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TECHNICAL REPORT

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FINAL TEST - OPTIMIZATING OIL CHANGE INTERVALS FOR NAVY SUPPORT VEHICLES

by

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ABSTRACT

This report "Optimizing Oil Change Intervals for Navy Support Vehicles" documents efforts in determining the feasibility of using Bypass filter and in-line oil sensor for extending oil change intervals. Eight (8) Navy non-tactical or support vehicles were evaluated, some were equipped with a bypass filter or an oil sensor, and two with no bypass filter installed which served as a "control". After a period of just over three years, only one vehicle with bypass filter showed excessive oil wear and most likely due to bad or worn out engine. And one vehicle with no bypass filter lasted more than three years without the need for oil change. It is therefore inconclusive to the true effectiveness of the bypass filters to extend oil life. But more importantly, the economics of installing this technology even if it was effective is not favorable or practical due to the extra efforts required to monitor oil condition when it has past the normal period.

An oil sensor was necessary to quickly determine the oil condition before oil change could be extended. The in-line oil sensor (by VSI) tested, showed good correlation with laboratory test results. However, its application can only be warranted for larger oil capacity vehicles with cautions used in installing the oil sensor underneath the vulnerable oil pan.

EXECUTIVE SUMMARY

This report documents the test and demonstration of an oil bypass filter technology to reduce operational cost and oily waste generated at Navy vehicle maintenance facilities. Eight (8) Navy support vehicles were tested for over a 3 year period, from Aug 2003 through Nov 2006. During the early part of the demonstration, it was determined that an on-site or in-line oil sensor, which could indicate the true condition of the oil, was needed for faster feedback.

The VSI in-line oil sensor provides current ongoing information regarding the status and condition of the oil. It allows users to quickly assess the need for oil changes and could extend oil change intervals. And based on these reported results, the readout is typically realistic; however, further testing would better verify its use, applicability and accuracy.

The oil bypass test showed there is not a discernable difference in oil degradation as measured by oxidation, TBN, viscosity or soot between the diesel vehicles with bypass oil filters and the control vehicles (with no filters). The use of bypass filters failed to show that it could economically extend the life of the oil. These results would indicate that bypass oil filters may not be a viable or needed option for DOD operated vehicles. But more importantly, the economics of installing this technology even if it was effective is not favorable or practical due to the extra efforts required to monitor oil condition when it has past the normal period.

However, it may be possible to safely extend oil change intervals from once per year to once every other year by simply monitoring the oil quality or condition. Incorporating this type of oil change interval and management could provide cost savings in procurement and disposal.

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1.0 INTRODUCTION

The US Navy disposes of over 280 thousand gallons of used oil annually from vehicle maintenance activities at a cost of about $1M/yr, representing the second largest waste stream from Navy shore facilities. The Naval Facilities Engineering Service Center (NAVFAC ESC) was tasked by Naval Facilities as part of the Pollution Prevention Abatement Program (0817) to find a technology or better management practice to reduce and minimize this abundant and sometimes hazardous waste (e.g. under California law).

Bypass filter technology has been promoted to prolong engine oil life and minimize waste oil generation, making it a viable option for a significant number of applications. Bypass filters used in conjunction with traditional full-flow oil filters can remove smaller contaminant particles (1 micron or less). The use of bypass filters has been said to increase oil change intervals to over 100,000 miles in some applications, and double or triple the oil change intervals in other engines. However, these are mostly from manufacturer's claims and actual applicability/practicability for DOD agencies warrants further investigation.

In addition, it has been promoted that an in-line oil analysis system can further decrease oil change intervals by providing constant up-to-date information about the oil condition. Many of these sensors measure oil oxidation and breakdown, providing a means to determine the oil degradation. There is little research or effort in utilizing this technology in the DOD, but further investigation could provide a cost savings means to extending oil change intervals.

This project evaluated the effectiveness of bypass filter and in-line oil analysis systems on reducing Navy major waste streams and operational costs.

2.0 PROBLEM STATEMENT

The Navy operates a large number of support vehicles (e.g. non-military trucks, vans, and cars) that require regular and periodic maintenance. Oil changes for these vehicles are currently guided by scheduled time intervals or numbers of miles driven by the specific vehicle, and not by the quality or condition of the engine oil. The current Navy standard is to change oil once a year or follow the manufacturers' recommended schedule of 3,500 to 5,000 miles depending on the type of vehicle. This schedule maintenance is not the most cost effective and environmentally friendly option because it tends to be on the conservative side. Optimizing oil change intervals based on the condition or quality of the oil has the potential to significantly reduce vehicle operational, maintenance, and hazardous waste disposal costs.

3.0 OBJECTIVES

The objective of this project was to test and evaluate bypass filter technology coupled with an in-line oil analysis system. Specific objectives include:

- Determine bypass filter technology's effectiveness in reducing oil degradation.
- Determine methodology for implementation
- Determine the accuracy of the in-line oil analysis system by comparing to lab analyses.
- Determine in-line oil analysis system's applicability in extending oil change intervals.

- Evaluate the Navy's current scheduled oil change practice and determine if the intervals could be extended.

4.0 BACKGROUND

4.1 DOD Needs

There are approximately 35,000 non-tactical or support vehicles in the Navy (NOTE: approximately one third (1/3) of these vehicles are GSA or contractor owned and maintained). Oil change schedule for all these vehicles is based on the number of miles driven or once per year regardless of the oil condition. Maintenance is performed at numerous large Navy vehicle maintenance facilities that performed various repairs and other preventive maintenance procedures. GSA vehicles are maintained by people outside the Navy or private sector.

At the Public Works Center, San Diego, where the test evaluation was performed, engine oil changes are performed annually following the vehicle's operations procedure manual (OPM) schedule. Changing oil based on condition could extend the oil change interval, while still satisfying the Original Equipment Manufacturer (OEM) engine warranty as long as one could prove the oil is still in good condition. While it would be possible to collect oil samples on a regular basis and send them offsite for a laboratory analysis, the turnaround time and cost is unacceptable with current operational requirements.

Around the year 2001, bypass filtration was installed in approximately 250 vehicles at MCB Camp Pendleton as part of a Naval Air Warfare Center study. However, sending the oil samples to a remote laboratory for analysis proved to not be cost effective or practical. An onboard oil analysis system here could have been beneficial in reducing laboratory costs, oil and oil filter change intervals, and oil and oil filter procurement and disposal costs.

Therefore, a simple onsite analysis system that could be operated by current maintenance personnel with minimal additional training and cost would be preferable.

4.2 Technology Description

There are several manufacturers with technologies that claim to extend oil change intervals. NAVFAC ESC did extensive research, including the Navy "Sources Announcement", to solicit outside sectors for their technologies. The technologies range from: synthetic oil, bypass filters, and vortex full flow filters, to using onsite oil condition monitoring systems. After careful evaluation and due to limited project funds, two technologies; a bypass filter and an oil condition monitor, were selected for demonstration and validation for applicability.

4.2.1 Bypass Filter

Removing and controlling contamination of oil while in use can only be accomplished by filtration. Bypass filters used in conjunction with traditional full-flow oil filters can remove smaller contaminant particulates (1 micron or less) where as typical full-flow filter removes particles 40 to 60 microns in size. Bypass filters have been publicized by many manufacturers to substantially increase the intervals between oil changes from as much as 2 to 10 times. There are about a dozen or so bypass manufacturers out there with similar aspect of the technology but some have unique features such as additive packages and heating chambers which adds substantial cost to the unit. Based on costs, design simplicity and claimed performance, the OilGuard Bypass Oil Filter was chosen for this demonstration.

The OilGuard bypass filter (see Figure 1) is a depth filter made of an interlocking pattern of cotton fibers giving 1 micron filtration. The pattern makes up hundreds of identical, tapered and decreasing in size, spiral passageways. Larger particles are filtered near the outside, while smaller particles are captured in the inner portions. The element is housed in a steel and aluminum container that mounts to the vehicle. The only maintenance is changing the replacement element inside the filter.

Figure 1. Oil Guard Bypass Filter

4.2.2 Oil Condition Monitor Systems

An oil sensor or in-shop oil condition monitoring system is required for any maintenance program extending oil change intervals. As mentioned earlier, it must be proven that oil is still in good condition to extend oil change intervals. Therefore, an oil condition monitoring system must be used in conjunction with any technology (eg. bypass filter) to give the user a real time oil condition quality.

At the beginning of the test program, an oil sensor by Lubrisensor (see Figure 2) was used as way to quickly test the oil condition. This unit and most oil condition monitoring system are based on the dielectric constant of the oil. This type of sensor did not provide a very accurate condition reading of the oil as explained below.

The Lubrisensor provided false readings. For example, when water or fuel inadvertently mixed with oil, the Lubrisensor reading went from “bad” oil condition (high dielectric reading) to “normal”. It is not possible for the oil condition to get better as it ages or after it has been subjected through loading conditions. It is because of this that dielectric readings based on oil

Figure 2. Lubrisensor Oil Monitor

conductivity alone are not sufficient in determining oil condition. The use of the Lubrisensor instrumentation was terminated after one year of testing due to false and unreliable readings.

The Voelker Sensors Inc. (VSI) oil analysis system (see Figure 3) was selected for this demonstration due to its unique design. The test site was at a large Navy vehicle maintenance facility - PWC Transportation Department, NAVSTA San Diego. The Oil Advantage by Voelker Sensors Inc.(VSI) is an on-board system that determines oil quality based on a number of inputs from the oil pan. The sensor element (Figure 4) is mounted in the drain pan and the display unit is mounted in the cab.

Figure 3. VSI Display Unit

Figure 4. VSI Sensor Element

The VSI Oil Advantage sensor element (Figure 4) measures three parameters: temperature, oil conductivity, and conductivity of a charged polymeric bead matrix, which provides information about soot contamination, the oxidative conditions and the amount of additive depletion. One major advantage of this unit is the capability to read both oil conductivity and oil additive content which have opposing effect on conductivity. This avoids many false readings encountered with typical dielectric type sensors. The signals are processed by a computer in the display unit which provides a simple LED readout based on oxidation, oil quality, additive depletion, conductivity and temperature. It combines the two-step method of sampling and analysis into a single automated process by continuously measuring the indicators of oil wear.

5.0 TEST PLAN

A test plan was developed and approved by the users (Navy PWC Transportation Department San Diego) in order to evaluate the effectiveness of bypass filter technology and onsite oil analysis system in comparison to the current time-based oil change (see Appendix-A for the Test Plan). Data was collected and evaluated to determine the overall effectiveness and applicability of both units in extending oil change intervals and in reducing disposal of used oil and oil filters. Emphasis was placed on the system's performance, optimizing the oil change intervals, and integrating with existing maintenance procedures.

5.1 Special Consideration/Assumptions

In order to extend the oil change interval past the one year normal period, the actual oil condition has to be known. The user or person in charge of vehicle maintenance needs assurance that the oil is still good.

Off-site analysis is available through commercial laboratories that specialize in engine oil analysis. However, this is not a viable option due to the costs and the turnaround times associated with off-site analysis. Implementation of an onsite, full-scale laboratory for these analyses might solve turnaround problem, but would be impractical from both personnel training and cost perspectives. A reduced-scale analysis system or a handheld unit that could be operated onsite by regular maintenance personnel with minimal additional training would be preferable from the above, but none has proven to be accurate (Ref. 1). This type of unit involves proper collection and sampling techniques which is still very labor extensive (Ref. 2.). An in-line oil condition analysis system that could be operated with minimal operator or user's intervention and cost effective is therefore required.

5.2 Test Description

NAVFAC ESC personnel collected data about once per month, working closely with PWC personnel to provide the best results possible. Comments from users were solicited for any events relating to maintenance/repairs or performance related issues of the test vehicles. This included but was not limited to topping off of oil. An example of the data log sheet used is provided in Appendix-B. It includes dates of any repairs or maintenance, a description of the repair work completed, estimated number of hours to complete the repair, and a list of parts and consumables needed for the repair. A bright yellow label was put on the inside of the vehicle's cab and engine compartment to call or notify NAVFAC ESC if any above mentioned is performed.

Eight (8) PWC vehicles were used in the demonstration to test the bypass filter technology and the in-line oil sensor. Six (6) were equipped with the bypass filtration system and seven (7) were equipped with the in-line sensors (VSI). One vehicle had neither a bypass filter nor an in-line sensor. Table 5.2.1 lists the vehicles and their corresponding installed technologies.

Table 5.2.1 Test vehicles and corresponding installed technologies.

Manufacturer	Model	Year	Engine Type	Equipment Number	Bypass Filter	VSI
Chevrolet	Express Van	2002	Vortec 5000-V8 SFI 5.0L	93-35498	☒	☒
Chevrolet	Express Van	2002	Vortec 5700-V8 SFI 5.7L	93-35537	☒	☒
Chevrolet	Express Van	2002	Vortec 5700-V8 SFI 5.7L	93-35542	☒	☒
Chevrolet	Express Van	2000	Vortec 5700-V8 SFI 5.7L	93-34135	☒	☒
A/G/V*	Americ WG 64	1995	Cummins* L10-260 10.0L	58-02531	☒	☒
A/G/V*	Americ WG 64	1995	Cummins* L10-260 10.0L	58-02532	☒	☒
A/G/V*	Americ WG 64	1994	Cummins* L10-260 10.0L	58-02525	☐	☒
A/G/V*	Americ WG 64	1994	Cummins* L10-260 10.0L	58-02526	☐	☐

* Diesel Engine

Before the test period started, all vehicles selected above were inspected for mechanical problems. All test vehicles were equipped with hour meters to record engine-run time. Each vehicle received an oil change at the beginning of the test period, and during the initial oil change process, one sample of each type of new oil being used was collected from the original container. The sample was split, with one portion sent for laboratory analysis and additional portions analyzed with the onsite system in accordance with the manufacturer's suggested method. These analyses were performed about once a month to provide a baseline condition of the oil before its introduction into the engine and to ensure that no bad batches of oil were used. The test period ran for a little over three years.

NOTE: Cars or vehicles are inherently different it the way they are built, driven, driving conditions, etc. which makes direct test comparison difficult. Even if we could have tested 1,000 or more vehicles, not one would be identical.

5.2.1 Chevy Vans

The Chevrolet (Chevy) passenger vans (see Figure 5) with their V8 gasoline engines were chosen because they represent a large number of this type of vehicles at the NAVSTA San Diego and are used in frequent but short mileage trips. All four Chevy vans had similar starting mileage and were equipped with both the bypass filter and the in-line sensor.

Figure 5. Chevy passenger van with bypass filter installed

5.2.2 Diesel Trucks

Four diesel roll-off trucks were tested (see Figure 6). The four diesel trucks are typically used for hauling Navy trash and taking them to far away landfills for disposal. These trucks are older and have logged on many miles prior to the demonstration. They were chosen due to high mileage driven per occasion and large capacity oil (40 quarts) crankcase reservoir. Only two of the diesel trucks were equipped with the bypass filter and three had oil monitoring unit installed. Three of the trucks, VSI in-line sensor were installed. One truck ("control") did not have any technologies (e.g. bypass filter or oil sensor) installed. However, all four trucks were continuously monitored for their oil condition, where oil samples were taken approximately once a month and sent to an independent laboratory for analyses. The laboratory generates a computerized report for each vehicle indicating levels of contaminants, additives and other parameters.

Figure 6. Diesel roll-off trucks and bypass filter

One truck in particular we called “Old Smokey”, spouted a lot of smoke from its old and-warn-out engine and hence called by its name. The oil appears to be leaking into the cylinders from warn out piston rings or seals. This truck provided us with good information for rapid oil degradation.

NOTE: Two of the four roll of trucks serve as “control” and did not have a bypass filter installed but were continuously monitored for their oil condition.

5.3 Parameters measured

Four parameters were chosen to gauge oil degradation and the performance of the bypass filter and the in-line sensor: oxidation, total base number (TBN), viscosity and soot (for diesels only). The descriptions and explanations for use are described below. Other parameters can be measured and evaluated including metals, water, etc.. but these parameters are used as a diagnostic tool to give indication of engine condition.

Table 5.3.1. Oil Quality Criteria

Physical Properties	Units	Limit
Viscosity	cSt	*12.5 to 16.3
Oxidation	absorption units	< 25
TBN	KOH (mg)/ml Oil	> 3
Soot	absorbance units (%)	< 4

* Crankcase oil 15W40 rerefined from Safety-Kleen.

5.3.1 Oxidation

Oil oxidation is the primary culprit of lubricant degradation. A form of combustion, it occurs at elevated temperatures when the oil is exposed to the air. It is a normal oil aging process, but eventually will break down the oil to the point the oil can no longer adequately lubricate machines. Once the break down of the hydrocarbons has begun, the compounds can not handle the load between two moving machine parts. Additionally, the changed molecules will react with other molecules and result in viscous heating.

As the primary degradation indicator, oxidation is analyzed in the laboratory analysis, as well as with the VSI. Results from the lab are given in absorption units. The VSI unit displays oxidation on a scale from 0-9, where 0 represents new oil and 9 represents worn oil. The values of 1, 5, and 9 correlate to 17, 25, and 50 O.D./cm (infrared spectroscopy) respectively.

