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Oil Bypass Filter Technology Evaluation

Second Quarterly Report
January – March 2003

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Idaho National Engineering and Environmental Laboratory
Bechtel BWXT Idaho, LLC

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ABSTRACT

This report details the ongoing fleet evaluation of an oil bypass filter technology by the Idaho National Engineering and Environmental Laboratory (INEEL) for the U.S. Department of Energy's FreedomCAR & Vehicle Technologies Program. Eight full-size, four-cycle diesel-engine buses used to transport INEEL employees on various routes have been equipped with oil bypass filter systems from the PuraDYN Corporation. Because of the reported filtering (down to 0.1 microns) capability of bypass filter systems, the technology is intended to extend oil-drain intervals. To validate the extended usability of the oil, an oil analysis regime is used to monitor the presence of necessary additives in the oil, to detect undesirable contaminants and engine wear metals, and to evaluate the fitness of the oil for continued service. The eight buses have accumulated 101,000 miles to date and some preliminary results are reported. The INEEL light-duty vehicle fleet is also being evaluated to identify candidate vehicles for inclusion in the test fleet.

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INTRODUCTION AND BACKGROUND

This quarterly report of the oil bypass filter technology performance evaluation covers the evaluation period January through March 2003.[1] Eight PuraDYN oil bypass filter systems (Figure 1) are being tested on Idaho National Engineering and Environmental Laboratory buses. The eight buses are all equipped with four-cycle diesel engines:

- Three Series-50 Detroit Diesel engines
- Four Series-60 Detroit Diesel engines
- One Caterpillar engine.

Most of the first quarter effort was spent preparing the test plan, receiving INEEL organizational approval (including management and health and safety groups), ordering parts, installing the oil bypass systems, performing the initial engine oil changes, and accumulating the initial test miles. Test data are accumulated as the buses log miles once the bypass filters have been installed and oil changes are avoided. At the end of the first quarter (December 31, 2002), the combined miles logged by the buses were approximately 30,000 miles.

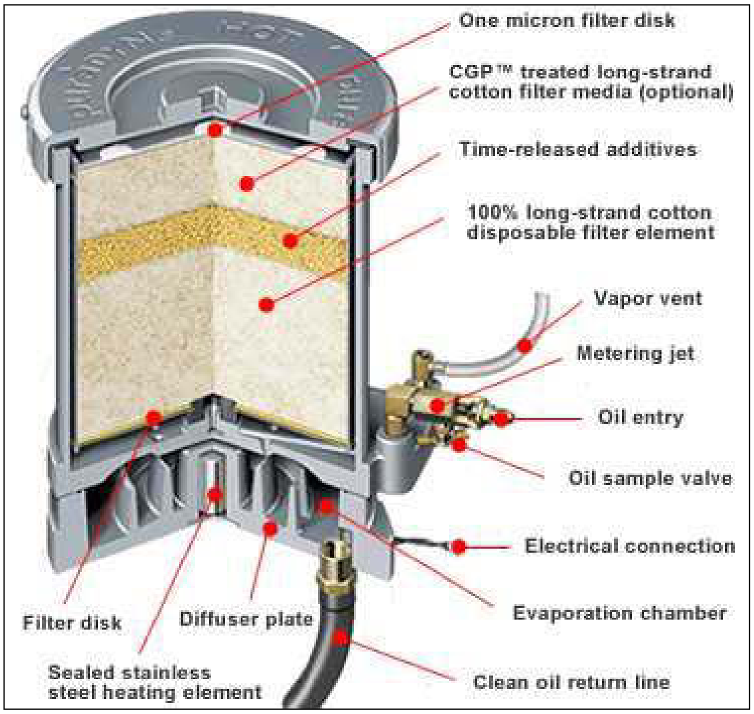

Figure 1. Cutaway drawing of a puraDYN oil-bypass filter.

