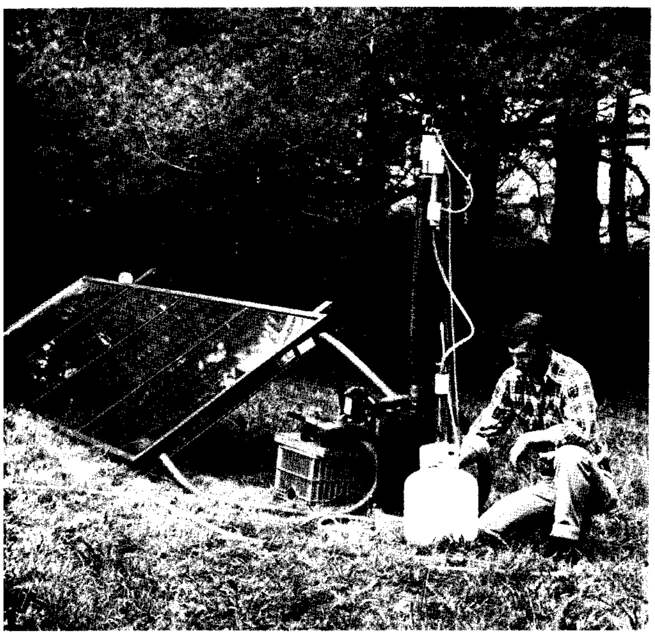
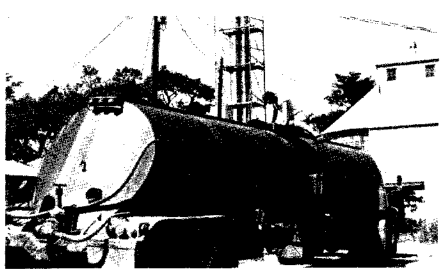
Alcohol fuel

Can you make your own?





Alcohol still linked to solar panel, above, looks impressive—but results were poor. At right, Dennis Day, atop tanker, checks fermentation progress of 3000 gallons of mash. His tall still is at rear.

Yes—but it may not be as cheap, economical, or practical as some claim

By RAY HILL

Besides my mortgage payments, my biggest yearly expense is for fuel. Gasoline for my cars, motorcycles, lawn mower, chain saw, and portable generator. Heating oil for the furnace. Propane for the kitchen stove, outdoor grill, and the furnace and cookstove in my RV.

Would I be happy to eliminate that expense? You bet. And according to the instruction manual that comes with one alcohol-producing still, I can. "Congratulations," it says. "You have just taken a major step toward energy independence."

It goes on to say that by using the still I can fill all my "auto- and heating-fuel needs at little or no cost." Other makers of stills sometimes make similar claims.

Can I really make my own fuel for little or no money? To find out, I traveled around the country and talked to people who have built and are operating alcohol stills of varying sizes and sophistication—some small and simple, others very large and complex.

I talked with scientists and others knowledgeable in alcohol production. I even called the maker of the alcohol still with the instruction manual that promises so much. How would he like to personally demonstrate his still to me? He would.

Here is what I learned from my investigation.

You *can* make alcohol fuel. There are stills on the market that work. There are some that don't. And there are some that don't work as well as their over-eager sellers would lead you to believe.

The problem isn't so much in making the alcohol; the basic techniques have been around for thousands of years. You use yeast to convert sugar into alcohol (fermentation), then refine this rather weak mixture to remove most of the water and get a highly purified product (distillation). That product is ethyl alcohol, also called ethanol. The difficulty comes from two main sources. First, the process, so simple in principle, is very tricky in practice. And second, it isn't cheap. Both the raw materials and the energy needed to turn them into alcohol can be expensive.

A lot of ambitious hopes have been dashed against these twin rocks of reality. For example, Sue Shellenbarger, a *Wall Street Journal* reporter, recently investigated the problems some people encounter when they try to make alcohol fuel. One man, she reported in her article, has spent more than $144,000 over a one-year period on an alcohol plant. His return so far: about 300 gallons of low-grade alcohol.