5.3.2 Total Base Number

Total Base Number (TBN) is a calculated measurement of the oil's additive reserve. Alkaline additives are typically added to oil to neutralize acidic contaminants that result from combustion and would degrade the oil. A low TBN indicates that the oil is no longer serviceable and requires changing. By definition, TBN is the amount of potassium hydroxide needed to neutralize an acidic solution through reverse titration and is reported in milligram (mg KOH).

5.3.3 Viscosity

Viscosity is a calculated measurement indicating a fluid's resistance to deform under shear stress. For this project, it is the oil's ability to flow and lubricate moving parts in an engine, or more simply, whether the oil is too thick or too thin. For this project, 15W40 oil was used in all vehicles. Viscosities should range between 12.5 and 16.3 cSt (centistokes), where cSt = cp (centipoise) multiplied by specific gravity. Centistokes are $1/100^{th}$ of a stoke, the fundamental unit of measure for kinematic viscosity.

5.3.4 Soot

Soot, a dark powdery deposit of unburned fuel residue caused by burning carbon-rich fuels with insufficient oxygen, is measured in diesel engines by infrared absorption at a fixed wavelength, and is reported in absorbance units. It is a normal combustion byproduct of diesel fuel and appears as a contaminant in the engine oil. It increases oil viscosity and higher than even normal oil degradation numbers can indicate an improper air-to-fuel ratio or defective air intake and can cause deposition, oxidation and degradation of additives. Greater than or equal to four (4) absorbance units is considered a problem level.

6.0 RESULTS

After just over three year of monitoring the vehicles, only one vehicle ('Old Smokey) exhibit oil condition below our threshold limits mentioned on Table 5.3.1). In fact, two of the vehicles tested (control vehicles) without a bypass filter, faired as well as the ones with bypass filter installed. This is indicated by oil condition reports from an independent laboratory and readings on the VSI unit. A summary of vehicle engine and oil mileage is presented in Table 6.

Table 6. Vehicle and Oil Mileage

Vehicle ID #	Vehicle Type	Vehicle Mileage	Oil Mileage	Comments
93-35498	Chevy Van	22,002	11,635	
93-35537	Chevy Van	30,190	23,514	
93-35542	Chevy Van	31,910	19,931	

93-34135	Chevy Van	49,998	13,971	
58-02531	Diesel Roll-Off Truck	243,130	39,498	"Old Smokey"
58-02532	Diesel Roll-Off Truck	224,848	47,134	
58-02525	Diesel Roll-Off Truck	168,729	18,512	Without bypass filter. Broken oil pan replaced.
58-02526	Diesel Roll-Off truck	248,652	52,116	Without bypass filter.

6.1 Impact of bypass filter technology on oil degradation

The oxidations, TBN's, and viscosities for the Chevy vans are depicted in Figures B.1 through B.12 in Appendix B. For each Van, all of the parameters are depicted over cumulative mileage. The oxidations, TBN's, viscosities and soot for the Chevy diesels are depicted in Figures B.13 through B.28, Appendix B, where the parameters were also depicted over cumulative mileage.

Figures 7 and 8 below summarize the oxidation data over time for the Chevy van and diesel trucks respectively. Despite the slight increase of oxidation over time, the upper limit for oxidation was only exceeded by truck # 58-02531 ("Old Smokey"). As discussed in 5.2.2, this vehicle had severe maintenance and operational issues, although rare occurrence, but a representative of what's in the fleet and can not be ignored. It was also determined near the end of the test program that oil was being added (by the driver) about 4 quarts every two to three months.

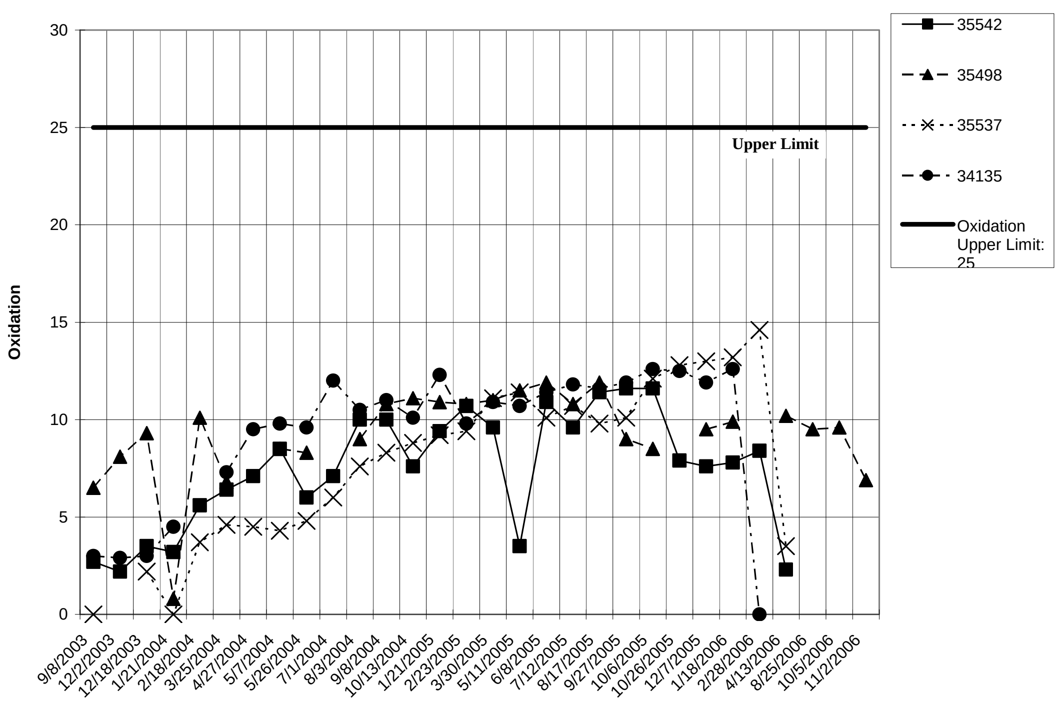

Figure 7. Oil oxidation for all Chevy vans

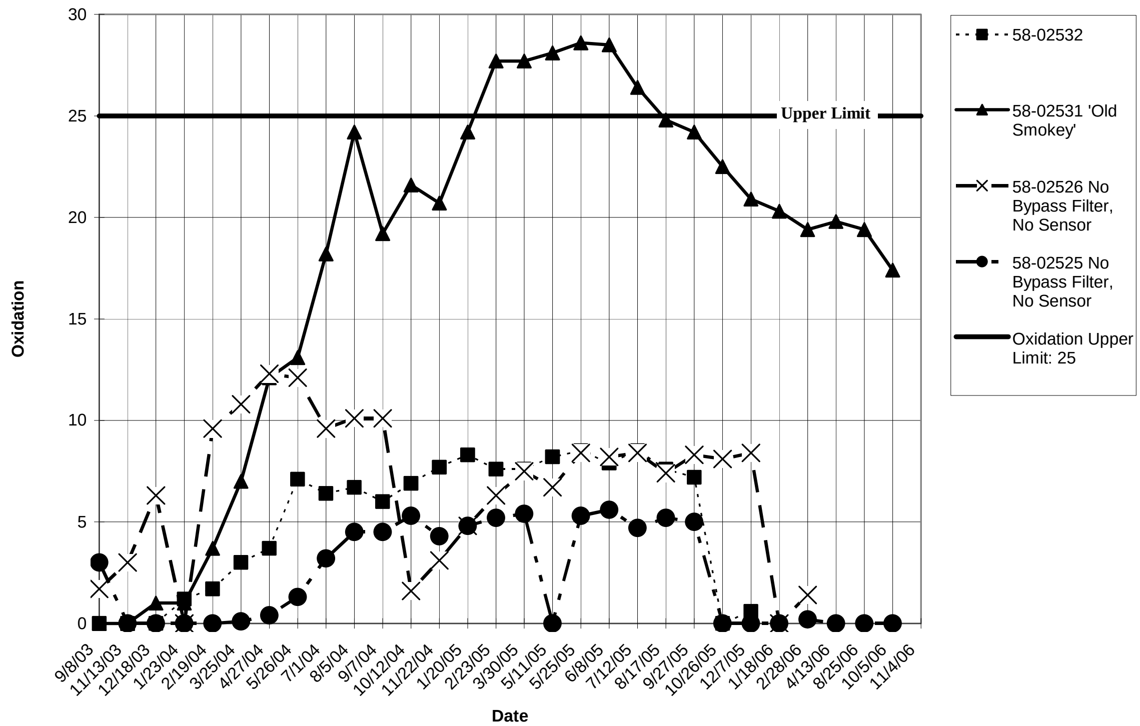

Figure 8. Oil oxidation over time for all diesel trucks

Figures 9 and 10 show the TBN data over time for all of the vans and diesels respectively, while 11 and 12 depict the viscosities. Like the oxidation data, the majority of the results remained within the acceptable range for TBN and for the viscosities. There were a few TBN data points that exceeded the lower limit for three of the van trucks. Two of the points appear to be either sampling or analysis errors, but for van 93-35537, the TBN appears to be truly low. Furthermore, the trend for this vehicle consistently decreased over the test period. The viscosities were extremely consistent and with the exception of a couple of points, were within the upper and lower limits for all test vehicles.

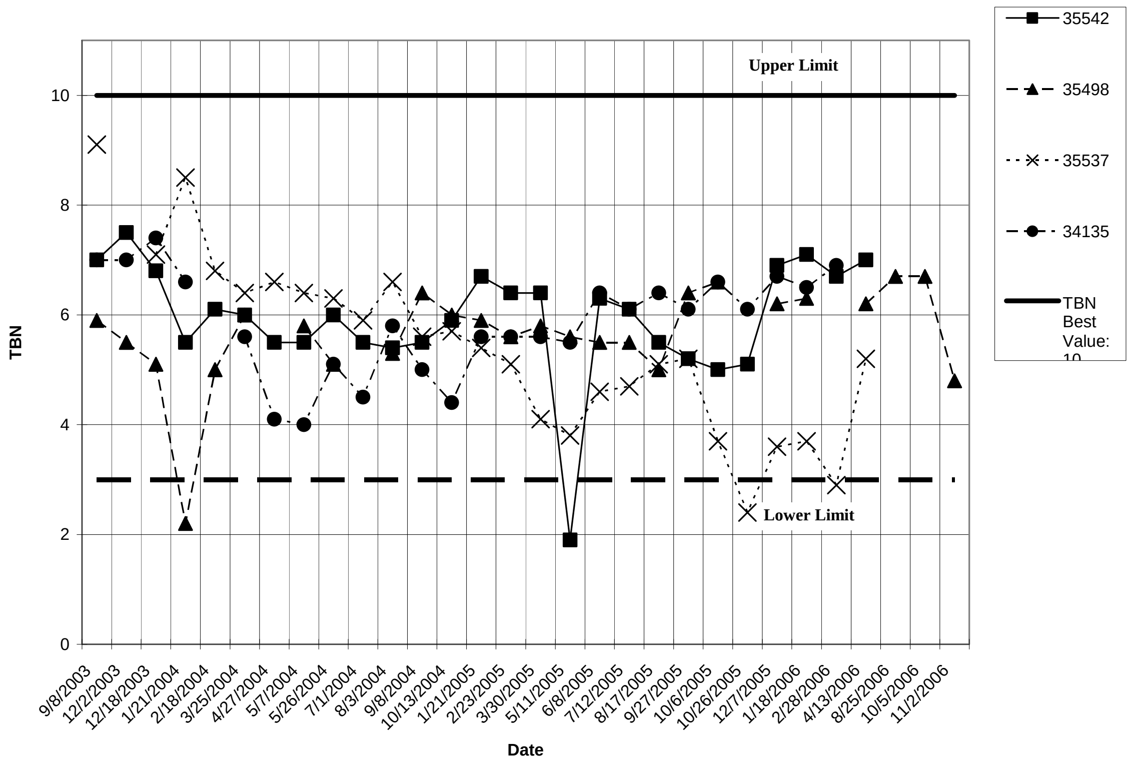

Figure 9. TBN over time for all vans

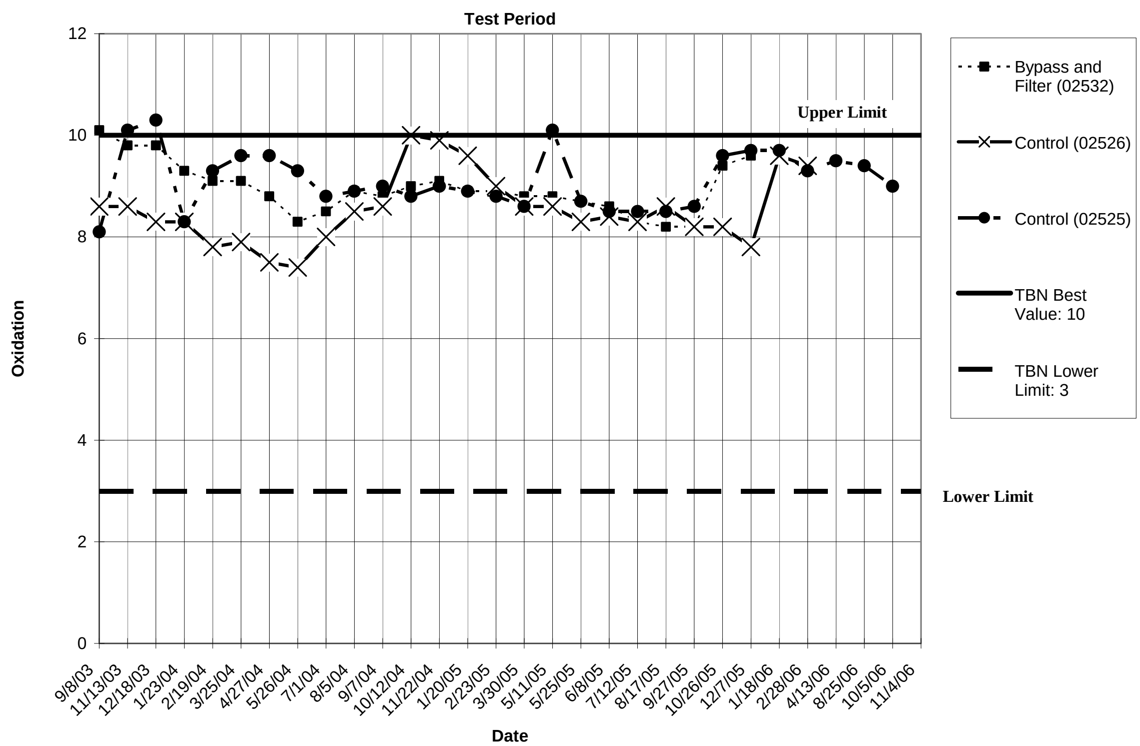

Figure 10. TBN over time for all diesel trucks, minus "Old Smokey"

