas boiler.

The alcohol produced runs in the 185 to 190 proof range and is sold to local farmers for tractor and truck use. The distillers grains are also sold to farmers.

Normal Procedures and Techniques

The plant studied has six 1,280 gallon stainless steel cone bottom tanks with two-inch fiberglass insulation on the top and sides. Each of these tanks is used as a cooker-fermenter. Since there are six tanks, one of the tanks is available for distillation each day. The process described applies to each of the tanks. The second tank is started on the second day and the remaining tanks follow the same procedure. The grain is ground using either a hammermill or a rollermill. The following is the day by day process for each of the tanks:

DAY 1: The tank is automatically filled with 900 gallons of 190 degree Fahrenheit water. Fifty bushels of corn are added at a moderate rate. This slow addition of corn requires some of the operator's time, but minimizes potential lumping problems. The pH level of the batch is checked and corrected as needed.

Harvestzyme #1 is added now. It helps break down the starch of the corn to produce dextrins. First, the mash thickens slightly, a process called gelatinization, as the starch is liquified.

The tank is then held at 185 degrees Fahrenheit for 8-12 hours.

DAY 2: At the start of day 2, the tank is cooled to 140 degrees Fahrenheit. As the temperature drops, which takes eight to nine hours, the heat is transferred through the system to help warm incoming water for a new batch in another tank.

When the tank reaches 140 degrees Fahrenheit, the pH level is adjusted and Harvestzyme #2 is added. Bacteria protection is provided by adding sodium bisulfite. The tank is held at this point for 8-12 hours to allow Harvestzyme #2 to work.

DAY 3: The batch is tested for sugar content and the tank temperature controls are adjusted to cool the tank contents to 90 degrees Fahrenheit. When cooling is completed, pH is adjusted and yeast is added.

DAY 4 and 5: The fermentation stage lasts 60 hours. During this stage, live yeast cells convert the sugars to alcohol. The process tank develops a blanket to CO_2 over the tank's contents preventing oxygen from entering the tank.

During this stage the temperature control maintains 90 degrees Fahrenheit. The operator measures the sugar content. When the sugar is gone, no more alcohol can be made, and the contents are ready for distillation.

DAY 6: The mash in the tank is now pumped into the two-part solid separator. The liquid, called "beer," is pumped into the beer tank where it will be stored until it is distilled in the column. The solids, called distillers grains, are squeezed through a screw auger which brings the moisture content down to 60%.

The fermented beer which is approximately 12% alcohol by volumne is distilled, producing up to 115 gallons of 190 proof alcohol. Waste heat from the column is used to warm the water to start a new batch in the empty tank and begin the cycle again.

During the process a fuel log sheet is used, an example follows:

FUEL LOG SHEET

Schedule Day	Schedule Time	Complete Day	Complete Time		Operation	Comments
1st	AM				Fill tank with 900 gal. water at 185°	
	PM			( ) ( ) ( ) ( )	Stirrer on Temperature ________ 3750 ml calcium chloride 1/2 corn 800 ml Harvestzyme #1 1/2 corn pH = 6.8, ______ ml NaOH HEAT CYCLE; 185°	
2nd	AM			 ( )	Temperature ________ COOL CYCLE: 140°	
	PM			 ( ) ( ) ( )	Temperature ________ pH - 4.0, ______ ml HCl 1500 ml Harvestzyme #2 275 ml bisulfite HEAT CYCLE; 140° F	
3rd	AM			 ( )	Temperature ________ Sugar test, 1:10 dilution, _____ % sugar COOL CYCLE; 90° F.	
	PM				Temperature ________ pH - 5.0, ________ ml NaOH Yeast: ( ) 3½ lbs. in 5 gal. water or ( ) 60 gal. mash from Day 4 tank	
4th	PM				Temperature ________ Sugar test (24 hrs.) ______ % sugar 60 gal. mash to day 3 tank ( )	
5th	PM				Temperature ________ Sugar test, (48 hrs.) % sugar	
6th	AM				Temperature ________ Sugar test (60 hrs.) ______ % sugar Separate Beer from solids Distill beer	
	PM				Clean tank, mash line and separator	

OPERATOR ______________________

PRODUCT ANALYSIS

NUMBER OF GALLONS: __________

BATCH NO. __________ TANK NO. __________

PROOF: __________

FEEDSTOCK ______________________

PROOF GALLONS: __________
(proof x no. gal)/100

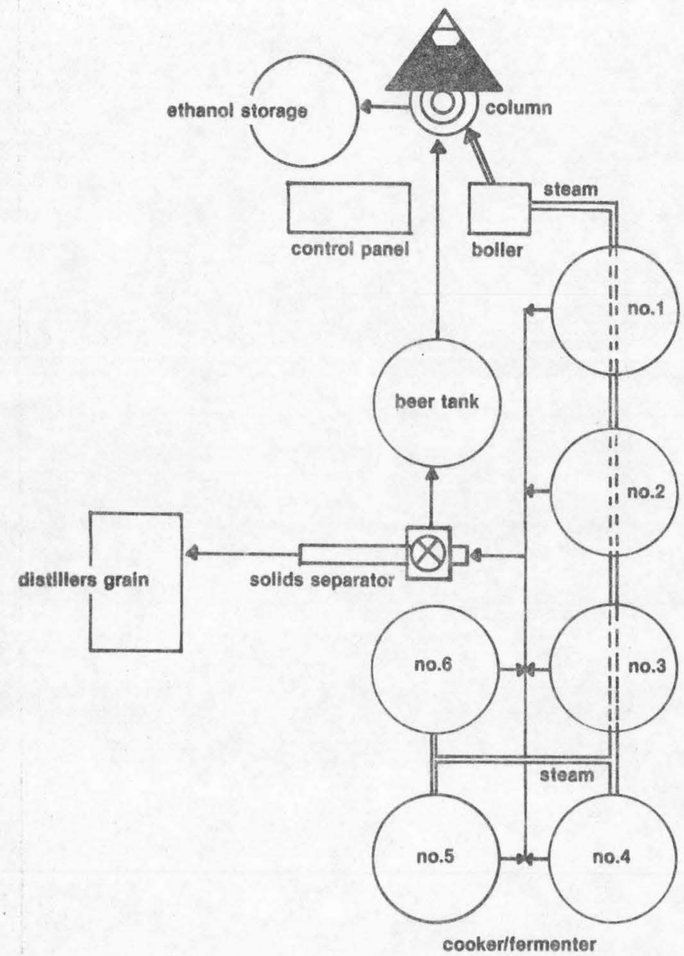
Profitability Statement

Prices of consumable materials at the time of the survey resulted in a profitability statement. The price of corn as well as cost of fuel resulted in comparatively high operating costs. Presently, one of these new plants is using coal which results in a fuel cost of $.04 per gallon ethanol. The other high cost was capital costs which is based on a ten-year cash flow schedule. The utilization of other alternate fuels might be helpful in lowering the costs of such a plant. The facility consistently produces high-proof alcohol with minimum labor. Since the column is 10 inches in diameter, the column capacity exceeds 123,000 gallons per year thus allowing the operator to add additional fermentation capacity as his livestock feeding capabilities increase and as he expands his marketplace for excess alcohol.

