U.S. Department of Energy
Energy Efficiency and Renewable Energy

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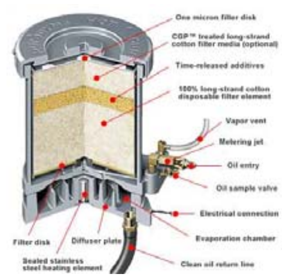
U.S. Department of Energy
FreedomCAR & Vehicle Technologies Program

Oil Bypass Filter Technology Evaluation Ninth Quarterly Report October–December 2004



TECHNICAL REPORT

Larry Zirker
James Francfort
Jordan Fielding

February 2005

Idaho National Laboratory
Operated by Bettelle Energy Alliance

INL/EXT-05-00040

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Assistant Secretary for Energy Efficiency and Renewable Energy
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ABSTRACT

This Oil Bypass Filter Technology Evaluation quarterly report (October–December 2004) details the ongoing fleet evaluation of oil bypass filter technologies being conducted by the Idaho National Laboratory (INL; formerly Idaho National Engineering and Environmental Laboratory) for the U.S. Department of Energy's FreedomCAR & Vehicle Technologies Program. Eight INL four-cycle diesel-engine buses used to transport INL employees on various routes and six INL Chevrolet Tahoes with gasoline engines are equipped with oil bypass filter systems from the puraDYN Corporation. This quarter, three additional buses were equipped with bypass filters from Refined Global Solutions. Oil bypass filters are reported to have an engine oil filtering capability of less than 1 micron. Both the puraDYN and Refined Global Solutions bypass filters have a heating chamber to remove liquid contaminate from the oil.

During the quarter, the eleven diesel engine buses traveled 62,188 miles, and as of January 3, 2005 the buses had accumulated 643,036 total test miles.

Two buses had their engine oil changed this quarter. In one bus, the oil was changed due to its degraded quality as determined by a low total base number (<3.0 mg KOH/g). The other bus had high oxidation and nitration numbers (>30.0 Abs/cm). Although a total of six buses have had their oil changed during the last 26 months, by using the oil bypass filters the buses in the evaluation avoided 48 oil changes, which equates to 1,680 quarts (420 gallons) of new oil not consumed and 1,680 quarts of waste oil not generated. Therefore, over 80% of the oil normally required for oil-changes was not used, and, consequently, the evaluation achieved over 80% reduction in the amount of waste oil normally generated.

The six Tahoe test vehicles traveled 39,514 miles, and as of January 3, 2005 the Tahoes had accumulated 189,970 total test miles. The Tahoe filter test is in transition. To increase the rate of bypass filter oil flow on the Tahoes, puraDYN provided a larger orifice assembly, and these are being changed out as the Tahoes come in for regular service.

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Oil Bypass Filter Technology Evaluation
Ninth Quarterly Report

INTRODUCTION AND BACKGROUND

This Oil Bypass Filter Technology Evaluation quarterly report covers the evaluation period October through December 2004. PuraDYN oil bypass filter systems (Figure 1) are being tested on eight diesel buses and six Chevrolet Tahoes (eight-cylinder gasoline engines) in the Idaho National Laboratory (INL; formerly Idaho National Engineering and Environmental Laboratory) fleet. This quarter, INL fleet mechanics installed bypass filter systems from Refined Global Solutions (RGS) on three additional fleet buses. This expands the number of test vehicles and data points to evaluate oil bypass filter technology to 17 vehicles (11 buses and 6 Tahoes). Typically, the INL fleet of 99 buses travels established routes, carrying workers during their morning and evening trips to and from the INL test site (over 100 miles per round trip). The Tahoes are used within the 900-square-mile INL site or between the INL site facilities and Idaho Falls, a distance of 50 miles each way. The Oil Bypass Filter Technology Evaluation is being performed for the U.S. Department of Energy's FreedomCAR and Vehicle Technologies Program.

The eleven buses are equipped with the following types of four-cycle diesel engines:

- Six buses with Series 50 Detroit diesel engines (three with RGS and three with puraDYN filters)
- Four buses with Series 60 Detroit diesel engines (all puraDYN filters)
- One bus with a Model 310 Caterpillar engine (puraDYN filter).

This quarterly report covers the following:

- Status of bus mileage and performance
- Analysis and reporting of bus engine oil
- Diesel engine idling wear-rate evaluation initial testing
- Refined Global Solutions bypass filter installations
- Status of light-duty vehicle mileage and performance.

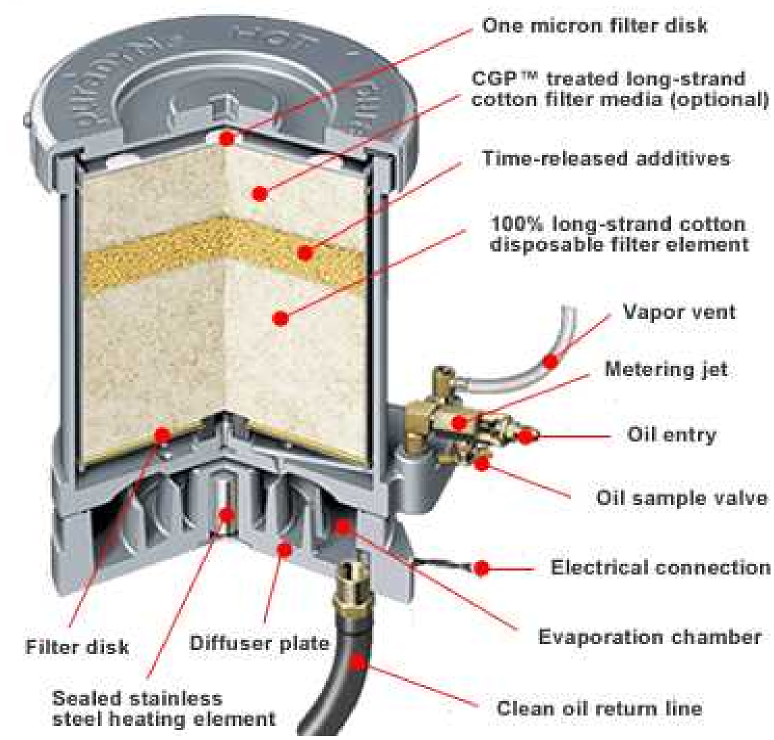

Figure 1. Cutaway view of a puraDYN oil bypass filter.

