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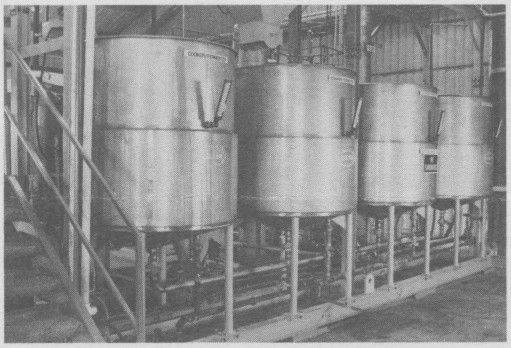
Production and Use of Alcohol on the Farm



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Production and Use of Alcohol on the Farm

Henry O'Neal and Joe M. Rothe*

To become energy independent, many agricultural producers have considered on-farm fuel production. The most popular home-made fuel is ethyl alcohol (ethanol) produced from feedstocks such as corn, grain sorghum, wheat, potatoes, sugar cane, sugar beets and sweet sorghum.

The technology for alcohol production is ancient. It has been used primarily for producing beverages so many people believe alcohol production is as easy as making corn liquor. However, moonshiners produce a product of only 80 to 100 proof. Modern alcohol fuel plants produce a product up to 200 proof in large quantities. Such production is not a simple operation and takes careful planning and processing.

Alcohol Fuel Plant Bonds and Permits

Bond Requirements

Bond requirements for alcohol production are based on the number of proof gallons produced annually by a given plant. A proof gallon is one gallon of 100 proof alcohol. For example, one gallon of 200 proof alcohol is the equivalent of two proof gallons. One thousand gallons of 200 proof alcohol equals 2,000 proof gallons (1,000 gallons x 200° ÷ 100 = 2,000 proof gallons).

An operations or surety bond must be submitted to the Bureau of Alcohol Tobacco and Firearms (ATF). The amount depends on the plant size. ATF categorizes alcohol fuel plants into three sizes based on the number of proof gallons produced by a plant annually. The three categories and corresponding bond requirements are as follows:

Small plant: A facility producing no more than 10,000 proof gallons annually. There is no bond requirement for this size plant.

Medium plant: A facility producing 10,000 to 500,000 proof gallons per year. The *face* amount of the bond ranges from a minimum $2,000 to a maximum $50,000 depending on the production volume. To calculate the amount of bond, figure $1,000 for each 10,000 proof gallons (or fraction) produced. Therefore, 30,000 proof gallons would require a bond of $3,000. This does not mean you pay $3,000. The cost of the bond is similar to the premium paid for an insurance policy. Only a fraction of the face amount is actually paid.

Large plant: A facility producing more than 500,000 proof gallons per year. The face amount of the bond is a minimum $50,000 plus $2,000 for each additional 10,000 proof gallons (or fraction) produced. The maximum bond is $200,000 regardless of yearly production.

Permit Requirements

Federal Permits: Applications for a federal permit to establish an alcohol fuel plant may be obtained from the:

Regional Regulatory Administrator
Bureau of Alcohol, Tobacco and Firearms
Main Tower, Room 345
1200 Main Street
Dallas, Texas 75202

State Permits: A Local Industrial Alcohol Manufacturer's Permit is required to produce fuel alcohol in Texas. It is issued by the Texas Alcoholic Beverage Commission.

Applications for the permit may be obtained from Texas Alcoholic Beverage Commission district offices. Local commission inspectors also have application blanks available.

The Texas Clean Air Act authorizes the Texas Air Control Board (TACB) to regulate the emissions of air contaminants through the permitting of certain new construction and renovations. Because an alcohol production facility involves the handling, storing and processing of grain, as well as the possible use of a boiler for steam production, it requires a construction permit or an exemption from the permit procedures.

The type and size of an operation, the proposed abatement equipment and the location determine if a facility qualifies for a permit exemption. If a facility is considered an insignificant source of air pollution it may be exempted.

