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POTENTIAL IMPACT OF BIODIESEL ON SDDOT

Study SD2002-12-F
Final Report

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DISCLAIMER

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16. Abstract Research was conducted to determine the impact of a 5% blend (B5) of biodiesel with 95% petroleum diesel fuel on the South Dakota Department of Transportation (SDDOT). Biodiesel is made from vegetable oil or animal fat that has been transesterified. This process removes the glycerol from the oil. The transesterified oil can be used as a substitute for, or as an additive to, petroleum diesel fuel. Biodiesel is similar to #2 diesel fuel. It has a higher flash point, and is nontoxic and biodegradable. Biodiesel has a higher cloud point and cold filter plugging point than petroleum diesel fuels. Blending procedures and the impact of cold weather operation were evaluated to determine if a low level blend of biodiesel could be used reliably during South Dakota winters. Although previous biodiesel research indicated that neat biodiesel caused problems with rubber elastomers, no elastomer problems were noted during the test. The impact of a low level blend on engine performance was evaluated and the SDDOT fleet noted small reductions in fuel economy. The operators did not report reductions in power or torque when fueled with B5. Engine oil analysis suggested that engine component wear was essentially the same (or slightly lower) in vehicles fueled with B5 as compared to diesel fueled engines. Economic analyses of biodiesel fueling indicated a slight increase in fuel costs.			
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EXECUTIVE SUMMARY

In its 2002 session, the South Dakota legislature considered legislation mandating use of 2% (B2) biodiesel blend in all South Dakota Department of Transportation vehicles exempt from fuel taxes. This legislation failed, but was expected to resurface during later legislative sessions. Before SDDOT moved to adopt biodiesel blends, it set out to determine the impact that a biodiesel blend might have on its vehicle fleet.

Biodiesel is made from a number of sources including vegetable oil, tallow, lard, and waste cooking oils (yellow grease). Each can be transesterified using an alcohol that has been mixed with a catalyst such as potassium hydroxide or sodium hydroxide. The most commonly used alcohol is methanol. Methanol reacts easily and is less expensive to use than other alcohols such as ethanol.

Converting plant and animal oils into biodiesel results in a fuel that is very much like petroleum diesel fuel. This fuel is renewable, biodegrades quickly in comparison to petroleum diesel fuel, and forms a solution when mixed with petroleum diesel fuel. Biodiesel is naturally oxygenated and burns efficiently and cleanly in a modern diesel engine.

The SDDOT furnished the fuels and fuel storage facilities at four locations in the state. A total of twenty vehicles were initially selected by SDDOT for this research. More specifically, four trucks were selected at Aberdeen, Sioux Falls, and Pierre while eight trucks were identified at Rapid City. At each city half of the trucks were fueled with a B5 blend and half were fueled with petroleum diesel fuel. Also, although not part of the state DOT fleet, four trucks at the Brown County Highway Department were included in the study, with two fueled on the B5 blend and two fueled with petroleum diesel fuel. At each test site, SDDOT collected engine oil analysis data as well as vehicle maintenance data and this data were forwarded to the researchers. The vehicles were operated by SDDOT and Brown County employees for the duration of the project.

Fuel analyses were conducted to determine cetane, flash point, cloud point and cold filter plugging point as compared to petroleum diesel fuels. Blending procedures and the impact of cold weather operation were evaluated to determine if a low level blend of biodiesel could be used reliably during South Dakota winters. Although previous biodiesel research indicated that neat biodiesel caused problems with rubber elastomers, no elastomer problems were noted during the B5 test.

The impact of a low level blend on engine performance was evaluated and the SDDOT B5 fleet noted small differences in fuel economy. The operators did not report reductions in power or torque when fueled with B5. Engine oil analyses suggested that engine component wear was essentially the same in vehicles fueled with B5 as compared to diesel engines that had been fueled on 100% petroleum diesel fuel.

Economic analyses of biodiesel fuel use indicated that the substitution of the higher priced B100 (when blending) had a very small impact on price, generally from 1 to 5 cents per gallon, depending upon the B100 price used and the blend percentage. Based on the fleet trial results, vehicle maintenance costs for B5 biodiesel blended fuel were similar to costs for vehicles fueled with petroleum diesel fuel. Diesel engines, for the most part had higher maintenance costs for preventative maintenance, engine replacement, and fuel system repairs. Biodiesel (B5) engines, for the most part, had higher repair costs for lubrication and inspection, engine repairs, exhaust, and other repairs.

FINDINGS AND CONCLUSIONS

SURVEY OTHER STATE TRANSPORTATION DEPARTMENTS

A total of 31 DOTs had used, or considered using, a biodiesel blend. Nineteen DOTs had used the fuel in pilot projects or conducted tests that compared the performance of a biodiesel blend with petroleum diesel fuel. A total of 15 states have tested B20, two states have tested B2, and one state has tested B5 and B10. A total of eight DOTs experienced fuel filter plugging problems during warm weather operation. However, none of the agencies reported continuing problems with fuel filters. The renewable component of the blend was in most cases derived from soybean oil. Of the 48 states that responded, only Minnesota had a mandate that will require general use of a biodiesel blend by agencies and the public. Missouri, Kansas, and Washington reported limited state agency (DOT) mandates to use a blended fuel. The aggregated responses from the survey suggest that the biodiesel blend was a seamless replacement for petroleum diesel fuel.

REVIEW SDDOT'S VEHICLE INVENTORY

Over 1200 diesel engines are used in the SDDOT fleet. These engines are made by 35 different engine manufacturers (Cummins, Detroit Diesel, etc.). Further, SDDOT has vehicles that are manufactured by 78 different companies (John Deere, Ford, etc.).

Two findings surfaced in this review. The first issue is that Case New-Holland (CNH) is the manufacturer responsible for the largest share of the SDDOT diesel fleet. Because of the recent merger of Case and New Holland, CNH is responsible for approximately 50% of the engines in the SDDOT fleet. Caterpillar, Cummins, Ford, Detroit, and Deere each have less than 10% of the total fleet respectively. Second, and perhaps most important, is that over fifty percent of the SDDOT fleet is less than five years old. This is important because by 1996 most of the engine manufacturers changed the composition of their fuel system gaskets to prevent leaks that surfaced with the introduction of low sulfur diesel fuel (500 ppm). The composition of these gaskets are such that the newer engine fuel systems should not see any adverse affects from fueling with a biodiesel blend.

CNH identified four issues that they felt must be addressed when fueling with a biodiesel blend[1]. As noted below, these issues pertained to biodiesel solvency, blending, material compatibility, and fuel quality.

- Fuel Quality—In the US, the biodiesel fuel is unregulated and biodiesel fuel quality is sometimes lower than the specifications in the ASTM Standard. Fuel quality issues can have a significant impact on engine reliability and performance. In Europe, where more stringent

[1] G. Stanek (personal communication, June 20, 2003)

standards for biodiesel fuel are in place, engines are warranted using higher blends of rape methyl ester (RME) biodiesel fuel.

- Solvency—Biodiesel fuel acts as a solvent. When used in older vehicles, the biodiesel fuel can dissolve deposits left from previous fuels. When these particles enter the fuel system, filter plugging is the most common problem.
- Blend—The higher the blend of biodiesel, the more problems should be expected. A B5 fuel would not be expected to cause any problems. When the blend is increased beyond B20, the effects associated with solvency and material compatibility can increase.
- Material Compatibility—In newer engines (post 1996) material compatibility should not be a concern for B5 blends. In older engines, particularly with worn and cracked fuel lines, problems are more likely to occur. Materials of concern are fuel lines, diaphragms in fuel transfer pumps, and seals and o-rings in fuel pumps.

Several engine manufacturers (Deere, Cummins, Detroit, and International as well as the Engine Manufacturers Association) have issued position statements concerning fueling with a biodiesel blend. These statements can be found in the Appendix B.

TEST ENGINE COMPONENTS

Although previous biodiesel research indicated that neat biodiesel caused problems with rubber elastomers, no elastomer problems were noted during the B5 test. The National Renewable Energy Laboratory (NREL) recently completed a set of tests of five common fuel system polymers using a B20 biodiesel blend, a comparison petroleum diesel fuel and a 15% ethanol-diesel fuel blend. Samples exposed to the reference diesel fuel and the B20 biodiesel blend generally behaved the same. The polymers were affected to a much greater degree by the 15% ethanol blend than by the biodiesel blend. NREL is in the process of completing a more extensive biodiesel elastomer project, which will include highly oxidized fuel samples, as well as engine fuel pump endurance tests with biodiesel blends. Information from this study is currently expected to be released to the general public and the SDDOT in the spring of 2005. Since many of the diesel fueled vehicles in service at SDDOT are late model vehicles/engines, this data should provide insight concerning material compatibility for these engines.

EVALUATE OPERATIONAL PERFORMANCE

Blending procedures used to mix biodiesel and petroleum diesel fuel were a concern identified by the SDDOT technical panel. An incident occurred during the research project that prevented one truck operator from refilling his fuel tank at the Brown County site in Aberdeen. The researchers believe that this may have been a result of improper blending of the biodiesel and diesel fuel. The biodiesel blend stock was kept at room temperature (~70°F) to facilitate blending. However, the ambient temperature was approximately 0°F at the time that biodiesel was blended with a new shipment of diesel fuel. It was not possible to confirm the sequence and duration of events used in blending that day and thus identify the exact cause of the problem. However, biodiesel fuel has a higher density than petroleum diesel fuel, and warm biodiesel added to very cold diesel fuel could settle to the bottom of the tank. Without adequate agitation during the blending process this fuel would cool and solidify at the bottom of the tank. In this case the operator was unable to pump fuel from the B5 tank the day following the blending. No other incidents of cold flow problems were reported during the research project, and no truck was taken out of service due to cold weather operation as a result of fueling with a biodiesel blend. The B5 fuel that had caused filter blockage was recirculated in its tank and was eventually able to be pumped in a normal way. This incident, occurring with one of the only above-ground storage tanks involved in the study, emphasizes the need for a thorough understanding of the impact of blending fuels under adverse conditions, and for the strict adherence to appropriate procedures established for blending as published by the National Renewable Energy Laboratory (NREL/TP-540-36182; November 2004).

It is important to note that while two of the Brown County trucks could not draw fuel from the fuel supply tank (on that cold day) that the trucks had been filled the night before and completed their work for that day while using the B5 blend (the fuel that was left in their tank from the day before). Further, the testing spanned two winters and no truck was taken out of service due to cold weather operation (13 trucks were fueled with a B5 blend) as a result of fueling with a biodiesel blend (B5).

The impact of a low level biodiesel blend on engine performance was evaluated and the SDDOT fleet noted very small reductions in fuel economy (B5=4.7 mpg and Diesel Fuel= 4.9 mpg). This was expected, as the energy value [British Thermal Unit (BTU)] of a B5 blend is slightly lower than 100% petroleum diesel fuel. The operators did not report reductions in power or torque when fueled with B5. Engine oil analysis suggested that engine component wear was essentially the same in vehicles fueled with B5 as compared to diesel fueled engines.

CONDUCT PHYSICAL AND CHEMICAL TESTS

The diesel fuel met or exceeded the specifications established by ASTM D975. The biodiesel (B100) met or exceeded all specifications established by ASTM D6751 except flashpoint. The flashpoint for the B100 sample was slightly lower than the standard in D6751 (114°C and 118° C vs. 130°C). The researchers then examined ASTM D6751 in more detail. The flashpoint for biodiesel is intended to be 100°C minimum. However, the specification for flashpoint in D6751 is set 30°C higher than this specification. This document explains why flashpoint was set higher when the ASTM committee developed D6751. This was because the committee members realized that meeting this criterion was a cost effective way to determine excess amounts of unreacted alcohol that remained in the finished biodiesel. The researchers also noted that since the biodiesel would be mixed with diesel fuel (flashpoint minimum for ASTM D975 ranges from 38°C to 52°C), that the flashpoint of the B5 blend would still be significantly higher than the flashpoint specification established for either number one or number two diesel fuel in ASTM D975.

Stability of diesel fuel is important as oxidative breakdown or biological conversion of the fuel can leave residues that can plug filters and adhere to injector pump parts reducing pump life. Stability is of particular concern in biodiesel as its compounds are considered to be more susceptible to oxidation than petroleum products. Fuel can be tested for changes in filterable residues over time as a measure of the stability of the fuel.

Two types of stability tests were conducted on samples of the B5 blended fuel. A test of total insolubles filtration (ASTM D2276) was conducted on B5 that had been aged in the fuel tanks of two infrequently used trucks (Figure 9). An identical test was conducted on a sample of B5 that had been stored undisturbed in a barrel for the duration of the research project A sample of B5 was also subjected to an accelerated oxidative stability test (ASTM D2274) at the outset of the project. The accelerated test provided a total insolubles level of 3.2 mg/1000ml (Figure 9). Storage of the fuel in the truck fuel tanks for periods of approximately 6 months and one year respectively caused total insolubles in both samples to rise from a level of 2 to a level of 3 mg/1000 ml. The sample of fuel stored in a barrel for the duration of the project produced a total insolubles filtration result of 4 mg/1000ml. The results are in agreement with the accelerated test and are well below the 10 ppm level threshold that some major municipalities (New York) have set as a maximum allowable level for delivered diesel fuel. The researchers contacted the fuel suppliers to determine if any anti-oxidants or other fuel additives had been added to either the biodiesel or the diesel fuel. The biodiesel suppliers reported that only pour point depressants had been added to the biodiesel. The importance of these findings is significant. First, this means that the fuel which was delivered for use with the project was a fuel that met the standards as established by ASTM D975 and ASTM D6751. Second, and more importantly, this finding suggests that if the fuel tank of a vehicle were topped off with B5 and subsequently not used for several months, that the B5 fuel should not age prematurely.

Evaluate Vehicle Maintenance Histories

Engines fueled with diesel fuel had higher maintenance and repair costs than did the B5 fueled engines. Several comparisons were made with the data from the engine oil analysis samples to see if differences in engine wear might be apparent. All engine oil analyses data were found to be within normal levels for both the B5 and the diesel fueled engines. In short, these comparisons showed no differences between the levels of wear metals found in the used engine oil analysis samples regardless of the fuel used.

The trucks were in a good state of repair at the beginning of the test, and only a limited number of parts were replaced on the diesel “fueled” engines and the B5 fueled engines. The researchers felt that the parts that were replaced were items that would have been replaced regardless of the fuel used to fuel the engine. For example, the copper tubes surrounding the injectors in the heads cracked on an engine that was fueled with diesel fuel. One B5 fueled engine underwent a major overhaul. In this case a valve keeper came loose and allowed the valve to contact the piston with the result that the valve was imbedded into the top of the piston, destroying the piston and damaging nearby pistons. One of the diesel fueled engines experienced a main bearing failure. The engine for this truck was replaced with a factory rebuild and put back into service. In each case the repairs that resulted were not attributed to the fuel (diesel versus B5) that was used to fuel the engine.

ASSESS COSTS, BENEFITS, AND ECONOMIC IMPACT

Diesel “fueled” engines had a higher mortality rate, resulting in higher engine repairs for these engines and ultimately the total replacement of one diesel “fueled” engine. The failure mode of the engine, as reported by the technicians, was not a result of fuel used, but normal engine mortality. As such, these expenses were removed from the calculations, reducing the difference in maintenance costs per-mile for the diesel “fueled” and B5 fueled engines to five cents. Maintenance costs for B5 biodiesel blended fuel were similar to petroleum diesel fuel. Diesel engines, for the most part had higher maintenance costs for preventative maintenance, engine replacement, and fuel system repairs. B5 engines, for the most part, had higher repair costs for lubrication and inspection, engine repairs, exhaust, and other repairs.

Economic analyses of biodiesel fueling indicated that the substitution of the higher priced B100 (when blending) had a very small impact on price, generally from 1 to 5 cents per gallon ($0.02/gallon). This price varied depending on the B100 price used and the blend used to fuel the engine. Also, the cost differential for implementation of a B5 blend will be much less as the cost of petroleum diesel fuel approaches $2.00 per gallon. This is due to the fact that as petroleum costs increase the cost of petroleum moves closer to the market cost of biodiesel. Currently 100% biodiesel sells for ~$2.30 / gallon.

PREPARE GUIDELINES AND SPECIFICATIONS

A survey of fuel storage tanks at SDDOT was conducted to determine how SDDOT stores fuel across the state. The survey indicated that over 98 percent of SDDOT’s fuel is stored underground. This type of fuel storage reduces the likelihood that fuel would gel even in extremely cold weather and provides a relatively constant temperature for the fuel, improving fuel stability. Finally, if the biodiesel could not be blended prior to delivery, the higher temperature below ground during cold weather would facilitate homogenous blending of the biodiesel with the petroleum diesel fuel. This is due to the fact that underground fuel tanks are typically set below the frost line, thus resulting in a more uniform daily fuel temperature in the storage tank.

Much of the knowledge developed as a result of this task is found in the Implementation Recommendations section of this report. These recommendations were developed based on the findings of the investigation, the aforementioned fuel storage investigation, as well as the researchers’ review of literature.

IMPLEMENTATION RECOMMENDATIONS

The researchers outlined the following implementation plan for SDDOT. The importance of purchasing biodiesel that meets or exceeds the specifications set forth by the ASTM D6751 cannot be over emphasized. In addition, regular fuel tank maintenance and fuel filter maintenance procedures recommended by the original equipment manufacturer must be adhered to by the truck drivers and truck maintenance personnel.

The biodiesel that is purchased for blending must meet or exceed the standards set forth in ASTM D6751. This is a requirement that all engine manufacturers expect vehicle operators to do when buying fuel for the engine.

The biodiesel must be readily available. A contract will need to be drawn up with the local fuel distributors with an option to provide petroleum diesel fuel in the event that the fuel distributor is unable to deliver a biodiesel blend as required.

In the event that fuel is NOT available, the SDDOT should have the option of using standard diesel fuel. Since low level blends, (such as B5), are interchangeable with standard diesel fuel, changing fuels can be done as necessary to accommodate market issues or availability.

- **Cleaning of fuel storage tanks prior to a change to a blended fuel is not required.** *It is not common practice among fuel distributors to clean tanks unless the tank is to be used for gasoline rather than diesel fuel. The cost to clean each tank and dispose of the fuel from the bottom of the tank as hazardous waste is substantial. Further, since few of the tanks have manhole access, it is virtually impossible to remove all of the debris that has settled to the bottom of the tank. If SDDOT feels a need to clean these tanks it should be a result of a regular tank cleaning system/program and not because they have decided to change to a biodiesel blend.*
- **Storage tank fuel filters should have a water trap incorporated into the filter.** *This type of filter is readily available, and should already be in place at each fueling station.*
- **The distributor should deliver pre-blended fuel.** (Cenex has already adopted this policy for their customers.)
- **Inform all vendors who bid on the biodiesel blend contract regarding expected procedures for blending biodiesel with the petroleum diesel fuel.** (Note the Biodiesel Handling and Guidelines available from the National Renewable Energy Laboratory, NREL/TP-540-36182; November 2004)
- **Follow your existing plan for number one vs. number two usage patterns.** (October through April is when number one fuel is used)

PROBLEM DESCRIPTION

Biodiesel is a renewable fuel that is being actively considered by many agencies. The fuel is made from vegetable oil or animal fat that has been transesterified. Biodiesel can be used directly or blended with petroleum diesel to fuel a compression ignition engine. Biodiesel is renewable and is considered an alternative fuel in the United States. Biodiesel is produced by reacting vegetable oil or animal fat with alcohol in the presence of a catalyst such as potassium hydroxide or sodium hydroxide. The excess alcohol and catalyst are removed through water washing, leaving the end product methyl ester (if reacted with methanol) or ethyl ester (if reacted with ethanol) and the by-product glycerin.

B100, which is 100% biodiesel, is an excellent solvent. Diesel fuel with as little as 5% ethyl or methyl ester, known as B5, could increase the maintenance costs of the fuel system due to the solvent action cleansing the vehicle fuel tank and lines during initial use. It was also known that biodiesel blends above B20 have degraded certain elastomers in fuel systems. The SDDOT vehicle fleet included many different types and ages of diesel engines/fuel systems. Little information was available on older diesel engines/fuel systems using any blend of biodiesel. The potential for degradation of elastomers in the fuel system, engine seals and/or gaskets may be greater for older engines (1996 or later).

Concerns were raised regarding engine and fuel system warranties. Storage issues, vehicle performance during cold weather, and the potential for sludge formation were also legitimate concerns for the SDDOT. Blending procedures and their potential impacts on fleets operating in cold weather were important considerations in this region. Biodiesel has pour point temperatures and cloud point temperatures that are considerably higher than corresponding values for petroleum diesel fuel. Cold flow issues have been reported by other agencies and were appropriate for study here. Anytime fuel is stored in storage tanks, above or below ground, the potential for water accumulation from condensation and sludge formation exists. An unknown with biodiesel was whether the formation of sludge will increase, decrease, or remain about the same as regular diesel fuel.

Finally, the Department needed to determine the financial impact of using B5 in its vehicle fleet. Some of the other potential costs associated with using B5 in SDDOT vehicle fleet were equipment conversion, engine deterioration, fuel consumption, and an additional fuel storage tank at each fueling center. On the other hand, there could be economic benefits for SDDOT. For example: reduced fuel system wear due to biodiesel's superior lubricity as compared to the poor lubricity of low-sulfur and future mandated ultra-low sulfur diesel fuels.

OBJECTIVES / METHODS

The South Dakota Department of Transportation defined three objectives for this study:

1. Assess the compatibility of B5 fuel with SDDOT's vehicle fleet and storage facilities.
2. Determine the conversion and ongoing cost for SDDOT to use B5 in its vehicle fleet.
3. Estimate the overall economic impact to the Department if SDDOT were to use B5 in its vehicle fleet.

Researchers at the University of Missouri and South Dakota State University met with SDDOT maintenance personal and truck drivers to explain how the trucks would be fueled and how the data would be collected for the study. A total of four locations were originally selected for the study: Aberdeen, Rapid City, Pierre, and Sioux Falls. Originally the trucks were to be operated on a B5 blend for one year, however, the winter was exceptionally mild. The researchers and the SDDOT technical panel recommended extending the length of the project so that data would be collected during two South Dakota winters.

The University of Missouri collected journal articles related to biodiesel fueling from 1991 – 2005. The researchers took advantage of this database of journal articles and also reviewed journal articles that were available via the internet to gain insight for the study. The websites at Iowa State University, the University of Idaho, the University of Georgia, and the National Biodiesel Board were also reviewed. The end result was the first interim report which was a comprehensive review of biodiesel related literature.

The researchers gathered information from DOTs concerning biodiesel fueling across the United States using an email questionnaire. The response rate was excellent, with 48 of the 50 states responding. This effort helped address both agency as well as statewide efforts to utilize biodiesel by DOTs. The data were compiled by the researchers, reported at ASAE conferences that were held in Ottawa, Canada and St. Joseph, Missouri. The data were also reported at a biodiesel educational forum for DOTs held in Boise, Idaho.

Data were queried using SDDOT computers to determine the make and model of the diesel engines and diesel powered vehicles owned and operated by SDDOT. These data were reviewed by the researchers to determine the composition of gaskets and other engine systems that might be impacted by using a biodiesel blend. Grouping of the data by manufacturer and by date of manufacturer revealed that over 50% of the SDDOT fleet were manufactured by CNH and that over 50% of the fleet was less than five years old. Discussions with the engine manufacturers also revealed that several engine manufacturers have published a position statement concerning the use of biodiesel and biodiesel blends in the engines that they sell.

The researchers contacted both private and United States government labs about biodiesel. For example the researchers learned that NREL, the National Renewable Energy Laboratory in Golden, Colorado had hired Southwest Research Institute (SwRI) in San Antonio, Texas to perform biodiesel material compatibility tests. Due to the scope of an on-going SwRI material compatibility project, and the fact that the researchers were to conduct a material compatibility test that would essentially duplicate nearly all of the data already gathered by SwRI, the SDDOT technical panel elected to wait for the results from this research. The SDDOT material compatibility testing was cancelled and the funding for this effort was redirected by the technical panel to evaluate the cold flow properties of the biodiesel blend.

A concern was raised early in the study about the changes that have been made to the fuel filters used on diesel engines. The standard size opening at one time was 45 micron so ASTM test procedures typically used a 45 micron mesh to determine the temperature when a fuel would plug a fuel filter. Fuel filters openings have now been reduced to as small as 2-10 microns. As such, the SDDOT asked that the researchers determine if adding the biodiesel to the diesel might increase the chances of fuel filter plugging (the biodiesel cold filter plugging point is higher than either number one or number two diesel fuel). Researchers at the University of Missouri designed and tested a device that dropped the temperature of the biodiesel. Fuel filters purchased from CAT were fitted and tested with this device.

SDDOT coordinated the operation, fueling, and maintenance of the trucks. SDDOT personnel ordered the diesel fuel and the biodiesel and blended the biodiesel with the diesel fuel using splash blending techniques. Some of the B5 fuel was blended by the distributor prior to delivery. Fuel samples were gathered by SDDOT and sent to ANA Labs in Maryland for chemical analysis.

One of the truck drivers was unable to refuel with a B5 blend when the ambient temperature dropped to 0 degrees F. The researchers subsequently devoted resources from the project to analyze the cold flow properties of the blend. They also contacted cold flow additive vendors, blended the cold flow additive with the B5, and repeated the experiment. All the cold flow testing as well as the fuel analysis were conducted using testing procedures established by the ASTM (American Standard Testing Materials International).

SDDOT was concerned about fuel stability over time. The researchers monitored this by filling the fuel tank of two trucks that were used very little throughout the year. These trucks were essentially not refueled for nearly twelve months. Fuel samples were drawn from these fuel tanks over time and analyzed to determine if the quality of the fuel was degrading using standard ASTM test procedures.

The truck operators did not report differences in power although the B5 blend would have been lower in energy as compared to the number two diesel fuel. Fuel economy was monitored using data reported by the truck operators. For the most part, the use of a B5 blend slightly reduced the fuel economy of the trucks.

The parts that were needed to maintain the trucks were tracked using the SDDOT vehicle maintenance data collection system. The researchers reviewed the parts that were replaced to determine if any of the failed parts were related to the fueling system of the truck. The researchers felt that the parts that were replaced were items that would have been replaced regardless of the fuel used to fuel the engine.

Some of the engines failed during the test, but the researchers determined that the engine failures were not a result of the fuel that was used to fuel the engine. As such, these expenses were removed from the calculations, reducing the difference in maintenance costs for the engines. Data were then examined to determine if the B5 fueled engines had higher or lower operating expenses.

Economic analysis was conducted on the use of the fuel using several pricing scenarios. The researchers noted that the use of B5 increased the cost of the fuel by just $0.02 per gallon, depending on the price of the diesel fuel and the price of the biodiesel.

The researchers conducted a survey of SDDOT's fuel storage facilities to determine how fuel was stored at each location, when the fuel tanks were last cleaned, and the volume of fuel that can be stored at each facility. With the exception of one location, all SDDOT facilities used underground storage tanks.

After all the aforementioned tasked were completed, the researchers then developed a set of guidelines that should be followed when adopting a biodiesel fueling program.

TASK DESCRIPTION

TASK 1. MEET WITH TECHNICAL PANEL

Meet with the project's technical panel to review project scope, work plan, and draft survey of state transportation departments.

Leon G. Schumacher, Daniel S. Humburg, Ajit K. Mahapatra, Gary L. Taylor and Tonya J. Hansen met in November of 2002 with the project's technical panel and reviewed project scope and work plan.

TASK 2. REVIEW LITERATURE

Review literature on previous and on-going biodiesel research and potential problems that can occur with components in fuel systems.

Ajit K. Mahapatra traveled to University of Missouri, Columbia for two weeks (11/15/02 to 11/29/02) and prepared a review of biodiesel literature for SDDOT. During his stay in Columbia, he identified several papers in the extensive University of Missouri (MU) biodiesel archive that had been written by biodiesel researchers and examined each paper for relevancy. He reviewed the papers and copies of various biodiesel conference proceedings on file at MU, and summarized the findings for each paper. He also used search engines such as YAHOO and GOOGLE to identify additional information that related to the objectives of the investigation.

Tonya Hansen and Gary L. Taylor reviewed economics-related biodiesel literature at SDSU immediately following the approval of the project. Articles that were reviewed were specifically related to: biodiesel fuel use, biodiesel fleet methodology and results, biodiesel economic impact methodology, biodiesel economic impact results, and biodiesel policy research findings. Engineering-related biodiesel literature encountered was shared with engineers on the research team. A comprehensive set of biodiesel references was established relative to existing literature.

A report essentially consisting of this review of literature was submitted to SDDOT in December 2002. This review presented preliminary findings, recommendations and conclusions. This report was revised per SDDOT technical review. A copy of this report is published separately and can be obtained from SDDOT.

TASK 3. SURVEY OTHER STATE TRANSPORTATION DEPARTMENTS

Survey other state transportation departments that have used or are using biodiesel in their fleets to identify benefits, problems, and overall experience with biodiesel.

Humburg, Mahapatra, Adams and Schumacher drafted a survey questionnaire for use in determining experience of other departments of transportation (Appendix A). The survey was reviewed by the technical panel prior to distribution via email. A list of E-mail addresses for state DOT's was assembled for distribution of the survey. Adams developed a locked word document for this questionnaire so that DOT's would have an option of returning a paper copy of the questionnaire or an electronic version of the questionnaire by email.

Responses were obtained from 48 states. Thirty-one of those states had actively considered, used, or tested a biodiesel blended fuel for their fleets. A total of 15 states have tested B20, two states have tested B2, and one state has tested B5 and B10. State policy has been one of the driving forces behind initial adoption of this alternative fuel. Nine departments of transportation reported being mandated to study, test, or use a biodiesel blend. Five of those states had in place a policy or mandate to require current or future use of a biodiesel blend by their DOT agency. Minnesota was the lone state with a mandate scheduled to require comprehensive use of a biodiesel blend statewide.

Results of the survey are summarized here. An ASAE paper giving the results of the survey can be obtained through ASAE, paper number 046072, St. Joseph, MI 49085.

A high level of interest in this alternative fuel exists among DOTs. Nineteen states (39.6% of those responding) reported program experience with the use or testing of biodiesel blended fuel in their operations. Over half of these states reported no state mandate driving their use or testing of the fuel. For the fourteen states that have considered or tested the fuel, but elected not to utilize it, the most common deterrents to adoption were additional cost of the blended fuel and cold weather behavior of the fuel. The weighted average price differential for those DOTs reporting volumes and prices was $ 0.0923/gallon above the price of petroleum diesel fuel. A total of 8,925,172 gallons of blended fuel had been used to fuel DOT fleets.

Soy Methyl Ester (SME) was the dominant feedstock used as the biodiesel component. SME was reported by all but one of the states with experience using or testing biodiesel blended fuel. A 20% biodiesel composition was the most common blend level, with 78% of the responses reporting this level for tests or use. Blend levels of 2%, 5%, and 10% were also reported. Among five states with agency policies or state mandated use, a blend level of 2% was reported in three. The other two states with a use policy or mandate were utilizing 20% biodiesel specifically to meet Epact mandates for alternative fuel vehicle use.

The blending procedures that were reported for biodiesel were not uniform or standardized. Five states with biodiesel experience indicated the fuel was splash mixed (blended) with biodiesel added atop the petroleum component. Splash blending with petroleum added above biodiesel was reported by two states. Storage tank blending at the agency was reported by four states, and terminal blending with pipeline delivery was reported by two. Similarly, the composition of the petroleum component varied by state and season. Nine of the states using or testing biodiesel blends utilized number two diesel fuel throughout the year. The remaining states used #1 fuel, or a blend of #1 and #2 diesel fuel for the petroleum component during specified months of the year. North Dakota reported discontinuing use of the biodiesel blend during the winter months. Otherwise, responding agencies did not generally indicate that changes were made to specifically accommodate the biodiesel blended fuel for cold weather operation.

Plugging of filters may be expected during the introduction of a biodiesel blended fuel. Eight of the seventeen states that responded to this question reported fuel filter plugging problems. However, all of them reported that the problems were resolved after the filters were replaced. Responses did not suggest that any one type of filter was more prone to plugging than others.

Cold weather behavior of biodiesel blended fuel was not found to be a widespread problem. Iowa and Ohio reported that filter plugging problems had occurred but only during cold weather. South Dakota did not experience fuel filter plugging problems. However, during the winter of 2003 two Brown County trucks at Aberdeen were not able to be fueled from the above ground B5 fuel tank. No other problems were reported that were attributed exclusively to cold weather operation.

The experience of state Departments of Transportation with biodiesel blends indicated that this alternative fuel is gaining acceptance as a viable part of the fuel supply for state agencies. In most respects, the blended fuel was a seamless replacement for 100% petroleum diesel. The responses to this survey indicated that the strongest deterrent to more widespread adoption of the fuel was the cost differential that existed between petroleum diesel fuel and biodiesel blends. In addition, the combination of non-uniform blending procedures and unanswered questions related to blending and storing biodiesel blended fuel under very cold temperatures has delayed widespread adoption of the fuel. Additional research on these issues could assist DOTs and other organizations currently contemplating the use of a diesel fuel with a biodiesel component.

TASK 4. REVIEW SDDOT'S VEHICLE INVENTORY

Review SDDOT's inventory of diesel vehicles and equipment to identify the potential nature and extent of compatibility problems with biodiesel.

A list of vehicles in inventory was provided by the SDDOT. This list was reviewed to identify the range of engines and fuel systems that could possibly be affected by a B5 blend. Manufacturers of fuel systems were contacted to identify polymer materials used in these engines and fuel systems. Paul Oien provided additional information when data were missing from the SDDOT equipment database. In short, SDDOT has a very diverse inventory with over 1200 diesel engines. There are 78 different vehicle manufacturers and 75 different engine manufacturers.

Case New Holland (CNH) has been assessing the compatibility of the Case and CaseIH products with biodiesel fuels. They do not foresee any major problems with material compatibility using B5 in products produced after 1996. In Europe, they allow higher blends using Rape Methyl Ester (RME) biodiesel fuel. As the biodiesel blend level increases, the likelihood of problems occurring with the engine also increases.

The concerns expressed by CNH in regard to the use of biodiesel fuel are as follows[2]:

1) Fuel Quality—In the US, the biodiesel fuel is unregulated and the biodiesel fuel quality tends to be lower than the ASTM Standard specifies based on the problems they have seen using biodiesel. These fuel quality issues can have a significant impact on engine reliability and

[2] G. Stanek (personal communication, June 20, 2003)

performance. In Europe, where more stringent standards for biodiesel fuel are in place, engines are warranted using higher blends of RME biodiesel fuel.

Table 1: SDDOT Diesel Engine Fleet Sorted by Manufacturer

Manufacturer	Number	Percent of fleet
International	320	25.6
Case New Holland (CNH)	270	21.7
Ford	147	12.3
Sterling	79	6.2
Osh Kosh	48	3.8
John Deere	41	3.2
Ingersol Rand	27	2.1
Gallion	25	1.9
Komatsu	18	1.4
Other		21.8
Note: Other manufacturers included BobCat, Massey Ferguson, Hyundai, Mack, Volvo, etc.		

Table 2: SDDOT Diesel Engine Fleet Sorted by Engine Manufacturer

Engine Make	Number	Percent
International	297	23.2
Cummins	243	19.0
Case	197	15.4
Cat	148	11.6
John Deere	106	8.2
Ford	78	6.1
Detroit	50	3.9
Perkins	39	3.0
Isuzu	25	2.0
Deutz	24	1.9
Other		5.7
Note: Other engine manufacturers include Allis Chalmers, Fiat, Komatsu, Kubota, Lombardini, etc.		

Table 3: SDDOT Diesel Engine Fleet Sorted by Year of Manufacture

Year (range)	Number	Percent
1991—1995	347	27.1
1996- 2000	302	23.6
1986—1990	251	19.6
2000+	164	12.8
1971—1980	85	6.6
1981—1985	76	5.9
1961—1970	52	4.1
Older than 1960	1	

2) Solvency—Biodiesel (B100) fuel acts as a solvent. When used in older vehicles, the biodiesel fuel can dissolve deposits from previous fuels. When these particles enter the fuel system, filter plugging is the most common problem.

3) Blend—The higher the blend of biodiesel, the more problems should be expected. A B5 fuel would likely not cause any problems. When the blend is increased beyond B20, the issues associated with the solvency and material compatibility can increase rapidly.

4) Material Compatibility—In newer engines (post 1996) material compatibility should not be an issue for B5 blends. In older engines, particularly with worn and cracked fuel lines, problems are more likely to occur. Materials of concern are fuel lines, diaphragms in fuel transfer pumps, and seals and o-rings in fuel pumps.

In regards to recommending specific materials to test for Task 5, engine and fuel system manufacturers can identify groups of materials that vendors were asked to use for various fuel system components. However, most cannot identify the particular material used in a specific component on a specific vehicle. CNH reported that elastomer materials used after 1996 should be compatible with biodiesel due to the marketing demands in Europe.

Several engine manufacturers including the Engine Manufacturers Association (EMA) in the United States have developed position statements for biodiesel use. Copies of statements were secured from the John Deere, Cummins, Detroit Diesel, and International. These statements can be found in full in Appendix B. In general, most engine manufacturers are willing to warranty engines that have been fueled with a B5 (or lower) blend of biodiesel and petroleum diesel fuel.

TASK 5. TEST ENGINE COMPONENTS

Conduct swell and other appropriate tests on engine and fuel system components that may be potentially be impacted by the use of specific biodiesel concentrations (B2, B5 and B20).

Dr. Humburg contacted Robert McCormick at the National Renewable Energy Laboratory (NREL) and learned that NREL had recently completed a material compatibility study at the Southwest Research Institute (SwRI), much like what the SDDOT had envisioned. This study included a set of tests of five common fuel system polymers using a B20 biodiesel blend, a comparison petroleum diesel fuel and a 15% ethanol-diesel fuel blend. Polymer samples were tested for swell and breaking strength. Samples exposed to the reference diesel fuel and the B20 biodiesel blend generally behaved the same. The polymers were affected to a much greater degree by the 15% ethanol blend than by the biodiesel blend. The complete report for this study is found in Appendix C. McCormick also reported that NREL was administering a much more detailed biodiesel material compatibility study and that this project would end late 2004. The elastomers that NREL were examining as a part of this project were: Medium Swell/Hydrogenated Nitrile (28-29% Acrylonitrile) Cummins P/N 145544, Low Swell/Hydrogenated Nitrile (33-34% Acrylonitrile) Cummins P/N 70415, Viton B, Fluorel, cured with bisphenol and phosphonium salt catalyst Cummins P/N 193736 (Parker VW153), Another Viton, Parker V1164, and another high nitrile elastomer commonly used in diesel fuel systems. Both soybean and canola biodiesel are being tested in this study at 5% and 20% blend levels. An oxidative stability agent will be used to ensure that the biodiesel blendstock is within specifications. Some biodiesel will be artificially oxidized and then used as a comparison fuel for this research.

While not a part of the SDDOT task, it is also notable that the NREL study is to include injector pump endurance tests using both high quality and highly oxidized biodiesel blended fuel. The most recent contact with NREL suggests that results from the study may be released in the spring of 2005. SDDOT should review these findings as soon as they are released as they should be of immediate interest to the biodiesel user community. The study was sponsored by the Coordinating Research Council and the results, when released, will be posted at the following website: http://www.crcao.com/.

Alternate Cold Flow Study

A potential problem with cold flow behavior was identified early in the study and is described below. Since the initially proposed polymer tests would be a duplication of the larger NREL studies, the research team proposed that a cold weather effects study be conducted in its place using current fuel filters found on new diesel engines.

The cold filter plugging point (CFPP) is measured according to ASTM D6731 and is commonly used to assess the cold flow properties of biodiesel and diesel fuels. However, this standard uses a 45 micron wire mesh to measure the CFPP. Most current diesel engines manufactured use fuel filters with 15 to 25 micron filter paper to remove the impurities from the fuel. Filters on some current model diesel engines utilize a filter paper with a pore size that has been reduced to 2 microns. The large disparity between the ASTM CFPP test (45 micron filter) and actual industry practice (2 micron filter) suggests that that the standard test for diesel fuel (CFPP) may not accurately reflect the temperature at which sufficient crystals in the fuel would form to plug the fuel filter on an engine. In fact, it could be that fuel filters would plug at temperatures above the tested CFPP for a fuel sample. This would be a problem for biodiesel fuel users in colder climates. Diesel fuel pour point suppressants do not change the temperature at which the fuel starts to form crystals, they just reduce the size of the crystals so they can pass more easily through the fuel filter and fuel system.

The specific objectives of the alternate test were to:

- measure pressure drop across the fuel filter;
- determine effect of blend on pressure drop; and
- determine effect of pour point suppressants on pressure drop across the filter at cold temperatures.

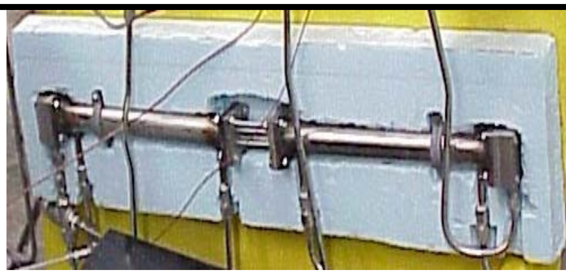
Three SME biodiesel blends (B2, B5, and B20), one biodiesel fuel, two diesel fuels (number one and number two, both ultra-low sulfur), and two treatments (with and without a pour point suppressant) were prepared to run through two sizes of fuel filters (2 and 15 micron—Caterpillar part numbers 1R-0751 and 1R-1740 respectively). One diesel fuel sample taken at the pump in Columbia, and two pump grade samples of diesel fuel that were provided by Ron Gorder in South Dakota were prepared for testing using the procedures outlined above. The pressure drop was to be measured as the temperature of the fuel was reduced from room temperature until the pressure drop exceeded the manufacturer's specifications (45 psi) at their design flow rate. The experiment was to be replicated 3 times in a complete randomized block design for a total of 108 samples. The cloud point (CP) and cold filter plugging point (CFPP) were measured using ASTM D2500 and ASTM D6371, respectively, for all 18 of the fuel and blend combinations. The results of the fuel tests are shown in Table 4. With the exception of the 100% biodiesel sample, the BioFlo-875 either improved or no difference was noted in the cold flow properties of the fuels. A complete fuel analysis of these tests along with other fuel analysis data can be found in Appendix D.

A test stand shown in Figure 1 was used to test the biodiesel fuel samples. The fuels were mixed based on a volumetric basis for each blend. The fuel was then circulated through the system and chilled with a dry ice bath.

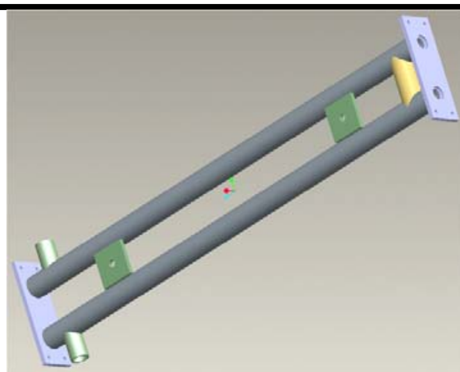
As the temperature of the fuel was reduced, the pressure drop across the filter was measured. However, the research design where the researchers would gradually drop the temperature of the fuel until the pressure drop exceeded the manufacturer's minimum operating requirements (45 psi) was not possible even after five modifications were made to the heat exchanger (Figure 2).

Unfortunately, the fuel tended to freeze to the wall of the heat exchanger, plugging the heat exchanger before the fuel filter. As noted above several modifications were made to the heat exchanger in an effort to plug the fuel filter. The original heat exchanger was modified one time since it was unable to cool the fuel satisfactorily. Neither design was effective so a new heat exchanger was designed that would allow more surface area for cooling. The end result was that the researchers plugged the heat exchanger and not the fuel filter. The researchers worked with SDDOT engineers to develop two more heat exchangers that would provide a more passive transfer of temperature to the fuel. A PTFE (Teflon) tube was inserted inside the stainless steel tube of the second heat exchanger. This reduced temperature difference between the fuel and the wall of the heat exchanger in contact with the fuel. The end result was that the heat exchanger again plugged, it just took a longer for the plug to take place. The final heat exchanger design involved the use of copper tubing. It too produced the same results- the fuel plugged the heat exchanger.

Figure 1: Test Stand to Evaluate Cold Flow Properties of Biodiesel



The first (original) heat exchanger. This device was originally designed to allow cooling in the left side of the device and if necessary heating in the right side of the device (to speed the testing along in the event the heat exchanger froze solid) (Experiment one). This device was later modified such that both the right and the left sides of the device were used to remove heat from the fuel (Experiment two).



Experiment three utilized the heat exchanger on the left. This redesign was necessary since the original heat exchanger was unable to freeze the biodiesel. Experiment four used this same heat exchanger, but the tubes were lined with Teflon tubing. Experiment five used the Coleman cooler and two copper coils (note above image). The copper coils were immersed in alcohol

Figure 2: Heat Exchangers Tested to Chill Biodiesel.

Table 4: Cold Flow Properties for Diesel Fuel and Biodiesel Fuel Blends

Petroleum Diesel	Biodiesel	Additive	Avg. Cloud Point (°C) ASTM D2500	CFPP(°C) ASTM D6371
0%	100%		1.0	-4
0%	100%	0.1%	0.7	0
80% ULSD#2	20%		-20.0	-30
80% ULSD#2	20%	0.1%	-20.0	-30
95% ULSD#2	5%		-24.3	-24
95% ULSD#2	5%	0.1%	-24.7	-33
98% ULSD#2	2%		-25.3	-31
98% ULSD#2	2%	0.1%	-25.7	-31
100% ULSD#2	0%		-26.7	-32
100% ULSD#2	0%	0.1%	-26.7	-32
80% ULSD#1	20%		-24.0	-24
80% ULSD#1	20%	0.1%	-24.3	-26
95% ULSD#1	5%		-39.0	-44
95% ULSD#1	5%	0.1%	-39.3	-46
98% ULSD#1	2%		-64.3	-64
98% ULSD#1	2%	0.1%	-65.3	-73
100% ULSD#1	0%		-67.0	-71
100% ULSD#1	0%	0.1%	-67.0	-73

ULSD#1 refers to number one Ultra low sulfur diesel fuel. ULSD #2 refers to number two ultra low sulfur diesel fuel. Biodiesel refers to SoyGold soy methyl ester. The additive used was BioFlo-875 from Octel Starreon, LLC.

There was concern that the biodiesel would separate from the diesel fuel in extremely cold weather. Samples of biodiesel, number one diesel and number two diesel were placed in plastic containers. Zero, two, five, and 20 percent biodiesel blends were volumetrically prepared and placed in plastic containers. A duplicate set of samples were prepared and these were additized with cold flow additive made by Octel Starren—BioFlow 875. All the samples were placed in a cooler, and packed with dry ice. The cooler was placed in a freezer overnight. The samples were allowed to thaw naturally without any agitation. As noted by Figure 3, even the number one diesel fuel that had a cold flow rating that exceeded -60°C appeared frozen when removed the next morning. As noted in Figure 3, no visual phase separation was present when the samples were removed from the freezer. No phase separation was apparent after the samples warmed over a three hour period to ambient temperatures.

The samples on the left were frozen using dry ice. The Number One diesel fuel was solid when removed from the freezer. The blends were composed of 0, 2, 5, 20 and 100 percent biodiesel. Note that no distinct layers exist.

The samples on the left were allowed to thaw under ambient conditions. No distinct layers are visible regardless of the blend.

Figure 3: Number 1 Diesel Fuel and Biodiesel Blends

TASK 6. MEET WITH DRIVERS AND MECHANICS

Meet with drivers and mechanics at SDDOT's Aberdeen, Sioux Falls, Pierre, and Rapid City shops to explain procedures and responsibilities for a twelve month field comparison between vehicles operating on B5 and regular diesel.

This task involved meeting with drivers and supervisory personnel prior to the beginning of operation of test vehicles with the B5 blend of fuel. The task was completed in conjunction with meetings held in November 2002.

TASK 7. EVALUATE OPERATIONAL PERFORMANCE

Evaluate the operational performance of twelve SDDOT and county trucks (half with non-electronically and half with electronically fueled injection systems) operating on a B5 blend for 12 months at SDDOT's Aberdeen, Sioux Falls, Pierre, and Rapid City shops, and compare the performance to the same number and type of trucks operating on regular diesel fuel.

A total of four trucks at each of the following locations: Pierre, Aberdeen, Sioux Falls, and Brown County highway departments, were selected for B5 blend/diesel fueling. A total of eight trucks at Rapid City were selected for B5 blend/diesel fueling. One-half of these trucks were fueled with the B5 blend. The balance were fueled with either number one or number two diesel fuel (depending on the season of the year)

A driver's log sheet was developed to facilitate daily record keeping in the test vehicles. A spreadsheet was developed to allow for assembly of the daily log sheet data into a form for later statistical analyses. Drivers recorded the data, and personnel from the SDDOT transferred those data to a spreadsheet for each vehicle. Data were then forwarded to SDSU for analysis.