PROFITABILITY STATEMENT

	Units Used	Unit Cost	Cost/ Gal.
Expenses			
Operating Labor	3 hrs.	$5.00	$ .13
Materials			
Corn	50 bu.	2.50	1.09
Fuel (#2 fuel oil)	* 33.6		.32
Electricity	* 300. kwh	.046	.12
Water	Under electricity		
Supplies (enzymes, disinfectants & other process chemicals)			.29
Sub Total			$1.95
Repairs & Maintenance	$75,500	$750.	.01
Insurance	$75,500	2.25/$1000	.04
Taxes			
Depreciation			
Capital costs	cash flow schedule		.32
Other Plant valuation	$75,500		
Transportation	$75,500	$750.	.01
Sub Total			.38
TOTAL EXPENSES			$2.33
Revenue			
Ethanol			1.40
Distillers grains	70% of cash price of corn		.76
Ethanol incentives	$.40 plus tax credits		.47
TOTAL REVENUE			$2.63
NET PROFIT			$ .30

50 Bu. batch *112.5 gal/batch
*2.25 gal/bu. 41,000 gal./yr.
*Consumption documented in accordance with ASTM performance evaluation standard for fuel ethanol manufacturing facilitie


ethanol storage
column
steam
control panel
boiler
no.1
beer tank
no.2
distillers grain
solids separator
no.6
no.3
steam
no.5
no.4
cooker/fermenter

SUMMARY

This plant is one of the better examples of a commercial type facility which is simple yet automated, designed to fit a farm operation which is energy efficient. A further accommodation for this plant is the fact that the company submitted the basic plant for testing based on the American Society for Testing Materials schedule. Thus, the facility has been fully tested to meet established and stated parameters. The schedule for this testing is shown in Appendix B.

INVESTMENTS

Item	Quantity S- 1	Quantity S- 2	Quantity S- 3	Description Survey 1	Description Survey 2	Description Survey 3
Land	0	2 A	½ A		2 A	½ A
Building	1	1		40' x 40'	77' x 52'	24' x 32'
Storage bins	0	1	0	0	1,000 bu	Farm bin
Grinding mill	0	1	1	0	40 H.P.	Portable Grinder
Conveyors		1			3½"	
	1		2	For stillage		20' augers
		2			5"	
Cookers		1			2,600 gal.	
			1			1,200 gal.
		1			3,000 gal.	
	1			combined		
Fermenters		1			10,000 gal.	
			1			1,500 gal.
		1			12,000 gal.	
Distillation column		1			24" x 10'	
	1	1	1	12" x 30'	24" x 10'	8" x 32'
		1			39" x 18'	
Storage tanks		1			600 gal.	
	1	1	4	1,500 gal.	600 gal.	1,000
		1			600 gal.	
Pumps	5	10	7	1 to 10 g.p.m.	1 to 10 g.p.m.	1 50 10 g.p.m.
	1					

Item	Quantity S-1	S-2	S-3	Description Survey 1	Survey 2	Survey 3
Controllers	0			0		
Pipes and valves	as needed	as needed	as needed	½" to 2"	½" to 2"	
Metering controls	0	1	1	0	Fuel	5 - 15 gal/min
Micro-processors	0	0		0	0	
Safety valves	3	3	2	15 psi	15 psi	15 lb.
Heat exchangers	1	1	1	Tube In Take	Column	Tube In Tube
Instrumentation	1	10	3	Temp. Panel	Thermometer	Thermometer
Insulation	2"	2"	2"	On column	On column	On column
Boiler	0	1 1	1	City steam	40 H.P. Gas 30 H.P.	50 H.P.
Fuel handling equipment	0	2	2	0	Storage tanks	1000 gal. tanks
Feedstock handling equipment	1	1 1 1	1	150 bu. wagon gravity flow	conveyor scale grinder	centrifuge

Item	Quantity			Description		
	S-1	S-2	S-3	Survey 1	Survey 2	Survey 3
Storage for stillage	0	1	1	0	Truck	Wagon
Stillage treatment equipment	0	1 1	1		Rotating Screen Compresser	Centrifuge
CO_2 handling equipment	0	0	0	0	0	0
Ethanol dehydration equipment	0	1		0	Column	
Extruder	0	0		0	0	
Fuel	0		5T	0	Storage Tank	Coal
Water	City	City	Deep Well	City	City	City
Supplies	1	1	5 gal.	Barrel of each - enzyme acid alkaline	Barrel of each supply element	Barrel
Other						
Motor(s)	6	10	10	½ to 55 H.P.	½ to 5 H.P.	½ to 10 H.P.

INVESTMENTS

Item	Quantity S-4	S-5	S-6	Description Survey 4	Survey 5	Survey 6
Land	.5 A	.10 A	.5 A			
Building	1	1		25' x 50'	25' x 50'	Old barn
Storage bins		1	1	5,000 bu.	800 bu. grain bin	4,000 bu. bin
Grinding mill	1	1	1	Portable mill	Portable mill	Portable mill
Conveyors	1	2	2	50' grain	Corn	5" augers 35'
Cookers	1	1	1	4,000 gal.	750 gal.	750 gal.
Fermenters	1	3	1 1	8,000 gal.	1,500 gal.	700 gal 500 gal.
Distillation column	1	1	1	12"	8" stainless steel	12"
Storage tanks	1	3	1	9,000 gal	1,000 gal.	200 gal.
Pumps	5	5	6	1 to 10 gpm	1 to 10 gpm	1 t0 to gpm

Item	Quantity S- 4	S-5	S- 6	Description Survey 4	Survey 5	Survey 6
Controllers	0	1	0	0	On column	0
Pipes and valves	As needed	As needed	As needed	½" to 2"	½" to 2"	½" to 2"
Metering controls		1	1	0 to 5 gal.	0 to 5 gal.	0 to 5 gal.
Micro-processors	0	0	0	0	0	0
Safety valves	2	2	2	15 lb.	15 lb.	15 psi.
Heat exchangers	1	1	1	Tube in tube	Pipe in pipe	0
Instrumentation	6	6	3	Thermometer	Thermometer	Temp. gauges
Insulation	0	1	0	0	Column	0
Boiler	1	1	1	50 H.P.	50 H.P.	24 H.P.
Fuel handling equipment	1	1	1	9,000 gal. tank	1,000 gal. tank	200 gal.
Feedstock handling equipment		1	1	wagon	Conveyors	5" auger