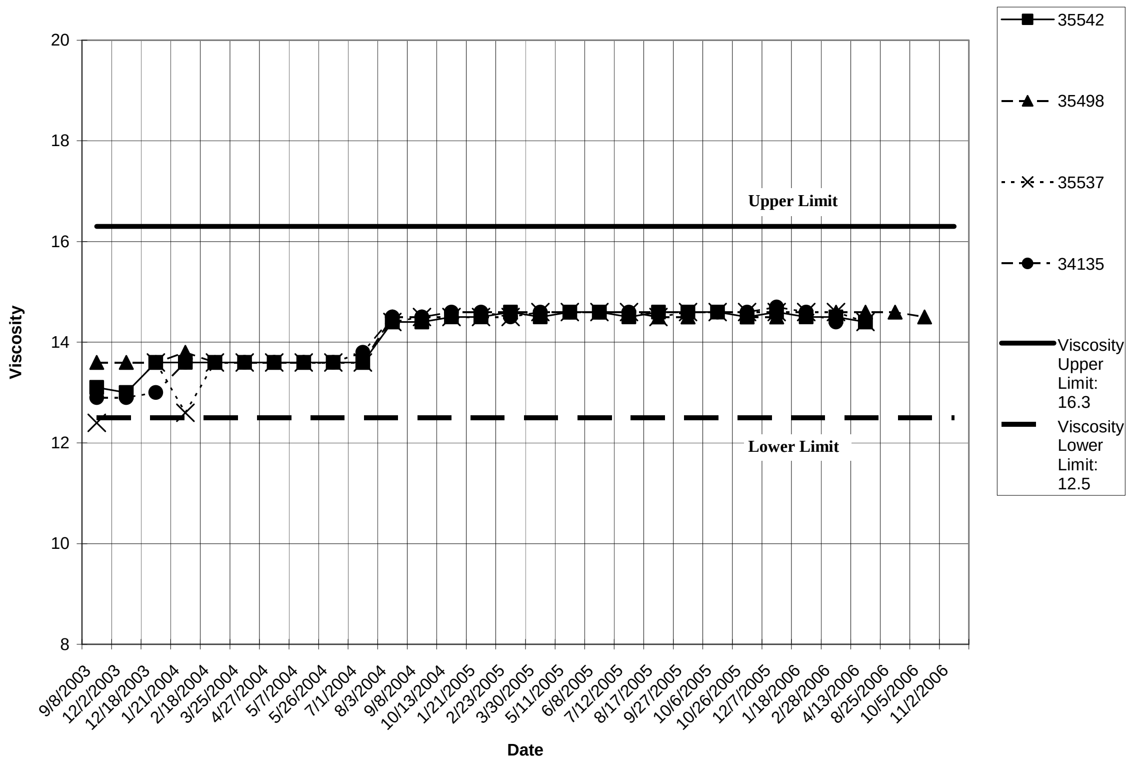

Figure 11. Viscosity over time for all vans

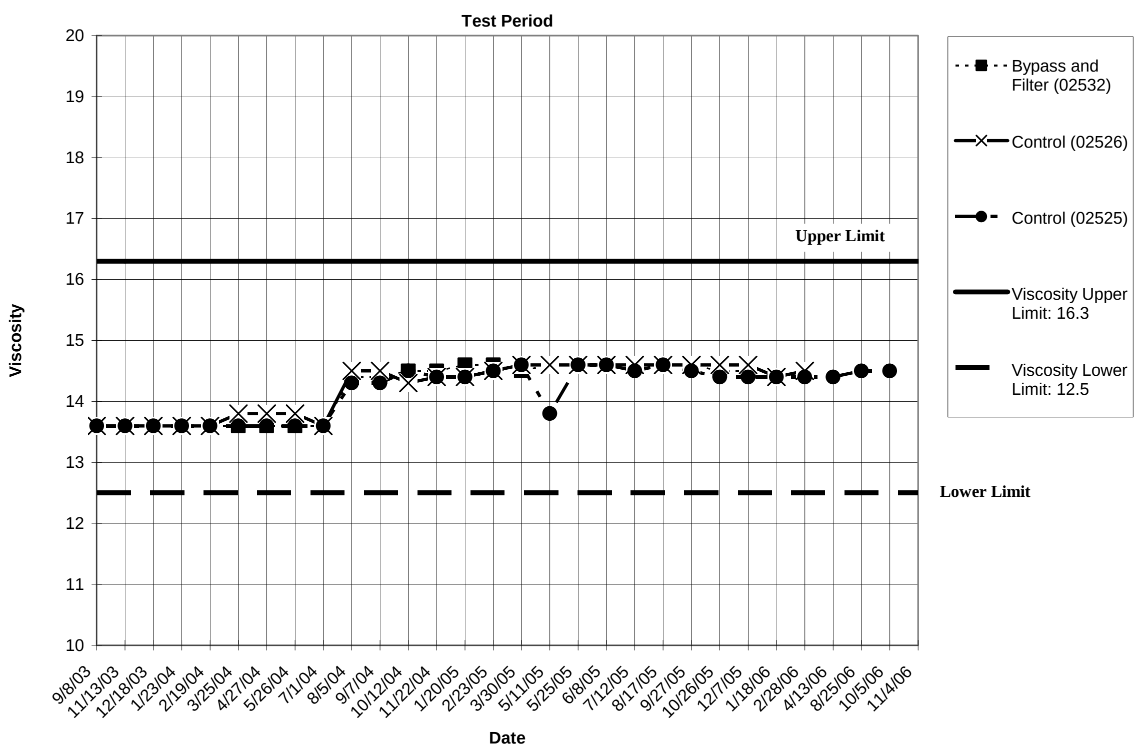

Figure 12. Viscosity over time for all diesel trucks, minus "Old Smokey"

The soot for the diesel trucks is graphed in Figure 13, showing one more time that all vehicles, whether equipped with the bypass filter or not, maintained soot levels acceptable for oil use continuation.

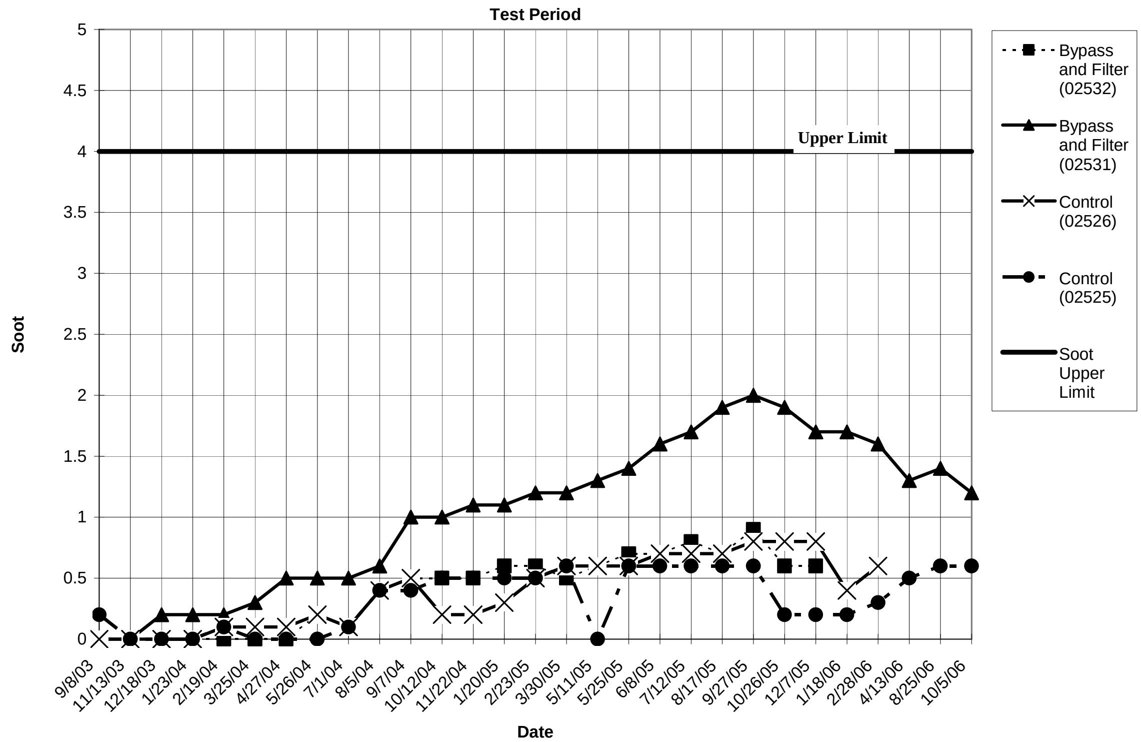

Figure 13. Soot over time for all diesel trucks

As a means of extending oil change intervals, the results shown above are inconclusive for the bypass filter technology. For the majority of the vehicles (with the exception of “Old Smokey”) the results do not fully indicate that the bypass filter is necessary. Most data points remained within acceptable limits for all vehicles and parameters. More importantly, the control vehicles had acceptable results, indicating oil degradation is slower than previously thought. Moreover, there is not a discernable difference in oil degradation as measured by oxidation, TBN, viscosity or soot between the diesel vehicles with bypass oil filters and the control vehicles (with no filters). These results would indicate that bypass oil filters may not be a viable or needed option for DOD operated vehicles, but perhaps better oil change interval management would provide cost savings in procurement and disposal.

6.2 Comparison results of in-line oil analysis system (VSI) and lab analysis

Tables 6.2.1 and 6.2.2 demonstrate the accuracy and comparability of the VSI to lab analysis data for the vans and diesel trucks respectively. The scale for the readout and the lab analysis is based on: Good, Okay, Fair, and Change. Good and Okay indicate numbers well within all limits. Fair indicates numbers approaching the limit, usually one to two measured units from worn. And Change indicates measurements outside of the parameter limits.

For all of the vans, the VSI LED was typically verified by the lab analysis data. There were a few inconsistencies, but the overall trend confirmed the oil condition.

Table 6.2.1 Comparison of VSI LED readout to lab analysis results for Vans

Van 93-35498		Van 93-35537		Van 93-34135		Van 93-35542	
Lab Analysis	VSI LED	Lab Analysis	VSI LED	Lab Analysis	VSI LED	Lab Analysis	VSI LED
Good	Good	Good	Good	Good	Good	Good	Good
Good	No reading	Good	Good	Good	No Reading	Good	No Reading
Good	Good	Good	Good	Good	Good	Good	Good
Good	No reading	Good	No reading	Good	Good	Good	No Reading
Good	Good	Good	Good	Good	No Reading	Good	Good
Good	Good	Warning	Good	Good	Good	Good	Good
Good	Good	Good	Good	Good	Good	Good	Good
Good	Good	Good	Good	Good	Good	Good	Good
Good	Good	Good	Good	Good	Good	Good	Good
Good	Good	Good	Good	Good	Good	Good	No Reading
No data	Good	Warning	No reading	Good	Good	Good	No Reading
Good	No reading	Worn	Good	Good	No Reading	Good	Good
Good	Good	Warning	Good	Good	Good	Good	Good
No data	Good	Warning	Good	Good	Good	Good	Good
Good	Good	Worn	Good	Good	Good	Good	Good
Good	Good	Good	Worn	Good	Good		
Good	No reading						
Warning	Good						

Only diesel trucks 58-02525, 58-02531, and 58-02532 were equipped with the VSI sensor. Only diesel 02525 had consistent readings of confirmation. For 02531 (Old Smokey), the LED readings were inconsistent with the lab results. As oil ages without oil being changed (in the case of Old Smokey - approximately 4 quarts of oil are added in the 40 quarts oil pan capacity every few months), sludge formation begins to occur. Sludge formation is a detrimental effect on the oil condition but analytically is not measured; however it can be detected through VSI and thus the inconsistent readings. For truck 02532, the trend was more consistent, but the readout was off a level of condition. Minor calibration adjustment was later made to the VSI sensor which made it correspond with analytical results as shown on the last two readings.

Table 6.2.2 Comparison of VSI LED readout to lab analysis results for Diesel Trucks

Diesel 58-02525		Diesel 58-02531 (Old-Smokey)		Diesel 58-02532	
Lab Analysis	VSI LED	Lab Analysis	VSI LED	Lab Analysis	VSI LED
Good	Good	Warning	Worn	Good	Warning
Good	Good	OK	Warning	Good	Warning
Good	Good	Warning	Worn	Good	Warning
Good	Good	Warning	Warning	Good	Warning
Good	Good	Warning	Worn	Good	Warning
Good	Good	Worn	Warning	Good	Warning
Good	No Reading	Worn	Worn	Good	Warning
Good	No Reading	Worn	Warning	Good	Warning
Good	Good	Worn	Warning	Good	Warning
Good	Good	Worn	Warning	Good	Warning
Good	Good	Worn	Worn	Good	Warning
Good	Good	Warning	Worn	Good	Warning
Good	Good	Warning	Worn	Good	Warning
Good	No Reading	Warning	No Reading	Good	Good
		Warning	Worn	Good	Good
		Warning	No Reading		
		OK	Worn		
		OK	Worn		
		OK	Worn		
		OK	Worn		

The VSI sensor provides current ongoing information regarding the status and condition of the oil. It allows users to quickly assess the need for oil changes and could extend oil change intervals. And based on these reported results, the readout is typically realistic; however, further testing would better verify its use, applicability and accuracy.

6.3 Evaluation of in-line oil analysis system's DOD applicability

The VSI by Volker System Instrument showed good correlations betweens its readings and readings obtained from the independent laboratory. In this case, the problem of sending the oil to a laboratory for analysis can be eliminated, as this is a time consuming process.

The cost for the sensor and the readout unit could off-set the labor and material (oil and filter) costs if oil change can be extended three (3) fold for large capacity vehicles.

The location of the oil sensor however (at the bottom of the oil pan) makes it vulnerable to being accidentally damaged (see Figure 6.8). In fact, on one occasion, roll-off truck (58-02526), scrapped and damaged the bottom of the oil pan during offloading of trash at the landfill. This truck therefore required getting new oil pan and subsequently new oil was put in. Fortunately, this truck didn't have an oil sensor installed. The location of the oil sensor is critical and that it must be in a safe location or have a fail safe feature if this system is to be implemented.

Figure 14. Oil sensor location at the bottom of oil pan

6.4 Evaluation of the Navy's current scheduled oil change practice

The current Navy practice is to change oil once a year regardless of the oil condition. This is also the time other maintenance (e.g. tire air pressure, fluid level check, etc.) are performed on the vehicle. Some activities follow the manufacturer's recommended oil change intervals of 5,000 to 8,000 miles based on the type of vehicle. There are no current requirements to check the oil condition or to modify the oil change period based on actual oil condition. Therefore, it is possible that oil and filters are being disposed of prematurely.

7.0 ECONOMIC ANALYSIS

The bypass filter even it they worked as claimed by the manufacturers is not economically viable. It is expensive and shows no benefit in extending oil change intervals. It still requires the oil to be monitored or the oil condition to be known when passed the one year period or manufacturer's suggested miles.

The approximate costs (material and labor) for the economic analysis performed and other assumption is presented below:

Bypass filter (Oil Guard): $290

Bypass filter mounting hardware (e.g. hoses, fittings, bracket, etc..): $ 22

Labor to install bypass filter (initial): 2 hrs @ $50/hr: $100

Regular Oil Change: Labor =1.5hr; full flow filter= $21; 40 qt of Oil = $48

Interest rate = 4%

Scenario 1: Install VSI sensor for each vehicle, one in shop monitoring unit, monitor oil once a month after the first year, extend oil change intervals to three (3) years. Notice: result payback is 4 yrs.

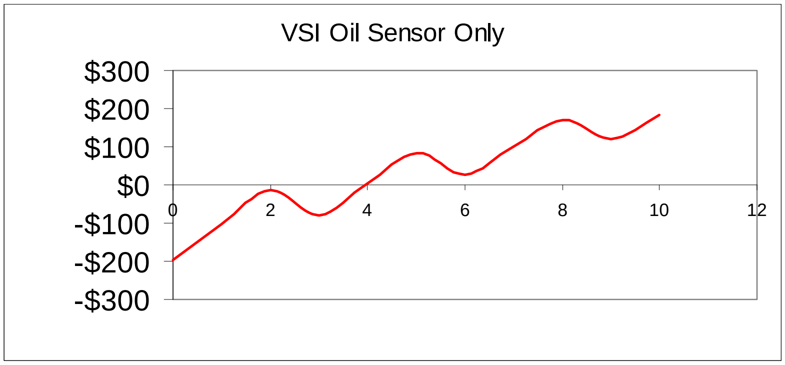

Figure 15. Payback period if using an oil sensor for each vehicle with one in-shop monitor

Scenario 2: Install only bypass filter w/out oil sensor and extend oil change interval to 3 years.

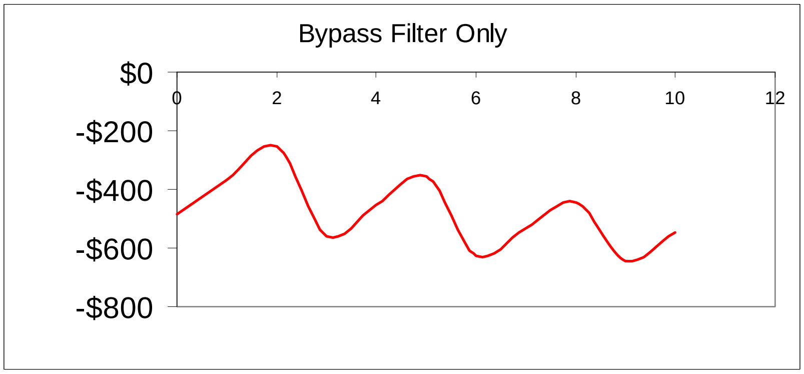

Figure 16. Payback period if using bypass filter only (w/out oil sensor) and extending oil change interval by 3 fold

Different scenarios were tried but none had a payback less than four years. For example:

Scenario 3: VSI sensor and monitor for each vehicle, results in payback of 7 years.

Scenario 4: Bypass filter and checking oil condition once every month after the first year results in negative payback.

8.0 CONCLUSION & RECOMMENDATIONS

Through out the years, oil quality and car engines have improved. Other countries have even adopted longer oil change intervals because of this. However, in the US we still adhere to the old practice of changing oil regardless of condition based on manufacturer's recommendation. This practice may be too conservative, unnecessary, and costly and in ways not good to the environment.

It is recommend that a maintenance facility or organization in charge of navy vehicle maintenance program evaluate their current practice and attempt to increase their oil change intervals the way they feel comfortable. This could be done by:

1. Monitor oil condition once a month of specific types of vehicles (common usage) AFTER the first year without any technology (e.g. without bypass filter, in-line monitoring unit).
2. Using the criteria identified in Section 5.3, note the period (time) when oil condition becomes unacceptable.
3. For safety measure, subtract 6 months to the time noted in step 2 to obtain the new oil change interval. This will be then the new schedule set for that type vehicle.
4. Or, use an in-line oil monitor like VSI. As noted on the economic analysis above, only the large vehicles could benefit (w/ a reasonable payback period) from this technology and only with one oil sensor mounted on each vehicle and one monitoring unit in the shop to reduce overall capital cost of the equipment.

ACKNOWLEDGEMENTS

We would like to acknowledge San Diego PW Transportation Department personnel in their support and participation. Specifically, Mr. Mike Malaga and Mr. Mike Pasquan of PW San Diego Transportation Department. Also, contribution from VSI president Mr. Joe Hedges in providing sensors, instruments, and insight to oil technology.