The heavy-duty vehicle evaluation test plan (Evaluation Plan EVH-TP-146) is available as Attachment 1 to the *Oil Bypass Filter Technology Performance Evaluation – First Quarterly Report* (INEEL/EXT-03-00129; http://avt.inel.gov/oil_filter/pdf/oilfilter_bypass1.pdf). The first quarterly report extensively details the project background and the test plan.

OIL BYPASS SYSTEM PERFORMANCE EVALUATION STATUS

For this quarter, the work with INEEL Fleet Operations focused on ensuring the eight buses continue to accumulate evaluation miles, as various issues do affect their use. One bus was out of service for six weeks when its transaxle failed and had to be rebuilt. The only negative affect on the oil system evaluation was the lack of accumulated test miles by this bus. Another potential mileage accumulation impact can result from the seniority status of the drivers, as each driver bids on specific routes and buses,

[1] The DOE FreedomCAR and Vehicle Technology Program Office funds these activities.

and driver vacations and sickness affect mileage accumulation; one bus was driverless for a couple of weeks due to a driver illness. This is part of the nature of any fleet testing process—real-world variables can impact the progression of the evaluation process. However, accumulating real-world evaluation data provides highly valuable insight into how well the bypass filter system works. In spite of these minor impacts, 71,000 miles were accumulated this quarter, and over 100,000 test miles have been accumulated on the oil to date (Table 1).

Table 1. Test buses and test miles on the oil to date as of April 3,2003.

Bus Number	**Starting Date**	**Bus Mileage at Start Date**	**Current Bus Mileage** (04/03/03)	**Total Oil Evaluation Miles**
449	11/13/2002	110,572	121,367	10,795
448	11/14/2002	150,600	161,059	10,459
425	12/18/2002	41,969	46,116	4,147
433	12/4/2002	198,582	208,708	10,126
432	2/11/2003	47,612	57,712	10,100
447	11/14/2002	98,069	105,368	7,299
446	10/23/2002	117,668	137,362	19,694
450	11/20/2002	113,502	142,374	28,872
Total Test Miles (04/03/03)				101,492

In addition to the accumulation of evaluation miles, other activities conducted during this quarter included:

- Monitoring the filter replacement regimen
- Oil analysis sampling
- Extending the evaluation to include light-duty vehicles.

MONITORING FILTER REPLACEMENT

The focus of the bypass filter program in general is on keeping the oil clean through regular filter replacement with high efficiency filters, not by continual oil changes. The schedule for the filter-changing regimen was established in the test plan (EVH-TP-146, Rev 0). This schedule includes:

- After the first 6,000 miles, both the full-flow and bypass filters are replaced (this half-interval change-out is suggested by the PuraDYN manual)
- Hereafter, at each 12,000-mile increment, the bypass filter only is changed (this interval is the established interval for also performing other regular maintenance and servicing on buses)
- When 48,000 total miles have accrued, both the full-flow and bypass filters are replaced (this filter change-out is suggested by the PuraDYN manual)
- This cycle of the bypass filter change-out at 12,000-mile increments and after four increments of 12,000 miles each, or 48,000-miles, the full-flow and the bypass filters are changed, is repeated for the duration of the test.

Revised Filter Replacement Schedule

No one on the evaluation team noticed that the initial cycle would prove to be problematic to the Fleet Operations. Since the buses are on an established 12,000-mile maintenance schedule, the initial 6,000 mile filter change-out schedule forced the buses to be brought in for a heretofore-unscheduled mid-term filter service for the remainder of the test. To avoid missing a filter change interval and to alleviate the mid-term scheduling problems and pulling buses out of service, it was decided to adjust the schedule and bring the filter servicing back into sequence with the regularly scheduled maintenance. The new schedule includes the following intervals:

- After the first 6,000 miles, both the full-flow and bypass filters are replaced (this half-interval change-out is suggested by the PuraDYN manual)
- The next scheduled full-full and bypass filter change is after another 6,000 mile interval (this put the buses back onto the regularly scheduled maintenance schedule)
- Hereafter, at each 12,000-mile increment, the bypass filter only is changed (this interval is the established interval for performing other regular maintenance and servicing on the buses)
- Then, both the full-flow and bypass filters are replaced at the regularly established 48,000-mile bus-servicing interval.