The TACB permit application requests an area map of the plant location, a legal description of the property, a plot plan of the property showing all emission sources, a process flow diagram and

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a description of the process. In addition, detailed descriptions and drawings must be supplied for all air pollution abatement equipment. This includes product receiving and processing rates, as well as an estimate of the type and quantities of air contaminants to be emitted.

Direct any questions about the permit procedures to the:

Texas Air Control Board
Permits Section
6330 Highway 290 East
Austin, Texas 78723
512-451-5711

Selecting an Alcohol Production Plant

One of the most important considerations in producing alcohol is the type of production plant to be used. Designs vary depending on the size of the operation, degree of automation and desired alcohol proof level. Most plants consist of at least a grinder, cooking tank, fermenting tank, distillation column, condenser, boiler, pipes, pumps, gages and controls. Some plants have separate cooking and fermenting tanks while others perform the two processes in the same tank.

Most farmers interested in an alcohol fuel plant will either purchase plans and build the plant from scratch or purchase the complete system. When building the plant yourself, consider the following:

1. Before purchasing any plans, ask if an alcohol plant has actually been built from them. Ask for the location and visit the owner. Ask the owner what successes and problems he has had.
2. Do the plans provide sufficient detail to build the plant? You need more than just a schematic plan showing layout. The most complex component design is the distillation column.
3. Consider the construction materials. The cooker may be made from mild steel or stainless steel. For a separate fermenter tank, use mild steel, stainless steel, copper, wood, fiberglass, reinforced plastic or concrete coated on the inside with sprayed-on vinyl. Stainless steel is recommended for the distillation columns. The distillation process is highly corrosive to mild steel.
4. Can the still be cleaned in place or disassembled for easy cleaning?
5. Before purchasing plans, study what is involved. Determine if there is a market for the by-products or if there is a use for these by-products on your farm. Take a look at the economic feasibility. Unless the primary reason for building an alcohol production plant is to be fuel independent, you may find it more feasible to continue purchasing petroleum fuel from a distributor. Also consider the reports, permits and bond required for alcohol production.
6. Do you have the appropriate shop facilities and tools for fabricating the equipment?

Before purchasing a manufactured unit, consider the following:

1. Find out if the manufacturer has units in operation. Visit these units and ask questions.
2. Will the sales company provide the training necessary to successfully operate the facility? Training should include both fermentation and distillation procedures.
3. Determine the amount of daily labor required to operate the production unit. If you cannot give adequate time to your alcohol operation, you may have to hire labor or leave the unit idle. Even your own labor is not free. Consider the opportunity costs of using your time on this operation instead of other farm projects.
4. The plant manufacturer should be able to guarantee the following production factors:
   - Yield factor (gallons of alcohol produced per unit volume or weight of feedstock at a given dry starch and/or sugar content; for example, gallons per bushel or ton)
   - Production proof
   - Distillation rate
   - Gallons of fuel or cubic feet of natural gas required per gallon of alcohol produced
   - Water requirements
   - Electricity requirements

Production Steps

The production process and recipe for making ethyl alcohol varies. However, the basic steps for producing alcohol through fermentation of grain are the same. These steps include grinding the grain, cooking, saccharification, fermentation and distillation.

Grain is ground into a fine meal to expose the starch for conversion to sugar. A hammer mill or roller mill may be used. Cooking the grain ruptures the starch cells, making them more accessible for conversion to sugar. A liquefying enzyme is used in this step. Saccharification is the conversion of starch to fermentable sugars by addition of a saccharifying enzyme. Fermentation is the conversion of sugar to alcohol by yeast. The fermented mixture is referred to as beer, which contains 8 to 10 percent alcohol.

The final step is distilling the beer. Distillation separates the alcohol from the beer by boiling off or vaporizing the alcohol and condensing the vapor to a liquid. Most small scale alcohol plants will have two distillation columns, a beer column and a refining column, to produce up to 190 proof alcohol. The production of 200 proof alcohol will require an additional distillation or drying process and will probably not be done in most small or farm-scale production plants.

