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**Ethanol Is the New Homebrew**

**The E-Fuel 100 allows motorists to make their own ethanol from sugar or even leftover booze**

**Joseph Ogando, Senior Editor -- Design News, July 17, 2008**

A new kind of filling station may soon be coming to a backyard near you, maybe even your own. And these filling stations take self-service to a whole new level because the motorists not only pump their own fuel — in this case ethanol — but also make it from ordinary sugar or even the dregs of a few cocktails.

Called the E-Fuel 100, this self-contained ethanol micro-refinery is aimed at consumers wanting to cut their fuel consumption by topping off their gas tanks with some home-brewed ethanol. The entire system takes up about the same space as a single conventional gas pump. It even looks a little like a conventional gas pump, right down to its hose, nozzle and LCD screen.

Take a look inside the E-Fuel's housing, however, and you will find automated fermentation and solid-state distillation technologies that promise to make home ethanol production a breeze. "Sugar, water, yeast and power go in, ethanol and water come out. It's as simple as that," says Tom Quinn, the Silicon Valley entrepreneur who founded E-Fuel in 2007 with ethanol scientist Floyd Butterfield.

According to Quinn, who's best known as the inventor of the motion control technology used in the Nintendo Wii, the system can produce about 5 gal of ethanol per day with each gallon requiring 10 to 14 lb of sugar. Beet, cane, corn or even cellulosic sugars are all fair game. The units run off of standard 110 or 220V power supplies and typically eat up about 150W of electricity per day. The E-Fuel takes about a week to produce a 35-gal batch of ethanol from sugar. With alcohol as the feedstock, the process takes less time, allowing the machine to turn out 70 gal per week. The system, which starts shipping later this year, will cost $9,995.

Quinn estimates the total cost of the fuel will come to less than $1 per gallon once users take advantage of expected sugar subsidies and carbon offset credits. The economics get even better with booze, which drops the cost per gallon to about 10 cents.

Whatever the feedstock, motorists would typically combine ethanol with gasoline, mixing the two right in the gas tank with the ethanol proportions as high as 65 percent for modern unmodified engines. "People think we need a nationwide, billion-dollar infrastructure just to mix ethanol and gasoline, but that's not necessarily true. They mix well right in the gas tank," he says.

Ethanol production usually takes place in huge commercial plants run by chemical engineers, so designing a system simple and safe enough for consumers to use was no easy task. In fact, Butterfield and Quinn had to completely rethink how the fermentation and distillation would work at a small scale, as well as develop a control system that makes these processes transparent to the user. The system they came up with in some ways has more in common with a consumer electronic device than a conventional refinery.

**Home Brew Breakthroughs**

The E-Fuel's technical innovations start on its fermentation side, where a tailor-made yeast strain developed by Butterfield converts sugar to alcohol. "Fermentation has been around for 2,000 years and hasn't changed all that much," says Quinn. Yet, the E-Fuel really does change things when you consider the way it maintains ideal fermentation conditions without any input — or guesswork — from users.

As Quinn explains, the E-Fuel keeps the yeast happy and hungry in a couple of ways. One is by carefully controlling the amounts of feedstock elements that go into the system. Load sensors measure the amount of sugar or discarded alcohol that go into the system. The system then calculates how much water and yeast the user needs to add for the ideal fermentation process.

The other yeast-friendly provision comes down to tight temperature control. E-Fuel units contain a patented thermoelectric cooling device and oil-filled heat exchanger that keep the temperature below 96F, the point at which the yeast culture will start to die off. In the winter, the same thermoelectric device warms the yeast as necessary. In fact, these devices can inherently switch back and forth between heating and cooling in a matter of microseconds. Quinn says E-Fuel controls send a PWM signal to the thermoelectric device, changing the polarity to switch it from heating to cooling mode. Quinn says the system can maintain the temperature within a 10-degree range.

In a forthcoming version of the system, Quinn and Butterfield have even refined the physical design of the tank itself. The rigid tank found on the earliest prototypes of the E-Fuel have been replaced with an elastomeric tank that expands and contracts to match the volume of feedstock, taking away the headspace that would create a less-than-ideal fermentation environment.

E-Fuel's technical breakthroughs extend to the distillation side of the system, too. Like commercial-scale distillation units, the system separates the alcohol from the water. Unlike commercial-scale systems, which have multiple distillation columns to boil and remove the water in stages, the E-Fuel uses a single solid-state distillation column. It doesn't require combustion at all. "Combustion was a show stopper from a safety standpoint," Quinn says.

Rather than boiling off the water, E-Fuel separates from the alcohol using pressure and a membrane with nanoscale pores. "The water molecules are forced through the membrane and the larger alcohol molecules stay behind in the center of the column," Quinn says. He won't disclose how the company builds up the pressure in the system, other than to say it's not through the action of a pump.

The final piece of the E-Fuel's technology package relates to its controls. An ARM processor runs the show and Quinn says it handles about 60 channels of data — including i/o dedicated to the load and temperature sensors.

To make both the fermentation and distillation processes self-governing, and thus transparent to the user, Butterfield performed a thorough behavior analysis of how the E-Fuel's physical systems work. This analysis involved translating all the steps taken by an expert manually running the system into software algorithms that run on the microprocessor. There's really no need for any knob twisting on the user's part. "The controller handles everything except loading the sugar and pumping the alcohol," Quinn says.

**Economies of Small Scale**

The use of a microprocessor that often turns up in consumer electronic products highlights an important aspect of the E-Fuel's design: Its small scale allowed the use of cost-effective, efficient technologies that wouldn't be possible on a commercial scale. Quinn calls it the "magic of micro." He points out that the ARM microprocessor E-Fuel uses costs something like $100, while control systems for a commercial plant can run more than hundreds of thousands of dollars. "We're coming from the micro world of Silicon Valley and were able to take advantage of all the processing power being developed for the consumer devices," he says.

Another example of that magic is the use of the nanopore separation membrane, a design feature not currently feasible at the commercial scale. It not only allows a combustion-free distillation, it also has quality implications. Quinn says the yield is 99 percent pure ethanol versus no better than 96 percent pure from commercial plants. "The quality is unbelievable. We're making a better fuel than commercial plants can produce," he says.

Much of the debate about the viability of ethanol as an alternative fuel has so far rested on assumptions it will need to be produced in commercial-scale production facilities. Yet, Quinn argues that smaller actually has better economics when it comes to making ethanol.

His $1-per-gallon price estimate does rest on assumptions about the release of government surplus sugar for ethanol production at 2 cents per pound, as well as the availability of carbon offset credits for anyone making their own ethanol.

The E-Fuel, however, can also be looked at independently of specific price-per-gallon targets, which can fluctuate, and instead be considered in terms of the energy needed to make ethanol. “Corn is not really the best feedstock for producing ethanol. Sugar is,” Quinn says, citing the energy requirements and infrastructure needed to turn the corn starch into sugar before the fermentation can begin. Quinn claims the E-Fuel system is eight times more efficient than commercial-scale systems when looked at through the lens of the energy required to make ethanol — and he says that figure includes the energy used to make the sugar.

Going the booze route reduces the energy requirement even more and reclaims alcohol that would otherwise end up down the drain. And lest you think there isn’t enough booze around, Quinn says E-Fuel did an informal survey of the bars and restaurants in the company’s Los Gatos hometown and found that 60,000 gal of leftover beer, wine and drinks were wasted every year. “There’s really no need to rush out and buy a big bag of sugar when there’s so much wasted alcohol around,” he says.

GALLERY »


- The E-Fuel 100 is the first ethanol micro-refinery for consumer use.