These changes to the schedule alleviate the extra out-of-sequence maintenance scheduling of the buses and makes less work for the servicing mechanics, bus drivers, and maintenance foreman.

OIL ANALYSIS SAMPLING

Oil analysis samples are taken at each filter replacement (initially at the start of the test, at 6,000 and 12,000 miles, and subsequently at each 12,000-mile interval) and sent to two laboratories for analysis (discussed in the *First Quarterly Report*). The data from both analysis reports are compiled to document the oil quality and the engine metal-wear pattern profiles and trends.

Only one bus (450) has had three oil analyses performed to date; these data are reported in Table 2. Based on only three data points per sampling variable, preliminary trends may be developing. However, it is too early in the evaluation process to pronounce any definitive conclusions, but it is worth discussing the format of the oil analysis reports. As seen in Table 2, Column 1 presents the test variables. Columns 2 through 5 are the testing results from the CTC Analytical Services laboratory. Columns 6 through 9 are the testing results from ANA Laboratory. Columns 2 and 6 are the respective test results on the new oil before it went into the bus. Column groups 3 and 7, 4 and 8, and 5 and 9 are the sets of respective testing results from each lab at 6,934; 14,545; and 25,871 miles. Column 10 presents the available approximate value limits (again, discussed in the *First Quarterly Report*).

There is no definitive science base to draw from when determining the suitability of the oil. That is, there is no specific value that once reached can then be used to pronounce the oil is or is not suitable for use. Rather, the experience of the mechanics and the testing laboratories, as well as any testing trends are used to identify the health of the engines and the condition of the oil in each engine. Trending test results have historically been used by INEEL to identify potential engine problems, as each engine tends to have its own unique signature oil analysis test results. In addition, a single out-of-norm test result for one test variable may not be reason for concern. For example, the test result for copper in Column 8 (96 parts per million) varies significantly from the 6-ppm result in Column 4 (both results were obtained with 14,545 miles on the oil). The two subsequent tests in Columns 5 and 9 also suggest that the 96-ppm test result does not indicate an engine wear problem. Therefore, the 96-ppm result was ignored. Similarly, the reported "Abnormal" status of the oil in Column 3 probably results from the 58 ppm for the potassium in Column 3, which is a significant change from the 0 ppm result in Column 2. Again, the other testing results suggest that in this instance the 58-ppm result is of little concern. It would be of concern if the trend continued for the copper or any of the other engine-wear test metals, including iron, chromium, lead, tin, aluminum, nickel, or silicon.

Table 2. Oil analysis results for test bus number 450. The data include the testing results from both the CTC Analytical Services and ANA laboratories. The value limits are also given when established. The measurement units are provided in the *First Quarterly Report*, Attachment 1.