REFERENCES

1. Department of Navy National Clean/Alternative Vehicle Implementation Plan. May 1999
2. Idaho National Laboratory (INL). Technical Report, INL/EXT-06-01355: Oil Bypass Filter Technology Evaluation Final Report. March 2006.

APPENDIX A

Test Plan

BYPASS FILTER AND OIL ANALYSIS TEST PLAN
AT
NAVY PWC TRANSPORTATION DEPARTMENT
SAN DIEGO

1.0 OBJECTIVE

This test plan describes the data collection procedure for testing a bypass oil filter in conjunction with an oil analysis system. The data will used to determine the overall effectiveness and applicability of both units in extending oil change intervals and thus reduce the amount of used oil and filters required for disposal. In addition NFESC will develop methodologies/technologies for reduction of all other oily wastes generated from a typical vehicle maintenance facility.

Studies conducted by NFESC indicate the Navy used oil account for about 280K gal/yr at a disposal cost of about $1M. This does not take into account the thousands of oil filters and management costs (storage, etc.) associated with disposal. Significant amount money and reduction of waste generated can be realized with a simple oil change extension.

2.0 DESCRIPTION

Bypass filters used in conjunction with traditional full-flow oil filters can remove smaller contaminant particles (1 micron or less). Removing and controlling contamination is a job that can only be accomplished by filtration. Bypass filters can substantially reduce the numbers of oil changes required by increasing the intervals between oil changes from as much as 2 to 10 times. A bypass filter manufactured by Oil Guard (Figure 1) has been selected based on costs, design simplicity and claimed performance.

Figure 1. Oil Guard

At PWC San Diego, engine oil changes are performed annually along with the vehicle's OPM schedule; although oil analysis is not performed to determine its condition. Changing oil based on condition would improve engine life but also satisfy OEM engine warranty. While it would be possible to collect oil samples on a regular basis and send them offsite for a laboratory analysis, the turnaround time and cost is unacceptable with current operational requirements. Therefore, a simple onsite analysis system that could be operated by current maintenance personnel with minimal additional training and cost would be preferable.

The Lubri-Sensor oil analysis system (Figure 2), by Northern Instruments Corporation, has been selected for assessment at the PWC Transportation Department NAVSTA San Diego. Oil samples will be collected once per month using the Lubri-Sensor and a split sample will be sent to a certified independent laboratory. This independent testing will provide data necessary to observe any trends in overall oil condition.

The Lubri-Sensor measures the dielectric constant of the oil. The dielectric constant is a property of insulating (non-conducting) materials. It is a sensitive measure of the average response to an electric field. This is not to be mistaken as conductivity, the ability of the material to carry a flow of electric charge (a current). In oil systems the value of the dielectric constant depends on the base oil plus additives or contaminants present. As oil breaks down, peroxides, acids and other chemicals are formed. Some molecules in the oil become somewhat polar. As the number of polarized molecules increases, the dielectric constant of the oil increases. The dielectric constant also increases as particles of dirt, soot and metal accumulate in the oil. This measure (in microamperes) will be compared to results obtained from laboratory analysis. If proven to be accurate with significant correlation exist between the two units, the onsite system can be used as a stand-alone.

Figure 2. Lubri-Sensor

Soot levels will be measured on site using InfraCal soot meter (Figure 3). It measures the amount of suspended soot in diesel engine lubricating oils from infrared absorption at a fixed wavelength. Results are displayed directly as % soot, relative to a standard TGA (thermogravimetric analysis) reference method. Although the Lubri-Sensor can determine overall oil condition, the soot measurement will provide a separate indication of actual soot build-up in oil.

Figure 3. InfraCal soot meter

3.0 TEST PLAN

This test plan will be used to evaluate the effectiveness of bypass filter and onsite oil analysis system versus the current time-based oil change. Emphasis will be placed on system's performance, optimizing oil change intervals, and integration with existing maintenance procedures.

Six (6) PWC vehicles will be used in the demonstration, which will be equipped with bypass filtration system.

Manufacturer	Model	Year	Engine Type	Equipment Number
Chevrolet	Express Van	2002	Vortec 5000 V8 SFI 5.0L	93-35498
Chevrolet	Express Van	2002	Vortec 5700	93-35537

			V8 SFI 5.7L	
Chevrolet	Express Van	2002	Vortec 5700 V8 SFI 5.7L	93-35540
Chevrolet	Express Van	2000	Vortec 5700 V8 SFI 5.7L	93-34135
A/G/V	Americ WG 64	1995	Cummins* L10-260 10.0L	58-02531
A/G/V	Americ WG 64	1995	Cummins* L10-260 10.0L	58-02532

Note: * Diesel Engine

Another two (2) similar vehicles will be monitored without bypass filters installed to use as comparison and provide baseline data. These vehicles are identified below:

Manufacturer	Model	Year	Engine Type	Equipment Number
A/G/V	Americ WG 64	1994	Cummins* L10-260 10.0L	58-02525
A/G/V	Americ WG 64	1994	Cummins* L10-260 10.0L	58-02526

3.1 Approach

Before the test period starts, all vehicle selected above will be inspected for mechanical problem. Any mechanical problems will be noted and repaired. All test vehicles will be equipped with hour-meter to record engine-run time. Each vehicle will receive an oil change at the beginning of the test period. During the initial oil change process, one sample of each type of new oil being used will be collected from one of the original containers. This sample will be split, with one portion sent for laboratory analysis and additional portions analyzed with the onsite system in accordance with the manufacturer's suggested method. These analyses will be performed both to provide a baseline condition of the oil before its introduction into the engine and to ensure that no bad batches of oil were used. It is projected that the test period will run for a little over a year.

3.2. Data Collection

NFESC personnel will collect data about ones a month. NFESC will be working closely with PWC personnel to provide best results as possible. Comments from users will be solicited for any events relating to maintenance/repairs or performance related issues of test vehicles. This may include but not limited to topping off of oil. A data log sheet provided in Appendix-A, will include date of any repairs or maintenance, a description of the repair work completed, estimated number of hours to complete repair, and a list of parts and consumables needed for the repair.

4.0 REPORTING

A final report will include detailed results and observations, comparison between LubriSensor and laboratory results, cost effectiveness, unit operability, maintainability, and ability of the unit to interface with site operations.

By: Sonny F. Maga, NFESC
6/27/03

Example Log Data Sheet

Sample Collection Data Sheet (PWC San Diego Transportation Dept.)

Collector's Name: (Print)__________________________________ **Date:** / /

Vehicle Type:

Equipment# - _____________________

Make - _____________________

Model - _____________________

Year - ______

Oil Changed: yes ___ no ___

Oil Topped-off: Quantity - ______ quarts

Hour Meter Reading: | | | | | | 1/10

Odometer Reading: ______________

On Site Test Results:

Test #	D.C. Micro-Amperes	Deviation Scale	Soot %	Comments

APPENDIX B

Individual Vehicle Graphed Results

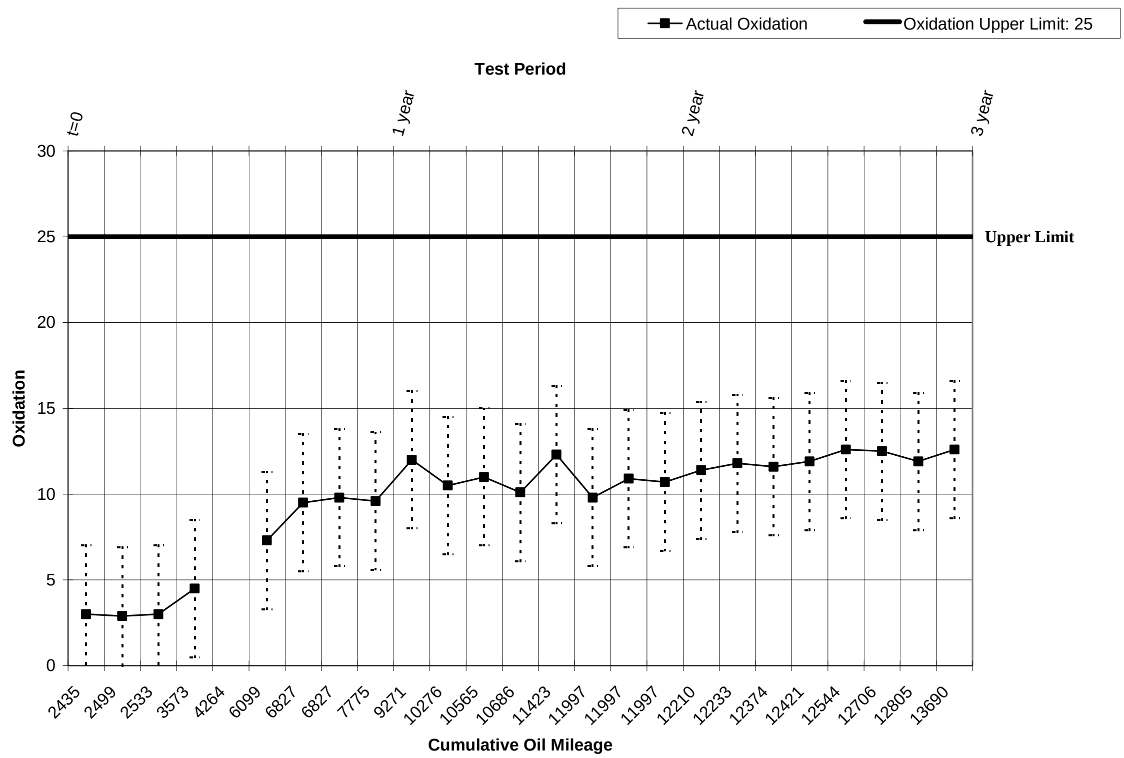

Figure B.1 Van 93-34135 Cumulative Oil Mileage vs. Oxidation.

