Environmental and Regulatory Benefits Derived From The Truck In The Park Biodiesel Emissions Testing and Demonstration in Yellowstone National Park

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ABSTRACT

The "Truck in the Park" Project was designed with two purposes: to define a market for biodiesel and to provide data on emissions and performance that could be used by land managers, regulators, and providers of commercial tourism transportation. This project was a first-step to reduce environmental impacts resulting from diesel fuel use in the tourism industry. Basically, the project placed a unaltered diesel pickup truck into service in Yellowstone National Park, fueled this truck with 100 percent rapeseed ethyl ester, and monitored performance and emissions. Data were collected to determine the reliability, benefits, and costs of using biodiesel in Yellowstone National Park and the surrounding region. The project included fuel characterization, detailed performance and emissions tests before and after (approximately) 160,000 km (100,000 miles) (using EPA protocols), and other quality control testing to document benefits and costs. The technical data and results of this demonstration are being documented in other papers and referred to in this text. This paper describes the implications of these results for the Yellowstone region and challenges of bringing this fuel technology to market.

Keywords: alternate fuels, biodiesel, transportation, tourism, Yellowstone National Park

OVERVIEW

Over 12 million visitors come to Montana each year, and consume about 33 percent of the state's total transportation energy. Most of these visitors are in Montana for 3 to 4 days. It is difficult to influence the energy choice of this transient population. If the industries that provide visitor services in popular tourist areas begin using more environmentally friendly fuels and products, and advertise this use, then their visitors may be more amenable to use such products on their own. Efforts focused on Yellowstone National Park because it attracts about 3 million visitors a year to a region where Montana is experiencing considerable growth.

This project was a first-step to assess and reduce the environmental impacts resulting from diesel fuel use in the tourism industry. The project supplied data and information on safety, performance, emissions, and benefits of using regionally produced biodiesel fuel in a diesel-powered vehicle. The project built partnerships among the Department of Energy, states of Montana and Wyoming, the National Park Service, regional businesses, and regulators. The technical results on emissions, performance, safety, and other findings have been or are being presented by others. This paper describes how these findings have helped define a market and the challenges facing any move to a regionally derived alternate (biodiesel) fuel.

<u>Background</u>

Each year about 3 million people visit Yellowstone National Park (YNP). The nearly 900,000 automobiles that travel to the Park burn thousands of gallons of fuel and produce tons of pollution, endangering the clear air and water that people expect to see during their visit to the Park. The air in the Park meets EPA standards, but not always the visitors' expectations. For example, visitors complain about the smoke and odors of diesel-fueled vehicles operating in the Park. Existing regulations may not adequately resolve these concerns.

With visitation increasing steadily over several decades, concern has arisen over increasing congestion on park roads and the related pollution. One possible solution is to limit visitation, an option not likely to please the public. Limiting visitation also is not favored by park concessionaires or economic interests in gateway communities.

A more desirable option is to reduce congestion by encouraging use of high occupancy vehicles, such as buses, and by reducing the amount of pollution produced by each vehicle. One way of doing this is to use fuel that produces low emissions with exhaust that is less obnoxious to riders and visitors. Vegetable oil can be processed into a diesel fuel--"biodiesel"--that produces less pollution than conventional diesel fuel. Exhaust from biodiesel does not have the unpleasant odor of conventional diesel exhaust. Toxicity and low biodegradability associated with conventional diesel fuel also are undesirable in areas valued for environmental cleanliness. Reformulated diesel fuel, intended to meet air emission requirements, is not sufficient to meet visitor expectations in areas like Yellowstone.

Rapeseed ethyl ester (REE) biofuel was developed by the University of Idaho (UI) and the DOE from feedstocks in Montana and Idaho. UI research indicates that REE has greater biodegradability and reduced emissions, odor, and smoke than petroleum diesel fuel. REE was at the stage of development where a higher value market, such as this tourist-related application, was the next logical step on the way to commercialization.