Table 1 lists all prior quarterly reports and the major topics presented in them.

Table 1. Major topics of previous quarterly reports, all of which are on line at http://avt.inel.gov/obp.html.

Reporting Quarter	Report Number	Major Topics
Oct 2–Dec 2 2002	INEEL/EXT-03-00129	• Background on fleet operations, vehicles, filters, and oil selection • Performance evaluation status • Economic analysis • Photographs of installed systems • Bypass Filtration System Evaluation Test Plan
Jan 3–Mar 3 2003	INEEL/EXT-03-00620	• Background on reports • Bus mileage and performance status • Revised filter replacement schedule • Oil-analysis sampling • Light-duty vehicle test status
Apr 3–Jun 3 2003	INEEL/EXT-03-00974	• Background on reports • Bus mileage and performance status • Preliminary trends in oil analysis reports • Revised economic analysis • Ancillary data • Light-duty vehicle test status
Jul 3–Sep 3 2003	INEEL/EXT-03-01314	• Background on prior quarterly reports • Bus mileage and performance status • Used engine-oil disposal costs • Unscheduled oil change • Light-duty vehicle test status
Oct 3–Dec 3 2003	INEEL/EXT-04-01618	• Bus mileage and performance status • Bus oil analysis testing and reporting • Light-duty vehicle filter installations • Light-duty vehicle filter installations lessons learned • Light-duty vehicle filter evaluation status
Jan 4–Mar 4 2004	INEEL/EXT-04-02004	• Bus mileage and performance status • Bus oil analysis testing and reporting • Bus engine oil particulate count analysis • Light-duty vehicle mileage and performance status • Light-duty vehicle filter evaluation lessons learned
Apr 4–Jun 2004	INEEL/EXT-04-02194	• Bus mileage and performance status • Bus oil analysis testing and reporting • Lessons learned from the evaluation of heavy-vehicle filters • Light-vehicle mileage and performance status • Lessons learned from the evaluation of light-vehicle filters

Reporting Quarter	Report Number	Major Topics
Aug–Sept 2004	INEEL/EXT-04-02486	• Bus mileage and performance status • Bus oil analysis testing and reporting • Oil use • Lessons learned on the heavy vehicle • Upcoming INEEL tests • Oil bypass filter system manufactures • Light-vehicle mileage and performance status • Lessons learned from the evaluation of light-vehicle vehicles

HEAVY-VEHICLE TESTING

Status of Bus Mileage and Performance

During this reporting quarter (October–December 2004), the 11 diesel-powered buses traveled 62,188 miles. Fewer miles (19,935) were travel this quarter (compared to the July-September quarter) mainly due to holidays and the annual INL work curtailment in December. Figure 2 shows the quarterly and cumulative evaluation miles. Table 2 details the mileage status of the eleven test buses. Figure 3 shows the total evaluation miles per bus by evaluation quarter. And Figure 4 shows the mileage per oil change history by bus.

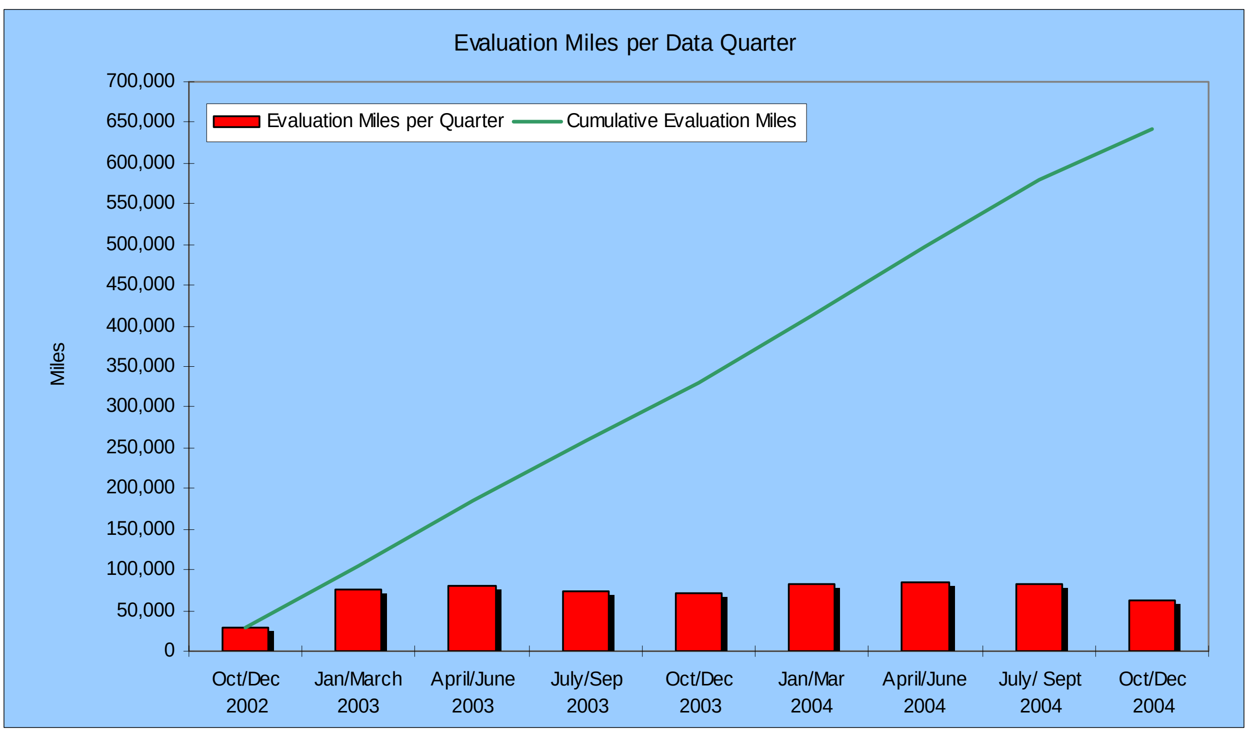

Figure 2. Quarterly and cumulative miles traveled by the test buses.