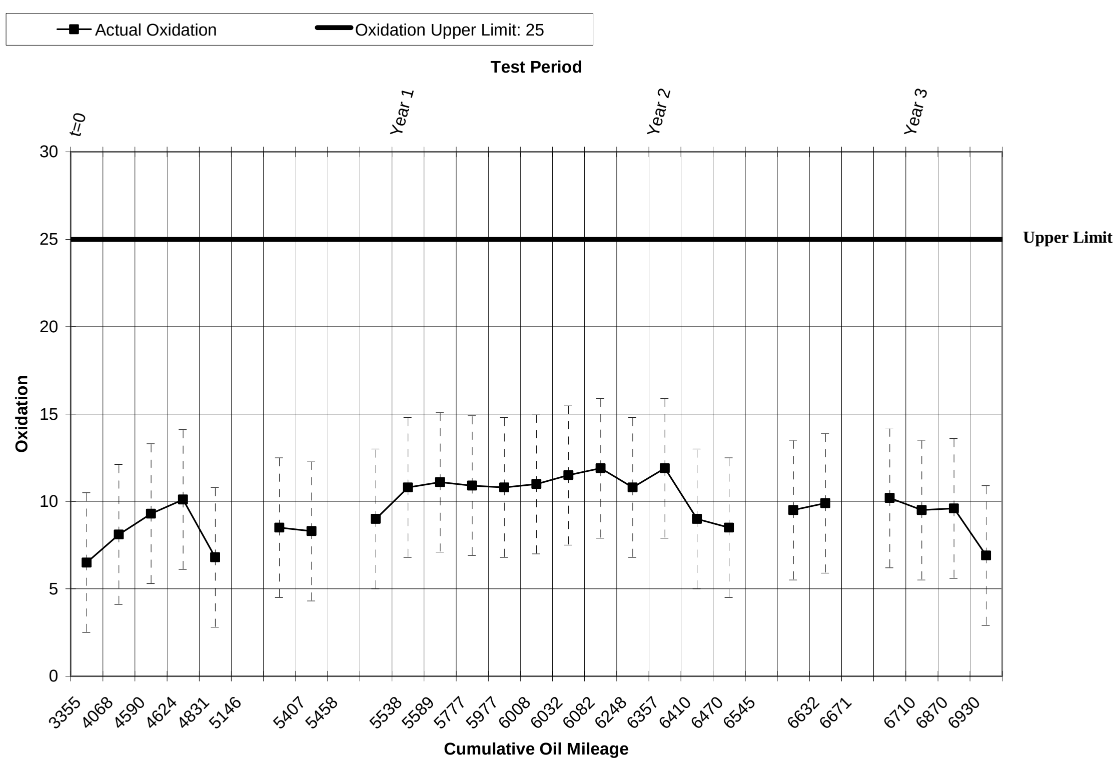

Figure B.2 Van 93-35498 Cumulative Oil Mileage vs. Oxidation

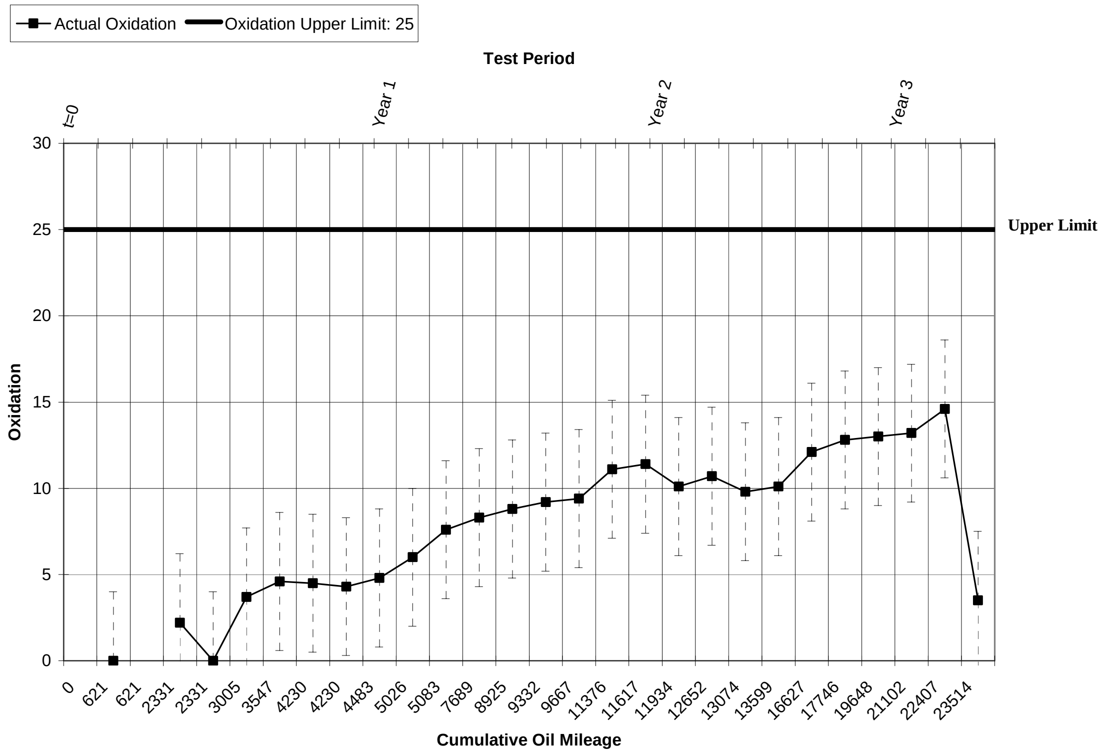

Figure B.3 Van 93-35537 Cumulative Oil Mileage vs. Oxidation

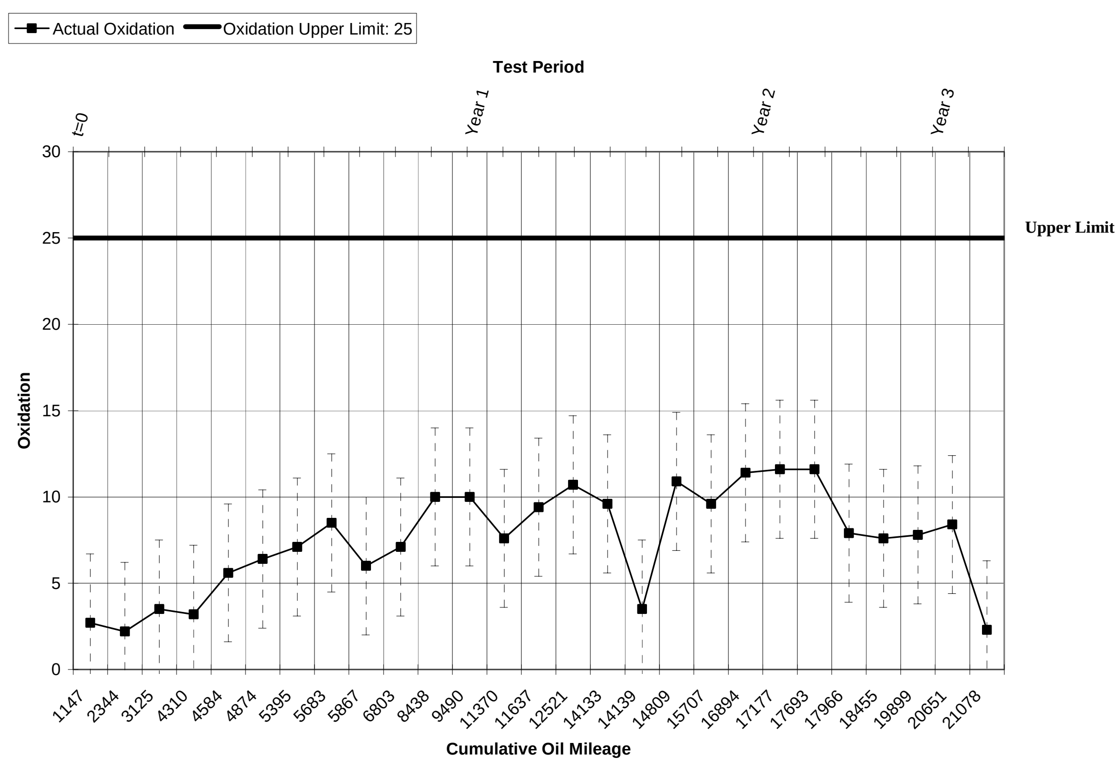

Figure B.4 Van 93-35542 Cumulative Oil Mileage vs. Oxidation

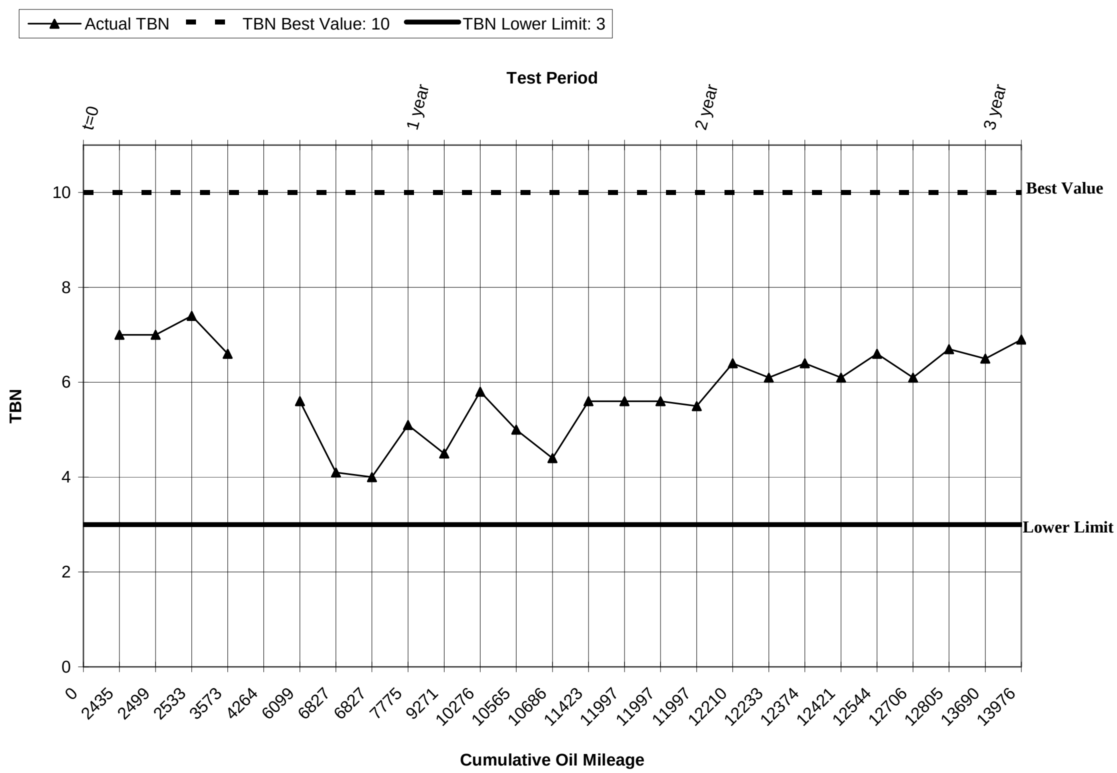

Figure B.5 Van 93-34135 Cumulative Oil Mileage vs. TBN

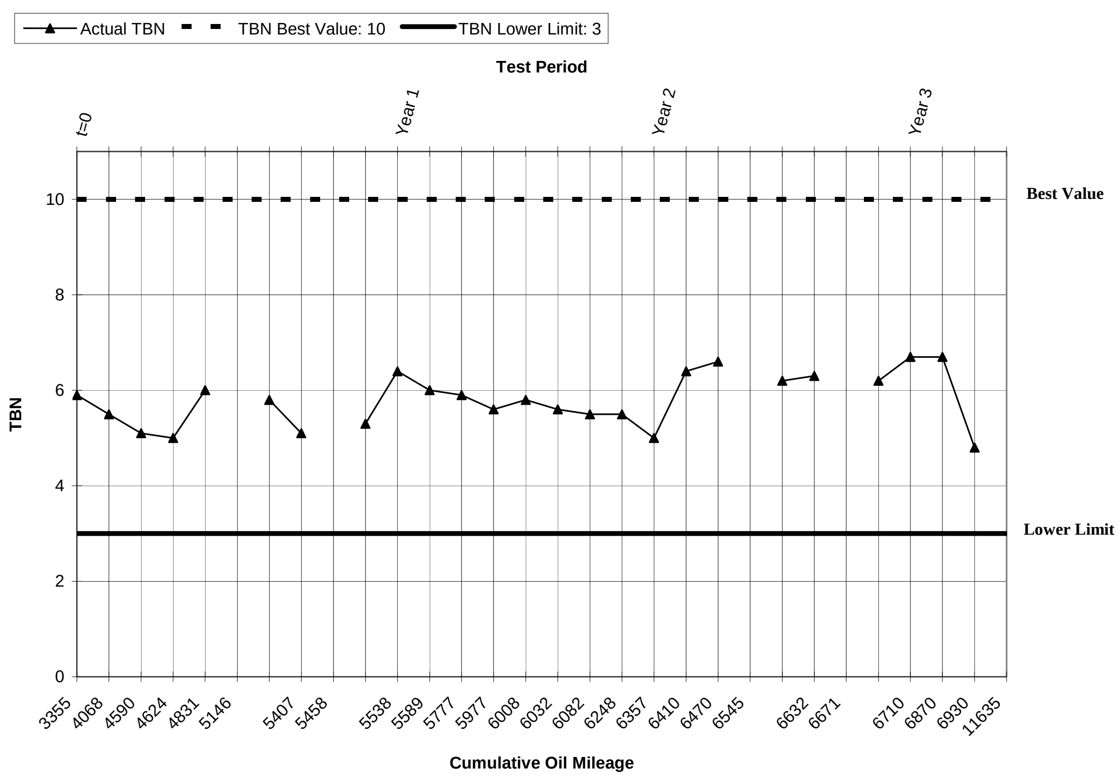

Figure B.6 Van 93-35498 Cumulative Oil Mileage vs. TBN

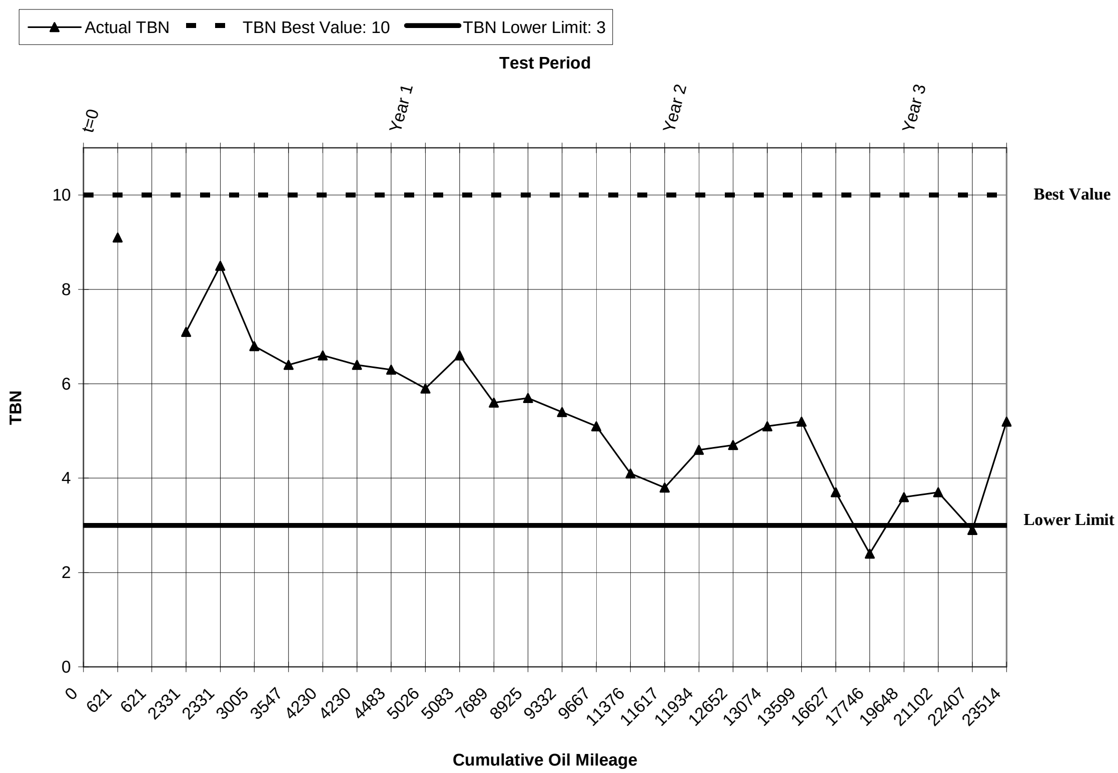

Figure B.7 Van 93-35537 Cumulative Oil Mileage vs. TBN

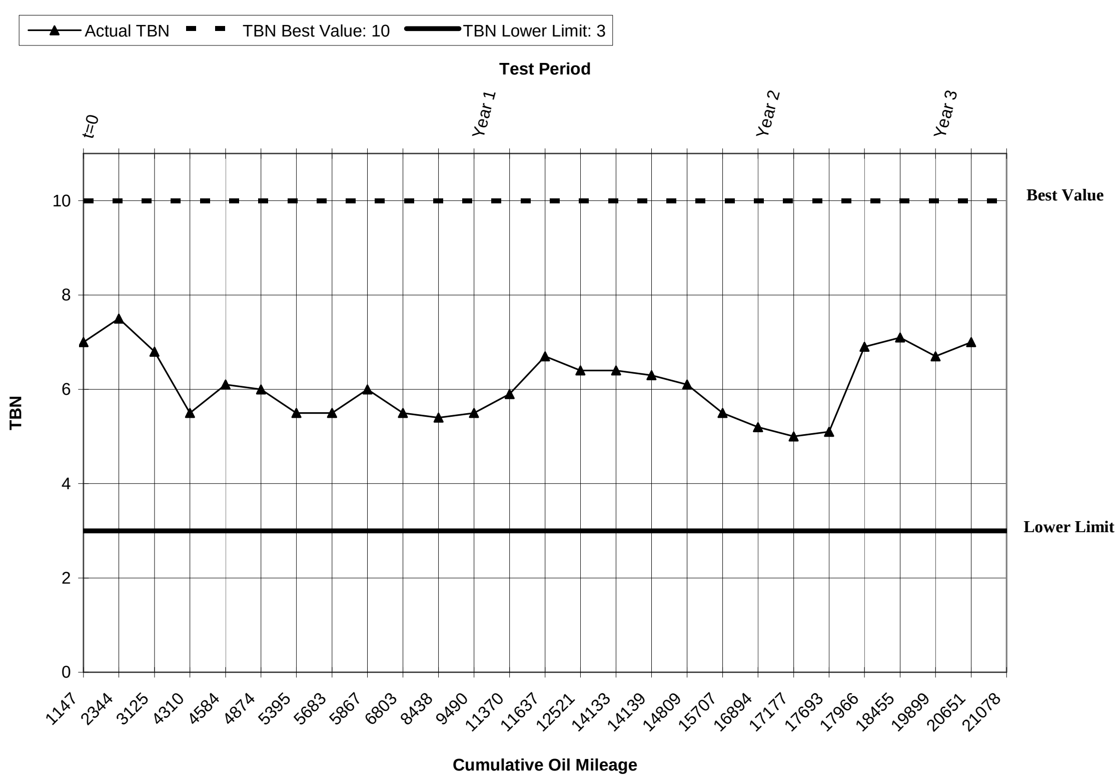

Figure B.8 Van 93-35542 Cumulative Oil Mileage vs. TBN

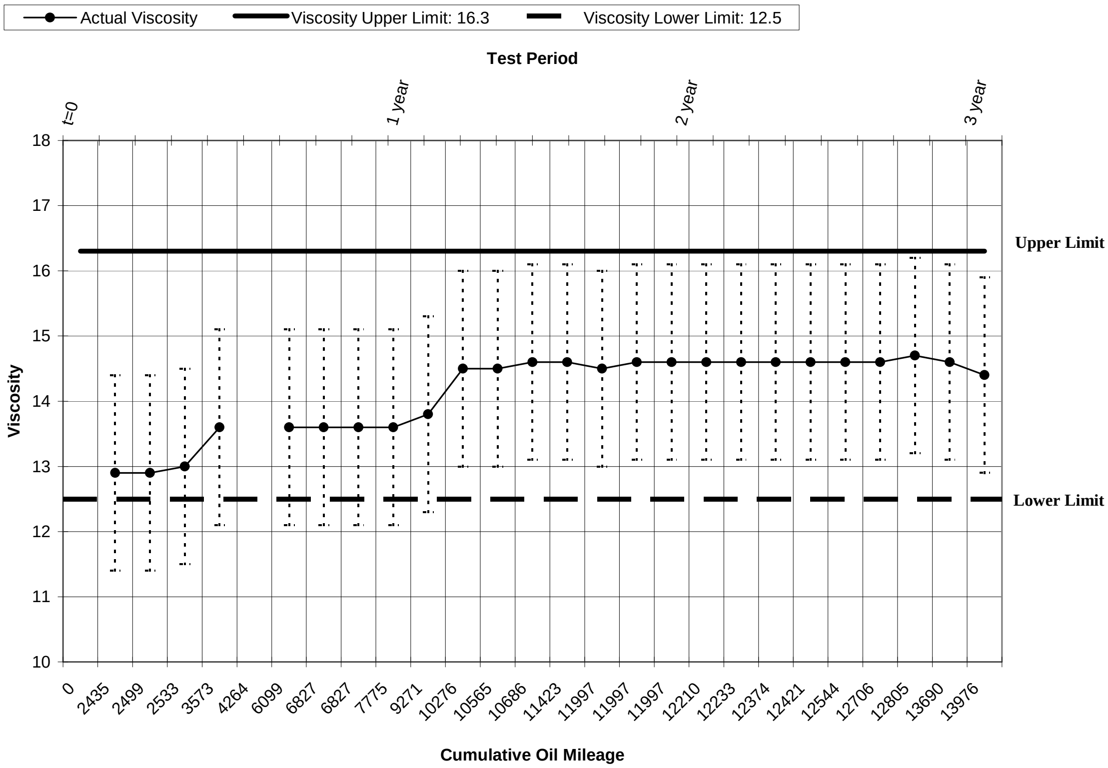

Figure B.9 Van 93-34135 Cumulative Oil Mileage vs. Viscosity