For a more detailed explanation of the production process of ethyl alcohol, refer to Extension publication B-1374 *Ethyl Alcohol Production.*

By-Product Use

After producing alcohol from grain, there will be a grain and water residue commonly called stillage. This stillage will be the primary by-product in on-farm plants. Depending upon the process conditions, about 30 gallons of stillage is produced from a bushel of original grain. The stillage is low in dry matter, approximately 5 to 10 percent. This material has been fed to livestock with varying success.

If the stillage is run through a press or filter, much of the liquid is removed and wet distillers grain remains. The distillers grain may be used for the protein portion of livestock rations. It has a moisture content of 65 to 75 percent.

Stillage yields about 8 pounds of distillers grain (dry basis) per bushel of grain processed and contains 27 to 28 percent protein. About 8 to 9 pounds of grain residue remain as solubles in the water. If the wet distillers grain is processed further through drying, it is referred to as distillers dried grain (DDG).

Water separated from the stillage may be eliminated, returned to the cooker and reused or processed to produce distillers dried solubles. When the dried solubles and dried grain are combined, they are called distillers dried grain and solubles (DDGS). Drying the distillers grain and solubles consumes large amounts of energy and requires a significant investment in capital equipment. In a small-scale production plant, the drier probably should not be included and the wet distillers grain fed to livestock. The wet grains should be fed to livestock within 1 to 2 days to avoid spoilage.

Before constructing an alcohol fuel plant, decide what to do with the by-product. You could sell it to a local feedlot or use it on the farm as a feed supplement. Either way, it is important to use the by-product to reduce production costs and enhance the economic viability of the alcohol fuel plant.

Determine if a market exists and to what extent the by-product has to be processed. The more by-product processing involved, the higher the cost. Most small-scale alcohol fuel plants cannot economically justify complete by-product dehydration. Also keep in mind the distance between your operation and the market and the cost of transportation. Costs are greater for high-moisture by-products.

Use of Ethyl Alcohol as a Fuel

Gasohol

Gasohol is a mixture of 10 percent anhydrous or water-free (200 proof) ethyl alcohol and 90 percent unleaded gasoline. Even small amounts of water in the alcohol/gasoline blend results in an alcohol-water attraction, causing the alcohol and water to separate from the gasoline. This is known as phase separation and causes erratic engine performance. Most small-scale distilling units produce 160 to 190 proof (5 to 20 percent water) alcohol, which cannot be mixed successfully with gasoline.

Engine modifications are not necessary to use gasohol. However, because alcohol is a solvent, it dissolves buildups of gum and varnish in the fuel system, which may clog the fuel filter. Probably only one fuel filter change will be required.

Octane rating measures a fuel's resistance to auto-ignition. High octane fuels promote smooth burning in spark ignition engines while low octane fuels cause knocking and auto-ignition. Because alcohol has a high octane rating, gasohol has a slightly higher octane rating than gasoline alone. For most vehicles, the performance of gasohol should be the same as that of gasoline with the same octane rating.

Straight Ethyl Alcohol for Spark Ignition Engines

One hundred ninety proof, and possibly as low as 160 proof alcohol, can be burned directly in a spark ignition engine without gasoline. The primary modification required for successful performance is to increase the fuel jet orifice diameter in the carburetor. The increased jet size meters an energy charge equivalent to gasoline. It takes about 1.8 gallons of 160 proof alcohol or 1.5 gallons of 190 proof alcohol to replace 1 gallon of gasoline. Alcohol does not vaporize as readily as gasoline so it may be necessary to add a small gasoline tank to allow starting on gasoline, then switching to alcohol. Alcohol may also be vaporized by using engine heat, and taken into the carburetor much like LP gas.

Part of the alternate fuels program in the Agricultural Engineering Department at Texas A&M University is a long-term (1,000 hours) engine test using alcohol. Although straight alcohol performs in spark ignition engines, engine wear under long-term use and any unusual maintenance considerations need to be documented.