"Anybody who tells you that learning to make fuel-grade alcohol in any quantity is easy isn't telling you straight," Dennis Day told me. Day is a Grimes, Iowa farmer who started out making alcohol on a small scale. After learning the necessary techniques, he constructed a large vacuum-type still with the intention of selling the alcohol commercially. At press time he still didn't have all the bugs worked out of his system, but he was optimistic.

The problems

Alcohol is made from sugar. But in America, regular refined sugar isn't cheap or easily available in large quantities. So the first step is to produce sugar from more readily available sources, such as corn or milo (grain sorghums), which contain a lot of it. You do this by combining water, enzymes, and the grain, and cooking them. This produces a mash in which the enzymatic action and the cooking release the sugar. Then yeast is added and the mash ferments into beer (not to be confused with the stuff you buy in beverage stores). The low-proof beer is then distilled into high-proof ethanol.

Proof is the measure of a liquid's alcohol content. Divide the proof number by two to get the alcohol content. For example, 100-proof alcohol is 50 percent water and 50 percent alcohol; 200 proof is pure or "neat" alcohol. Experts generally agree that fuel-grade alcohol for running an engine should be 160 proof or better. If you're going to make gasohol by mixing alcohol and gas, the alcohol must be 200 proof (anhydrous). Otherwise, phase-separation can occur. This results in the formation of an erratically combustible fluid in the bottom of the gas tank—which can cause an engine to run roughly or die.

Not only is alcohol production tricky, but the cost can be prohibitive. Take my own situation. I don't own a sugar-cane plantation, so my first step is to get sugar from some starchy product such as corn.

It takes a bushel of corn to make 2½ gallons of ethanol. I can't buy corn where I live, but I can buy corn meal. My friendly grocer charges me 63 cents for 1½ pounds of it. A bushel of corn meal (56 lbs.) would cost about $23.50. So that means my feedstock cost alone would work out to $9.40 a gallon—not very economical.

Now you might say: Of course buying corn meal at a grocery store is uneconomical. You should use free potato culls from restaurants, supermarkets, and so on. Well, assuming I can talk the appropriate people into it, I'm talking about large quantities. It takes one ton of potatoes to make about 23 gallons of ethanol. The logistics alone makes this unattractive to me, and probably to many others.

Let's say that I live in a farming community, and don't have any free feedstock. I can go to my local feed store and buy corn at $3.14 a bushel (the cost of corn at one feed store in Kansas at the time this is written; it might be more or less, depending on where you live and the time of year). Then each gallon of alcohol costs me $1.25, just for the feedstock. That's more attractive. But unleaded gasoline at my local gasoline station is selling for $1.29 a gallon. Regular is $1.24.

And I still haven't included the costs for water (one expert recommends 30 gallons for each bushel of corn used), fuel to cook the mash and fire the still, enzymes, yeast, lime, muriatic acid, pH paper, incidental expenses, cost of the still, vessels—and perhaps most importantly, my time.

Regardless of what anybody tells you, making alcohol fuel takes time, and a fair amount of it (see accompanying box, next page, on how to make beer).

But let's say I have access to free corn, and that I have the time needed to make the alcohol. Then the economics would change. The next step is finding a good small still.

How do you know before you buy a still if it's any good? "There's no sure way at the moment," says Ken Runion, a chemical engineer with the National Center for Appropriate Technology (NCAT) in Butte, Montana. NCAT is funded by the government. One of its functions is to develop a program, just now getting started, that will result in an effective low-cost still that a farmer can build, along with good techniques for producing beer. The information about the still and beer-making techniques will be disseminated to farmers as it becomes available.

"One thing to be wary of," says Runion, "is extravagant claims."

A good example is the claim in the instruction manual of the still I mentioned earlier—the one that assured me I could supply all my own fuel needs. The inventor of this still brought it out to my house. After about five hours of operation, using both a solar panel and a 1200-watt electric heater, the unit produced a few spoonfuls of alcohol that, according to a hydrometer connected just under the still's condenser outlet, measured between 140 and 150 proof.

Does that mean all makers of stills make extravagant claims they can't live up to?

