REPLACEMENT OF PETROLEUM BASED HYDRAULIC FLUIDS WITH A SOYBEAN-BASED ALTERNATIVE

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(Sandia National Laboratories is a multiprogram laboratory operated by Corporation, a Lockheed Martin Company, for the United States Department of Energy under Contract DE-ACD4-94A185000)

ABSTRACT

Despite the best preventative measures, ruptured hoses, spills and leaks occur with use of all hydraulic equipment. Although these releases do not usually produce a RCRA regulated waste, they are often a reportable occurrence. Clean-up and subsequent administrative procedure involves additional costs, labor and work delays. Concerns over these releases, especially related to Sandia National Laboratories (SNL) vehicles hauling waste on public roads prompted Fleet Services (FS) to seek an alternative to the standard petroleum based hydraulic fluid.

Since 1996 SNL has participated in a pilot program with the University of Iowa (UNI) and selected vehicle manufacturers, notably John Deere, to field test hydraulic fluid produced from soybean oil in twenty of it's vehicles. The vehicles included loaders, graders, sweepers, forklifts and garbage trucks. Research was conducted for several years at UNI to modify and market soybean oils for industrial uses. Soybean oil ranks first in worldwide production of vegetable oils (29%), and represents a tremendous renewable resource. Initial tests with soybean oil showed excellent lubrication and wear protection properties. Lack of oxidative stability and polymerization of the oil were concerns. These concerns were being addressed through genetic alternation, chemical
modification and use of various additives, and the improved lubricant is in the field testing stage.

SNL was the largest test user in the pilot program. Samples from each vehicle were collected quarterly and sent to UNI. UNI and John Deere then analyzed and evaluated the samples. The soybean alternative requires no equipment modification or special handling for its use. The results from FS testing indicated performance equal to or better than the petroleum based product. The most impressive thing about the use of the soybean substitute is that it has been invisible to maintenance and operations personnel.

The soybean product costs twice as much as the petroleum based oil. However, as production increases, the price of the soybean oil should decrease. More significantly, the soybean oil is biodegradable, has no adverse environmental impact, utilizes an existing renewable resource, and will eliminate costs associated with spill cleanup. SNL's involvement in this program is indicative of its commitment to and understanding of pollution prevention, and it's willingness to work with industry and academia to seek solutions to common problems.

Because of the success of the pilot program and subsequent approval of the product for industrial applications, FS is in the process of converting all hydraulic equipment in it's fleet to the soybean product. FS is also investigating the use of other soybean base products, including parts cleaner solvent and automotive greases.

INTRODUCTION

In August of 1995, an employee operating a street sweeper at Sandia National Laboratories, New Mexico (SNL/NM) noticed a puddle of oil where he had just swept. The employee attempted to return the sweeper to the SNL/NM motor pool for repairs, but the sweeper stopped working. The operator then took actions to control the spill and initiated clean up. The cause of the spill was a ruptured hose, which resulted in the release of approximately 25 gallons of hydraulic oil. This release exceeded the DOE Order 5000.3B reportable threshold of 10 gallons, resulting in an off-normal occurrence.

In an effort to eliminate future occurrences and mitigate any environmental effects from hydraulic oil spills, SNL/NM Fleet Services (FS) began investigating alternatives to petroleum-based hydraulic oils. They found several vegetable-based products, including an off-the-shelf canola oil product. Canola, however, is a Canadian product and FS preferred to support an American industry, if possible. They learned of a soybean based hydraulic oil, developed by the University of Northern Iowa (UNI). UNI, which had completed laboratory testing and was in the process of field-testing the product, was very interested in having SNL/NM test the hydraulic oil in its fleet.

The subsequent test group of equipment at SNL/NM was the largest and most varied, and proved invaluable in the final development and marketing of the soybean hydraulic oil.
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SNL/NM in turn has found an environmentally preferable alternative to petroleum-based hydraulic oil.