Table 2. Test buses and test miles on the bus engine oils as of January 3, 2005.

Bus Number	Filter	Start Date	Mileage at Start	Total Test Miles
73413	RGS	Dec 14, 2004	202,233	1,825
73416	RGS	Dec 14, 2004	195,156	1,256
73425	puraDYN	Dec 18, 2002	41,969	53,065
73426	RGS	Dec 7, 2004	36,140	393
73432	puraDYN	Feb 11, 2003	47,612	79,610
73433	puraDYN	Dec 4, 2002	198,582	83,447
73446	puraDYN	Oct 23, 2002	117,668	77,239
73447	puraDYN	Nov 14, 2002	98,069	66,576
73448	puraDYN	Nov 14, 2002	150,600	65,489
73449	puraDYN	Nov 13, 2002	110,572	61,899
73450	puraDYN	Nov 20, 2002	113,502	152,805
			Total	643,604

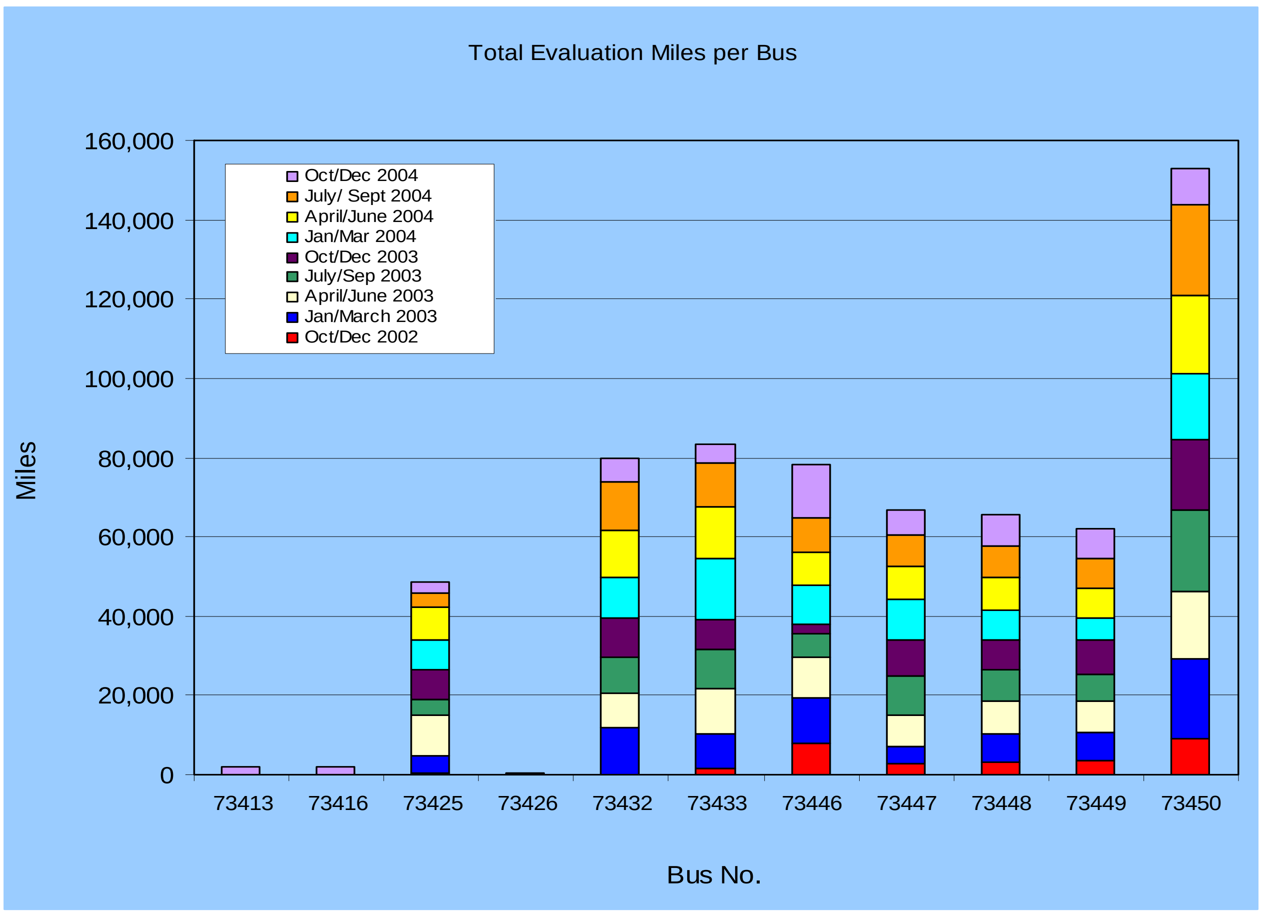

Figure 3. Total evaluation miles by bus for the October–December 2004 quarter.

