Beyond Biodiesel – Running on Straight Vegetable Oil (SVO)

The green tree has many branches. In the search for new fuels that will make our farms greener and less dependent on petroleum derivatives, several solutions are being investigated. For example, New Holland has been at the forefront in the development and promotion of biodiesel for nearly two decades.

Technologies based on the use of hydrogen and fuel cells are also being developed as clean alternatives to traditional fossil fuels to address climate change and reduce greenhouse gas emissions. The revolutionary prototype New Holland T6000 Series NH2, with hydrogen fuel cells generating the current to drive electric motors and power the tractor, has recently received awards and publicity.

Less well known is New Holland's involvement in producing alternative fuel from biomass, a promising fuel source for the future.

Another fuel alternative was recently reported on by Lori Burkholder of WGAL-TV in Lancaster, Pennsylvania, as one of that station's special "Green Week" presentations. She commented in her script, "In State College, PA, there's something new on the fields of Penn State University. For about a year, there have been a New Holland tractor and a Case wheel loader working there which are the first in the country to run continuously on straight vegetable oil."

Rudolf Diesel's first engine ran on peanut oil at the World Exhibition in Paris in 1900, much to the astonishment of scientists and engineers. Even then he could see the advantages in agriculture and for the environment. But he died before his vision of vegetable-oil powered engines became a reality, and the engines that bore his name were soon adapted to run on fuel derived from petroleum.

Single-cylinder diesel engine, circa 1906. Rudolf Diesel's first engine ran on peanut oil at the World Exhibition in Paris in 1900. (Photo courtesy www.speedace.info/speedace_images).

Several forward-thinking companies have invested in the resources and research to support higher blends of biodiesel. For some time, New Holland has been working with Penn State University to further its biodiesel agenda, as evidenced by this display of tractors running on a 100% blend.

Diesel's original engine injected fuel with the assistance of compressed air, which atomized the fuel and forced it into the engine through a nozzle, almost like an aerosol spray. The nozzle opening was closed by a pin valve lifted by the camshaft to initiate the fuel injection before the piston's top dead center. This is called air-blast injection, and worked reasonably well with pure oils derived from peanuts and oil seeds. As diesel engines evolved, however, fuel injection changed to suit petroleum fuel characteristics.

Diesel engines today raise fuel to extreme pressures by mechanical pumps and deliver it to the combustion chamber by pressure-activated injectors without compressed air. In common rail systems, the separate, pulsing, high-pressure fuel line to each injector is eliminated. Instead, a high-pressure pump pressurizes fuel at up to 2,000 bar (200 MPa, 30,000 psi), in a "common rail," a tube that supplies each computer-controlled injector containing a precision-machined nozzle and a plunger driven by a solenoid or actuator.

These sophisticated, high-precision systems can only tolerate vegetable oil if it is specially processed and introduced in a low-percentage mixture with petroleum fuel. Hence the development of biodiesel.

Paul Trella, New Holland Director of Product Marketing for Under 100-HP Tractors, is a graduate of Penn State University and has kept in close touch with his alma mater. Several forward-thinking companies, including New Holland, have invested in the resources and research to support higher blends of biodiesel, and, for some time, Trella has been working with Glen Cauffman, Farm Facilities Manager at Penn State, to further New Holland's biodiesel agenda.

Trella and Cauffman were invited to attend a Biodiesel Conference in Vienna, Austria, in 2007, to talk about the collaborative efforts between New Holland and Penn State on the subject. They also attended the renowned Agrotechnia Agricultural Exhibition in Hannover, Germany. Billed as the world's largest farm equipment show, Agrotechnia attracts some 2,200 exhibitors and 340,000 visitors from around the globe to a site 3.2 million square feet in size. The equipment and technology highlighted at this event reflect the increasing importance of farming efficiency to supply the people of the world with food and renewable energy while protecting the climate.

While at Agrotechnica, they were approached by a representative of Elsbett Technologie GmbH, an award-winning company in Thalmaessing, Germany, with a unique conversion technology. Elsbett has been converting diesel engines to operate on Straight Vegetable Oil (SVO) since 1977, extended to heavy goods vehicles in 1988, and regards itself as the world leader in this technology. Among their satisfied

customers, the representative pointed out, were a number of New Holland tractor owners in Europe.