BACKGROUND

The UNI Ag-based Industrial Lubricants (ABIL) Research program studied, developed and tested soybean oils for use in industrial hydraulic equipment. This work parallels other efforts to seek renewable, environmentally friendly alternatives to the standard petroleum-based industrial lubricants, including development of synthetic and other vegetable lubricants (i.e., rapeseed, canola, crambe and safflower oils). Interest in the development of soybean hydraulic oil stemmed from several factors, including:

• It is the most available vegetable oil. The U.S. production is 2.5 billion gallons/year, with over 6.0 billion gallons/year produced worldwide. Other vegetable hydraulic oils on the market are produced primarily in Canada (canola) and Europe (rapeseed). Soybeans are an American product, with significant production in Iowa.

• Crude Soybean oil has a viscosity close to that of mineral oil (29 centistokes at 40 degrees C), a high flash point (325 degrees C) and a high viscosity index (246), a measure of the oil’s resistance to viscosity changes due to changes in temperature. The commercially available product, BioSoy has a viscosity of 41 centistokes at 40 degrees C.

• Like other vegetable oils, major advantages include better actual lubricating ability, renewability, and biodegradability. Using the EPA Shake Flask test soybean oil degrades within 7 days. The petroleum oil takes 28 days.

• Vegetable oils are not skin irritants

Disadvantages of vegetable oils include low oxidative stability, high pour point and incompatibility with some additives. Oxidative stability, in particular, is of concern, especially with oil that is not fresh and has not been properly stored. Commodity soybean oils, for instance, are not adequately stable for use in common industrial applications. Turbulence and pressure generated heat cause the oils to oxidize an increase in viscosity, losing performance properties.

From 1991 to 1994 ABIL tested various soybean oils with other vegetable and mineral oils to determine if soybean-based oils could be used in industrial applications. By measuring viscosity changes in wear tests, 100 hour, American Society of Testing and Materials (ASTM) D-2281 and 1000 hour, ASTM D-2271, the oxidative stability of oils can be evaluated. In addition to these tests, changes in elemental composition and Total Acid Number were evaluated.

The results of the laboratory testing indicated that a soybean oil formulation, which had been chemically modified (through partial hydrogenation) and combined with an additive package, performed equal to or better than other commercial vegetable oils. It was further observed that changing the fatty acid composition of the oil seed (i.e. increasing the oleic acid content) through genetic modification also increases oxidative stability.
Following the laboratory-testing period, the field testing period began. Initially, the oil formulation was tested in a Curbtender, an automated refuse collection truck, and rail car movers. After thousands of hours of successful testing, UNI entered into an agreement with Sandia National Laboratories, New Mexico (SNL.NM) to test a several pieces of their mobile equipment.

The development of the soybean hydraulic fluid has truly been a cooperative effort involving academia, state, city and federal government, and private industry. Lou Honary of the UNI has managed the project from its inception. Initial funding was provided by the Iowa Soybean Promotion Board. In addition, considerable support and resources were received from John Deere Waterloo Works, John Deer Product Engineering Center, Northland Products Company, Hi-Bred International, Cargill, Vickers, Inc., Wayne Engineering, Lubrizol Corp., the City of Cedar Falls, IA, Iowa State University Center for Crops Utilization, the American Soybean Assoc., and the Department of Energy. Lubrizol Corp. is producing the additive package; Northland oil company is blending the additive with the soybean oil; and AGRI industries is marketing the product under the name BioSoy.

METHODOLOGY

IN 1996 SNL/NM entered into an agreement with UNI to test the soybean hydraulic oil. UNI provided the oil to SNL/NM at no charge, conducted the analyses, and agreed to replace any equipment damaged by the use of the oil. Twenty pieces of industrial equipment, maintained by SNL/NM FS, were included in the soybean hydraulic oil test. For each piece of equipment, the hydraulic system was completely drained and the fluid was replaced with the soybean oil. After 100 hours of usage, a 16-ounce sample was removed and sent to UNI for analysis. The analyses included tests for viscosity, Total Acid Number, and 14 elements, including iron, copper, silicon, and aluminum. In addition FS performed visual inspections of the hydraulic equipment on each vehicle, and provide complete maintenance records. Under the confidentiality agreement, SNL/NM would not disclose the test results without consultation with UNI.