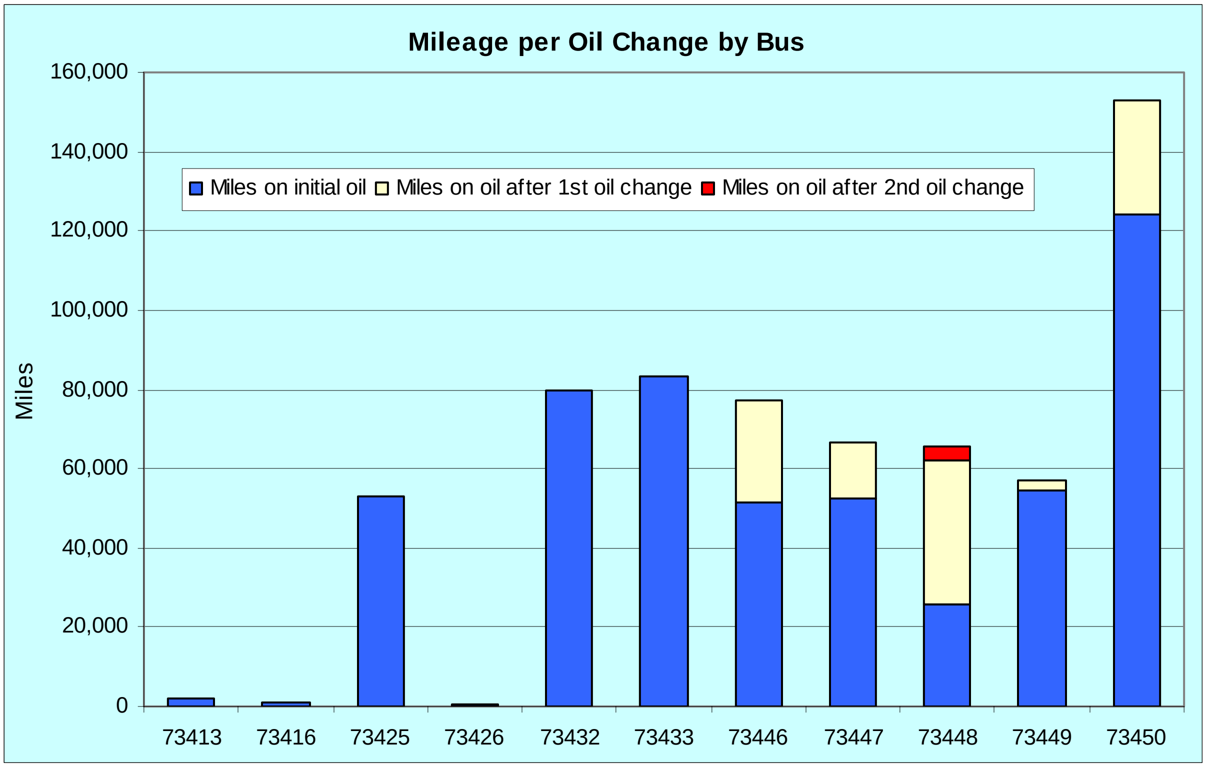

Figure 4. Test miles per oil change by individual bus. The oil on bus 73448 was inadvertently first changed in error on 9/16/03.

Analysis and Reporting of Bus Engine Oil

Five regular oil-servicing events (regularly at 12,000-mile intervals) occurred this quarter. The subsequent oil tests for three of the bus engine oils indicated they were within acceptable operating limits. The test results on the two other bus engine oils, however, failed to meet minimum oil quality levels, and the engine oils were changed. Bus 73448 had high oxidation and nitration levels, averaging 31.8 Abs/cm, which exceeds the oil change threshold of >30.0 Abs/cm. Bus 73449 had a total base number (TBN) of 2.5, which is less than the TBN threshold of 3.0 mg KOH/g, and it also had high oxidation and nitration levels, averaging 40 Abs/cm, which exceeds the >30.0 Abs/cm threshold.

The total base number indicates the acid reducing value of the oil, whereas oxidation and nitration levels are a measure of the chemical processes of aging in the oil resulting from such engine conditions as high temperature, catalysts present in the oil (water, air, and wear metals), and other contaminants present (fuels and process chemicals). As oxidation and nitration values increase, other oil quality elements, such as TBN and viscosity, tend to degrade and to reduce lubricant life. When the TBN is high, the oxidation/nitration numbers are normally low. Bus 73447 in Figure 5 is an example of this. Whereas the bus 73448 oil analysis report for 6/30/04 shows a TBN of 2.0 and an average oxidation and nitration level of 25, three months after the oil was changed (11/15/04) the TBN value was above 8, and the oxidation/nitration level was about 15. Most of the bus oils show this same basic relationship, though some are more dramatic than others.

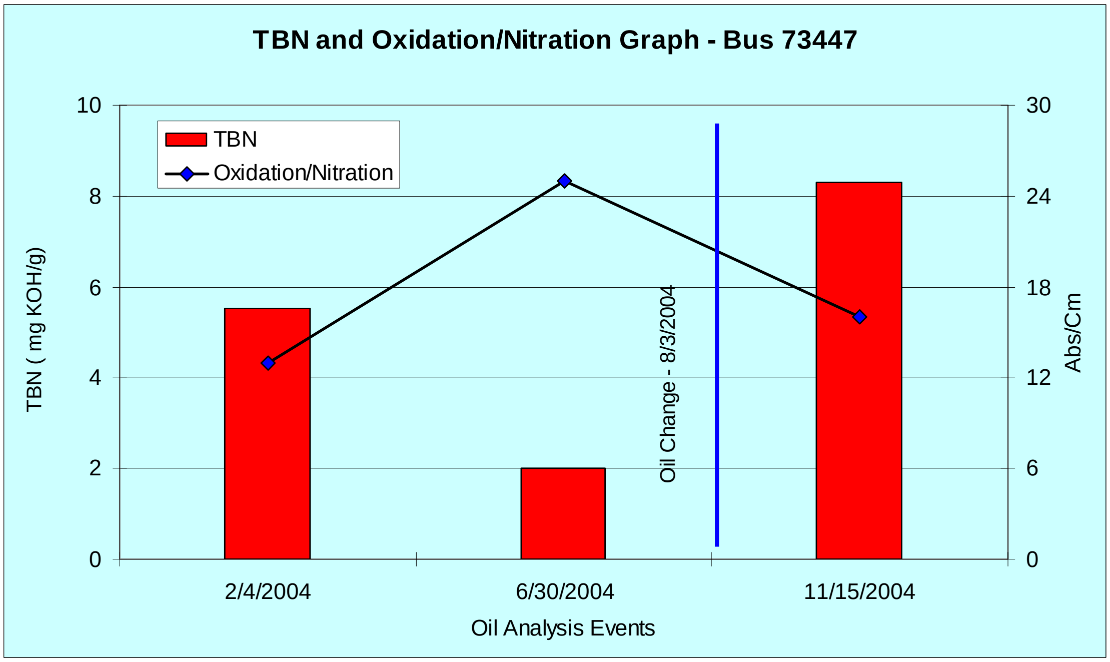

Figure 5. Inverse relationship between TBN and oxidation/nitration levels for three oil testing reports on bus 73447.