The Elsbett conversion system involves two separate fuel tanks. The engine starts on conventional diesel and switches automatically to SVO fuel, held in a separate tank, then switches back again. In this way, low temperature problems with the "gelling" or "crystalizing" characteristics of SVO can be avoided.

Coolant temperature is one parameter to be met, but the primary condition for the switching to SVO is exhaust temperature. Elsbett claims that the negative impacts of SVO on the engine are minimized or negated when the engine is operating at greater than 25% load. When the tractor goes back to idle or light load it switches back to conventional diesel, and before shutting off the engine, the operator must switch back to conventional diesel fuel in order to purge the system.

Back home again in Pennsylvania, Trella and Cauffman made arrangements for two Elsbett systems to be delivered to New Holland engineering, where they were installed in a T7060 New Holland tractor and a Case 621E wheel loader, both with tier 3 engines and common rail, high pressure fuel systems. These specially-equipped units were then transported to Penn State University, where they have now been working satisfactorily in normal agricultural conditions for the past year. Kenny Roush and his team at B & R Farm Equipment, New Holland dealer in Milroy, PA, have gone above and beyond the call of duty helping to support this project.

A field of canola with close-up of the plant in bloom. SVO fuel used by Penn State is made by cold-pressing canola seeds. The key is a crop indigenous to the area capable of creating a constant fuel supply. (Photos courtesy www.flickr.com).

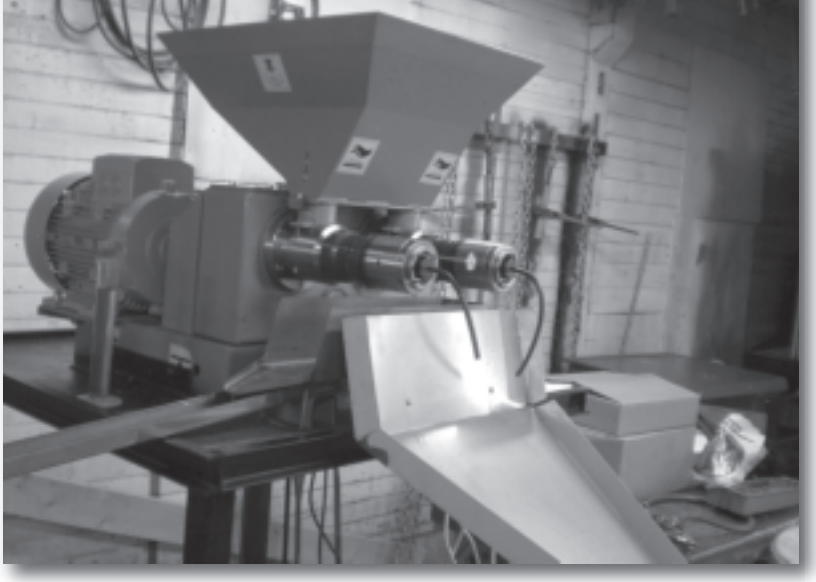
Another question arose – is it possible to press out the fuel on the farm? As a land-grant university, Penn State is always keen to answer such questions and to disseminate the resulting information to the public. After much searching, they found a "portable," on-site press capable of producing enough SVO to run both pieces of equipment. So, the SVO fuel used by Penn State in this research is made by cold-pressing canola seeds on campus. Any oil-seed crop such as soybeans or Camelina can also be used. The key is a crop indigenous to the area that is capable of creating a constant supply of fuel. The cool thing is that, after the oil is pressed out of the crop seeds, what's left over is an oily cake called the meal. This meal gets used to feed the animals on the farm, and they seem to like it.

Penn State grows on their own farmland all the canola they need to supply the fuel to keep both units running. They raised 10 acres of the crop last year and another 25 acres this year, using both spring and fall varieties. Studies in Germany indicate that 20% of a farm's acreage can produce enough oil to fuel all the equipment and still have some left over for cooking and heating. In the U. S., using no-till methods, less acreage would probably suffice, maybe as low as 10%.