Ethyl Alcohol for Diesel Engines

Direct use of alcohol in diesel equipment is unlikely without major modifications to the engine. Lower proof alcohol may be used to supplement diesel fuel through fumigation. This method carburets or injects alcohol into the intake air of diesel engines, while diesel fuel is still supplied by the diesel injection system. This increases the power output of the engine because more energy is introduced into each cylinder.

Mixing anhydrous alcohol and diesel fuels has been investigated at universities other than Texas A&M. During field tests on tractors, fuel consumption for diesel/alcohol blends exceeded diesel fuel in nearly all operations. This is because the heat value of alcohol is lower than diesel fuel. Engine noise also increased as the alcohol content of diesel/alcohol blends increased.

Diesel/alcohol blends, like gasohol, can undergo phase separation if the fuel blend contains even small traces of water. Anhydrous alcohol (water free — 200 proof) must be used when blending with diesel fuel. Most alcohol produced on the farm will be less than 200 proof and not suitable for blending.

Production Costs*

The following cost estimates are based on physical data obtained from trial runs of the Texas A&M University alcohol plant. Costs for materials, supplies, fuel, etc. are either actual or typical costs for the local area. In some cases, costs had to be estimated.

For any given plant size and type, total costs will vary by the intensity or degree of plant utilization. Costs drop as the degree of plant utilization increases due to price discounts on volume buying of supplies; more efficient use of heat, water and labor; and, most importantly, lower fixed cost per unit of output.

To emphasize the range of costs for different levels of plant utilization, this study presents two cost estimates. The first is a one-batch or 30-gallon per day operation producing 9,000 gallons per year based on a 300-day operation. This is the current capacity of the Texas A&M plant, which is limited by the number and size of the fermenters. The plant cost is approximately $90,000 without a building.

The second set of costs is for a continuous, 24-hour per day operation producing 144,000 gallons per year. To reach this capacity, the Texas A&M plant would need larger and additional fermenters and a larger, more efficient boiler. Not including a building, the total investment is estimated to be $125,000.

Variable Costs

Variable costs are those which vary with the volume of production and could be reduced to zero or near zero if production stopped. However, some of the variable costs of certain plants, when calculated on a per gallon of output basis, change little with changes in annual output. Other variable costs per gallon of output typically decrease as annual output increases due to price discounts on volume purchases of supplies and more efficient use of energy and labor. Estimates of variable costs for the two cases are shown in Table 1.

The continuous or 144,000 gallon per year case has lower estimated costs for natural gas because heat is maintained constantly; for labor because of better utilization; and for enzymes because of price discounts on volume buying.

Fixed Costs

Fixed costs are primarily those associated with ownership of the plant. *Total* fixed costs change little if any with volume of output for a given plant. However, average fixed costs *per unit* of output decrease as output increases. Fixed costs for the two sample cases are shown in Table 2.

The wide range in average fixed cost per gallon is typical of the differences found for low and high degrees of plant utilization. Since total fixed costs are constant or nearly so for a given plant configuration, fixed cost per unit of output will drop rapidly as annual output increases.

Total Costs

Total cost per gallon of production is simply the sum of variable and fixed costs. Table 3 summarizes the cost for both cases.

There are two main conclusions to be drawn from these cost figures: 1) it is difficult for small-scale alcohol plants (particularly part-time operations) to be cost competitive with large commercial plants and 2) plants must be operated at full capacity around the clock to keep fixed cost per gallon as low as possible and to minimize some of the variable costs, particularly labor.

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*This information was prepared by Ronald D. Kay and Ronald C. Griffin; respectively, associate professor and assistant professor, Department of Agricultural Economics, Texas Agricultural Experiment Station, The Texas A&M University System.