Oil Analysis Basics

The basic oil analysis report is a widely used tool to measure the condition of the oil and of the engine. The report indicates essentially three things: (1) metals from engine-wear, (2) the condition of additives and the presence of contaminates, and (3) oil quality. Generally, the cost of an oil analysis is based on the number and kind of test performed. A barebones oil analysis costs between 10 and 20 dollars. Extra and out-of-the-ordinary tests (such as oxidation and nitration testing) increase costs. Various tests address the need for esoteric information. Tests are available that directly measure particle sizes while other tests can measure particle sizes indirectly. A graph reporting the relative ability of three indirect tests to detect the presence of particles of various sizes is found on the Website of National Tribology Services Inc. (http://www.natrib.com/appnotes/app20.htm) and is reprinted here by permission (Figure 6):

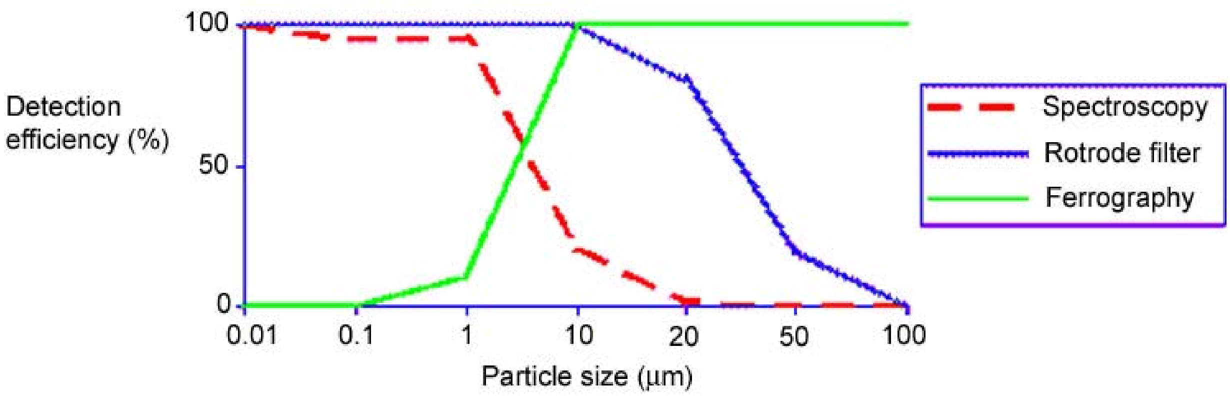

Figure 6. Detection efficiency of indirect tests in terms of their ability to detect particles of various sizes.

Although spectrometric analysis is the mainstay of oil analysis reports, spectrometric analysis reveals essentially only those particles of less than ten microns, as Figure 6 graphically shows, and is blind to those of larger size. The figure also shows that rotrode filter spectroscopy best reveals wear-metal particles between 10 and 50 microns, and that analytical ferrography best reveals ferrous particles greater than 10 microns.

Quantification of PPM Volumes

Values of wear metals are stated in parts per million (ppm) on the typical oil analysis report. A partial list of wear metals will include iron, copper, lead, and chromium. But when an engine oil analysis reports 50 ppm of iron, what does that mean in terms of the entire volume of engine oil? The volume that 50 ppm of iron displaces in 106 liters (28 quarts or 7 gallons) of engine oil is 1.3 ml of fine iron (less than 10 microns in size), which is equivalent to one teaspoon. (The calculation is shown below).

Assumptions:

- 1 liter of oil is equivalent to about 1 kilogram of oil
- A 28-quart oil sump is 26.5 liters, or 26,500 ml
- 1 ml equals 0.2 teaspoons
- 1/1,000,000 is 1 ppm
- 100% is 1,000,000 ppm.

Equation:

$100\% \div 1{,}000{,}000 \text{ ppm} = X\% \div 50 \text{ ppm} = 0.005\%$

$0.00005 \times 26{,}500 \text{ ml} = 1.3 \text{ ml}$

$1.3 \text{ ml} \times 0.2$ (teaspoons) = 0.26 teaspoon of fine iron particles in 28 quarts of oil.

Diesel Engine Idling Wear-Rate Evaluation Test

INL is undertaking a diesel engine idling evaluation in support of DOE’s effort to minimize diesel engine truck idling in the United States and the associated consumption of over 850 million gallons of diesel fuel during periods of engine idling for heating, cooling, and auxiliary power generation. In addition to the economic advantage of minimizing the use of fuel by avoiding or eliminating engine idling, engine life should be extended and oil change intervals lengthened. When fuel use is decreased by eliminating tractor engine idling for heating, cooling, and auxiliary power (or using a substitute energy source such as a small auxiliary engine or diesel-fired heater), and the difference in the amount of fuel used is determined, the economics of fuel cost savings is a simple mathematical exercise.

The trucking industry believes that there are operational and economic benefits from reduced engine wear, and that there should be subsequent extended engine-life and possible oil-change intervals, but there is no definitive consensus on the economic value of these benefits. Therefore, at DOE’s request, INL has undertaken a project to characterize diesel engine wear and lubricating degradation during extended periods of engine idling versus normal engine operation: two INL buses equipped with Detroit Diesel Series 50 engines will be idled for 1,000 hours each. These two buses have been part of INL’s oil bypass filter evaluation project since December 2002, so there are two years of oil analysis reports as background data on which to build the idling test database. In addition to the current oil analysis, engine-wear metals will be characterized by analyzing the engine oils and by destructively analyzing the bypass and full-flow oil filters to measure the engine-wear metal particles captured.

To develop baseline data before starting the idling test, a bypass and a full-flow oil filter from bus 73433 were sent to National Tribology Services (NTS), Inc. of Minden, Nevada for analysis. A secondary benefit of this initial destructive analysis is to establish and refine the filter testing protocol before the filters from the test period are examined. There is only a single opportunity to capture the data from the filters because the examination is very intrusive and nonrepeatable.