Item	Quantity S- 4	S- 5	S- 6	Description Survey 4	Survey 5	Survey 6
Storage for stillage	0	1	1	0	1,200 gal tank	10' x 10'
Stillage treatment equipment	0	0	0	0	0	0
CO_2 handling equipment	0	0	0	0	0	0
Ethanol dehydration equipment	0	0	0	0	0	0
Extruder	0	0	0	0	0	0
Fuel	1,000 bu.	1,000 bu.	500 gal.	Cobs	Cobs	Used oil
Water	Well	Well	Well	Farm system	Farm system	Farm system
Supplies	5 gal.	5 gal.	5 gal.	Miles	Miles	Miles
Other						
Motor(s)	8	10	6	½ to 5 H.P.	½ to 5 H.P.	½ to 5 H.P.

INVESTMENTS

Item	Quantity			Description		
	S- 7	S- 8	S- 9	Survey 7	Survey 8	Survey 9
Land	2 A	5 A	.5 A	-	-	-
Building	1	1	1	35 - 40	104 x 50	old barn
Storage bins	1	1	1	800	1,000	4,000 bu.
Grinding mill	1	1	1	25 hp	25 HP	Portable Hammermill
Conveyors	500	1,000'	1,000'	augers	augers	35' by 5" augers
Cookers	2 - 9000 gal.	4 - 6000 gal.	1 - 750 gal	steel	steel	stainless steel
Fermenters	4 - 30000	"	1	steel	"	750 gal. 500 gal.
Distillation column	3 col.	3 col. 3 col.	1	24"x17' 20"x17' 20"x17'	14'x17' 10'x13'	8" diam. 30' high
Storage tanks	1 - 45000	1 - 7,000 gal.	1 - 200 gal	steel	steel	steel
Pumps	5	8 10	6	500 psi	5 to 300 gal/min. 2-10 gal/min 8 to 100	1 to 10 g.p.m.

Item	Quantity S- 7	S- 8	S- 9	Description Survey 7	Survey 8	Survey 9
Controllers	0	0	0	0	0	0
Pipes and valves	as needed	as needed	½" to 2" as needed	½" to 2" steel, plastic	½" to 2" bronze, steel, plastic	½" to 2"
Metering controls	2	2	1	for distill-ation	for distill-ation	for dis-tillation
Micro-processors						
Safety valves	6	8	2	pressure on boilers & cookers	high or low pressure on boilers & cookers	pressure on boilers & cookers
Heat exchangers	2	8	1	tube in tube	tube in tube	tube in tube
Instrumentation	1	1	3	column heat	column heat	column heat
Insulation	1	1	1	on column	on column	on column
Boiler	1-35 HP 1-120 HP	1 1	1	gas	50 HP used oil	24 HP used oil
Fuel handling equipment	0	0	0	0	0	0
Feedstock handling equipment	1	1	1	conveyor	conveyor	5" auger

Item	Quantity			Description		
	S- 7	S- 8	S-9	Survey 7	Survey 8	Survey 9
Storage for stillage	1	1	1	truck	1000 gal. tank	10' x 10' tank
Stillage treatment equipment	1	1 1	1	sieve	sieve dryer	sieve
CO_2 handling equipment	0	0	0	0	0	0
Ethanol dehydration equipment	1	0	0	sieve dehydra-tion	0	0
Extruder	0	0	0	0	0	0
Fuel	1	1	1	1,000 gal. gas	used oil wood	used oil or waste
Water	1	1	well	11000 gal tank	cooling reser-voir	farm system
Supplies	1	1	1	Miles	Alltech	Miles
Other	0	0	0	0	0	0
Motor(s)	35	30	5 to 10 HP	6	3/4 to 10	1/2 to 5 HP

INVESTMENTS

Item	Quantity			Description		
	S-10	S-11	S-12	Survey 10	Survey 11	Survey 12
Land	.5 A		.1			acre
Building	1	1	40'x30x 14'	old barn	40-28	steel
Storage bins	4,000 bu.	1 steel bin 5,000 bu	1 - 1,300 gal.	steel	3,500 bu.	beer
Grinding mill	1	1	0	portable fram grinder	grinder-mixer 3/16 mesh	0
Conveyors	0	0	0	0	0	0
Cookers	1	2	6 - 1,280 gal.	50 gal. barrel	1,500	cone-shaped stainless steel
Fermenters	1			50 gal. barrel		
Distillation column	1	2	1	3" x 5'	12" 20 high	29' 10" diameter stainless steel
Storage tanks	1	1	1 - 1,800 H_2O 1,500 gal.	5 gal.	2,500	H_2O storage alcohol storage
Pumps		5 - 5 to 300 gal/min.	10		5 - 100	5 to 100 gal/min capacity

Item	Quantity S-10	S-11	S-12	Description Survey 10	Survey 11	Survey 12
Controllers		4 V -9	1		3/4 1½ gate	panel
Pipes and valves		50' 30' 200' 40' 23'	300'			1" to 3"
Metering controls		1	1		sieve	column
Micro-processors			0			0
Safety valves		1	10		8 - 15 lb.	15 lb.
Heat exchangers Hose	1	1 20'	1		Tube in tube 1¼"	column
Instrumentation Agitator Garden Hose		3' 25' 50' 25'	1		9' shaft 1 shaft 1 shaft	
Insulation		1 col.	2"			column
Boiler	1	1 15 hp	1 5 hp	spare burner	625,000 BTU	350,000 BTU
Fuel handling equipment		1	0		1,000 gal tank	0
Feedstock handling equipment		1	1		1,000 tank	conveyor

Item	Quantity			Description		
	S-10	S-11	S-12	Survey 10	Survey 11	Survey 12
Storage for stillage	1		10	50 gal. barrel		50 gal. barrel
Stillage treatment equipment			1 1			screen squeezer
CO_2 handling equipment			0			0
Ethanol dehydration equipment			0			0
Extruder			0			0
Fuel	1	1	natural gas	5 gal.	1,000 gal. propane	city gas line
Water		1 1	1		2,000 gal. H_2O 700 gal.	city H_2O system
Supplies	5 gal.	20 40 yeast	50 gal.	BiCon		enzyme yeast
Other						
Motor(s)	1	3 2 1 1	6 2 1 1	1 hp elec		2 hp 1/3 hp 5 hp 5 gas