In July 2003, Paul Oien reported that trucks DL016 and DL017 had been transferred to Mitchell for the fall surplus equipment sale. Both of these trucks had International DTA466 engines. DL017 was being fueled with B5 and DL016 was being fueled with regular diesel fuel. A new truck (DL109) was then included in the project. It had the same type of engine as DL017. The fuel tanks were drained and the fuel filters changed prior to fueling with B5.

Three engines experienced failures requiring large repairs and in one case, complete replacement of an engine. One engine (operated on B5) experienced a valve keeper failure that damaged or destroyed several pistons, requiring engine teardown and repair. Another engine required replacement of the copper tubes surrounding the injectors in the heads at substantial repair cost. A single engine (operated on diesel fuel) experienced a main bearing failure. After teardown a decision was made at that shop to replace the engine. These infrequent but large repairs tend to distort comparisons between small groups of trucks operating on the two comparative fuels. With over 250,000 total miles added to truck engines that were not new when the tests were started, the statistical likelihood of one or more engine failures was substantial. None of the personnel in the maintenance shops attributed these failures to the fuel used. On the contrary, they suggested that these incidents were unrelated to the fuel. As a result the researchers excluded these large failure occurrences from some of the per-mile cost analysis later in the study. In general caution should be used in extrapolating results that include these events.

The parts delivery truck, commonly referred to as the "Bumble Bee", was a new truck equipped with the new Caterpillar ACERT engine. The ACERT engine utilizes Caterpillar's Advanced Combustion

Emissions Reduction Technology to achieve regulatory compliance of exhaust composition. Most other engine manufacturers are using Cooled Exhaust Gas Recirculation as a principal component of their emissions strategy. The Caterpillar engine uses an integrated management of electronic injection control and turbocharging control and other variables to achieve emissions reductions. Because Caterpillar is unique in this approach, and because this was the first example of an ACERT engine in the SDDOT fleet this truck was added to the study as an example of alternative technology. A single truck was used, and no comparative engine was available to operate on diesel fuel, so the results are anecdotal.

The ACERT engine operated under warranty during the test period. SDDOT records show only routine inspection and maintenance for this vehicle. SDDOT personnel have reported that the engine did experience a warranty repair in which injectors were replaced after a problem of rapid oil consumption. This event took place prior to the operation of the engine on the B5 blend. No engine service expenditures appear in the record for this truck after the switch to the B5 blend. Questions arose regarding potential interaction of the aluminum fuel tank on this truck with the blended fuel. The solvent properties of biodiesel could cause the sloughing of adherent residue in this tank as in a steel tank. However, the vehicle gave no indication that filtration issues were any different in than in the general fleet. Fuel economy for this truck averaged 6.73 miles per gallon on the B5 blend. Because this truck has a much different load application than the road maintenance truck fuel economy was not generally comparable with those of the other vehicles involved in the study. While the data from this one truck are not definitive, they suggest that the ACERT engines should operate just as other engines in the fleet on a B5 blend. If differences occur they might be expected in the area of filtration as the ACERT system generally employs a higher level of filtration with a mesh size of 2 microns. Residue sloughed from tanks and lines of vehicles converted from diesel fuel use would be expected to plug filters. This finding is not different than for other engines and fuel systems, but might occur sooner as the smaller filter mesh would be expected to trap finer material.

Fuel economy averages for locations by fuel type are given in Table 5. In most cases the fuel economy between trucks fueled with diesel fuel and the B5 biodiesel blend were very similar. At Aberdeen, Pierre, and Rapid City the difference between the average mileage obtained between the two fuel types is less than 3.5%. Mileage was lower in general in the Rapid City trucks. This was not unexpected as the Rapid City trucks must operate in the Black Hills under more severe grade conditions than exist in the Pierre, Sioux Falls, and Aberdeen areas.

Two locations stand out. Brown County produced a relatively large difference of 0.60 mpg between the diesel and B5 trucks. In this case, one of the diesel trucks appears to have been out of service for some time as it had large repair costs and accrued less than half the miles of the other trucks. It is not known what time this occurred and what operations duty the three other trucks were subjected to during that time period. It is possible that the disparity is due to the differential operation of the one diesel fueled truck.

A large disparity in fuel economy also existed in the trucks from Sioux Falls. One of the two diesel fueled trucks at that location (DL016) had a calculated fuel economy of 7.2 miles per gallon. This is roughly two mpg or 40% higher than the fleet in general. This was also one of the two trucks that were mistakenly surplussed during the course of the study. The disparity suggests a record keeping error for the fuel or miles for that truck that distorts the fuel economy for this site. After the two trucks were taken out of service a single truck was added into the study and fueled on B5 for the remainder of the test period. The fuel economy data for trucks operated on diesel fuel at Sioux Falls then rely on an anomalous value for the surplussed truck and data for a single truck thereafter. As a result the data from this site are of questionable reliability for drawing conclusions regarding fuel economy. The values for Aberdeen, Rapid City, and Pierre probably provide reliable indications of genuine differences in fuel economy. If looking at these three sites the average fuel economy for diesel fueled trucks was 4.79 mpg, while the B5 fueled trucks achieved 4.69 mph. The difference is approximately 2%. This was not unexpected as the biodiesel has a slightly lower heating value (BTU) than petroleum diesel fuel (note the fuel analysis data in Appendix E).

Table 5: Fuel Economy Using Diesel Fuel and a B5 Blend

Location	Average mpg for All Trucks (Diesel)	Average mpg for All Trucks (Biodiesel)
Aberdeen	4.99	5.01
Brown County	5.13	4.53
Pierre	5.31	5.12
Rapid City	4.44	4.31
Sioux Falls	5.52*	4.96
Average for all Locations	4.99	4.70

*One of two diesel trucks at this site operated over relatively few miles and may distort the fuel economy here.
** The fuel economy for one truck at this site was over 7.4 mpg which suggests a record keeping error. The truck was also taken out of service during the test period.

A graphical presentation of fuel economy versus year of engine manufacture is given in Figure 4. Since an attempt was made to select trucks for the study in pairs of identical engine designs and similar ages the data frequently show a diesel engine and a B5 fueled engine at a given year of manufacture. The data were graphed to see if a trend in fuel economy versus year of engine manufacture was apparent, and to see if the engines operated on B5 had different economy than diesel fueled engines for different years of manufacture. The data suggest that there is no trend of fuel economy as a function of engine year, and that there is no apparent difference in economy between performance for the two fuel types as a function of engine year. SDDOT should not expect to see differences in fuel economy between newer and older trucks if a B5 blend is implemented. The diesel fueled trucks at Sioux Falls again appear as outliers, and the Bumblebee (DB031) has a different work cycle and so stands out from the other trucks in fuel economy.

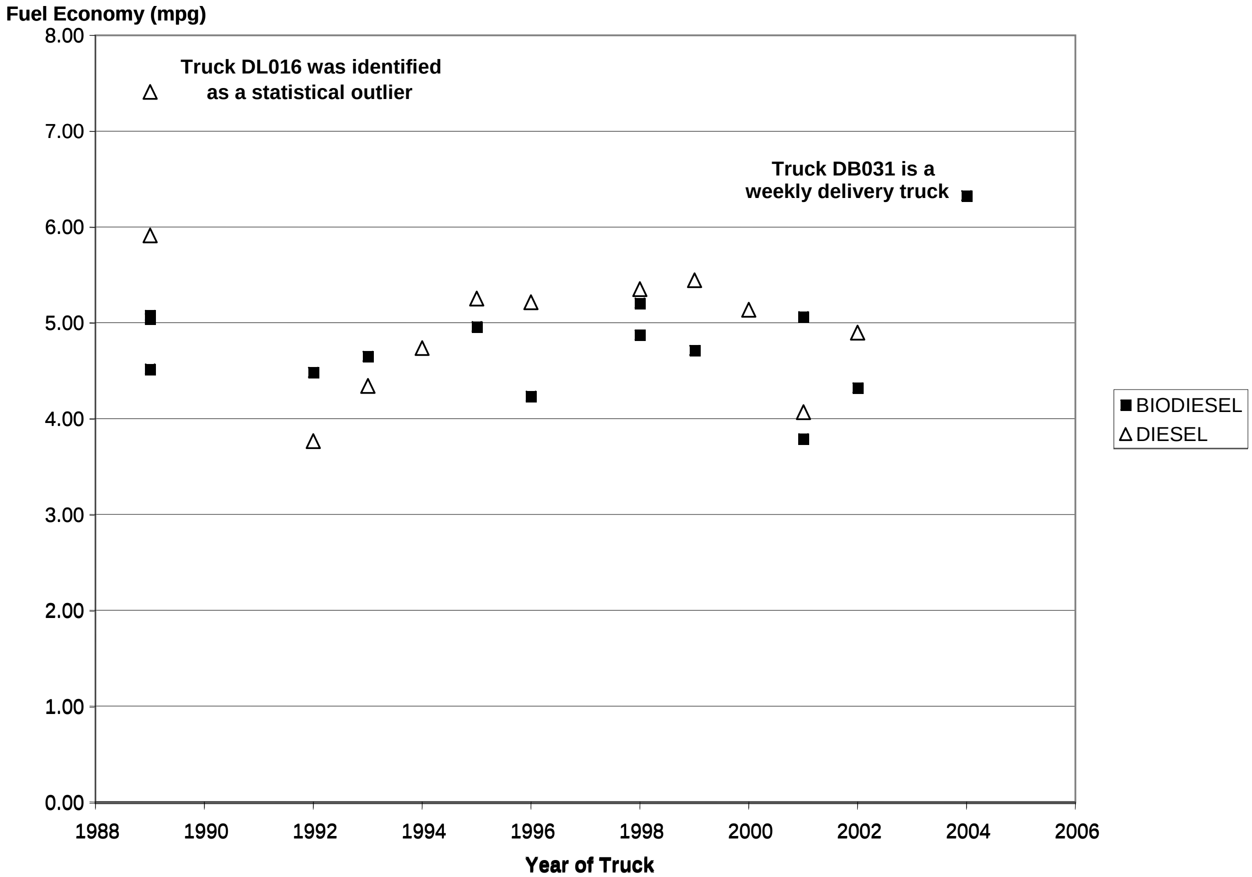


Figure 4: Fuel Economy for Trucks in the SDDOT Fleet

TASK 8. CONDUCT PHYSICAL AND CHEMICAL TESTS

Conduct physical and chemical tests to assess fuel quality: at the time of delivery from the supplier; after storage in SDDOT's underground storage tank at Rapid City and temporary, supplier-furnished, above-ground storage tanks at Pierre, Sioux Falls, Aberdeen; and in the fuel systems of the test vehicles.

Due to the cold weather blending issues that surfaced during the 2003 South Dakota winter, cold flow testing was undertaken by Chemical Engineering at the University of Missouri (Chiu, C., Schumacher, L. G., Suppes, G. J. (2004). Paul Oien prepared 20 samples using #1, #2, and Biodiesel in various proportions and shipped these to MU (Chuang-Wei Chiu) for analysis. Chiu performed a Low Temperature Flow Test (LTFT) using these samples.

QUALITY OF BIODIESEL BLENDED FUEL IN SDDOT TRIALS

Fuel quality is a legitimate concern to the SDDOT; both for petroleum based fuels and for biodiesel blended fuels. As a part of this research effort, fuel quality was tested to determine potential impacts on the SDDOT.

TESTS CONDUCTED

Samples of fuel used in blending were tested for quality characteristics using ASTM procedures at the outset of the field trials. A sample of number one diesel fuel was acquired from the contract vendor and was tested as per ASTM D975. Additional samples of number one diesel and number two diesel were taken from tanks at Pierre and Rapid City respectively and stored as representative samples of the petroleum fuel used during the trial period. A sample of neat Soy Methyl Ester, as used by the vendor for blending B5, was acquired and tested according to the ASTM procedures comprising test D6751. Five additional samples were taken and stored from deliveries of B100 to Aberdeen where onsite blending was practiced.

Samples of blended fuels were taken periodically at delivery and stored for analysis. A total of 29 samples of typical B5 blend were taken from storage tanks or delivery trucks during the 17 months of trial use at the five sites. In addition to these typical fuels, additional samples were collected for specific purposes at other times. Two SDDOT trucks under limited yard use were fueled with B5 at the start of the field trials. These trucks were intended to run the length of the trial on a single tank of fuel, while providing that fuel with an opportunity to aerate and oxidize when the vehicle was used and fuel circulated. Four samples of blended fuel were drawn from each of these two vehicles over the 17 months of the trial. A sample of the original fuel that was placed in these trucks was also stored. A sample was taken from a truck that experienced engine failure. A sample was taken from the bottom third of the underground tank in Rapid City approximately 11 months into the trial period.

Sub-samples of the fuel samples described above were submitted to ANA Laboratories for testing. Currently the ASTM has not developed a specification for a biodiesel blend. There is a quality test for B100 (D6751), and a test for diesel fuel (D975). The ASTM D971 specification is made up of a number of ASTM procedures. A set of 8 ASTM tests (D93, D1796, D445, D130, D613, D2500, D974, and IP-309) were conducted on eight samples of B5 acquired across the time period of the research. These eight tests represented components of the tests for diesel fuel (ASTM D975) and biodiesel (ASTM D6751) that were common to each other and applicable to both. These eight tests were used to evaluate the quality of regularly delivered blended fuel.

One sample of B5 was also used to conduct an accelerated oxidative stability test (ASTM D2274). This was used as a measure of the oxidative potential of the fuel placed in the limited use trucks at Aberdeen and Mitchell.

Four of the samples of B5 taken from these limited use trucks over the course of the trial period were used to conduct tests of fuel as it aged. The ASTM procedure D2276, Total Insolubles Filtration, was used to quantify the oxidative stability of these samples.

RESULTS OF FUEL ANALYSIS

The quality of the diesel fuel used when blending was in full compliance with the standard, ASTM D975. An initial set of laboratory tests for the B100 obtained from Stern Oil and used in blending indicated that the biodiesel appeared to be outside the specification set forth in D6751 for the categories of free and total glycerin, and flash point. A second sample of B100 was submitted for testing with similar results. The ASTM D6751 specification allows 0.020% free glycerin and 0.240% total glycerin on a mass basis. The initial test results reported by ANA Laboratories were substantially above these limits. Discussion with the ANA Laboratories revealed an error in the method of presenting the test results. ANA Laboratories corrected and issued a revised report. The corrected report format showed the two samples of biodiesel to have free glycerin levels of 0.00%, and 0.004% respectively, and total glycerin levels of 0.210% and 0.050%. These levels are within the specification for B100.

Flashpoints for the two biodiesel fuel samples from ASTM tests were 114°C and 118°C. The flash points were below the 130°C specified in the ASTM standard. Flashpoints in biodiesel are often affected by small variations in residual methanol from the biodiesel conversion process. Note that while these values were below the current ASTM specification for B100, they are above the DIN 51606 German standard of 110°C, and much higher than the 38°C minimum for petroleum diesel fuel specified in ASTM D975. Additionally, flash points in the B5 blended fuel were well above the minimum specification for either number one or number two diesel fuels. The flash point from the B100 used in the trials should not present problems for the SDDOT fleet. The lab analysis reports from ANA Labs can be found in Appendix E.

Kinematic viscosity of the fuel samples tested is given in Figure 5. Viscosity for biodiesel fuel is typically higher than petroleum fuels. The fuel delivered during the period of the research project was very consistent in viscosity with values ranging from 2.9 to 3.1 centistokes (cSt). For comparison, allowable ranges for the ASTM fuel specifications are 1.3 to 2.4 cSt for #1 diesel, 1.9 to 4.1 cSt for #2 diesel, and 1.9 to 6.0 cSt for Soy Methyl Ester. The values for the blended fuel samples in this case are in the range for #2 diesel fuel and SME, and slightly above the specification for pure #1 fuel. They suggest consistent quality in the fuel delivered to the SDDOT and should not represent a problem in operation. (Note: All viscosity data were within the ASTM specification for number two diesel or 100 percent biodiesel.)

The number one diesel fuel failed the lubricity specification as outlined in ASTM D975. ASTM D6078 (SLBOCLE) and ASTM D6079 (HFRR) were used when determining this data. Values of 2900 grams and a 0.581mm wear scar diameter were reported respectively. Engine manufacturers have indicated that a minimum of 3100 grams (SLBOCLE) or a maximum wear scar diameter of .450 mm (HFRR) must be maintained to prevent the fuel system from self destruction. Although these lubricity test procedures were not conducted for the B5 blends used in the study or for B100, research reported in the SDDOT Potential Impact of Biodiesel on SDDOT Interim Report, (Tables 6 & 7) outlined the increase in lubricity associated with the blending of biodiesel with diesel fuel. By replacing as little as two percent of the diesel fuel with biodiesel, the lubricity of the blended fuel exceeded OEM recommendations. This is important to SDDOT for three reasons. First, the SDDOT number one fuel in this project failed both the SLBOCLE and the HFRR. Second, SDDOT typically fuels with 100 percent number one fuel during the winter months. And third, beginning June 2006, the new 15 ppm low sulfur diesel fuel, due to the hydrotreating during the removal of sulfur from the diesel fuel, exhibits lubricity qualities that are worse than the lubricity of the diesel fuel that SDDOT used during this project. SDDOT will need to use lubricity additives for both number one and number two diesel fuel unless they blend two to five percent biodiesel (number two vs. number one) with their petroleum diesel fuel.

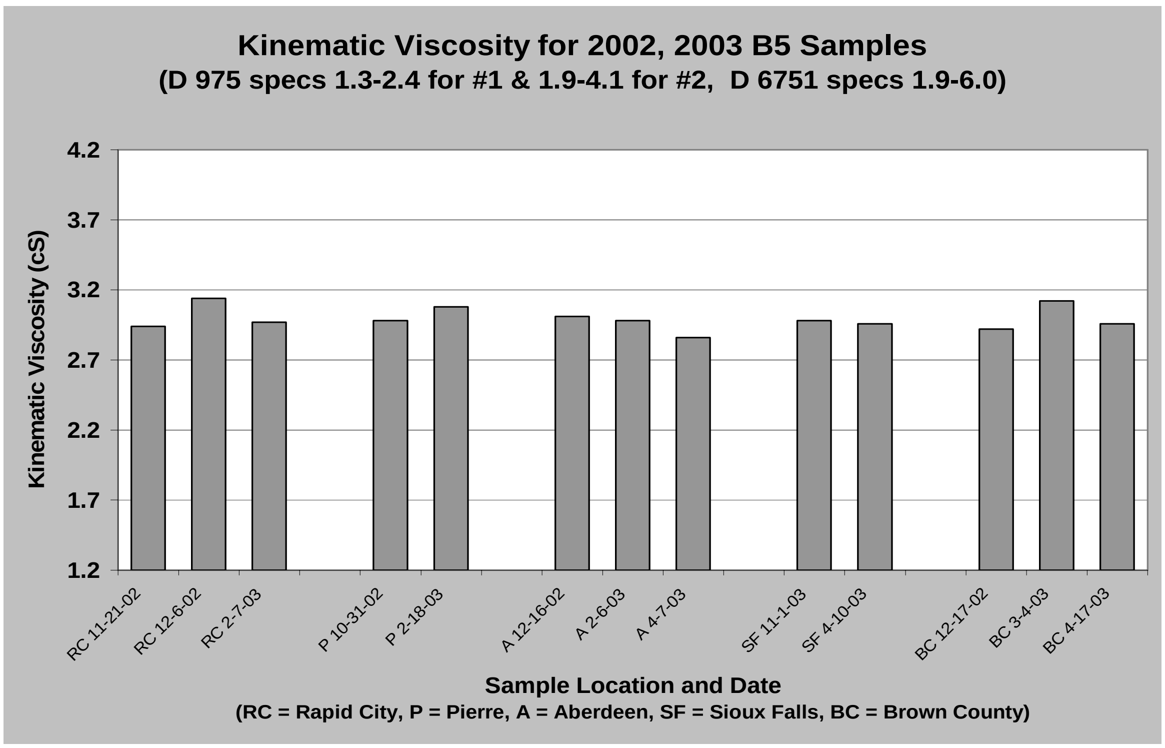


Figure 5: Kinematic Viscosity for SDDOT B5 Fuel

Cloud point data found in Figure 6 reveal the temperature when wax crystals begin to form and cloud the appearance of the fuel. Figure 6 also reports the Cold Filter Plugging Point (CFPP). All but three of the samples indicate a CFPP of -35 to -47 degrees F. Cloud points are generally 12 to 20 degrees higher than the CFPP. A single sample from Brown County shows a low CFPP of -46 degrees F, but a Cloud Point that is above zero. The reason for the disparity between the two temperatures for this sample is not known. Cold flow performance for these samples would not be expected to represent a problem for SDDOT. Three samples show dramatically higher cold flow temperatures.

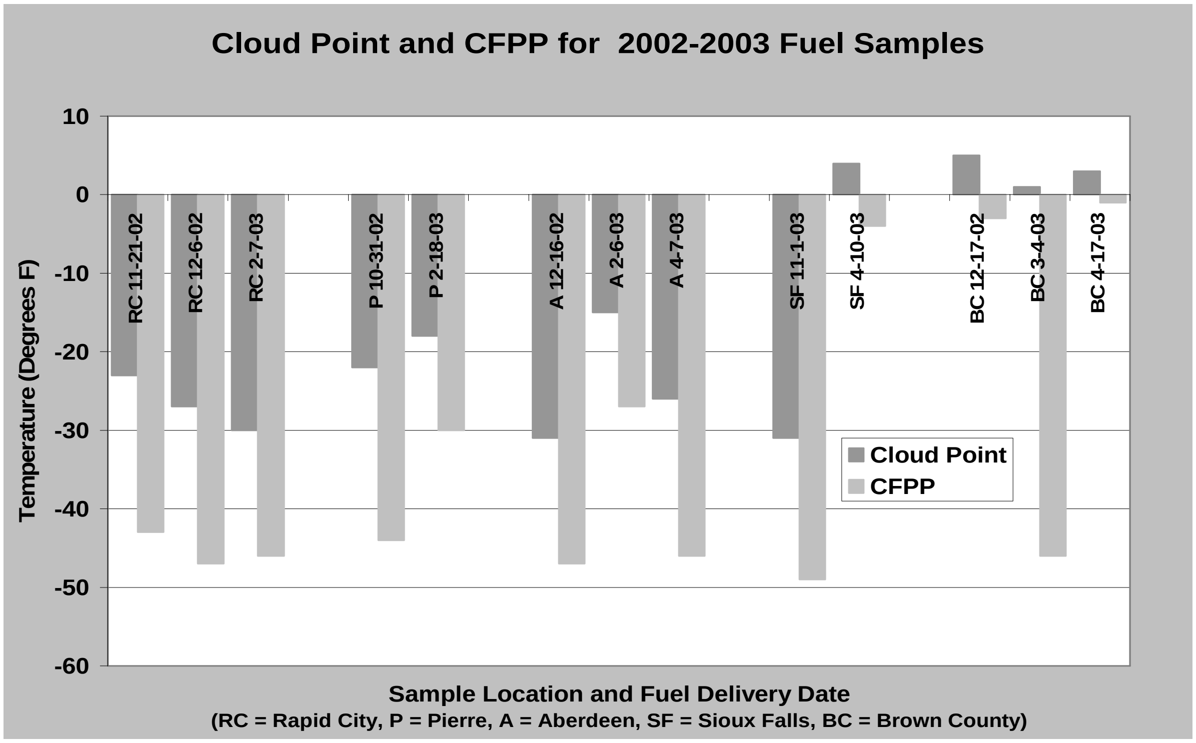


Figure 6: Cloud Point and CFPP Properties for SDDOT B5 Fuel

The sample drawn from Sioux Falls in April of 2003 was a blend of B100 and number 2 diesel fuel, as the Sioux Falls depot would have changed over to number two fuel by that date. The Brown County sample from December of 2002 also shows high Cloud and CFPP temperatures. This fuel was most likely a blend of number 1 and remaining number 2 diesel fuel with 5% biodiesel. The April sample from Brown County would also have been a blend of B100 with number 2 diesel fuel, accounting for the high Cloud Point and Cold Filter Plugging Point. The cold flow temperatures of these samples would not be expected to represent problems at the times they were drawn. However, biodiesel added to petroleum fuel will raise cold flow temperatures. The issue of filter meshes size and the ASTM standard mesh size for CFPP was discussed earlier. These data reinforced the need for that work as it is possible that a fine mesh filter would plug at a temperature between the CFPP and the Cloud Point. Cold filter plugging point temperatures of blended fuel will also be dependent upon the feed stock used for the biodiesel component. Converted vegetable oils will have a small range of variation, but methyl esters derived from tallow or yellow grease will have considerably higher cold flow temperatures and blended fuel will be affected according to the characteristics of the feed stock and the blend percentage. In the case of the B5 blend, the impact on the base fuel will be small. While cold flow in properly blended fuel does not appear to be a problem for SDDOT, the samples that included some #2 fuel show how much impact blending procedures could impact a batch of fuel if proper procedures are not followed.

Alkali or mineral acids values are given for the B5 fuel samples in Figure 7. The acceptable threshold for this variable in the ASTM standard for biodiesel fuel is 0.80. The blended fuel samples have acid numbers of 0.011 to 0.22. These are low values and indicate that the fuel delivered was of high quality.

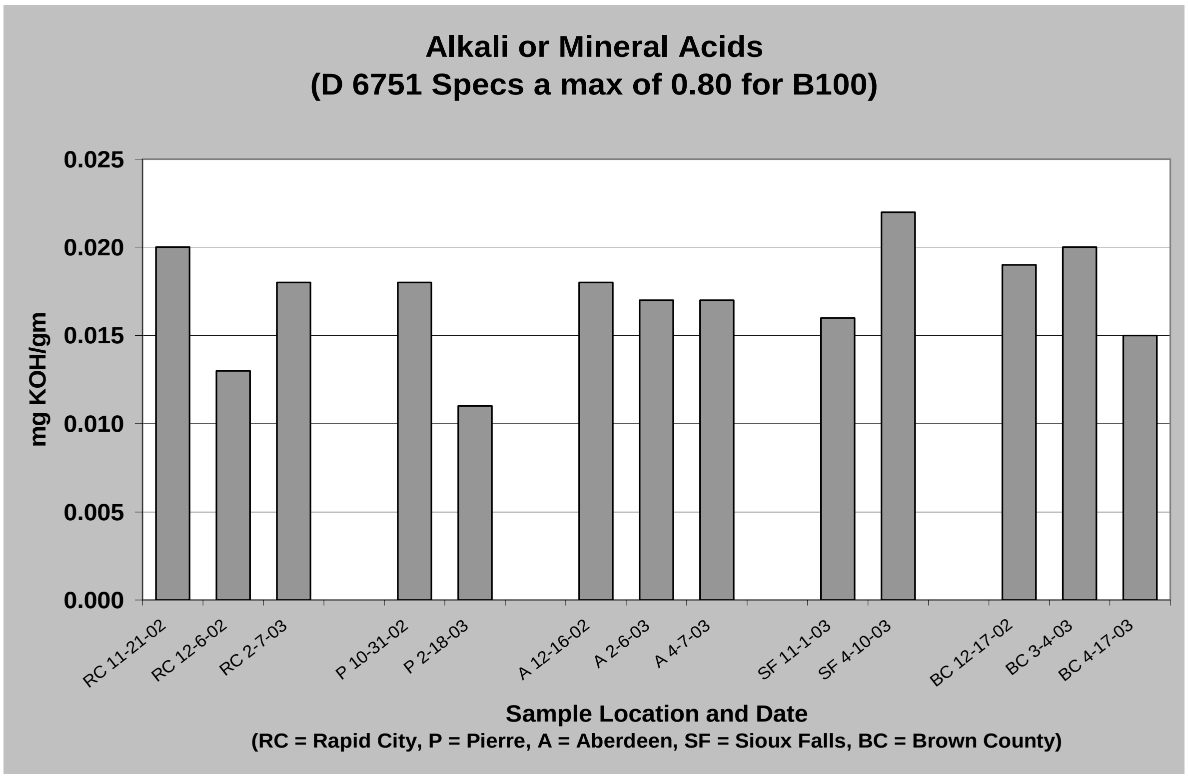


Figure 7: Alkali or Mineral Acids for SDDOT B5 Fuel

Cetane number for the fuel samples is given in Figure 8. All samples tested are well above the minimum value specified in ASTM standards for diesel fuel (40) and the minimum value specified for biodiesel blend stock of 47. The values in these samples should not represent problems for the SDDOT and may be a slight improvement over pure petroleum fuel.

The samples from the limited use trucks were tested as an indication of the oxidative stability of the blended fuel. A consultation with the fuel blender (Stern Oil) and the supplier of the B100 (Soy Gold) indicated that a pour point depressant was added to the SME blend stock during cold weather months by the B100 supplier, but that no antioxidants of any kind were added to the B100 by either Stern or Soy Gold. A graph of the insolubles filtration results is presented in Figure 9. The graph shows that the filterable insolubles increased in the fuel stored in the tanks of the limited use trucks over the time period of the trials. The value rose from roughly 2 ppm to 3 ppm between April of 2003 and September of 2003 for one sample.

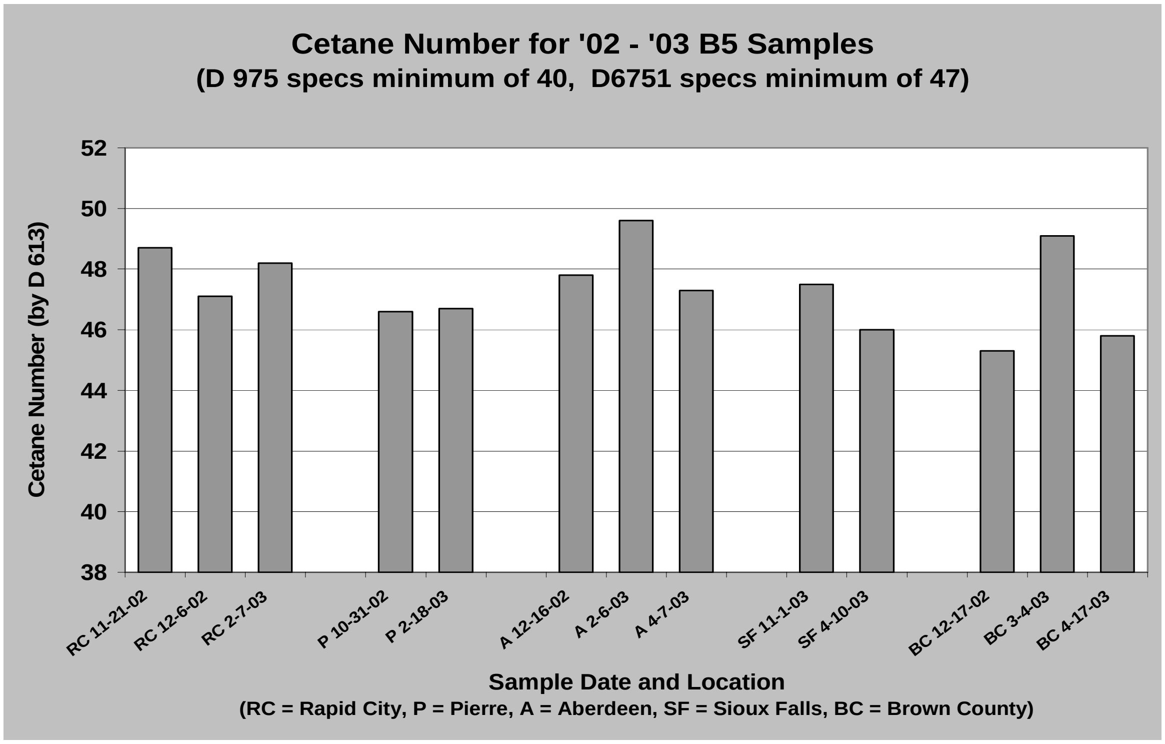


Figure 8: Cetane Number for SDDOT B5 Fuel

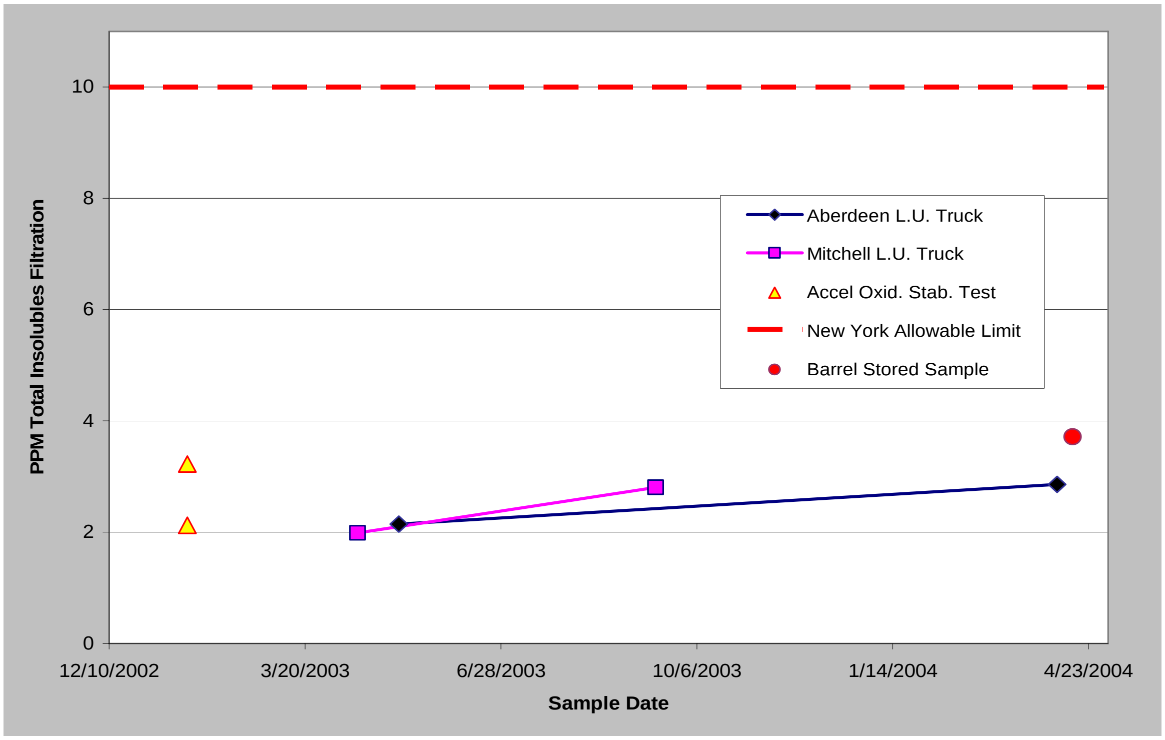


Figure 9: Oxidation Potential of B5 Fuel

The triangular markers at the beginning of the period reflect an accelerated oxidative stability test (ASTM D2274). The markers are for filterable insolubles and the sum of these and the adherent insolubles. (Note: All levels are well below a threshold of 10 ppm).

A very similar rise occurred for a sample between April of 2003 and April of 2004. Also, the accelerated test conducted on the original fuel used to operate these trucks indicated very similar levels of filterable insoluble material. The higher marker in the graph for the accelerated test includes adherent insolubles. The last marker shown near the right hand end of the graph is the filterable insolubles level for a sample of the original fuel stored in a clean can for 17 months. All of the levels indicated in this test are well below the threshold of 10 ppm, which is the level used by some major municipalities as a maximum allowable level for delivered diesel fuel. This result suggests that fuel oxidative stability was not a problem in the fuel used in these trials.

TASK 9. EVALUATE VEHICLE MAINTENANCE HISTORIES

Through a review of vehicle maintenance records, engine oil analysis, forensic evaluation of failed engine or fuel system components, and interviews with drivers and mechanics involved in testing, evaluate and compare maintenance histories of vehicles operated with B5 and those compared with regular diesel fuel.

Very little data were logged on the vehicles due to the extremely mild weather in South Dakota during the winter of 2003. The research team recommended that the project be extended at no cost to allow more miles to be logged on the vehicles to increase the confidence in the final recommendations. The review panel supported this recommendation.

Table 6: SDDOT Vehicle Work Codes

Repair Code	Repair Name	Work Description
4011	Lubrication and inspection	1. Complete chassis lubrication, 2. change of oil and filter, 3. Check tires and air pressure, 4. Check battery, 5. Check radiator and hoses, 6. Check belts, 7. Check air filter, 8. Check for signs of leaking, 9. General inspection of unit including loose bolts or connections, 10. Check all fluid levels, 11. Check exhaust system.
4012	Major preventative maintenance and inspection	1. Starter, distributor, spark plugs, battery terminals, fuel filter, PCV valve, 2. Smooth operation of engine, tappet noise, 3. Brakes, hand & foot, 4. Clutch/automatic transmission for smooth operation, 5. Steering, 6. Wheel bearings, 7. Exhaust system, 8. Hydraulic system, hoist, etc., 9.Performance of all gauges. 10. Lights, horns, mirrors, windshield wipers.
4051	Engine Repair	Valve adjustment, reboring blocks, timing gears, & chains, rings, pistons, crankshaft, oil pans, head gaskets, grinding valves, replacing head, reseal engine valve cover gaskets, main seals, pan gasket and timing chain gaskets.
4052	Engine Replacement	Replacement of gas or diesel engines or short blocks.
4070	Fuel System Work	Work performed on carburetors, air cleaners, fuel pumps and filter, fuel tank, fuel lines, injectors, injector pumps, and external governors, etc.
4080	Exhaust System Work	Work on manifolds, manifold gaskets, mufflers, tail pipes, antismog devices, catalytic converters, and turbo chargers.
4210	Other Work	This category includes any repairs that do not explicitly fit into one of the other SDDOT repair and maintenance codes.

Maintenance and repair costs by category are given for trucks operating on the two comparison fuels in. Categories used in this chart are taken from the repair codes used by the SDDOT in its shop record keeping system. Only repair codes that included some aspect of the vehicle that could possibly be impacted by the fuel were included in. Table 6 lists the SDDOT repair and maintenance codes that were summarized and included in the analysis.

A number of repair procedures were excluded from this analysis. Categories such as steering and suspension, tires and wheel work, electrical systems and lighting, and washing and cleanup were not analyzed as they would not be expected to have any reasonable linkage to the fuel used by the vehicle. It is important to recognize that most of the items in the repair codes do not have direct contact with the fuel and are probably not related to the fuel in any way. However, the records do not allow sufficient detail to isolate individual items such as a fuel line and separate it from items such as replacement of the air cleaner. They are part of the same repair code.

Three events occurred during the course of the study that required substantial repair or replacement costs to an engine. Truck DL073 from Rapid City experienced failure of a valve keeper, with subsequent damage to several pistons. The engine was repaired and returned to service. A truck from Sioux Falls, (DL159) experienced failure of the copper tubes surrounding the injectors in the heads. This engine was repaired and returned to service. A truck from Pierre (DL 120) suffered a main bearing failure. This engine was replaced with a rebuilt engine. These three events had large associated costs. Maintenance personnel did not associate any of the failures specifically with the fuel used. To prevent these events from distorting the aggregate maintenance costs for the study they were excluded from the subsequent analysis. A graph of aggregate maintenance cost totals for diesel and B5 fueled trucks is given in Figure 10.

Trucks from this study had very similar total costs in the categories of exhaust system repairs, and “other” items. Trucks fueled on the B5 blend had somewhat higher total costs in the category of lubrication and inspection, and slightly lower costs in the preventative maintenance category. The higher total in lubrication and inspection cost for the B5 fueled trucks may be a result of higher total miles applied to these vehicles, with correspondingly higher numbers of oil and filter changes. In the categories of engine repair and fuel system repair the diesel fueled engines had higher aggregate costs. Caution should be used in drawing conclusions from these numbers. Engine repairs were relatively infrequent events in the study. One or two repairs can make the data appear lopsided in either direction. In this case, a single diesel fueled truck, (DL083) from Aberdeen, accounts for over 1/3 of the aggregate costs of fuel system repair, over ½ of the engine repair costs, and a substantial portion of the preventative maintenance costs. While there is no known reason to exclude this truck and its maintenance costs, it would be wrong to conclude that trucks fueled with diesel fuel have much higher fuel system maintenance costs based on these data alone. In truth, these fuels are similar enough that it might take the lifetime of a set of trucks to reliably identify and quantify differences in maintenance costs that are due to the fuel alone.

Further discussion of maintenance costs and impacts on the SDDOT are given in the section of this report on economic impacts, where fuel and maintenance costs are addressed on a per mile basis.

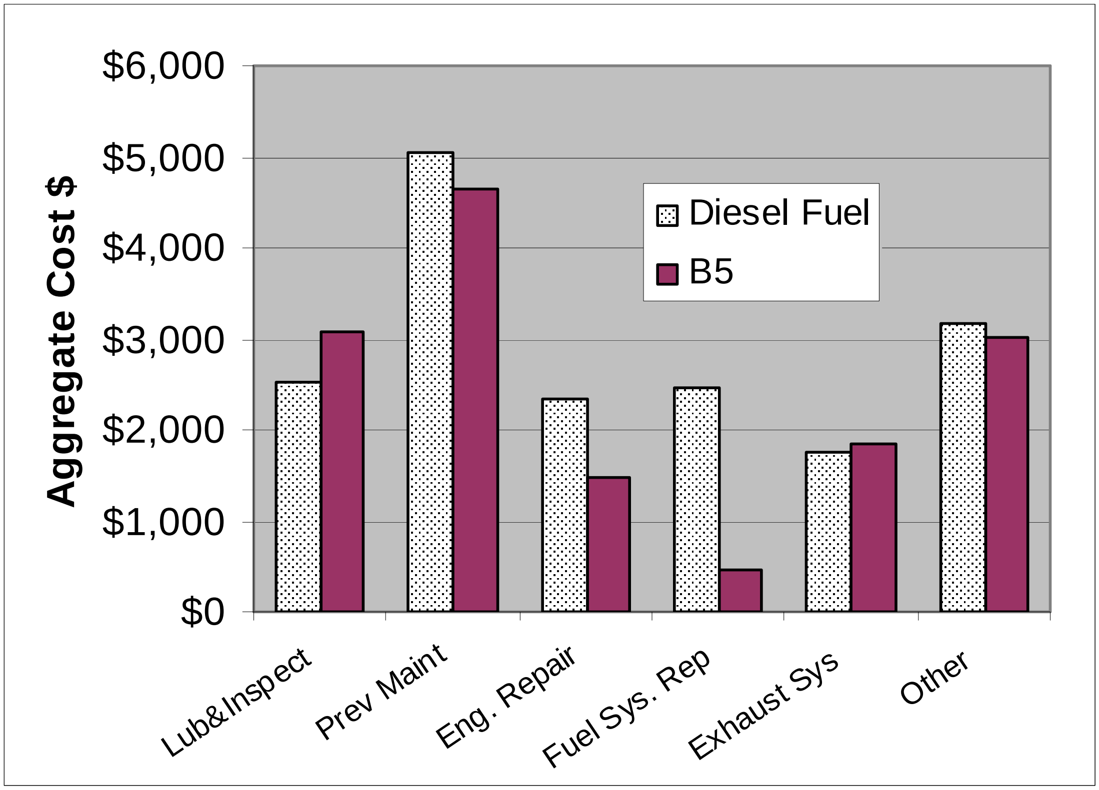


Figure 10: Maintenance Costs by Selected Category for Trucks in SDDOT Field Trials

*Note: Care is needed when reviewing these data (Figure 10) as the repair costs would have occurred regardless of the composition of the fuel used to power the engine.

Brown County repair data were not part of the SDDOT data set. As such, these data were secured and recorded by hand, one job ticket at a time. Dollar amounts for parts and labor are not a part of the Brown County job repair tickets. Table 7 illustrates that these vehicles experienced normal, routine repairs throughout the duration of the project.

Table 7: Type and Frequency of Maintenance Procedures for Brown County Trucks

Procedure	Frequency
Replacement of front or rear tires	7
250 hour service	18
Rear chipper bar	1
Adjust valves	1
Repair tail gate	1
Install snow lights	1
Cracked leaf spring	1
Replaced injector	1
Replaced brake switch	1
Fuel Filter replacement	1
Front end alignment	1

ENGINE OIL ANALYSES

Routine engine oil analyses were conducted on samples taken from engines powering the trucks used in the field trials. The Brown County Highway Department utilizes Butler Cat to analyze a sample of oil from each 250 hour engine service. The results of these tests were available going back to a year or more prior to the start of the B5 blend use. Graphs of the wear metals, copper, lead, and iron over time are given below in Figure 11 through Figure 12. Graphs of the engine oil oxidation test values and nitrate levels are given in Figure 14 and Figure 15. All of these graphs depict the levels of the variable from time prior to the introduction of biodiesel through the period of the field tests. A complete breakout of all the oil analysis data for the SDDOT fleet that was part of this research effort can be found in Appendix G.

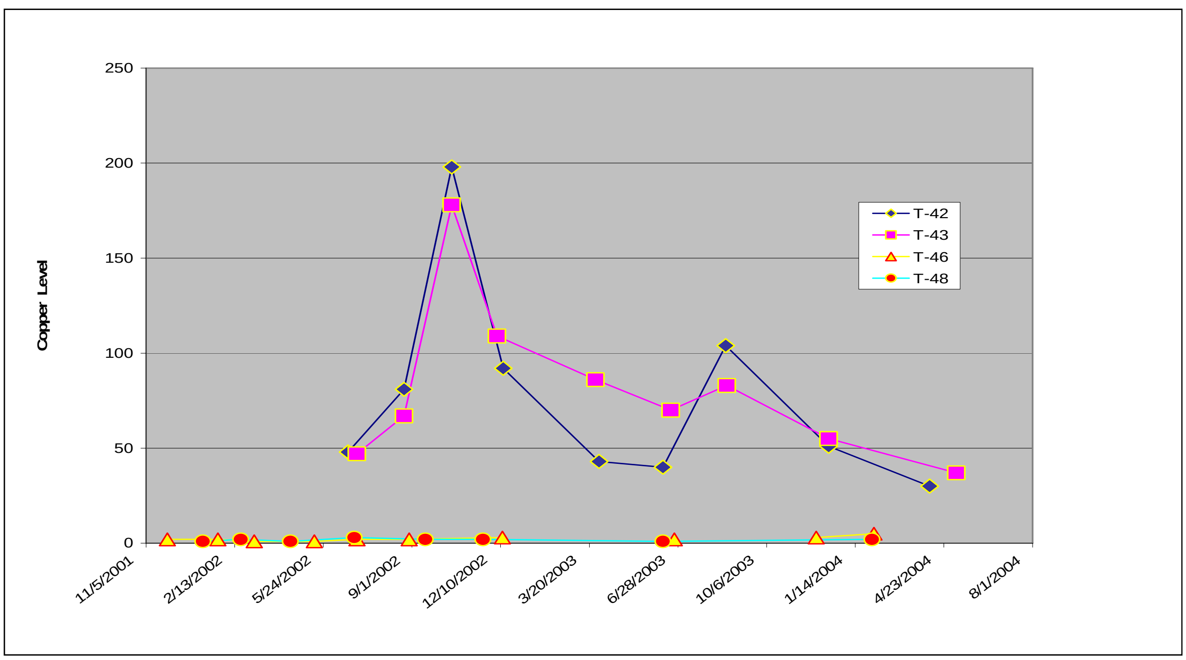


Figure 11: PPM Copper Levels in Engine Oil of Brown County Trucks

Note: The two trucks with high levels are new vehicles exhibiting a wear-in behavior. (The old trucks, T46 and T48, have baseline levels of copper at 1 or 2 ppm.)

A graph of parts per million copper in the engine oil of the four Brown County trucks is given in Figure 11. Copper is one of the wear metals that is part of the construction of the main and rod bearings. The two older trucks (T46 and T48) are characterized by the very low copper levels near the X axis. These were both 2002 International model 2674 trucks powered with Cat C-12 engines. The higher values are associated with two new trucks (T42 and T43). These were both 1999 International model 2574 trucks powered with Cummins M-11 engines The graph suggests a wear-in behavior in the two new trucks with initial high levels of the wear metals that then rapidly taper off. This might be expected as new bearing surfaces shed small surface imperfections and become smoother. Variations in the levels of these indicator metals in the oil samples can also result from variation in the operating hours between oil service events. The X axis in the case of these graphs is not a linear scale and shows the date of the oil sample taken. This was done so that levels of wear metals could be examined in the context of the time period representing the field test to see if wear metals might trend differently under the comparative fuels. The two old trucks include one operating on B5 and one on diesel fuel. Similarly with the new engines, one is operated on each fuel. The data shows no trend of separation between the paired trucks running on the comparison fuels.

A similar graph in Figure 12 shows lead levels that seem to confirm the wear-in behavior of the two CAT engines. Lead is also a component of the main and rod bearings. The differences between new and old engines is not as pronounced in the case of this wear metal but the paired trucks still behave similarly, although operated on the two comparison fuels. The lead levels measured here are not high enough to warrant any corrective action.

Figure 13 shows levels of iron in the oil samples for the same four engines. Levels are similar for both new and old trucks (Figure 13). The paired trucks again performed similarly, while one operated on B5 blended fuel and the other used petroleum diesel. Again, the levels detected here are not high enough to suggest any corrective action.