No. "It's the same in any new growth industry," says biomass expert John Ferchak, a biochemist at the University of Pennsylvania. Ferchak is part of a research group studying cellulosic-biomass conversion into alcohol. "A few years ago, many small entrepreneurs were trying to get into the solar-energy field producing collectors—and most of them folded. A lot of people came in, without sufficient technical expertise or enough capital

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Making alcohol fuel

To make alcohol fuel legally, you must get a permit from the federal government. Write to the Bureau of Alcohol, Tobacco, and Firearms, Box 15, Church St. Station, New York, N.Y. 10008. This is a regional office. It will issue you a permit (if you happen to live in its region), or it will forward your letter to the BATF office in your region.

For more information on where to buy stills and how to make alcohol fuel, there is a government agency you can call—the Solar Energy Research Institute, in Golden, Colo. The toll-free number is (800) 525-5555 (Colorado residents: call (800) 332-8339).

If you're interested in the still made by the Tallgrass Research Center, you can write to the Center at Route 2, Box 21, Formoso, Kan. 66942. The Center sells everything you need to produce alcohol fuel—enzymes, hydrometers, stills, recipes for making beer, etc.

How to make beer, and how a still works

Making alcohol is basically a three-stage process: Produce a sugary mash, ferment the mash into beer, and then distill the alcohol out of the beer. The procedure involves several steps—most of which can go awry. It's also a fairly tedious undertaking, takes a good bit of time, and can involve quite a bit of tinkering before you get it right.

Two people who have got it right are Lynn Doxon and Bob Brautigam. Together they formed the Tallgrass Research Center to explore various alternate-energy sources. Most of their time is spent on alcohol-fuel production. Doxon is a biologist. Brautigam is an ex-farmer and air-conditioning and refrigeration expert. Together they have put together one of the best small stills we have seen.

The following section describes how Doxon makes beer, a process many people have trouble with, and how a remote-post still, which Brautigam developed, works. Other stills may work a little differently, but the principles are the same.

Sugar can be obtained from any starchy product, such as wheat, corn, milo, oats, potatoes, sugar beets, sugar cane, and so on. Let's say you're using corn.

First, grind the corn to the consistency of corn meal and put it in a container with 15 gallons of water for each bushel of corn used.

Check the pH of the mixture with test paper, available at chemical-supply houses. If it's not between five and six (slightly acid), correct it by adding lime if it is too low or muriatic acid if it's too high.

Add one ounce of an enzyme called alpha-amylase (Miles Laboratories sells this enzyme under the name Taka-Therm) for each bushel of corn. When heated, the enzyme breaks a chemical bond in the starch, liberating complex sugars (which later will be broken down further by another enzyme into simple sugars that can be fermented into alcohol).

Heat the mash slowly and stir until it boils. Then shut the heat off and let it sit for one-half hour or so until it becomes creamy and a little thicker than split-pea soup.

Cool the mash to 130–140 degrees Fahrenheit by adding up to 15 gallons of additional water for each bushel of corn. If you add 15 gallons and the temperature still isn't low enough, let it cool.

Check the pH again, and adjust it if necessary. This time it should be between 3.5 and 4.5.

Add 1½ to two ounces of glucoamylase enzyme (Miles Laboratories calls it Diazyme) for each bushel of corn. This breaks the second of the two bonds between the sugar molecules, liberating the simple sugars.

Cool for two hours. Then add the remainder of the water—if any is left. The mash should now be between 80–90 degrees. If it's hotter, let it cool. Check the pH and adjust it to between 3.5 and five if necessary.

Add two ounces of dry brewer's yeast for each bushel of grain (test first to make sure the yeast is active).

The container must be airtight during fermentation, a chemical reaction during which the yeast consumes the sugar in the mash and produces alcohol and carbon dioxide as waste products. To let the carbon dioxide escape, Lynn Doxon runs a hose from the lid of her airtight container into a quart jar filled with water. The CO_2 will bubble through the water and escape, but air can't get in.

When the water in the jar stops bubbling, fermentation is finished. Fermentation generally takes from two to three days to complete.

When fermentation stops you have beer, which, if everything went well, is about 10 percent alcohol (ethanol).