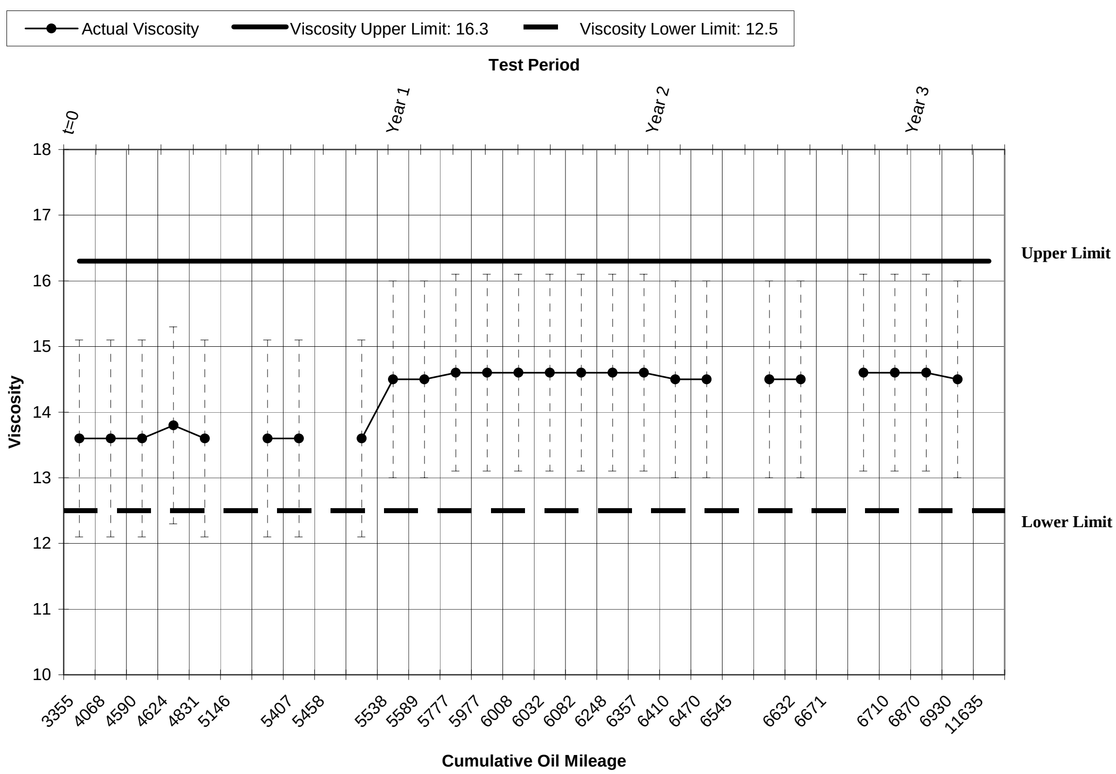

Figure B.10 Van 93-35498 Cumulative Oil Mileage vs. Viscosity

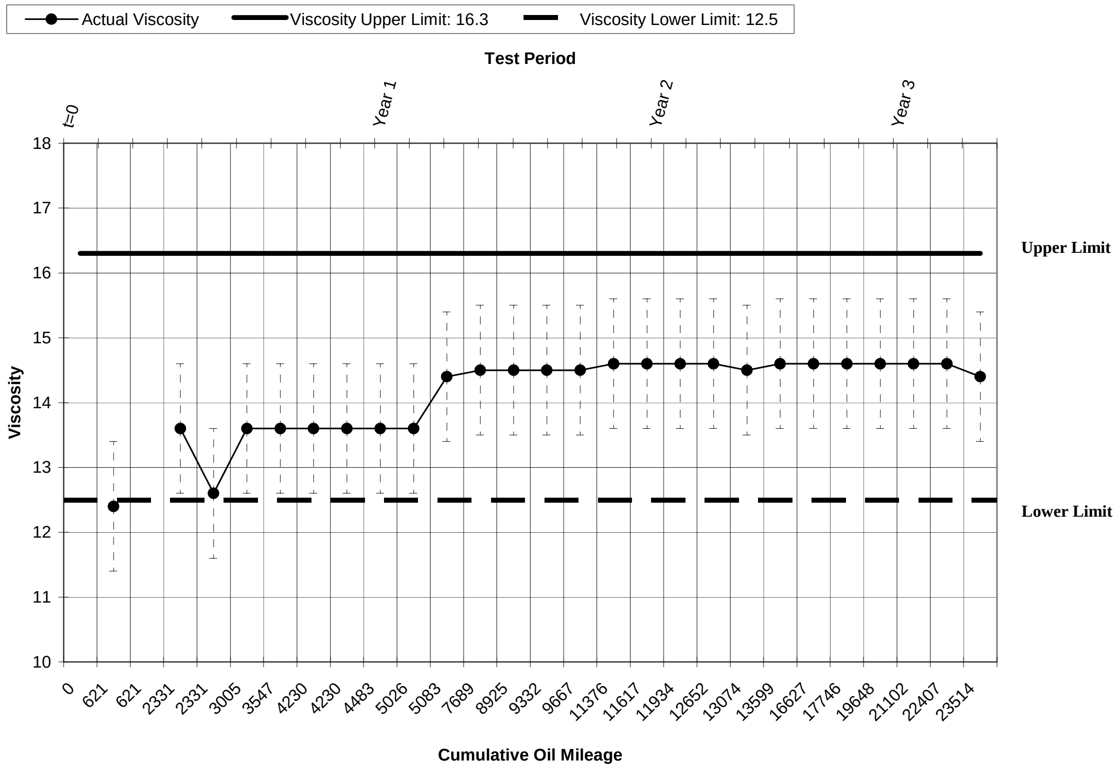

Figure B.11 Van 93-35537 Cumulative Oil Mileage vs. Viscosity

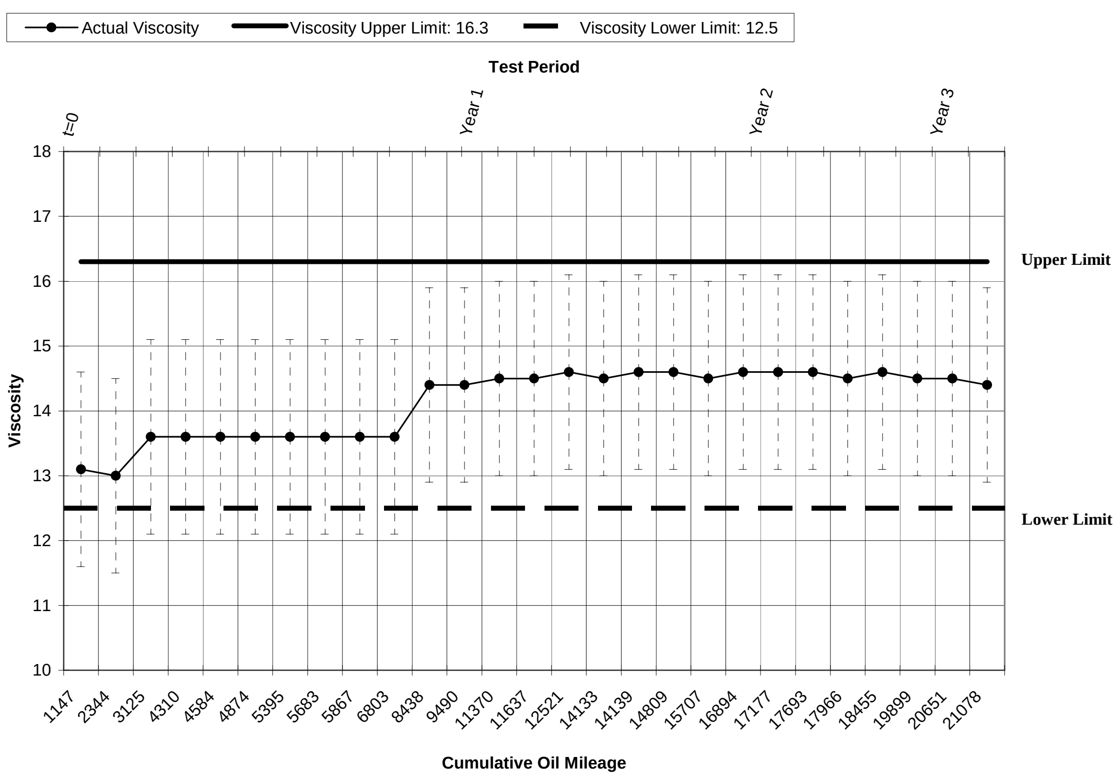

Figure B.12 Van 93-35542 Cumulative Oil Mileage vs. Viscosity

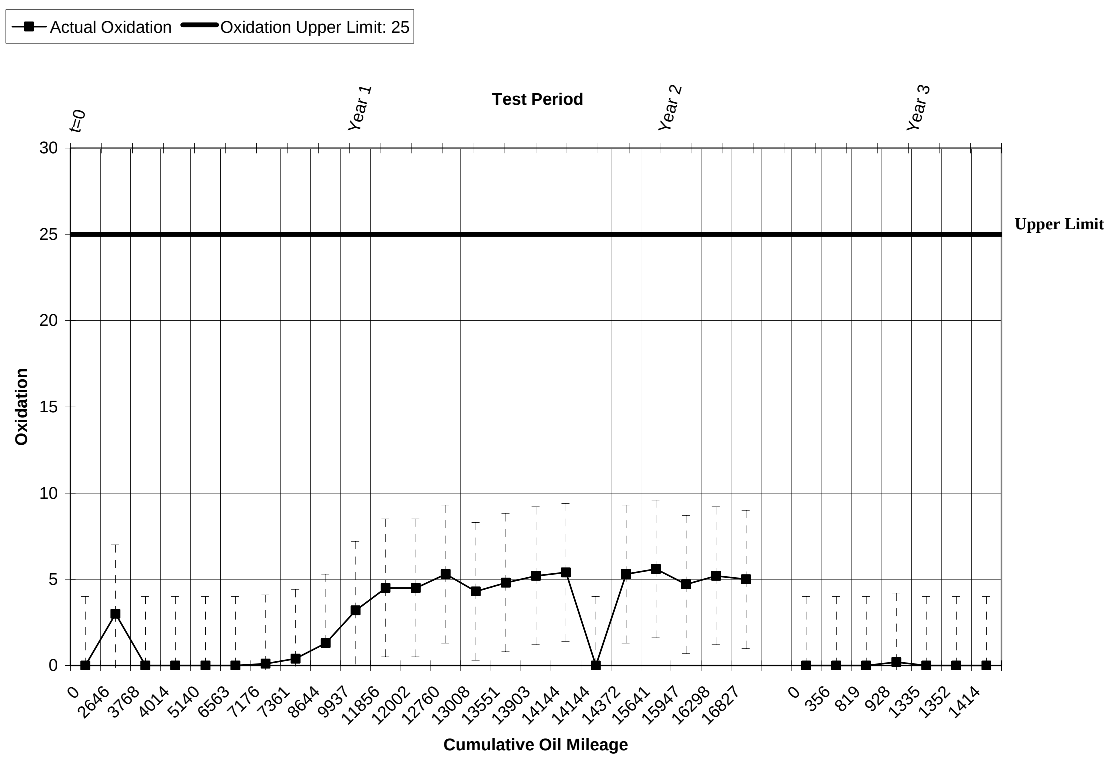

Figure B.13 Diesel Truck 58-02525 Cumulative Oil Mileage vs. Oxidation.

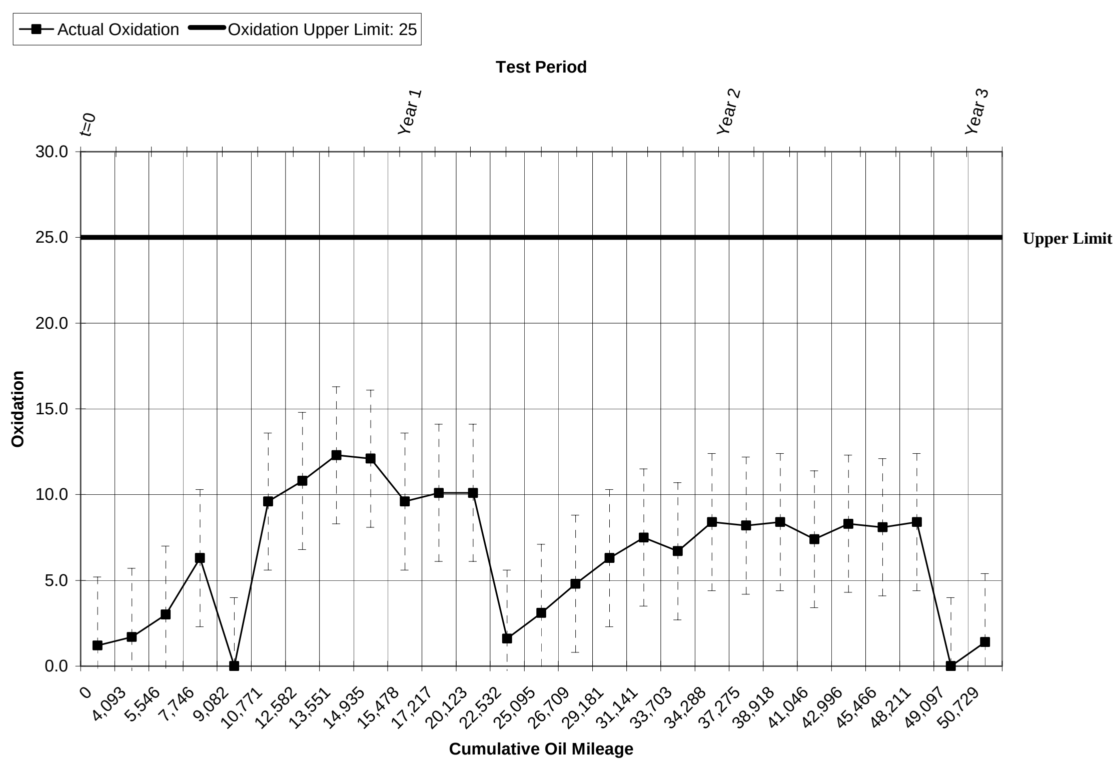

Figure B.14 Diesel Truck 58-02526 Cumulative Oil Mileage vs. Oxidation.

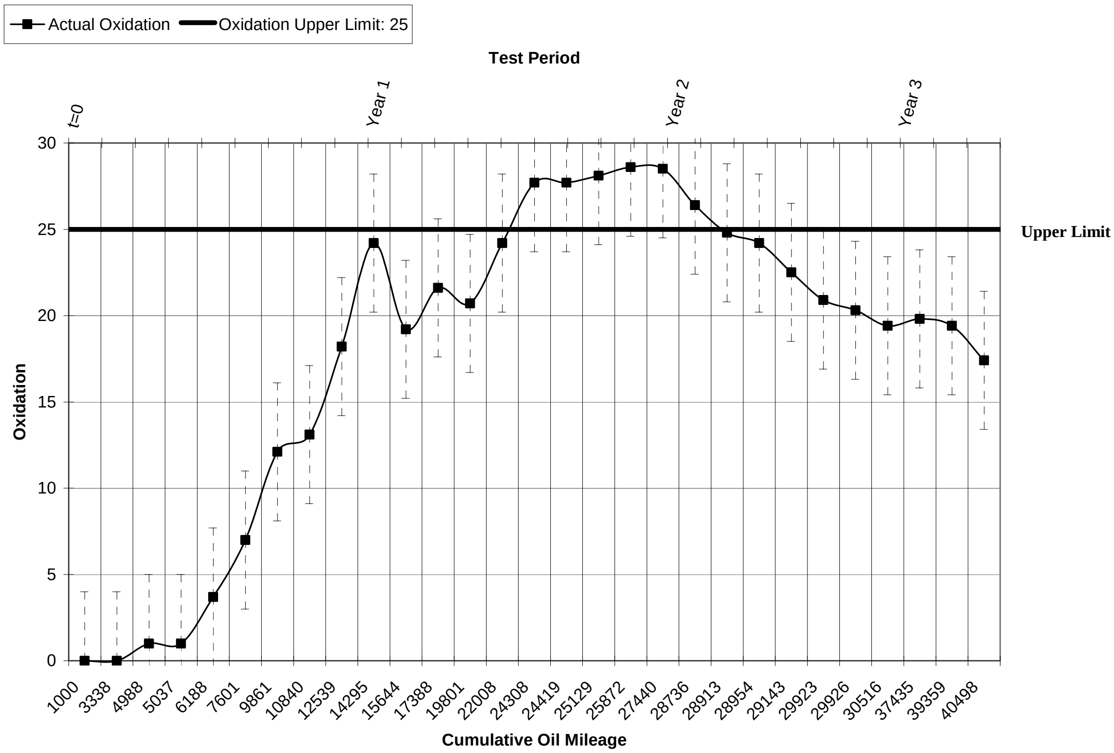

Figure B.15 Diesel Truck 58-02531 Cumulative Oil Mileage vs. Oxidation.

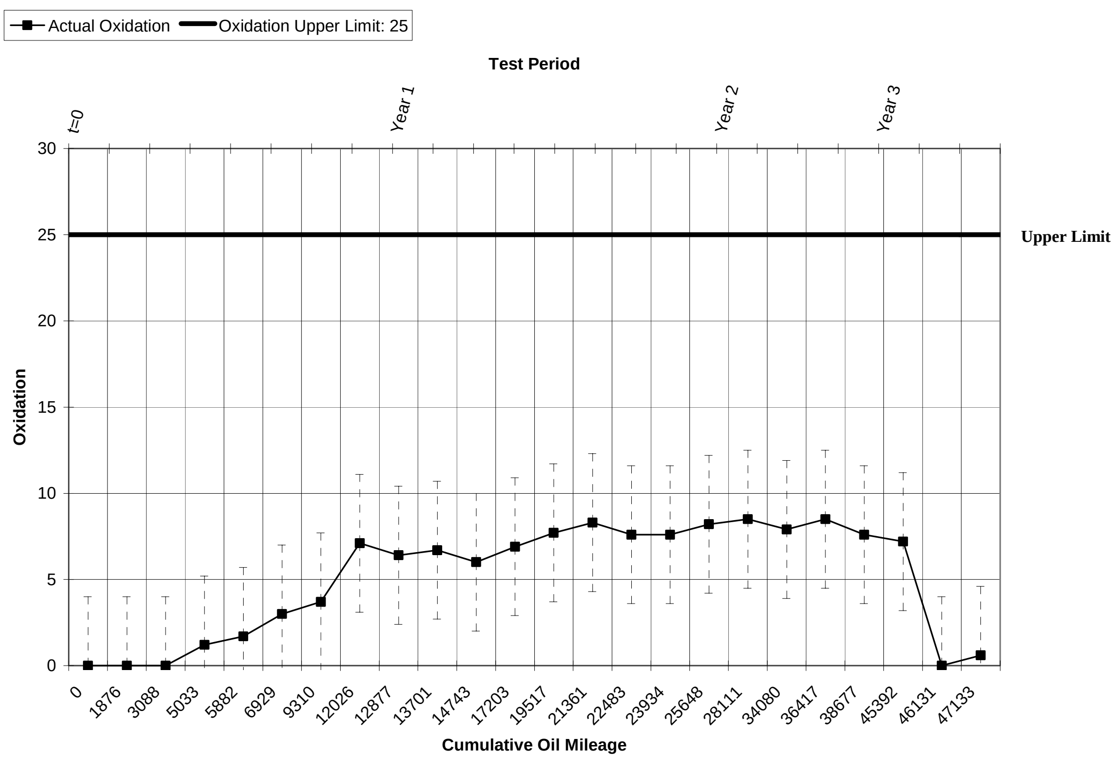

Figure B.16 Diesel Truck 58-02532 Cumulative Oil Mileage vs. Oxidation.