Demonstration Goals and Objectives

The project had two goals: to provide data on emissions and performance that could be used by land managers, regulators, and providers of commercial tourist transportation, and to define a market for biodiesel. The objectives were to determine the impacts and results from using biodiesel. Specifically, these objectives were to:

- Identify differences in safety and operation when using biodiesel as compared to conventional diesel fuel.
- Determine problems and possible solutions of using biodiesel at high elevations and temperatures that range from 32°C (90°F) to -40°C or F.
- Determine changes in performance and emissions (with and without an exhaust catalyst) over 160,900 km (100,000 miles) of operation. Performance would be measured periodically with chassis dynamometer tests. Emissions would be measured at the beginning and end of the project.
- Develop information on costs, benefits and trade-offs.
- Distribute information and demonstrate to potential users the benefits and drawbacks of biodiesel use in environmentally sensitive areas.

PROJECT DEVELOPMENT AND PRELIMINARY FINDINGS

In May 1994, the Montana Department of Natural Resources and Conservation (DNRC), predecessor agency to the Montana Department of Environmental Quality (DEQ), arranged a meeting among senior staff of the National Park Service (NPS), the U. S. Department of Energy Pacific Northwest and Alaska Regional Bioenergy Program (DOE) and the University of Idaho Department of Agricultural Engineering (UI). The biodiesel demonstration was one option to address several Park Service and visitor concerns with diesel fuel. Simply put, a diesel powered vehicle would be fueled with biodiesel for an adequate amount of time to determine the benefits and drawbacks of using this biodiesel fuel. A technical plan was developed to monitor safety, fuel quality, performance, emissions, maintenance, and outreach activities.

Safety

Dr. Chuck Peterson and Daryl Reece from UI drove their 1994 Dodge pickup fueled with 100 percent REE biodiesel to Mammoth in May, 1994. The concern voiced by park personnel was the odor of the biodiesel might attract bears. The exhaust from a diesel engine fueled with REE smells like a french fry cooker, and might attract bears if they connect the scent to a food reward. Attracting bears to vehicles operated by humans was to be avoided. A bear attractant analysis was conducted, first to determine if bears were attracted to the scent of biodiesel, and second to determine whether a blend of petroleum diesel with biodiesel can reduce the attraction.

The bear attractant analysis was conducted at Washington State University Bear Research Conservation and Education Facility in Pullman, Washington, April, 1995. Operational and wildlife safety were the main concerns for the tests. The conclusion was that biodiesel is no more attractive to bears than diesel fuel (Biel *et al.* 1995). These data are important for other users located in environmentally sensitive applications.

Operations and refueling facilities were based in Mammoth where assistance from the Maintenance Division was easily accessible, if needed. UI provided a Materials Data Safety Sheet for the fuel, and supplied data on the emissions, biodegradability and toxicity. Water quality specialists in state environmental agencies were informed about differences in cleanup strategies between biodiesel and diesel fuel. UI studies performed on acute dermal toxicity. This was all part of introducing a new fuel into an existing infrastructure.

<u>Equipment</u>

Diesel engines are used extensively in the Park and tourism industry for road maintenance, snow groomers, buses and other equipment. A combination of fuel availability and successful experience with the Cummins B series engines helped the project target the engine to be used in the project. DEQ was charged with putting this piece of the project in place. Dodge Truck Division donated the use of a 1995 Dodge 3/4 ton 4X4 pickup with 5.9 liter Cummins diesel engine to the project. DEQ was the project coordinator, the UI provided technical assistance and fuel, and NPS operated the truck and performed maintenance. It was equipped with a standard winterization package for diesel engines. No modifications were made to the truck's engine or fuel system.

The exhaust and fuel line were modified for the emissions tests at Los Angeles County Metropolitan Transit Authority Emissions Test Facility (LA-MTX). UI installed valves in the fuel and fuel return lines to facilitate quick changes of fuel types between tests. At that time, the rubber fuel hoses were replaced with Viton hoses because the 100 percent ester fuel can dissolve rubber hoses and gaskets over time. Dodge, Cummins, UI and NPS were interested in the effects on emissions both with and without the catalytic converter. With oversight by Dodge Truck, the catalytic converter in the exhaust train was equipped with flanges to facilitate its removal for emissions tests. For tests without the catalytic converter, a piece of straight flanged pipe would replace the flanged catalytic converter. A 6-inch section of bus-diameter tailpipe was welded to the end of the exhaust to facilitate hook-up with the emissions collection equipment.