You can check the percentage with a beer hydrometer. Or you can heat a little of the beer and note at what temperature it starts to boil. Water boils at 212 degrees; pure alcohol boils at 173 degrees. The greater the percentage of alcohol, the lower the boiling point. Beer containing 10 percent alcohol will boil at 190 degrees (see accompanying graph).

To distill the beer into alcohol, pour it into a boiler. Brautigam and Doxon often use a modified 30-gallon oil drum for demonstrations.

In the bottom of the drum is a shaft with blades, which rotates at about 10 rpm. It's powered by a small electric motor. A safety-release valve prevents pressure from rising above dangerous levels.

The boiler is heated by a propane burner. The rotating blades stir the beer during distillation to keep the grain from being scorched. Unlike some people, Brautigam does not remove the grain from the beer before distillation, because he feels you lose some alcohol that way.

With the boiler about three-quarters full—in this case, 20–25 gallons—it usually takes about 30 minutes before the temperature rises to about 200 degrees, enough to vaporize the liquid and force the vapors into the still.

Before the beer vaporizes in the boiler, it is alcohol and water blended together. Once it vaporizes, however, it becomes two separate gases—alcohol vapor and water vapor. Much of the water vapor condenses and falls back into the beer. But the alcohol vapor, along with some water vapor, passes through the vapor line into a pool of water at the bottom of the still—a three-inch-diameter copper tube capped on each end—and quickly warms the water to nearly 200 degrees. (All metal parts are copper—to prevent electrolysis, and because copper provides very good heat transfer.)

The pool, called a doubler, removes much of the water vapor coming from the boiler. But the alcohol vapor and some water vapor pass through the water, rising through the column.

As the alcohol and water vapors rise, they pass through the condensing material in the column, which is made of marbles. At first, the vapors meet the relatively cold marbles and condense, falling back down into the doubler.

But soon the marbles are hot, and vapors rise out of the marbles toward the top of the column.

With the column at operating temperature, the water and alcohol vapors pass around the stripping coil. The temperature of the stripping coil is about 173 degrees, the temperature at which alcohol vaporizes. When the vapors hit the stripping coil, most of the water vapor condenses and falls back down into the marbles, along with some alcohol vapor.

Most of the alcohol vapor continues to rise, passing through the inverted funnel. There it makes contact with the condens-

to make a product that's really efficient. But they got weeded out."

One small still I've seen that works pretty well is made by the Tallgrass Research Center in Formoso, Kansas. It can produce alcohol in the 170–180-proof range at a rate of about 2½ gallons per hour (the accompanying box describes how this still works). Tallgrass sells plans to build this still. Or you can buy a more sophisticated version—which is too difficult for most people to build, but which has a greater capacity and will produce alcohol of around 180 proof.

Bob Brautigam, the still's developer, makes no staggering claims for his still. "What we have here," he says, "is a still the farmer can operate to make alcohol with a minimum of fuss." Some stills require a lot of tinkering just to get them to work, and even then are pretty crude devices. Brautigam's still, once initially adjusted, works pretty much automatically. But it requires fuel to cook the mash and run the still.

And there's the rub. If a still is used only part time, and is relatively small, it may take as much or more energy to make the beer and run the still as you'd get back in the alcohol fuel you produce. But it may not.

Let's take a look at Brautigam's still. He says it takes about 3½ pounds of propane to produce three gallons of 170–180-proof alcohol (this includes cooking the mash as well as running the still). Where I live, propane costs 35 cents a pound. That works out to about 40 cents for propane for each gallon of ethanol produced.

A gallon of 200-proof ethanol produces 84,400 Btu of energy when you burn it; a gallon of 180 proof would produce about 75,960 Btu. A pound of liquid propane contains about 21,000 Btu. So, using Brautiing coil, which is considerably colder than 173 degrees. The alcohol (and any water vapor that managed to make it this far) condenses, and falls down into the inverted funnel, through the funnel outlet into a storage container sitting beside the still.

The temperature of the stripping coil is critical. It must stay as close to 173 degrees as possible, so that only alcohol vapors will rise into the condenser section of the column. It does this with the help of a temperature probe connected by a gas-filled tube to a refrigeration valve (commonly used on water-cooled condensers).