The field test consisted of the following equipment:
- John Deer 570 Motor Grader
- Caterpillar 14 E Motor Grader
- John Deere Front End Loader
- John Deere Motor Grader
- Clark Fork Lift
- Massey Ferguson Tractor
- FMC Power Sweeper
- Tennant Power Sweeper
- John Deere Front End Loader
- Mack Load Packer
- White Load Packer
- Clark Fork Lift (2)
- Caterpillar Fork Lift
RESULTS

During the field test the equipment was operated in excess of 3000 hours under normal operating conditions. No unusual hydraulic system failures, abnormal, viscosity changes or excessive wear was observed on any of the test equipment. Test results were within expected limits and industry limits. (The actual test results, however, are covered under the Confidentiality agreement between SNL/NM and UNI, and cannot be released by SNL/NM).

FS has been completely satisfied with the performance of the BioSoy product. The performance was equal to any high-grade petroleum-based oil, required no special equipment modification prior to use, and was “invisible” to FS maintenance and operations personnel.

Based on the successful field trial, FS decided to switch it’s entire fleet to BioSoy hydraulic oil. In March, 1998, FS submitted a proposal to the SNL/NM Pollution Prevention (P2) team to use Generator Set-Aside Fees (GSAF) to purchase of 1200 gallons of BioSoy for all hydraulic equipment at SNL locations in New Mexico and California (SNL/CA). Because SNL/CA does not participate in the GSAF program, the P2 Team agreed to provide 50% of the requested funds, with FS providing the remaining monies. SNL FS has purchased the BioSoy product and will complete change out of all hydraulic systems by September, 1998. During regularly scheduled equipment maintenance, the hydraulic systems will be flushed and replaced with BioSoy.

Under the agreement with UNI the twenty pieces of equipment included in the test group will continue to be evaluated. This will provide UNI with long-term data on the performance and the effects of the BioSoy product. SNL/NM will benefit from the continued feedback on the use of this product in their equipment and the opportunity to test new product formulations.

Table 1, below, presents a simple cost-benefit analysis for the BioSoy alternative. Presently, the BioSoy waste oil is handled the same way as all used oil at SNL – as chemical waste processed through the Hazardous Waste Facility, where it is sampled and dispositioned accordingly. Other than fixed, overhead costs, there are no processing costs assessed to this waste. In the event of spill, petroleum wastes are assessed charges as industrial waste, however, BioSoy cleanup materials can be placed in a dumpster as sanitary waste. The analysis assumes 50 gallons (150kg of oil + 350 kg of debris) of spills and hydraulic annually.

- Yale Fork Lift
- Geo-Probe Soil Probe Unit
- Mack Dumpster
- Capacity Trailer Jockey
- John Deere Front End Loader
- Trojan 5500Z Front End Loader
 TABLE 1. Economic Analysis for Replacement of petroleum-based hydraulic oil with BioSoy

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<tr>
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<th>Initial Cost</th>
<th>Replacement Cost</th>
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<tr>
<td>Annual Purchase (300 gal)</td>
<td>$1,500.00</td>
<td>$3,195.00</td>
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<tr>
<td>Waste Costs</td>
<td></td>
<td></td>
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<tr>
<td>- 1000 kg/yr @$0/kg</td>
<td>$0.00</td>
<td>$0.00</td>
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<tr>
<td>- 6 drums @ $50/drum</td>
<td>$300.00</td>
<td>$0.00</td>
</tr>
<tr>
<td>Spill (500 kg/yr)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Admin Costs</td>
<td>$2,400.00</td>
<td>$0.00</td>
</tr>
<tr>
<td>- Dumpster waste ($0/kg)</td>
<td>$0.00</td>
<td>$0.00</td>
</tr>
<tr>
<td>- Waste Min Fees</td>
<td>$1,000.00</td>
<td>$0.00</td>
</tr>
<tr>
<td></td>
<td>$5,200.00</td>
<td>$3,195.00</td>
</tr>
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Initial investment costs are $12,780 (1200 gal * $10.65/gal).