FINDINGS

1. Labor costs range from $1.42 to 13 cents per gallon of ethanol produced. These costs were materially affected by the hourly rate of pay, the number of hours required per batch of ethanol produced and the proof gallons of alcohol produced per bushel of corn.
2. Normally feedstuffs is the highest cost item and also one of the most variable factors affecting profitability. Corn prices varied from $1.54 to 93 cents per gallon of alcohol produced. The price of corn and gallons produced per bushel of corn significantly affected the feedstuff costs.
3. Fuel costs ranged from 77 cents to one cent per gallon of alcohol produced. Natural gas, city steam, and fuel oil were the highest cost fuels. The use of coal was slightly less expensive than the higher priced fuels. Corn cobs, waste products, used oil and flamable solvents were the least expensive fuels.
4. The cost of electricity ranged from 14 cents to four cents per gallon of alcohol produced. The higher costs were reflected in the higher rates in urban centers.
5. Water costs were low cost items and were generally reflected under electricity as a cost of water transfer or pumping.
6. Supply costs ranged from 6.5 cents to 29 cents per gallon of alcohol produced. These costs were materially affected by the volumne used and transportation.

7. The variable costs ranged from $4.46 to $1.36 per gallon of alcohol produced. Labor, feedstuffs and fuel were the significant costs in this category.
8. Based on 190 proof ethanol, revenue ranged from $1.80 per gallon to $1.00 per gallon. The higher price was determined by the proof of the alcohol and the time and place of sale. Two of the cooperators sold anhydrous alcohol. The ethanol was used on farms and also sold direct for upgrading.
9. Revenue from distillers grains ranged in price from $1.00 per gallon of ethanol produced to 45 cents per gallon. All the respondents except one were either feeding the distillers grains wet to livestock on the farm or selling it to other farmers to feed wet. One producer drying distillers grains was selling the dry product to a feed company, however later arrangements were made to sell the distillers grains wet to a cattle feeder.
10. Where the farmers were using ethanol on the farm, the tax incentive was received. Eight of the twelve cooperators were getting this support.
11. The net profit per gallon of alcohol produced ranged from a minus $2.76 to plus 56 cents per gallon. Major factors determining profitability for this study were labor costs, fuel costs, capital costs, feedstuffs and revenue. *
12. Based on 190 proof alcohol, the number of gallons of alcohol produced per bushel of corn ranged from 1.8 to 2.5. The total

* See Appendix C for composite chart.

number of gallons produced per year ranged from 5,000 gallons to 450,000 gallons per year. The number of gallons of alcohol produced per bushel and the total number of gallons of alcohol produced per year are significant factors in determining overall profitability of a plant.

13. Plant capitalization ranged from $15,000 to $250,000. If the plant capitalization was high for the volumne of alcohol produced, the fixed costs were detrimental to plant profitability.
14. When the producers did much of the plant fabrication themselves, lower plant costs resulted. However, modifications and changes were often needed later resulting in additional costs.
15. A number of "turn-key" operations were sold which were inefficient.
16. A period of time is required by plant operators to learn the techniques of producing ethanol and getting acquainted with the operation of the equipment.
17. Transportation was a nominal cost item.
18. Taxes and insurance were low cost items, however in some cases these costs were carried as a part of the farm enterprise or were not included especially when less than a cent per gallon.
19. If the capitalization was low a straight line depreciation schedule was generally used.
20. The lack of financial support by the Federal government for the development of small ethanol plants has significantly decreased farm and farm cooperative interest in ethanol production; however, some ethanol plants are being built, some plants are being modified and improved, some plants are on "hold" for a more profitable ethanol market and a few plants are available for purchase.

CONCLUSIONS

1. Under the present price structure, the farm and farm cooperative ethanol plants which were economically constructed, properly operated, and modestly financed showed a profit.
2. A profitable procedure for handling distillers grains is to feed the product wet on the farm where produced or find a market close by where the product can be fed wet.
3. Feeding trials of wet distillers grains to calves weighting from 400 to 800 pounds have shown a higher value for distillers grains than soybean oil meal.
4. High priced and inadequate equipment has resulted in unprofitable small ethanol plants. By checking with successful small operators, those venturing into the ethanol business can avoid many of the mistakes made by those having had such experiences.
5. Proficiency in the techniques of producing ethanol are of major importance for profitability, particularly in the procedures for cooking and fermenting.
6. A farm ethanol plant is a means of vertically integrating the farm operation.
7. A community cooperative ethanol plant is not only a means of developing a local industry but also a means of utilizing local labor.

8. An ethanol plant is particularly adaptable to a farmers grain cooperative in that it not only utilizes the products bought and sold in the elevator, but it also utilizes labor particularly in the off season.
9. Some of the cost items of farm ethanol production are low because they are an integral part of the farming system and, therefore, each part does not carry the full cost. Such items as the water system, storage system, buildings, drainage, taxes, and labor are examples of these items.
10. A farm ethanol plant becomes a part of the total farm system. The extent to which it is utilized is dependent on the other farm operations, the availability of labor, and the profitability of each enterprise.
11. Since feedstuffs is generally the most expensive cost item in producing ethanol, any means of lowering this cost will be an important factor in obtaining higher net returns. Assuming 2.5 gallons of ethanol per bushel of corn selling at $2.50 a bushel, a change in price of 25 cents per bushel up or down will affect production costs by 10 cents per gallon.
12. As motor carburetion is developed, more use will be made of wet ethanol resulting in an increased market for this product.
13. The utilization of alternate fuels such as wood, coal, used oil, crop residues and solvents are significant innovations in reducing fuel costs in ethanol production.

14. The utilization of solar panels can be an integral part of ethanol equipment, particularly in the preheating of water used in the facility.
15. Variable and fixed costs for each enterprise will vary according to the type and management procedures of the operation.
16. A preliminary profitability statement is a necessary first step in the development of a farm or cooperative ethanol enterprise. By analyzing such a statement, the range of variables can be determined and a close estimate made of the economic outcome.
17. Uses for ethanol other than automotive need to be explored to increase demand at the local level.
18. Feedstuffs costs may be kept at a minimum by utilizing off-grade corn and also purchasing and storing corn for future use. Some government corn might be used in this way.
19. An adequate boiler which can utilize alternate fuels is an important factor affecting profitability.
20. Research and development in farm ethanol plants are needed as a growth factor in both urban and rural industry.
21. A small ethanol plant does not necessarily have to be run continuously to be a profitable adjunct to the farm enterprise.
22. Plant utilization is directly correlated with profitability.
23. Those plants that can survive will serve as a model for those who want to establish a small ethanol industry.
24. The small ethanol industry will continue to grow. The growth will be directly correlated with the development of markets for the products produced.