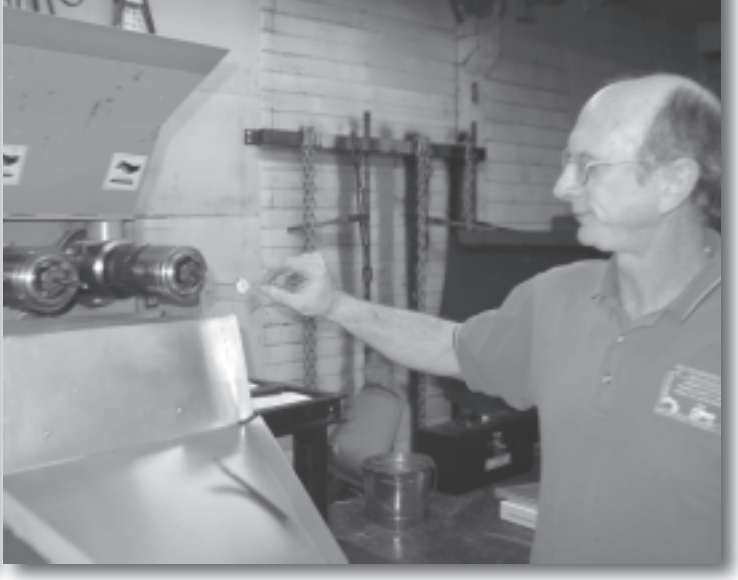
The T7060 tractor has been used in just about every job that could be expected of it on a 1,500 acre farm, from hauling and spreading manure to mowing hay with a 15 ft. disc mower-conditioner to pulling a no-till drill and a 12-row corn planter. It

continued onpage 22

Elsbett systems were installed in a T7060 New Holland tractor and a Case 621E wheel loader, both with tier 3 engines and common rail, high pressure fuel systems, then the specially equipped units were transported to Penn State.



Is it possible to press out the fuel on the farm? Penn State University found this "portable," on-site press capable of producing enough SVO to run both pieces of equipment.



Douglas H. Schaufler, P.E., Ph.D, Senior Project Associate in Farm Operation & Services, checks out the Penn State on-site press.

has also been used as a stationary power source to run their power-hungry pneumatic grain-bin-filling system.

In all cases, the performance did not change one bit when the system switched from diesel fuel to SVO and back again. In fact, the only way to know that the switch had occurred was by the lights on the system monitor. Running on SVO, the exhaust has less black smoke and smells a little like cooking oil in a hot pan on the stove. Emissions such as carbon monoxide, hydrocarbons and particulates are all significantly lower than from burning conventional diesel.

Although the agreement between Penn State University and New Holland calls for the tractor and wheel loader to continue working until the end of 2009, Glen Cauffman is hoping that the period can be extended. The units are performing extremely well, and he is convinced that the more hours they can work before teardown to examine the effects of SVO usage, the more that can be learned. He comments, "At this point, we are not ready to endorse or promote the use of SVO fuel, but the results so far are very impressive. In fact, I'm so impressed that I want the university to buy the units afterwards so they can stay at Penn State."

"We found that cold weather was easier to deal with using the SVO system than burning biodiesel. We just parked the units outside all winter, not even under roof. Even on the coldest days, they started normally because they were operating on pure diesel fuel until they warmed up enough to switch over. We didn't winterize our biodiesel, so we had to keep the biodiesel-fueled units inside a warm shed to avoid problems," says Cauffman. "Another advantage I see with SVO is that the hazardous chemicals and hard-to-dispose-of by products of the biodiesel production process are avoided entirely."

"We believe that producing and burning SVO will open doors to permit farms to be self-sustaining," Cauffman continues. "In fact, our broader vision is to create a model for the environmentally friendly enhancement of rural economies that can be duplicated in all parts of the world. It would involve townspeople and farmers coming together to produce and process oil for fuel, cooking and heating in sufficient quantities to greatly reduce or even eliminate the need for petroleum fuels."

Trella and Cauffman have been invited by the A.O.C.S., an association of international chemists, to make a presentation about the joint New Holland-Penn State work on the use of SVO fuel at an international biodiesel conference in Munich, Germany, in November of this year. That will be an honor both for the university and for New Holland. What the future will bring for this interesting and unique branch of the "green tree" remains to be seen, but at this point, the outlook is very promising.

The New Holland T7060 tractor has been used in just about every job that could be expected of it on a 1,500 acre farm.

Straight Vegetable Oil (SVO) as a Fuel for New Holland Engines

by: P. Trella with input from Glen Cauffman, Farm Facilities Manger, Penn State University and Professor Andre Boehman, Professor of Fuel Science, Department of Energy & Mineral Engineering, Penn State University

Reliance on imported petroleum and fluctuating prices is creating apprehension among users. The desire to move away from dependency on fossil fuels created an interest in alternatives. Many of our customers are still involved in basic agriculture – raising livestock and crops to feed the masses. By its very nature, farming is full of uncertainties – after all, we don't want to mess with Mother Nature for she can be somewhat fickle. Planning has become more difficult as fuel and energy account for higher percentage of input costs. Farmers are constantly looking for ways to minimize risks and control costs.