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<td>Return on Investment (%)</td>
<td></td>
<td></td>
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<tr>
<td>Payback (years)</td>
<td>4.8</td>
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This analysis does not include the labor costs to flush the lines, but this is considered to be minimal since it will be done at scheduled maintenance. The return on investment (ROI) of 5.7% would not normally be considered for P2 funding. This analysis, however, does not include potential one-time costs or intangible benefits, such as:

- In the event of a DOE 5000.3B reportable occurrence (spill of >10 gal. of petroleum product), the costs for a root cause analysis are substantial. SNL experience indicates that a root cause analysis involves a minimum of 7 FTEs for a 3-day period at an estimated cost of $14,280.
- Since the BioSoy product contains 70% vegetable oil and 30% additives, the DOE limit for a reportable occurrence increases to 30 gallons, and the likelihood of a reportable spill is much reduced.
- The BioSoy is a friendlier product form both an environmental (renewability and biodegradability) and health and safety (skin irritant and flammability) point of view.
- The use of a renewable, safer American product is consistent with the mission and purpose of a National Laboratory.

The successful use of BioSoy hydraulic oil prompted FS to evaluate the use of other soybean-based automotive products. FS replaced it’s parts cleaner solvent (d-limolene based) with a soybean cleaner. The d-limolene cleaner is considered non-toxic and non-hazardous; however, the odor is considered offensive to some FS maintenance personnel. The soybean solvent cleans well, does not have an offensive odor, and is considered a better product by FS. FS also plans to test a soybean automotive grease and will work will UNI in the development of a 2-cycle engine oil. FS will ship two, excess, EZ-go carts, 2-cycle, gasoline powered carts used by employees for short trips on the SNL/NM campus, to the UNI for testing. They will be used as carts on a golf course to evaluate the 2-cycle oil.
DISCUSSION AND CONCLUSION

The choice to use a vegetable based hydraulic oil, rather than a recycled content petroleum-based product, has implications under Executive Order (E.O.) 12873, "Federal Acquisition, Recycling and Waste Prevention". The beneficial characteristics of BioSoy, classifies it as an environmentally preferable product (EPP), according to Executive Order (E.O.) 12873. Although it is often referred to simply as the "Buy Recycled" order, it is important to note that the acquisition and purchase of EPPs is the first priority. EPPs are defined as products "that have a lesser or reduced effect on human health and the environment". EPP evaluation criteria include raw materials acquisition, production, manufacturing, packaging, distribution, reuse, operation, maintenance, or disposal of the product. The purchase use of a petroleum-based hydraulic oil with 25% base stock recovered content, the Comprehensive Procurement Guideline for automotive lubricating oils, has a reduced environmental effect compared to the same product produced from 100% virgin material. BioSoy, however, eliminates the environmental and health effects associated with the production and use of the petroleum product. Although a complete life cycle cost-benefit comparison of vegetable and petroleum oils has not been completed, FS contends the BioSoy is the environmentally preferred alternative.

BioSoy also satisfies another key component of E. O. 12873, stated as background for the development of the order.

"WHEREAS, the use of recycled and environmentally preferable products and services by the Federal Government can spur private sector development of new technologies and use of such products, thereby creating business and employment opportunities and enhancing regional and local economies and the national economy."

SNL’s participation with UNI resulted in the successful development of a soybean based hydraulic oil, BioSoy. SNL is retrofitting the oil in all of it’s hydraulic systems with the BioSoy alternative, a product that is produced from a renewable resource, is readily biodegradable in the environment, and is safer for maintenance personnel to use. The development of this product has significant economic impacts to the soybean industry, and has the potential to lessen the U.S. dependence on foreign oil.

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