RECOMMENDATIONS

1. Ethanol producers in local areas hold regular meetings to discuss needs and developments in the industry.
2. Ethanol producers communicate with state and national legislators on matters relating to the industry.
3. The National Secretary of Agriculture be encouraged to support present legislation to utilize "set-aside" acres for alcohol production as an incentive for further development of farm ethanol plants.
4. Area colleges support the ethanol program by having a resource person available for consultation on ethanol production, maintain a reference library on ethanol production, hold seminars on ethanol development as needed and offer courses on ethanol production when interest is sufficient to warrant such a course.
5. State and Federal energy departments continue to provide grants and loans to encourage the development of alternate fuels.
6. Ethanol producers keep in contact with special interest groups to promote ethanol production.
7. Those purchasing ethanol plants should require that the facility pass specific standards similar to those developed by the American Society for Testing Materials.

8. Producers anticipating investment in an ethanol plant should work out a profitability statement for the enterprise. Specific questions on the variables may be answered by contacting individuals associated with this study or other plant operators.
9. State development agencies and farm organizations continue to keep abreast of developments in the ethanol industry. Each group can do much to further the growth of the industry by actively participating in the promotion of such an endeavor.

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Dr. Edwin L. Barbour, Superintendent, Iowa Central Community College, Fort Dodge, Iowa.

Mr. Jonathan Chapman, Agriculture Engineering Department, Iowa State University, Ames, Iowa.

Mr. Berkley Bedell, United States Representative, Storm Lake, Iowa.

Mr. Jim Montgomery, Producer, Manly, Iowa.

Mr. Dennis O'Toole, Producer, Sac City, Iowa.

Mr. and Mrs. J. R. Mapel and Sons, Producers, Lake City, Iowa

Mr. Donald Duke, Producer, Storm Lake, Iowa.

Mr. Hugh Vogel, Producer, Lenox Grain Fuels, Lenox, Iowa

Mr. Matt Holden, Producer and Research, Engineering Department, University of Iowa, Iowa City, Iowa.

Mr. Marvin Means, Producer, Mapleton, Iowa.

Mr. Richard Lambirth and Dean Hoy, Producers, Marion County Alcohol Fuels, Bussey, Iowa.

Mr. Bob Thornberg, Producer and Marketing, Conklin Company, Inc., Minneapolis, Minnesota.

Dr. Marvin B. Lind, Producer and Coordinator, Rippey, Iowa.

Dr. Allen Trenkle, Research, Agriculture and Home Economics Experiment Station, Iowa State University, Ames, Iowa.

Mr. Lee Castens, Barton Solvents, Des Moines, Iowa.

Mr. Craig Coleman, Skillestad Engineering, Inc., Cannon Falls, Minnesota.

Mr. Herb Hanson, Engineering, Elgin, Illinois.

Mr. Bob Campbell and Mr. Bruce Henning, Iowa Department of Environmental Quality, Des Moines, Iowa.

Mr. Tom Pearson, Iowa Development Commission, Des Moines, Iowa.

Mr. Dave Hallberg, Renewable Fuels Association, Washington, D.C.

Mr. Michael Carleton, Iowa Energy Policy Council, Des Moines, Iowa.

Appendix A

EVALUATION OF CORN STILLAGE, CORN GLUTEN MEAL AND SOYBEAN MEAL AS PROTEIN SUPPLEMENTS FOR CATTLE

When interest developed in production of fuel alcohol from corn grain, questions were asked about the feeding value of the remaining residue (stillage). Wet stillage was found to be equal to corn grain as a source of energy for fattening heifers when added to a finishing ration at 15% of the total ration dry matter (A.S. Leaflet R307, 1980). Most of the proteins present in corn escape degradation during the fermentation to produce alcohol, so the crude protein content of stillage on a dry basis is about three times that of corn. Previously, we have reported the high metabolizable protein value of the proteins in corn gluten meal (A.S. Leaflet R269, 1978). The purpose of this study was to evaluate wet corn stillage in a feeding trial as a course of supplemental protein for young cattle in comparison with feeding soybean meal, corn gluten meal or urea. The results presented in this report were obtained after the cattle were fed for 168 days. The cattle have continued to be fed these rations to further evaluate replacement of corn with stillage as a source of energy. The final results will be reported later.

Methods

Eighty Charolais cross steers averaging 491 lb. were used in this experiment. The cattle were divided into five outcome groups according to weight and one steer from each group allotted at random to each of 16 pens. The order of rations was then assigned at random to the pens.

The composition of the rations fed the cattle is given in Table 1. The slurry of stillage was obtained from a farm scale experimental still built and maintained by personnel in the Department of Agricultural Engineering. Corn was finely ground and processed in 40-bushel batches in the still once or twice per week. The slurry taken from the still was allowed to settle in a gravity flow grain wagon and water slowly drained from the stillage so the average dry matter of the wet stillage mixed in the ration was 21.5% (ranged from 13.2 to 26.1%). Other chemical data on the stillage are given in Table 2. All the rations contain about 11% crude protein and 60% TDN on a dry basis. The average moisture contents of the soybean, corn gluten, stillage and urea rations were 13.1, 13.2, 42.6 and 13.1%, respectively. The three rations containing preformed protein were formulated to contain 6.3% metabolizable protein. These calculations were based upon 75, 56 and 56% ruminal degradation for the proteins in soybean, corn gluten and stillage and 62, 75 and 90% for the proteins in corn, cobs and molasses.

The cattle were weighed every 14 days after being withheld from feed and water for 12 hours.

Results and Discussion

1. The results are summarized in Table 2 and 3.

2. The chemical analyses indicate the proteins in stillage are similar to those in corn gluten meal. The proteins in stillage and corn gluten, however, were less soluble in artificial saliva and less degraded during a 3-hour period by rumen microorganisms than

the proteins in soybean meal. The higher insolubility of nitrogen of stillage in acid detergent indicates there was some heat damage to the proteins which tends to lower its value as a supplemental protein.

3. During the summer, stillage was stored at the research farm for up to one week with no noticeable spoilage. During the winter, stillage was held for periods up to 2 weeks with no apparent spoilage. The slurry of stillage taken from the still contained 0.5 to 1.0% alcohol which apparently served as a preservative. The mixed feed which contained on the average 43% moisture could be stored for 7 to 10 days at the farm during the winter, but during the summer (mid-June through mid-September), mold developed within 3 to 4 days.