Table 1. Variable Costs for Ethyl Alcohol Production for Two Representative Plant Sizes

	Variable Cost Per Gallon (182 Proof)	
	9,000 gal./year	144,000 gal./year
Corn (@ $3.25 per bu. with 2.5 conversion rate)	$1.30	$1.30
Natural gas ($3.00 per MCF)	0.24	0.12
Labor ($8.00 per hour)	1.60 (0.2 hr.)	0.40 (0.05 hr.)
Electricity (6¢ per kilowatt-hour)	0.06	0.06
Water heat exchanger water reused ($1.00 per 1,000 gallons)	0.02	0.02
Enzymes and yeast	0.20	0.16
Other chemicals	0.01	0.01
Repairs	0.01	0.01
Subtotal	$3.44	$2.08
Less by-product credit (not including solubles) 3.2 lbs. @ 8¢	−0.26	−0.26
Total Variable Costs	$3.18	$1.82

Table 2. Fixed Costs for Two Representative Plants and Scale of Operation

	Total Fixed Cost	
	9,000 gal./year	144,000 gal./year
Capital recovery (depreciation and interest)		
$ 90,000 × 0.1598	$14,382	
$125,000 × 0.1598		$19,975
Insurance (estimated)	500	650
Property taxes (estimated)	900	1,250
Misc. (permits, bonding, etc.)	200	500
Total Fixed Costs	$15,982	$22,375
Average Fixed Cost Per Gallon	$1.78	$0.16

Assumptions: Salvage value — $0
Useful life — 20 years
Interest rate — 15%

Table 3. Total Cost of Ethyl Alcohol Production for Two Representative Plant Sizes

	Total Cost Per Gallon	
	9,000 gal./year	144,000 gal./year
Variable cost	$3.18	$1.82
Fixed cost	1.78	0.16
Total Cost per Gallon of 182 Proof Ethyl Alcohol	$4.96	$1.98

Glossary

Alcohol: the family name for a group of compounds such as methyl alcohol, ethyl alcohol, isopropyl alcohol and others.

Anhydrous ethyl alcohol: 100 percent alcohol or 200 proof alcohol.

Beer: fermented ethyl alcohol feedstock.

BTU: British Thermal Unit. The quantity of heat needed to raise one pound of water one degree Farenheit.

DDG: Distillers Dried Grain. Dried solids that have been separated from stillage.

DDS: Distillers Dried Solubles. Dried solubles that have been separated from the liquid portion of stillage.

DDGS: Distillers Dried Grain and Solubles. Mixture of DDG and DDS.

Denaturant: substance added to ethanol to make it unfit for drinking without impairing its usefulness for other purposes.

Enzymes: any of numerous complex proteins which act as catalysts to change one chemical compound to another chemical compound.

Ethanol: same as ethyl alcohol.

Ethyl Alcohol: An alcohol that may be produced by fermentation. Can be burned as a fuel.

Feedstock: the raw material fermented to yield ethyl alcohol.

Gasohol: a blend of 10 percent anhydrous alcohol and 90 percent unleaded gasoline.

Proof: a measure of alcohol content. Proof is twice the percentage of alcohol, i.e. 200 proof is 100 percent alcohol.

pH: a measure of acidity or alkalinity on a scale of 0 to 14. The lower the pH, the higher the acid content. The higher the pH, the more alkaline. Neutral is pH7.

Saccharification: the breaking of complex carbohydrates (starch) into simple sugars.

Stillage: the residue left after distillation of fermented beer.

Yeast: a microorganism used to convert sugar into alcohol through fermentation.

Conversion Factors

1 gallon water = 8.34 pounds (at 60°F) = 0.134 cubic foot = 128 fluid ounces = 4 quarts = 8 pints = 3.785 liters

1 gallon of 200 proof ethyl alcohol weighs 6.6 pounds

1 BTU = heat required to raise 1 pound of water 1 degree Fahrenheit (°F).

1 bushel = 1.24 cubic feet

1 bushel of corn or grain sorghum = 56 pounds

1 United States liquid gallon = 4 quarts = 231 cubic inches = 3.78 liters

1 liter = 1.057 United States liquid quarts

1 fluid ounce = 29.6 milliliters

1 pound = 453.6 grams

1 cubic foot = 7.48 liquid gallons = 62.4 pounds H_2O (at 60°F)

1 acre = 43,560 square feet = 4,840 square yards

To convert from °F to °C, subtract 32 and then multiply by 5/9.

To convert from °C to °F, multiply by 9/5 and then add 32.

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