The pickup truck was to operate throughout Yellowstone National Park, but the refueling tank was located in Mammoth, Wyoming. The 112 liter (30-gallon) truck fuel tank would give the truck a range of 530 to 820 km (330 to 500 miles). A 375 liter (100-gallon) in-bed fuel tank, pump, fuel filter, and meter were installed in the bed of the truck to allow extended operation in the Park without having to return to Mammoth (roughly 2,300 - 3,550 km or 1,430 - 2,200 mile range). The in-bed tank was not attached to the fuel system. The operator re-fueled the truck only from the in-bed tank because the fuel meter on the tank was the method of determining the amount of fuel pumped into the truck. NPS later installed a 300-gallon, divided, in-bed slip tank to give the truck a 9,420 km (5,860-mile) range (for highway driving) for long-distance trips for emissions tests and extended operations within the Park. A heating loop was added to this tank. The operator would open isolation valves for a few minutes of operation before refueling to heat the biodiesel fuel in the slip tank so it would flow easily during winter operations. This operation would be similar to many on-road diesel trucks and locomotives operating in Montana that have an in-tank (automatic) heater for use during cold weather operation.

The truck was driven over 151,800 km (92,600 miles) without any major fuel related problems. Items carried with the truck as a precaution included: fuel filters for the truck and fuel pump; replacement fuel lines; and an L-shaped rubber fuel elbow that went from the fuel tank to the fuel pump. This rubber elbow piece was first replaced in spring 1996 when the end fell off the engine as the truck was pulling off the road to re-fuel. The 100 percent REE softened the rubber causing the part to become loose. After this incident, the elbow was regularly changed about every two oil changes. Spare fuel filters were carried because the REE reacted with the mild steel in the slip tank and caused the tank rust. The fuel filters appear to have caught these deposits.

Originally, the engine lubrication oil was changed and sampled for heavy metals, viscosity, and base number every 9,654 km (6,000 miles). The analysis of the first lube oil sample showed a high silica content. The manufacturer suggested that the source was probably due to the manufacturer's final engine preparation. This first analysis was similar to that for other UI Dodge engines (Peterson *et al.* 1995). The lube oil sample taken during the first cold weather (December 1995) showed a change in lube oil viscosity. The test indicated possible fuel dilution, but the test was not designed to detect biodiesel, so we did not know what caused a change in viscosity reading. The manufacturer recommended the winter interval for oil changes in this engine should be about 4,820 km (3,000 miles) due to the increased idling in winter. The engine oil, filter and fuel filter were changed and sent for analysis during these regular servicing intervals and fuel dilution was never again detected in the tests.

<u>Engine Performance Monitoring</u>

In addition to the oil analysis, periodic chassis dynamometer and injector inspection tests were run to monitor engine performance. These were performed by UI in March 1995, August 1995, March 1996, November 1997 and June 1998. As expected, the engine produced about 6 percent less power with 100 percent REE then with to 100 percent conventional diesel fuel because of the lower fuel density of biodiesel. Drivers did not notice the difference. The second dynamometer test was the only one to show a loss of power probably due to the high ambient temperature of 41.7°C (107 °F). The test was interrupted several times to allow the engine to cool down even though fans provided additional cooling. The final dynamometer test was completed in mid-June, 1998. A detailed report on engine performance is expected in late 1998.

The final step in performance monitoring was the disassembly and inspection of the engine by Cummins Intermountain, Pocatello, Idaho. The inspection occurred on July, 1998. These results are being analyzed and a report is expected from UI in late 1998.

<u>Chassis Dynamometer Emissions Testing</u>

Chassis dynamometer emissions tests used the EPA Dynamometer Driving Schedule for Heavy Duty Vehicles (40 CFR Part 86 Appendix I Cycle D), (Peterson *et al.* 1995). Emissions tests at 5,955 km

(3,700 miles, 1995) and at 139,466 km (86,660 miles) were done at the Los Angeles County Metropolitan Transit Authority Emissions Test Facility (LA-MTX) using the same driver and other personnel, facility, emissions-grade diesel fuel, biodiesel, (20, 50 and 100 percent) blends, and measuring systems. Regulated, polyaromatic hydrocarbons (PAH)**,** and select air toxic emissions were sampled. Two sets of tests were run to determine biodiesel's long term effects on emissions.