Bus 73433 Destructive Analysis Methods and Results

The tribologists (oil scientists) and laboratory technicians at NTS have experience in conducting destructive filter analysis, and they furnished a baseline of what previous filter analyses entailed. After discussions with NTS on the idle test data required, a plan was developed for a regimen of tests to acquire the data. The destructive filter testing entails three methods:

- Filter preparation
- Debris analysis
- Oil quality analysis.

Filter Preparation: Filter preparation consists of:

- Separating the metal filter jacket from the filter media
- Preparing the filter media samples for ultrasonic processing and weighing
- Processing the filter media samples by ultrasonic processing.

During filter preparation, the metal jackets were severed to facilitate removing the filter media, using two cutters (Figures 7 and 8). After the filter media is removed from the canisters, the media is dissected (Figure 9) to obtain representative samples of the filters—about one pound of media. The samples pieces are then placed into separate sample jars containing one liter of Chevron 100R Neutral Base Oil, and then sonicated (Figure 10) in a Branson Model 3500 Ultrasonic Cleaning Bath machine for 8 hours (per ASTM G131-96). This ultrasonic shaking separates the trapped particles from the filter media and places them into the neutral base oil.

Figure 7. Removing the metal casing from the full-flow filter (using first cutter)

Figure 8. Removing the metal casing from the bypass filter (using second cutter).

Figure 9. Filter media being dissected.

Figure 10. Sonication of filter media

Debris Analysis: Debris analysis consists of the following:

- *X-ray florescence of the filter media*. X-ray florescence of a small section of the filter media (before sonication) characterizes the filter media surface for metals. This test does not depend on particle size, and it sees all metals. Only three metals (iron, lead and zinc) were found. Their ppm concentrations are listed in Table 3 (see under Special Test Results at the bottom of the table).
- *Rotrode filter spectroscopy of the* oils. The rotrode filter spectroscopy (RFS) quantifies the course metals (10 to 50 micron size particles) in the oil samples. The RFS captures the larger particles that are deleterious to engine wear. Table 4 shows a relationship of the effectiveness between the two filters in catching iron particles measured by the RFS (see Table 3 toward the top under RFS COARSE Spectrometric Results [ppm]).
- *Particle count of the oils*. The particle count bins the particles into six sizes: >4, >6, >14, >21, >38, and >70 microns (toward the bottom of Table 3 under Particle Count Results).
- *Ferrography of the oils*. Ferrography is a microphotograph (Figure 11) of the ferrous materials trapped on a glass slide with the aid of a magnet.

Oil Quality Analysis: The oil quality analysis is performed on samples of used oil and of the neutral base oil. During the last service for bus 73433, when the filters were removed for analysis, a used oil sample was taken and submitted for analysis along with the filters (labeled "Used Oil" in Table 3). When the NTS technicians removed the filter media from the metal filter cases, there was adequate residual oil in the bypass filter case for analysis (identified as "Bypass Residual Oil" in Table 3). The sample designated "Bypass Filter," is an oil sample taken from the sonicated neutral base oil and bypass filter media. The sample designated "Full-Flow Filter" is an oil sample taken from the sonicated neutral base oil and full-flow filter media. These oil samples were also given the following analyses:

- Atomic emission spectroscopy of the oils: wear metals, additives and contaminants identification
- Fourier-transform infra-red (FI-IR) spectroscopy of the oils: oxidation and nitration determination
- Viscosity of the oils determined
- Total base number of the oils calculated
- Heptane pentane insoluble analysis of the used oil evaluated.

Of all of the test oils, the atomic emission spectroscopy data listed in Table 3 (see FINE Spectrometric Results (ppm) ASTM D 6595) are most valid because they measures the wear metals, additives, and contaminants. Although the oxidation/nitration, viscosity, and TBN tests on sonicated neutral base oil are reported in Table 3, they should not be considered valid or comparable to the actual used engine oil, because they are for the neutral base oil.

The particle count results for the full-flow filter seems very high, 35,898,800 for >4 microns, but this is believed to result from pieces of filter media that disintegrated during the eight-hour ultrasonic cleaning of the filter media. A more accurate measure of wear metals is to be found in the fine spectrometric results and RFS coarse spectrometric results in Table 3. Although these are the first data from destructive filter analysis, it is interesting to compare what the filters caught. This is shown in Table 4.

The heptane/pentane insoluble analysis measures the quantity of insolubles suspended in the used oil. These fine particles (typically less than 0.02 microns) are suspended in the oil and are believed to be harmless to the lubrication value of the oil. A drop in the insoluble level suggests that the particles have agglomerated, forming sludge or engine deposits. The values shown in Table 3 are the initial values from the test, but without subsequent values for comparison, the relative worth of these numbers are unknown. By tracking the insoluble levels, however, an important measure of lubricant quality is obtained.

Table 3. Destructive filter analysis results for Bus 73433.

Sample Number	86976 (Used Oil)	87160 Bypass Residual Oil)	86905 (Bypass Filter)	86906 (Full-Flow Filter)	June Baseline Sample	March Baseline Sample
Date	9/22/04	9/22/04	9/22/04	9/22/04	6/7/04	3/4/04
Miles on Oil	77067	77067	77067	77067	63023	49676
FINE Spectrometric Results (ppm) ASTM D 6595						
Wear Metals						
Iron	77	77	31	41	82	79
Chromium	1	1	0	0	2	2
Lead	15	15	5	4	7	6
Copper	2	2	1	1	3	3
Tin	2	2	1	0	3	3
Aluminum	2	3	0	1	3	4
Nickel	0	0	0	0	0	1
Silver	0	0	0	0	0	0
Molybdenum	0	0	0	0	0	0
Titanium	0	0	0	0	1	0
Additives/Contaminants						
Silicon	5	6	4	6	6	6
Boron	0	0	0	0	2	2
Sodium	6	5	2	1	8	7
Magnesium	18	19	7	5	18	18
Calcium	3507	3450	1230	1010	3749	3460
Barium	0	0	0	0	1	1
Phosphorous	1063	1060	359	320	1232	1160
Zinc	1064	1070	408	385	1226	1090
Vanadium	N/G	N/G	N/G	9999	N/G	N/G