The gas inside this tube expands or contracts in accordance with the temperature probe. The expanding or contracting gases push or pull against a spring-loaded diaphragm in the refrigeration valve, opening or closing the restriction at the outlet end of the stripping coil.

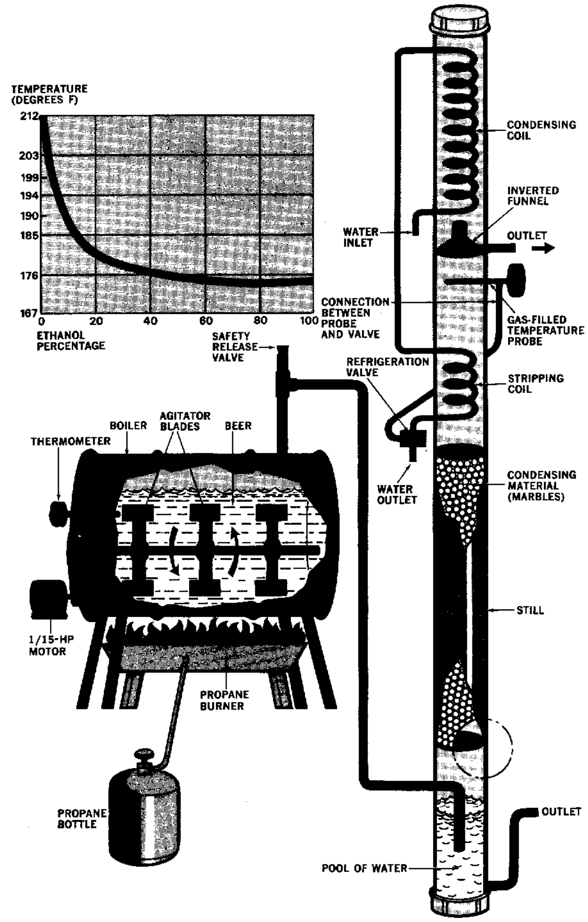
The valve is calibrated so that water flow through the condensing and stripping coils is increased or decreased as necessary to keep the temperature of the stripping coil at 173 degrees.

When the water and alcohol vapors hit the stripping coil and fall back down through the marbles, the water vapor condenses, falls into the pool of water at the bottom, and eventually, as the water level in the pool tries to rise, flows out the doubler's outlet. The alcohol vapor hits the hot marbles, revaporizes, and rises again. This re-evaporation process is referred to by distillers as "reflux action."

This still can produce about 2½ gallons of 170–180-proof alcohol in an hour. If you started out with, say, 30 gallons of 10 percent beer to produce 180-proof alcohol, you would end up with three gallons of 180-proof alcohol, 1½ gallons of runoff water, and 25½ gallons of liquid and grain left in the boiler.

The grain can be removed and dried. It is called Distillers Dried Grain (DDG), and it can be fed to livestock.

Doxon says her figures indicate a farmer can make alcohol fuel for $1.73 a gallon (using his own feedstock). But by using the DDG as feed, that figure can drop to as low as 44 cents a gallon. For each gallon of alcohol made, Doxon says, approximately seven pounds of high-protein DDG is produced.



gam's figures, you are using some 73,500 Btu of propane to produce 227,880 Btu of 180-proof alcohol—an energy surplus.

Better energy efficiency's desirable, though. "The next big step," Brautigam says, "is to cook the mash and fire the still with heat from an inexpensive or free renewable fuel resource." Wood, straw, and other similar combustibles immediately come to mind.

"The trouble with these," he continues, "is that it is very hard to control the rate of burn." And in cooking mash (which is then fermented into beer) and firing the still, you need to be able to control the temperature.

Dennis Will, a vocational agricultural teacher in Chapman, Kansas, has, with his students, built a small, simple pot still that has a firebox under it with dampers that can be opened and closed to control air flow to the burning wood. This, he says, works pretty well on this small still.

Even so, the hardware doesn't exist now to let you burn wood, straw, and similar materials with the ease and temperature control that you can with, say, natural gas.