Oil oxidation levels in engine oil might vary with the two fuels as biodiesel fuel is generally assumed to be more susceptible to oxidation, and small amounts of the fuel may show up in the engine oil over time. Similarly, biodiesel has been shown to produce somewhat higher levels of NOx in combustion products and nitrates could be present in the engine oil as a result of blowby gases in the crankcase. In this case oxidation levels are similar in magnitude for old and new trucks, as well as for trucks using both fuels (Figure 14). The graphs show some variation over time in oxidation levels that is probably reflective of the interval between oil changes. Nitration levels are given in Figure 15. Here, the two new engines enter with very low nitration levels in their first samples, but they quickly join the older engines in what is probably a more normal level of nitration in the oil. Again, the fact that the paired trucks behaved quite similarly, (and somewhat in parallel) indicates that the fuel was not a variable that caused differences among these oil analyses.

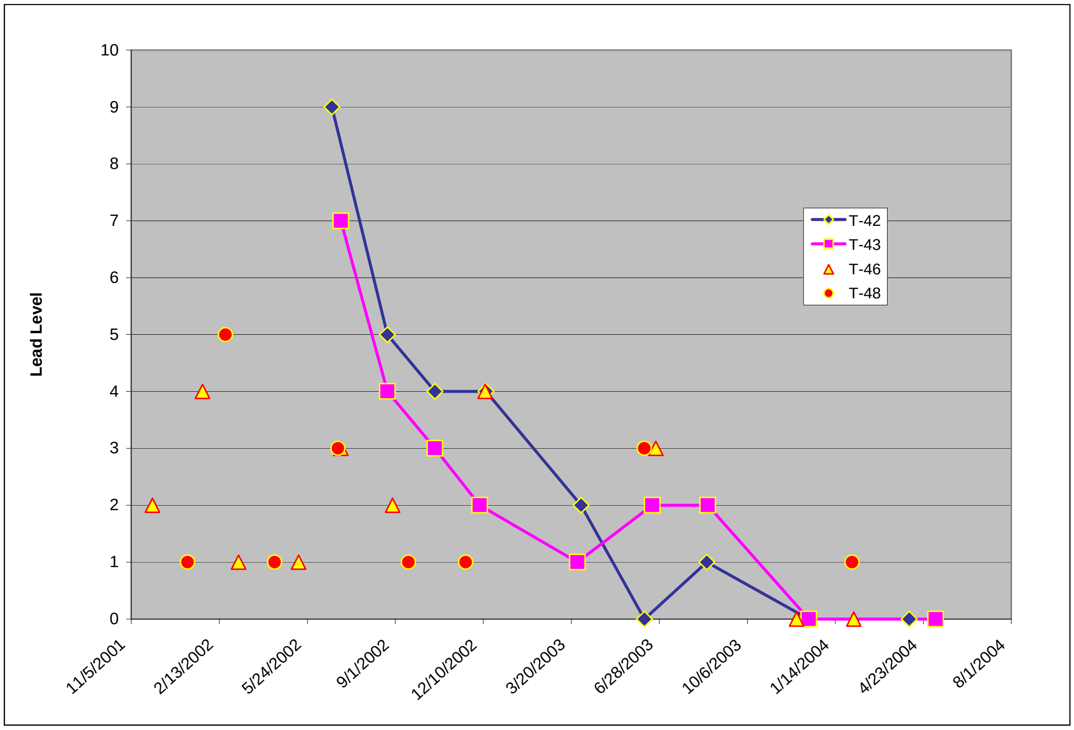


Figure 12: PPM Lead Levels in Engine Oil of Brown County Trucks

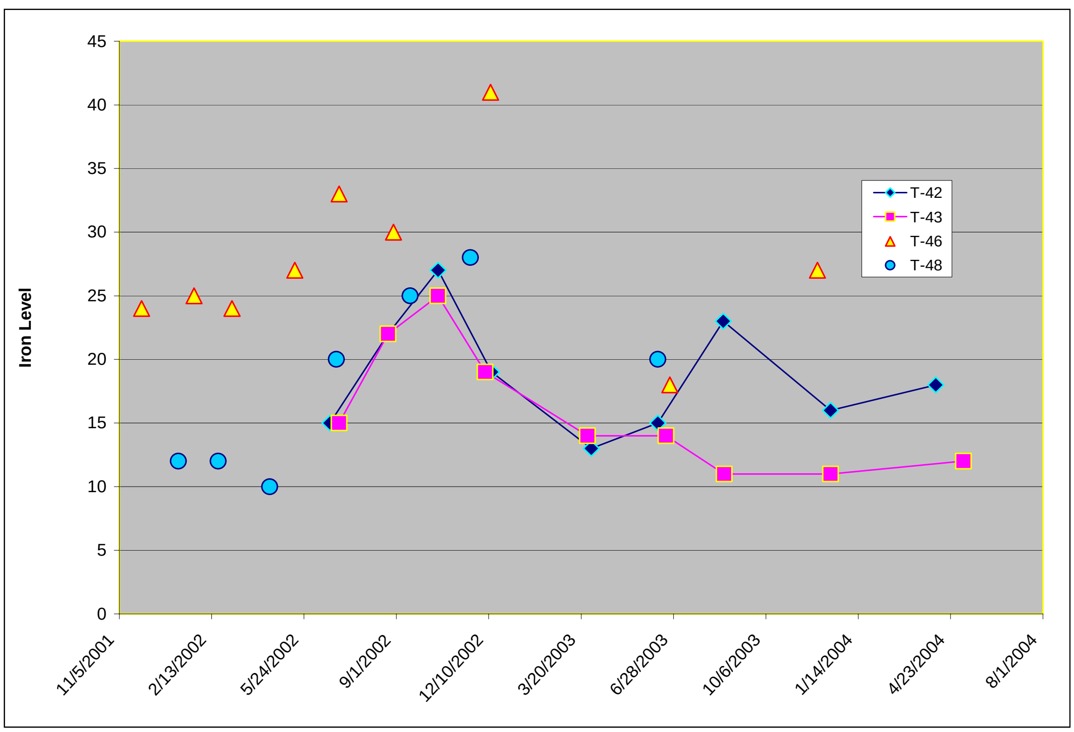


Figure 13: PPM Iron Levels in Engine Oil of Brown County Trucks

Note: Paired trucks behaved similarly while operating on a B5 blend as compared to the control truck on diesel fuel.

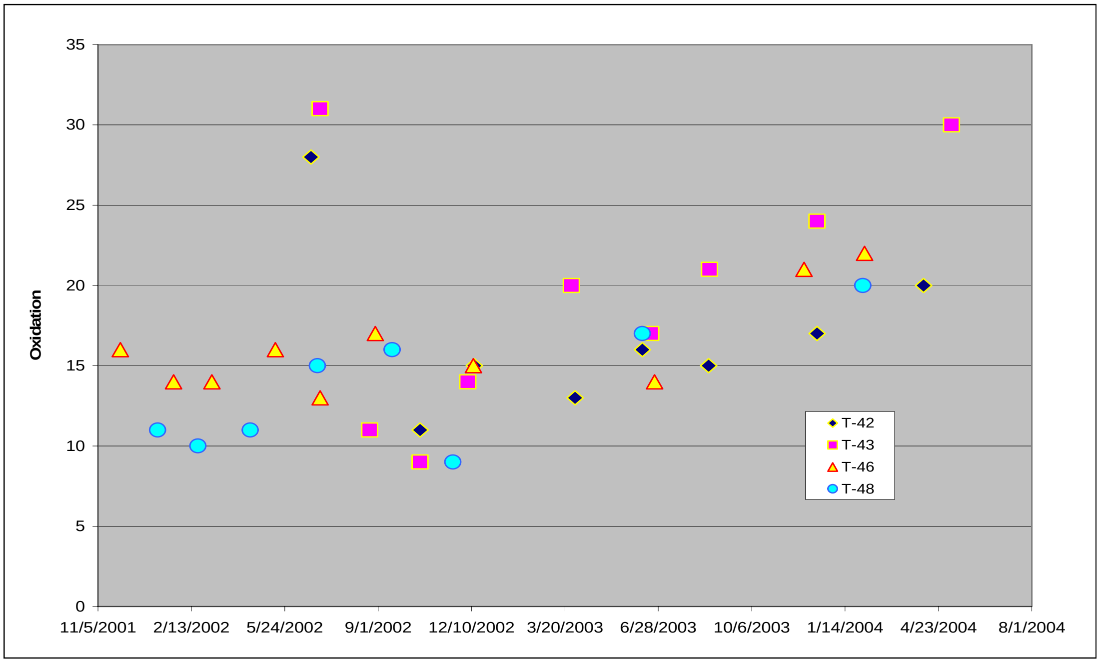


Figure 14: PPM Oil Oxidation Levels in Engine Oil of Brown County Trucks

Note: No difference was noted for biodiesel fueled trucks as opposed to those operating on diesel fuel.)

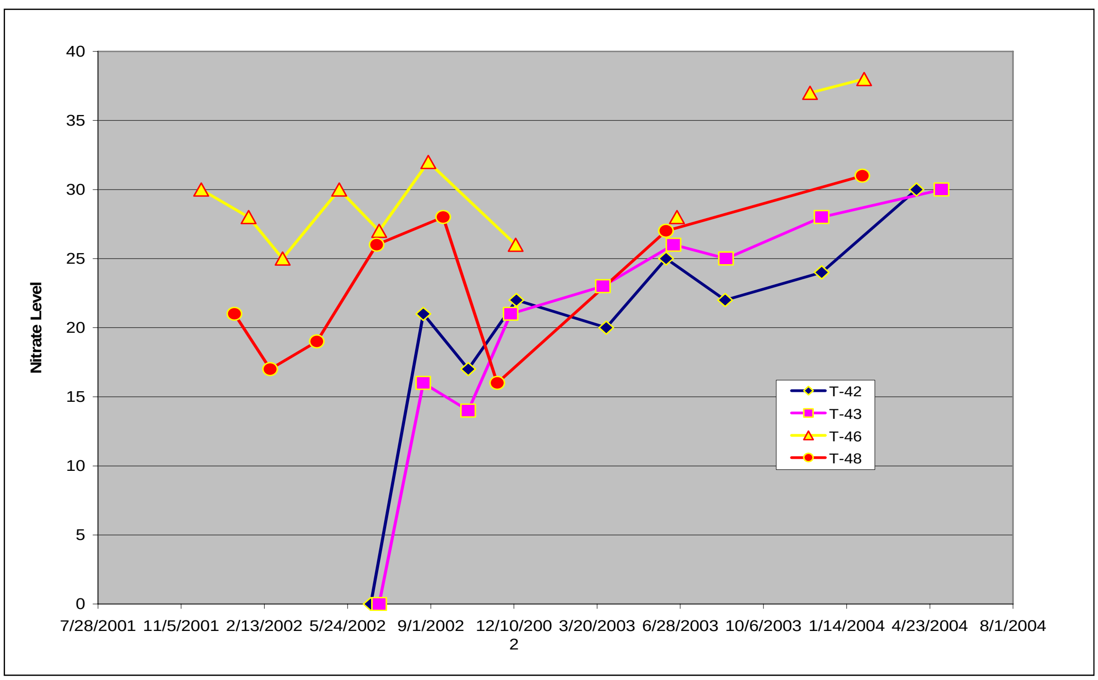


Figure 15: PPM Nitrate Levels in Engine Oil of Brown County Trucks

Note: Paired trucks have similar levels and no apparent differences are evident that can be associated with the fuel.

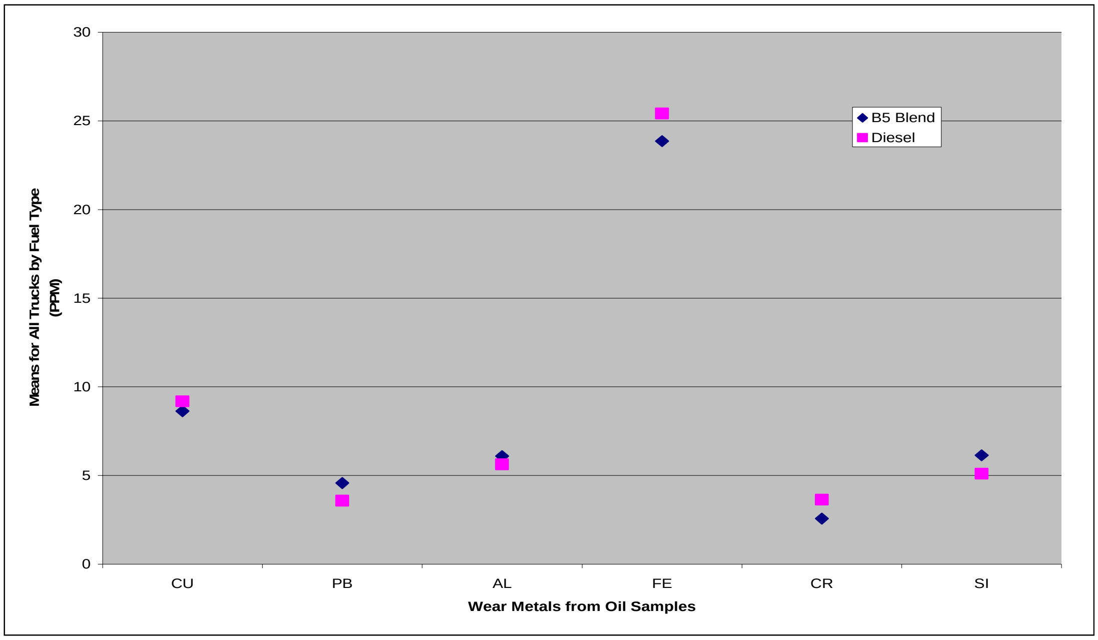


Figure 16: PPM Wear Metal Levels in Engine Oil of Brown County Trucks

Note: All averages in Figure 16 were below threshold levels established by oil analysis laboratories.

Trucks operated by the SDDOT have oil samples from each oil change analyzed by ANA Laboratories. In this analysis the samples were aggregated to show average values of wear variables for trucks operating on the petroleum diesel fuel and B5. The wear metals of aluminum and chromium, as well as silicon were a part of the ANA Labs reports and were included in the chart. Figure 16 shows the mean values of these wear variables for trucks operated on each fuel. Since these are averages for the groups of trucks operated on diesel fuel and on the B5 biodiesel blend the values would not be expected to be outside of thresholds established by oil analysis laboratories. What the graph shows is that the mean values for each of the wear variables are very similar for the trucks operated on the two comparison fuels. Statistical tests of the means for these wear variables indicated that the means are not significantly different between the two fuels. In other words, the oil sample analysis indicated no statistical difference between the levels of wear metals for petroleum diesel fuel and the B5 biodiesel blend.

Individual oil analyses were reviewed for anomalies and for trends that might be associated with the different fuels. One truck (DL159) showed slightly higher than normal wear metals for copper and aluminum. This engine subsequently underwent a repair that indicated that the copper tubes surrounding the injectors in the heads were cracked. The engine was operating on conventional diesel fuel and a review of oil analyses prior to the start of the B5 trial shows that it had a history of high wear metals, indicating a prior condition. Two other trucks (DL426 and DL427), one running B5 and one running diesel fuel, produced oil samples that had very high levels of copper present in the oil. All other wear metals were normal for these samples. The engines involved were CAT C12 engines and were the only caterpillar engines in the SDDOT trucks tested. It may be characteristic of these engines to show elevated copper from some component specific to that engine. Neither of the trucks experienced engine problems, despite the higher than expected copper wear metals in the oil. The mean values of oil wear metals for the groups of trucks running the two comparative fuels are shown in Figure 16. The high copper levels of the two Caterpillar engines were left out of the data in this graph. Student T-tests of the data indicate that the wear metal means for the engines operated on the B5 blend and the engines operating on diesel fuel were not significantly different.

In total, the used engine oil analyses did not indicate any difference between wear metal levels concerning oxidation or nitration for the B5 blend as compared to petroleum diesel fuel. All of the levels reported were well within levels established by oil analysis laboratories. For example the Minnesota Valley Testing Laboratory and Trigard labs would expect to find 3-15 ppm and 5-40 ppm of CU in the oil sample. The CU average for the SDDOT trucks was 6.43 ppm. The same was true for lead (1-12 and 2-25 ppm vs. 7.18 ppm), aluminum (1-15 ppm vs. 5.71 ppm), iron (10-40 and 20-60 ppm vs. 20.28 ppm), chromium ((0.5-8 ppm and 1-10 ppm vs. 2.00 ppm), and silicon (0-12 ppm and 1-15 ppm vs. 11.0 ppm). The result is that a B5 blended fuel implementation by the SDDOT would not be expected to produce measurable differences for these wear metal indicator values.

TASK 10: ASSESS COSTS, BENEFITS, AND ECONOMIC IMPACT

Assess the costs, benefits, and overall economic impact to SDDOT's use of biodiesel at 2%, 5%, and 20% concentrations in its vehicle fleet. The assessment should consider future federal specification changes to diesel fuels, potential additional storage needs that maybe created by using biodiesel, costs of vehicle modifications, fuel availability, and fuel.

FLEET TRIAL COST COMPARISON

Maintenance and fuel cost data from SDDOT trucks fueled with B5 biodiesel blended fuel or petroleum diesel fuel at the Aberdeen, Pierre, Sioux Falls, and Rapid City locations are included in Table 8 and Table 9. The results in Table 8 assume the removal of three large engine repair or replacement events discussed earlier. These included the engine replacement in truck DL120, the major repair in Rapid City truck DL073, and the repair of the copper tubes surrounding the injectors in the heads for the Sioux Falls truck DL159.

Table 8: Comparison of Maintenance Costs per Mile for SDDOT

	Maintenance Costs	Miles	Cost per Mile
Biodiesel (B5)	$14,520.16	146,322	$0.10
Diesel	$17,328.69	105,106	$0.16

Table 9: Comparison of Fuel Cost per Mile for SDDOT

	Fuel Costs	Miles	Costs per Mile
Biodiesel (B5)	$40,560.57	146,322	$0.28
Diesel	$27,257.51	105,106	$0.26

Note: The data reported in Figure 10 and Tables 8 and 9 do not include data from Brown County trucks because Brown County used a different procedure for tracking maintenance costs than the other location. In order to consistently compare costs, Brown County fuel costs were omitted.

Maintenance Costs: Based on the fleet trial results, total maintenance costs for B5 biodiesel blended fuel were similar to petroleum diesel fuel. SDDOT trucks at the Aberdeen, Pierre, Sioux Falls, and Rapid City locations that were fueled with a B5 biodiesel blend traveled 146,322 miles during the study. The maintenance costs for these trucks over the same time period totaled $14,520.16, resulting in maintenance costs per mile of $0.10 for trucks fueled with B5 biodiesel blended fuel. SDDOT trucks from the same locations fueled with petroleum diesel fuel traveled 105,106 miles and accumulated maintenance costs of $17,328.69. Therefore, maintenance costs for petroleum diesel fuel trucks were calculated at $0.16 per mile over the course of the study. Specific maintenance cost comparisons for trucks fueled with B5 biodiesel blended fuel and petroleum diesel fuel during the fleet trial are displayed in Figure 170.

Total lubrication and inspection costs ran higher on trucks running on B5 fuel than petroleum diesel fuel during the course of the study. Increased lubrication and inspection costs among trucks fueled with B5 fuel may be explained by the fact that these trucks ran 41,216 more miles than trucks fueled on petroleum diesel fuel during the fleet trial. Preventive maintenance costs incurred by trucks fueled on petroleum diesel fuel were slightly higher than those of trucks fueled with B5 blended fuel. Total engine repair costs were lower for the group of trucks operating on the B5 fuel. Similarly, repairs to the fuel system were lower for trucks running on B5 biodiesel blended fuel during the course of the study. Total exhaust system costs under the two types of fueling were within $100 of one another at the close of the study, suggesting little difference for vehicles running on petroleum diesel fuel or B5 fuel. Similarly, other maintenance costs were less than $200 different between trucks fueled on petroleum diesel fuel or B5 fuel. Caution should be used when drawing conclusions from these data. Large maintenance events (two engine overhauls and one engine replacement) that were determined to be unrelated to the fuel used were removed to prevent them from distorting the data. Even so, the data were derived from a very small number of trucks over relatively few miles. Also, the repair codes used in the record keeping system were not designed to separate repairs into categories specifically related to the fuel. As such, the records probably include many items that have little if anything to do with the fuel used.

Fuel Costs: Fuel costs were calculated according to the gallons of fuel purchased and used during the fleet trial. Specifically, the costs for each type of fuel were as follows: Petroleum Diesel Fuel ($1.27/gal), B5 ($1.33/gal), and B100 ($2.11/gal). Based on the field study comparison, fuel costs for biodiesel blends were similar to petroleum diesel fuel (Table 9). SDDOT trucks at the Aberdeen, Pierre, Sioux Falls, and Rapid City locations that were fueled with B5 biodiesel traveled 146,322 miles during the field study. The fuel costs for these trucks over the same time period totaled $40,560.57, resulting in fuel costs per mile of $0.28 for trucks fueled with B5. SDDOT trucks from the same locations fueled with petroleum diesel fuel traveled 105,106 miles and accumulated fuel costs of

$27,257.51. The fuel costs for petroleum diesel fuel trucks were $0.26 per mile over the course of the study.

Due to the noticeable difference in maintenance costs per mile observed in Table 9 and the small sample size of trucks included in the fleet trials, total costs were compared (fuel costs + maintenance costs) after removing three extreme maintenance events (engine replacement of Pierre Truck #DL120, engine repair of Rapid City Truck DL073 and Sioux Falls Truck DL159). The results for the remaining trucks fueled with B5 fuel and petroleum diesel fuel are displayed in Table 10.

Table 10: Combined Fuel and Maintenance Costs per Mile

Location	Biodiesel Costs	Miles	Costs per Mile
Aberdeen	$ 12,785.87	35,615	$ 0.36
Pierre	$ 13,463.14	37,361	$ 0.36
Rapid City	$ 16,660.72	35,651	$ 0.39
Sioux Falls	$ 10,455.79	30,174	$ 0.32
All Locations	$ 53,365.52	138,801	$ 0.36
Location	**Diesel Costs**	**Miles**	**Costs per Mile**
Aberdeen	$ 12,332.55	23,305	$ 0.53
Pierre	$ 5,166.54	14,718	$ 0.35
Rapid City	$ 15,691.54	41,336	$ 0.38
Sioux Falls	$ 7,206.05	19,342	$ 0.37
All Locations	$ 40,396.88	98,701	$ 0.41

The results presented in Table 10 display a $0.05 per mile cost difference in favor of B5 biodiesel blended fuel based on the SDDOT fleet results. When comparing the costs per mile results for trucks fueled on B5 fuel and petroleum diesel fuel by location, the largest cost variation was observed in the Aberdeen trucks.

Costs of fuel and maintenance were reviewed for the Aberdeen site, since a large difference appeared to exist between the trucks at this site. Truck DL083, operated on diesel fuel, had unusually high maintenance costs. This truck encountered $1555 in major preventative maintenance, $1685 in engine repair, $59 in exhaust repair, and $803 in "other repairs". At the same time this truck experienced high repair costs, it was operated over 7870 total miles compared with 15,345, 17,310, and 18,485 miles for the other three trucks at Aberdeen. The high maintenance costs, and low miles for this one vehicle distorted the operating costs for the diesel fueled trucks. If the operating costs and miles for this single truck are removed from the totals the cost per mile for diesel trucks at Aberdeen falls to $0.34, which is quite similar to costs at other sites. Similarly if truck DL083 is removed from the totals the average per mile fuel and maintenance costs for all diesel trucks falls to $0.37 per mile, which is much closer to the $0.36 per mile encountered in the B5 fueled trucks.

It is not clear what caused the higher repair costs for truck DL083. The repair codes available in the SDDOT record system only provide general categories for the description of repairs. It is not possible to determine from the computer records the nature of the engine repair, or the specific parts replaced as a part of major preventative maintenance. It is also not clear what caused truck DL083 to be

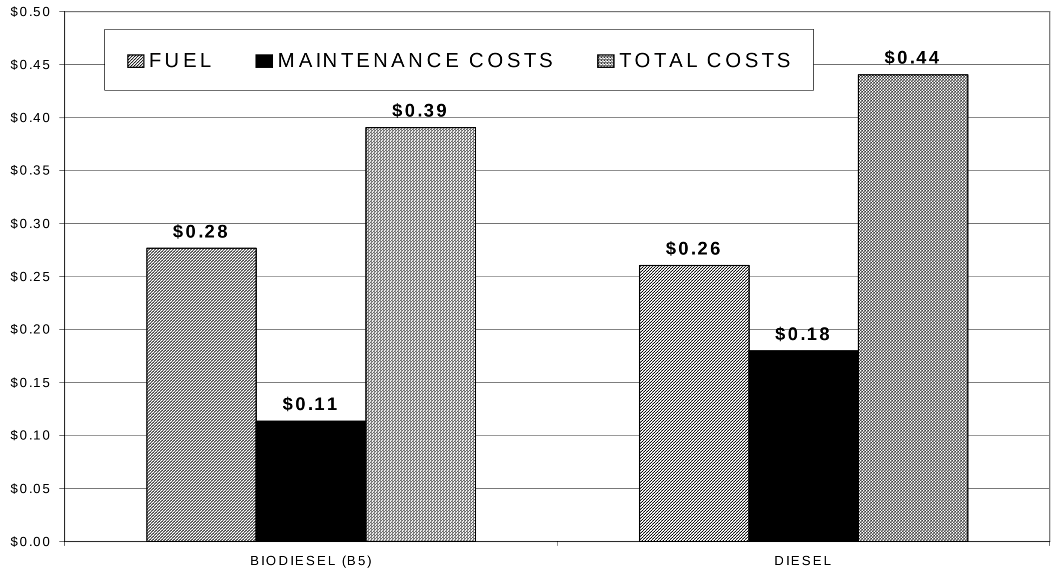


Figure 17: Fuel, Maintenance, and Total Cost Breakdown Per Mile

operated fewer miles. However, it is not the opinion of the researchers that this single truck is indicative of higher general maintenance costs for vehicles operated on petroleum diesel fuel.

The price competitiveness of B5 trucks on a cost per mile basis is driven by the fact that B5 fueled trucks ran over 40,000 more miles than diesel fueled trucks during the study and incurred less maintenance costs than trucks fueled on petroleum diesel fuel. Specifically, the maintenance costs pictured in Figure 10 totaled $14,800 for trucks fueled on petroleum diesel fuel, compared to $11,438 for trucks fueled on B5 fuel. The difference in costs per mile between trucks fueled on B5 fuel and petroleum diesel fuel is further reflected in Figure 17, which categorizes the costs as fuel, maintenance, and total costs.

Based on the results of the SDDOT fleet trial, maintenance costs when using B5 biodiesel blended fuel are expected to be comparable to those incurred when using petroleum diesel fuel. Since maintenance costs are expected to be similar, uncertainty associated with adopting biodiesel-blended fuel is generally related to changes in fuel prices.

Biodiesel Fuel Price Sensitivity

As we have been able to observe from the prior information on the total fuel and maintenance costs of using B5, the actual costs for the fuel are approximately 70% of the total cost. This fact requires us to take a closer look at the actual costs of three different blends of biodiesel, B2, B5, and B20 which are 2%, 5%, and 20% biodiesel respectively. These three different fuel blends were compared at three different diesel fuel prices and three different soybean oil prices to determine the possible economic impacts to the SDDOT.

The three prices chosen for diesel fuel were $1.25, $1.50, and $1.75 per gallon, excluding all taxes. These represent a low, medium, and high price scenario for diesel fuel. As a baseline comparison for these prices we can compare prices from 2003 and current prices from May of 2004. The average price for number two diesel fuel in the US during 2003 was $1.01 per gallon and in May of 2004 the price was $1.20 per gallon (Petroleum Marketing Monthly, July 2004). Due to supply uncertainties and increasing demand, the prices chosen may be slightly high but would be a more conservative estimate than using the lower 2003 price which could dramatically underestimate prices.

The soybean oil prices chosen for this example were $.20, $.25, and $.30 per pound. These prices were obtained, or extrapolated, from Soybean Oil futures prices on the Chicago Board of Trade on 6/8/04. Soybean oil is traded on the board in 60,000 lb contracts. These prices correspond to soybean prices of approximately $4.00, $6.75, and $10.00 per bushel, also a low, medium, and high price scenario in the soybean market. In addition, a processing charge of $.50 per gallon is included to convert the soybean oil into B100 biodiesel. These prices were then converted into dollars per gallon of B100, using the factor of soybean oil weighing 7.2 lbs/gal. This transformation yields B100 prices of $1.95, $2.30, and $2.66 per gallon. Table 11 through Table 13 illustrate the price scenarios described above.

Table 11: Cost of B2 Biodiesel Blended Fuel at Selected Prices

	Diesel Fuel		
B100	**$1.25**	**$1.50**	**$1.75**
$1.95	$1.26	$1.51	$1.75
$2.30	$1.27	$1.516	$1.76
$2.66	$1.28	$1.52	$1.77

Table 12: Cost of B5 Biodiesel Blended Fuel at Selected Prices

	Diesel Fuel		
B100	**$1.25**	**$1.50**	**$1.75**
$1.95	$1.29	$1.52	$1.76
$2.30	$1.30	$1.54	$1.78
$2.66	$1.32	$1.55	$1.79

Table 13: Cost of B20 Biodiesel Blended Fuel at Selected Prices

	Diesel Fuel		
B100	**$1.25**	**$1.50**	**$1.75**
$1.95	$1.39	$1.59	$1.79
$2.30	$1.46	$1.66	$1.86
$2.66	$1.51	$1.71	$1.91

As shown in Table 11 through Table 13, especially for the B2 and B5 blends, the addition of the higher priced B100 has a very small impact on price, generally from 1 to 5 cents per gallon, depending upon the B100 price used and the blend being examined. The price impact is greater for the B20 blend due to the greater amount of B100 being used in the blend.

STORAGE NEEDS

The petroleum diesel fuel storage system for SDDOT is largely underground. Only one tank was an above ground storage tank for petroleum diesel fuel (Table 14).

Table 14: Fuel Storage Location and Volume at SDDOT as of 2004

Type of Tank	Capacity (gal)	Number	Total Gallons
Underground	1,000	23	23,000
	2,000	18	36,000
	2,500	10	25,000
	3,000	1	3,000
	4,000	2	8,000
	5,000	2	10,000
	6,000	1	6,000
	10,000	3	30,000
	12,000	1	12,000
Above Ground	2,000	1	2,000
Total		62	155,000
Transfer Tanks	20-120	122	7,084

The SDDOT does not have a fuel tank cleaning policy in place, and several of these tanks have never been cleaned. Several of the persons who were contacted about these fuel storage tanks did not know when (if ever) the tanks were last cleaned. One might argue that a fuel tank cleaning policy should be part of regular fuel system maintenance. However, very few persons/companies who fuel with petroleum diesel fuel establish such a plan. This is primarily due to the fact that very few fuel tanks have an opening large enough for a man to move through and into the tank so that the tank can be completely cleaned. Much debris remain in the tank after such a "make-do" cleaning and the re-suspended debris often finds its way into fuel filters, and in some instances disrupts fuel delivery to the engine.

TASK 11: PREPARE INTERIM REPORT

Prepare an interim report that presents preliminary findings, recommendations, and conclusions by December 15, 2002.

A summary of existing biodiesel research was reported and included in the interim report submitted to the SDDOT.

TASK 12: PREPARE GUIDELINES AND SPECIFICATIONS

Prepare guidelines and specification for the potential phasing in of biodiesel fuel at all SDDOT locations.

SDDOT provided a list of all SDDOT locations that used B5 as a part of this project. The SDDOT developed and sent out a questionnaire to all SDDOT locations in the state so that the researchers could determine the fueling equipment at each SDDOT facility. The questions in the questionnaire focused on: 1) the number and size of tanks, 2) the type of fuel stored, 3) the date when the tank was last cleaned, 4) the date when the tank was last treated with a biocide, and 5) if the tank was treated, the biocide that was used to treat the tank (The questionnaire can be found in Appendix F).

Based on the tank data collected and the data collected from the rest of the investigation, the researchers outlined the following implementation plan for SDDOT to begin using a biodiesel blend (the researchers are making the assumption that SDDOT would ensure that the biodiesel which was blended with the petroleum diesel fuel met or exceeded the specifications outlined in ASTM D6751).

The biodiesel that is purchased for blending must meet or exceed the standards set forth in ASTM D6751. This is a requirement that all engine manufacturers expect vehicle operators to do when operating the vehicle.

The biodiesel must be readily available. A contract will need to be drawn up with the local fuel distributors with an option to provide petroleum diesel fuel in the event that the fuel distributor is unable to deliver a biodiesel blend as required.

In the event that fuel is NOT available, the SDDOT should have the option of using standard diesel fuel. *Since low level blends, such as B5, are interchangeable with standard diesel fuel, changing fuels can be done as necessary to accommodate market issues or availability.*

- **Cleaning of fuel storage tanks prior to a change to a blended fuel is not required.** *It is not common practice among fuel distributors to clean tanks unless the tank is to be used for gasoline rather than diesel fuel. The cost to clean each tank and dispose of the fuel from the bottom of the tank as hazardous waste is substantial (note the costs that were incurred when cleaning one tank is available from SDDOT). Further, since few of the tanks have a manhole access, it is virtually impossible to remove all of the debris that has settled to the bottom of the tank. If SDDOT feels a need to clean these tanks it should be a result of a regular tank cleaning system/program and not because they have decided to change to a biodiesel blend.*
- **Fuel filters that filter the fuel on the storage tanks should have a water trap incorporated into the filter.** *This type of filter is readily available, and should already be in place at each SDDOT fueling station.*
- **One set of fuel filters for each vehicle may need to be replaced earlier than you would otherwise change these filters**.–Estimated cost is essentially the cost of one fuel filter for all vehicles that will be fueled with a B5 blend (1200 * $12.50/filter=$15,000) Rather than replace filters immediately when changing to the B5 blend, we encourage SDDOT to replace filters as needed and preferably during regular maintenance windows. If an engine is short on power, then a filter change is needed. If not, then SDDOT should operate the truck as if fueled with petroleum diesel fuel.
- **The distributor should deliver pre-blended fuel.** (Cenex has already adopted this policy for their customers.)
- **Inform <u>all</u> vendors who bid on the biodiesel blend contract regarding expected procedures for blending biodiesel with the petroleum diesel fuel.** (note the Biodiesel

Handling and Guidelines available from the National Renewable Energy Laboratory, NREL/TP-540-36182; November 2004)

- **Follow the existing SDDOT plan for number one vs. number two fuel usage patterns.** (October through April is when number one fuel is used)

TASK 13. PREPARE FINAL REPORT

Prepare a final report and executive summary of the research methodology, findings, conclusions, and recommendations.

In June 2004, Leon G. Schumacher, Daniel S. Humburg, Ajit K. Mahapatra, Gary L. Taylor and Tonya J. Hansen presented an overview of the findings to the Research Review Board outlining the research methods, findings, conclusions, and recommendations for the study.

TASK 14. MAKE EXECUTIVE PRESENTATION

Make an executive presentation to the SDDOT Research Review Board at the conclusion of the project.

Leon G. Schumacher, Daniel S. Humburg, Gary L. Taylor and Tonya J. Hansen met on June 10, 2004 with the Research Review Board and presented an overview of their findings. Their report focused on:

- technical findings;
- the state DOT survey;
- the economic impact to SDDOT;
- the tank survey; and
- suggested guidelines for implementation of biodiesel fueling at SDDOT.

FINDINGS & CONCLUSIONS

SURVEY OTHER STATE TRANSPORTATION DEPARTMENTS

A total of 31 DOTs have used a biodiesel blend and 19 DOTs had conducted tests that compared the performance of a biodiesel blend with petroleum diesel fuel. A total of 15 states have tested B20, two states have tested B2, and one state has tested B5 and B10. A total of eight DOTs experienced fuel filter plugging problems during warm weather operation. However, most all the DOTs generally reported that the biodiesel blend was a seamless replacement for petroleum diesel fuel. A majority of the states have fueled with a soybean derived biodiesel blend. Of the 48 states that responded, only Minnesota had a mandate that will require fueling with a biodiesel blend.

REVIEW SDDOT'S VEHICLE INVENTORY

Over 1200 diesel engines are used in the SDDOT fleet. These engines are made by 75 different engine manufacturers (Cummins, Detroit Diesel, etc.). Further, SDDOT has vehicles that are manufactured by 78 different companies (John Deere, Ford, etc.).

Two important issues surfaced from this review. The first issue is that Case New-Holland (CNH) is the primary vendor that SDDOT will most likely turn to in the event material compatibility concerns surface with B5 fueling. CNH is responsible for the manufacture of over 60% of the engines in the SDDOT fleet due to the recent mergers of Case-International with Ford & New Holland. The second, and perhaps most important, is that over fifty percent of the SDDOT fleet is less than five years old. This is important because many of the engine manufacturers changed the composition of their fuel system gaskets to prevent leaks that surfaced with the introduction of low sulfur diesel fuel (500 ppm) in October of 1993. The composition of these gaskets are such that these engine fuel systems should not see any adverse affects from fueling with a biodiesel blend, as these compounds are relatively inert and not affected by the composition of a biodiesel blend.

CNH raised four issues that they felt must be addressed when fueling with a biodiesel blend[3]. As noted below, these issues pertained to biodiesel solvency, blending, material compatibility, and fuel quality.

- Fuel Quality—In the US, the biodiesel fuel is unregulated and the biodiesel fuel quality tends to be lower than the ASTM Standard. These fuel quality issues can have a significant impact on engine reliability and performance. In Europe, where more stringent standards for biodiesel fuel are in place, engines are warranted using higher blends of rape methyl ester (RME) biodiesel fuel.
- Solvency—Biodiesel (B100) fuel acts as a solvent. When used in older vehicles, the biodiesel fuel can dissolve deposits left from previous fuels. When these particles enter the fuel system, filter plugging is the most common problem.

[3] G. Stanek (personal communication, June 20, 2003)

- Blend—The higher the blend of biodiesel, the more problems should be expected. A B5 fuel would likely not cause any problems. When the blend is increased beyond B20, the issues associated with the solvency and material compatibility can increase rapidly.
- Material Compatibility—In newer engines (post 1996) material compatibility should not be an issue for B5 blends. In older engines, particularly with worn and cracked fuel lines, problems are more likely to occur. Materials of concern are fuel lines, diaphragms in fuel transfer pumps, and seals and o-rings in fuel pumps.

Several engine manufacturers (Deere, Cummins, Detroit, and International as well as the Engine Manufacturers Association) have issued position statements concerning fueling with a biodiesel blend. These statements can be found in Appendix B.

TEST ENGINE COMPONENTS

Although previous biodiesel research indicated that neat biodiesel caused problems with rubber elastomers, no elastomer problems were noted during the B5 test. NREL recently completed an elastomer compatibility research project (Appendix C) and is in the process of completing a second biodiesel similar project. NREL reported that another more extensive study was underway using soy and canola based B5 and B20 blend levels. Samples of biodiesel were treated to insure oxidative stability and samples of biodiesel were rapidly oxidized. These fuels were then used to prepare the B5 and B20 blends for pump and injector durability testing. NREL was expected to release this information to the general public during the early months of 2005. This information will be of value to the SDDOT as these findings will add to the anecdotal evidence about elastomer compatibility while fueling with biodiesel. Since many of the diesel fueled vehicles in service at SDDOT are late model vehicles/engines, these data should provide insight concerning material compatibility for these engines. A website to check back for additional information is: http:/www./crcao.com.

EVALUATE OPERATIONAL PERFORMANCE

Blending procedures used to mix biodiesel and petroleum diesel fuel were a concern identified by the SDDOT technical panel. An incident occurred during the demonstration that prevented two truck operators from refilling their fuel tanks at Aberdeen. The researchers believed that this may have been a result of improper blending of the biodiesel and diesel fuel. The biodiesel was heated to room temperature (~70 ^{o}F) to facilitate blending. However, the ambient temperature dropped to nearly 0 ^{o}F on the same day that biodiesel was blended with a new shipment of diesel fuel. If blending did not occur, then much of the biodiesel may have settled to the bottom of the fuel supply tank. And, since the suction pipe for the fuel storage tank fuel pump draws from a position that is near the bottom of the tank, this may have prevented the Brown County truck operators from filling their trucks with a biodiesel blend that day (unblended biodiesel freezes solid at 32 ^{o}F). One solution for the Brown County truck operators would have been to fill their fuel tanks with diesel fuel as no changes were made to the engine/vehicle when switching to the B5 blend. In short, the entire SDDOT fleet can be switched to 100 percent petroleum diesel fuel in the event of a fuel shortage.

It is important to note that while two of the Brown County trucks could not draw fuel from the fuel supply tank that cold day that the trucks had been filled the night before and completed their work for the next day using a B5 blend (fuel left over from a previous refueling). Further, the testing spanned two winters and no truck was taken out of service due to cold weather operation as a result of fueling with a biodiesel blend (11 SDDOT and 2 Brown County trucks were fueled with a B5 blend).

The impact of a low level blend on engine performance was evaluated and the SDDOT fleet noted very small reductions in fuel economy (B5 =4.7 mpg; Diesel Fuel=4.9). This was expected, as the energy value [British Thermal Unit (BTU)] of a B5 blend is slightly lower than 100% number two diesel fuel. The operators did not report reductions in power or torque when fueled with B5. Engine oil analysis suggested that engine component wear was essentially the same in vehicles fueled with B5 as compared to diesel fueled engines.

CONDUCT PHYSICAL AND CHEMICAL TESTS

The diesel fuel met or exceeded the specifications established by ASTM D975. The biodiesel (B100) met or exceeded all specifications established by ASTM D6751 except flashpoint. The flashpoint for B100 sample was slightly lower than the standard in D6751 (114°C and 118°C versus 130°C). The researchers then examined ASTM D6751 in more detail. The flashpoint for biodiesel is intended to be 100°C minimum. However, the specification for flashpoint in D6751 is set 30°C higher than this specification. This document explains why flashpoint was set higher when the ASTM committee developed D6751. This was because the committee members realized that this criterion was a cost effective way to determine excess amounts of unreacted alcohol that remained in the finished biodiesel. The researchers also noted that since the biodiesel would be mixed with diesel fuel (flashpoint minimum for ASTM D975 ranges from 38°C to 52°C), that the flashpoint of the B5 blend would still be significantly higher than the flashpoint specification established for either number one or number two diesel fuel in ASTM D975.

Stability of diesel fuel is important as oxidative breakdown or biological conversion of the fuel can leave residues that can plug filters and adhere to injector pump parts reducing pump life. Stability is of particular concern in biodiesel as its compounds are considered to be more susceptible to oxidation than petroleum products. Fuel can be tested for changes in filterable residues over time as a measure of the stability of the fuel.

Two types of stability tests were conducted on samples of the B5 blended fuel. A test of total insolubles filtration (ASTM D2276) was conducted on B5 that had been aged in the fuel tanks of two infrequently used trucks (Figure 9). An identical test was conducted on a sample of B5 that had been stored undisturbed in a barrel for the duration of the research project A sample of B5 was also subjected to an accelerated oxidative stability test (ASTM D2274) at the outset of the project. The accelerated test provided a total insolubles level of 3.2 mg/1000ml (Figure 9). Storage of the fuel in the truck fuel tanks for periods of approximately 6 months and one year respectively caused total insolubles in both samples to rise from a level of 2 to a level of 3 mg/1000 ml. The sample of fuel stored in a barrel for the duration of the project produced a total insolubles filtration result of 4 mg/1000ml. The results are in agreement with the accelerated test and are well below the 10 ppm level threshold that some major municipalities (New York) have set as a maximum allowable level for delivered diesel fuel. The researchers contacted the fuel suppliers to determine if any anti-oxidants or other fuel additives had been added to either the biodiesel or the diesel fuel. The biodiesel suppliers reported that only pour point depressants had been added to the biodiesel. The importance of these findings is significant. First, this means that the fuel which was delivered for use with the project was a fuel that met the standards as established by ASTM D975 and ASTM D6751. Second, and more importantly, this finding suggests that if the fuel tank of a vehicle were topped off with B5 and subsequently not used for several months, that the B5 fuel should not age prematurely.

EVALUATE VEHICLE MAINTENANCE HISTORIES

As noted in the findings in Task Ten, the diesel "fueled" engines had higher maintenance and repair costs than the B5 fueled diesel engines. Several comparisons were made with the data from the engine oil analysis samples. All engine oil analysis data were found to be within normal levels for both the B5 and the diesel fueled engines. In short, these comparisons showed no differences between the levels of wear metals found in the used engine oil analysis samples regardless of the fuel used to fuel each engine.

The trucks were in a good state of repair at the beginning of the test, and only a limited number of parts were replaced on the diesel "fueled" engines and the B5 fueled engines. The researchers felt that the parts that were replaced were items that would have been replaced regardless of the fuel used to fuel the engine. For example, the copper tubes surrounding the injectors in the heads cracked on an engine that was fueled with diesel fuel. One B5 fueled engine underwent a major overhaul. The valve keeper came loose and this allowed the valve to move down toward the piston. The end result was that the valve was imbedded in the top of the piston. One of the diesel fueled engines turned a main bearing. The engine for this truck was replaced with a factory rebuild and put back into service. In each case the repairs that resulted were not attributed to the fuel (diesel vs. B5) that was used to fuel the engine.

ASSESS COSTS, BENEFITS, AND ECONOMIC IMPACT

For no reason known by the researchers, the diesel "fueled" engines had a higher mortality rate, resulting in higher engine repairs for these engines and ultimately the total replacement of one diesel "fueled" engine. The researchers felt that the condition of the engine, as reported by the technicians, was not a result of fuel used, but normal engine mortality. As such, these expenses were removed from the calculations, reducing the difference between the maintenance costs for the diesel "fueled" as compared to the B5 fueled engines to five cents. Maintenance costs for B5 biodiesel blended fuel were similar to petroleum diesel fuel. Diesel engines, for the most part had higher maintenance costs for preventative maintenance, engine replacement, and fuel system repairs. B5 engines, for the most part, had higher repair costs for lubrication and inspection, engine repairs, exhaust, and other repairs.

Economic analyses of biodiesel fueling indicated that the substitution of the higher priced B100 (when blending) had a very small impact on price, generally from 1 to 5 cents per gallon ($0.02/gallon for the SDDOT). This price varied depending on the B100 price used and the blend used to fuel the engine. The cost differential for implementation of a B5 blend will become much less as the cost of petroleum diesel fuel approaches $2.00 per gallon. This is due to the fact that as petroleum costs increase the cost of petroleum moves closer to the market cost of biodiesel. (Note: At the time of the study 100% biodiesel sold for ~$2.30 / gallon.

PREPARE GUIDELINES AND SPECIFICATIONS

A survey of fuel storage tanks at SDDOT was conducted to determine how SDDOT stores fuel across the state. The fact that over 98 percent of SDDOT's fuel is stored underground is significant. This type of fuel storage reduces the likelihood that fuel would gel even in extremely cold weather. Further, the temperature of the fuel would be relatively constant in comparison to fuel that is stored above ground. Finally, if the biodiesel could not be blended prior to delivery, the temperature below ground would facilitate homogenous blending of the biodiesel with the petroleum diesel fuel. This is due to the fact that underground fuel tanks are typically set below the frost line, thus resulting in a more uniform daily fuel temperature in the storage tank. Ultimately, the guidelines published by the National Renewable Energy Laboratory should be reviewed concerning appropriate blending practices prior to moving forward (. Biodiesel Handling and Use Guidelines. Report No. NREL/TP-540-36182; November 2004).

Much of the knowledge developed as a result of this task is found in the Implementation Recommendations section of this report. These recommendations were developed based on the findings of the investigation, the aforementioned fuel storage investigation, as well as the researchers' review of literature.

IMPLEMENTATION RECOMMENDATIONS

The researchers outlined the following implementation plan for SDDOT to begin using a biodiesel blend under Task 12. Again, the researchers cannot emphasize enough the importance of purchasing biodiesel that meets or exceeds the specifications set forth by the American Standard of Testing Materials D6751. In addition regular fuel tank maintenance and fuel filter maintenances procedures, as recommended by the original equipment manufacturer must be adhered to by the truck drivers and truck maintenance personnel.

The biodiesel that is purchased for blending must meet or exceed the standards set forth in ASTM D6751. This is a requirement that all engine manufacturers expect vehicle operators to follow when operating the vehicle.

The biodiesel must be readily available. A contract will need to be drawn up with the local fuel distributors with an option to provide petroleum diesel fuel in the event that the fuel distributor is unable to deliver a biodiesel blend as required.

In the event that biodiesel or B5 is NOT available, the SDDOT should have the option of using standard diesel fuel. Since low level blends, such as B5, are interchangeable with standard diesel fuel, changing fuels can be done as necessary to accommodate market issues or availability.