Sample Number	86976 (Used Oil)	87160 Bypass Residual Oil)	86905 (Bypass Filter)	86906 (Full-Flow Filter)	June Baseline Sample	March Baseline Sample
			RFS COARSE Spectrometric Results (ppm)			
			Wear Metals			
Iron	7	43	90	18	3	6
Chromium	0	1	0	0	1	1
Lead	0	0	0	0	0	0
Copper	0	0	0	0	0	0
Tin	0	3	1	1	0	0
Aluminum	0	2	0	1	0	1
Nickel	1	1	0	1	0	0
Silver	0	0	0	0	0	0
Molybdenum	0	0	0	0	0	0
Titanium	0	0	0	0	0	0
Contaminants						
Silicon	1	10	0	3	0	1
Boron	0	2	0	3	0	0
Sodium	1	4	1	1	1	0
			Viscosity Results (cSt)			
Viscosity @100^{o}C	15.15	15.27	6.41	7.17	14.88	14.33
			FT-IR Results (Abs/. 1mm or Percent)			
Oxidation	0.11	0.11	0.03	0.03	0.12	0.17
Sulfation	0.22	0.22	0.05	0.05	0.16	0.23
Nitration	0.14	0.14	0.04	0.04	0.17	0.20
Water %	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Fuel dilution	N/G	N/G	N/G	N/G	<2.00	<2.00
Glycol %	<0.05	<0.05	<0.05	<0.05	0.48	<0.05
Soot	0.51	0.52	0.20	0.23	0.23	0.28
Zinc depl	-0.09	-0.09	-0.16	-0.17	-0.17	-0.10
			Titration Results			
TBN	7.57	7.89	3.22	2.57	9.00	8.33
			Particle Count Results (μm[c])			
>4	116600	289700	10290100	35898800	361500	1530800
>6	63500	157800	5605400	19555600	196900	833900
>14	10800	26800	955000	3331800	33500	142000
>21	3600	9000	322200	1124300	11300	47900
>38	500	1400	49700	173600	1700	7400
>70	0	100	5100	17900	100	700
ISO >4	1166	2897	102901	358988	3615	15308
ISO > 6	635	1578	56054	195556	1969	8339
ISO >14	108	268	9550	33318	335	1420
ISO Code	17/16/14	19/18/15	24/23/20	26/25/22	19/18/16	21/20/18
SAE Code	9	10	12	12	11	12
			Special Test Results			
XRF-Fe			7 ppm	2 ppm		
XRF-Pb			7 ppm	9 ppm		
XRF-Zn			86 ppm	89 ppm		
Hepthane/penthane insoluble	0.7%	1.0%	1.6%	0.6%		

Table 4. Filter effectiveness in capturing 10 to 50 micron size particles.

	Weight of Filter Media with Oil (lb)	Weight of Filter Media Sample (lb)	Iron (10–50 μ size) (ppm)	Adjusted Iron Captured per Filter, (ppm)
Full-flow filter	1.4	1.0	18	25
Bypass filter	9.6	1.0	90	900

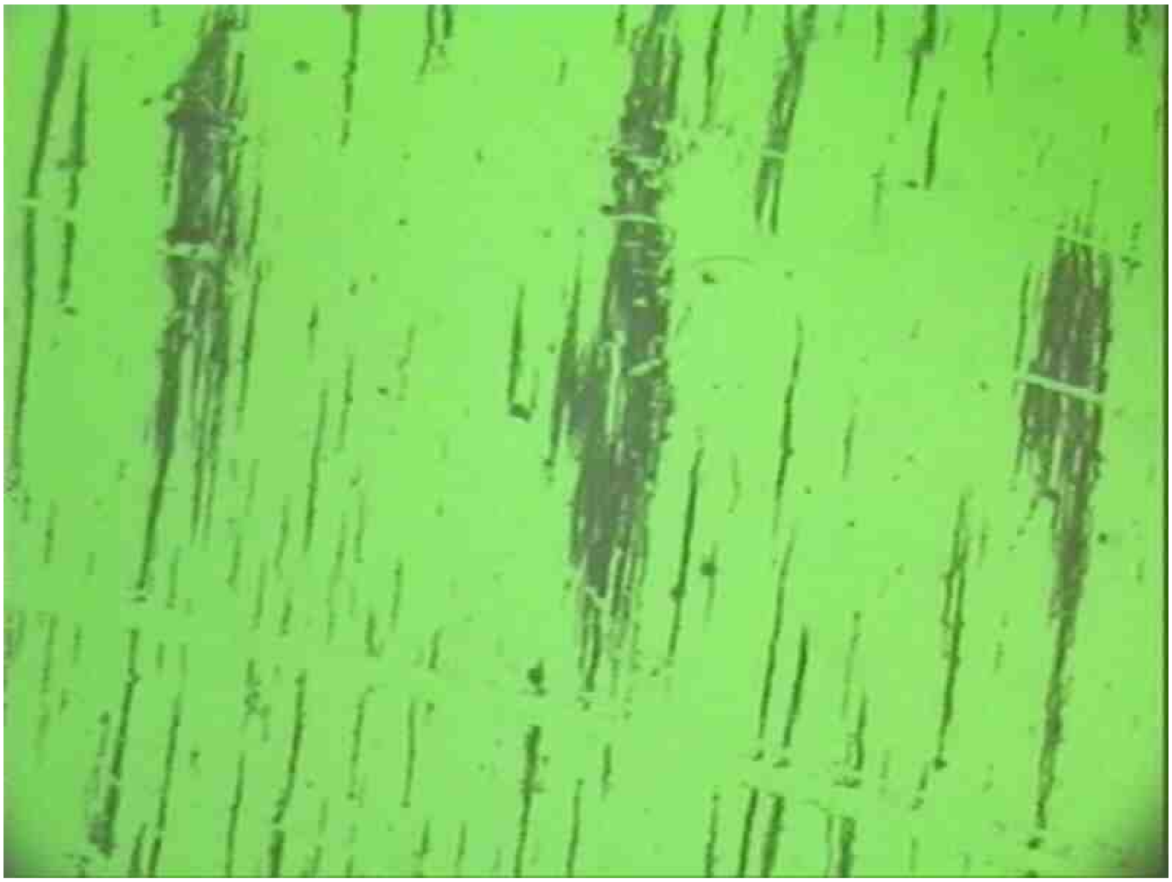

Figure 11. Ferrogram of light amount (<10 micron) of ferrous particulate typical of normal rubbing wear.