Biomass generated fuels are predicted to fill the void for both personal consumption and powering industry, replacing some of the dependence on fossil fuel. Agriculture has a coveted position in this new arena as the stock for many on the new "alternatives" have their base in animals or crops raised on the farm. Many of us with a little time under our belts can remember a father, grandfather or neighbor concocting a favorite brew to run an old tractor or pickup truck or stationary engine thus stopping the fuel truck from driving down the lane.

Biodiesel is an alternative made from vegetable oils or animal fats through a chemical process called transesterification. This involves a chemical reaction with methanol using caustic soda (sodium hydroxide) as a catalyst. It's a popular option to replace diesel fuel. New Holland supports the use of biodiesel in the engines we make in house with some simple guidelines. The conversion from crops to fuel takes several steps and requires a basic knowledge of chemistry. This process also poses some environmental and safety hazards for a novice. The energy equation - amount of energy out as a ratio of the amount used to create the fuel - while marginal is positive at roughly 3 units of energy out for 1 unit if input. We've come a long way to understand the formation of biodiesel – in fact, it has opened the door into the direct use of vegetable oils as straight or raw vegetable oil (SVO or RVO).

These options are appealing because SVO and RVO can be used without intermediate processing. However, SVO is not the same as biodiesel, and is generally not considered to be an acceptable vehicle fuel for large-scale or long-term use. New Holland does not recommend the use of SVO as a fuel in your engine. Although SVO or mixtures of SVO and diesel fuel have been used by some over the years, the impact on the engine and fuel systems are unknown. Current commercially available SVO technology uses canola oil as fuel. Canola, at 125 gallons of oil per acre yield, compares superiorly to soybeans that average 50 gallons of oil per acre. Canola meal, the byproduct of canola oil pressing, is a high quality animal protein supplement. Fall seeded canola can serve as a soil protecting winter cover crop that is harvested in early summer in time to establish another crop.

The question to answer is what impact does SVO have on the modern diesel engine? The published engineering literature suggests that using SVO leads to reduced engine life. The main risk is caused by the buildup of carbon deposits inside the engine, as well as negative impacts on the engine oil. Both carbon deposits and excessive buildup of SVO in the lubrication system are caused by the very high boiling point and viscosity relative to the required boiling range for diesel fuel. The carbon buildup doesn't necessarily happen quickly, but over a longer period. These conclusions are consistent across a significant body of technical information in multiple articles and reports.

A recent technical paper[1] reviews published data on the use of SVO in engines. Quoting from this paper:

Compared to No. 2 diesel fuel, all of the vegetable oils are much more viscous, are much more reactive to oxygen, and have higher cloud point and pour point temperatures. Diesel engines with vegetable oils offer acceptable engine performance and emissions for short-term operation. Long-term operation results in operational and durability problems.

Some investigators have explored modifying the vehicle to preheat the SVO prior to injection into the engine. Others have examined blends of vegetable oil with conventional diesel. These techniques may mitigate the problems, but do not eliminate them entirely. Studies show that carbon build up continues over time, resulting in higher engine maintenance costs and shorter engine life.

Another issue that is particularly critical for use of SVO is fuel viscosity. The viscosity of SVO is much higher than that of diesel fuel at normal operating temperatures.[2] This can cause premature wear of the fuel pump, injectors, and also can dramatically alter the structure of the fuel spray coming out of the injectors to increase droplet size, decrease spray angle, and increase spray penetration. All of these changes to the fuel spray will tend to increase wetting of engine internal surfaces with the fuel leading to increased tendency to form carbon deposits and dilute the lubricant.

1 Babu, A.K.; Devaradjane, G. "Vegetable Oils And Their Derivatives As Fuels For CI Engines: An Overview." SAE Technical Paper No. 2003-01-0767.

2 Bruwer, J.J., et al. "Use of Sunflower Seed Oil in Diesel Engined Tractors." Proceedings of the IV International Symposium on Alcohol Fuels Technology; October 5, 1980, Guaruja, SP, Brazil.