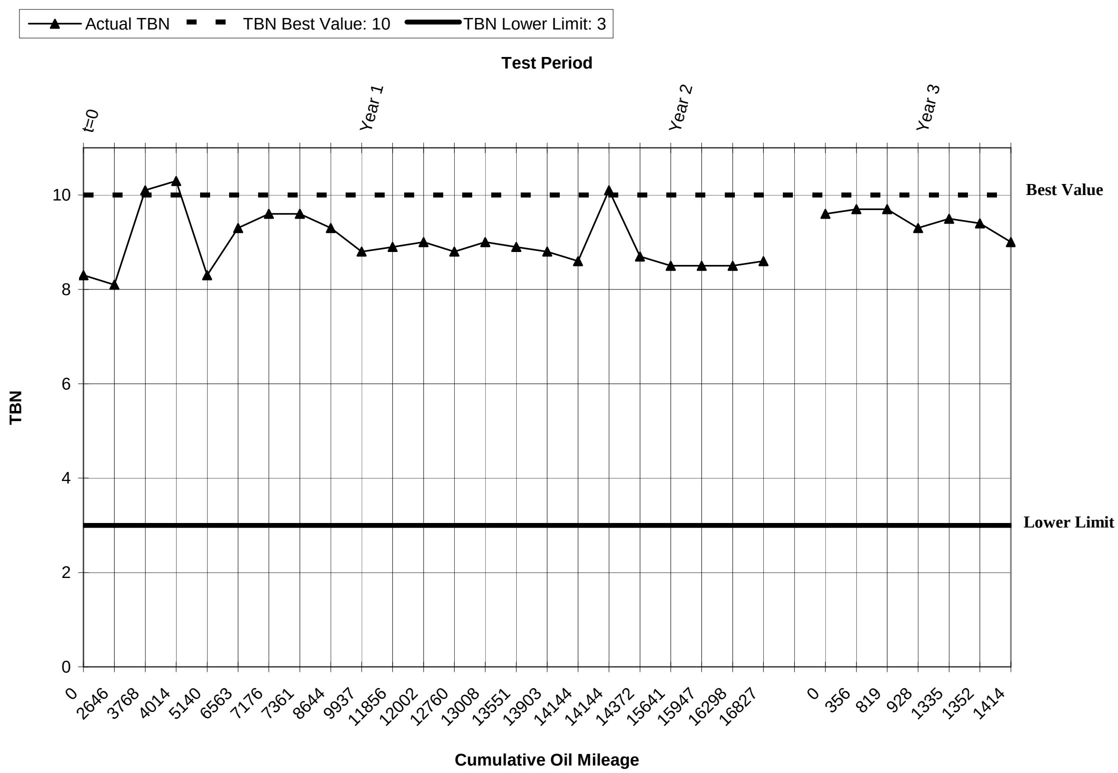

Figure B.17 Diesel Truck 58-02525 Cumulative Oil Mileage vs. TBN.

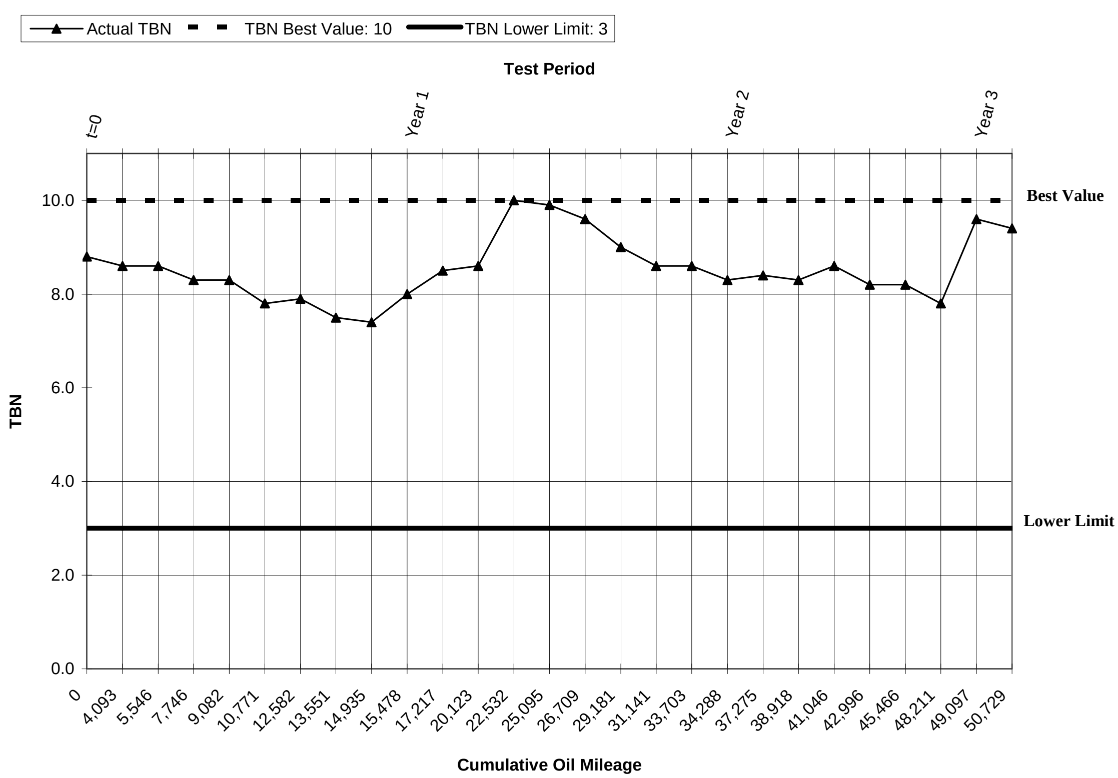

Figure B.18 Diesel Truck 58-02526 Cumulative Oil Mileage vs. TBN.

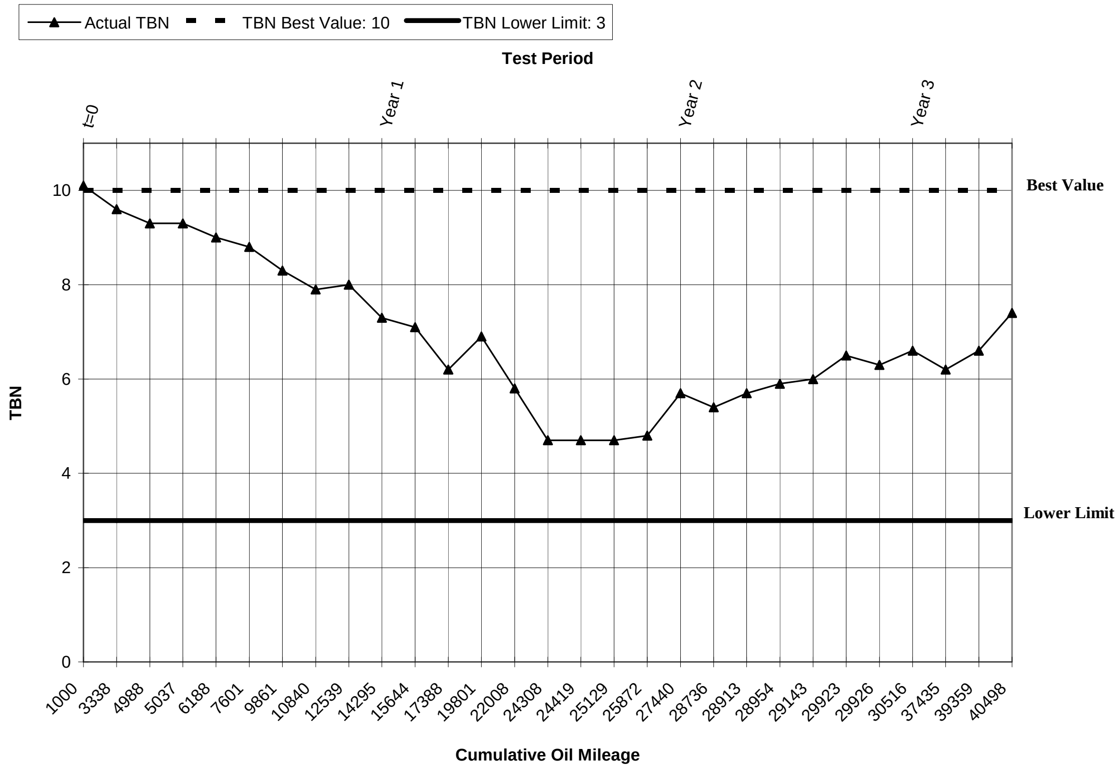

Figure B.19 Diesel Truck 58-02531 Cumulative Oil Mileage vs. TBN.

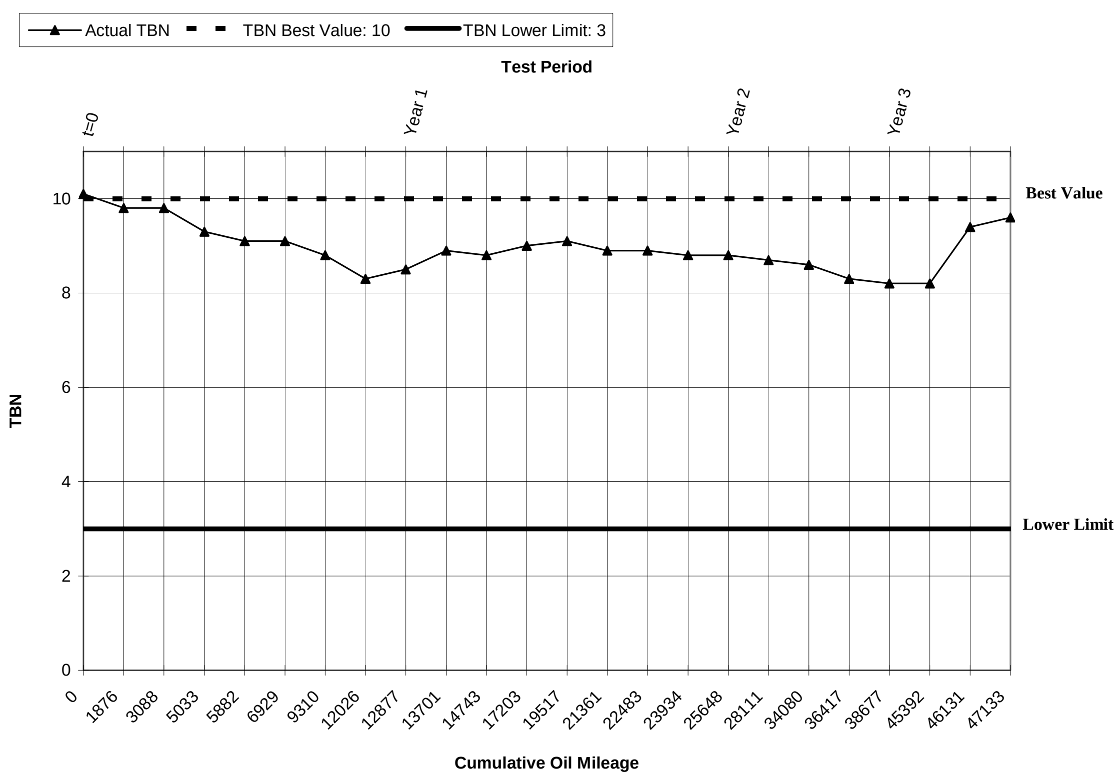

Figure B.20 Diesel Truck 58-02532 Cumulative Oil Mileage vs. TBN.

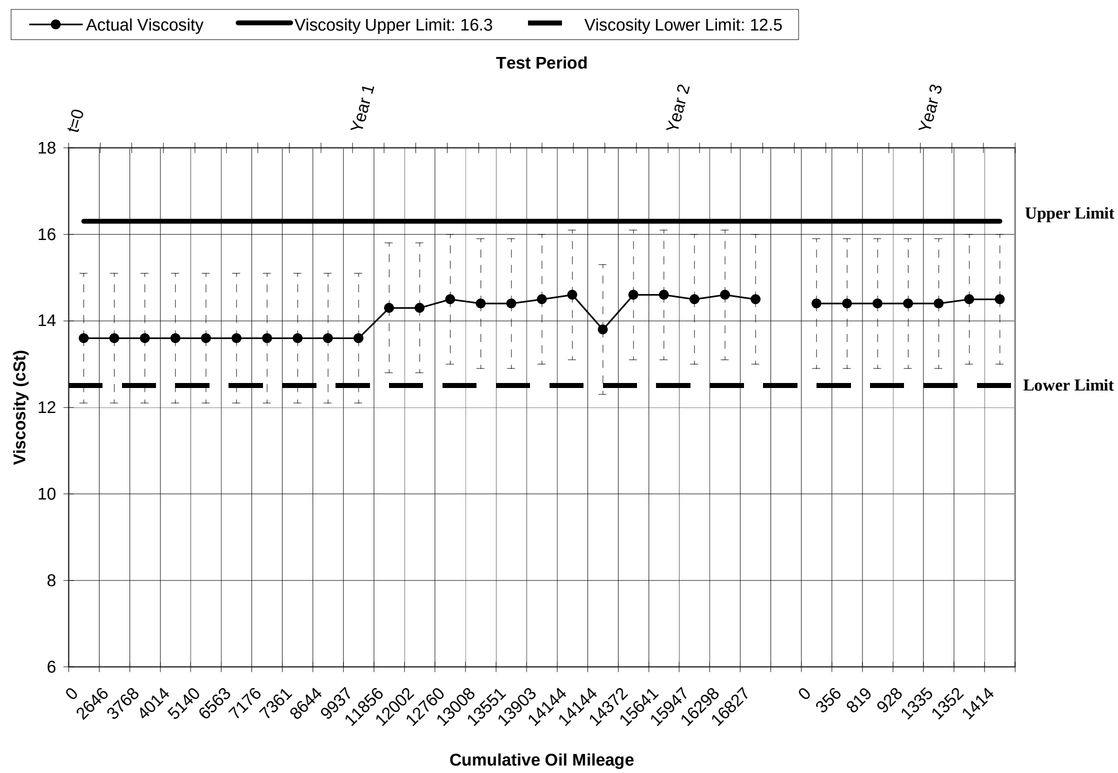

Figure B.21 Diesel Truck 58-02525 Cumulative Oil Mileage vs. Viscosity.

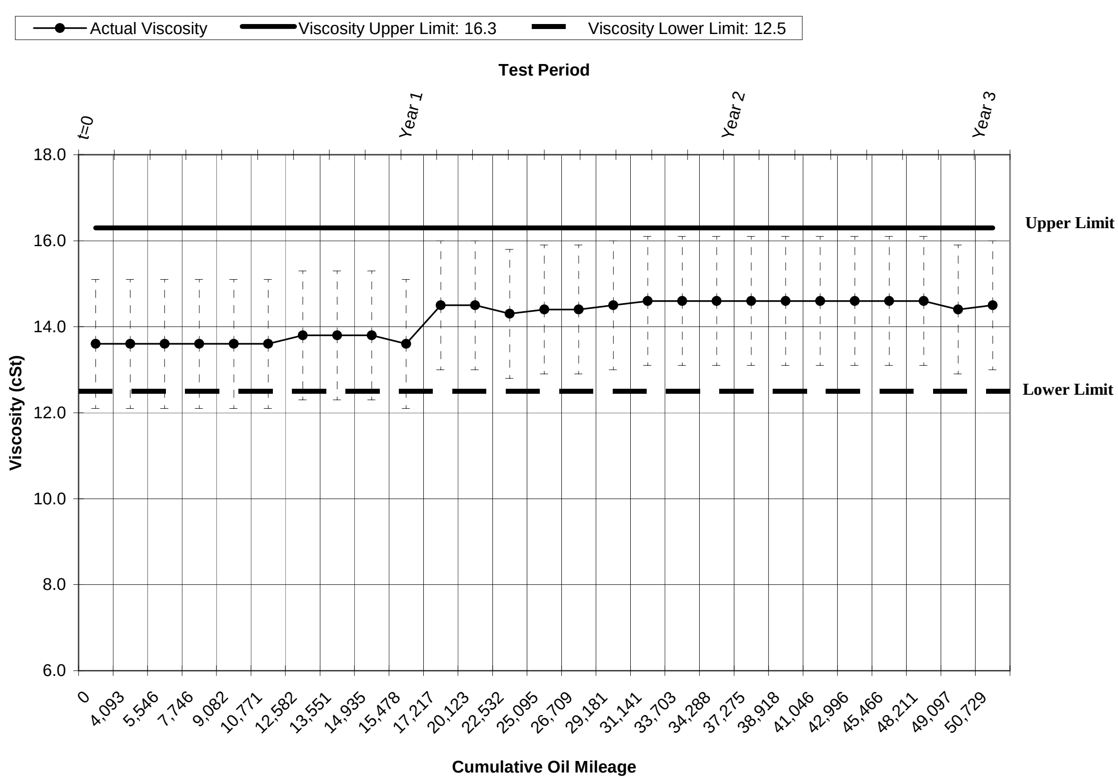

Figure B.22 Diesel Truck 58-02526 Cumulative Oil Mileage vs. Viscosity.

