A new wave of products for power transformers offers cleaner, safer and more cost-effective alternatives to traditional petroleum oil.

by Scott Fields
“We had about a 20-gallon spill that cost us $27,000 to clean it up,” says Glenn Cannon, general manager of Waverly Light and Power in Waverly, Iowa. “I knew there had to be a better way.”

That better way, he says, is transformer oil made from plant products. While transformer oils are not really considered lubricants, their development helps foster the production of bio-oils, which are increasingly finding uses as biofriendly and high-performance lubricants.

Bio-based oils—produced by such companies as Cargill and Cooper Power Systems and made from such renewable resources as rapeseed and soybeans—may offer a cleaner and safer alternative to traditional petroleum oils, Cannon says. He helped develop one of these bio-oils working with the University of Northern Iowa’s Agriculture-Based Industrial Lubricants (UNI-ABIL) research group. Since 1998 Waverly Light and Power has installed only transformers that use bio-based oil.

In the United States newly manufactured transformers are free of PCBs (polychlorinated-biphenyl). But many older transformers aren’t. As of 1994 about 200,000 U.S. transformers still used PCB-spiked oil, according to the EPA.

“About 40% of transformers still in use are PCB contaminated,” says Cannon. “So there’s a large amount of transformers that needs to be changed.” EPA rules require that mineral oil spills—even if PCB-free—from transformers must be cleaned up. The new, plant-based oils may change all that and can offer other benefits as well, says Mike Rudek, process coordinator for Distribution Design and Standards at California’s Sacramento Municipal Utility District (SMUD).

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“These transformers will last longer because bio-oil is easier on the paper that insulates a transformer’s coils, says John Luksich, a senior engineer specializing in dielectric fluids at Cooper Power Systems in Waukesha, Wis. In tests the company conducted, kraft paper, which is similar to paper insulation, took five to eight times longer than conventional oil to deteriorate to a point at which it is ineffective.

“The thing that limits transformer life is generally the integrity of the paper that’s used in lining the transformer coil wires,” says Brent Aufdembrink, technology manager for Cargill Industrial Oils and Lubricants. “The paper is a special cellulose polymer, and this polymer is broken down by heat, reaction to water—hydrolysis—and that is catalyzed by heat and acid.”
Vegetable oils have a much higher solubility, Aufdembrink says, and can hold more water. As a result, the vegetable oil can draw out and retain moisture from the paper as it ages, preventing paper molecules from severing from each other. “By reducing the amount of water in the paper,” he says, “you reduce the aging of that paper significantly.”

Another option, says Luksich, is to take advantage of the now-more-durable insulation to run the transformers at higher loads. It’s the combination of moisture and heat that accelerate a transformer’s aging. The primary source of heat is the current passing through the transformer. “If you have something that is going to increase the life of a transformer, as this oil would,” he explains, “there’s the possibility that you can increase the power you put through that same transformer and still get the same life if you’re willing to accept a higher heat. You can use a smaller transformer that can tolerate a higher overload.”

This is especially useful for utilities, whose transformers are often running well below capacity during most periods. That’s why SMUD, Rudek says, is considering re-rating transformers that use bio-oil. “You can have the same line operating the transformer at higher temperatures, which means you load them higher, which makes it more efficient,” says Cannon, “or you can operate at the same temperature and have a longer life.”

**REDUCED FIRE HAZARD**

The new bio-oils are also safer, says Rudek. Transformers can catch on fire, sometimes because the transformer has failed as it aged and other times through natural causes, such as lightening strikes. Mineral oils can sustain a fire and the byproducts of combustion can be carcinogenic; the products of burning bio-oil are primarily water, carbon dioxide and carbon monoxide. But bio-oils are unlikely to burn, since they have much higher flash and fire points.

According to Luksich, “these are very fire-resistant oils. In fact, they are classified by the National Electrical Code as a ‘less-flammable’
Bio-oils such as Canola are now processed to resist oxidation; however, they have been tested and used in transformers dating back to the 1800s. Oil ‘That means they’re self-extinguishing. It’s very tough to get them to burn.” That could save lives, especially in commercial, industrial and military applications, which combined account for two-thirds of Cooper Power Systems’ bio-oil sales.

“They [transformer fires] happen every day. Every year lives are lost. And every year there’s millions of dollars in property damage,” says Luksich. “It’s a very small percentage of transformers that fail in that way, but there are so many transformers installed that it happens a lot.”

In addition to installing new, bio-oil-filled transformers, some users—including Waverly Power and Light—are retrofitting existing transformers. No re-engineering is necessary because the bio-oils are near to exact replacements, says Lou Honary, director of the UNI-ABIL research group. Transformer oil serves two functions: cooling and insulation. Bio-oils cool just as well and insulate better, he says, because the dielectric is somewhat higher.