4. The rates of gain were similar for the cattle fed soybean, corn gluten and stillage but greater ($P<.01$) than those fed urea. These higher rates of gain of the cattle fed preformed protein as compared with those fed urea were maintained throughout the 168-day trial. The cattle fed soybean meal consumed more feed (P .01) than those fed any of the other rations. The cattle fed corn gluten meal consumed more feed than those fed urea ($P<.05$), but there were not statistically significant differences between those fed corn gluten or stillage or between those fed stillage or urea. The efficiency of feed conversion was improved ($P<.01$) for the cattle fed soybean, corn gluten or stillage as compared with those fed urea. The cattle fed stillage or corn gluten were also more efficient ($P<.05$) than those fed soybean meal.

5. Based upon the performance of the cattle fed the different

sources of protein in this experiment, the nutritive value of stillage and corn gluten in terms of increased response per unit of supplemental preformed protein was 1.85 and 2.44 times that of soybean meal. This difference in nutritive value resulted from the improvement in feed efficiency of the cattle fed corn proteins and the similar gain response with lesser amounts of supplemental preformed protein. The nutritive value of the corn proteins is probably somewhat over estimated when expressed per unit of supplemental preformed protein because the urea added with these feeds would provide additional metabolizable protein. The higher nutritive value of the corn proteins seems to be the result of less degradation of these proteins in the rumen. This explanation is consistent with decreased degradation of the two sources of corn proteins when incubated with rumen microorganisms.

6. The economic value of the two corn protein supplements in comparison with soybean meal was calculated from the performance of the cattle per unit of gluten meal or stillage dry matter and the different amounts of corn, minerals and urea needed to balance the rations containing the corn proteins. With soybean meal priced at $250 per ton of dry matter delivered to the feedlot, corn gluten and stillage would have a value of $573 and $256 per ton of dry matter. The additional cost of transporting and storing the wet versus dry supplemental proteins would have to be subtracted from the value of stillage.

7. The results of this experiment were those observed over a 168-day period starting with 491 lb. calves fed a control ration with a low concentration of metabolizable protein. The increased nutritive or economic value of the corn proteins over soybean meal

or of the three preformed proteins over urea was observed when supplementation with urea did not result in adequate supplies of metabolizable protein to the animals. As cattle become larger and consume more feed, supplementation with urea alone will eventually provide the metabolizable protein needs of the animals. At that time, preformed proteins would have no additional nutritional value over urea, and the corn proteins would have no additional nutritional or economic value over soybean meal. The point in time when that occurs is determined by two factors. One is the size of the animals with respect to quantity of feed consumed and the amino acids required for weight gain. The second is the ingredient composition of the ration with respect to how closely the ingredients furnish the amino acid needs of the animal without supplementation.

Table 1. Composition of Rations on a Dry Basis

Ingredient	Soybean	Corn gluten	Stillage	Urea
Ground cobs	63.00	63.00	63.00	63.00
Cracked corn	8.57	16.84	6.66	20.84
Molasses	12.00	12.00	12.00	12.00
Soybean meal	15.00	-	-	-
Corn gluten meal	-	5.20	-	-
Stillage	-	-	15.33	-
Urea	-	1.20	1.27	2.30
Dicalcium phosphate	0.96	1.27	1.25	1.33
Salt	0.30	0.30	0.30	0.30
Vitamin A premix	0.12	0.12	0.12	0.12
Trace mineral premix	0.024	0.024	0.024	0.024
Rumensin premix	0.024	0.024	0.024	0.024
Elemental sulfur	-	0.023	0.022	0.057
Calculated crude protein, %	10.8	10.8	10.8	10.9
Analyzed crude protein, %	11.5	10.8	11.6	10.5
Analyzed dry matter, %	86.9	86.8	57.4	86.9
Calculated digestible nutrients, %	60.5	60.1	60.1	59.8
Calculated metabolizable protein, %	6.32	6.35	6.26	5.00

Table 2. Chemical Analyses of Stillage and Other Supplemental Proteins

Analysis	Stillage	Corn gluten	Soybean
Dry matter, %	21.5 (13.2-26.1)	94.9	90.3
Starch, %	20.2 (9.6-25.6)	-	-
Crude protein, %	28.5 (21.9-34.4)	66.0	48.7
Percent of crude protein insoluble[a]	97.2	92.9	57.0
Acid detergent insoluble nitrogen[b], %	15.6	6.9	1.7
Acid detergent fiber	15.2	8.2	11.2
Percent crude protein degraded[c]	57.0	53.0	76.2

[a] Insoluble in simulated cow saliva.

[b] The proteins insoluble in acid detergent are considered to be indigestible.

[c] These estimates were obtained from in vitro experiments in which the feeds were incubated with rumen bacteria for 3 hours.

Table 3. Cattle Performance During 168 Day Feeding Trial

4 pens per ration 5 cattle per pen	Soybean	Corn gluten	Stillage	Urea
Starting weight, lb.	492	490	494	487
Ending weight, lb.	821	820	814	727
Daily gain, lb.	1.96[a]	1.96[a]	1.91[a]	1.43[b]
Daily feed dry matter, lb.	16.2[a]	14.7[b]	14.2[b,c]	13.5[c]
Feed per unit gain, lb.	8.26[a]	7.49[b]	7.48[b]	9.51[c]

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Agriculture and Home Economics Experiment Station
Ames, Iowa, December 1981

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A.S. Leaflet R321

APPENDIX B

METHODS FOR PERFORMANCE EVALUATION OF FERMENTATION FUEL MANUFACTURING FACILITIES

1. Scope *

1.1 This proposed method covers the determination of relative performance characteristics of pre-engineered alcohol manufacturing plants.

1.2 This proposed method is applicable to all fermentable feedstocks.

1.3 This proposed method is applicable to both batch and continuous alcohol manufacturing processes.

2. Applicable Documents

2.1 American Society For Testing and Materials (ASTM) Standards

D-1252 Test for chemical oxygen demand (COD)

D-1293 Test for pH of water

D-1826 Calorific values of gaseous fuels

D-1888 Test methods for particulate and dissolved matter solids in water

D-2382 Heat of combustion of hydrocarbon fuels

D-2458 Flow measurement of water

D-3250 Test for total oxygen demand (TOD)

D-3286 Test for gross calorific values of solid fuels

D-3590 Crude protein analysis

E-100 Specifications for ASTM hydrometers and thermometers

2.2 Association of Official Analytical Chemists (AOAC) Standards

10.142 Test for percent fat content

10.145 Test for percent crude fiber content

10.196 Test for percent moisture of brewers' grain

14.063 Test for percent moisture in feedstocks

14.081-14.082 Starch/sugar assay technique

2.3 American Association of Cereal Chemist (AACC) Standards

76-11 Starch - sugar analysis technique - as modified by Chiang and Johnson (1977)

2.4 American Society of Brewing Chemist (ASBC) Standards

Adjunct Materials Cereals - 3 Corn Moisture Test

Adjunct Materials Cereals - 4 Fat Content Test

Adjunct Materials Cereals - 6 Protein Content Test

Summary of Method

3.1 An alcohol manufacturing plant's performance shall be characterized by four (4) main parameters. These are 1) conversion efficiency 2) energy of conversion

3) production rate 4) mass balance. This proposed method shall establish the procedures required to measure, interpret, and assign values for the parameters. This test method shall be applicable to a broad spectrum of pre-engineered alcohol plants. To this end, some of the testing procedures will be a function of the plant's size and configuration. This method shall consider each plant as a single "black box" with certain necessary inputs and outputs. The advantage of a single black box approach is that it allows the testing of more creative and innovative designs.