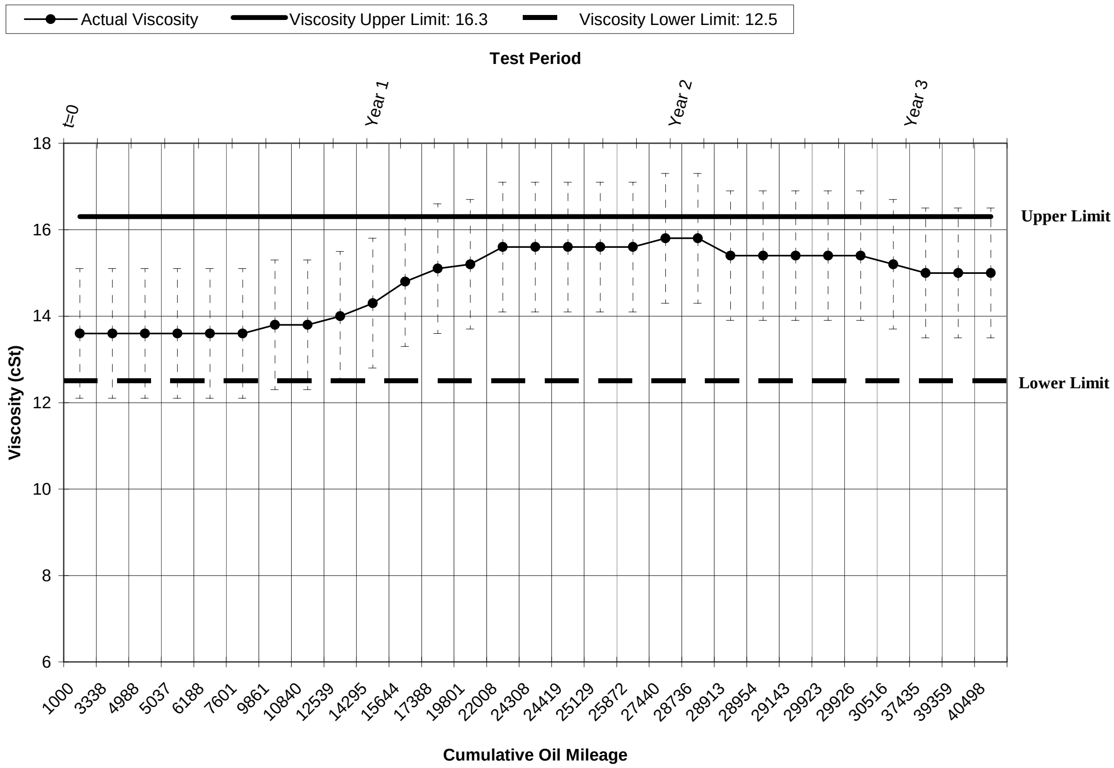

Figure B.23 Diesel Truck 58-02531 Cumulative Oil Mileage vs. Viscosity.

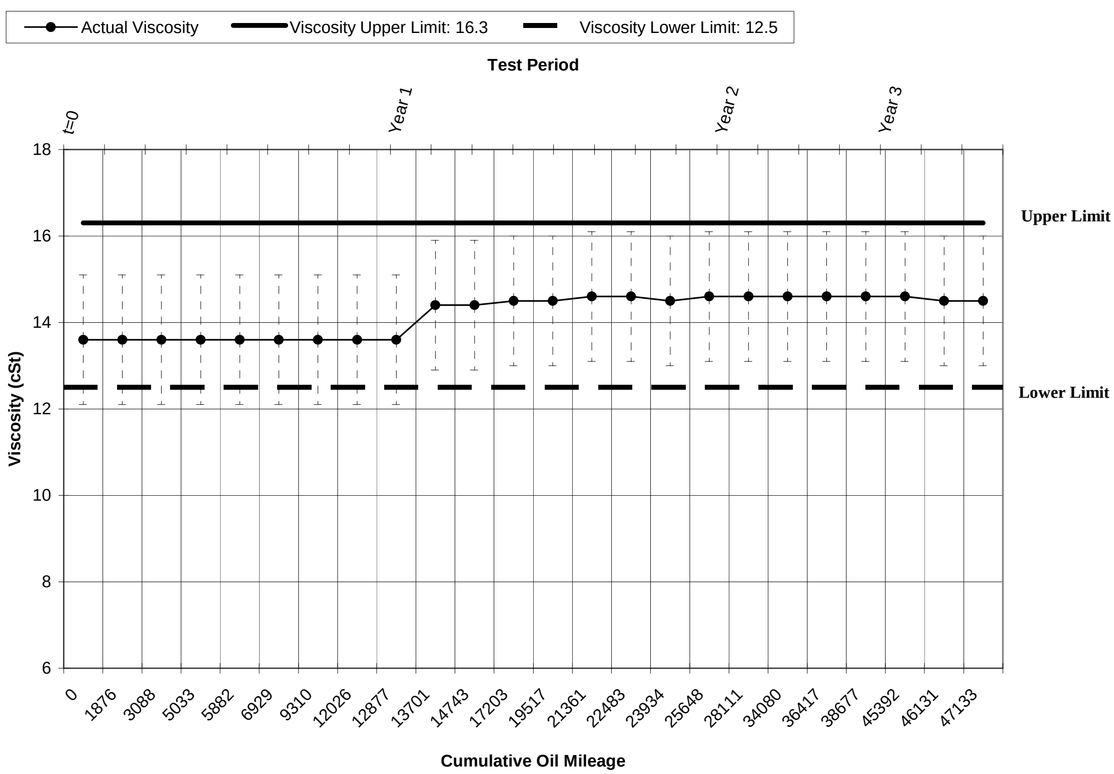

Figure B.24 Diesel Truck 58-02532 Cumulative Oil Mileage vs. Viscosity.

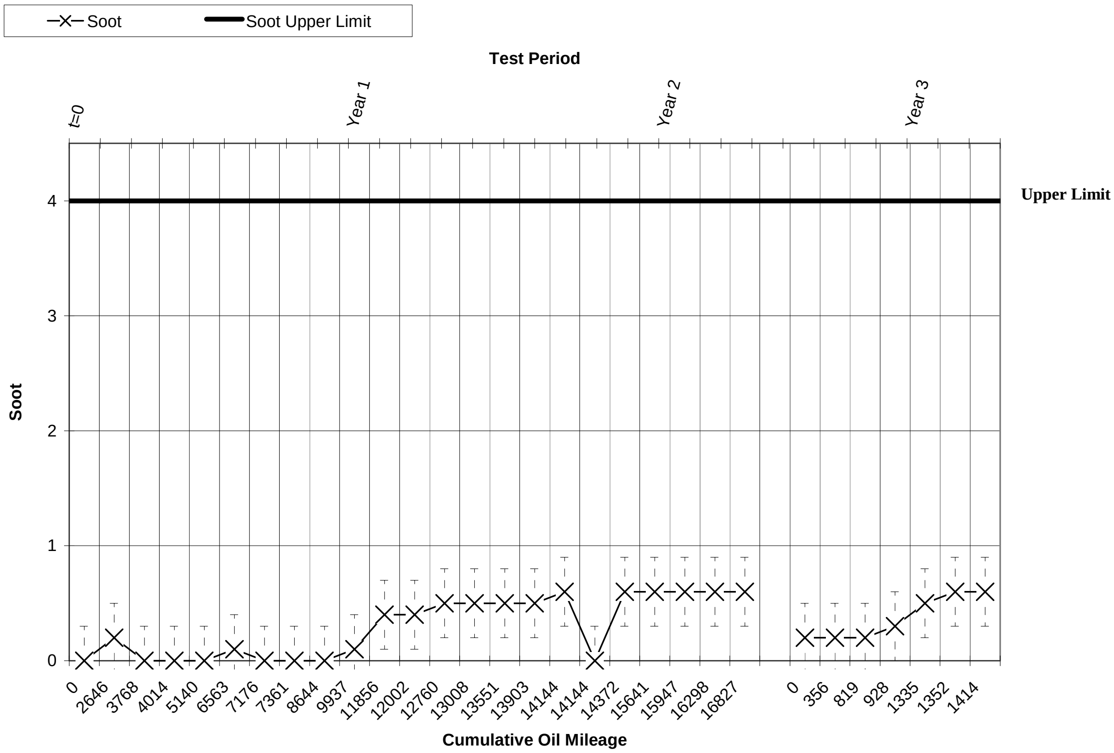

Figure B.25 Diesel Truck 58-02525 Cumulative Oil Mileage vs. Soot.

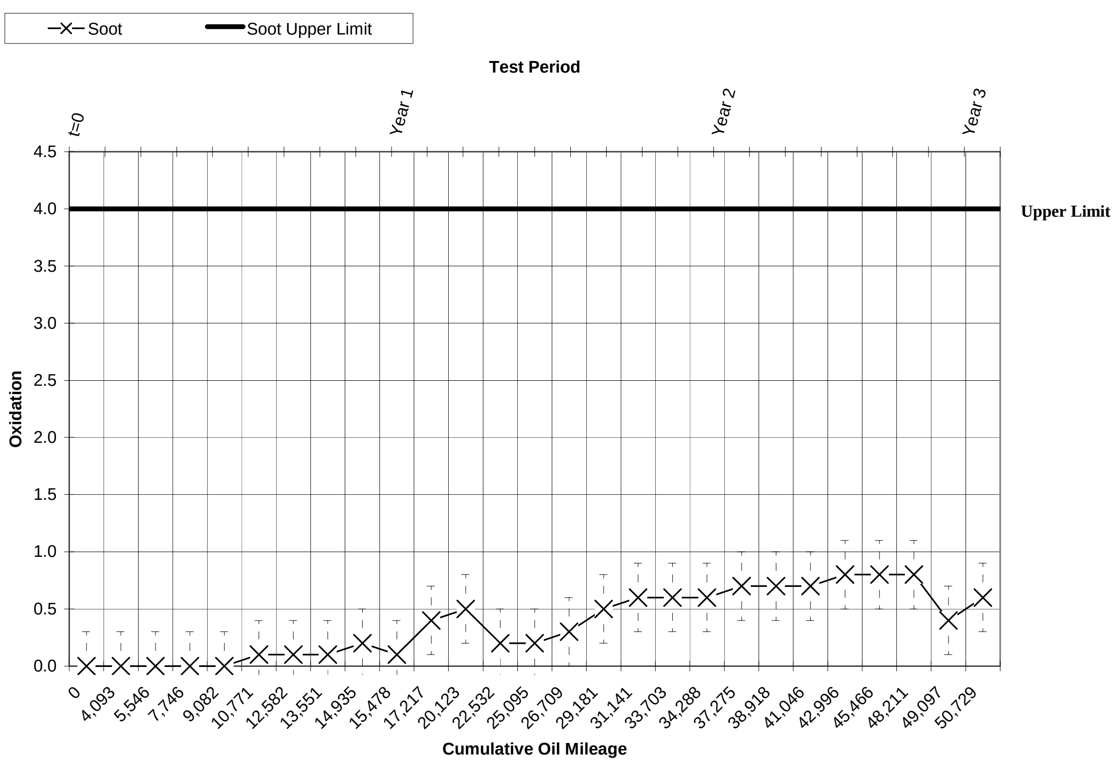

Figure B.26 Diesel Truck 58-02526 Cumulative Oil Mileage vs. Soot.

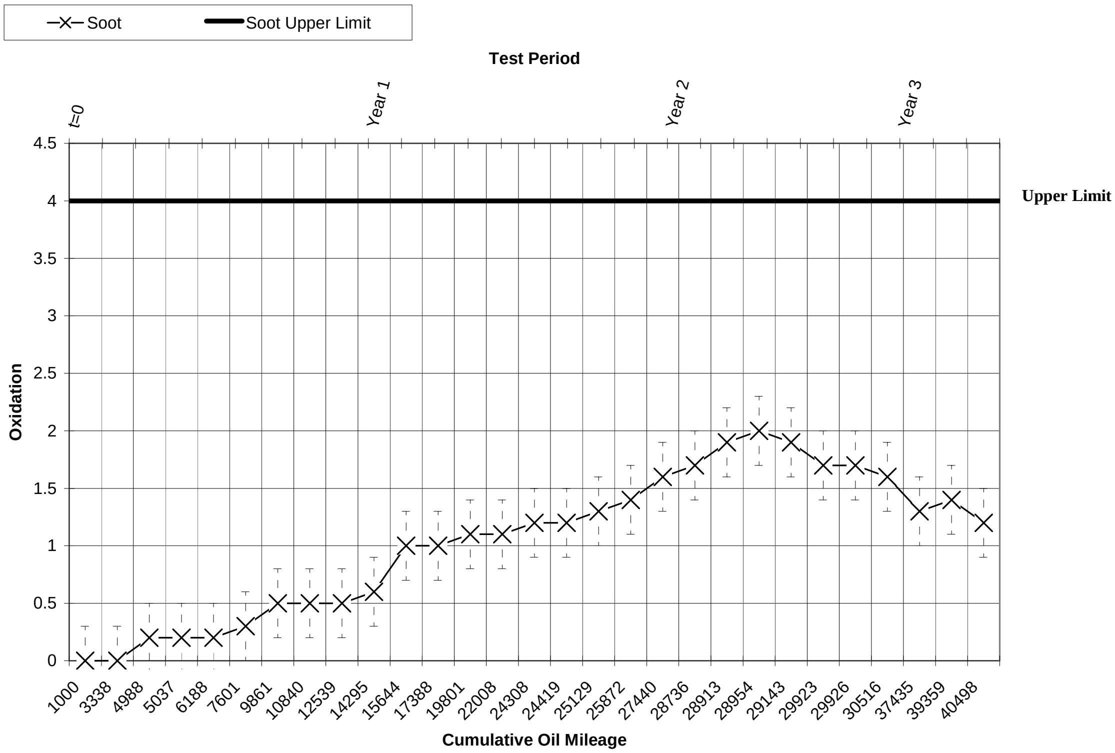

Figure B.27 Diesel Truck 58-02531 Cumulative Oil Mileage vs. Soot.

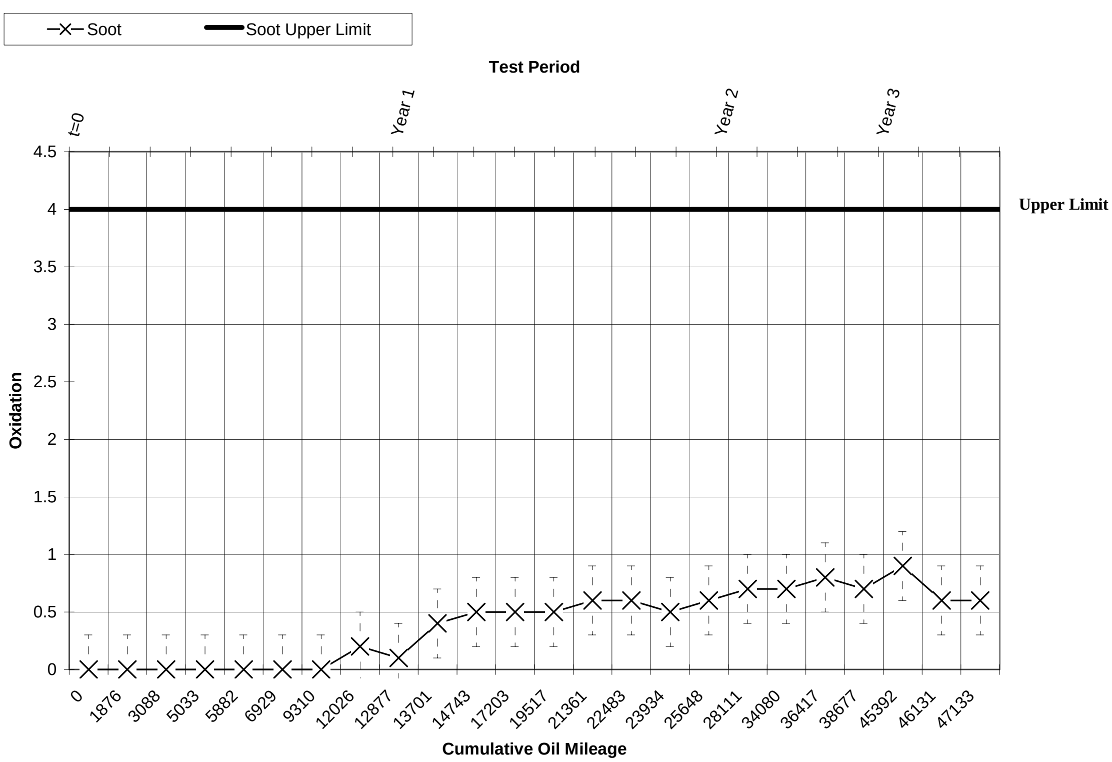

Figure B.28 Diesel Truck 58-02532 Cumulative Oil Mileage vs. Soot.