- **Cleaning of fuel storage tanks prior to a change to a blended fuel is not required.** It is not common practice among fuel distributors to clean tanks unless the tank is to be used for gasoline rather than diesel fuel. The cost to clean each tank and dispose of the fuel from the bottom of the tank as hazardous waste is substantial. Further, since few of the tanks have a manhole access, it is virtually impossible to remove all of the debris that has settled to the bottom of the tank. If SDDOT feels a need to clean these tanks it should be a result of a regular tank cleaning system/program and not because they have decided to change to a biodiesel blend.
- **Fuel filters that filter the fuel on the storage tanks should have a water trap incorporated into the filter.** This type of filter is readily available, and should already be in place at each fueling station.
- **One set of fuel filters for each vehicle may need to be replaced earlier than you would otherwise change these filters.** Estimated cost is essentially the cost of one fuel filter for all vehicles that will be fueled with a B5 blend (1200 * $12.50/filter=$15,000) Rather than replace filters immediately when changing to the B5 blend, we encourage SDDOT to replace filters as needed and preferably during regular maintenance windows. If an engine is short on power, then a filter change is needed. If not, then SDDOT should operate the truck as if fueled with petroleum diesel fuel.
- **The distributor should deliver pre-blended fuel.** (Cenex has already adopted this policy for their customers.)

- **Inform all vendors who bid on the biodiesel blend contract regarding expected procedures for blending biodiesel with the petroleum diesel fuel.** (note the Biodiesel Handling and Guidelines available from the National Renewable Energy Laboratory–NREL/TP-540-36182; November 2004)
- **Follow the existing SDDOT plan for number one vs. number two usage patterns**. (October through April is when number one fuel is used)

ANALYSIS OF RESEARCH BENEFITS

The use of B5 by SDDOT fleets can provide benefits to both the South Dakota state government as well as the people of South Dakota. Our evaluation of the use of B5 fuels in SDDOT storage facilities and fleets suggests that the use of a low level blend (B5) did not significantly impact the day to day operation of the SDDOT fleet. Small differences were noted concerning fuel economy but this was expected as the energy content of biodiesel is lower than number two diesel fuel.

This research identified key issues associated with the implementation of a biodiesel blend fueling program and identified solutions that will insure a prompt and effective transition to fueling with biodiesel blends.

Although this research did not focus on the state-wide economic benefits of B5 fueling, the researchers documented through their review of literature that biodiesel fuel has been shown to decrease many types of regulated engine exhaust emissions from diesel engines.

State-wide economic benefits also exist. The use of biodiesel should stimulate a new industry in South Dakota- the sale (and possibly the production) of biodiesel. Approximately 146 million gallons of diesel fuel are consumed in South Dakota by automobiles and trucks for transportation (Energy Information Administration, 2001). Approximately 114 million gallons of dyed diesel fuel is consumed by agriculture and other non-road taxed operations in South Dakota. This brings the total gallons of diesel fuel used by South Dakota to 260 million gallons. According to the same source, these numbers are increasing each year at the rate of one million gallons. Replacing five percent of these amounts represents 7,300,000 to 13,000,000 gallons of biodiesel that has a market value of ranging from $2.50–$3.50 per gallon.

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APPENDIX A: BRIEF SURVEY OF BIODIESEL USE IN STATE DOTS

Brief Survey of Biodiesel Use in State DOTs

As a part of a research effort involving the use of biodiesel blends in road maintenance trucks we are surveying departments of transportation across the U.S. with regard to their experience with biodiesel. We understand that your time is valuable and have tried to structure this survey to allow you to proceed quickly. The first few questions ***may*** **be best answered by a program officer** within the DOT. Many of the other questions may be more easily answered by an individual in charge of fleet maintenance and monitoring. **The survey may be saved and forwarded as necessary to the appropriate individuals via E-Mail.** Once complete, we request that it be forwarded or E-mailed to daniel_humburg@sdstate.edu.

Thank you very much for your time.

Dr. Leon G. Schumacher
University of Missouri – Columbia

Dr. Daniel S. Humburg
South Dakota State University

Please answer by marking the appropriate box preceding the appropriate response. In questions requesting additional input you may type in the underline area as necessary. Don't worry about formatting your response.

1) Are you aware of any effort in your state to mandate the use of biodiesel in any blend?

☐ Yes

☐ No

2) If a mandate has been enacted, or is being considered,

a) What is the blend percentage involved or proposed? _____

b) When would the mandate take effect? _____

3) Has your department of transportation used or tested the use of biodiesel fuel in any way at this time?

☐ Yes **Proceed to question 6.**

☐ No

4) Has your department of transportation ***studied or considered*** using biodiesel or a biodiesel blend?

☐ Yes

☐ No **In this case you need proceed no further, but please forward this survey with your marked responses to** daniel_humburg@sdstate.edu. **Thank you for your time**.

5) If you considered a biodiesel blend but elected not to use it at this time, what factors affected your department's decision? Check all that apply.

- ☐ a) Cost of fuel
- ☐ b) Questions regarding storage
- ☐ c) Questions regarding performance or endurance
- ☐ d) Questions regarding cold weather properties of the fuel
- ☐ e) Other factors ?

6) When did you begin to use or test the use of biodiesel blends? _____

7) What is the feedstock for the biodiesel blend used?

- ☐ a) Soy Methyl Ester?
- ☐ b) Rape Methyl Ester?
- ☐ c) Yellow Grease?
- ☐ d) Other?
- ☐ e) Don't know

8) What is your petroleum component?

- ☐ a) #2 diesel year around
- ☐ b) #1 diesel during the months of ______
- ☐ c) Blend of _____#1 and _____#2 during the months of

9) How is your fuel blended?

- ☐ a) Blended at a terminal and delivered by pipeline?
- ☐ b) Blended at a terminal and "splash mixed" in a tanker delivery vehicle?
  - ☐ Biodiesel added atop petroleum?
  - ☐ Petroleum added atop biodiesel?
- ☐ c) Blended in your storage tank(s)?
- ☐ d) Blended at the point of fueling in the vehicle fuel tank?
- ☐ e) Other
- ☐ f) Don't know

10) Have you made changes in your fuel storage routines to accommodate biodiesel blends? If so, what type of changes? ______

11) Have you made changes in your storage system to accommodate biodiesel blends in cold weather storage differently?

- ☐ a) Yes. ..... What type of accommodations? _____
- ☐ b) No changes needed.

12) What type of vehicles are utilizing the biodiesel blend fuel?

- ☐ a) Road maintenance trucks
- ☐ b) Off-road machinery (tractors, payloaders, skidsteers, etc)
- ☐ c) Other diesel equipment
- ☐ d) All diesel engines in the fleet

13) Are you tracking, or have you tracked performance in biodiesel fueled vehicles for comparison to other fuels?

- ☐ Yes
- ☐ No If so, how? _____

14) Since beginning the use of biodiesel, have you experienced any documented or anecdotal problems with filtering fuel that you consider in excess of your experience with petroleum fuel?

- ☐ a) No problems? **Skip to question 18**
- ☐ b) Filters plugging at the pump?
- ☐ c) Filters plugging at the engine?
- ☐ d) Any unusual residue or material noted in the filter or fuel system?

If so... can you describe the type of material that appeared to plug the filter? _____

e) Were you able to identify the material causing filter problems? _____

15) If you encountered fuel filter problems, have you found these problems to persist (repeat), or have they abated? _____

16) If you encountered fuel filter problems, did the problems occur across different fuel filter types, or in a particular filter type and system?

- ☐ a) Multiple types of filters
- ☐ b) One type What were the types? _____
- ☐ c) Don’t know.

17) Did they do anything to fix the problem? _____

18) Have you encountered any problems associated with cold weather and the fuel?

- ☐ a) No cold weather problems?
- ☐ b) Plugging of engine fuel filters under very cold conditions
- ☐ c) Gelling of fuel in vehicle supply lines
- ☐ d) Other problems that you associate with cold weather?

19) Have you or your operators noted any differences in vehicle power when using biodiesel?

☐ Yes ☐ More or ☐ Less

☐ No

20) Have you noticed or documented any change in vehicle fuel efficiency (mileage) since beginning the use of biodiesel or biodiesel blends?

☐ a) Not measured

☐ b) No change noted

☐ c) Documented difference of _____ mpg when compared to historical use of petroleum

21) Have you noticed or documented any differences in fuel pump or injector durability in vehicles using biodiesel or biodiesel blends?

☐ a) Not monitored.

☐ b) Fuel systems routinely monitored, but no differences detected.

☐ c) Fuel pump problems have been encountered. Please describe in a few words the types of problems: _____

22) Have you noticed any differences in used engine oil analyses from engines operating on a biodiesel blend?

☐ a) No changes noted.

☐ b) Change in viscosity

☐ c) Change in oil acidity

☐ d) Change in other oil characteristic ☐ e) Change in indicated engine wear? ☐ More or ☐ Less

23) Have you found reason to alter your oil change interval in vehicles utilizing a biodiesel blend?

☐ a) No.

☐ b) How has your oil maintenance schedule changed? _____

24) Have any parts of your engines' fuel systems developed fuel leaks since the change to a biodiesel blend, including leaks in fuel lines?

☐ a) None noted **Skip to question 25**

☐ b) Leaks have developed.

i) Do you know the engine type and manufactured year for models that developed leaks? _____

ii) Can you identify the component that caused the leak? Fuel supply return hose, fuel pump O ring, gasket, etc? _____

25) Have you encountered any other vehicle maintenance issues that you believe to be associated with the use of biodiesel blend in your fleet?

- ☐ Yes Please briefly describe the problem or issue. _____
- ☐ No

Thank you for taking the time to answer these questions. Please forward this marked survey as an attachment to daniel_humburg@sdstate.edu.

APPENDIX B: ENGINE MANUFACTURERS' POSITION STATEMENTS CONCERNING THE USE OF BIODIESEL

CATERPILLAR

Information Release Memo **PMP01-01**

Preventive Maintenance Products

March 2001

CATERPILLAR POSITION ON THE USE OF BIODIESEL FUEL

This document applies, within the stated limitations, to Caterpillar engines.

Introduction:

With increased world interest in emissions and reducing the use of petroleum distillate based fuels, many governments and regulating bodies encourage the use of biofuels. Governmental incentives and/or environmental legislation to use biofuels may have an impact on the sales and use of Caterpillar engines and equipment. This document outlines Caterpillar's criteria and parameters when using biodiesel fuel.

Biodiesel is a fuel that can be made from a variety of sources, primarily from soybean oil or rapeseed oil. Without esterification, these oils gel in the crankcase and fuel tank and may not be compatible with many of the elastomers used in today's engines. In their original form, these oils are not suitable for use as a fuel in compression ignition engines. To use these oils as fuel, they must be esterified. Alternate base stocks for biofuel may include animal tallow, waste cooking oils, or a variety of other feedstocks.

ASTM has recently authored a provisional specification for biodiesel, PS121. Caterpillar recognizes BioFuels meeting the ASTM PS121, DIN 51606 or the Caterpillar biodiesel specification.

Caterpillar certifies its engines using the prescribed EPA and European Certification Fuels. Caterpillar does not certify engines on any other fuel. It is the user's responsibility to use the correct fuel as recommended by the manufacturer and allowed by EPA or other local regulatory agencies. It is the responsibility of the user to obtain the proper local, regional, and/or national exemptions required for the use of biodiesel in any emissions regulated Caterpillar engine.

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Warranty and the Use of Biodiesel Fuel in Caterpillar Engines

Caterpillar neither approves nor prohibits the use of biodiesel fuels. Caterpillar is not in a position to evaluate the many variations of biodiesel fuels, and the long-term effects on performance, durability or emissions compliance of Caterpillar products. The use of biodiesel fuel does not affect Caterpillar's materials and workmanship warranty. **Failures resulting from the use of any fuel are not Caterpillar factory defects and therefore the cost of repair would NOT be covered by Caterpillar's warranty.**

Recommendation for the use of Biodiesel Fuel in Caterpillar Engines

For Caterpillar 3046, 3064, 3066, 3114, 3116, 3126, 3176, 3196, 3208, 3306, C-10, C-12, 3406, C-15, C-16, 3456, 3408, 3412, 3500 series, 3600 series, CM20, CM25 and CM32 engines: Biodiesel meeting the requirements listed in Caterpillar's biodiesel specification or, meeting either ASTM PS121 or DIN 51606, are acceptable. They may also be blended in any percentage with an acceptable diesel fuel, provided the biodiesel constituent meets the requirements outlined in the Table prior to blending.

For Caterpillar 3003 through 3034, 3054 and 3056 engines: Biodiesel meeting the requirements listed in Caterpillar's biodiesel specification, or meeting either ASTM PS121 or DIN 51606, may be blended with an acceptable diesel fuel at a maximum of 5% biodiesel fuel blended with 95% diesel fuel. The biodiesel must meet the requirements outlined in the Table prior to blending. Use of more than a 5% biodiesel fuel can cause premature failures whose repair would not be covered under Caterpillar warranty.

When burning biodiesel, or any blend of biodiesel, it is the responsibility of the user to obtain the proper local, regional, and/or national exemptions required for the use of biodiesel in any emissions regulated Caterpillar engine. When using a fuel that meets the Caterpillar's Biodiesel specification, ASTM PS121, or DIN 51606 specifications, and when adhering to the following recommendations, the use of biodiesel should pose no problems.

Recommendations:

- The oil change interval can be affected by the use of biodiesel fuel. Use Scheduled Oil Sampling (SOS) to monitor the engine oil condition and to determine the optimum oil change interval.
- Biodiesel provides approximately 5-7% less energy per gallon of fuel when compared to distillate fuels. To avoid engine problems when the engine is converted back to 100% distillate diesel fuel, do not change the engine rating to compensate for the power loss.
- Elastomer compatibility with biodiesel is still being monitored. The condition of seals and hoses should be monitored regularly.
- Biodiesel fuels may pose low ambient temperature problems for both storage and operation. At low ambient temperatures, fuel may need to be stored in a heated building or a heated storage tank. The fuel system may require heated fuel lines, filters, and tanks. Filters may plug and fuel in the tank may solidify at low ambient temperatures if precautions are not taken. Consult your biodiesel supplier for assistance in the blending and attainment of the proper cloud point fuel.
- Biodiesel has poor oxidation stability, which can result in long term storage problems. The poor oxidation stability qualities may accelerate fuel oxidation in the fuel system. This is especially true in engines with electronic fuel systems because they operate at higher temperatures. Consult the fuel supplier for oxidation stability additives.
- Biodiesel fuel is an excellent medium for microbial growth. Microbes cause fuel system corrosion and premature filter plugging. The effectiveness of conventional anti-microbial additives, when used in biodiesel is not known. Consult your fuel and additive supplier for assistance.
- Care must be taken to remove water from fuel tanks. Water accelerates microbial growth. Water is naturally more prevalent in biodiesel fuels than in distillate fuels.

Caterpillar Biofuel Specification

Property	Test Method	Test Method	Units	Limits
	United States	International	Fuel Specific Properties	
Density @ 15°C	ASTM D1298	DIN/ISO 3675	g/cm^3	0.86-0.90
Viscosity @ 40°C	ASTM D445	DIN/ISO 3104	mm^2/s	4.0-6.0
Flash Point	ASTM D93	DIN/ISO 22719	°C	100 min
Cold Filter Plugging - Summer - Winter	ASTM D4539	DIN EN 116	°C	 0 6 below ambient
Pour Point - Summer - Winter	ASTM D97	ISO 3016	°C	 -9 max -20 max
Sulfur Content	ASTM D2622	ISO 8754	% weight	0.01 max
Distillation • 10% Evaporation - 90% Evaporation	ASTM D1160	ISO 340	°C	 To Be Determined 345
Carbon Residue, Conradson (CCR)	ASTM D189	DIN/ISO 10370	% weight	0.5 max
Cetane Number	ASTM D613	ISO 5165		45 min
Ash Content	ASTM D482	DIN 51575 ISO 6245	mg/kg	0.02 max
Water Content	ASTM D1796	DIN51777-1 ISO3733	g/m^3	500 max
Particulate Matter	DIN 51419	DIN 51419		15
Copper Corrosion	ASTM D130	DIN/ISO 2160		No.1
Oxidation Stability	ASTM D2274	IP 306 mod.	mg/100 mL	15 max
Esterification			% volume	98.0 min
Acid Value	ASTM D664	DIN 51558	mg NaOH/g	0.5 max
Methanol Content	GC Method	DIN 51608	% weight	0.2 max
Monoglycerides	GC Method	DIN 51609	% weight	0.8 max
Diglycerides	GC Method	DIN 51609	% weight	0.2 max
Triglycerides	GC Method	DIN 51609	% weight	0.2 max
Free Glycerin	GC Method	DIN 51609	% weight	0.02 max
Total Glycerin	GC Method	DIN 51609	% weight	1.2 max
Iodine Number	DIN 53241 or IP 84/81	DIN 53241 or IP 84/81	cg I_2/g	110 max
Phosphorus Content	DGF C-VI4	DIN 51440-1	mg/kg	0.2

Maintenance Products and Services Group
Product Support Division
LC2172 - 309-636-5136

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01-04-05-04
Functional Group: 0400
DTAC Solutions Legacy: KX50441; Web: 50441

JOHN DEERE

14 September 2001

John Deere Power Systems

BIODIESEL FUEL IN JOHN DEERE DIESEL ENGINES

John Deere PowerTech® and Non PowerTech® Diesel Engines

The expression "Biodiesel" describes the various fuels collectively known as Fatty Acid Methyl Ester (FAME):

- Rape Methyl Ester (RME)
- Plant Methyl Ester (PME)
- Soybean Methyl Ester (SOME)

Biodiesel fuels may be used in John Deere diesel engines only if the fuel meets the ASTM PS121 or DIN 51606 specification (Table A). Performance loss or failures related to the use of these products are not considered the responsibility of John Deere. John Deere product warranty covers defects in workmanship and material as manufactured and sold by John Deere.

NOTE: Raw pressed vegetable oils are NOT acceptable for use for fuel in any concentration. In John Deere engines, these oils do not burn completely, and will cause engine failure by leaving deposits on injectors and in the combustion chamber.

Emission certified engines are equipped with fuel injection pumps (FIP) that are compatible with Biodiesel with the exception of engines with Delphi DP200 series FIP. Refer to Table B for a parts list needed to make the Delphi DP200 compatible with Biodiesel. Consult your local ADS shop for all other FIP.

When using a blend of Biodiesel fuel in a rotary FIP, the engine oil level must be checked daily when the air temperature is -10° C (14° F) or lower. If oil becomes diluted with fuel, oil change intervals must be shortened. Correct intervals may be established by using OilScan®/OilScan Plus™ programs. Another factor due to cold temperatures is the cloud point of the fuel. When blending Biodiesel the minimum temperature at which the fuel will start to cloud is raised.

While a major environmental benefit of a Biodiesel fuel is its ability to biodegrade, users must recognize that storage and handling is of prime importance as indicated below:

- Ensure the quality of the fresh fuel, (fuel meets the specifications in Table A).
- Keep storage and vehicle tanks as full as possible to prevent moisture from collecting inside.
- Ensure all tank caps and covers are installed properly to prevent water from entering.

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- Monitor water content of the fuel regularly (Bonds with water, creating acids).
- Limit the storage tanks from extreme temperatures (i.e. Direct sun or frost).
- Problems due to aging of the fuel (Store properly, degrades quickly).
- Wash down spills with clean water immediately to prevent corrosion and damage to pain
- Fuel filter may need to be replaced more often due to premature plugging.
- Check engine oil sump level daily prior to starting, a rising level may indicate lubricating oil delution.
- Instability resulting from blending Biodiesel with mineral diesel fuel.
- Consult your fuel supplier for additives to improve storage and performance of Biodiesel fuels.

Potential problems resulting from deficiencies in the above areas when using Biodiesel fuel in concentrations above 5% may lead to the following symptoms:

- Power loss and deterioration of performance
- Fuel leakage through seals and hoses
- Corrosion of fuel injection equipment
- Coked/blocked injector nozzles, leading to poor atomization of fuel
- Filter plugging
- Lacquering/seizure of internal injection system components
- Sludge and sediments
- Reduced service life

Table A

Biodiesel Property List			
Property	**Unit**	**ASTM PS121-99**	**DIN 51606 Sept 1997**
Density at 15° C (59° F)	g/cm^3 (lb/ft^3)		0.875- - 0.900 (55- - 56)
Viscosity at 40° C (104° F)	mm^2/s (cST)	1.9 - 6.0	3.5—5.0
Cloud Point	°C (°F)	Report to Customer	
Flash Point	°C (°F)	Min. 100	Min. 110 (230)
Total Sulfur	% Mass	Max. 0.05	Max. 0.01
Cetane Number	—	*Min. 40*	*Min. 49*
Ash Content	% Mass	Max. 0.02	Max. 0.03
Water Content	% Mass	Max. 0.050	Max. 0.03
Copper Corrosion (3 hours, 50° C) (3 hours, 122° F)	Degree of Corrosion	No. 3 Max.	No. 1
Free Glycerin	% Mass	0.02Max.	Max. 0.02
Total Glycerin	% Mass	0.240 Max.	Max. 0.25
Carbon Residue 100% sample	% Mass	0.05 Max.	
Acid Number	Mg KOH/gm	0.80 Max.	
Total Contamination	% Mass		Max. 0.002
Neutralization Value	mg KOH/g		Max. 0.5
Methanol Content	% Mass		Max. 0.3
Monoglycerides	% Mass		Max. 0.8
Diglycerides	% Mass		Max. 0.4
Trigycerides	% Mass		Max. 0.4
Iodine Number	—		Max. 115
Phosphorus	% Mass		Max. 0.001
Alkali Content (Na + K)	% Mass		Max. 0.0005
(Cold Filter Plugging Point)—Summer	°C (°F)		Max. 0 (32)
(Cold Filter Plugging Point)—Winter	°C (°F)		Max. -20 (-4)

Table B

Delphi (Lucas) DP200 Fuel Injection Pump			
LSN	**Part Number**	**Qty.**	**Description**
Without Boost Control:			
106	7185-816	1	Drive Shaft Seal
With Boost Control:			
106	7185-816	1	Drive Shaft Seal
732	7185-781A	1	Boost Diaphragm Assembly
802	5855-30GG	1	O-Ring

LSN - Line Sequence Number

NOTE: Experience shows that Biodiesel is not always conforming to standards defined. In addition, the specifications listed in Table A are broadly defined which results in variation of the Biodiesel quality. The FAME fuel composition can vary in quality. This variation of quality can cause fuel injection system failures with all engines. The operator must ensure the supply of qualified Biodiesel does not harm any parts of the engines fuel system.

3

JOHN DEERE

AGRICULTURAL MARKETING CENTER

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John Deere approves eco-friendly Biodiesel fuel for its products*

Lenexa, Kansas – February 21, 2002 – John Deere has approved the use of up to 5% concentration soy-based Biodiesel fuel in its PowerTech® diesel engines. This announcement is just the latest step in John Deere's ongoing 35-year commitment to the development of bio-based alternative fuels that benefit both the environment and the agricultural community.

"We're excited to be able to support the use of Biodiesel in our products," notes Ted Breidenbach, Manager of Worldwide Engine Engineering for John Deere Power Systems. "Biodiesel is a valuable tool for helping reduce engine emissions. It also stands as one of the linchpins in the movement to develop alternative uses for commodity products that can ultimately deliver more value to our producer customers.

"The quality of Biodiesel as a fuel source has improved tremendously in recent years," Breidenbach adds. "We're confident that when it's used per factory specifications it will generate the performance producers have come to expect from their John Deere equipment."

After thorough testing and analysis John Deere engineers have developed the following guidelines to help ensure optimum use of Biodiesel:

- Customers should consult with their local fuel suppliers to be sure the Biodiesel fuel meets the ASTM PS 121-99 or DIN 51606 fuel specifications.

- Biodiesel, by definition is biodegradable, so the higher the concentration of Biodiesel in a fuel blend, the more susceptible the fuel is to degradation and water absorption. Concentrations of no more than five percent Biodiesel are approved to minimize the potential problems associated with fuel degradation. Concentrations beyond 5%, by volume, could adversely affect engine performance and fuel system durability.
- Operators should keep storage and vehicle tanks as full as possible to prevent moisture. Storage tanks should be protected from extreme temperatures and extended storage of Biodiesel fuel should be limited. Routine monitoring of the fuel's water content is also recommended.

Following these guidelines will ensure normal warranty coverage on products fueled by Biodiesel blends.**

John Deere will continue to support further development and use of Biodiesel and additional alternative uses for agricultural commodities. This commitment is evident in the company's support of renewable fuels legislation and in John Deere's ongoing exploration and use of soy-based resins to replace sheet metal on products. An example of this technology is the HarvestForm panels that will be used on John Deere Combines built in 2002. These panels are made from a special polymer derived from corn and soybeans.

"These are exciting technologies that will have long-term benefits for producers, consumers and every citizen with environmental concerns," Breidenbach says.

One of the world's oldest and most respected enterprises, John Deere (www.JohnDeereAg.com) creates smart and innovative solutions, in the form of advanced machines, services and concepts, for customers on the farmsite, worksite, and homesite worldwide.

**Editor's note: This is a revised news release, the original was distributed December 3, 2001.*

*** Users of John Deere Emission Certified Engines, are responsible for obtaining any appropriate local, state, and national exemptions required for the use of Biodiesel.*

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DETROIT DIESEL ENGINE COMPANY

Notes to Table 5–1

1. The flash point temperature is a safety-related property which must be established according to applicable local requirements.
2. The cloud point should be 10° F (6° C) below the lowest ambient temperature to prevent clogging of fuel filters by wax crystals.
3. The filter plugging point temperature should be equal to or below the lowest expected fuel temperature.
4. No free water visible.

NOTE:
When prolonged idling periods or cold weather conditions below 32 °F(0 °C) are encountered, the use of 1-D fuel is recommended. Note, however, that transit coach engines are emission certified on either No.1 or No.2 fuel. To maintain emission compliance, only the correct certified fuel should be used.

5.1.1 FUEL LUBRICITY

It is recommended that all fuels used in DDC engines meet the minimum lubricity requirements listed in Table 5-1, "Diesel Fuel Specifications." Fuels not meeting the lubricity requirements may be additized to meet them.

5.1.2 PREMIUM DIESEL FUEL

Premium diesel fuels are not covered by any existing industry specification. It is recommended that the customer obtain additional information from the fuel marketer and compare properties to those listed in Table 5-1 before using.

5.1.3 HEAVY FUELS NOT RECOMMENDED

Heavy fuels intended for use in slow speed diesel engines and as burner fuel are not recommended for use in any Detroit Diesel engine. Marine fuels specified by ASTM D2609 are examples of such fuels. These fuels are known to cause combustion deposits and will likely reduce engine durability.

5.1.4 BIODIESEL FUELS

Biodiesel fuels are alkyl esters of long chain fatty acids derived from renewable resources. Biodiesel fuels must meet ASTM Specification D 6751. Biodiesel meeting the D 6751 specifications can be blended up to 20% maximum by volume in diesel fuel. The resulting mixture must meet the fuel properties listed in Table 5-1. Failures attributed to the use of biodiesel will not be covered by Detroit Diesel product warranty.

The following quotation is extracted from *World-Wide Fuel Charter – Draft for comments – June 2002, page 46* for reference and guidance:

"Based on the technical effects of FAME [Fatty Acid Methyl Esters], it is strongly advised that FAME content be restricted to less than 5%. As a pure fuel, or at higher levels in diesel fuel, the vehicles need to be adapted to the fuel, and particular care is needed to avoid problems."

5.1.5 OTHER FUELS

Fuels listed in Table 5-2 and Table 5-3 have provided economic and availability advantages for some applications, particularly where No. 1 type fuels are required. These do not meet requirements listed in Table 5-1. Although not recommended, they have demonstrated acceptable performance in controlled applications.

Property	Jet A/A-1 D 1655	JP-5	JP-8[1]	CONUS DF-1	CONUS DF-2	OCONUS DF-2
API Gravity, @ 60° F	44.3	41.1	45.6	42.3	34.2	38.5
Flash Point, °C	38	62	45	50	74	70
Viscosity, Kin., cSt @ 40° C	—	1.5	1.2	1.6	2.8	3.0
Cloud Point °C	-40	-46	-47	-41	-12	-19
Sulfur, % mass	0.3 Max.	0.4 Max.	0.4 Max.	0.05 Max.	0.05 Max.	0.3 Max.
Cetane Number	—	42	45	44	47	49
Distillation % Vol. Rec., °C						
–IBP	—	180	157	174	190	176
–10% Typical	205	191	175	196	222	219
–50% Typical	Report	215	200	219	265	365
–90% Max.	Report	242	236	246	313	311
Final Boiling Point, Max. Temp.	300	—	—	—	—	—
Heat Content, Btu/gal., Net	123, 608	125, 270	123, 069	125, 960	131, 207	127, 820

1. JP + 100 is not recommended in equipment with water-coalescing filters.

Table 5-2 Selected Typical Fuel Properties

Type	NATO Spec.	Mil. Spec	Application
JP-4	F-40	Mil-T-5624	Jet Fuel, Contains 50% Gasoline: Not Recommended
JP-5	F-44	Mil-T-5624	Jet Fuel, Kerosene Based
JP-8	F-34	Mil-T-83133	Jet A-1 with De-Icer and Corrosion Inhibitor
Jet A	None	None	Industry Standard Jet Fuel
Jet A-1	F-35	None	Jet Fuel, ASTM D 1655
DL-1/DL-2	F-54	W-F 800 CONUS	Specified Military Use Inside Continental U.S.
DA-2	F-54	W-F 800 OCONUS	Specified Military Use Outside Continental U.S.

Table 5-3 Fuel Type Specifications and Applications

Lower density fuels, such as those listed in Table 5-2 and Table 5-3 and "winter blended" diesel fuels, have a lower volumetric heat content than the standard No. 2 fuel listed in Table 5-1, "Diesel Fuel Specifications." Operating with these fuels will result in reduced engine output and reduced fuel mileage, compared to standard No. 2 fuel. Reductions of 5% are not unusual and may be as high as 10%. A good rule of thumb is this: *The engine power is proportional to the heating value of the fuel.*

Lower density fuels also tend to have lower viscosity and poor lubrication characteristics. Fuel filtration should be changed to that recommended for "Severe Duty Service" to prevent potential injector seizure from dirt contamination of fuel.

CUMMINS ENGINE COMPANY

Field Announcement – August 30, 2001

Subject: Cummins Position on the use of Biodiesel Fuel

Background

With increased interest in emissions and reducing the use of petroleum distillate based fuels, some governments and regulating bodies are encouraging the use of bio fuels. Biodiesel fuels should be considered experimental at this time. Governmental incentives and/or environmental legislation to use bio fuels may have an impact on the sales and use of Cummins engines. This document outlines Cummins criteria and parameters when using biodiesel fuel.

SME or SOME 'Soy Methyl Ester' Diesel is the most common bio diesel in the U.S. and is derived from soybean oil. Soy Diesel is a biodiesel/petrodiesel blend based on SME. RME 'Rape Methyl Ester' Diesel is the most common biodiesel in Europe and is derived from rapeseed oil. These fuels are collectively known as Fatty Acid Methyl Esters (FAME).

Fuel Characteristics

Biodiesel fuels are methyl/ethyl ester-based oxygenates derived from a broad variety of renewable sources such as vegetable oils, animal fats, and cooking oils. Their properties are similar to diesel fuel, as opposed to gasoline or gaseous fuels, and thus are capable of being used in compression ignition engines. Biodiesel fuels have a lower energy content; about 89% of #2 diesel fuel, and is therefore a less efficient fuel. Its higher viscosity range (1.9-6.0 centistokes) vs 1.3-5.8 centistokes for diesel) helps offset the lower energy content through reduced barrel/plunger leakage resulting in slightly improved injection efficiency. Combining lower energy content and slightly improved injection efficiency, biodiesel fuel provides 5-7% less energy per gallon compared to diesel fuel. The cetane value of biodiesel fuel is 40 minimum compared to 42 minimum for Cummins diesel fuel specification. Biodiesel fuel has improved lubricity compared to standard diesel fuel.

There are provisional specifications for FAME issued in Germany under DIN V 51 606, and also recently through ASTM PS-121, however these standards are under development and are subject to change. For additional information, refer to the Cummins diesel fuel specifications listed in Table 1 and to the ASTM provisional specification PS-121 for biodiesel fuels.

Emissions

It is the responsibility of the user to obtain the proper local, regional, and/or national exemptions required for the use of biodiesel in any emissions regulated Cummins engine. From the Comprehensive Health and Environmental Effects testing, a fuel blend consisting of 20% biodiesel and 80% diesel fuel (B20) can yield percent reductions ranging from 16-

33% in particulates, 11-25% in Carbon Monoxide (CO), and 19-32% in Hydrocarbon (HC) emissions. The B20 biodiesel fuel blend will cause an increase in NOx of 2%.

Performance and Durability Results

Cummins test data on the operating effects of biodiesel fuels indicates that typically smoke, power, and fuel economy are all reduced. However, as there are no firm industry standards on the content and properties for bio fuels, consistency and predictability of biodiesel operation is not well documented.

Biodiesel provides approximately 5-7% less energy per gallon of fuel when compared to distillate fuels. To avoid engine problems when the engine is converted back to 100% distillate diesel fuel, do not change the engine rating to compensate for the power loss when operated with biodiesel fuels.

Elastomer compatibility with bio diesel is still being monitored. The condition of seals, hoses, gaskets, and wire coatings should be monitored regularly.

Cummins certifies its engines using the prescribed EPA and European Certification Fuels. Cummins does not certify engines on any other fuel. It is the user's responsibility to use the correct fuel as recommended by the manufacturer and allowed by EPA or other local regulatory agencies. In the United States, the EPA allows use of only registered fuels for on-highway applications. The EPA has additional alternative fuel information at: http://www.epa.gov/otaq/consumer/fuels/altfuels/altfuels.htm

Given the current industry understanding of bio fuels and blending with quality diesel fuel, it would be expected that blending up to a 5% volume concentration should not cause serious problems. For customers intent on blending bio fuels above a 5% volume concentration, the following concerns represent what is currently known in the industry. Concentrations beyond 5% by volume could have an adverse effect on the engine's performance and the fuel system integrity/durability. The affects are more serious with increasing concentration levels.

Areas of concern when operating with biodiesel fuels include low temperature operability (fuel gelation, filter plugging), heat content (poor fuel economy), and storage and thermal stability (filter plugging, injector deposits). The oil change interval can be affected by the use of biodiesel fuels and some applications may require shortening intervals to half of the diesel equivalent. Lube oil dilution in applications with significant part load operation will fall under this guideline.

In addition, from Cummins' fuel systems suppliers, the following issues are also noted: swelling and hardening/cracking of some elastomer seals within the fuel system/engine, corrosion of fuel system and engine hardware - especially aluminum and zinc, solid particle blockage of fuel nozzles and passages, filter plugging, injector coking, higher injection pressures due to physical flow properties - reduced fuel system life, added stress and heat to injection components - especially rotary fuel pumps - increased pump seizures and early life failures, poor fuel spray atomization - reduced fuel economy. Pure biodiesel fuel is not stable and its acid content increases over time which can damage powder metal components

Fuel System Vehicle Issues and Storage

The oil change interval can be affected by the use of biodiesel fuel. End users are advised to use oil sampling to monitor the engine oil condition and to determine the optimum oil change interval. Pure biodiesel fuel can cause a chemical reaction with lube oil resulting in oil sludging.

Elastomer compatibility with biodiesel is still being monitored. The condition of seals, hoses, gaskets, and wire coatings should be monitored regularly.

Biodiesel fuels contain residual alcohol from the esterification process, which can remove deposits from fuel tanks and lines causing filter plugging during initial testing. The fuel system should be flushed with this fuel before operation, and the fuel filters will need frequent replacement in the early stages of operation in older units.

Biodiesel fuels may pose low ambient temperature problems for both storage and operation. At low ambient temperatures, fuel may need to be stored in a heated building or a heated storage tank. The fuel system may require heated fuel lines, filters, and tanks. Filters may plug and fuel in the tank may solidify at low ambient temperatures if precautions are not taken. Consult your bio diesel supplier for assistance in the blending and attainment of the proper cloud point fuel.

Biodiesel has poor oxidation stability, which can result in long term storage problems. The poor oxidation stability qualities may accelerate fuel oxidation in the fuel system. This is especially true in engines with electronic fuel systems because they operate at higher temperatures. Consult the fuel supplier for oxidation stability additives.

Biodiesel fuel is an excellent medium for microbial growth. Microbes cause fuel system corrosion and premature filter plugging. The effectiveness of conventional anti-microbial additives, when used in biodiesel is not known. Consult your fuel and additive supplier for assistance.

Care must be taken to remove water from fuel tanks. Water accelerates microbial growth. Water is naturally more prevalent in biodiesel fuels than in distillate fuels.

Warranty and the use of Biodiesel Fuel in Cummins Engines

Cummins neither approves or disapproves of the use of biodiesel fuel. Cummins is not in a position to evaluate the many variations of biodiesel fuels or other additives, and their long-term effects on performance, durability or emissions compliance of Cummins products. The use of biodiesel fuel does not affect Cummins Material and Workmanship warranty. Failures caused by the use of biodiesel fuels or other fuel additives are **NOT** defects of workmanship and/or material as supplied by Cummins, Inc and can **NOT** be compensated under the Cummins' warranty.

Bosch states in their Diesel Fuel Quality – Common Position Paper (03/05/99) that no guarantee on FIE is given so far to any alternative fuel except for Diesel + 5% FAME. There is a major difference between operating on pure (100% concentration) biodiesel fuels and biodiesel/petro diesel fuel blends.

From the ASTM provisional specification PS-121, Base 100% biodiesel must meet the following specifications before being mixed :

ASTM PS-121 Provisional Specification for Biodiesel Fuel B100

Property	Test Method	Test Method	Units	Limits
	United States	*International*	*Fuel Specific Properties*	
Density @ 15°C	ASTM D1298	DIN/ISO 3675	g/cm^3	0.86-0.90
Viscosity @ 40°C	ASTM D445	DIN/ISO 3104	mm^2/s	4.0-6.0
Flash Point	ASTM D93	DIN/ISO 22719	°C	100 min
Cold Filter Plugging - Summer - Winter	ASTM D4539	DIN EN 116	°C	 0 6 below ambient
Pour Point - Summer - Winter	ASTM D97	ISO 3016	°C	 -9 max -20 max
Sulfur Content	ASTM D2622	ISO 8754	% weight	0.01 max
Distillation - 10% Evaporation - 90% Evaporation	ASTM D1160	ISO 340	°C	 To Be Determined 345
Carbon Residue, Conradson (CCR)	ASTM D189	DIN/ISO 10370	% weight	0.5 max
Cetane Number	ASTM D613	ISO 5165		45 min
Ash Content	ASTM D482	DIN 51575 ISO 6245	mg/kg	0.02 max
Water Content	ASTM D1796	DIN51777-1 ISO3733	g/m^3	500 max
Particulate Matter	DIN 51419	DIN 51419		15
Copper Corrosion	ASTM D130	DIN/ISO 2160		No.1
Oxidation Stability	ASTM D2274	IP 306 mod.	mg/100 mL	15 max
Esterification			% volume	98.0 min
Acid Value	ASTM D664	DIN 51558	mg NaOH/g	0.5 max
Methanol Content	*GC Method*	*DIN 51608*	*% weight*	*0.2 max*
Monoglycerides	GC Method	DIN 51609	% weight	0.8 max
Diglycerides	GC Method	DIN 51609	% weight	0.2 max
Triglycerides	GC Method	DIN 51609	% weight	0.2 max
Free Glycerine	GC Method	DIN 51609	% weight	0.02 max
Total Glycerine	GC Method	DIN 51609	% weight	1.2 max
Iodine Number	*DIN 53241 or IP 84/81*	*DIN 53241 or IP 84/81*	*cg I_2/g*	*110 max*
Phosphorus Content	DGF C-VI4	DIN 51440-1	mg/kg	0.2

Table 1: Cummins Recommended Diesel Fuel Properties

Property (Test Method)	Recommended Specifications	General Description
Viscosity (ASTM D 445, ISO 3104)	1.3 to 5.8 centistokes (1.3 to 5.8 mm per second) at 40 °C (104 °F)	Proper viscosity provides adequate pumping and lubricating characteristics to fuel system components.
Cetane Number (ASTM D 613, ISO 5165))	42 Minimum above O °C (32 °F) 45 Minimum below O°C (32 °F)	Cetane number is a measure of the starting and warm-up characteristics of a fuel. In cold weather or in service with prolonged low loads, a higher cetane number is desirable.
Sulfur Content (ASTM D2622, ISO 4260)	Not to exceed 0.5 mass percent*	Diesel fuels contain varying amounts of various sulfur compounds. Fuel sulfur contributes to acid formation and exhaust particulates. Reduced sulfur is required to meet particulate emissions and to avoid poisoning aftertreatment devices. Higher sulfur fuel also needs higher TBN lubricants to compensate for acid corrosion.
Active Sulfur (ASTM D 130, ISO 2160)	Copper Strip Corrosion not to exceed No. 2 rating after three hours at 50°C (122-F).	Some sulfur compounds in fuel are actively corrosive.
Water and Sediment (ASTM DI796)	Not to exceed 0.05 volume percent.	The amount of water and solid debris in the fuel is generally classified as water and sediment. It is good practice to filter fuel while it is being put into the fuel tank. More water vapor condenses in partially filled tanks due to tank breathing caused by temperature changes. Filter elements, fuel screens in the fuel pump and fuel inlet connections on injectors must be cleaned or replaced whenever they become dirty. These screens and filters, in performing their intended function, become clogged when using a poor or dirty fuel and will need to be changed more often.
Carbon Residue (ASTM D524, ASTM D189, ISO 10370)	Not to exceed 0.35 mass percent on 10 volume percent residuum.	The tendency of a diesel fuel to form carbon deposits in an engine can be estimated by determining the Ramsbottom or Conradson carbon residue of the fuel after 90 percent of the fuel has been evaporated.
Density (ASTM D287, D4052, ISO 3675)	0.816 to 0.876 g/cc at 15°C(60°F).	Density is an indication of the energy content of the fuel. Higher density indicates more thermal energy and better fuel economy.
Cloud Point (ASTM D97, ISO 3015)	6°C [10°F] below lowest ambient temperature at which the fuel is expected to operate.	The cloud point of the fuel is the temperature at which crystals of paraffin wax first appear. Crystals can be detected by cloudiness of the fuel. These crystals will cause filters to plug.
Ash (ASTM D482, ISO 6245)	Not to exceed 0.02 mass percent (0.05 mass percent with lubricating oil blending).	The small amount of non-combustible metallic material found in almost all petroleum products commonly is called ash.
Distillation (ASTM D86, ISO 3405)	The distillation curve must be smooth and continuous.	At least 90 percent of the fuel must evaporate at less than 360 degC [680 degF). All of the fuel must evaporate at less than 385 degC (725 degF).
Lubricity SLBOCLE (ASTM D6078), HFRR (ASTM D6079, ISO 12156)	3100 grams or greater SLBOCLE, or Wear Scar Diameter (WSD) less than 0.45 mm at 60'C HFRR.	Lubricity is the ability of a liquid to provide hydrodynamic and/or boundary lubrication to prevent wear between moving parts. Fuel with lower sulfur and/or viscosity tends to have lower lubricity.

*Regional, national, or international regulations may require a lower sulfur content than 0.5%. Consult all applicable regulations before selecting a fuel for a given engine application. Fuel with sulfur higher than 0.5% is not allowed without prior approval by Cummins. Fuel system corrosion, heightened emissions, and reduced oil drain intervals are just some of the possible adverse effects of fuels with very high sulfur.

NOTE: Special hardened parts are available for some PT and HPI fuel systems to operate on fuel with lubricity lower than required. Contact Cummins distributors for options.

INTERNATIONAL ENGINE CORPORATION

INTERNATIONAL ENGINE CORPORATION
10400 WEST NORTH AVENUE, MELROSE PARK, IL 60160

11/2/2000

To Whom It May Concern:

International Engine Corporation acknowledges that biodiesel that meets the ASTM PS 121 specification is an approved alternative fuel recognized by the U.S. Department of Energy. However, International Engine Corporation neither approves nor disapproves any product not manufactured or sold by International. The use of products such as biodiesel is at the discretion of the end-user. Any engine performance problem or failure attributed to biodiesel would not be recognized as the responsibility of International Engine Corporation.

International's engine warranty covers defects caused by material or workmanship. The International engine warranty, workmanship and material is not affected simply by the use of biodiesel regardless of the product's origin. Fuel is not warranted by International under any condition.

T.A. Biros
Chief Engineer – Engineering Customer Relations
International Engine Corp.

ENGINE MANUFACTURERS ASSOCIATION

Engine Manufacturers Association
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Suite 200
Chicago, IL 60602
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TECHNICAL STATEMENT ON THE USE OF BIODIESEL FUEL IN COMPRESSION IGNITION ENGINES

Introduction

The Engine Manufacturers Association ("EMA") is an international membership organization representing the interests of manufacturers of internal combustion engines.

In 1995, EMA published a "Statement on the Use of Biodiesel Fuels for Mobile Applications." Since that time, increased worldwide interest in reducing reliance on petroleum-based fuels and improving air quality has led many stakeholders, including engine manufacturers, to continue to investigate the use of alternative, renewable fuels, including biodiesel fuels, as a substitute for conventional diesel fuel. In addition, recent government proposals in the United States and Europe have called for incentives or mandates to increase the production and use of such renewable fuels.

This Statement, which takes into consideration additional laboratory and field research conducted since the publication of the 1995 Statement, sets forth EMA's position on the use of biodiesel fuels with current engine technologies. It should be noted, however, that only limited data is available regarding the use of biodiesel with those technologies that have been, or are about to be, introduced to meet the (US) Environmental Protection Agency's ("EPA's") 2004 heavy-duty on-highway emission standards. Moreover, because of the absence of available data, the Statement does not address the potential use of biodiesel fuels with advanced emission control technologies, including aftertreatment systems designed for future ultra-low emission engines.

Biodiesel

Biodiesel fuels are methyl or ethyl esters derived from a broad variety of renewable sources such as vegetable oil, animal fat and cooking oil. Esters are oxygenated organic compounds that can be used in compression ignition engines because some of their key properties are comparable to those of diesel fuel.

"Soy Methyl Ester" diesel ("SME" or "SOME"), derived from soybean oil, is the most common biodiesel in the United States. "Rape Methyl Ester" diesel ("RME"), derived from rapeseed oil, is the most common biodiesel fuel available in Europe. Collectively, these fuels are sometimes referred to as "Fatty Acid Methyl Esters" ("FAME").

Biodiesel fuels are produced by a process called transesterification, in which various oils (triglycerides) are converted into methyl esters through a chemical reaction with methanol in the presence of a catalyst, such as sodium or potassium hydroxide. The by-products of this chemical reaction are glycerols and water, both of which are undesirable and need to be removed from the fuel along with traces of the methanol, unreacted triglycerides and catalyst. Biodiesel fuels naturally contain oxygen, which must be stabilized to avoid storage problems. Although biodiesel feedstock does not inherently contain sulfur, sulfur may be present in biodiesel fuel because of contamination during the transesterification process and in storage.

Biodiesel Specifications

Biodiesel is produced in a pure form (100% biodiesel fuel referred to as "B100" or "neat biodiesel") and may be blended with petroleum-based diesel fuel. Such biodiesel blends are designated as BXX, where XX represents the percentage of pure biodiesel contained in the blend (e.g., "B5," "B20").

Several standard-setting organizations worldwide have recently adopted biodiesel specifications. Specifically, ASTM International recently approved a specification for biodiesel referenced as D 6751. In addition, German authorities have issued a provisional specification for FAME under DIN 51606. And, Europe's Committee for Standardization ("CEN") is in the final stages of setting a technical standard for biofuels to be referred to as EN 14214. The European specifications include more stringent limits for sulfur and water, as well as a test for oxidation stability, which is absent from the current ASTM specification.

Depending on the biomass feedstock and the process used to produce the fuel, B100 fuels should meet the requirements of either ASTM D 6751 or an approved European specification, such as DIN 51606 or EN 14214 (once adopted).

In addition, it should be noted that the National Biodiesel Board has created the National Biodiesel Accreditation Commission to develop and implement a voluntary program for the accreditation of producers and marketers of biodiesel. The Commission has developed a standard entitled, "BQ-9000, Quality Management System Requirements for the Biodiesel Industry," for use in the accreditation process.

Biodiesel Blends

Public and private bodies recently have taken positions regarding the use of biodiesel blends. For example, the (United States) Energy Policy Act of 1992 ("EPACT") was amended in 1998 to allow covered fleets to use biodiesel to fulfill up to fifty percent (50%) of their annual alternative fuel vehicle (AFV) acquisition requirements. Under EPACT's Biodiesel Fuel Use Credits provisions, covered fleets are allocated one biodiesel fuel use credit (the equivalent of a full vehicle credit) for each 450 gallons of B100 purchased and consumed. Such credits are awarded only if the blended fuel contains at least twenty percent biodiesel (B20) and is used in new or existing vehicles weighing at least 8500 pounds. No credits are awarded for biodiesel used in a vehicle already counted as an AFV.