One possible solution for farmers with livestock might be a methane digester. Livestock produce manure. And manure heated in a methane digester produces methane (nearly identical to natural gas), which could then be stored for use when cooking mash and running the still. But a methane digester and storage system that you can buy does not now exist for use with a still.

Several experts I talked with, though, feel that a methane digester and storage system that will work with an alcohol-production plant will soon be developed. "When that happens," one expert said, "the farmer

[Continued on page 140]

[Continued from page 93]

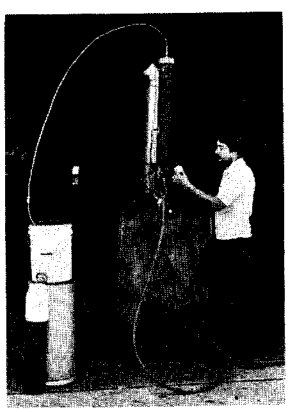
will get a free ride on his heat. Manure doesn't cost anything. And a 300-watt light bulb will supply enough heat to run the digester."

Where does this leave the would-be alcohol producer today? Until hardware becomes available for burning an inexpensive renewable fuel at controlled temperatures to cook mash and operate a still, producing alcohol fuel on a small scale is neither practical nor economical. And with many stills, especially the small stove-top pot stills, the process isn't energy efficient.

However, when alcohol fuel is produced on a larger scale, it can be energy efficient, even when using a nonrenewable fuel to supply heat to operate the alcohol-production plant. An example of this is a $400,000 steam-type still on the Gene Schroder farm in Campo, Colo. The still is owned and operated by the Schroder family, who farms 7000 acres.

The still produces 100 gallons of 200-proof ethanol an hour; currently it is being operated 12 hours a day. But soon Schroder plans to go to round-the-clock operation. The plant is fired by diesel fuel.

A study done by the Solar Energy Research Institute, a government agency in Golden, Colo., indicates that for each gallon of ethanol produced, 29,000 Btu of diesel fuel is used (this includes the heat used to cook the mash, as well as distillation). A gallon of 200-proof ethanol contains 84,400 Btu. When it becomes practical, Schroder plans to switch to a renewable fuel to fire the plant.



Simple pot still designed and built by Dennis Will and his students uses wood or other renewable resource for heat. Fire is built in the bottom of the still, and dampers can be opened and closed to control combustion.

Milo, grown on the Schroder farm, is used as feedstock to make the alcohol. The ethanol is sold for two dollars a gallon.

There are several differences between the Schroder still and small stills you can buy or build. Some of the important ones are these:

- Cost: The Schroder family has spent two years and $400,000 perfecting its alcohol-production facility. Most individuals can't afford that kind of money and time.
- Efficiency: The plant makes extensive use of heat exchangers and heat recycling, something that small stills that are run only a few hours a week can't do very effectively.

A high-quality product—200-proof (anhydrous) ethanol—is the end result. With small, simple stills you are lucky to produce 190-proof ethanol in any volume. A more likely figure is in the 160 to 180 range. And many simple pot stills may not be able to reach 160 with any consistency.

Once you get past 190 proof in the distillation process, you shortly run into something chemists call the azeotropic point. Past this point (which varies, but can be around 195 proof), you can distill all you want, but the ethanol doesn't get any purer. Special, expensive techniques must be employed to remove the remainder of the water. These techniques are not practical or economical on a small scale.

What does the future hold for individuals who want to make alcohol fuel? Professor E. Kendell Pye, a biochemist at the University of Pennsylvania and the director of its cellulosic conversion research program, says, "A farmer can't be expected to run his farm and a still, too. To produce any reasonable quantity of fuel, he would need to run the plant on a 24-hour-a-day basis—for a number of reasons.

"My feeling," he says, "is that the best way to go is for a group of farmers to get together, form a cooperative and run, say, a 10-million-gallon-a-year unit, and train and pay somebody who is technically competent to run the still—someone who doesn't have to go off and feed his chickens or plow the fields whenever the sun shines."

All this doesn't mean that commercially produced alcohol fuel won't play an important role in our future. But as conditions are now, most one-man alcohol-fuel production schemes are not practical or economical. ■