3.2 Conversion Efficiency - This parameter represents the plant's ability to convert a feedstock into alcohol. This shall be expressed as the ratio between the yield per unit mass of the feedstock.

3.3 Energy of Conversion - This parameter reflects the energy required to run the process. There is a non-linear relationship between the final alcohol product proof and the energy required to process it.

3.4 Production Rate - This third parameter of performance expresses the plant's ability to convert a feedstock to alcohol during a specified unit of time. Since this proposed method shall apply to a large variety of plant sizes and configurations, this parameter can be expressed as the total alcohol yield (in moisture-free fuel ethanol) divided by the cycle time in hours.

3.5 Mass Balance - This performance parameter reflects the plant's ability to generate usable "co-products" in addition to alcohol. This shall be represented as a mass ratio between the inputs of feedstock and outputs of alcohol (as moisture-free fuel ethanol) and moisture-free distiller's grain and/or applicable moisture-free co-products.

3.6 By repeated application of these proposed methods, a performance curve shall be generated which represents the parameters described as a function of the plant's designed proof-range of operation.

4. Significance and Use

4.1 This proposed test method shall yield data that will form a "performance profile" for an alcohol manufacturing plant. The significance of this profile is that it can be compared to another plant's performance profile and yield a relative measurement and shall provide a measure of expected plant performance under field conditions. Based on the four (4) main parameters highlighted earlier, two (2) alcohol plants of significant different designs can be relatively evaluated.

4.2 The single "black box" technique applied to performance evaluation looks at only the gross input/output relationship. This implies that the operation of the plant during the tests shall be maximized within the limits of the prescribed test conditions and shall be consistent with good engineering practice.

5. Terminology

5.1 Definition

5.1.1 Pre-engineered alcohol manufacturing plant - An alcohol manufacturing plant that is designed for replication of a prototype.

5.1.2 Moisture-free fuel ethanol-- Ethyl alcohol that is fuel grade and free of water.

5.1.3 Fermentation cycle - The series of operations required to process the typical displacement volume of the fermentation system. In a batch fermentation process, the typical displacement volume is equal to one batch. In a continuous fermentation process, the typical displacement volume is equal to the sum of the volumes of each stage of fermentation.

5.1.4 Cycle Time - The time required by an alcohol plant to complete one fermentation cycle.

6. Procedure

6.1 This proposed method calls for the measurement of the major inputs/outputs of a plant's operation throughout the specified test period. This test shall consist of no less than five (5) consecutive fermentation cycles after the plant has reached normal operating conditions. Those inputs to be measured are fuel, electrical power, feedstock, and process water. Not included as measured inputs are the in-process chemicals, enzymes/yeasts, and water used for heating/cooling. However, these materials must be specified by the manufacturer along with the approximate quantities used. The outputs to be measured are alcohol, distiller's grains (or applicable usable feedstock co-products) and waste process water. The necessary measurements, recommended methods, and calculations to quantify the four (4) parameters are as follows.

6.2 Conversion Efficiency: Using the manufacturer's specified feedstock, calculate the theoretical starch/sugar content by AOAC test 14.081 - 14.082, or AACC test 76-11. From this, calculate the theoretical alcohol yield by using the following relationship: 1 unit mass starch/sugar = .57 unit mass moisture-free fuel ethanol. The actual yield shall be measured and adjusted to moisture-free fuel ethanol equivalents. The ratio of actual to theoretical yield represents the conversion efficiency for the process.

6.3 Energy of Conversion: This parameter is a function of the proof of the ethanol produced. It is represented as a ratio of the energy input to the alcohol output. Energy input shall be the sum of the measured electrical power demand plus the fuel input. Fuel input shall be expressed as fuel rate x heat value/unit measure. Recommended tests for heat value of fuel are D-2382, D-1826, and D-3286. Alcohol product output is the production quantity measured as moisture-free fuel ethanol during the cycle time.

6.4 Production Rate: This relationship shall be expressed as the total measured alcohol yield (in moisture-free fuel ethanol equivalents) divided by the cycle time in hours.

6.5 Mass Balance: Performance according to this parameter shall be expressed as the mass ratio of inputs to outputs during the cycle time. Input is feedstock. Feedstock mass shall be calculated by quantity measurement corrected for percent moisture by AOAC test 14.063 or ASBC test AMC-3. Process water quantity shall be determined with ASTM D-2458. Process water quantity must be recorded while not represented in the calculations. Input water "quality" while not represented in the calculations, is a necessary measurement. ASTM D-1293, D-1888, E-100, and applicable potable water standards shall be used. Outputs are alcohol and distillers grains (or equivalent). Mass quantities of alcohol shall be expressed as moisture-free fuel ethanol. Distillers grains are a measured quantity with adjustments for moisture content. AOAC test 10.196 shall be used for these adjustments. Quantative analysis shall be determined with ASTM D-3590, AOAC 10.142, AOAC 10.145, or ASBC AMC-4, ASBC ASM-6. Waste process water is a measured quantity according to ASTM D-2458 while not being represented in the calculations.

7. Calculation

7.1 Format for reporting data - As described in 3.6 an alcohol plant's performance is a function of proof. There shall be a set of data that forms a profile for that proof. Each cycle of operation during the test shall generate data that can be reported.

7.2 Data Collection - (See Attached Form)

7.3 Data Calculations - (See Attached Form)

7.4 Data Summary - (See Attached Form)

8. Precision and Accuracy

8.1 Because of the large number of variables, reproducability of results is not anticipated. Therefore, the results should not be considered as absolute measurements, but should be used only for relative performance appraisal.