During the same time period, however, a consortium of diesel fuel injection equipment manufacturers ("FIE Manufacturers") issued a position statement concluding that blends greater than B5 can cause reduced product service life and injection equipment failures.[1] According to the FIE Manufacturers' Position Statement, even if the B100 used in a blend meets one or more specifications, "the enhanced care and attention required to maintain the fuels in vehicle tanks may make for a high risk of noncompliance to the standard during use." As a result, the FIE Manufacturers disclaim responsibility for any failures attributable to operating their products with fuels for which the products were not designed.

Based on current understanding of biodiesel fuels and blending with petroleum-based diesel fuel, EMA members expect that blends up to a maximum of B5 should not cause engine or fuel system problems, provided the B100 used in the blend meets the requirements of ASTM D 6751, DIN 51606, or EN 14214. If blends exceeding B5 are desired, vehicle owners and operators should consult their engine manufacturer regarding the implications of using such fuel.

Engine Operation, Performance and Durability

The energy content of neat biodiesel fuel is about eleven percent (11%) lower than that of petroleum-based diesel fuel (on a per gallon basis), which results in a power loss in engine operation. The viscosity range of biodiesel fuel, however, is higher than that of petroleum-based diesel fuel (1.9 – 6.0 centistokes versus 1.3 – 5.8 centistokes), which tends to reduce barrel/plunger leakage and thereby slightly improve injector efficiency. The net effect of using B100, then, is a loss of approximately five to seven percent (5-7%) in maximum power output. The actual percentage power loss will vary depending on the percentage of biodiesel blended in the fuel. Any adjustment to the engine in service to compensate for such power loss may result in a violation of EPA's anti-tampering provisions. To avoid such illegal tampering, as well as potential engine problems that may occur if the engine is later operated with petroleum-based diesel fuel, EMA recommends that users not make such adjustments.

Neat biodiesel and higher percentage biodiesel blends can cause a variety of engine performance problems, including filter plugging, injector coking, piston ring sticking and breaking, elastomer seal swelling and hardening/cracking, and severe engine lubricant degradation. At low ambient temperatures, biodiesel is thicker than conventional diesel fuel, which would limit its use in certain geographic areas. In addition, elastomer compatibility with biodiesel remains unclear; therefore, when biodiesel fuels are used, the condition of seals, hoses, gaskets, and wire coatings should be monitored regularly.

There is limited information on the effect of neat biodiesel and biodiesel blends on engine durability during various environmental conditions. More information is needed to assess the viability of using these fuels over the mileage and operating periods typical of heavy-duty engines.

1 See, "Diesel Fuel Injection Equipment Manufacturers Common Position Statement on Fatty Acid Methyl Ester Fuels as a Replacement or Extender for Diesel Fuels" (May 1, 1998).

Emission Characteristics

In October 2002, U.S. EPA released a draft report entitled, "A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions." The draft technical report can be found on the EPA Web site at: http://www.epa.gov/otaq/models/biodsl.htm.

Use of neat biodiesel and biodiesel blends in place of petroleum-based diesel fuel may reduce visible smoke and particulate emissions, which are of special concern in older diesel engines in non-attainment areas. In addition, B100 and biodiesel blends can achieve some reduction in reactive hydrocarbons ("HC") and carbon monoxide ("CO") emissions when used in an unmodified diesel engine. Those reductions are attributed to the presence of oxygen in the fuel. Oxygen and other biodiesel characteristics, however, also increase oxides of nitrogen ("NOx") in an unmodified engine. As a result, B100 and biodiesel blends produce higher NOx emissions than petroleum-based diesel fuel. As such, EMA does not recommend the use of either B100 or biodiesel blends as a means to improve air quality in ozone non-attainment areas.

Storage and Handling

Biodiesel fuels have shown poor oxidation stability, which can result in long-term storage problems. When biodiesel fuels are used at low ambient temperatures, filters may plug, and the fuel in the tank may thicken to the point where it will not flow sufficiently for proper engine operation. Therefore, it may be prudent to store biodiesel fuel in a heated building or storage tank, as well as heat the fuel systems' fuel lines, filters, and tanks. Additives also may be needed to improve storage conditions and allow for the use of biodiesel fuel in a wider range of ambient temperatures. To demonstrate their stability under normal storage and use conditions, biodiesel fuels, tested using ASTM D 6468, should have a minimum of 80% reflectance after aging for 180 minutes at a temperature of 150°C. The test is intended to predict the resistance of fuel to degradation at normal engine operating temperatures and provide an indication of overall fuel stability.

Biodiesel fuel is an excellent medium for microbial growth. Inasmuch as water accelerates microbial growth and is naturally more prevalent in biodiesel fuels than in petroleum-based diesel fuels, care must be taken to remove water from fuel tanks. The effectiveness of using conventional anti-microbial additives in biodiesel is unknown. The presence of microbes may cause operational problems, fuel system corrosion, premature filter plugging, and sediment build-up in fuel systems.

Health & Safety

Pure biodiesel fuels have been tested and found to be nontoxic in animal studies. Emissions from engines using biodiesel fuel have undergone health effects testing in accordance with EPA Tier II requirements for fuel and fuel additive registration. Tier II test results indicate no biologically significant short term effects on the animals studied other than minor effects on lung tissue at high exposure levels. Biodiesel fuels are biodegradable, which may promote their use in applications where biodegradability is desired (e.g., marine or farm applications). Biodiesel is as safe in handling and storage as petroleum-based diesel fuel.

Warranties

Engine manufacturers are legally required to provide an emissions warranty on their products (which are certified to EPA's diesel fuel specification) and, typically, also provide commercial warranties. Individual engine manufacturers determine what implications, if any, the use of biodiesel fuel has on the manufacturers' commercial warranties. It is unclear what implications the use of biodiesel fuel has on emissions warranty, in-use liability, anti-tampering provisions, and the like. As noted above, however, more information is needed on the impacts of long-term use of biodiesel on engine operations.

Economics

The cost of biodiesel fuels varies depending on the basestock, geographic area, variability in crop production from season to season, and other factors. Although the cost may be reduced if relatively inexpensive feedstock, such as waste oils or rendered animal fat, is used instead of soybean, corn or other plant oil, the average cost of biodiesel fuel nevertheless exceeds that of petroleum-based diesel fuel.

That said, users considering conversion to an alternative fuel should recognize that the relative cost of converting an existing fleet to biodiesel blends is much lower than the cost of converting to any other alternative fuel because no major engine, vehicle, or dispensing system changes are required.

Conclusions

- Depending on the biomass feedstock and the process used to produce the fuel, B100 fuels should meet the requirements of either ASTM D 6751 or an approved European specification.
- Biodiesel blends up to a maximum of B5 should not cause engine or fuel system problems, provided the B100 used in the blend meets the requirements of ASTM D 6751, DIN 51606, or EN 14214. Engine manufacturers should be consulted if higher percentage blends are desired.
- Biodiesel blends may require additives to improve storage stability and allow use in a wide range of temperatures. In addition, the conditions of seals, hoses, gaskets, and wire coatings should be monitored regularly when biodiesel fuels are used.
- Although the actual loss will vary depending on the percentage of biodiesel blended in the fuel, the net effect of using B100 fuel is a loss of approximately 57% in maximum power output.
- Neat biodiesel and biodiesel blends reduce particulate, HC and CO emissions and increase NOx emissions compared with petroleum-based diesel fuel used in an unmodified diesel engine. Neither B100 nor biodiesel blends should be used as a means to improve air quality in ozone non-attainment areas.
- Biodiesel fuels have generally been found to be nontoxic and are biodegradable, which may promote their use in applications where biodegradability is desired.
- Individual engine manufacturers determine what implications, if any, the use of biodiesel fuel has on the manufacturers' commercial warranties.
- Although several factors affect the cost of biodiesel fuel, its average cost exceeds that of petroleum-based diesel fuel. The relative cost of converting an existing fleet to biodiesel blends, however, is much lower than the cost of converting to other alternative fuel.

DATED: February 2003

APPENDIX C: ELASTOMER COMPATIBILITY TESTING OF RENEWABLE DIESEL FUELS

SOUTHWEST RESEARCH INSTITUTE®

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ENGINE AND VEHICLE RESEARCH DIVISION
U.S. ARMY TARDEC FUELS AND LUBRICANTS RESEARCH FACILITY (SWRI)

HTTP://ENGINEANDVEHICLE.SWRI.ORG

FAX No. 210/522-3270

ISO 9001 Certified
ISO 14001 Certified

January 30, 2003

National Renewable Energy Laboratory
Attn: Robert McCormick, PhD
Center for Transportation Technologies and Systems
1617 Cole Blvd. Mailstop 1633
Golden, CO 80401

Subject: Elastomer Compatibility Testing of Renewable Diesel Fuels
Southwest Research Institute® (SwRI®) Project No. 03.40.30.04902.01.028

Dear Dr. McCormick:

The following information describes the elastomer compatibility tests performed by Southwest Research Institute for the National Renewable Energy Laboratory.

TEST DETAILS

The following fuels were included in the investigation:

1. Fuel designated CL02-576, which was EPA certification diesel fuel, 29.2%vol aromatics, 346 ppm sulfur. A certificate of analysis for this fuel is Attachment 1.

2. Fuel CL02-577 was a blend of 15%vol ethanol and 85%vol certification diesel fuel. The fuel grade ethanol was supplied by NREL.

3. Fuel CL02-578 was a blend of 20%vol soy-biodiesel and 80%vol certification diesel fuel. The B-100 used for the blend was Soy Gold (AL-25842).

4. No fuel, a set of samples were exposed to air only and served as a baseline.

The test matrix of elastomers included:

Code	Elastomer description (o-rings)
N674	General purpose Nitrile
N0497	High Aceto-Nitrile content for better fuel resistance
N1059	Peroxide cured Nitrile
V747	Flourocarbon Carbon Black filled
V884	Flourocarbon without carbon black

SAN ANTONIO, TEXAS

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All elastomer tests were performed using four (4) specimens so any outliers could be removed based on statistics or engineering judgment. The elastomers stored in fuel were exposed for 500 hours at 40°C. The baseline samples were only exposed to ambient laboratory room temperature. The following measurements were made after storage on all samples:

- O-ring thickness
- O-ring inside diameter
- Break load

Sample volume and tensile strength were calculated from the primary measurements.

RESULTS

The raw data, data with outliers removed, calculated values and plots are in the spreadsheet files in Attachment 2 (CD). No individual sample results were dropped based on statistical considerations; however, the following three tests were removed based on engineering judgment that their break loads were unusually low:

- Sample 1 of N1059 in CL02-578
- Sample 4 of V747 in CL02-577
- Sample 2 of V884 in CL02-578

Bar graphs with 95% confidence bands are presented for the following parameters in Attachment 3:

- Break load
- Break stress
- O-ring inside diameter
- O-ring thickness
- O-ring volume

SUMMARY

The following statistically significant differences were observed within each elastomer type.

N1059
The average break load and corresponding break stress was lowest when exposed to the ethanol containing fuel. Compared to the baseline, break load was reduced by 32%. The results with base fuel, biodiesel and air were the same statistically.

O-ring volume was the lowest for the samples stored in air, and the same for samples stored in the fuels. With this elastomer, each fuel type produced the same level of swell (approximately 18% compared to the baseline).

N674

The average break load and stress was the lowest for samples exposed to the ethanol-containing fuel (37% less than baseline). Similar break load and stress values were observed with the base fuel and biodiesel. Samples exposed to air had the highest break load and stress.

O-ring volume was lowest for samples exposed to air. Samples exposed to base fuel and biodiesel had the same level of increased volume (approximately 14-18%), while the samples exposed to the ethanol-containing fuel had the largest volume increased compared to the baseline (35%).

N0497

Trends similar to N674 were observed. Break load was 13% lower for ethanol-exposed samples, and volume increase was 11% compared to baseline.

V747

The average break load and stress was substantially lower for the samples exposed to ethanol (32% compared to baseline).

O-ring volume increase was highest with the ethanol-containing fuel (7%).

V884

Trends similar to V747 were observed. Compared to baseline, break load was reduced by 28%, and volume increase was 10%.

Overall, for each elastomer type, the ethanol-containing fuel had the largest impact on elastomer properties after storage.

If you have any questions regarding this data, please do not hesitate to contact me at (210) 522-2515, or by email at eframe@swri.org.

Approved

Edwin C. Owens
Director
Fuels and Lubricants Technology

Sincerely:

Edwin A. Frame
Manager
Fuels, Lubricants & Fluids Research

This report must be reproduced in full, unless SwRI approves a summary or abridgement.

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cc: SwRI: V. Parr (Contracts), B. Clark (03), L. Cura-Campos (03)

ATTACHMENT 1
Certificate of Analysis: Diesel .05 LS Cert Fuel (#2)

Chevron Phillips Chemical Company LP

Em-4712-F

DATE OF SHIPMENT
09-05-02

CUSTOMER PO NO.
282264-S

SALES ORDER NO.
5596161

TRAILER NO. 59-83007

MFG. DATE: 08-2002

CERTIFICATE OF ANALYSIS

DIESEL .05 LS CERT FUEL (# 2)
LOT 2HP05201

TESTS	RESULTS	SPECIFICATIONS	METHOD
Specific Gravity, 60/60	0.8490	0.8398 – 0.8654	ASTM D-4052
API Gravity	35.17	32 – 36	ASTM D-1298
Corrosion, 50°C, 3 hrs	1A	3 Max	ASTM D-130
Sulfur, ppm	346	300 – 500	ASTM D-2622
Flash Point, °F	164.1	130 Min	ASTM D-93
Pour Point, °F	-10	0 Max	ASTM D-97
Cloud Point, °F	+3	Report	ASTM D-2500
Viscosity, cs 40°C	2.6	2.2 – 3.2	ASTM D-445
Carbon wt%	86.84	Report	Phillips
Hydrogen wt%	13.16	Report	Phillips
Carbon Density (gm/gal)	2785	2750 – 2806	Calculated
Net Heat of Combustion BTU/LB	18440	Report	ASTM D-3338
Particulate Matter (mg/l)	5.2	15 Max	ASTM D-2276
Cetane Index	47.3	40 – 48	ASTM D-976
Cetane Number	46.03	40 – 48	ASTM D-613
DISTILLATION, °F			**ASTM D-86**
IBP	364.9	340 – 400	
5%	405.9		
10%	427.4	400 – 460	
20%	455.5		
30%	476.3		
40%	494.7		
50%	510.1	470 – 540	
60%	526.1		
70%	543.2		
80%	562.7		
90%	587.3	560 – 630	
95%	606.7		
EP	633.1	610 – 690	
Loss	0.9		
Residue	0.5		
HYDROCARBON TYPE, VOL%			**ASTM D-1319**
Aromatics	29.2	28 – 31	
Olefins	1.0	Report	
Saturates	69.8	Report	

D.G. Doerr teh

D.G. Doerr
Fuels Unit Team Leader

DGD: teh
09/05/02

ATTACHMENT 2
Raw Data, Data With Outliers Removed, Calculated Values And Plots

Elastomer	Fuel	Specimen ID	Inside Diameter *(in)*	Outside Diameter *(in)*	O-ring Diameter *(in)*	Break Load *(lbs)*	Std Dev Break Load *(lbs)*	95% CI Break Load *(lbs)*	Break Stress *(psi)*	Std Dev Break Stress *(psi)*	95% CI Break Stress *(psi)*	Average Break Stress *(psi)*	Volume *(in^3)*	Volume *(in^3)*	Volume *(in^3)*
N647	CL02-576	1	1.034	1.182	0.0743	14.08			1626			1803	0.015078	0.015169	6.65E-05
		2	1.033	1.182	0.0746	16.83			1927				0.015199		
		3	1.031	1.180	0.0745	16.58	1.26	1.24	1904	140	138		0.015135		
		4	1.036	1.185	0.0746	15.36			1756				0.015262		
	CL02-577	1	1.072	1.226	0.0774	12.55			1336			1255	0.016967	0.017373	0.00026
		2	1.075	1.231	0.0782	11.83			1231				0.017415		
		3	1.068	1.227	0.0791	13.30	1.14	1.11	1353	116	113		0.017726		
		4	1.068	1.225	0.0784	10.63			1102				0.017384		
	CL02-578	1	1.029	1.177	0.0740	15.36			1785			1811	0.014916	0.014671	0.000294
		2	1.029	1.176	0.0734	15.37			1816				0.014666		
		3	1.031	1.174	0.0722	14.66	3.07	3.01	1792	28	28		0.014175		
		4	1.029	1.177	0.0740	15.91			1848				0.014926		
N0497	CL02-576	1	1.185	1.324	0.0694	12.48			1648			1598	0.014928	0.015211	0.000159
		2	1.180	1.321	0.0705	12.26			1572				0.015328		
		3	1.182	1.323	0.0703	12.22	0.12	0.12	1575	35	34		0.015269		
		4	1.188	1.329	0.0702	12.38			1598				0.015317		
	CL02-577	1	1.225	1.372	0.0734	11.28			1335			1392	0.017248	0.016466	0.000935
		2	1.225	1.372	0.0735	11.39			1343				0.017311		
		3	1.230	1.366	0.0682	11.01	0.16	0.16	1507	436	427		0.014905		
		4	1.219	1.363	0.0718	11.19			1384				0.016403		
	CL02-578	1	1.185	1.323	0.0694	11.80			1559			1570	0.014918	0.015207	0.000226
		2	1.189	1.330	0.0708	12.00			1527				0.015558		
		3	1.173	1.314	0.0705	12.49	0.31	0.30	1601	34	33		0.015247		
		4	1.175	1.315	0.0701	12.29			1592				0.015104		
N1059	CL02-576	1	1.243	1.386	0.0713	16.59			2078			1948	0.016491	0.016964	0.000456
		2	1.238	1.383	0.0730	17.36			2074				0.017239		
		3	1.242	1.385	0.0714	17.66	2.56	2.51	2206	347	341		0.016527		
		4	1.248	1.395	0.0735	12.16			1435				0.017599		
	CL02-577	1	1.282	1.429	0.0733	9.34			1106			1421	0.017993	0.01733	0.000521
		2	1.283	1.423	0.0703	12.79			1649				0.016494		
		3	1.276	1.421	0.0726	12.10	1.52	1.49	1464	227	223		0.017509		
		4	1.275	1.419	0.0722	11.99			1465				0.017325		
	CL02-578	1	1.232	1.369	0.0688	6.97			939			1798	0.015172	0.016084	0.000575
		2	1.242	1.382	0.0702	16.84			2179				0.015934		
		3	1.241	1.384	0.0715	18.15	5.00	4.90	2260	605	593		0.016567		
		4	1.238	1.382	0.0718	14.69			1815				0.016664		
V747	CL02-576	1	0.863	1.001	0.0693	13.91			1845			1854	0.011044	0.011109	0.000441
		2	0.874	1.008	0.0669	13.73			1953				0.010397		
		3	0.868	1.008	0.0702	14.51	0.36	0.35	1877	183	179		0.011394		
		4	0.863	1.005	0.0710	13.77			1742				0.011603		
	CL02-577	1	0.898	1.041	0.0718	9.88			1222			999	0.012321	0.011957	0.000233
		2	0.893	1.033	0.0700	9.41			1223				0.011643		
		3	0.900	1.041	0.0707	9.66	3.59	3.51	1232	453	444		0.011955		
		4	0.900	1.041	0.0705	2.49			319				0.011909		
	CL02-578	1	0.861	1.007	0.0731	15.02			1789			1798	0.012324	0.01169	0.00065
		2	0.854	1.001	0.0736	14.32			1685				0.012393		
		3	0.875	1.011	0.0684	13.76	0.56	0.55	1871	83	81		0.010901		
		4	0.871	1.010	0.0693	13.93			1848				0.011141		
V884	CL02-576	1	0.986	1.124	0.0688	13.21			1778			1749	0.012319	0.012571	0.000182
		2	0.981	1.120	0.0695	13.00			1712				0.012536		
		3	0.992	1.130	0.0693	13.46	0.19	0.18	1784	37	36		0.012579		
		4	0.993	1.133	0.0700	13.25			1723				0.012850		
	CL02-577	1	1.008	1.151	0.0719	10.28			1266			1215	0.013783	0.013951	0.00052
		2	1.013	1.154	0.0709	9.93			1259				0.013433		
		3	1.015	1.164	0.0743	10.10	0.37	0.36	1164	54	53		0.014856		
		4	1.015	1.158	0.0716	9.43			1173				0.013733		
	CL02-578	1	0.991	1.125	0.0668	12.82			1833			1559	0.011634	0.012267	0.00051
		2	0.987	1.127	0.0698	6.30			823				0.012721		
		3	0.988	1.123	0.0675	13.21	3.43	3.36	1848	494	484		0.011860		
		4	0.988	1.128	0.0702	13.40			1733				0.012855		
N674	Air	1	0.990	1.132	0.0708	19.4	0.11	0.11	2463	43	42.00	2495	0.013114	0.012905	0.000151
		2	0.989	1.130	0.0704	19.2			2465				0.012950		
		3	0.991	1.130	0.0696	19.4			2555				0.012678		
		4	0.990	1.130	0.0702	19.3			2496				0.012877		
N0497	Air	1	1.174	1.313	0.0695	12.9	0.54	0.53	1705	75	73.58	1696	0.014821	0.014885	3.98E-05
		2	1.169	1.308	0.0698	12.6			1651				0.014877		
		3	1.167	1.307	0.0699	12.5			1630				0.014926		
		4	1.175	1.315	0.0697	13.7			1799				0.014916		
N1059	Air	1	1.176	1.311	0.0677	19.5	2.05	2.01	2710	374	366.57	2276	0.014062	0.014629	0.000686
		2	1.168	1.303	0.0673	17.4			2444				0.013805		
		3	1.171	1.312	0.0703	14.5			1872				0.015156		
		4	1.168	1.310	0.0712	16.5			2077				0.015492		
V747	Air	1	0.865	1.005	0.0701	15.2	0.49	0.48	1968	77	75.75	1901	0.011328	0.011242	0.000124
		2	0.866	1.004	0.0692	14.7			1953				0.011052		
		3	0.864	1.004	0.0697	14.4			1886				0.011202		
		4	0.860	1.001	0.0704	14.0			1799				0.011386		
V884	Air	1	0.988	1.126	0.0687	14.4	0.65	0.64	1943	119	116.47	1818	0.012325	0.012693	0.000238
		2	0.989	1.130	0.0704	13.0			1676				0.012944		
		3	0.985	1.124	0.0696	14.3			1884				0.012615		
		4	0.992	1.132	0.0701	13.7			1768				0.012888		

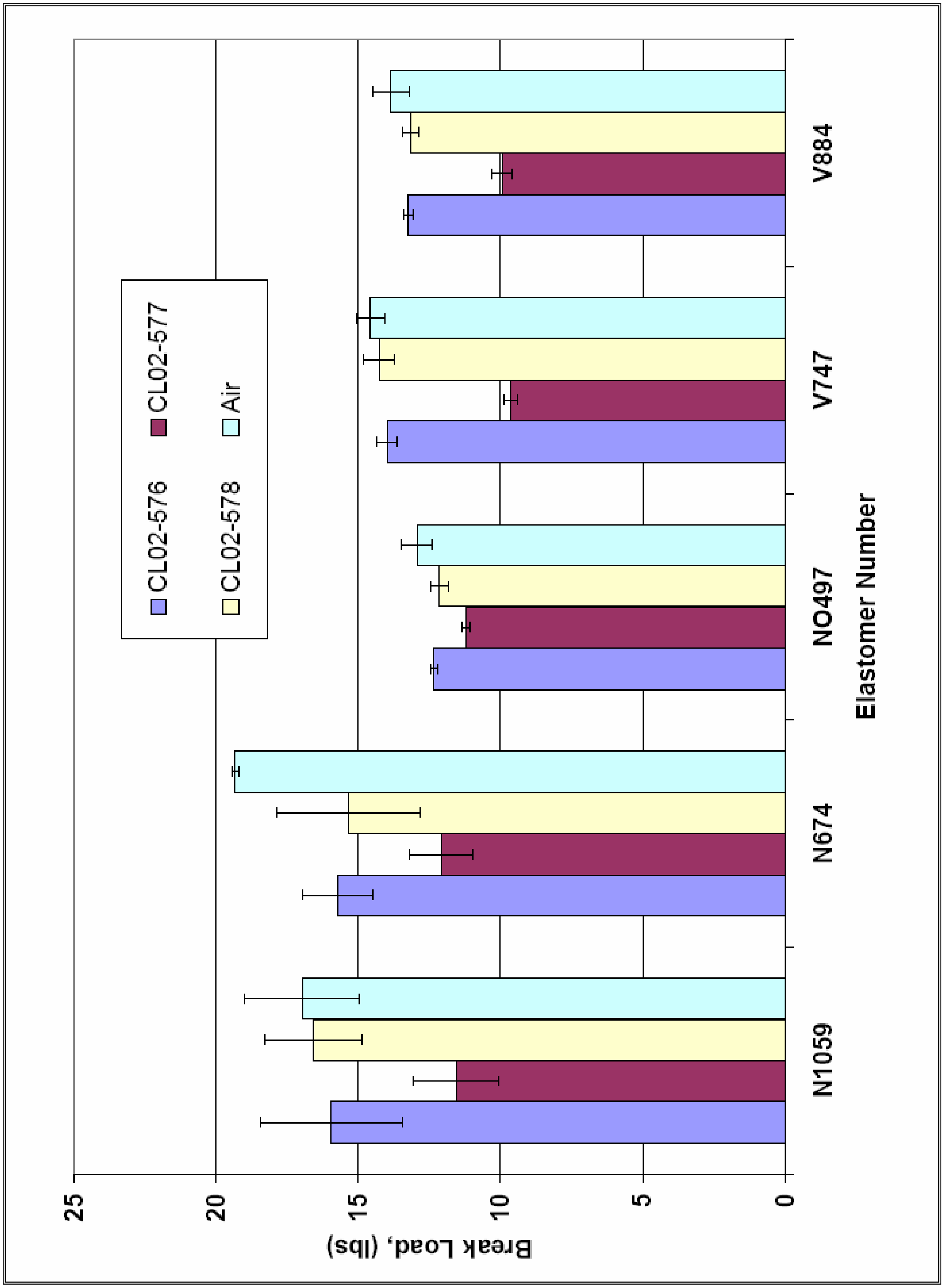
OUTLIERS

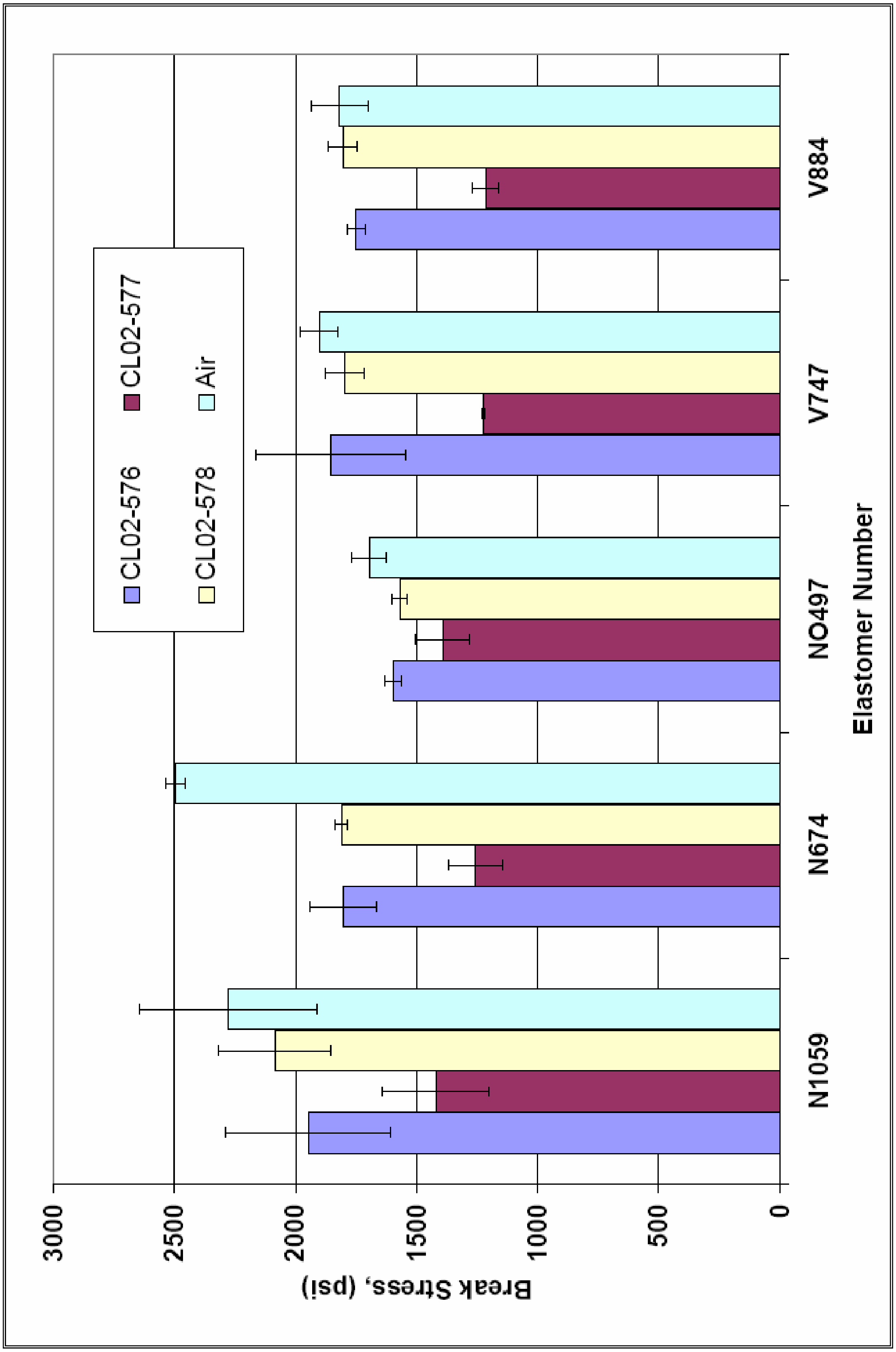
5	Fuel	Specimen ID	Inside Diameter *(in)*	Outside Diameter *(in)*	O-ring Diameter *(in)*	Break Load *(lbs)*	Std dev Break Load *(lbs)*	95% CI Break Load *(lbs)*	Break Stress *(psi)*	St dev Break Stress *(psi)*	95% CI Break Stress *(psi)*	Average Break Stress *(psi)*	Break Stress *T*	Volume *(in^3)*	Average Volume *(in^3)*	95% C.I. Volume *(in^3)*	avg Id *In*	95% CI Id *in*	avg thickness *In*	95& CI thickness *in*
N674	CL02-576	1	1.034	1.182	0.0743	14.08			1626				-1.26	0.015078						
		2	1.033	1.182	0.0746	16.83			1927				0.88	0.015199						
		3	1.031	1.180	0.0745	16.58	1.26	1.24	1904	140	138	1803	0.72	0.015135	0.015169	7.80268E-05	1.033	0.001661	0.074	0.000164
		4	1.036	1.185	0.0746	15.36			1756		138		-0.34	0.015262						
	CL02-577	1	1.072	1.226	0.0774	12.55			1336					0.016967						
		2	1.075	1.231	0.0782	11.83			1231					0.017415						
		3	1.068	1.227	0.0791	13.30	1.14	1.11	1353	116	113	1255		0.017726	0.017373	0.000305667	1.071	0.003092	0.078	0.000709
		4	1.068	1.225	0.0784	10.63			1102				-1.33	0.017384						
	CL02-578	1	1.029	1.177	0.0740	15.36			1785					0.014916						
		2	1.029	1.176	0.0734	15.37			1816					0.014666						
		3	1.031	1.174	0.0722	14.66	2.58	2.52	1792	28	28	1811		0.014175	0.014671	0.000344597	1.030	0.000702	0.073	0.00086
		4	1.029	1.177	0.0740	15.91			1848					0.014926						
	Air	1	0.990	1.132	0.0708	19.4			2463					0.013114						
		2	0.989	1.130	0.0704	19.2			2465					0.012950						
		3	0.991	1.130	0.0696	19.4	0.11	0.11	2555	43	42.00	2495		0.012678	0.012905	0.000177505	0.990	0.000775	0.070	0.000476
		4	0.990	1.130	0.0702	19.3			2496					0.012877						
N0497	CL02-576	1	1.185	1.324	0.0694	12.48			1648					0.014928						
		2	1.180	1.321	0.0705	12.26			1572					0.015328						
		3	1.182	1.323	0.0703	12.22	0.12	0.12	1575	35	34	1598		0.015269	0.015211	0.000186108	1.184	0.003321	0.070	0.000445
		4	1.188	1.329	0.0702	12.38			1598					0.015317						
	CL02-577	1	1.225	1.372	0.0734	11.28			1335					0.017248						
		2	1.225	1.372	0.0735	11.39			1343					0.017311						
		3	1.230	1.366	0.0682	11.01	0.16	0.16	1507	115	113	1392	1.00	0.014905	0.016466	0.001097997	1.225	0.004176	0.072	0.002409
		4	1.219	1.363	0.0718	11.19			1384					0.016403						
	CL02-578	1	1.185	1.323	0.0694	11.80			1559					0.014918						
		2	1.189	1.330	0.0708	12.00			1527					0.015558						
		3	1.173	1.314	0.0705	12.49	0.31	0.30	1601	34	33	1570		0.015247	0.015207	0.000264984	1.180	0.007388	0.070	0.000561
		4	1.175	1.315	0.0701	12.29			1592		28			0.015104						
	Air	1	1.174	1.313	0.0695	12.9			1705					0.014821						
		2	1.169	1.308	0.0698	12.6			1651					0.014877						
		3	1.167	1.307	0.0699	12.5	0.54	0.53	1630	75	73.58	1696		0.014926	0.014885	4.67679E-05	1.171	0.004006	0.070	0.000178
		4	1.175	1.315	0.0697	13.7			1799					0.014916						
N1059	CL02-576	1	1.243	1.386	0.0713	16.59			2078					0.016491						
		2	1.238	1.383	0.0730	17.36			2074					0.017239						
		3	1.242	1.385	0.0714	17.66	2.56	2.51	2206	347	341	1948		0.016527	0.016964	0.000534857	1.243	0.004292	0.072	0.001079
		4	1.248	1.395	0.0735	12.16			1435				-1.48	0.017599						
	CL02-577	1	1.282	1.429	0.0733	9.34			1106				-1.39	0.017993						
		2	1.283	1.423	0.0703	12.79			1649					0.016494						
		3	1.276	1.421	0.0726	12.10	1.52	1.49	1464	227	223	1421		0.017509	0.01733	0.000521499	1.279	0.004061	0.072	0.001266
		4	1.275	1.419	0.0722	11.99			1465					0.017325						
	CL02-578	1	1.232	1.369	0.0688															
		2	1.242	1.382	0.0702	16.84			2179					0.015934			1.240	0.014909	0.071	0.001239
		3	1.241	1.384	0.0715	18.15	1.75	1.71	2260	237	232	2084		0.016567	0.016388	0.000382348				
		4	1.238	1.382	0.0718	14.69			1815					0.016664						
	Air	1	1.176	1.311	0.0677	19.5			2710					0.014062						
		2	1.168	1.303	0.0673	17.4			2444					0.013805						
		3	1.171	1.312	0.0703	14.5	2.05	2.01	1872	374	366.57	2276		0.015156	0.014629	0.000804831	1.171	0.003557	0.069	0.001886
		4	1.168	1.310	0.0712	16.5			2077					0.015492						
V747	CL02-576	1	0.863	1.001	0.0693	13.91			1845					0.011044						
		2	0.874	1.008	0.0669	13.73			1953					0.010397						
		3	0.868	1.008	0.0702	14.51	0.36	0.35	1877	316	310	1854		0.011394	0.011109	0.000517376	0.867	0.005321	0.069	0.001714
		4	0.863	1.005	0.0710	13.77			1742					0.011603						
	CL02-577	1	0.898	1.041	0.0718	9.88			1222					0.012321						
		2	0.893	1.033	0.0700	9.41			1223					0.011643						
		3	0.900	1.041	0.0707	9.66	0.24	0.23	1232	6	6	1226		0.011955	0.011973	0.000384081	0.897	0.003164	0.071	0.000727
		4	0.900	1.041	0.0705															
	CL02-578	1	0.861	1.007	0.0731	15.02			1789					0.012324						
		2	0.854	1.001	0.0736	14.32			1685					0.012393						
		3	0.875	1.011	0.0684	13.76	0.56	0.55	1871	83	81	1798		0.010901	0.01169	0.00076343	0.865	0.009136	0.071	0.002566
		4	0.871	1.010	0.0693	13.93			1848					0.011141						
	Air	1	0.865	1.005	0.0701	15.2			1968					0.011328						
		2	0.866	1.004	0.0692	14.7			1953					0.011052						
		3	0.864	1.004	0.0697	14.4	0.49	0.48	1886	77	75.75	1901		0.011202	0.011242	0.000144988	0.864	0.002365	0.070	0.000497
		4	0.860	1.001	0.0704	14.0			1799					0.011386						
V884	CL02-576	1	0.986	1.124	0.0688	13.21			1778					0.012319						
		2	0.981	1.120	0.0695	13.00			1712					0.012536						
		3	0.992	1.130	0.0693	13.46	0.19	0.18	1784	37	36	1749		0.012579	0.012571	0.00021365	0.988	0.005334	0.069	0.000494
		4	0.993	1.133	0.0700	13.25			1723					0.012850						
	CL02-577	1	1.008	1.151	0.0719	10.28			1266					0.013783						
		2	1.013	1.154	0.0709	9.93			1259					0.013433						
		3	1.015	1.164	0.0743	10.10	0.37	0.36	1164	54	53	1215		0.014856	0.013951	0.000610001	1.013	0.003421	0.072	0.001471
		4	1.015	1.158	0.0716	9.43			1173					0.013733						
	CL02-578	1	0.991	1.125	0.0668	12.82			1833					0.011634						
		2	0.987	1.127	0.0698															
		3	0.988	1.123	0.0675	13.21	0.30	0.29	1848	62.59	61	1805		0.011860	0.012116	0.000734811	0.989	0.001911	0.069	0.001671
		4	0.988	1.128	0.0702	13.40			1733					0.012855						
	Air	1	0.988	1.126	0.0687	14.4			1943					0.012325						
		2	0.989	1.130	0.0704	13.0			1676					0.012944						
		3	0.985	1.124	0.0696	14.3	0.65	0.64	1884	119	116.47	1818		0.012615	0.012693	0.000279043	0.989	0.003021	0.070	0.000704
		4	0.992	1.132	0.0701	13.7			1768					0.012888						

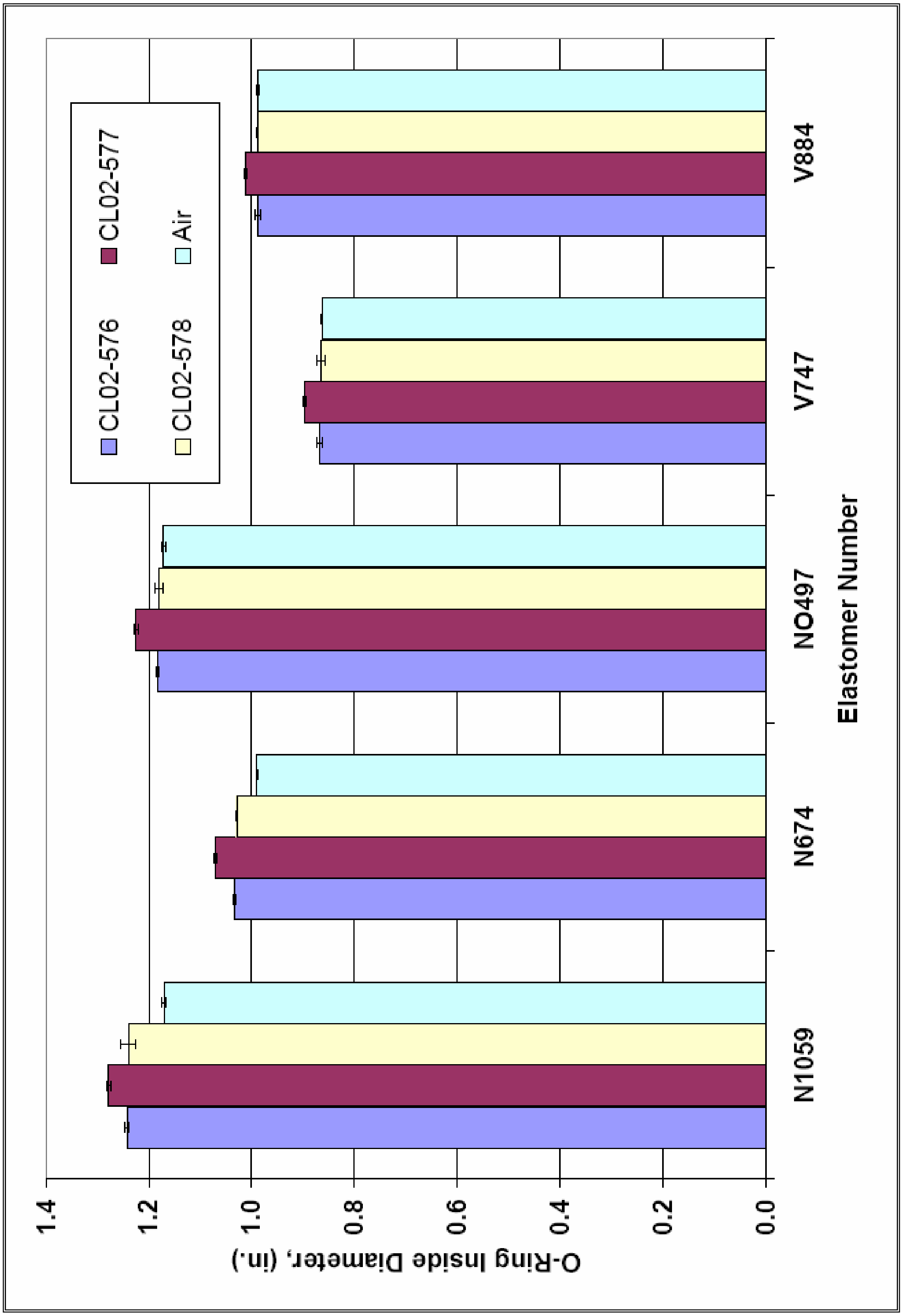
0-ring	Condition	Average Break Load (lbs)	Std. Dev. Break Load (lbs)	95% Conf. Int. Break Load (lbs)	Average Break Stress (psi)	Std. Dev. Break Stress (psi)	95% Conf. Int. Break Stress (psi)
N1059	CL02-576	15.94	2.56	2.51	1948	347	341
	CL02-577	11.56	1.52	1.49	1421	227	223
	CL02-578	16.56	1.75	1.71	2084	237	232
	Air	16.98	2.05	2.01	2276	374	367
N674	CL02-576	15.71	1.26	1.24	1803	140	138
	CL02-577	12.08	1.14	1.11	1255	116	113
	CL02-578	15.33	2.58	2.52	1811	28	28
	Air	19.32	0.11	0.11	2495	43	42
NO497	CL02-576	12.34	0.12	0.12	1598	35	34
	CL02-577	11.22	0.16	0.16	1392	115	113
	CL02-578	12.15	0.31	0.30	1570	34	33
	Air	12.95	0.54	0.53	1696	75	74
V747	CL02-576	13.98	0.36	0.35	1854	316	310
	CL02-577	9.65	0.24	0.23	1226	6	6
	CL02-578	14.26	0.56	0.55	1798	83	81
	Air	14.56	0.49	0.48	1901	77	76
V884	CL02-576	13.23	0.19	0.18	1749	37	36
	CL02-577	9.94	0.37	0.36	1215	54	53
	CL02-578	13.14	0.30	0.29	1805	63	61
	Air	13.8575	0.65	0.64	1818	119	116

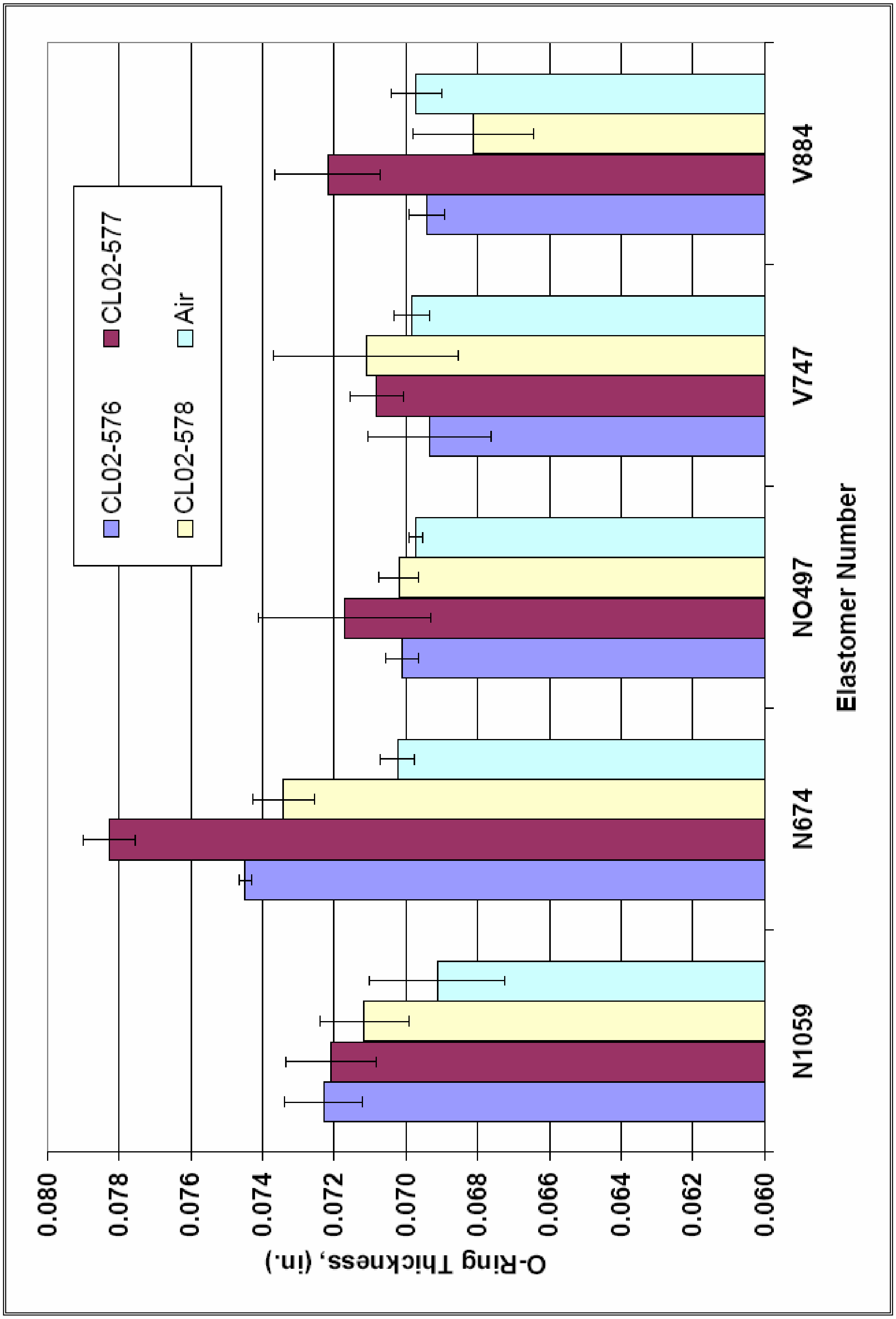
0-ring	Exposure	Average Inside Diameter *(in)*	95% Conf. Int. Inside Diameter *(in)*	Average O-ring Thickness *(in)*	95% Conf. Int. O-ring Thickness *(in)*	Average Break Load (lbs)	95% Conf. Int. Break Load (lbs)	Average Break Stress (psi)	95% Conf. Int. Break Stress (psi)	Average Volume *(in^3)*	95% C.I. Volume *(in^3)*
N1059	CL02-576	1.243	0.004292	0.072	0.001079	15.94	2.51	1948.3	340.5	0.016964	0.000535
	CL02-577	1.279	0.004061	0.072	0.001266	11.56	1.49	1421.0	222.6	0.017330	0.000521
	CL02-578	1.240	0.014909	0.071	0.001239	16.56	1.71	2084.4	232.4	0.016388	0.000382
	Air	1.171	0.003557	0.069	0.001886	16.98	2.01	2275.7	366.6	0.014629	0.000805
N674	CL02-576	1.033	0.001661	0.074	0.000164	15.71	1.24	1803.4	137.6	0.015169	0.000078
	CL02-577	1.071	0.003092	0.078	0.000709	12.08	1.11	1255.4	113.3	0.017373	0.000306
	CL02-578	1.030	0.000702	0.073	0.000860	15.33	2.52	1810.6	27.7	0.014671	0.000345
	Air	0.990	0.000775	0.070	0.000476	19.32	0.11	2494.8	42.0	0.012905	0.000178
NO497	CL02-576	1.184	0.003321	0.070	0.000445	12.34	0.12	1598.4	34.4	0.015211	0.000186
	CL02-577	1.225	0.004176	0.072	0.002409	11.22	0.16	1392.0	112.8	0.016466	0.001098
	CL02-578	1.180	0.007388	0.070	0.000561	12.15	0.30	1569.8	33.2	0.015207	0.000265
	Air	1.171	0.004006	0.070	0.000178	12.95	0.53	1696.4	73.6	0.014885	0.000047
V747	CL02-576	0.867	0.005321	0.069	0.001714	13.98	0.35	1854.4	309.6	0.011109	0.000517
	CL02-577	0.897	0.003164	0.071	0.000727	9.65	0.23	1225.5	5.6	0.011973	0.000384
	CL02-578	0.865	0.009136	0.071	0.002566	14.26	0.55	1798.3	81.3	0.011690	0.000763
	Air	0.864	0.002365	0.070	0.000497	14.56	0.48	1901.4	75.8	0.011242	0.000145
V884	CL02-576	0.988	0.005334	0.069	0.000494	13.23	0.18	1749.2	36.4	0.012571	0.000214
	CL02-577	1.013	0.003421	0.072	0.001471	9.94	0.36	1215.2	53.2	0.013951	0.000610
	CL02-578	0.989	0.001911	0.068	0.001671	13.14	0.29	1804.7	61.3	0.012116	0.000735
	Air	0.989	0.003021	0.070	0.000704	13.86	0.64	1817.7	116.5	0.012693	0.000279