Results of the first set of emissions tests were reported by Peterson *et al.* (October 1995). Particulate samples were analyzed for PAH and genotoxicity was investigated using a bioassay by Kado (1997). These initial screening tests showed toxicity and mutagenicity decreased with increasing percentages of biodiesel. The amounts of volatile organic compounds (VOC) were significantly decreased with 100 percent biodiesel. A final report is expected in early 1999 on the PAH and bioassay results of the second series of tests and comparison to the first set of tests.

Both sets of tests showed carbon monoxide (CO), total unburned hydrocarbons (HC), and, in contrast to other non-REE tests, oxides of nitrogen (NO_x) were reduced by increasing the percentage (to 20, 50 and 100 percent) of biodiesel in the fuel. Particulate matter (PM) was unaffected or slightly increased with increasing percentages of biodiesel. The catalytic converter operated more efficiently when biodiesel was used. The preliminary findings indicate that emissions have not increased over time, and the catalytic converter does not appear to be fouled by the use of biodiesel. A detailed comparison of regulated emissions data is given by Taberski *et al.* (October 1998).

Engine Dynamometer Tests

In support of this demonstration, dynamometer tests conducted using two rapeseed esters and blends (of 20, 50 and 100 percent) at Southwest Research Institute (SwRI). Cummins Engine Company supplied a Cummins 1995 B5.9L engine with catalytic converter like the one in the truck for these tests. In these tests, biodiesel fuels reduced transient emission levels of CO, HC, and PM compared to conventional diesel fuel. Rapeseed ester biodiesel fuels had no significant effect on levels of NO_x. Biodiesel and the addition of the catalyst were more effective at reducing PM than either biodiesel by itself or the catalyst without biodiesel (Sharp *et al.* 1996).

Kado (1998) conducted PAH and bioassay analyses on both particulate and aerosol (polyurethane foam, PUF) samples collected from the tests at SwRI. PAH analysis results confirmed the SwRI results, although Kado was able to detect some breakthrough.
These tests provided data for modeling emissions, provided data on hydrocarbon speciation (C1-C22), and confirmed trends observed in the chassis dynamometer tests. The information can be used to model the effects of biodiesel use on air quality in an airshed. The significant reductions in VOC and air toxics make biodiesel the preferred fuel for restricted or stagnant air conditions.

Fuel and Quality

Fuel type and quality were crucial to the success of this project. The results of emissions and performance testing over the length of the project would be worthless unless a uniform, standardized fuel was used. Fuel used was 100 percent REE as a worst-case scenario to develop data for warranty purposes. UI adopted the German DIN biodiesel speciation and confirmed this standard by running the American

Society of Agricultural Engineers (ASAE)x tests on each 2,550 liter (675 gallon) batch of fuel delivered.

Most of the vegetable oil feedstock was supplied by Koch Ag Services, Great Falls, Montana. The feedstock oil of 24,043 kg (25,830 liters, 6,825 gallons) was of off-spec (not food grade in color) de-gummed canola oil. McGreggor and Company supplied a storage tank for the oil at UI. Fuel ethanol and catalyst for processing the feedstock were supplied by J. R. Simplot Company, Caldwell, Idaho. Fuel ethanol was denatured with methanol. UI processed the 25,830 liters of feedstock oil into 24,648 liters (6,560 gallons) of biodiesel fuel (Peterson *et al.* August 22, 1995 and 1998) (about a 4.5 percent process loss). UI tested and delivered each batch to NPS at Mammoth Hot Springs, YNP.

NPS stored the biodiesel fuel at Mammoth in a 37,850 liter (10,000 gallon), unheated, gravity flow, above-ground (diesel) fuel tank. The cloud point characteristics of biodiesel cause us to originally plan to store the truck in the maintenance garage through the winter. However, NPS was sufficiently confident at the success of the project that it decided to continue the project throughout the winter. Biodiesel fuel would flow from the outside tank at -17.7 °C (0°F) if the nozzle was first cleared of solidified biodiesel. An 1,890 liter (500 gallon) double-lined fuel tank was placed in the maintenance garage and filled with biodiesel fuel to provide backup biodiesel availability for winter use. No cold-flow or other petroleum additives were used in the biodiesel.