7.2 DATA COLLECTION

Start/Finish Date ____________

Start/Finish Time ____________

Ambient Temperature (°F) ____________

Cycle Time (HRS) ____________

Type of Fuel ____________

Measured Fuel Use (units of volume) ____________

Measured Electrical Power Use (BTU) ____________

Feedstock Type ____________

Measured Feedstock Used (LBS) ____________

Percentage Moisture of Feedstock (%) ____________

Percentage Starch/Sugar Content (%) ____________

Enzymes/Process Chemicals Used - List Separately

Amounts (LBS) ____________

____

____

____

Measure Amount of Water Used in Process (GAL) ____________

Water Temperature (°F) ____________

Measure Amount of Water Used in Non-process (GAL) ____________

Water Temperature (°F) ____________

Measure Amount of Alcohol (GAL) ____________

Measured Product Proof ____________

Product Temperature (°F) ____________

Measured Amount of Distillers Grains or Equivalent (LBS) ____________

Measured Percentage Moisture of Distillers Grains (%) ____________

Water Quality Analysis ____________

Process Water ____________

Waste Water ____________

7.3 DATA CALCULATIONS

1) $$\text{Conversion Efficiency} = \frac{\text{Actual Alcohol Yield}}{\text{Theoretical Alcohol Yield}} = \underline{\qquad\qquad}$$

$$\text{Where Theoretical Yield} = \left(\left[\frac{\text{Measured \% 1-Moisture}}{100\%}\right] \times \left[\text{Measured Amount of Feedstock}\right]\right) \times \left[\text{Measured \%Starch/Sugar Content}\right] \times .57 = \underline{\qquad\qquad}$$

$$\text{Actual Yield} = \left[\text{Measured Alcohol Amount}\right] \times \left[\frac{(\text{Measured Proof})}{200}\right] = \underline{\qquad\qquad}$$

2) $$\text{Energy of Conversion } \frac{\text{BTU}}{\text{GAL}} = \frac{\text{Energy Input}}{\text{Alcohol Output}} = \underline{\qquad\qquad}$$

$$\text{Where Energy Input} = \left[\text{Measured Elec. Power (BTU)}\right] + \left(\left[\text{Measured Fuel Use}\right] \times \left[\text{Fuel Heat Value (BTU)}\right]\right)$$

$$\text{Alcohol Output} = \left[\text{Measured Alcohol Amount}\right] \times \left[\frac{\text{Measured Proof}}{200}\right]$$

3) $$\text{Production Rate (GAL/HRS)} = \frac{\text{Alcohol Output}}{\text{Cycle Time}} = \underline{\qquad\qquad}$$

$$\text{Where Alcohol Output} = \left(\text{Measured Amount of Alcohol}\right) \times \left(\frac{\text{Measured Proof}}{200}\right)$$

4) $$\text{Mass Balance} = \frac{\text{Input Mass}}{\text{Output Mass}} = \underline{\qquad\qquad}$$

$$\frac{\text{Input Mass}}{\text{Alcohol Output}} = \underline{\qquad\qquad}$$

$$\frac{\text{Input Mass}}{\text{Distillers Grains Output}} = \underline{\qquad\qquad}$$

$$\text{Where Input Mass} = \left(\text{Dry Feedstock Mass}\right)$$

$$\left(\text{Dry Feedstock Mass}\right) = \left[\text{Measured Feedstock}\right] \times \left[1 - \left(\frac{\text{Measured \% Moisture}}{100\%}\right)\right]$$

$$\text{Output Mass} = \left[\text{Alcohol Output}\right] + \left[\text{Distillers Grains Output}\right]$$

$$\text{Alcohol Output} = \left(\left[\text{Measured Alcohol}\right] \times \left(\frac{\text{Measured Proof}}{200}\right)\right) \times \left(6.625 \text{ LBS/GAL}\right)$$

$$\text{Distillers Grains Output} = \left[\text{Measured Distillers Grain Output}\right] \times \left[1 - \left(\text{Measured \% Moisture} \,/\, 100\%\right)\right]$$

7.4 DATA SUMMARY

Results from the five data points can be summarized as follows:

Conversion Efficiency

Highest Value ______________

Lowest Value ______________

Average of the Five Values ______________

Energy of Conversion

Highest Value ______________

Lowest Value ______________

Average of the Five Values ______________

Production Rate

Highest Value ______________

Lowest Value ______________

Average of the Five Values ______________

Mass Balance

Input mass / output mass ratio

Highest Value ______________

Lowest Value ______________

Average of the Five Values ______________

Input Mass/Alcohol Output Ratio

Highest Value ______________

Lowest Value ______________

Average of the Five Values ______________

Input Mass/Distillers Grains Output Ratio

Highest Value ______________

Lowest Value ______________

Average of the Five Values ______________

APPENDIX C

COST PER GALLON OF ETHANOL

PROFITABILITY STATEMENT COMPARISON

Expenses	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	S-10	S-11	S-12
Operating Labor	1.42	.30	.78	.40	.40	.88	.24	.14	.66	2.22	.31	.13
Materials												
Corn	1.54	1.41	1.36	1.27	.93	1.25	.95	1.02	1.02	1.30	1.04	1.09
Fuel	.22	.25	.06	.02	.01	.04	.10	.01	.01	.77	.33	.32
Electricity	.14	.05	.06	.05	.04	.05	.04	.05	.05	.05	.04	.12
Water		.03			.02		.006	.002				
Supplies	.22	.15	.08	.15	.12	.12	.065	.135	.61	.12	.10	.29
Sub Total	3.54	2.19	2.34	1.89	1.52	2.34	1.40	1.36	1.85	4.46	1.82	1.95
Repairs & Main.	.71	.02	.01	.05	.03	.05	.03	.01	.04		.05	.01
Insurance		.02	.01	.01	.05	.005	.02	.013	.04		.01	.04
Taxes			.01				.0015	.01				
Depreciation		.10		.04	.07	.10	.14	.057	.15	.06	.05	
Capital costs	1.18		.23									.32
Other							.19	.07				
Transportation		.01	.01	.01	.01	.01		.02	.01		.01	.01
Sub Total	1.89	.15	.27	.11	.16	.16	.38	.17	.24	.06	.12	.38
TOTAL EXPENSES	5.43	2.35	2.61	2.00	1.68	2.50	1.78	1.53	2.09	4.52	1.94	2.33
Revenue												
Ethanol	1.70	1.80	1.50	1.30	1.26	1.30	1.70	1.33	1.30	1.00	1.30	1.40
Distillers grns.	.97	.59	1.00	.64	.68	.95	.56	.45	.64	.75	.57	.76
Ethanol incent.			.30	.30	.30	.30			.30	.30	.30	.47
TOTAL REVENUE	2.67	2.39	2.80	2.24	2.24	2.56	2.26	1.78	2.24	2.05	2.17	2.63
NET PROFIT	-2.76	.05	.19	.24	.56	.06	.48	.25	.15	-2.47	.23	.30