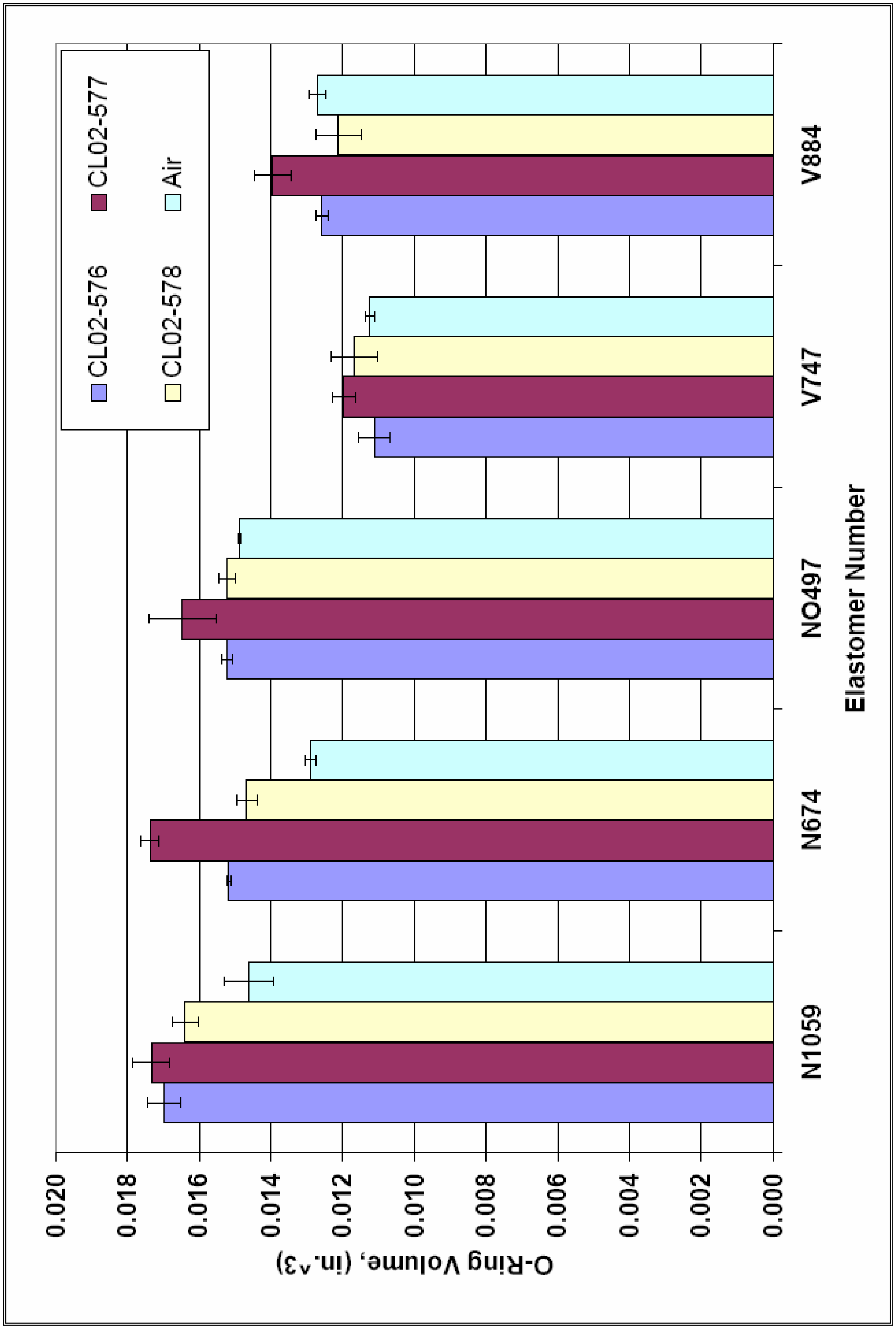
ATTACHMENT 3
Bar Graphs With 95% Confidence Bands


Break Load, (lbs)
0
5
10
15
20
25
Elastomer Number
N1059
N674
NO497
V747
V884
CL02-576
CL02-577
CL02-578
Air


Break Stress, (psi)
0
500
1000
1500
2000
2500
3000
N1059
N674
NO497
V747
V884
Elastomer Number
CL02-576
CL02-577
CL02-578
Air


CL02-576
CL02-577
CL02-578
Air
O-Ring Inside Diameter, (in.)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
N1059
N674
NO497
V747
V884
Elastomer Number


O-Ring Thickness, (in.)
0.080
0.078
0.076
0.074
0.072
0.070
0.068
0.066
0.064
0.062
0.060
CL02-576
CL02-577
CL02-578
Air
N1059
N674
NO497
V747
V884
Elastomer Number


O-Ring Volume, (in.^3)
0.020
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
CL02-576
CL02-577
CL02-578
Air
N1059
N674
NO497
V747
V884
Elastomer Number

APPENDIX D: CLOUD POINT AND COLD FILTER PLUGGING POINT DATA

ANA LABORATORIES, INC.
P.O. Box 29 Bellmawr, N.J. 08099 PHONE: (800)648-2625

LAB#	S04F20617
Cust Code:	UNIMISMO
Requi.Date:	N/A
Source:	TYPE 1
Product:	FUEL
Report Date:	07-15-04
P.O#	P.P

Attn: BRYAN ADAMS, ASST.PROF.
Dept: FOOD SCIENCE & ENGINEERING UNIT
UNIVERSITY OF MISSOURI
ADDRESS: 215 AGRICULTURAL ENGINEERING BUILDING
COLUMBIA, MO 65211

"ASTM D-975"

	ASTM	DESCRIPTION	RESULTS
1)	D-1796	SEDIMENT & WATER	NIL
2)	D-287	API GRAVITY @ 60	60
3)	D-86	DISTILLATION IBP	161 Deg.C
		" " 10%	173 Deg.C
		" " 20%	181 Deg.C
		" " 30%	188 Deg.C
		" " 40%	193 Deg.C
		" " 50%	203 Deg.C
		" " 60%	213 Deg.C
		" " 70%	225 Deg.C
		" " 80%	238 Deg.C
		" " 90%	252 Deg.C
		" " 95%	261 Deg.C
		END POINT	270 Deg.C
		TOTAL RECOVERED VOL.	99.0 %
		RESIDUE	1.0 %
4)	D-613	CETANE NUMBER	43.7
5)	D-93	FLASH POINT	51 Deg.C
6)	D-2622	SULFUR	.0003 wt. %
7)	D-130	COPPER CORROSION	1A
8)	D-482	ASH CONTENT wt.%	0.003 %
9)	D-2500	CLOUD POINT	-26 Deg.C *
10)	D-97	POUR POINT	-28 Deg.C *
11)	D-445	VISCOSITY @ 40 C	2.04 cSt
12)	D-524	CARBON RESIDUE	0.042 %
13)	D-974	ALKALI OR MINERAL ACIDS	neutral
14)	D-2274	ACCELERATED STABILITY	
		filterable insoluable	0.2000
		adherent insoluable	0.6000
		total insoluable	0.8000 mg/100ml

COMMENT: TEST DATA PER YOUR REQUEST.

Respectfully,
ANA LABORATORIES. INC

A N A L A B O R A T O R I E S, I N C.
P.O. Box 29 Bellmawr, N.J. 08099 PHONE: (800)648-2625

LAB#	S04F20619
Cust Code:	UNIMISMO
Requi.Date:	N/A
Source:	BIOSME
Product:	FUEL
Report Date:	07-15-04
P.O#	P.P

Attn: BRYAN ADAMS, ASST.PROF.
Dept: FOOD SCIENCE & ENGINEERING UNIT
UNIVERSITY OF MISSOURI
ADDRESS: 215 AGRICULTURAL ENGINEERING BUILDING
COLUMBIA, MO 65211

"ASTM D-6751"

	ASTM	DESCRIPTION	RESULTS
1)	D-2709	SEDIMENT & WATER	28 ppm
2)	D-1160	DISTILLATION AT REDUCED PRESSURE(10mm Hg)	
			10 mm Hg
		" " IBP	202 Deg.C
		" " 10%	345 Deg.C
		" " 20%	345 Deg.C
		" " 30%	346 Deg.C
		" " 40%	348 Deg.C
		" " 50%	349 Deg.C
		" " 60%	349 Deg.C
		" " 70%	350 Deg.C
		" " 80%	350 Deg.C
		" " 90%	351 Deg.C
		" " 95%	354 Deg.C
		END POINT	407 Deg.C
		TOTAL RECOVERED VOL.	99.0 %
		RESIDUE	1.0 %
3)	D-613	CETANE NUMBER	62.4
4)	D-93	FLASH POINT	135 Deg.C
5)	D-5453	SULFUR	.0052 wt. %
6)	D-130	COPPER CORROSION	1A
7)	D-874	SULFATED ASH	0.005 %
8)	D-2500	CLOUD POINT	+1 Deg.C
9)	D-445	VISCOSITY @ 40 C	3.12 cSt
0)	D-4530	CARBON RESIDUE	0.081 %
1)	D-664	ALKALI OR MINERAL ACIDS	0.02 mg/KOH/g
2)	D-6584	FREE & TOTAL GLYCERIN	
		0.002 mass%	Free Glycerin
		0.408 mass%	Monoglyceride
		0.183 mass%	Diglyceride
		0.020 mass%	Triglyceride
		0.137 mass%	Tot. Glycerin

COMMENT: TEST DATA PER YOUR REQUEST.

Respectfully,
ANA LABORATORIES. INC

A N A L A B O R A T O R I E S, I N C.
P.O. Box 29 Bellmawr, N.J. 08099 PHONE: (800)648-2625

LAB#	S04F20618
Cust Code:	UNIMISMO
Requi.Date:	N/A
Source:	TYPE 2
Product:	FUEL
Report Date:	07-15-04
P.O#	P.P

Attn: BRYAN ADAMS, ASST.PROF.
Dept: FOOD SCIENCE & ENGINEERING UNIT
UNIVERSITY OF MISSOURI
ADDRESS: 215 AGRICULTURAL ENGINEERING BUILDING
COLUMBIA, MO 65211

"ASTM D-975"

	ASTM	DESCRIPTION	RESULTS
1)	D-1796	SEDIMENT & WATER	NIL
2)	D-287	API GRAVITY @ 60	38.8
3)	D-86	DISTILLATION IBP	197 Deg.C
		" " 10%	214 Deg.C
		" " 20%	225 Deg.C
		" " 30%	232 Deg.C
		" " 40%	239 Deg.C
		" " 50%	248 Deg.C
		" " 60%	253 Deg.C
		" " 70%	259 Deg.C
		" " 80%	268 Deg.C
		" " 90%	287 Deg.C
		" " 95%	310 Deg.C
		END POINT	340 Deg.C
		TOTAL RECOVERED VOL.	99.0 %
		RESIDUE	1.0 %
4)	D-613	CETANE NUMBER	57.7
5)	D-93	FLASH POINT	53 Deg.C
6)	D-2622	SULFUR	.0018 wt. %
7)	D-130	COPPER CORROSION	1A
8)	D-482	ASH CONTENT wt.%	0.005 %
9)	D-2500	CLOUD POINT	-67 Deg.C *
.0)	D-97	POUR POINT	-70 Deg.C *
.1)	D-445	VISCOSITY @ 40 C	2.31 cSt
.2)	D-524	CARBON RESIDUE	0.063 %
.3)	D-974	ALKALI OR MINERAL ACIDS	neutral
.4)	D-2274	ACCELERATED STABILITY	
		filterable insoluable	0.2285
		adherent insoluable	0.6286
		total insoluable	0.8571 mg/100ml

COMMENT: TEST DATA PER YOUR REQUEST.

Respectfully,
ANA LABORATORIES. INC

A N A L A B O R A T O R I E S, I N C.
P.O. Box 29 Bellmawr, N.J. 08099
800-648-2625 IN NJ 856-931-0011

LABORATORY ANALYSIS REPORT

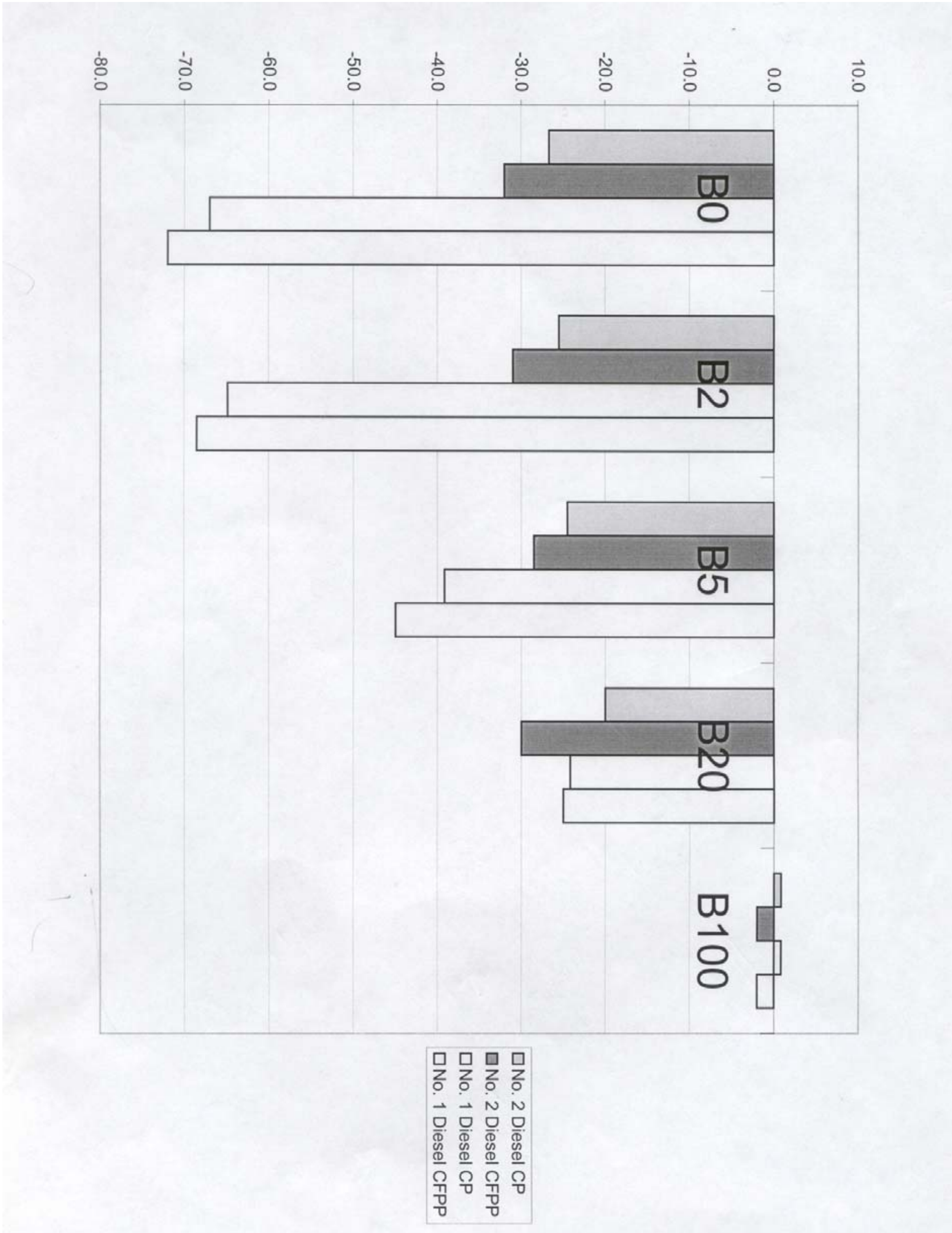
LAB#	S04F20597-F60616
Cust Code:	UNIMISMO
Requi.Date:	N/A
Source:	N/A
Product:	FUEL
Report Date:	07-13-04
P.O#	P.P

Attn: BRYAN ADAMS, ASST.PROF.
Dept: FOOD SCIENCE & ENGINEERING UNIT
UNIVERSITY OF MISSOURI
ADDRESS: 215 AGRICULTURAL ENGINEERING BUILDING
COLUMBIA, MO 65211

	DESCRIPTION				RESULTS	
	LAB#	Petroleum Diesel	Bio.	Additive	CLOUD POINT(C) (D-2500) (SUPPLIED)	CFPP(C) (D-637)
1)	F20597	100% ULSD#2	0%	0.1%	-26.67	-32.0
2)	F20598	95% ULSD#1	5%	--	-39.00	-44.0
3)	F20599	95% ULSD#1	5%	0.1%	-39.33	-46.0
4)	F20602	95% ULSD#2	5%	--	-24.33	-24.0
5)	F20603	95% ULSD#2	5%	0.1%	-24.67	-33.0
6)	F20604	0%	100%	--	1.00	-4.0
7)	F20605	100% ULSD#2	0%	--	-26.67	-32.0
8)	F20606	100% ULSD#1	0%	--	-67.00	-71.0
9)	F20607	100% ULSD#1	0%	0.1%	-67.00	<-73.0
10)	F20608	0%	100%	0.1%	0.67	0.0
11)	F20609	98% ULSD#1	2%	--	-64.33	-64.0
12)	F20610	98% ULSD#2	2%	--	-25.33	-31.0
13)	F20611	98% ULSD#2	2%	0.1%	-25.67	-31.0
14)	F20612	98% ULSD#1	2%	0.1%	-65.33	<-73.0
15)	F20613	80% ULSD#1	20%	0.1%	-24.33	-26.0
16)	F20614	80% ULSD#1	20%	--	-24.00	-24.0
17)	F20615	80% ULSD#2	20%	0.1%	-20.00	-30.0
18)	F20616	80% ULSD#2	20%	--	-20.00	-30.0

COMMENT: TEST DATA PER YOUR REQUEST.

Respectfully,
ANA LABORATORIES. INC


10.0
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
-70.0
-80.0
B0
B2
B5
B20
B100
No. 2 Diesel CP
No. 2 Diesel CFPP
No. 1 Diesel CP
No. 1 Diesel CFPP

APPENDIX E: FUEL ANALYSIS DATA FOR BIODIESEL, DIESEL, AND BIODIESEL BLENDS

A N A L A B O R A T O R I E S, I N C.
P.O. Box 29 Bellmawr, N.J. 08099
800-648-2625 IN NJ 856-931-0011

Lab #: S03B15364
Cust Code: SDTPSD
Sample Date: 01-21-03
Product Type: #1 DIESEL FUEL
Project #: 2002-12

Attn: DR. DAN HUMBERG
Dept: AG/BIO ENGINEERING
Customer: SOUTH DAKOTA STATE UNIVERSITY
AE 113, Box 2120
BROOKINGS, SD 57007

ASTM CODES	DESCRIPTION	RESULTS
1) D-86	DISTILLATION	
	INITIAL BOILING POINT	182 C
	5% Recovery	196 C
	10% Recovery	206 C
	20% Recovery	217 C
	30% Recovery	223 C
	40% Recovery	230 C
	50% Recovery	235 C
	60% Recovery	243 C
	70% Recovery	250 C
	80% Recovery	259 C
	90% Recovery	272 C
	95% Recovery	283 C
	FINAL BOILING POINT	297 C
	99.0 Vol.%	
	1.0 Vol.%	
2) D-1796	BOTTOM SEDIMENT & WATER	0.00 %
3) D-287	API GRAVITY @ 60 Deg F	39.9
4) D-613	CETANE NUMBER	46.5 min 38
5) D-93	FLASH POINT (PMCC)	49 Deg. C
6) D-5453	SULFUR	0.0214 mass %
7) D-130	COPPER CORROSION	1A
8) D-482	ASH CONTENT	0.004 %
9) D-2500	CLOUD POINT	-36 Deg. C
10) D-97	POUR POINT	-64 Deg. C
11) D-445	VISCOSITY @ 40 C	1.94 cSt
12) D-524	CARBON RESIDUE	0.039 mass %
13) D-974	ALKALI OR MINERAL ACIDS	
	BASE NUMBER, mG KOH/gm	0.018 mG KOH/gm
14) D-6078	LUBRICITY, APPLIED LOAD(SLBOCLE) (SCUFFING LOAD)	2900 grams
15) D-6079	LUBRICITY, WSD, @ 60 C (HFRR)	0.581 mm

Respectfully Submitted,

ANA LABS

ANA LABORATORIES, INC.
P.O. Box 29 Bellmawr, N.J. 08099
800-648-2625 IN NJ 856-931-0011

Lab #: S03B15365
Cust Code: SDTPSD
Sample Date: 01-21-03
Product Type: SOY Methyl ESTERS
Project #: 2002-12

Attn: DR. DAN HUMBURG
Dept: AG/BIO ENGINEERING
Customer: SOUTH DAKOTA STATE UNIVERSITY
AE 113, Box 2120
BROOKINGS, SD 57007

ASTM CODES	DESCRIPTION	RESULTS
1) D-1160	DISTILLATION AT REDUCED PRESSURE (10 mm Hg)	
	REPORTED in ATMOSPHERIC EQUIVALENT TEMPERATURES (AET)	
	INITIAL BOILING POINT	193 C AET
	5% Recovery	342 C AET
	10% Recovery	344 C AET
	20% Recovery	345 C AET
	30% Recovery	346 C AET
	40% Recovery	346 C AET
	50% Recovery	347 C AET
	60% Recovery	348 C AET
	70% Recovery	348 C AET
	80% Recovery	349 C AET
	90% Recovery	351 C AET
	95% Recovery	352 C AET
	FINAL BOILING POINT	371 C AET
	99.0 Vol.%	
	1.0 Vol.%	
2) D- 93	FLASH POINT	114 Deg. C
3) D-2709	BOTTOM SEDIMENT & WATER	0.00 mass %
4) D- 445	VISCOSITY @ 40C	4.12 cSt
5) D- 874	SULFATED ASH	0.005 mass %
6) D-5453	SULFUR	0.00077 mass %
7) D- 130	COPPER CORROSION	1A
8) D- 613	CETANE NUMBER	51.7
9) D-2500	CLOUD POINT	+02 Deg C
10) D-4530	CARBON RESIDUE	0.015 %
11) D- 664	ACID NUMBER	0.01
12) D-6584	FREE & TOTAL GLYCERIN	
	FREE GLYCERIN	0.00 mass %
	MONOGLYCERIDE	0.65 mass %
	DIGLYCERIDE	0.24 mass %
	TRIGLYCERIDE	0.01 mass %
	GLYCERIN	0.21 mass %
13) D-4951	PHOSPHOROUS	< 1 mg/Kg

Respectfully Submitted,
ANA LABS.INC.

Corrected Originals

A N A L A B O R A T O R I E S, I N C.
P.O. Box 29 Bellmawr, N.J. 08099
800-648-2625 IN NJ 856-931-0011

LAB# :	S03K3813
Cust Code:	SDSUBSD
Sample Date:	N/A
Product Type:	SAMPLE#16,17& 18
Project #:	2002-12

Attn: DR. DAN HUMBURG
Dept: AG/BIO ENGINEERING
Customer: SOUTH DAKOTA STATE UNIVERSITY
AE 113, Box 2120
BROOKINGS, SD 57007

ASTM CODES	DESCRIPTION	RESULTS
1) D-1160	DISTILLATION AT REDUCED PRESSURE (10 mm Hg)	
	REPORTED in ATMOSPHERIC EQUIVALENT TEMPERATURES (AET)	
	INITIAL BOILING POINT	218 C AET
	5% Recovery	344 C AET
	10% Recovery	346 C AET
	20% Recovery	348 C AET
	30% Recovery	348 C AET
	40% Recovery	349 C AET
	50% Recovery	349 C AET
	60% Recovery	350 C AET
	70% Recovery	351 C AET
	80% Recovery	352 C AET
	90% Recovery	354 C AET
	95% Recovery	355 C AET
	FINAL BOILING POINT	392 C AET
	99.0 Vol.%	
	1.0 Vol.%	
2) D- 93	FLASH POINT	118 Deg. C
3) D-2709	BOTTOM SEDIMENT & WATER	0.00 mass %
4) D- 445	VISCOSITY @ 40C	3.19 cSt
5) D- 874	SULFATED ASH	0.006 mass %
6) D-5453	SULFUR	0.00090 mass %
7) D- 130	COPPER CORROSION	1A
8) D- 613	CETANE NUMBER	50.8
9) D-2500	CLOUD POINT	+03 Deg C
10) D-4530	CARBON RESIDUE	0.018 %
11) D- 664	ACID NUMBER	0.01
12) D-6584	FREE & TOTAL GLYCERIN	
	FREE GLYCERIN	0.004 mass %
	MONOGLYCERIDE	0.146 mass %
	DIGLYCERIDE	0.039 mass %
	TRIGLYCERIDE	0.018 mass %
	TOTAL GLYCERIN	0.050 mass %
13) D-4951	PHOSPHOROUS	0.0042 mass %

Respectfully Submitted,
ANA LABS.INC.

A N A L A B O R A T O R I E S, I N C.
P.O. Box 29 Bellmawr, N.J. 08099
800-648-2625 IN NJ 856-931-0011

Lab #: S03K3806
Cust Code: SDSUBSD
Sample Date: 11-18-02
Product Type: DIESEL FUEL
Sample# 4
Project #: 2002-12

Attn: DR. DAN HUMBERG
Dept: AG/BIO ENGINEERING
Customer: SOUTH DAKOTA STATE UNIVERSITY
AE 113, Box 2120
BROOKINGS, SD 57007

ASTM CODES	DESCRIPTION	RESULTS
1) D-93	FLASH POINT	58 Deg. C
2) D-1796	BOTTOM SEDIMENT & WATER	0.00 %
3) D-445	VISCOSITY @40 C	2.98
4) D-130	COPPER CORROSION	1A
5) D-613	CETANE NUMBER	46.6
6) D-2500	CLOUD POINT	-22 Deg. F
7) IP 309	CFPP	-44 Deg. F
8) D-974	ALKALI OR MINERAL ACIDS	0.018 mG KOH/gm

Respectfully Submitted,

ANA LABS

ANA LABORATORIES, INC.
P.O. Box 29 Bellmawr, N.J. 08099
800-648-2625 IN NJ 856-931-0011

LABORATORY ANALYSIS REPORT

Lab #: S03K3816
Cust Code: SDSUBSD
Sample Date: 03-05-03
Product Type: DIESEL FUEL
Sample# 3
Project #: 2002-12

Attn: DR. DAN HUMBERG
Dept: AG/BIO ENGINEERING
Customer: SOUTH DAKOTA STATE UNIVERSITY
AE 113, Box 2120
BROOKINGS, SD 57007

ASTM CODES	DESCRIPTION	RESULTS
1) D-93	FLASH POINT	55 Deg. C
2) D-1796	BOTTOM SEDIMENT & WATER	0.00 %
3) D-445	VISCOSITY @40 C	2.97
4) D-130	COPPER CORROSION	1A
5) D-613	CETANE NUMBER	48.2
6) D-2500	CLOUD POINT	30 Deg. F
7) IP 309	CFPP	-46 Deg. F
8) D-974	ALKALI OR MINERAL ACIDS	0.018 mG KOH/gm

Respectfully Submitted,

ANA LABS

A N A L A B O R A T O R I E S, I N C.
P.O. Box 29 Bellmawr, N.J. 08099
800-648-2625 IN NJ 856-931-0011

Lab #: S03K3820
Cust Code: SDSUBSD
Sample Date: 12-08-02
Product Type: DIESEL FUEL
Sample# 2
Project #: 2002-12

Attn: DR. DAN HUMBERG
Dept: AG/BIO ENGINEERING
Customer: SOUTH DAKOTA STATE UNIVERSITY
AE 113, Box 2120
BROOKINGS, SD 57007

ASTM CODES	DESCRIPTION	RESULTS
1) D-93	FLASH POINT	57 Deg. C
2) D-1796	BOTTOM SEDIMENT & WATER	0.00 %
3) D-445	VISCOSITY @40 C	3.14
4) D-130	COPPER CORROSION	1A
5) D-613	CETANE NUMBER	47.1
6) D-2500	CLOUD POINT	-27 Deg. F
7) IP 309	CFPP	-47 Deg. F
8) D-974	ALKALI OR MINERAL ACIDS	0.013 mG KOH/gm

Respectfully Submitted,

ANA LABS

A N A L A B O R A T O R I E S, I N C.
P.O. Box 29 Bellmawr, N.J. 08099
800-648-2625 IN NJ 856-931-0011

Lab #: S03K3807
Cust Code: SDSUBSD
Sample Date: 11-22-02
Product Type: DIESEL FUEL
Sample# 1
Project #: 2002-12

Attn: DR. DAN HUMBERG
Dept: AG/BIO ENGINEERING
Customer: SOUTH DAKOTA STATE UNIVERSITY
AE 113, Box 2120
BROOKINGS, SD 57007

ASTM CODES	DESCRIPTION	RESULTS
1) D-93	FLASH POINT	56 Deg. C
2) D-1796	BOTTOM SEDIMENT & WATER	0.00 %
3) D-445	VISCOSITY @40 C	2.94
4) D-130	COPPER CORROSION	1A
5) D-613	CETANE NUMBER	48.7
6) D-2500	CLOUD POINT	-23 Deg. F
7) IP 309	CFPP	-43 Deg. F
8) D-974	ALKALI OR MINERAL ACIDS	0.020 mG KOH/gm

Respectfully Submitted,

ANA LABS

A N A L A B O R A T O R I E S, I N C.
P.O. Box 29 Bellmawr, N.J. 08099
800-648-2625 IN NJ 856-931-0011

Mitchell

Lab #: S03K3812
Cust Code: SDSUBSD
Sample Date: 04-16-03
Product Type: DIESEL FUEL
Sample# 15
Project #: 2002-12

Attn: DR. DAN HUMBERG
Dept: AG/BIO ENGINEERING
Customer: SOUTH DAKOTA STATE UNIVERSITY
AE 113, Box 2120
BROOKINGS, SD 57007

ASTM CODES	DESCRIPTION	RESULTS
1)	TOTAL INSOLUBLES(0.8 u Filter)	1.9846 ~~mL/100mL~~ mg/1000 mL (PPm)

Respectfully Submitted,

ANA LABS

A N A L A B O R A T O R I E S, I N C.
P.O. Box 29 Bellmawr, N.J. 08099
800-648-2625 IN NJ 856-931-0011

Lab #: S03K3811
Cust Code: SDSUBSD
Sample Date: 05-07-03
Product Type: DIESEL FUEL
Sample# 14 Aberdeen
Project #: 2002-12

Attn: DR. DAN HUMBERG
Dept: AG/BIO ENGINEERING
Customer: SOUTH DAKOTA STATE UNIVERSITY
AE 113, Box 2120
BROOKINGS, SD 57007

ASTM CODES	DESCRIPTION	RESULTS
1)	TOTAL INSOLUBLES(0.8 u Filter)	2.1482 mL/100mL

mg/1000 mL

Respectfully Submitted,

ANA LABS

A N A L A B O R A T O R I E S, I N C.
P.O. Box 29 Bellmawr, N.J. 08099
800-648-2625 IN NJ 856-931-0011

Lab #:	S03K3822
Cust Code:	SDSUBSD
Sample Date:	05-07-03
Product Type:	DIESEL FUEL
Sample#	13
Project #:	2002-12

Attn: DR. DAN HUMBERG
Dept: AG/BIO ENGINEERING
Customer: SOUTH DAKOTA STATE UNIVERSITY
AE 113, Box 2120
BROOKINGS, SD 57007

ASTM CODES	DESCRIPTION	RESULTS
1) D-93	FLASH POINT	57 Deg. C
2) D-1796	BOTTOM SEDIMENT & WATER	0.00 %
3) D-445	VISCOSITY @40 C	2.96
4) D-130	COPPER CORROSION	1A
5) D-613	CETANE NUMBER	45.8
6) D-2500	CLOUD POINT	+03 Deg. F
7) IP 309	CFPP	-01 Deg. F
8) D-974	ALKALI OR MINERAL ACIDS	0.015 mG KOH/gm

Respectfully Submitted,

ANA LABS

A N A L A B O R A T O R I E S, I N C.
P.O. Box 29 Bellmawr, N.J. 08099
800-648-2625 IN NJ 856-931-0011

Lab #: S03K3810
Cust Code: SDSUBSD
Sample Date: 03-04-03
Product Type: DIESEL FUEL
Sample# 12
Project #: 2002-12

Attn: DR. DAN HUMBERG
Dept: AG/BIO ENGINEERING
Customer: SOUTH DAKOTA STATE UNIVERSITY
AE 113, Box 2120
BROOKINGS, SD 57007

ASTM CODES	DESCRIPTION	RESULTS
1) D-93	FLASH POINT	57 Deg. C
2) D-1796	BOTTOM SEDIMENT & WATER	0.00 %
3) D-445	VISCOSITY @40 C	3.12
4) D-130	COPPER CORROSION	1A
5) D-613	CETANE NUMBER	49.1
6) D-2500	CLOUD POINT	+01 Deg. F
7) IP 309	CFPP	-46 Deg. F
8) D-974	ALKALI OR MINERAL ACIDS	0.020 mG KOH/gm

Respectfully Submitted,

ANA LABS

A N A L A B O R A T O R I E S, I N C.
P.O. Box 29 Bellmawr, N.J. 08099
800-648-2625 IN NJ 856-931-0011

Lab #: S03K3808
Cust Code: SDSUBSD
Sample Date: 01-09-02
Product Type: DIESEL FUEL
Sample# 11
Project #: 2002-12

Attn: DR. DAN HUMBERG
Dept: AG/BIO ENGINEERING
Customer: SOUTH DAKOTA STATE UNIVERSITY
AE 113, Box 2120
BROOKINGS, SD 57007

ASTM CODES	DESCRIPTION	RESULTS
1) D-93	FLASH POINT	58 Deg. C
2) D-1796	BOTTOM SEDIMENT & WATER	0.00 %
3) D-445	VISCOSITY @40 C	2.92
4) D-130	COPPER CORROSION	1A
5) D-613	CETANE NUMBER	45.3
6) D-2500	CLOUD POINT	+05 Deg. F
7) IP 309	CFPP	-03 Deg. F
8) D-974	ALKALI OR MINERAL ACIDS	0.019 mG KOH/gm

Respectfully Submitted,

ANA LABS

A N A L A B O R A T O R I E S, I N C.
P.O. Box 29 Bellmawr, N.J. 08099
800-648-2625 IN NJ 856-931-0011

Lab #: S03K3809
Cust Code: SDSUBSD
Sample Date: 04-16-03
Product Type: DIESEL FUEL
Sample# 10
Project #: 2002-12

Attn: DR. DAN HUMBERG
Dept: AG/BIO ENGINEERING
Customer: SOUTH DAKOTA STATE UNIVERSITY
AE 113, Box 2120
BROOKINGS, SD 57007

ASTM CODES	DESCRIPTION	RESULTS
1) D-93	FLASH POINT	57 Deg. C
2) D-1796	BOTTOM SEDIMENT & WATER	0.00 %
3) D-445	VISCOSITY @40 C	2.96
4) D-130	COPPER CORROSION	1A
5) D-613	CETANE NUMBER	46.0
6) D-2500	CLOUD POINT	+04 Deg. F
7) IP 309	CFPP	-04 Deg. F
8) D-974	ALKALI OR MINERAL ACIDS	0.022 mG KOH/gm

Respectfully Submitted,

ANA LABS

ANA LABORATORIES, INC.
P.O. Box 29 Bellmawr, N.J. 08099
800-648-2625 IN NJ 856-931-0011

LABORATORY ANALYSIS REPORT

Lab #:	S03K3817
Cust Code:	SDSUBSD
Sample Date:	11-19-03
Product Type:	DIESEL FUEL
Sample#	9
Project #:	2002-12

Attn: DR. DAN HUMBERG
Dept: AG/BIO ENGINEERING
Customer: SOUTH DAKOTA STATE UNIVERSITY
AE 113, Box 2120
BROOKINGS, SD 57007

ASTM CODES	DESCRIPTION	RESULTS
1) D-93	FLASH POINT	60 Deg. C
2) D-1796	BOTTOM SEDIMENT & WATER	0.00 %
3) D 445	VISCOSITY @40 C	2.98
4) D-130	COPPER CORROSION	1A
5) D-613	CETANE NUMBER	47.5
6) D-2500	CLOUD POINT	-31 Deg. F
7) IP 309	CFPP	-49 Deg. F
8) D-974	ALKALI OR MINERAL ACIDS	0.016 mG KOH/gm

Respectfully Submitted,

ANA LABS

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P.O. Box 29 Bellmawr, N.J. 08099
800-648-2625 IN NJ 856-931-0011

Lab #: S03K3823
Cust Code: SDSUBSD
Sample Date: 05-07-03
Product Type: DIESEL FUEL
Sample# 8
Project #: 2002-12

Attn: DR. DAN HUMBERG
Dept: AG/BIO ENGINEERING
Customer: SOUTH DAKOTA STATE UNIVERSITY
AE 113, Box 2120
BROOKINGS, SD 57007

ASTM CODES	DESCRIPTION	RESULTS
1) D-93	FLASH POINT	58 Deg. C
2) D-1796	BOTTOM SEDIMENT & WATER	0.00 %
3) D 445	VISCOSITY @40 C	2.86
4) D-130	COPPER CORROSION	1A
5) D-613	CETANE NUMBER	47.3
6) D-2500	CLOUD POINT	-26 Deg. F
7) IP 309	CFPP	-46 Deg. F
8) D-974	ALKALI OR MINERAL ACIDS	0.017 mG KOH/gm

Respectfully Submitted,

ANA LABS

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P.O. Box 29 Bellmawr, N.J. 08099
800-648-2625 IN NJ 856-931-0011

Lab #: S03K3805
Cust Code: SDSUBSD
Sample Date: 03-04-03
Product Type: DIESEL FUEL
Sample# 7
Project #: 2002-12

Attn: DR. DAN HUMBERG
Dept: AG/BIO ENGINEERING
Customer: SOUTH DAKOTA STATE UNIVERSITY
AE 113, Box 2120
BROOKINGS, SD 57007

ASTM CODES	DESCRIPTION	RESULTS
1) D-93	FLASH POINT	57 Deg. C
2) D-1796	BOTTOM SEDIMENT & WATER	0.00 %
3) D-445	VISCOSITY @40 C	2.98
4) D-130	COPPER CORROSION	1A
5) D-613	CETANE NUMBER	49.6
6) D-2500	CLOUD POINT	-15 Deg. F
7) IP 309	CFPP	-27 Deg. F
8) D-974	ALKALI OR MINERAL ACIDS	0.017 mG KOH/gm

Respectfully Submitted,

ANA LABS

ANA LABORATORIES, INC.
P.O. Box 29 Bellmawr, N.J. 08099
800-648-2625 IN NJ 856-931-0011

LABORATORY ANALYSIS REPORT

Lab #: S03K3818
Cust Code: SDSUBSD
Sample Date: 01-19-03
Product Type: DIESEL FUEL
Sample# 6
Project #: 2002-12

Attn: DR. DAN HUMBERG
Dept: AG/BIO ENGINEERING
Customer: SOUTH DAKOTA STATE UNIVERSITY
AE 113, Box 2120
BROOKINGS, SD 57007

ASTM CODES	DESCRIPTION	RESULTS
1) D-93	FLASH POINT	58 Deg. C
2) D-1796	BOTTOM SEDIMENT & WATER	0.00 %
3) D-445	VISCOSITY @40 C	3.01
4) D-130	COPPER CORROSION	1A
5) D-613	CETANE NUMBER	47.8
6) D-2500	CLOUD POINT	-31 Deg. F
7) IP 309	CFPP	-47 Deg. F
8) D-974	ALKALI OR MINERAL ACIDS	0.018 mG KOH/gm
9) D-2274	ACCELERATED STABILITY	
	Filterable Insolubles	2.1216
	Adherent Insolubles	1.1018 mg/1000 mL
	Total	3.2234 ~~mg/100mL~~

Respectfully Submitted,

ANA LABS

A N A L A B O R A T O R I E S, I N C.
P.O. Box 29 Bellmawr, N.J. 08099
800-648-2625 IN NJ 856-931-0011

Lab #: S03K3821
Cust Code: SDSUBSD
Sample Date: 03-03-03
Product Type: DIESEL FUEL
Sample# 5
Project #: 2002-12

Attn: DR. DAN HUMBERG
Dept: AC/BIO ENGINEERING
Customer: SOUTH DAKOTA STATE UNIVERSITY
AE 113, Box 2120
BROOKINGS, SD 57007

ASTM CODES	DESCRIPTION	RESULTS
1) D-93	FLASH POINT	58 Deg. C
2) D-1796	BOTTOM SEDIMENT & WATER	0.00 %
3) D-445	VISCOSITY @40 C	3.08
4) D-130	COPPER CORROSION	1A
5) D-613	CETANE NUMBER	46.7
6) D-2500	CLOUD POINT	-18 Deg. F
7) IP 309	CFPP	-30 Deg. F
8) D-974	ALKALI OR MINERAL ACIDS	0.011 mG KOH/gm

Respectfully Submitted,

ANA LABS

APPENDIX F: SURVEY OF FUEL STORAGE TANKS AT ALL SDDOT FACILITIES

Survey of Fuel Storage Tanks
at all SDDOT Facilities

As a part of research project "SD2002-12 Potential Impact of Biodiesel on SDDOT" the researcher is to access the cost of SDDOT using biodiesel blends in 2%, 5%, and 20% concentrations. In order to make a valid assessment it is necessary for SDDOT to furnish the size and number of fuel storage tanks currently in use at each facility as well as other available storage tanks at each shop, area, and region. **The survey may be saved and forwarded as necessary to the appropriate individuals via E-Mail.** Once completed the survey can be forwarded or E-mailed to paul.oien@state.sd.us

Thank you very much for your time.

Paul Oien
SDDOT
Office of Research
700 East Broadway Avenue
Pierre, SD 57501

Please answer by marking the appropriate box preceding the appropriate response. In questions requesting additional input you may type in the underline area as necessary. Don't worry about formatting your response.

Which SDDOT AREA is this shop located in?

1) Mark the appropriate box

Rapid City Region	Pierre Region	Aberdeen Region	Mitchell Region
☐ Rapid City	☐ Pierre	☐ Aberdeen	☐ Mitchell
☐ Custer	☐ Winner	☐ Huron	☐ Sioux Falls
☐ Belle Fourche	☐ Mobridge	☐ Watertown	☐ Yankton

2) In the Blank Below print the name of the town this facility is located in.

____

3) Indicate type and size of storage tank used for **DIESEL FUEL**. If size is not listed select other and indicate size.

TYPE

☐ Above ground ☐ Underground

SIZE

☐ 1000 gallon ☐ 2000 gallon ☐ 10,000 gallon

☐ 1500 gallon ☐ 5000 gallon ☐ 15,000 gallon ☐ Other __________

4) Is there another fuel tank available for **DIESEL FUEL** storage? Do not include fuel tanks that are used for gasoline storage. ☐ No proceed to question 6

☐ Yes proceed to question 5

5) Indicate type and size of second storage tank that can be used for **DIESEL FUEL**. If size is not listed select other and indicate size.

TYPE

☐ Above ground ☐ Underground

SIZE

☐ 1000 gallon ☐ 2000 gallon ☐ 10,000 gallon

☐ 1500 gallon ☐ 5000 gallon ☐ 15,000 gallon ☐ Other __________

6) Indicate type and size of storage tank used for **GASOLINE**. If size is not listed select other and indicate size.

TYPE

☐ Above ground ☐ Underground

SIZE

☐ 1000 gallon ☐ 2000 gallon ☐ 10,000 gallon

☐ 1500 gallon ☐ 5000 gallon ☐ 15,000 gallon ☐ Other __________

7) Do other storage tanks exist at this facility that can be used for fuel storage that are not described in items 3, 5, and 6 above. (Do not include temporary above ground storage tanks that are currently used with biodiesel project)

☐ Yes, proceed to question 8 ☐ No, proceed to question 9

8) Indicate type and size of other storage tanks that can be used for fuel storage. If size is not listed select other and indicate size.

TYPE

☐ Above ground ☐ Underground

SIZE

☐ 1000 gallon ☐ 2000 gallon ☐ 10,000 gallon

☐ 1500 gallon ☐ 5000 gallon ☐ 15,000 gallon ☐ Other __________

9) How many fuel transfer tanks for use with pickups are available at this site?

Please indicate number: _____

10) What is the fuel capacity of each of the tanks identified in item 9?

Transfer tank one: _____

Transfer tank two: _____

Transfer tank three: _____

11) Please indicate the date of the last fuel tank cleaning. This would involve emptying fuel from the tank and have any remaining fuel, water, and residue pumped from the tank. **Tank** **Cleaning date**

Tank in item 3. ______________

Tank in item 5. ______________

Tank in item 6. ______________

Tank in item 7. ______________

12) Please indicate if the fuel in any of these tanks is treated with an additive (cetane improver, biocide, cloud point depressant, etc.) and the date when additive was last added.

Tank **Treatment/Date** **Treatment Brand Name**

(example: biocide 10/01/2003) (example: Total Treat)

Tank in item 3. ______________________ _____________________________

Tank in item 5. ______________________ _____________________________

Tank in item 6. ______________________ _____________________________

Tank in item 7. ______________________ _____________________________

THANK YOU for taking the time to answer these questions. Please forward this marked survey as an attachment to paul.oien@state.sd.us

APPENDIX G: ENGINE OIL ANALYSIS FOR SDDOT TRUCKS

ANA LABORATORIES, INC.

641 Creek Road Bellmawr, New Jersey 08031-2409 (800) 648-2625 (856) 931-0011

SAMPLE SEVERITY **N**

UNIT/BUS # DL062 SYSTEM ENG

SAMPLE DATA / ELEMENTAL ANALYSIS (VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT)

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
R02A004494	12/12/200 1/10/2002	3661 M 58936 M	32	3	12	8	5	5	0	0	4	178	60	789	669	0	883	962	0	0	1

OIL QUALITY

LAB #	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R02A004494	0		13.02	0	0.40	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02A004494	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02A004494	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

LAB #	ANALYSIS RECOMMENDATIONS

ANA LABORATORIES, INC.

641 Creek Road Bellmawr, New Jersey 08031-2409 (800) 648-2625 (856) 931-0011

SAMPLE SEVERITY **N**

UNIT/BUS # DL075 SYSTEM ENG

SAMPLE DATA / ELEMENTAL ANALYSIS (VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT)

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
R02A004496	12/12/200 1/10/2002	820 M 48050 M	11	0	14	9	5	0	0	0	3	199	18	708	640	0	872	950	0	0	1

OIL QUALITY

LAB #	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R02A004496	0		12.61	0	0.10	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02A004496	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02A004496	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

LAB #	ANALYSIS RECOMMENDATIONS

ANA LABORATORIES, INC.

641 Creek Road Bellmawr, New Jersey 08031-2409 (800) 648-2625 (856) 931-0011

SAMPLE SEVERITY **N**

UNIT/BUS # DL040 SYSTEM ENG

SAMPLE DATA

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT
R02A004497	12/27/200	1840 M
	1/10/2002	65890 M

ELEMENTAL ANALYSIS — VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT

Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
9	0	13	3	6	0	0	0	3	218	18	852	672	0	920	1003	0	0	1

OIL QUALITY

FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
0		11.52	0	0.10	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02A004497	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02A004497	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

LAB #	ANALYSIS RECOMMENDATIONS

ANA LABORATORIES, INC.

641 Creek Road Bellmawr, New Jersey 08031-2409 (800) 648-2625 (856) 931-0011

SAMPLE SEVERITY **A**

UNIT/BUS # DL426 SYSTEM ENG

SAMPLE DATA

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT
R02A004499	12/26/200	1040 M
	1/10/2002	1040 M

ELEMENTAL ANALYSIS — VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT

Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
24	0	7	34	11	1	0	0	32	175	0	304	1767	0	913	995	0	0	1

OIL QUALITY

FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
0		13.43	0	0.00	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02A004499	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02A004499	WEAR METALS -NORMAL. LUBE CONTAMINANTS SILICON -MILDLY ABOVE NORMAL. FOLLOW ESTABLSIHED MAINTENANCE PROCEDURES.