The truck was delivered using conventional diesel fuel. It was broken-in for 1,735 miles using the regular diesel fuel before being switched to biodiesel fuel. The truck was run on 100 percent rapeseed ethyl ester biodiesel (REE) for the remainder of the project.

CONCLUSIONS AND FOLLOW-UP ACTIVITIES

This technical phase of the project will soon be successfully completed with several reports now under development. We have been able to determine that the effects of biodiesel on criteria emissions with and without the catalytic converter were unaffected over the course of time, and that no new compounds are generated in blends of biodiesel with conventional diesel. The project also developed data for use in modeling air quality so the impacts can be assessed before a large scale conversion is implemented. The information also shows that biodiesel or a blend may be the fuel of choice for restricted or poor air dispersion conditions. Tests also showed that the sweet odor of biodiesel exhaust does not attract bears, which was a concern to Park and land management officials.

Operation during two Yellowstone winters showed that normal cold-weather diesel modifications were sufficient to enable use of biodiesel in cold weather operations. These included engine coolant, an engine block heater, battery heaters, an external (electric, magnetic) fuel tank heater, and a heating loop to the slip tank. The truck was parked in a garage at night or plugged into an outlet when night temperatures dipped below -6.7°C (20° F). The truck failed to run on only one occasion with a daytime temperature of -38.3° C (-37°F), a time when most things were only running for cover).

Although fuel consumption increased 14 percent (by weight measure) from the initial emission test to the final emissions test, no apparent reason for the increase was readily seen. Records are being reviewed to determine if the increase in fuel consumption was due to a need for more power in the drive train since the increase was measured at the wheels. This measurement is affected by changes such as different tires, weight (slip tank), and other changes affecting power transmission.

The benefits of biodiesel include reduced toxicity, emissions, smoke, unpleasant odor, and increased safety and biodegradability. Two challenges yet remain: availability and cost. For this project, the refueling infrastructure and availability was carried in the bed of the truck, somewhat reducing the truck's usefulness for work. The cost factor was overcome in part by the generous contributions from our many sponsors.

Outreach Activities

The Truck in the Park, "french fry truck" or "canola truck" as it was referred to in the local communities, provided an introduction to alternate fuels in the greater Yellowstone Region. It received recognition from EPA for the environmental partnership that developed to conduct the project. People drawn to the truck pointed out that the U. S. should be doing more of this type of work. Truck operators identified that the public primarily wanted to know six things:

1) What changes were made to the engine? No changes to the engine or truck fuel system.
2) What was the mileage? About 16.3 mpg, or 1 mile per gallon less than diesel fuel.
3) How did it perform? For the most part, the driver did not notice much of a difference in performance (Peterson Survey, 1997).
4) How much did the fuel cost? For this project, about $7.50 per gallon which includes the emissions tests. A commercial-scale process might possibly produce biodiesel for $2-$3.50 per gallon, but no developer has stepped up to produce the 500,000 gallons per year to make the fuel a viable option in the Yellowstone tourism trade.
5) What is the yield of fuel per acre? About 100 gallons of rapeseed oil per acre, net.
6) When will this fuel be available to the public? The fuel is available for public use in Germany, France and Austria. A regional producer is needed before it is available here.

Follow-up Activities

The Phase I of the project will conclude with technical reports on emissions (LA-MTX and Kado), performance, and overall technical summary (UI). In Phase II, Chrysler Corporation has donated the truck to the Park for inclusion in its permanent vehicle collection. Cummins Engine Company has donated the disassembled engine to the University of Idaho. The University of Idaho will conduct some additional measurements and work with the National Park Service to complete the vehicle for the collection. NPS has developed a plan to expand the use of biodiesel into other parts of its fleet including a snow groomer, and dump truck. The outreach activities will continue with the truck being featured in the Greening of Yellowstone proceedings and a publication on sustainability and greening activities "From Yellowstone to Your Home," a booklet now in planning for Yellowstone's visiting public on sustainable products and practices that can be employed in the reader's residence and community.

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