Retrofitted transformers have the same advantages as native bio-oil units in proportion to the amount of bio-oil used, says Luksich. Although in the field it’s virtually impossible to drain a transformer completely, the two types of oil are compatible and they mix rather than stratify.

“The material there biodegrades as if it were two separate materials,” he says. “If you start out 96% or 97% vegetable oil, that much of the spill will still biodegrade as if it’s vegetable oil and that very small 3 or 4% mineral oil biodegrades as though it’s mineral oil, even though they are mixed together.”

Similarly, Luksich says, substituting oils will extend the life of the coil insulation. Engineers at Cooper Power Systems conducted experiments to simulate retrofit.

“We aged—in our aging system—paper in mineral oil and then, when it was partially aged, we dumped out the mineral oil and put in vegetable oil,” he says. “We saw the aging rate of the paper change from the rate at which it ages in mineral oil to the rate it ages in vegetable oil immediately.” Another reason to retrofit, he says, is to bring installed transformers up to meet new fire codes by using bio-oil, which has a much higher flash point than mineral oil.

EvolVevolution of Success

The idea of using plant oils in transformers is by no means new. Mineral-oil filled transformers date back to 1892, when General Electric produced the first prototype. By 1899, the transformers were in commercial production. During the same period, bio-oils were also tested in transformers. But they oxidized too easily and were no cheaper than mineral oils.

Today’s bio-oils, which were developed in the 1990s—are processed to resist oxidation, as well as other characteristics. “It has to have a certain viscosity to have a low vapor pressure,” says Aufdembrink. “At the same time you can’t have it too heavy or it won’t circulate and provide its cooling function. You don’t want it to be too heavy, because then it can’t self-circulate in certain size transformers.” To reduce processing time, Honary says, some oils can use another modern innovation: genetic engineering to tame oxidation by increasing oleic acid levels.

In 1995 DuPont released a GM high-oleic soybean designed for frying applications. “The oleic content of regular soybean oil is about 18%,” says Honary. “The oleic content of this high oleic soybean oil is over 83%.” When Honary’s group evaluated conventional, unprocessed soybean oil, it lasted seven hours in an oxidation-testing machine. Canola oil (which is made from rapeseed) lasted 36 hours, as did chemically modified soybean oil.

“The high oleic soybean oil lasts 192...
Many power companies are testing the waters of bio-based transformers. And at least two in the United States have jumped into the deep end of the pool with large-scale commitments to the product. But very few have tried a bio-based grease that would help keep clean the waters below hydroelectric dams, says Ken Brown, an engineer for Utility Service Associates in Toronto.

In a hydroelectric dam, “wicket gates” control the flow of water to turbines. Because the bushings on these gates are steadily exposed to fast-moving water, their lubricating grease must be renewed frequently. These greases—traditionally petroleum-based products that sometimes contain lead, phosphorous, lithium and benzene compounds—can make their way into waterways and eventually the food chain.

To provide a safer lubricant, Utility Service Associates developed a food-grade, canola-based grease called VSG.

“We started looking for greases that could meet the current specifications as well as offering some sort of environmental advantages,” says Brown. “They would be low toxic and biodegradable and lack heavy metals and other things in them. And perform—we hope—as well as current products.”

The canola grease, Brown says, meets the specifications of two of Canada’s largest electricity supplies, Hydro Québec and Ontario Hydro Energy, his employer when he started working on the product. And although the canola grease is more expensive than traditional wicket-gate greases, it performs better, he says. Like bio-transformer oils, bio-grease for wicket gates, Brown says, can be justified based on the performance alone, without considering their environmental benefits. Because the grease lasts longer, it doesn’t have to be replaced as often.

In spite of these advantages, Brown says, only a very few utilities—such as the Canadian utilities and the U.S. Department of Interior’s Bureau of Reclamation-operated Parker Dam in California—have adopted the bio-grease. Part of the reason, he says, is that utilities are by nature large, conservative bureaucracies. But existing regulations also present roadblocks. All oil is treated as equally polluting, he says. Regulations that considered the biodegradability of bio-greases and exempted utilities from fines for small release would create an additional incentive to switch to the product.

Within the current regulatory environment, adoption of the technology has been far slower than its characteristics justify, he says.

“Here’s a product that is at least as good if not better than current products, and it’s made of canola oil, which is a renewable resource, natural and readily bio-degradable. Plus it has no zinc, no chlorine, no lead,” says Brown. “You would have thought that people would have been falling over each other.”

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