LAB #	ANALYSIS RECOMMENDATIONS

ANA LABORATORIES, INC.

641 Creek Road Bellmawr, New Jersey 08031-2409 (800) 648-2625 (856) 931-0011

SAMPLE SEVERITY **N**

UNIT/BUS # DL006 SYSTEM ENG

SAMPLE DATA

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT
R02A004504	12/20/200 1/10/2002	5485 M 93660 M

ELEMENTAL ANALYSIS — VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT

Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
29	0	7	2	5	0	0	0	2	162	17	777	734	0	898	979	0	0	1

OIL QUALITY

FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
0		11.99	0	0.20	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02A004504	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02A004504	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

LAB #	ANALYSIS RECOMMENDATIONS

ANA LABORATORIES, INC.

641 Creek Road Bellmawr, New Jersey 08031-2409 (800) 648-2625 (856) 931-0011

SAMPLE SEVERITY **A**

UNIT/BUS # DL230 SYSTEM ENG

SAMPLE DATA

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT
R02A008113	12/10/200 1/17/2002	92 H 92 H

ELEMENTAL ANALYSIS — VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT

Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
48	0	12	12	14	5	0	0	27	8	3	31	3079	0	935	1019	0	0	0

OIL QUALITY

FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
0		12.48	0	0.30	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02A008113	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02A008113	WEAR METALS -NORMAL. LUBE CONTAMINANTS SILICON -MILDLY ABOVE NORMAL. FOLLOW ESTABLSIHED MAINTENANCE PROCEDURES.

LAB #	ANALYSIS RECOMMENDATIONS

ANA LABORATORIES, INC.

641 Creek Road Bellmawr, New Jersey 08031-2409 (800) 648-2625 (856) 931-0011

SAMPLE SEVERITY: **N**

UNIT/BUS # DL096 SYSTEM ENG

SAMPLE DATA			ELEMENTAL ANALYSIS VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT																			OIL QUALITY					
LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R02A014455	1/17/2002 1/30/2002	4000 M 106500 M	36	4	8	10	3	7	0	0	11	145	27	1058	507	0	970	1086	0	0	0	0		15.15	0	0.30	N

ADDITIONAL TESTS															
LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX								
R02A014455	0.00	0.00													

LAB #	ANALYSIS RECOMMENDATIONS
R02A014455	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

LAB #	ANALYSIS RECOMMENDATIONS

ANA LABORATORIES, INC.

641 Creek Road Bellmawr, New Jersey 08031-2409 (800) 648-2625 (856) 931-0011

SAMPLE SEVERITY: **A**

UNIT/BUS # DL427 SYSTEM ENG

SAMPLE DATA			ELEMENTAL ANALYSIS VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT																			OIL QUALITY					
LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R02B003535	1/30/2002 2/8/2002	3459 M 3459 M	23	0	5	36	7	0	0	0	67	179	3	287	2036	0	885	956	0	0	0	0		12.42	0	0.10	N

ADDITIONAL TESTS															
LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX								
R02B003535	0.00	0.00													

LAB #	ANALYSIS RECOMMENDATIONS
R02B003535	WEAR METALS -NORMAL. LUBE CONTAMINANTS SILICON -MODERATELY HIGH. FOLLOW ESTABLSIHED MAINTENANCE PROCEDURES.

LAB #	ANALYSIS RECOMMENDATIONS

ANA LABORATORIES, INC.

641 Creek Road Bellmawr, New Jersey 08031-2409 (800) 648-2625 (856) 931-0011

SAMPLE SEVERITY: **N**

UNIT/BUS # DL126 SYSTEM ENG

SAMPLE DATA			ELEMENTAL ANALYSIS — VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT																			OIL QUALITY					
LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R02B007172	2/11/2002 2/17/2002	4000 M 40100 M	23	0	4	1	0	0	0	0	3	224	0	619	383	0	760	828	0	0	0	0		11.06	0	0.20	N

LAB #	ADDITIONAL TESTS: TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02B007172	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02B007172	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

ANA LABORATORIES, INC.

641 Creek Road Bellmawr, New Jersey 08031-2409 (800) 648-2625 (856) 931-0011

SAMPLE SEVERITY: **N**

UNIT/BUS # DL121 SYSTEM ENG

SAMPLE DATA			ELEMENTAL ANALYSIS — VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT																			OIL QUALITY					
LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R02B010911	2/8/2002 2/25/2002	3800 M 95985 M	15	0	4	7	0	2	0	0	5	185	0	679	395	0	812	885	0	0	0	0		12.67	0	0.20	N

LAB #	ADDITIONAL TESTS: TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02B010911	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02B010911	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

ANA LABORATORIES, INC.

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SAMPLE SEVERITY: **C**

UNIT/BUS # DL059 SYSTEM ENG

SAMPLE DATA

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT
R02C005872	2/14/2002 3/13/2002	2264 81365

ELEMENTAL ANALYSIS — VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT

Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
392	1	12	15	2	2	0	0	11	158	19	988	551	0	1165	1293	0	0	0

OIL QUALITY

FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
0		11.92	0	0.00	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02C005872	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02C005872	WEAR METALS (IRON) -EXCESSIVE(CRITICAL). LUBE CONTAMINANTS -NORMAL. TAKE CORRECTIVE ACTION. DRAIN OIL IF NOT DRAINED. CHANGE FILTER IF NOT CHANGED.

LAB #	ANALYSIS RECOMMENDATIONS

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SAMPLE SEVERITY: **N**

UNIT/BUS # DL130 SYSTEM ENG

SAMPLE DATA

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT
R02C014431	3/22/2002 3/29/2002	3282 M 52880 M

ELEMENTAL ANALYSIS — VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT

Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
13	0	1	2	0	0	0	0	2	186	0	695	388	0	935	1019	0	0	0

OIL QUALITY

FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
0		11.70	0	0.10	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02C014431	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02C014431	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

LAB #	ANALYSIS RECOMMENDATIONS

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SAMPLE SEVERITY

A

UNIT/BUS # DL073 SYSTEM ENG

SAMPLE DATA: LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R02D005970	3/26/2002 4/11/2002	6380 M 98530 M	186	0	6	30	0	0	0	0	8	192	43	876	546	0	993	1072	0	0	0	0		12.51	0	0.00	N

ELEMENTAL ANALYSIS: VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02D005970	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02D005970	WEAR METALS (IRON) -MILDLY ABOVE NORMAL. LUBE CONTAMINANTS -NORMAL. FOLLOW ESTABLSIHED MAINTENANCE PROCEDURES.

LAB #	ANALYSIS RECOMMENDATIONS

ANA LABORATORIES, INC.

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SAMPLE SEVERITY

N

UNIT/BUS # DL075 SYSTEM ENG

SAMPLE DATA: LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R02D005973	4/4/2002 4/11/2002	3978 M 52024 M	38	0	16	15	3	5	0	0	4	244	19	1130	576	0	1031	1113	0	0	0	0		11.80	0	0.00	N
R02A004496	12/12/200 1/10/2002	820 M 48050 M	11	0	14	9	5	0	0	0	3	199	18	708	640	0	872	950	0	0	1	0		12.61	0	0.10	N

ELEMENTAL ANALYSIS: VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02D005973	0.00	0.00					
R02A004496	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02D005973	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02A004496	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

LAB #	ANALYSIS RECOMMENDATIONS

ANA LABORATORIES, INC.

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SAMPLE SEVERITY

UNIT/BUS # DL062   SYSTEM ENG

N

SAMPLE DATA / ELEMENTAL ANALYSIS (VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT) / OIL QUALITY

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R02D005974	4/4/2002 4/11/2002	5000 M 63690 M	47	0	13	7	3	6	0	0	5	213	183	1085	656	0	979	1057	0	0	0	0		18.51	0	0.10	N
R02A004494	12/12/200 1/10/2002	3661 M 58936 M	32	3	12	8	5	5	0	0	4	178	60	789	669	0	883	962	0	0	1	0		13.02	0	0.40	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02D005974	0.00	0.00					
R02A004494	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02D005974	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02A004494	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

LAB #	ANALYSIS RECOMMENDATIONS

ANA LABORATORIES, INC.

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SAMPLE SEVERITY

UNIT/BUS # DL040   SYSTEM ENG

N

SAMPLE DATA / ELEMENTAL ANALYSIS (VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT) / OIL QUALITY

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R02D005976	4/4/2002 4/11/2002	5000 M 70400 M	53	0	14	12	2	0	0	0	2	244	54	1212	693	0	1041	1124	0	0	0	0		12.86	0	0.20	N
R02A004497	12/27/200 1/10/2002	1840 M 65890 M	9	0	13	3	6	0	0	0	3	218	18	852	672	0	920	1003	0	0	1	0		11.52	0	0.10	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02D005976	0.00	0.00					
R02A004497	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02D005976	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02A004497	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

LAB #	ANALYSIS RECOMMENDATIONS

ANA LABORATORIES, INC.

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SAMPLE SEVERITY **A**

UNIT/BUS # DL426 SYSTEM ENG

SAMPLE DATA

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT
R02D005978	4/5/2002 4/11/2002	4000 M 5037 M
R02A004499	12/26/200 1/10/2002	1040 M 1040 M

ELEMENTAL ANALYSIS — VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT

LAB #	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
R02D005978	36	0	11	194	2	0	0	0	9	255	39	1259	780	0	1076	1162	0	0	0
R02A004499	24	0	7	34	11	1	0	0	32	175	0	304	1767	0	913	995	0	0	1

OIL QUALITY

LAB #	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R02D005978	0		15.09	0	0.00	N
R02A004499	0		13.43	0	0.00	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02D005978	0.00	0.00					
R02A004499	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02D005978	WEAR METALS (COPPER) -HIGH(UNACCEPTABLE) LUBE CONTAMINANTS -NORMAL. CAUTION:May need corrective action SOON. Recheck to monitor seriousness.
R02A004499	WEAR METALS -NORMAL. LUBE CONTAMINANTS SILICON -MILDLY ABOVE NORMAL. FOLLOW ESTABLSIHED MAINTENANCE PROCEDURES.

LAB #	ANALYSIS RECOMMENDATIONS

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SAMPLE SEVERITY **N**

UNIT/BUS # DL120 SYSTEM ENG

SAMPLE DATA

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT
R02D013785	4/22/2002 4/26/2002	2000 M 75675 M

ELEMENTAL ANALYSIS — VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT

LAB #	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
R02D013785	6	0	4	2	2	0	0	0	2	167	0	636	526	0	881	960	0	0	0

OIL QUALITY

LAB #	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R02D013785	0		12.85	0	0.00	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02D013785	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02D013785	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

LAB #	ANALYSIS RECOMMENDATIONS

ANA LABORATORIES, INC.

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SAMPLE SEVERITY: **N**

UNIT/BUS # DL109 SYSTEM ENG

SAMPLE DATA		
LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT
R02E006591	5/8/2002	4813 M
	5/14/2002	46788 M

ELEMENTAL ANALYSIS — VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT

Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
34	8	6	7	3	6	0	0	6	108	0	762	359	0	1041	1156	0	0	0

OIL QUALITY					
FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
0		12.43	0	0.00	N

LAB #	ADDITIONAL TESTS: TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02E006591	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02E006591	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

LAB #	ANALYSIS RECOMMENDATIONS

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SAMPLE SEVERITY: **N**

UNIT/BUS # DL216 SYSTEM ENG

SAMPLE DATA		
LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT
R02E006611	5/7/2002	0
	5/14/2002	23582 M

ELEMENTAL ANALYSIS — VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT

Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
46	5	3	9	0	0	0	0	4	105	0	650	373	0	857	951	0	0	0

OIL QUALITY					
FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
0		11.19	0	0.50	N

LAB #	ADDITIONAL TESTS: TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02E006611	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02E006611	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

LAB #	ANALYSIS RECOMMENDATIONS

ANA LABORATORIES, INC.

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SAMPLE SEVERITY: **N**

UNIT/BUS # DL083 SYSTEM ENG

SAMPLE DATA

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT
R02E006617	5/7/2002	0
	5/14/2002	91400 M

ELEMENTAL ANALYSIS VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT

LAB #	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
R02E006617	16	7	4	5	3	4	0	0	5	124	0	731	330	0	987	1096	0	0	0

OIL QUALITY

LAB #	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R02E006617	0		11.44	0	0.00	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02E006617	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02E006617	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

LAB #	ANALYSIS RECOMMENDATIONS

ANA LABORATORIES, INC.

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SAMPLE SEVERITY: **N**

UNIT/BUS # DL230 SYSTEM ENG

SAMPLE DATA

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT
R02F004888	5/7/2002	3600 M
	6/11/2002	5640 M
R02A008113	12/10/200	92 H
	1/17/2002	92 H

ELEMENTAL ANALYSIS VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT

LAB #	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
R02F004888	29	0	0	12	4	0	0	0	4	169	0	547	1130	0	871	949	0	0	0
R02A008113	48	0	12	12	14	5	0	0	27	8	3	31	3079	0	935	1019	0	0	0

OIL QUALITY

LAB #	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R02F004888	0		11.59	0	0.80	N
R02A008113	0		12.48	0	0.30	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02F004888	0.00	0.00					
R02A008113	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02F004888	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02A008113	WEAR METALS -NORMAL. LUBE CONTAMINANTS SILICON -MILDLY ABOVE NORMAL. FOLLOW ESTABLSIHED MAINTENANCE PROCEDURES.

LAB #	ANALYSIS RECOMMENDATIONS

ANA LABORATORIES, INC.

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SAMPLE SEVERITY: **N**

UNIT/BUS # DL159 SYSTEM ENG

SAMPLE DATA / ELEMENTAL ANALYSIS (VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT) / OIL QUALITY

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R02F007302	6/3/2002	4476 M	32	0	0	2	4	0	0	0	2	162	0	821	691	0	897	978	0	0	0	0		11.88	0	0.20	N
	6/17/2002	51222 M																									

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02F007302	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02F007302	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

LAB #	ANALYSIS RECOMMENDATIONS

ANA LABORATORIES, INC.

641 Creek Road Bellmawr, New Jersey 08031-2409 (800) 648-2625 (856) 931-0011

SAMPLE SEVERITY: **N**

UNIT/BUS # DL126 SYSTEM ENG

SAMPLE DATA / ELEMENTAL ANALYSIS (VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT) / OIL QUALITY

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R02G004136	6/27/2002	3800 M	28	4	13	16	4	0	0	0	6	172	0	1716	344	0	1258	1396	0	0	0	0		11.64	0	0.20	N
	7/10/2002	43650 M																									
R02B007172	2/11/2002	4000 M	23	0	4	1	0	0	0	0	3	224	0	619	383	0	760	828	0	0	0	0		11.06	0	0.20	N
	2/17/2002	40100 M																									

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02G004136	0.00	0.00					
R02B007172	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02G004136	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02B007172	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

LAB #	ANALYSIS RECOMMENDATIONS

ANA LABORATORIES, INC.
641 Creek Road Bellmawr, New Jersey 08031-2409 (800) 648-2625 (856) 931-0011

SAMPLE SEVERITY **N**

UNIT/BUS # DL121 SYSTEM ENG

SAMPLE DATA			ELEMENTAL ANALYSIS VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT																				OIL QUALITY					
LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R02G009845	7/10/2002 7/18/2002	4215 M 100200 M	8	0	0	3	3	0	0	0	4	140	0	581	254	0	819	893	0	0	0	0		12.73	0	0.00	N
R02B010911	2/8/2002 2/25/2002	3800 M 95985 M	15	0	4	7	0	2	0	0	5	185	0	679	395	0	812	885	0	0	0	0		12.67	0	0.20	N

ADDITIONAL TESTS							
LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02G009845	0.00	0.00					
R02B010911	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02G009845	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02B010911	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

LAB #	ANALYSIS RECOMMENDATIONS

ANA LABORATORIES, INC.
641 Creek Road Bellmawr, New Jersey 08031-2409 (800) 648-2625 (856) 931-0011

SAMPLE SEVERITY **N**

UNIT/BUS # DL120 SYSTEM ENG

SAMPLE DATA			ELEMENTAL ANALYSIS VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT																				OIL QUALITY					
LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R02G011598	7/18/2002 7/23/2002	4165 M 78690 M	25	2	8	10	2	0	0	0	6	114	0	1003	607	0	1041	1156	0	0	0	0		13.33	0	0.10	N
R02D013785	4/22/2002 4/26/2002	2000 M 75675 M	6	0	4	2	2	0	0	0	2	167	0	636	526	0	881	960	0	0	0	0		12.85	0	0.00	N

ADDITIONAL TESTS							
LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02G011598	0.00	0.00					
R02D013785	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02G011598	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02D013785	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

LAB #	ANALYSIS RECOMMENDATIONS

ANA LABORATORIES, INC.

641 Creek Road Bellmawr, New Jersey 08031-2409 (800) 648-2625 (856) 931-0011

SAMPLE SEVERITY: **N**

UNIT/BUS # DL230 SYSTEM ENG

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R02G015629	7/11/2002	2800 H	32	2	7	9	4	0	0	0	3	133	0	712	482	0	914	996	0	0	0	0		12.67	0	1.00	N
	7/30/2002	9440 H																									
R02F004888	5/7/2002	3600 M	29	0	0	12	4	0	0	0	4	169	0	547	1130	0	871	949	0	0	0	0		11.59	0	0.80	N
	6/11/2002	5640 M																									
R02A008113	12/10/200	92 H	48	0	12	12	14	5	0	0	27	8	3	31	3079	0	935	1019	0	0	0	0		12.48	0	0.30	N
	1/17/2002	92 H																									

Elemental analysis values expressed in parts per million (PPM) by weight.

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02G015629	0.00	0.00					
R02F004888	0.00	0.00					
R02A008113	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02G015629	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02F004888	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02A008113	WEAR METALS -NORMAL. LUBE CONTAMINANTS SILICON -MILDLY ABOVE NORMAL. FOLLOW ESTABLSIHED MAINTENANCE PROCEDURES.

ANA LABORATORIES, INC.

641 Creek Road Bellmawr, New Jersey 08031-2409 (800) 648-2625 (856) 931-0011

SAMPLE SEVERITY: **N**

UNIT/BUS # DL130 SYSTEM ENG

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R02H006629	8/7/2002	3474 M	12	0	4	5	2	0	0	0	4	120	0	732	470	0	904	1003	0	0	0	0		11.99	0	0.30	N
	8/14/2002	56354 M																									
R02C014431	3/22/2002	3282 M	13	0	1	2	0	0	0	0	2	186	0	695	388	0	935	1019	0	0	0	0		11.70	0	0.10	N
	3/29/2002	52880 M																									

Elemental analysis values expressed in parts per million (PPM) by weight.

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02H006629	0.00	0.00					
R02C014431	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02H006629	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02C014431	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

ANA LABORATORIES, INC.

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SAMPLE SEVERITY: **N**

UNIT/BUS # DL216 SYSTEM ENG

SAMPLE DATA / ELEMENTAL ANALYSIS (VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT) / OIL QUALITY

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R02J000736	8/26/2002	4185 M	26	2	3	5	3	4	0	0	3	150	0	711	290	0	895	976	0	0	0	0		12.76	0	0.70	N
	9/4/2002	24605 M																									
R02E006611	5/7/2002	0	46	5	3	9	0	0	0	0	4	105	0	650	373	0	857	951	0	0	0	0		11.19	0	0.50	N
	5/14/2002	23582 M																									

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02J000736	0.00	0.00					
R02E006611	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02J000736	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02E006611	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

LAB #	ANALYSIS RECOMMENDATIONS

ANA LABORATORIES, INC.

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SAMPLE SEVERITY: **N**

UNIT/BUS # DL230 SYSTEM ENG

SAMPLE DATA / ELEMENTAL ANALYSIS (VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT) / OIL QUALITY

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R02J004692	11/21/200	4000 M	41	4	3	3	3	4	0	0	3	132	0	680	356	0	854	931	0	0	0	0		13.03	0	0.70	N
	9/11/2002	13265 M																									
R02G015629	7/11/2002	2800 H	32	2	7	9	4	0	0	0	3	133	0	712	482	0	914	996	0	0	0	0		12.67	0	1.00	N
	7/30/2002	9440 H																									
R02F004888	5/7/2002	3600 M	29	0	0	12	4	0	0	0	4	169	0	547	1130	0	871	949	0	0	0	0		11.59	0	0.80	N
	6/11/2002	5640 M																									
R02A008113	12/10/200	92 H	48	0	12	12	14	5	0	0	27	8	3	31	3079	0	935	1019	0	0	0	0		12.48	0	0.30	N
	1/17/2002	92 H																									

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02J004692	0.00	0.00					
R02G015629	0.00	0.00					
R02F004888	0.00	0.00					
R02A008113	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02J004692	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02G015629	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

LAB #	ANALYSIS RECOMMENDATIONS
R02F004888	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02A008113	WEAR METALS -NORMAL. LUBE CONTAMINANTS SILICON -MILDLY ABOVE NORMAL. FOLLOW ESTABLSIHED MAINTENANCE PROCEDURES.

ANA LABORATORIES, INC.

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SAMPLE SEVERITY **N**

UNIT/BUS # DL096 SYSTEM ENG

SAMPLE DATA

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT
R02J004693	8/19/2002	0
	9/11/2002	114675 M
R02A014455	1/17/2002	4000 M
	1/30/2002	106500 M

ELEMENTAL ANALYSIS — VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT

LAB #	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
R02J004693	18	5	4	2	5	4	0	0	4	171	5	772	494	0	1039	1133	0	0	0
R02A014455	36	4	8	10	3	7	0	0	11	145	27	1058	507	0	970	1086	0	0	0

OIL QUALITY

LAB #	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R02J004693	0		13.16	0	0.20	N
R02A014455	0		15.15	0	0.30	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02J004693	0.00	0.00					
R02A014455	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02J004693	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02A014455	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

LAB #	ANALYSIS RECOMMENDATIONS

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SAMPLE SEVERITY **N**

UNIT/BUS # DL216 SYSTEM ENG

SAMPLE DATA

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT
R02J004694	8/26/2002	0
	9/11/2002	0
R02J000736	8/26/2002	4185 M
	9/4/2002	24605 M
R02E006611	5/7/2002	0
	5/14/2002	23582 M

ELEMENTAL ANALYSIS — VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT

LAB #	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
R02J004694	83	4	4	4	5	4	0	0	3	112	0	723	426	0	884	964	0	0	0
R02J000736	26	2	3	5	3	4	0	0	3	150	0	711	290	0	895	976	0	0	0
R02E006611	46	5	3	9	0	0	0	0	4	105	0	650	373	0	857	951	0	0	0

OIL QUALITY

LAB #	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R02J004694	0		13.01	0	0.90	N
R02J000736	0		12.76	0	0.70	N
R02E006611	0		11.19	0	0.50	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02J004694	0.00	0.00					
R02J000736	0.00	0.00					
R02E006611	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02J004694	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02J000736	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

LAB #	ANALYSIS RECOMMENDATIONS
R02E006611	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

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SAMPLE SEVERITY **N**

UNIT/BUS # DL006 SYSTEM ENG

SAMPLE DATA			ELEMENTAL ANALYSIS VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT																			OIL QUALITY					
LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R02J006156	8/8/2002 9/13/2002	3985 M 97645	13	0	5	6	4	4	0	0	2	122	27	692	663	0	857	934	0	0	0	0		13.38	0	0.20	N
R02A004504	12/20/200 1/10/2002	5485 M 93660 M	29	0	7	2	5	0	0	0	2	162	17	777	734	0	898	979	0	0	1	0		11.99	0	0.20	N

LAB #	ADDITIONAL TESTS TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02J006156	0.00	0.00					
R02A004504	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02J006156	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02A004504	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

LAB #	ANALYSIS RECOMMENDATIONS

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SAMPLE SEVERITY **N**

UNIT/BUS # DL158 SYSTEM ENG

SAMPLE DATA			ELEMENTAL ANALYSIS VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT																			OIL QUALITY					
LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R02K005015	10/4/2002 10/10/200	6935 M 48935 M	25	1	0	6	4	4	0	0	2	106	0	465	449	0	747	814	0	0	0	0		11.79	0	0.50	N

LAB #	ADDITIONAL TESTS TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02K005015	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02K005015	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

LAB #	ANALYSIS RECOMMENDATIONS

ANA LABORATORIES, INC.

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SAMPLE SEVERITY

N

UNIT/BUS # DL121 SYSTEM ENG

SAMPLE DATA			ELEMENTAL ANALYSIS VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT																				OIL QUALITY					
LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R02M000111	11/14/200 12/2/2002	3480 M 103680 M	2	0	0	0	0	0	0	0	1	131	0	974	392	0	1088	1208	0	0	0	0		11.84	0	0.00	N
R02G009845	7/10/2002 7/18/2002	4215 M 100200 M	8	0	0	3	3	0	0	0	4	140	0	581	254	0	819	893	0	0	0	0		12.73	0	0.00	N
R02B010911	2/8/2002 2/25/2002	3800 M 95985 M	15	0	4	7	0	2	0	0	5	185	0	679	395	0	812	885	0	0	0	0		12.67	0	0.20	N

	ADDITIONAL TESTS						
LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02M000111	0.00	0.00					
R02G009845	0.00	0.00					
R02B010911	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02M000111	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02G009845	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02B010911	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

ANA LABORATORIES, INC.

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SAMPLE SEVERITY

N

UNIT/BUS # DL130 SYSTEM ENG

SAMPLE DATA			ELEMENTAL ANALYSIS VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT																				OIL QUALITY					
LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R02M000113	11/14/200 12/2/2002	3796 M 60150 M	5	0	0	0	0	0	0	0	0	116	0	972	312	0	969	1076	0	0	0	0		12.96	0	0.40	N
R02H006629	8/7/2002 8/14/2002	3474 M 56354 M	12	0	4	5	2	0	0	0	4	120	0	732	470	0	904	1003	0	0	0	0		11.99	0	0.30	N
R02C014431	3/22/2002 3/29/2002	3282 M 52880 M	13	0	1	2	0	0	0	0	2	186	0	695	388	0	935	1019	0	0	0	0		11.70	0	0.10	N

	ADDITIONAL TESTS						
LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02M000113	0.00	0.00					
R02H006629	0.00	0.00					
R02C014431	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02M000113	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02H006629	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02C014431	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

ANA LABORATORIES, INC.

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SAMPLE SEVERITY **N**

UNIT/BUS # DL126 SYSTEM ENG

SAMPLE DATA

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT
R02M000115	11/14/200 12/2/2002	3748 M 47398
R02G004136	6/27/2002 7/10/2002	3800 M 43650 M
R02B007172	2/11/2002 2/17/2002	4000 M 40100 M

ELEMENTAL ANALYSIS — VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT

LAB #	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
R02M000115	12	0	7	6	0	0	0	0	5	126	0	1059	340	0	1071	1189	0	0	0
R02G004136	28	4	13	16	4	0	0	0	6	172	0	1716	344	0	1258	1396	0	0	0
R02B007172	23	0	4	1	0	0	0	0	3	224	0	619	383	0	760	828	0	0	0

OIL QUALITY

LAB #	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R02M000115	0		10.99	0	0.20	N
R02G004136	0		11.64	0	0.20	N
R02B007172	0		11.06	0	0.20	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02M000115	0.00	0.00					
R02G004136	0.00	0.00					
R02B007172	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02M000115	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02G004136	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02B007172	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

ANA LABORATORIES, INC.

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SAMPLE SEVERITY **N**

UNIT/BUS # DL120 SYSTEM ENG

SAMPLE DATA

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT
R02M000116	11/14/200 12/2/2002	1706 M 80396 M
R02G011598	7/18/2002 7/23/2002	4165 M 78690 M
R02D013785	4/22/2002 4/26/2002	2000 M 75675 M

ELEMENTAL ANALYSIS — VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT

LAB #	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
R02M000116	0	0	0	0	0	0	0	0	0	105	0	742	333	0	895	993	0	0	0
R02G011598	25	2	8	10	2	0	0	0	6	114	0	1003	607	0	1041	1156	0	0	0
R02D013785	6	0	4	2	2	0	0	0	2	167	0	636	526	0	881	960	0	0	0

OIL QUALITY

LAB #	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R02M000116	0		13.87	0	0.10	N
R02G011598	0		13.33	0	0.10	N
R02D013785	0		12.85	0	0.00	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02M000116	0.00	0.00					
R02G011598	0.00	0.00					
R02D013785	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02M000116	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02G011598	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02D013785	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

ANA LABORATORIES, INC.

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SAMPLE SEVERITY **N**

UNIT/BUS # DL040 SYSTEM ENG

SAMPLE DATA			ELEMENTAL ANALYSIS VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT																				OIL QUALITY					
LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R02M001666	11/22/200 12/4/2002	3000 M 72683 M	36	2	5	15	3	4	0	0	4	167	30	605	780	0	989	1078	0	0	0	0		12.66	0	0.30	N
R02D005976	4/4/2002 4/11/2002	5000 M 70400 M	53	0	14	12	2	0	0	0	2	244	54	1212	693	0	1041	1124	0	0	0	0		12.86	0	0.20	N
R02A004497	12/27/200 1/10/2002	1840 M 65890 M	9	0	13	3	6	0	0	0	3	218	18	852	672	0	920	1003	0	0	1	0		11.52	0	0.10	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02M001666	0.00	0.00					
R02D005976	0.00	0.00					
R02A004497	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02M001666	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02D005976	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02A004497	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

ANA LABORATORIES, INC.

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SAMPLE SEVERITY **N**

UNIT/BUS # DL059 SYSTEM ENG

SAMPLE DATA			ELEMENTAL ANALYSIS VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT																				OIL QUALITY					
LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R02M001669	11/22/200 12/4/2002	5000 86500	19	4	6	3	3	4	0	0	5	153	33	539	709	0	975	1063	0	0	0	0		14.48	0	0.00	N
R02C005872	2/14/2002 3/13/2002	2264 81365	392	1	12	15	2	2	0	0	11	158	19	988	551	0	1165	1293	0	0	0	0		11.92	0	0.00	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02M001669	0.00	0.00					
R02C005872	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02M001669	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02C005872	WEAR METALS (IRON) -EXCESSIVE(CRITICAL). LUBE CONTAMINANTS -NORMAL. TAKE CORRECTIVE ACTION. DRAIN OIL IF NOT DRAINED. CHANGE FILTER IF NOT CHANGED.

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SAMPLE SEVERITY: **N**

UNIT/BUS # DL075 SYSTEM ENG

SAMPLE DATA			ELEMENTAL ANALYSIS — VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT																		OIL QUALITY					
LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R02M001671	11/6/2002 12/4/2002	4000 M 53005 M	9	2	5	4	3	4	0	0	4	186	25	571	558	0	966	1053	0	0	0	0		12.89	0	0.00	N
R02D005973	4/4/2002 4/11/2002	3978 M 52024 M	38	0	16	15	3	5	0	0	4	244	19	1130	576	0	1031	1113	0	0	0	0		11.80	0	0.00	N
R02A004496	12/12/200 1/10/2002	820 M 48050 M	11	0	14	9	5	0	0	0	3	199	18	708	640	0	872	950	0	0	1	0		12.61	0	0.10	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02M001671	0.00	0.00					
R02D005973	0.00	0.00					
R02A004496	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02M001671	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02D005973	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02A004496	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

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SAMPLE SEVERITY: **N**

UNIT/BUS # DL073 SYSTEM ENG

SAMPLE DATA			ELEMENTAL ANALYSIS — VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT																		OIL QUALITY					
LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R02M001673	11/22/200 12/4/2002	1439 M 99969 M	11	3	4	1	3	4	0	0	4	181	32	569	548	0	923	1006	0	0	0	0		12.09	0	0.00	N
R02D005970	3/26/2002 4/11/2002	6380 M 98530 M	186	0	6	30	0	0	0	0	8	192	43	876	546	0	993	1072	0	0	0	0		12.51	0	0.00	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02M001673	0.00	0.00					
R02D005970	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02M001673	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02D005970	WEAR METALS (IRON) -MILDLY ABOVE NORMAL. LUBE CONTAMINANTS -NORMAL. FOLLOW ESTABLSIHED MAINTENANCE PROCEDURES.

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SAMPLE SEVERITY **N**

UNIT/BUS # DL096 SYSTEM ENG

SAMPLE DATA

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT
R02M005822	12/2/2002 12/11/200	4000 M 118200 M
R02J004693	8/19/2002 9/11/2002	0 114675 M
R02A014455	1/17/2002 1/30/2002	4000 M 106500 M

ELEMENTAL ANALYSIS — VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT

LAB #	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
R02M005822	12	4	1	5	3	4	0	0	4	154	0	460	228	0	919	1002	0	0	0
R02J004693	18	5	4	2	5	4	0	0	4	171	5	772	494	0	1039	1133	0	0	0
R02A014455	36	4	8	10	3	7	0	0	11	145	27	1058	507	0	970	1086	0	0	0

OIL QUALITY

LAB #	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R02M005822	0		14.27	0	0.10	N
R02J004693	0		13.16	0	0.20	N
R02A014455	0		15.15	0	0.30	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02M005822	0.00	0.00					
R02J004693	0.00	0.00					
R02A014455	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02M005822	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02J004693	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02A014455	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

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SAMPLE SEVERITY **N**

UNIT/BUS # DL230 SYSTEM ENG

SAMPLE DATA

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT
R02M005831	12/4/2002 12/11/200	4000 M 18000 M
R02J004692	11/21/200 9/11/2002	4000 M 13265 M
R02G015629	7/11/2002 7/30/2002	2800 H 9440 H
R02F004888	5/7/2002 6/11/2002	3600 M 5640 M

ELEMENTAL ANALYSIS — VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT

LAB #	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
R02M005831	37	4	3	2	5	6	4	0	5	148	0	474	349	0	910	992	0	0	0
R02J004692	41	4	3	3	3	4	0	0	3	132	0	680	356	0	854	931	0	0	0
R02G015629	32	2	7	9	4	0	0	0	3	133	0	712	482	0	914	996	0	0	0
R02F004888	29	0	0	12	4	0	0	0	4	169	0	547	1130	0	871	949	0	0	0

OIL QUALITY

LAB #	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R02M005831	0		12.14	0	0.40	N
R02J004692	0		13.03	0	0.70	N
R02G015629	0		12.67	0	1.00	N
R02F004888	0		11.59	0	0.80	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02M005831	0.00	0.00					
R02J004692	0.00	0.00					
R02G015629	0.00	0.00					
R02F004888	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02M005831	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02J004692	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02G015629	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02F004888	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

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SAMPLE SEVERITY **N**

UNIT/BUS # DL109 SYSTEM ENG

SAMPLE DATA			ELEMENTAL ANALYSIS — VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT																		
LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
R02M007478	12/6/2002 12/13/200	4037 M 50825 M	33	0	1	1	2	3	0	0	4	129	0	524	295	0	983	1071	0	0	0
R02E006591	5/8/2002 5/14/2002	4813 M 46788 M	34	8	6	7	3	6	0	0	6	108	0	762	359	0	1041	1156	0	0	0

LAB #	OIL QUALITY: FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R02M007478	0		12.24	0	0.40	N
R02E006591	0		12.43	0	0.00	N

LAB #	ADDITIONAL TESTS: TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02M007478	0.00	0.00					
R02E006591	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02M007478	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02E006591	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

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SAMPLE SEVERITY **N**

UNIT/BUS # DL216 SYSTEM ENG

SAMPLE DATA			ELEMENTAL ANALYSIS — VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT																		
LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
R02M015014	12/13/200 12/26/200	0 0	45	2	3	1	5	3	4	0	4	153	0	597	360	0	992	1081	0	0	0
R02J004694	8/26/2002 9/11/2002	0 0	83	4	4	4	5	4	0	0	3	112	0	723	426	0	884	964	0	0	0
R02J000736	8/26/2002 9/4/2002	4185 M 24605 M	26	2	3	5	3	4	0	0	3	150	0	711	290	0	895	976	0	0	0
R02E006611	5/7/2002 5/14/2002	0 23582 M	46	5	3	9	0	0	0	0	4	105	0	650	373	0	857	951	0	0	0

LAB #	OIL QUALITY: FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R02M015014	0		12.50	0	0.90	N
R02J004694	0		13.01	0	0.90	N
R02J000736	0		12.76	0	0.70	N
R02E006611	0		11.19	0	0.50	N

LAB #	ADDITIONAL TESTS: TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02M015014	0.00	0.00					
R02J004694	0.00	0.00					
R02J000736	0.00	0.00					
R02E006611	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02M015014	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02J004694	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02J000736	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02E006611	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

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SAMPLE SEVERITY **C**

UNIT/BUS # DL426 SYSTEM ENG

SAMPLE DATA / ELEMENTAL ANALYSIS (VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT) / OIL QUALITY

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R02M016031	11/22/200 12/30/200	4000 6255	0	0	1	320	3	4	0	0	5	160	8	387	619	0	935	1019	0	0	0	0		11.74	0	0.00	N
R02D005978	4/5/2002 4/11/2002	4000 M 5037 M	36	0	11	194	2	0	0	0	9	255	39	1259	780	0	1076	1162	0	0	0	0		15.09	0	0.00	N
R02A004499	12/26/200 1/10/2002	1040 M 1040 M	24	0	7	34	11	1	0	0	32	175	0	304	1767	0	913	995	0	0	1	0		13.43	0	0.00	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02M016031	0.00	0.00					
R02D005978	0.00	0.00					
R02A004499	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02M016031	WEAR METALS (COPPER) -EXCESSIVE(CRITICAL). LUBE CONTAMINANTS -NORMAL. TAKE CORRECTIVE ACTION.
R02D005978	WEAR METALS (COPPER) -HIGH(UNACCEPTABLE) LUBE CONTAMINANTS -NORMAL. CAUTION:May need corrective action SOON. Recheck to monitor seriousness.
R02A004499	WEAR METALS -NORMAL. LUBE CONTAMINANTS SILICON -MILDLY ABOVE NORMAL. FOLLOW ESTABLSIHED MAINTENANCE PROCEDURES.

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SAMPLE SEVERITY **C**

UNIT/BUS # DL427 SYSTEM ENG

SAMPLE DATA / ELEMENTAL ANALYSIS (VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT) / OIL QUALITY

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R02M016032	11/26/200 12/30/200	4000 M 8389 M	0	0	1	327	3	4	0	0	3	165	8	397	665	0	983	1071	0	0	0	0		12.11	0	0.00	N
R02B003535	1/30/2002 2/8/2002	3459 M 3459 M	23	0	5	36	7	0	0	0	67	179	3	287	2036	0	885	956	0	0	0	0		12.42	0	0.10	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02M016032	0.00	0.00					
R02B003535	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02M016032	WEAR METALS (COPPER) -EXCESSIVE(CRITICAL). LUBE CONTAMINANTS -NORMAL. TAKE CORRECTIVE ACTION.
R02B003535	WEAR METALS -NORMAL. LUBE CONTAMINANTS SILICON -MODERATELY HIGH. FOLLOW ESTABLSIHED MAINTENANCE PROCEDURES.

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SAMPLE SEVERITY **N**

UNIT/BUS # DL006 SYSTEM ENG

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
R02M016033	12/18/200 12/30/200	0 99536 M	3	0	3	11	3	4	1	0	0	189	19	536	702	0	1035	1128	0	0	0
R02J006156	8/8/2002 9/13/2002	3985 M 97645	13	0	5	6	4	4	0	0	2	122	27	692	663	0	857	934	0	0	0
R02A004504	12/20/200 1/10/2002	5485 M 93660 M	29	0	7	2	5	0	0	0	2	162	17	777	734	0	898	979	0	0	1

ELEMENTAL ANALYSIS: VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT

OIL QUALITY

LAB #	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R02M016033	0		12.31	0	0.10	N
R02J006156	0		13.38	0	0.20	N
R02A004504	0		11.99	0	0.20	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02M016033	0.00	0.00					
R02J006156	0.00	0.00					
R02A004504	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02M016033	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02J006156	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02A004504	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

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SAMPLE SEVERITY **N**

UNIT/BUS # DL062 SYSTEM ENG

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
R02M016034	12/18/200 12/30/200	4000 M 66260 M	19	0	3	5	3	5	0	0	2	130	61	439	978	0	997	1087	0	0	0
R02D005974	4/4/2002 4/11/2002	5000 M 63690 M	47	0	13	7	3	6	0	0	5	213	183	1085	656	0	979	1057	0	0	0
R02A004494	12/12/200 1/10/2002	3661 M 58936 M	32	3	12	8	5	5	0	0	4	178	60	789	669	0	883	962	0	0	1

ELEMENTAL ANALYSIS: VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT

OIL QUALITY

LAB #	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R02M016034	0		13.03	0	0.30	N
R02D005974	0		18.51	0	0.10	N
R02A004494	0		13.02	0	0.40	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R02M016034	0.00	0.00					
R02D005974	0.00	0.00					
R02A004494	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R02M016034	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02D005974	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02A004494	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

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SAMPLE SEVERITY **N**

UNIT/BUS # DL083 SYSTEM ENG

SAMPLE DATA / ELEMENTAL ANALYSIS (VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT)

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
R03A010054	1/10/2003 1/17/2003	0 96960 M	17	4	1	3	0	3	0	0	3	105	5	949	408	0	1000	1090	0	1	0
R02E006617	5/7/2002 5/14/2002	0 91400 M	16	7	4	5	3	4	0	0	5	124	0	731	330	0	987	1096	0	0	0

OIL QUALITY

LAB #	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R03A010054	0		12.42	0	0.20	N
R02E006617	0		11.44	0	0.00	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R03A010054	0.00	0.00					
R02E006617	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R03A010054	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02E006617	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

LAB #	ANALYSIS RECOMMENDATIONS

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SAMPLE SEVERITY **N**

UNIT/BUS # DL159 SYSTEM ENG

SAMPLE DATA / ELEMENTAL ANALYSIS (VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT)

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
R03C004265	2/27/2003 3/9/2003	6909 M 58134 M	29	0	3	8	3	4	0	0	4	181	0	756	451	0	875	954	0	0	6
R02F007302	6/3/2002 6/17/2002	4476 M 51222 M	32	0	0	2	4	0	0	0	2	162	0	821	691	0	897	978	0	0	0

OIL QUALITY

LAB #	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R03C004265	0		10.61	0	0.40	N
R02F007302	0		11.88	0	0.20	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R03C004265	0.00	0.00					
R02F007302	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R03C004265	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02F007302	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

LAB #	ANALYSIS RECOMMENDATIONS

ANA LABORATORIES, INC.

641 Creek Road Bellmawr, New Jersey 08031-2409 (800) 648-2625 (856) 931-0011

SAMPLE SEVERITY: **N**

UNIT/BUS # DL126 SYSTEM ENG

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R03C006809	2/26/2003 3/12/2003	3819 M 1971 H	6	0	0	6	3	4	0	0	2	38	0	316	1434	0	951	1037	0	0	6	0		11.84	0	0.00	N
R02M000115	11/14/200 12/2/2002	3748 M 47398	12	0	7	6	0	0	0	0	5	126	0	1059	340	0	1071	1189	0	0	0	0		10.99	0	0.20	N
R02G004136	6/27/2002 7/10/2002	3800 M 43650 M	28	4	13	16	4	0	0	0	6	172	0	1716	344	0	1258	1396	0	0	0	0		11.64	0	0.20	N
R02B007172	2/11/2002 2/17/2002	4000 M 40100 M	23	0	4	1	0	0	0	0	3	224	0	619	383	0	760	828	0	0	0	0		11.06	0	0.20	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R03C006809	0.00	0.00					
R02M000115	0.00	0.00					
R02G004136	0.00	0.00					
R02B007172	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R03C006809	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02M000115	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02G004136	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02B007172	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

ANA LABORATORIES, INC.

641 Creek Road Bellmawr, New Jersey 08031-2409 (800) 648-2625 (856) 931-0011

SAMPLE SEVERITY: **N**

UNIT/BUS # DL059 SYSTEM ENG

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R03C008872	2/25/2003 3/16/2003	91750 M 0	31	3	11	8	0	5	1	0	5	13	21	359	2032	0	1380	1504	0	0	5	0		13.37	0	0.20	N
R02M001669	11/22/200 12/4/2002	5000 86500	19	4	6	3	3	4	0	0	5	153	33	539	709	0	975	1063	0	0	0	0		14.48	0	0.00	N
R02C005872	2/14/2002 3/13/2002	2264 81365	392	1	12	15	2	2	0	0	11	158	19	988	551	0	1165	1293	0	0	0	0		11.92	0	0.00	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R03C008872	0.00	0.00					
R02M001669	0.00	0.00					
R02C005872	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R03C008872	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02M001669	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02C005872	WEAR METALS (IRON) -EXCESSIVE(CRITICAL). LUBE CONTAMINANTS -NORMAL. TAKE CORRECTIVE ACTION. DRAIN OIL IF NOT DRAINED. CHANGE FILTER IF NOT CHANGED.

ANA LABORATORIES, INC.

641 Creek Road Bellmawr, New Jersey 08031-2409 (800) 648-2625 (856) 931-0011

SAMPLE SEVERITY **N**

UNIT/BUS # DL075 SYSTEM ENG

SAMPLE DATA / ELEMENTAL ANALYSIS (VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT)

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
R03C008876	2/25/2003 3/16/2003	4000 M 57910 M	28	3	10	32	0	6	0	0	6	17	27	387	1999	0	1366	1489	0	0	1
R02M001671	11/6/2002 12/4/2002	4000 M 53005 M	9	2	5	4	3	4	0	0	4	186	25	571	558	0	966	1053	0	0	0
R02D005973	4/4/2002 4/11/2002	3978 M 52024 M	38	0	16	15	3	5	0	0	4	244	19	1130	576	0	1031	1113	0	0	0
R02A004496	12/12/200 1/10/2002	820 M 48050 M	11	0	14	9	5	0	0	0	3	199	18	708	640	0	872	950	0	0	1

OIL QUALITY

LAB #	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R03C008876	0		12.16	0	0.20	N
R02M001671	0		12.89	0	0.00	N
R02D005973	0		11.80	0	0.00	N
R02A004496	0		12.61	0	0.10	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R03C008876	0.00	0.00					
R02M001671	0.00	0.00					
R02D005973	0.00	0.00					
R02A004496	0.00	0.00					

ANALYSIS RECOMMENDATIONS

LAB #	ANALYSIS RECOMMENDATIONS
R03C008876	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02M001671	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02D005973	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02A004496	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

ANA LABORATORIES, INC.

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SAMPLE SEVERITY **N**

UNIT/BUS # DL006 SYSTEM ENG

SAMPLE DATA / ELEMENTAL ANALYSIS (VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT)

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
R03C008878	2/24/2003 3/16/2003	4000 103970	19	1	3	6	0	2	0	0	3	43	8	515	1499	0	1240	1352	0	0	1
R02M016033	12/18/200 12/30/200	0 99536 M	3	0	3	11	3	4	1	0	0	189	19	536	702	0	1035	1128	0	0	0
R02J006156	8/8/2002 9/13/2002	3985 M 97645	13	0	5	6	4	4	0	0	2	122	27	692	663	0	857	934	0	0	0
R02A004504	12/20/200 1/10/2002	5485 M 93660 M	29	0	7	2	5	0	0	0	2	162	17	777	734	0	898	979	0	0	1

OIL QUALITY

LAB #	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R03C008878	0		13.16	0	0.20	N
R02M016033	0		12.31	0	0.10	N
R02J006156	0		13.38	0	0.20	N
R02A004504	0		11.99	0	0.20	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R03C008878	0.00	0.00					
R02M016033	0.00	0.00					
R02J006156	0.00	0.00					
R02A004504	0.00	0.00					

ANALYSIS RECOMMENDATIONS

LAB #	ANALYSIS RECOMMENDATIONS
R03C008878	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02M016033	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02J006156	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02A004504	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

ANA LABORATORIES, INC.

641 Creek Road Bellmawr, New Jersey 08031-2409 (800) 648-2625 (856) 931-0011

SAMPLE SEVERITY **C**

UNIT/BUS # DL426 SYSTEM ENG

SAMPLE DATA			ELEMENTAL ANALYSIS VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT																			OIL QUALITY					
LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R03C008880	2/25/2003	4545 M	17	0	4	1018	0	2	0	1	9	30	15	403	1603	0	1228	1339	0	0	1	0		12.27	0	0.10	N
	3/16/2003	10800 M																									
R02M016031	11/22/200	4000	0	0	1	320	3	4	0	0	5	160	8	387	619	0	935	1019	0	0	0	0		11.74	0	0.00	N
	12/30/200	6255																									
R02D005978	4/5/2002	4000 M	36	0	11	194	2	0	0	0	9	255	39	1259	780	0	1076	1162	0	0	0	0		15.09	0	0.00	N
	4/11/2002	5037 M																									
R02A004499	12/26/200	1040 M	24	0	7	34	11	1	0	0	32	175	0	304	1767	0	913	995	0	0	1	0		13.43	0	0.00	N
	1/10/2002	1040 M																									

	ADDITIONAL TESTS						
LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R03C008880	0.00	0.00					
R02M016031	0.00	0.00					
R02D005978	0.00	0.00					
R02A004499	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R03C008880	WEAR METALS (COPPER) -EXCESSIVE(CRITICAL). LUBE CONTAMINANTS -NORMAL. TAKE CORRECTIVE ACTION.
R02M016031	WEAR METALS (COPPER) -EXCESSIVE(CRITICAL). LUBE CONTAMINANTS -NORMAL. TAKE CORRECTIVE ACTION.
R02D005978	WEAR METALS (COPPER) -HIGH(UNACCEPTABLE) LUBE CONTAMINANTS -NORMAL. CAUTION:May need corrective action SOON. Recheck to monitor seriousness.
R02A004499	WEAR METALS -NORMAL. LUBE CONTAMINANTS SILICON -MILDLY ABOVE NORMAL. FOLLOW ESTABLSIHED MAINTENANCE PROCEDURES.