Refined Global Solutions Filter Installation

During December 2004, FP-1000 bypass filter systems from Refined Global Solution, Inc. (RGS), were installed on three INL MCI coach buses recently refurbished four-cylinder, four-cycle series 50, Detroit Diesel engines. This expands the number of INL buses under bypass filter evaluation from eight to eleven.

Installation of these filter systems required some preinstallation engineering, because of the existing auxiliary equipment on the buses and space limitations in the engine compartment. Upon examination of the space available for the filter system, RGS personnel and INL mechanics selected appropriate locations for the RGS filter systems.

The RGS FP-1000 filter system has two parts: filter housing and fluid evaporation unit. To facilitate the installation, the RGS engineers designed and built an angled bracket that would hold both filter system parts and the existing diesel fuel filter. The mechanics unbolted the diesel fuel filter, installed the bracket, and then attached the diesel fuel filter to the bracket. Then they installed the filter housing on one side of the diesel fuel filter and the fluid evaporation unit on the other side. Figure 12 shows a close-up view of the bracket. Figure 13 shows a view of the installed system in the passenger-side engine compartment. Note that the large blue filter housing is on one side of the diesel fuel filter, and the small, barely visible, blue fluid evaporation unit is on the far side of the fuel filter.

Figure 12. Close-up view of the angle bracket.

Figure 13. RGS bypass filter installation in the passenger side engine compartment.

LIGHT-VEHICLE TESTING

Status of Light-duty Vehicle Mileage and Performance

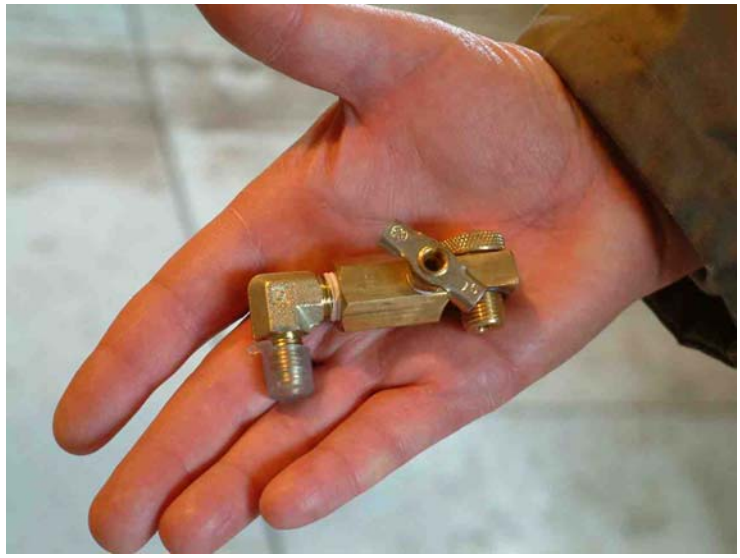

Figure 14. puraDYN orifice assembly with oil analysis sampling valve.

During this reporting quarter, the six light-duty Tahoe test vehicles traveled 39,514 miles, accumulating a total of 189,970 test miles. The Tahoe oils continued a trend of low TBN values with the Castrol 10W-30 oil. As a result of the low TBN values, INL consulted with puraDYN and they suggested increasing the oil metering orifice size to increase oil flow and bypass filtering to sustain higher TBN numbers. PuraDYN supplied six new meter jets and valve assemblies for installation (Figure 14). When the Tahoe's were originally outfitted with the bypass filter systems, the standard orifice (0.045 inch diameter) was used, but due to the cold weather in Idaho (−40°F is not unusual), this orifice allowed too much oil into the filter housing early in the mornings when the engines and oil were cold. The cold oil was too thick to flow through the filter media and would back up and overflow through a release valve in the filter housing. A valve with a cold weather orifice, 0.015625-inch (1/64-inch), was therefore installed, but it became apparent during the last year (low TBN values) that this valve was too restrictive to the flow. So puraDYN has provided a valve assembly with a 0.025-inch orifice to increase the bypass filter flow and the oil filtering. The new assemblies are being installed as the Tahoes are serviced. Details on the performance of the filters and oil in the Tahoes will be reported next quarter.

SUMMARY

Oil bypass filter systems are being tested on eleven INL buses. To date, the eleven buses have accumulated 643,036 miles since testing began. Six oil changes have been performed on the INL buses since the start of testing, and the buses have avoided 48 oil changes. This equates to 1,680 quarts (420 gallons) of new oil not consumed and 1,680 quarts of waste oil not generated, an almost 90% savings on oil purchases for oil changes and waste oil generation.

This quarter, bus 73448's oxidation and nitration values exceeded the predetermined (>30.0 Abs/cm) quality value limits, and its oil was changed. Bus 73449's TBN values fell below the predetermined quality value limit (<3.0 mg KOH/g), and its oil was also changed.

The first set of bus filters was destructively analyzed to obtain baseline data for the engine idling testing that began this quarter. The data will be compared to subsequent data to evaluate the consequences of prolonged engine idling. As a result of this analysis, the analysis procedures were revised and refined to ensure that correct data are obtained during the next filter analysis.

A trend in the oil analysis reports shows that when total base number goes down, oxidation and nitration values increase – both conditions are deleterious to oil quality.

FP-1000 oil bypass filter systems from Refined Global Solution, Inc. were installed in December on three INL fleet buses with recently refurbished four-cylinder, four-cycle Detroit Diesel engines. This expands the number of INL buses in the bypass filter evaluation from eight to eleven.

Five of the six Tahoe test vehicles have been retrofitted with new metering orifice assemblies having a larger orifice, 0.025, which provides a 63% increase in oil flow to the filter. This replacement is an attempt to sustain higher TBN values.