Test Lab	**CTC Analytical Services**				**ANA Laboratory**				**Value Limits**
Column 1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Test report No.	220486	5533	22936	63963	RO2K01 7508	R03A0 00013	R03A0 16418	R03C01 3020	
Test date	10/23/03	1/8/03	1/21/03	3/17/03	10/23/02	12/2/02	1/21/03	3/17/03	
Miles on oil	New oil	6,934	14,545	25,871	New Oil	6,934	14,545	25,871	
Status		Abnormal	Normal	Normal	Sat.	Sat.	Sat.	Sat.	
TBN	n.a.	8	6.4	5.5	10.5	7.9	8.2	5.4	>3.0
Iron	2	20	50	91	<1	13	114	86	<=100
Chromium	0	1	2	4	<1	<1	6	3	<=12
Lead	0	1	1	4	<1	<1	8	1	<=30
Copper	0	4	6	12	<1	<1	96	6	<=30
Tin	0	0	0	0	<1	<1	10	5	<=18
Aluminum	2	3	2	3	<1	<1	4	4	<=18
Nickel	0	0	0	0	<1	<1	<1	<1	<=10
Silver	0	1	2	1	<1	<1	<1	<1	
Silicon	8	4	2	4	<1	4	5	3	<=20
Boron	0	1	0	1	<1	<1	11	1	
Sodium	5	7	5	1	<1	<1	25	1	
Magnesium	15	32	33	28	17	24	74	12	
Calcium	3183	2907	3128	3381	2209	1510	1993	2216	
Barium	0	0	0	0	<1	<1	<1	<1	
Phosphor	1180	1091	1171	1082	1129	1072	870	789	
Zinc	1249	1282	1278	1220	1299	1190	948	860	
Molybdenum	0	0	1	1	<1	<1	2	<1	
Titanium	0	0	0	0	<1	<1	1	<1	
Vanadium	0	0	0	0	<1	<1	2	<1	
Potassium	0	58	30	24	<1	<1	9	7	
Fuel	n.a.	<1	<1	<1	<0.5	<0.5	<0.5	<0.5	
Viscosity at 100ºC	15.41	13.41	12.94	12.79	15.5	13.49	13.12	12.6	12.5 0–16.29 (SAE 40)
Percent water	0.0	0	0	0	<0.05	<0.05	<0.05	<0.05	<5.0
Soot % vol	n.a.	0.4	0.2	0.7	<0.2	<0.2	<0.2	1.1	<=3.0
Glycol	n.a.	Negative	Negative	Negative	N	N	N	N	<50

LIGHT-DUTY VEHICLE FILTER EVALUATION

A large number of light-duty vehicles are in use throughout both the INEEL and the DOE complex, and expanding the performance evaluation to include light-duty vehicles at the INEEL is in progress. A suitability analysis for installing appropriately-size PuraDYN systems in light-duty vehicles was conducted, and six 2002 Chevrolet Tahoe vehicles were identified as suitable test vehicles, based on vehicle age, miles driven annually, and the ability to install the PuraDYN systems within the engine compartment. The organization that owns the six Tahoes was contacted, and they agreed to make the vehicles available for inclusion in the evaluation fleet. The light-duty vehicle test plan is in review, and the filters systems, filter cartridges, and installation kits for these vehicles have been ordered. Several Ford bi-fuel pickup models that operated on compressed natural gas and gasoline were also considered for becoming test vehicles, but there is insufficient space within the engine compartment to install the PuraDYN systems.

SUMMARY

When implementing bypass filtering in a fleet operation, it is important to ensure that the filter change-out schedule matches the existing maintenance schedule to reduce vehicle downtime and extra servicing needs.

As more empirical oil analysis data are gathered, more accurate and complete analysis can be performed. A potential negative trend is appearing, which is a decrease in oil quality based on the degrading oil viscosity and total base number in bus 73450. However, it is much too premature to predict if this trend will continue; note that the oil viscosity and total base number testing results are all within acceptable limits.

The oil change mechanic indicated that several quarts of oil are removed when the bypass filter is changed and several quarts are also removed when the two full-flow filters are changed. The unused (new) and used (oil soaked) weights of both the full-flow and bypass-flow filters will be measured during the next evaluation period. The weight of the oil will also be determined in order to help identify the oil lost (and replaced) during the filter changes. The oil used and the impacts on the economics of the bypass filter system will be reported in the next quarterly report.

The major benefit of performing a fleet evaluation is the accumulation of real-world data; however, externalities do impact the accumulation of test miles, as the control of testing variables is not as perfect as possible in a laboratory-testing environment. The oil sampling and filter changes have not always occurred at the desired specific miles. While it might be argued that this has unknown impacts on the evaluation process, it is much closer to how such an oil bypass system would be used in a real-world fleet environment.