ANA LABORATORIES, INC.

641 Creek Road Bellmawr, New Jersey 08031-2409 (800) 648-2625 (856) 931-0011

SAMPLE SEVERITY **N**

UNIT/BUS # DL427 SYSTEM ENG

SAMPLE DATA			ELEMENTAL ANALYSIS VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT																			OIL QUALITY					
LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R03C008881	2/26/2003	4036 M	11	0	2	7	0	2	0	2	7	38	14	484	1537	0	1272	1386	0	0	1	0		12.87	0	0.10	N
	3/16/2003	12425 M																									
R02M016032	11/26/200	4000 M	0	0	1	327	3	4	0	0	3	165	8	397	665	0	983	1071	0	0	0	0		12.11	0	0.00	N
	12/30/200	8389 M																									
R02B003535	1/30/2002	3459 M	23	0	5	36	7	0	0	0	67	179	3	287	2036	0	885	956	0	0	0	0		12.42	0	0.10	N
	2/8/2002	3459 M																									

	ADDITIONAL TESTS						
LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R03C008881	0.00	0.00					
R02M016032	0.00	0.00					
R02B003535	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R03C008881	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02M016032	WEAR METALS (COPPER) -EXCESSIVE(CRITICAL). LUBE CONTAMINANTS -NORMAL. TAKE CORRECTIVE ACTION.
R02B003535	WEAR METALS -NORMAL. LUBE CONTAMINANTS SILICON -MODERATELY HIGH. FOLLOW ESTABLSIHED MAINTENANCE PROCEDURES.

ANA LABORATORIES, INC.

641 Creek Road Bellmawr, New Jersey 08031-2409 (800) 648-2625 (856) 931-0011

SAMPLE SEVERITY **N**

UNIT/BUS # DL040 SYSTEM ENG

SAMPLE DATA			ELEMENTAL ANALYSIS — VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT																			OIL QUALITY					
LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R03C008883	3/3/2003 3/16/2003	5000 M 77092 M	38	0	7	3	0	3	1	0	7	19	32	417	2179	0	1417	1545	0	0	1	0		13.25	0	0.30	N
R02M001666	11/22/200 12/4/2002	3000 M 72683 M	36	2	5	15	3	4	0	0	4	167	30	605	780	0	989	1078	0	0	0	0		12.66	0	0.30	N
R02D005976	4/4/2002 4/11/2002	5000 M 70400 M	53	0	14	12	2	0	0	0	2	244	54	1212	693	0	1041	1124	0	0	0	0		12.86	0	0.20	N
R02A004497	12/27/200 1/10/2002	1840 M 65890 M	9	0	13	3	6	0	0	0	3	218	18	852	672	0	920	1003	0	0	1	0		11.52	0	0.10	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R03C008883	0.00	0.00					
R02M001666	0.00	0.00					
R02D005976	0.00	0.00					
R02A004497	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R03C008883	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02M001666	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02D005976	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02A004497	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

ANA LABORATORIES, INC.

641 Creek Road Bellmawr, New Jersey 08031-2409 (800) 648-2625 (856) 931-0011

SAMPLE SEVERITY **N**

UNIT/BUS # DL062 SYSTEM ENG

SAMPLE DATA			ELEMENTAL ANALYSIS — VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT																			OIL QUALITY					
LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R03C016297	3/19/2003 3/28/2003	4184 M 70076 M	28	4	7	9	3	17	0	0	3	31	99	328	1931	0	1057	1152	0	0	8	0		13.41	0	0.40	N
R02M016034	12/18/200 12/30/200	4000 M 66260 M	19	0	3	5	3	5	0	0	2	130	61	439	978	0	997	1087	0	0	0	0		13.03	0	0.30	N
R02D005974	4/4/2002 4/11/2002	5000 M 63690 M	47	0	13	7	3	6	0	0	5	213	183	1085	656	0	979	1057	0	0	0	0		18.51	0	0.10	N
R02A004494	12/12/200 1/10/2002	3661 M 58936 M	32	3	12	8	5	5	0	0	4	178	60	789	669	0	883	962	0	0	1	0		13.02	0	0.40	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R03C016297	0.00	0.00					
R02M016034	0.00	0.00					
R02D005974	0.00	0.00					
R02A004494	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R03C016297	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02M016034	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02D005974	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02A004494	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

ANA LABORATORIES, INC.

641 Creek Road Bellmawr, New Jersey 08031-2409 (800) 648-2625 (856) 931-0011

SAMPLE SEVERITY: **N**

UNIT/BUS # DL121 SYSTEM ENG

SAMPLE DATA			ELEMENTAL ANALYSIS — VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT																			OIL QUALITY					
LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R03D003924	3/27/2003 4/8/2003	3370 M 107050 M	8	0	0	4	3	4	0	0	1	20	0	312	1769	0	1152	1256	0	0	9	0		13.86	0	0.10	N
R02M000111	11/14/200 12/2/2002	3480 M 103680 M	2	0	0	0	0	0	0	0	1	131	0	974	392	0	1088	1208	0	0	0	0		11.84	0	0.00	N
R02G009845	7/10/2002 7/18/2002	4215 M 100200 M	8	0	0	3	3	0	0	0	4	140	0	581	254	0	819	893	0	0	0	0		12.73	0	0.00	N
R02B010911	2/8/2002 2/25/2002	3800 M 95985 M	15	0	4	7	0	2	0	0	5	185	0	679	395	0	812	885	0	0	0	0		12.67	0	0.20	N

LAB #	ADDITIONAL TESTS — TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R03D003924	0.00	0.00					
R02M000111	0.00	0.00					
R02G009845	0.00	0.00					
R02B010911	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R03D003924	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02M000111	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02G009845	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02B010911	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

ANA LABORATORIES, INC.

641 Creek Road Bellmawr, New Jersey 08031-2409 (800) 648-2625 (856) 931-0011

SAMPLE SEVERITY: **N**

UNIT/BUS # DL096 SYSTEM ENG

SAMPLE DATA			ELEMENTAL ANALYSIS — VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT																			OIL QUALITY					
LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R03D004619	2/13/2003 4/9/2003	4000 M 122150 M	27	5	1	2	0	18	0	0	5	143	13	884	400	0	1152	1256	0	0	3	0		12.94	0	0.20	N
R02M005822	12/2/2002 12/11/200	4000 M 118200 M	12	4	1	5	3	4	0	0	4	154	0	460	228	0	919	1002	0	0	0	0		14.27	0	0.10	N
R02J004693	8/19/2002 9/11/2002	0 114675 M	18	5	4	2	5	4	0	0	4	171	5	772	494	0	1039	1133	0	0	0	0		13.16	0	0.20	N
R02A014455	1/17/2002 1/30/2002	4000 M 106500 M	36	4	8	10	3	7	0	0	11	145	27	1058	507	0	970	1086	0	0	0	0		15.15	0	0.30	N

LAB #	ADDITIONAL TESTS — TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R03D004619	0.00	0.00					
R02M005822	0.00	0.00					
R02J004693	0.00	0.00					
R02A014455	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R03D004619	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02M005822	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02J004693	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02A014455	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

ANA LABORATORIES, INC.

641 Creek Road Bellmawr, New Jersey 08031-2409 (800) 648-2625 (856) 931-0011

SAMPLE SEVERITY **N**

UNIT/BUS # DL230 SYSTEM ENG

SAMPLE DATA			ELEMENTAL ANALYSIS VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT																				OIL QUALITY					
LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R03D004620	3/20/2003 4/9/2003	4000 M 22000 M	42	1	2	3	0	1	0	0	4	115	2	809	473	2	1174	1280	0	0	3	0		11.55	0	0.40	N
R02M005831	12/4/2002 12/11/200	4000 M 18000 M	37	4	3	2	5	6	4	0	5	148	0	474	349	0	910	992	0	0	0	0		12.14	0	0.40	N
R02J004692	11/21/200 9/11/2002	4000 M 13265 M	41	4	3	3	3	4	0	0	3	132	0	680	356	0	854	931	0	0	0	0		13.03	0	0.70	N
R02G015629	7/11/2002 7/30/2002	2800 H 9440 H	32	2	7	9	4	0	0	0	3	133	0	712	482	0	914	996	0	0	0	0		12.67	0	1.00	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R03D004620	0.00	0.00					
R02M005831	0.00	0.00					
R02J004692	0.00	0.00					
R02G015629	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R03D004620	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02M005831	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02J004692	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02G015629	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

ANA LABORATORIES, INC.

641 Creek Road Bellmawr, New Jersey 08031-2409 (800) 648-2625 (856) 931-0011

SAMPLE SEVERITY **N**

UNIT/BUS # DL158 SYSTEM ENG

SAMPLE DATA			ELEMENTAL ANALYSIS VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT																				OIL QUALITY					
LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R03E008416	4/30/2003 5/15/2003	55714 6779	22	0	1	3	3	4	0	0	1	168	0	939	648	0	1329	1449	0	0	3	0		11.42	0	0.20	N
R02K005015	10/4/2002 10/10/200	6935 M 48935 M	25	1	0	6	4	4	0	0	2	106	0	465	449	0	747	814	0	0	0	0		11.79	0	0.50	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R03E008416	0.00	0.00					
R02K005015	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R03E008416	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02K005015	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

ANA LABORATORIES, INC.

641 Creek Road Bellmawr, New Jersey 08031-2409 (800) 648-2625 (856) 931-0011

SAMPLE SEVERITY **N**

UNIT/BUS # DL120 SYSTEM ENG

SAMPLE DATA			ELEMENTAL ANALYSIS VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT																				OIL QUALITY					
LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R03F002930	5/21/2003 6/6/2003	83940 3545	15	3	5	1	3	3	0	0	4	35	0	392	886	0	1307	1425	0	0	5	0		13.82	0	0.20	N
R02M000116	11/14/200 12/2/2002	1706 M 80396 M	0	0	0	0	0	0	0	0	0	105	0	742	333	0	895	993	0	0	0	0		13.87	0	0.10	N
R02G011598	7/18/2002 7/23/2002	4165 M 78690 M	25	2	8	10	2	0	0	0	6	114	0	1003	607	0	1041	1156	0	0	0	0		13.33	0	0.10	N
R02D013785	4/22/2002 4/26/2002	2000 M 75675 M	6	0	4	2	2	0	0	0	2	167	0	636	526	0	881	960	0	0	0	0		12.85	0	0.00	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R03F002930	0.00	0.00					
R02M000116	0.00	0.00					
R02G011598	0.00	0.00					
R02D013785	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R03F002930	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02M000116	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02G011598	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02D013785	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

ANA LABORATORIES, INC.

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SAMPLE SEVERITY **N**

UNIT/BUS # DL216 SYSTEM ENG

SAMPLE DATA			ELEMENTAL ANALYSIS VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT																				OIL QUALITY					
LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R03F006066	6/3/2003 6/11/2003	0 40955	40	6	7	3	6	4	3	0	5	127	0	727	913	0	1283	1398	0	0	8	0		12.43	0	0.30	N
R02M015014	12/13/200 12/26/200	0 0	45	2	3	1	5	3	4	0	4	153	0	597	360	0	992	1081	0	0	0	0		12.50	0	0.90	N
R02J004694	8/26/2002 9/11/2002	0 0	83	4	4	4	5	4	0	0	3	112	0	723	426	0	884	964	0	0	0	0		13.01	0	0.90	N
R02J000736	8/26/2002 9/4/2002	4185 M 24605 M	26	2	3	5	3	4	0	0	3	150	0	711	290	0	895	976	0	0	0	0		12.76	0	0.70	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R03F006066	0.00	0.00					
R02M015014	0.00	0.00					
R02J004694	0.00	0.00					
R02J000736	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R03F006066	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02M015014	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02J004694	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02J000736	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

ANA LABORATORIES, INC.

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SAMPLE SEVERITY

UNIT/BUS # DL230 SYSTEM ENG

SAMPLE DATA / ELEMENTAL ANALYSIS (VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT) / OIL QUALITY

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R03H008432	8/1/2003	4000 M	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0					
	8/17/2003	27100 M																									

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R03H008432							

LAB #	ANALYSIS RECOMMENDATIONS
R03H008432	

LAB #	ANALYSIS RECOMMENDATIONS

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SAMPLE SEVERITY

UNIT/BUS # DL216 SYSTEM ENG

N

SAMPLE DATA / ELEMENTAL ANALYSIS (VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT) / OIL QUALITY

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R03H012513	8/12/2003	0	43	1	4	3	0	2	2	0	5	16	3	503	2013	0	1399	1525	0	1	6	0		13.22	0	0.40	N
	8/24/2003	0																									
R03F006066	6/3/2003	0	40	6	7	3	6	4	3	0	5	127	0	727	913	0	1283	1398	0	0	8	0		12.43	0	0.30	N
	6/11/2003	40955																									
R02M015014	12/13/200	0	45	2	3	1	5	3	4	0	4	153	0	597	360	0	992	1081	0	0	0	0		12.50	0	0.90	N
	12/26/200	0																									
R02J004694	8/26/2002	0	83	4	4	4	5	4	0	0	3	112	0	723	426	0	884	964	0	0	0	0		13.01	0	0.90	N
	9/11/2002	0																									

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R03H012513	0.00	0.00					
R03F006066	0.00	0.00					
R02M015014	0.00	0.00					
R02J004694	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R03H012513	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R03F006066	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

LAB #	ANALYSIS RECOMMENDATIONS
R02M015014	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02J004694	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

ANA LABORATORIES, INC.

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SAMPLE SEVERITY

UNIT/BUS # DL126 SYSTEM ENG

N

SAMPLE DATA			ELEMENTAL ANALYSIS VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT																			OIL QUALITY					
LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R03L008515	11/6/2003 11/17/200	3793 M 55010 M	12	0	3	2	0	2	0	0	4	18	3	400	2157	0	1701	1854	0	0	2	0		11.75	0	0.10	N
R03C006809	2/26/2003 3/12/2003	3819 M 1971 H	6	0	0	6	3	4	0	0	2	38	0	316	1434	0	951	1037	0	0	6	0		11.84	0	0.00	N
R02M000115	11/14/200 12/2/2002	3748 M 47398	12	0	7	6	0	0	0	0	5	126	0	1059	340	0	1071	1189	0	0	0	0		10.99	0	0.20	N
R02G004136	6/27/2002 7/10/2002	3800 M 43650 M	28	4	13	16	4	0	0	0	6	172	0	1716	344	0	1258	1396	0	0	0	0		11.64	0	0.20	N

LAB #	ADDITIONAL TESTS TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R03L008515	0.00	0.00					
R03C006809	0.00	0.00					
R02M000115	0.00	0.00					
R02G004136	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R03L008515	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R03C006809	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02M000115	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02G004136	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

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SAMPLE SEVERITY

UNIT/BUS # DL130 SYSTEM ENG

SAMPLE DATA			ELEMENTAL ANALYSIS VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT																			OIL QUALITY					
LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R03L009918	10/3/2003 11/19/200	105 H 2954 H	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0					

LAB #	ADDITIONAL TESTS TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R03L009918							

LAB #	ANALYSIS RECOMMENDATIONS
R03L009918	

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SAMPLE SEVERITY

UNIT/BUS # DL230 SYSTEM ENG

SAMPLE DATA / ELEMENTAL ANALYSIS (VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT) / OIL QUALITY

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R03M001102		4000 M	32	1	1	3	0	2	1	0	4	3	4	319	2213	0	1336	1472	0	0	0	0		13.37	0	0.20	N
	12/2/2003	30000 M																									
R03H008432	8/1/2003	4000 M	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0					
	8/17/2003	27100 M																									

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R03M001102	7.85	0.00	4.5000	1.0000			
R03H008432							

LAB #	ANALYSIS RECOMMENDATIONS
R03M001102	NO CORRECTIVE ACTION NEEDED! SEE SPECIAL REPORT.
R03H008432	

LAB #	ANALYSIS RECOMMENDATIONS

ANA LABORATORIES, INC.

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SAMPLE SEVERITY

N

UNIT/BUS # DL040 SYSTEM ENG

SAMPLE DATA / ELEMENTAL ANALYSIS (VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT) / OIL QUALITY

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R03M002772	11/3/2003	3000 M	38	1	9	36	0	3	1	0	5	4	31	315	2343	0	1100	1221	0	0	4	0		13.74	0	0.40	N
	12/5/2003	80000 M																									
R03C008883	3/3/2003	5000 M	38	0	7	3	0	3	1	0	7	19	32	417	2179	0	1417	1545	0	0	1	0		13.25	0	0.30	N
	3/16/2003	77092 M																									
R02M001666	11/22/200	3000 M	36	2	5	15	3	4	0	0	4	167	30	605	780	0	989	1078	0	0	0	0		12.66	0	0.30	N
	12/4/2002	72683 M																									
R02D005976	4/4/2002	5000 M	53	0	14	12	2	0	0	0	2	244	54	1212	693	0	1041	1124	0	0	0	0		12.86	0	0.20	N
	4/11/2002	70400 M																									

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R03M002772	0.00	0.00					
R03C008883	0.00	0.00					
R02M001666	0.00	0.00					
R02D005976	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R03M002772	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R03C008883	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

LAB #	ANALYSIS RECOMMENDATIONS
R02M001666	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02D005976	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

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SAMPLE SEVERITY

UNIT/BUS # DL121 SYSTEM ENG

SAMPLE DATA			ELEMENTAL ANALYSIS — VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT																				OIL QUALITY					
LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R03M003111	11/18/200 12/5/2003	0 0	13	0	2	2	0	2	1	0	5	5	3	300	2032	0	1499	1521	0	0	0	0		13.91	0	0.00	N

LAB #	ADDITIONAL TESTS: TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R03M003111	8.20	0.00	5.5000	1.0000			

LAB #	ANALYSIS RECOMMENDATIONS
R03M003111	NO CORRECTIVE ACTION NEEDED! SEE SPECIAL REPORT.

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SAMPLE SEVERITY

N

UNIT/BUS # DL216 SYSTEM ENG

SAMPLE DATA			ELEMENTAL ANALYSIS — VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT																				OIL QUALITY					
LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R03M003922	11/26/200 12/8/2003	0 47045 M	18	1	2	2	0	2	1	0	3	3	2	304	1999	0	1119	1220	0	0	4	0		16.07	0	0.30	N
R03H012513	8/12/2003 8/24/2003	0 0	43	1	4	3	0	2	2	0	5	16	3	503	2013	0	1399	1525	0	1	6	0		13.22	0	0.40	N
R03F006066	6/3/2003 6/11/2003	0 40955	40	6	7	3	6	4	3	0	5	127	0	727	913	0	1283	1398	0	0	8	0		12.43	0	0.30	N
R02M015014	12/13/200 12/26/200	0 0	45	2	3	1	5	3	4	0	4	153	0	597	360	0	992	1081	0	0	0	0		12.50	0	0.90	N

LAB #	ADDITIONAL TESTS: TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R03M003922	0.00	0.00					
R03H012513	0.00	0.00					
R03F006066	0.00	0.00					
R02M015014	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R03M003922	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R03H012513	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R03F006066	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02M015014	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

ANA LABORATORIES, INC.

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SAMPLE SEVERITY

UNIT/BUS # DL158 SYSTEM ENG

SAMPLE DATA / ELEMENTAL ANALYSIS (VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT) / OIL QUALITY

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R03M004415	12/1/2003 12/8/2003	4461 M 60175 M	23	1	2	3	0	3	1	0	5	122	5	1023	630	0	1306	1424	0	0	0	0		11.78	0	0.20	

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R03M004415	8.60	0.00	4.0000	1.0000			

LAB #	ANALYSIS RECOMMENDATIONS
R03M004415	NO CORRECTIVE ACTION NEEDED! SEE SPECIAL REPORT.

LAB #	ANALYSIS RECOMMENDATIONS

ANA LABORATORIES, INC.

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SAMPLE SEVERITY

N

UNIT/BUS # DL059 SYSTEM ENG

SAMPLE DATA / ELEMENTAL ANALYSIS (VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT) / OIL QUALITY

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R04A000544	12/10/200 1/2/2004	4000 4000	45	5	11	4	5	12	0	0	4	3	109	327	2178	0	1403	1529	0	0	7	0		12.13	0	0.20	N
R03C008872	2/25/2003 3/16/2003	91750 M 0	31	3	11	8	0	5	1	0	5	13	21	359	2032	0	1380	1504	0	0	5	0		13.37	0	0.20	N
R02M001669	11/22/200 12/4/2002	5000 86500	19	4	6	3	3	4	0	0	5	153	33	539	709	0	975	1063	0	0	0	0		14.48	0	0.00	N
R02C005872	2/14/2002 3/13/2002	2264 81365	392	1	12	15	2	2	0	0	11	158	19	988	551	0	1165	1293	0	0	0	0		11.92	0	0.00	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R04A000544	0.00	0.00					
R03C008872	0.00	0.00					
R02M001669	0.00	0.00					
R02C005872	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R04A000544	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R03C008872	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

LAB #	ANALYSIS RECOMMENDATIONS
R02M001669	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02C005872	WEAR METALS (IRON) -EXCESSIVE(CRITICAL). LUBE CONTAMINANTS -NORMAL. TAKE CORRECTIVE ACTION. DRAIN OIL IF NOT DRAINED. CHANGE FILTER IF NOT CHANGED.

ANA LABORATORIES, INC.

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SAMPLE SEVERITY

UNIT/BUS # DL075 SYSTEM ENG

N

SAMPLE DATA			ELEMENTAL ANALYSIS VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT																				OIL QUALITY					
LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R04A001574	12/10/200 1/6/2004	4000 M 60780 M	33	20	6	19	0	7	0	0	4	3	25	291	2208	0	1403	1529	0	0	3	0		13.33	0	0.00	N
R03C008876	2/25/2003 3/16/2003	4000 M 57910 M	28	3	10	32	0	6	0	0	6	17	27	387	1999	0	1366	1489	0	0	1	0		12.16	0	0.20	N
R02M001671	11/6/2002 12/4/2002	4000 M 53005 M	9	2	5	4	3	4	0	0	4	186	25	571	558	0	966	1053	0	0	0	0		12.89	0	0.00	N
R02D005973	4/4/2002 4/11/2002	3978 M 52024 M	38	0	16	15	3	5	0	0	4	244	19	1130	576	0	1031	1113	0	0	0	0		11.80	0	0.00	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R04A001574	0.00	0.00					
R03C008876	0.00	0.00					
R02M001671	0.00	0.00					
R02D005973	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R04A001574	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R03C008876	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02M001671	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02D005973	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

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SAMPLE SEVERITY

UNIT/BUS # DL427 SYSTEM ENG

SAMPLE DATA			ELEMENTAL ANALYSIS VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT																				OIL QUALITY					
LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R04A003272	12/17/200 1/8/2004	0 0	14	0	3	688	0	2	0	2	5	4	15	296	2111	0	1297	1550	0	0	2	0		0.00	0	0.20	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R04A003272	0.00	0.00	8.3500	0.0100			

LAB #	ANALYSIS RECOMMENDATIONS
R04A003272	

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SAMPLE SEVERITY

UNIT/BUS # DL006 SYSTEM ENG

SAMPLE DATA		
LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT
R04A003273	12/16/200 1/8/2004	4000 M 108478 M

ELEMENTAL ANALYSIS — VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT

Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
28	1	4	8	0	3	0	0	4	6	29	323	2298	0	1224	1566	0	0	4

OIL QUALITY					
FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
0		0.00	0	0.20	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R04A003273	0.00	0.00	11.0000	0.0100			

LAB #	ANALYSIS RECOMMENDATIONS
R04A003273	

LAB #	ANALYSIS RECOMMENDATIONS

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SAMPLE SEVERITY

UNIT/BUS # DL073 SYSTEM ENG

SAMPLE DATA		
LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT
R04A003274	12/15/200 1/8/2004	3000 104285

ELEMENTAL ANALYSIS — VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT

Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
29	6	3	6	0	7	1	0	19	33	9	500	1797	0	1271	1586	0	0	4

OIL QUALITY					
FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
0		0.00	0	0.20	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R04A003274	0.00	0.00	3.6500	0.0100			

LAB #	ANALYSIS RECOMMENDATIONS
R04A003274	

LAB #	ANALYSIS RECOMMENDATIONS

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SAMPLE SEVERITY **N**

UNIT/BUS # DL109 SYSTEM ENG

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
R04A003911	12/22/200 1/9/2004	4290 M 59260 M	17	2	2	1	0	3	0	0	3	2	8	328	2321	0	1048	1142	0	0	6
R02M007478	12/6/2002 12/13/200	4037 M 50825 M	33	0	1	1	2	3	0	0	4	129	0	524	295	0	983	1071	0	0	0
R02E006591	5/8/2002 5/14/2002	4813 M 46788 M	34	8	6	7	3	6	0	0	6	108	0	762	359	0	1041	1156	0	0	0

SAMPLE DATA; ELEMENTAL ANALYSIS: VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT

OIL QUALITY

LAB #	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R04A003911	0		12.98	0	0.10	N
R02M007478	0		12.24	0	0.40	N
R02E006591	0		12.43	0	0.00	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R04A003911	0.00	0.00					
R02M007478	0.00	0.00					
R02E006591	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R04A003911	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02M007478	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02E006591	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

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SAMPLE SEVERITY **N**

UNIT/BUS # DL159 SYSTEM ENG

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
R04A003912	12/11/200 1/9/2004	8363 M 66497 M	20	1	3	8	0	4	1	0	4	10	8	406	2088	0	960	1046	0	0	5
R03C004265	2/27/2003 3/9/2003	6909 M 58134 M	29	0	3	8	3	4	0	0	4	181	0	756	451	0	875	954	0	0	6
R02F007302	6/3/2002 6/17/2002	4476 M 51222 M	32	0	0	2	4	0	0	0	2	162	0	821	691	0	897	978	0	0	0

SAMPLE DATA; ELEMENTAL ANALYSIS: VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT

OIL QUALITY

LAB #	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R04A003912	0		11.98	0	0.20	N
R03C004265	0		10.61	0	0.40	N
R02F007302	0		11.88	0	0.20	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R04A003912	0.00	0.00					
R03C004265	0.00	0.00					
R02F007302	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R04A003912	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R03C004265	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02F007302	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

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SAMPLE SEVERITY: **N**

UNIT/BUS # DL083 SYSTEM ENG

SAMPLE DATA

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT
R04A012010	1/5/2004 1/21/2004	0 101240 M
R03A010054	1/10/2003 1/17/2003	0 96960 M
R02E006617	5/7/2002 5/14/2002	0 91400 M

ELEMENTAL ANALYSIS – VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT

LAB #	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
R04A012010	14	5	1	3	0	8	0	0	5	10	7	425	2105	0	917	1018	0	0	4
R03A010054	17	4	1	3	0	3	0	0	3	105	5	949	408	0	1000	1090	0	1	0
R02E006617	16	7	4	5	3	4	0	0	5	124	0	731	330	0	987	1096	0	0	0

OIL QUALITY

LAB #	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R04A012010	0		12.96	0	0.20	N
R03A010054	0		12.42	0	0.20	N
R02E006617	0		11.44	0	0.00	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R04A012010	0.00	0.00					
R03A010054	0.00	0.00					
R02E006617	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R04A012010	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R03A010054	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02E006617	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

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SAMPLE SEVERITY: **N**

UNIT/BUS # DL130 SYSTEM ENG

SAMPLE DATA

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT
R04A012312	1/12/2004 1/21/2004	194 H 3148 H
R03L009918	10/3/2003 11/19/200	105 H 2954 H

ELEMENTAL ANALYSIS – VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT

LAB #	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
R04A012312	21	0	2	2	0	3	1	0	7	4	7	348	2398	3	1153	1291	0	0	0
R03L009918	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

OIL QUALITY

LAB #	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R04A012312	0		0.00	0	0.20	N
R03L009918	0					

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R04A012312	0.00	0.00	5.2500	2.1500			
R03L009918							

LAB #	ANALYSIS RECOMMENDATIONS
R04A012312	NO CORRECTIVE ACTION NEEDED!
R03L009918	

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SAMPLE SEVERITY: **N**

UNIT/BUS # DL062 SYSTEM ENG

SAMPLE DATA

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT
R04A016444	1/6/2004 1/27/2004	4000 M 20000 M

ELEMENTAL ANALYSIS — VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT

Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
43	14	12	26	0	33	2	0	7	8	92	322	2683	0	1385	1530	0	0	4

OIL QUALITY

FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
0		14.33	0	0.20	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R04A016444	0.00	0.00	15.2000	0.0200			

LAB #	ANALYSIS RECOMMENDATIONS
R04A016444	NO CORRECTIVE ACTION NEEDED!

LAB #	ANALYSIS RECOMMENDATIONS

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SAMPLE SEVERITY: **C**

UNIT/BUS # DL426 SYSTEM ENG

SAMPLE DATA

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT
R04A016445	12/31/200 1/27/2004	3930 M 14738 M

ELEMENTAL ANALYSIS — VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT

Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
22	0	3	1054	0	2	0	1	7	4	19	270	2000	0	1204	1365	0	0	4

OIL QUALITY

FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
0		11.99	0	0.20	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R04A016445	0.00	0.00	12.7000	0.0200			

LAB #	ANALYSIS RECOMMENDATIONS
R04A016445	WEAR METALS (COPPER) -EXCESSIVE(CRITICAL). LUBE CONTAMINANTS VISCOSITY LOW DRAIN OIL IF NOT DRAINED. CHANGE FILTER IF NOT CHANGED.

LAB #	ANALYSIS RECOMMENDATIONS

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SAMPLE SEVERITY: **N**

UNIT/BUS # DB031 SYSTEM ENG

SAMPLE DATA			ELEMENTAL ANALYSIS VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT																			OIL QUALITY					
LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R04B015953	2/13/2004	4079 M	13	1	11	9	8	0	0	0	21	6	0	331	1109	0	1210	1343	0	0	0	0		10.51	0	0.00	N
	2/25/2004	4079 M																									

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R04B015953	0.00	0.00					

ADDITIONAL TESTS

LAB #	ANALYSIS RECOMMENDATIONS
R04B015953	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

LAB #	ANALYSIS RECOMMENDATIONS

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SAMPLE SEVERITY: **N**

UNIT/BUS # DL126 SYSTEM ENG

SAMPLE DATA			ELEMENTAL ANALYSIS VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT																			OIL QUALITY					
LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R04B016641	2/3/2004	3937 M	10	0	3	2	0	2	0	0	3	4	3	297	2150	2	1198	1306	0	0	1	0		14.59	0	0.00	N
	2/25/2004	58947 M																									

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R04B016641	0.00	0.00	3.6000	0.0100			

LAB #	ANALYSIS RECOMMENDATIONS
R04B016641	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

LAB #	ANALYSIS RECOMMENDATIONS

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SAMPLE SEVERITY: **N**

UNIT/BUS # DL158 SYSTEM ENG

SAMPLE DATA

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	
R04C003149	2/26/2004	4744	M
	3/5/2004	64919	M
R03E008416	4/30/2003	55714	
	5/15/2003	6779	
R02K005015	10/4/2002	6935	M
	10/10/200	48935	M

ELEMENTAL ANALYSIS
VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT

LAB #	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
R04C003149	18	0	7	4	12	4	0	0	3	17	0	429	2012	0	1632	1779	0	0	13
R03E008416	22	0	1	3	3	4	0	0	1	168	0	939	648	0	1329	1449	0	0	3
R02K005015	25	1	0	6	4	4	0	0	2	106	0	465	449	0	747	814	0	0	0

OIL QUALITY

LAB #	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R04C003149	0		11.86	0	0.10	N
R03E008416	0		11.42	0	0.20	N
R02K005015	0		11.79	0	0.50	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R04C003149	0.00	0.00					
R03E008416	0.00	0.00					
R02K005015	0.00	0.00					

ANALYSIS RECOMMENDATIONS

LAB #	ANALYSIS RECOMMENDATIONS
R04C003149	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R03E008416	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02K005015	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

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SAMPLE SEVERITY: **N**

UNIT/BUS # DL096 SYSTEM ENG

SAMPLE DATA

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	
R04C011795	12/16/200	4000	M
	3/18/2004	131590	M

ELEMENTAL ANALYSIS
VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT

LAB #	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
R04C011795	17	5	1	2	0	10	0	0	6	4	9	373	2339	0	1369	1492	0	0	4

OIL QUALITY

LAB #	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R04C011795	0		13.62	0	0.20	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R04C011795	0.00	0.00	2.7500	0.0100			

ANALYSIS RECOMMENDATIONS

LAB #	ANALYSIS RECOMMENDATIONS
R04C011795	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

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SAMPLE SEVERITY

UNIT/BUS # DL121 SYSTEM ENG

SAMPLE DATA

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT
R04C015511	3/4/2004 3/24/2004	3975 115060
R03M003111	11/18/200 12/5/2003	0 0

ELEMENTAL ANALYSIS — VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT

LAB #	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
R04C015511	16	0	3	2	0	2	1	0	5	2	5	253	2018	0	1391	1516	0	0	0
R03M003111	13	0	2	2	0	2	1	0	5	5	3	300	2032	0	1499	1521	0	0	0

OIL QUALITY

LAB #	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R04C015511	0		0.00	0	0.00	N
R03M003111	0		13.91	0	0.00	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R04C015511	0.00	0.00	5.1500	0.0100			
R03M003111	8.20	0.00	5.5000	1.0000			

LAB #	ANALYSIS RECOMMENDATIONS
R04C015511	NO CORRECTIVE ACTION NEEDED!
R03M003111	NO CORRECTIVE ACTION NEEDED! SEE SPECIAL REPORT.

LAB #	ANALYSIS RECOMMENDATIONS

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SAMPLE SEVERITY

N

UNIT/BUS # DB031 SYSTEM ENG

SAMPLE DATA

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT
R04C015512	3/11/2004 3/24/2004	0 7946

ELEMENTAL ANALYSIS — VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT

LAB #	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
R04C015512	13	1	1	4	0	3	1	0	17	2	5	310	2234	0	1563	1704	0	0	0

OIL QUALITY

LAB #	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R04C015512	0		0.00	0	0.00	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R04C015512	0.00	0.00	1.4500	0.0100			

LAB #	ANALYSIS RECOMMENDATIONS
R04C015512	NO CORRECTIVE ACTION NEEDED!

LAB #	ANALYSIS RECOMMENDATIONS

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SAMPLE SEVERITY **N**

UNIT/BUS # DL230 SYSTEM ENG

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R04C015513	3/10/2004 3/24/2004	4000 34800	31	1	2	3	0	2	1	0	5	1	4	291	2223	0	1469	1601	0	0	0	0		0.00	0	0.00	N
R03M001102	 12/2/2003	4000 M 30000 M	32	1	1	3	0	2	1	0	4	3	4	319	2213	0	1336	1472	0	0	0	0		13.37	0	0.20	N
R03H008432	8/1/2003 8/17/2003	4000 M 27100 M	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0					

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R04C015513	0.00	0.00	1.8000	0.0100			
R03M001102	7.85	0.00	4.5000	1.0000			
R03H008432							

LAB #	ANALYSIS RECOMMENDATIONS
R04C015513	NO CORRECTIVE ACTION NEEDED!
R03M001102	NO CORRECTIVE ACTION NEEDED! SEE SPECIAL REPORT.

LAB #	ANALYSIS RECOMMENDATIONS
R03H008432	

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SAMPLE SEVERITY **N**

UNIT/BUS # DL040 SYSTEM ENG

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R04C015514	2/20/2004 3/24/2004	4230 84462	22	0	4	20	0	4	1	0	4	2	14	280	2122	0	1332	1452	0	0	0	0		0.00	0	0.00	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R04C015514	0.00	0.00	3.5000	0.0100			

LAB #	ANALYSIS RECOMMENDATIONS
R04C015514	NO CORRECTIVE ACTION NEEDED!

LAB #	ANALYSIS RECOMMENDATIONS

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SAMPLE SEVERITY: **N**

UNIT/BUS # DB031 SYSTEM ENG

SAMPLE DATA

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT
R04D014325	4/14/2004	5444
	4/23/2004	13390
R04C015512	3/11/2004	0
	3/24/2004	7946

ELEMENTAL ANALYSIS
VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT

LAB #	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
R04D014325	7	0	0	4	3	4	0	0	6	4	0	241	1781	0	1505	1640	0	0	8
R04C015512	13	1	1	4	0	3	1	0	17	2	5	310	2234	0	1563	1704	0	0	0

OIL QUALITY

LAB #	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R04D014325	0		0.00	0	0.00	N
R04C015512	0		0.00	0	0.00	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R04D014325	0.00	0.00	4.8300	2.7000			
R04C015512	0.00	0.00	1.4500	0.0100			

LAB #	ANALYSIS RECOMMENDATIONS
R04D014325	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R04C015512	NO CORRECTIVE ACTION NEEDED!

LAB #	ANALYSIS RECOMMENDATIONS

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SAMPLE SEVERITY: **N**

UNIT/BUS # DL130 SYSTEM ENG

SAMPLE DATA

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT
R04D014326	4/1/2004	0
	4/23/2004	74655
R04A012312	1/12/2004	194 H
	1/21/2004	3148 H
R03L009918	10/3/2003	105 H
	11/19/200	2954 H

ELEMENTAL ANALYSIS
VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT

LAB #	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
R04D014326	10	0	2	4	6	4	0	0	3	7	0	294	2251	0	1580	1722	0	0	10
R04A012312	21	0	2	2	0	3	1	0	7	4	7	348	2398	3	1153	1291	0	0	0
R03L009918	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

OIL QUALITY

LAB #	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R04D014326	0		0.00	0	0.00	N
R04A012312	0		0.00	0	0.20	N
R03L009918	0					

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R04D014326	0.00	0.00	4.8500	2.7000			
R04A012312	0.00	0.00	5.2500	2.1500			
R03L009918							

LAB #	ANALYSIS RECOMMENDATIONS
R04D014326	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R04A012312	NO CORRECTIVE ACTION NEEDED!

LAB #	ANALYSIS RECOMMENDATIONS
R03L009918	

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SAMPLE SEVERITY **N**

UNIT/BUS # DL109 SYSTEM ENG

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R04D017849	4/20/2004 4/28/2004	6245 H 65510 H	20	3	2	4	5	7	0	0	5	7	0	307	2432	0	1342	1463	0	0	10	0		13.62	0	0.00	N
R04A003911	12/22/200 1/9/2004	4290 M 59260 M	17	2	2	1	0	3	0	0	3	2	8	328	2321	0	1048	1142	0	0	6	0		12.98	0	0.10	N
R02M007478	12/6/2002 12/13/200	4037 M 50825 M	33	0	1	1	2	3	0	0	4	129	0	524	295	0	983	1071	0	0	0	0		12.24	0	0.40	N
R02E006591	5/8/2002 5/14/2002	4813 M 46788 M	34	8	6	7	3	6	0	0	6	108	0	762	359	0	1041	1156	0	0	0	0		12.43	0	0.00	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R04D017849	0.00	0.00					
R04A003911	0.00	0.00					
R02M007478	0.00	0.00					
R02E006591	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R04D017849	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R04A003911	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02M007478	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02E006591	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

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SAMPLE SEVERITY **N**

UNIT/BUS # DB031 SYSTEM ENG

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R04E007127	5/5/2004 5/12/2004	3268 M 16658 M	7	0	0	1	0	1	1	0	6	1	4	311	1945	0	1215	1324	0	0	1	0		15.24	0	0.00	N
R04D014325	4/14/2004 4/23/2004	5444 13390	7	0	0	4	3	4	0	0	6	4	0	241	1781	0	1505	1640	0	0	8	0		0.00	0	0.00	N
R04C015512	3/11/2004 3/24/2004	0 7946	13	1	1	4	0	3	1	0	17	2	5	310	2234	0	1563	1704	0	0	0	0		0.00	0	0.00	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R04E007127	0.00	0.00	3.8000	2.2000			
R04D014325	0.00	0.00	4.8300	2.7000			
R04C015512	0.00	0.00	1.4500	0.0100			

LAB #	ANALYSIS RECOMMENDATIONS
R04E007127	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R04D014325	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R04C015512	NO CORRECTIVE ACTION NEEDED!

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SAMPLE SEVERITY **N**

UNIT/BUS # DL216 SYSTEM ENG

SAMPLE DATA / ELEMENTAL ANALYSIS (VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT) / OIL QUALITY

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R04E010330	5/5/2004 5/18/2004	5000 M 52055 M	36	0	0	4	4	8	0	0	10	6	0	319	2305	0	1336	1456	0	0	7	0		10.17	0	0.60	N
R03M003922	11/26/200 12/8/2003	0 47045 M	18	1	2	2	0	2	1	0	3	3	2	304	1999	0	1119	1220	0	0	4	0		16.07	0	0.30	N
R03H012513	8/12/2003 8/24/2003	0 0	43	1	4	3	0	2	2	0	5	16	3	503	2013	0	1399	1525	0	1	6	0		13.22	0	0.40	N
R03F006066	6/3/2003 6/11/2003	0 40955	40	6	7	3	6	4	3	0	5	127	0	727	913	0	1283	1398	0	0	8	0		12.43	0	0.30	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R04E010330	0.00	0.00					
R03M003922	0.00	0.00					
R03H012513	0.00	0.00					
R03F006066	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R04E010330	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R03M003922	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R03H012513	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R03F006066	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

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SAMPLE SEVERITY **N**

UNIT/BUS # DL006 SYSTEM ENG

SAMPLE DATA / ELEMENTAL ANALYSIS (VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT) / OIL QUALITY

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R04E011330	 5/19/2004	0 0	15	1	4	5	0	2	1	0	3	2	32	295	2284	0	1149	1252	0	0	2	0		0.00	0	0.00	N
R04A003273	12/16/200 1/8/2004	4000 M 108478 M	28	1	4	8	0	3	0	0	4	6	29	323	2298	0	1224	1566	0	0	4	0		0.00	0	0.20	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R04E011330	0.00	0.00	7.5000	3.3000			
R04A003273	0.00	0.00	11.0000	0.0100			

LAB #	ANALYSIS RECOMMENDATIONS
R04E011330	NO CORRECTIVE ACTION NEEDED!
R04A003273	

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SAMPLE SEVERITY: **N**

UNIT/BUS # DL040 SYSTEM ENG

SAMPLE DATA

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT
R04E011332	 5/19/2004	0 85622 M
R04C015514	2/20/2004 3/24/2004	4230 84462

ELEMENTAL ANALYSIS – VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT

LAB #	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
R04E011332	9	1	7	15	0	3	0	0	3	1	15	274	2325	0	1153	1257	0	0	0
R04C015514	22	0	4	20	0	4	1	0	4	2	14	280	2122	0	1332	1452	0	0	0

OIL QUALITY

LAB #	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R04E011332	0		0.00	0	0.00	N
R04C015514	0		0.00	0	0.00	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R04E011332	0.00	0.00	4.3000	0.8000			
R04C015514	0.00	0.00	3.5000	0.0100			

LAB #	ANALYSIS RECOMMENDATIONS
R04E011332	NO CORRECTIVE ACTION NEEDED!
R04C015514	NO CORRECTIVE ACTION NEEDED!

LAB #	ANALYSIS RECOMMENDATIONS

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SAMPLE SEVERITY: **A**

UNIT/BUS # DL073 SYSTEM ENG

SAMPLE DATA

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT
R04E011333	5/12/2004 5/19/2004	0 107755 M
R04A003274	12/15/200 1/8/2004	3000 104285

ELEMENTAL ANALYSIS – VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT

LAB #	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium
R04E011333	24	4	19	60	0	14	1	0	10	3	30	357	2842	0	1253	1366	0	0	0
R04A003274	29	6	3	6	0	7	1	0	19	33	9	500	1797	0	1271	1586	0	0	4

OIL QUALITY

LAB #	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R04E011333	0		0.00	0	0.00	N
R04A003274	0		0.00	0	0.20	N

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R04E011333	0.00	0.00	7.2000	2.2000			
R04A003274	0.00	0.00	3.6500	0.0100			

LAB #	ANALYSIS RECOMMENDATIONS
R04E011333	WEAR METALS (COPPER) (ALUMINUM) -MILDLY ABOVE NORMAL. LUBE CONTAMINANTS -NORMAL. FOLLOW ESTABLSIHED MAINTENANCE PROCEDURES.
R04A003274	

LAB #	ANALYSIS RECOMMENDATIONS

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SAMPLE SEVERITY

N

UNIT/BUS # DL062 SYSTEM ENG

SAMPLE DATA			ELEMENTAL ANALYSIS VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT																			OIL QUALITY					
LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R04E011334	5/12/2004	0	20	8	4	22	0	18	1	0	5	3	72	296	2320	0	1152	1256	0	0	0	0		0.00	0	0.00	N
	5/19/2004	73765 M																									
R04A016444	1/6/2004	4000 M	43	14	12	26	0	33	2	0	7	8	92	322	2683	0	1385	1530	0	0	4	0		14.33	0	0.20	N
	1/27/2004	20000 M																									

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R04E011334	0.00	0.00	12.3000	0.0100			
R04A016444	0.00	0.00	15.2000	0.0200			

LAB #	ANALYSIS RECOMMENDATIONS
R04E011334	NO CORRECTIVE ACTION NEEDED!
R04A016444	NO CORRECTIVE ACTION NEEDED!

LAB #	ANALYSIS RECOMMENDATIONS

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SAMPLE SEVERITY

N

UNIT/BUS # DL075 SYSTEM ENG

SAMPLE DATA			ELEMENTAL ANALYSIS VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT																			OIL QUALITY					
LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R04E011336		0	16	5	4	16	0	4	1	0	5	1	11	305	2387	0	1089	1187	0	0	0	0		0.00	0	0.00	N
	5/19/2004	64240 M																									

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R04E011336	0.00	0.00	5.2000	2.4000			

LAB #	ANALYSIS RECOMMENDATIONS
R04E011336	NO CORRECTIVE ACTION NEEDED!

LAB #	ANALYSIS RECOMMENDATIONS

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SAMPLE SEVERITY

N

UNIT/BUS # DL059 SYSTEM ENG

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R04E011337	5/12/2004	0	49	4	13	10	0	12	1	0	7	2	68	307	2407	0	1419	1556	0	0	0	0		0.00	0	0.00	N
	5/19/2004	98440 M																									

SAMPLE DATA / ELEMENTAL ANALYSIS: VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT / OIL QUALITY

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R04E011337	0.00	0.00	6.5000	2.8000			

LAB #	ANALYSIS RECOMMENDATIONS
R04E011337	NO CORRECTIVE ACTION NEEDED!

LAB #	ANALYSIS RECOMMENDATIONS

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SAMPLE SEVERITY

UNIT/BUS # DL126 SYSTEM ENG

LAB #	DATE TAKEN/ TESTED	HRS/MI OIL UNIT	Iron	Chromium	Lead	Copper	Tin	Aluminum	Nickel	Silver	Silicon	Boron	Sodium	Magnesium	Calcium	Barium	Phosphorus	Zinc	Titanium	Vanadium	Potassium	FUEL	VISCOSITY @ 40C	VISCOSITY @ 100C	WATER	SOLIDS	GLYCOL
R04F001735	5/28/2004	4000 M	7	0	0	5	4	4	0	0	5	4	0	292	1061	0	1209	888	0	0	19	0			0	0.00	N
	6/2/2004	62790 M																									
R03L008515	11/6/2003	3793 M	12	0	3	2	0	2	0	0	4	18	3	400	2157	0	1701	1854	0	0	2	0		11.75	0	0.10	N
	11/17/200	55010 M																									
R03C006809	2/26/2003	3819 M	6	0	0	6	3	4	0	0	2	38	0	316	1434	0	951	1037	0	0	6	0		11.84	0	0.00	N
	3/12/2003	1971 H																									
R02M000115	11/14/200	3748 M	12	0	7	6	0	0	0	0	5	126	0	1059	340	0	1071	1189	0	0	0	0		10.99	0	0.20	N
	12/2/2002	47398																									

SAMPLE DATA / ELEMENTAL ANALYSIS: VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT / OIL QUALITY

ADDITIONAL TESTS

LAB #	TBN	TAN	OXIDATION	NITRATION	SMALL WEAR PARTICLES	LARGE WEAR PARTICLES	VISCOSITY INDEX
R04F001735							
R03L008515	0.00	0.00					
R03C006809	0.00	0.00					
R02M000115	0.00	0.00					

LAB #	ANALYSIS RECOMMENDATIONS
R04F001735	
R03L008515	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.

LAB #	ANALYSIS RECOMMENDATIONS
R03C006809	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.
R02M000115	ANALYSIS INDICATES OVERALL SATISFACTORY CONDITIONS.