Do you ever wonder why your Equipment Wears Out when you're trying hard to prevennt "wear"?

» **You change oil as recommended**

» **You use great oil (perhaps better than required)**

» **Operators are watched to guard against abusive operating characteristics**

» **Oil Analysis says everything's okay**

Typical Conclusion:

Our ***wear*** is "Normal"

Not much more can be done

Who do you depend on for "Wear Prevention" advice?

Typically is the equipment manufacturer and your Lube supplier

Do they have any vested interest in continuing your wear as is and confirming that it is "normal"?

Environmental Concepts WEAR REDUCTION Strategy:

- Eliminate the biggest cause of "normal wear" which is particulate in the 2-20 micron size
  - Soot is harder than steel and later model engines have the most soot–it's like sandblasting your wear surfaces.
  - Find out how much particulate is currently there through oil analysis which includes particle counts by size
  - Filter out troublesome particulate using "By-Pass" Filtration in addition to current "full-flow" filtration
- Improve the oil's ability to resist wear by using more "boundary lubricant" in the "additive package"
  - Also add more rust inhibitors, dispersants, detergents, acid neutralizers to lengthen the life of the Additive

In effect, you filter and strengthen the oil so that it does not need to be changed for perhaps 85,000 miles

In reality, the oil is changed based on the results of oil analysis—oil itself does not wear out

It's better than changing your oil every day before you drive!

How will your current "Wear Advisors" like this recommendation? It probably will not be well received.

Manufacturer impact—You would likely double your equipment life with a 50% reduction in parts

Lube Supplier impact—You will now buy about 80% less oil

Is anybody else following this strategy?

YES—too many to list here, but reference letters can certainly be provided

By-pass filtration is very common in Europe and some OEM's provide it standard

How much does it cost?

See the next pages for the financial implications which are very positive and do not even account for longer asset life.

Enhanced Lubrication Strategy

Evaluation Factors or Variables:	
Number Of Vehicles	30
Fluid Capacity in gal./veh	10.0 gal.
Oil Cost per gal. (currently)	$ 6.00
Full Flow Filter Costs (currently)	$ 22.00
Oil Change Interval in miles (now)	15,000mi.
Annual Miles driven/veh. (avg.)	85,000mi.
$ fuel economy expected to improve	2.0%
Hourly Labor Rate with fringe	$ 30
Hours per oil Change (currently)	1.00 hrs
Waste Oil Disposal Fee /gal.	$ 0.25
Average Cost of diesel per gal.	$ 2.25
Current fleet mileage (avg.)	5.2 mpg
Currently oil analysis cost per test	$ 10.00
By-Pass Filtration System:	
Filtration System Hardware Cost	$ 389
By-Pass Filter Cost each	$ 9
Better oil analysis (could be less frequent)	$ 18
Time to install by-pass filter housing	30 min.
Time to clean full flow & change by-pass filter	20 min.
Oil Change Interval Extended by	3.0 times
Add Pack Enhancement cost/gal	$ 172

or 45,000 mi. or in reality, not until Oil Analysis data calls for it

Supporting Statistics and Highlights of Interest	
170	oil changes per year *currently* fleet wide
$60	Cost for oil at vehicle's oil change
$82	Cost for oil & standard filter
$30	Cost for labor to change oil (fully burdened)
$3	Waste oil disposal fee per change per vehicle
$115	Total current cost for each oil change
$1,103,365	Annual Cost for Fuel currently at 5.2 mpg & $2.25 per gal.
$22,067	Savings with 2% (likely better) fuel economy improvement
$12,180	Total parts and supplies needed for *By-Pass Filtration*
$4,667	Total amount of *Power Up* need for 1st year
1,133	Less Oil used/yr.—*Environmentally GREAT!*
67%	Less Oil used/yr.—*Environmentally GREAT!*
9,808 gal.	Less Diesel Fuel used/yr.—*Environmentally GREAT!*

Other Cost Savings: less wear on significant engine components resulting in longer engine life; less spillage of used oil; less "oil soak" used; less overages on oil change intervals; less vehicle downtime; perhaps less vehicles needed for same work load; less chance for errors; and more productive shop workers.

Note: Oil Change intervals are determined by oil analysis not time nor miles.

First Year Analysis with 30 vehicles in the Fleet

Current Costs:			By-Pass Filtration & Cleanable Full-flow Filter Proposed Costs:	
By-Pass Filter Housing assembly	0	$	12,180	By-Pass Filter Parts for all vehicles
Labor to install by-pass filters	0	$	450	Labor to install 30 by-pass filters at 30 minutes each
New Oil Cost/yr for 1700 gal of oil	$ 10,200	$	3,400	Oil completely changed as determined by oil analysis or 567 gallons (est.)
Add Pack Enhancement	0	$	4,667	Power Up Additive at 5% when changed and 2% of crankcase with new filter
Full Flow Filter Cost	$ 3,740	$	1,700	Cost of cleaning Full-flow portion of filter at normal change intervals
By-Pass Filter Costs	0	$	1,530	by-pass cartridge changed when you normally changed oil before
Waste Oil Disposal Fee 5.7 per veh per year	$ 425	$	142	only 1.9 disposal fee(s) per year per vehicle
Oil analysis Cost doing 5.7 per veh. per yr.	$ 1,700	$	3,060	Better Oil analysis Cost (tested at same frequency as before)
No Fuel saving via less friction	0	$	(22,067)	Power Up Friction Reduction & clean oil yields 2% better mpg
Labor Cost for 170 oil chnages per year	$ 5,100	$	618	57 complete oil changes + 113 by-pass filter changes & cleanings
Total Cost per Year	$ 21,165	$	5,679	Total Cost for First Year

1st Year Savings = **$ 15,486** This is saves 1133 gal. of oil or 67% of your oil in this year!

Break even Point ***3.2 months*** **Note:** Mileage up from 5.2 to 5.3 mpg

Second Year Analysis

Currently:			By-Pass Filtration & Cleanable Full-flow Filter Proposed Costs:	
By-Pass Oil Housing assembly	0		0	By-Pass Parts for all vehicles
New Oil Cost/ yr	$ 10,234	$	1,800	Oil completely changed once per year
Add Pack Enhancement	0	$	3,119	Power Up Additive at 5% when changed and 2% of crankcase with new filter
Full Flow Filter Cost	$ 3,740	$	1,700	Cost of cleaning Full-flow portion of filter at normal change intervals
By-Pass Filter Costs	0	$	1,530	changed when you used to change oil (every 15000 miles)
Waste Oil Disposal Fee	$ 425	$	142	only one disposal fee per year per vehicle
Oil analysis Cost (at each change)	$ 1,700	$	3,060	Oil analysis Cost (test every 30000 mi.)
Fuel saving via less friction	0	$	(22,067)	Power Up Friction Reduction yields better mpg
Labor Cost involving oil	$ 5,100	$	2,600	one oil change/yr + by-pass filter changes
Total Cost per Year	$ 21,199	$	(8,117)	Total Cost for Second and Subsequent Years

2nd Year Savings = **$ 29,316** **$ 2,443 per month average savings**

Total Cost after Two Years $ 42,364 $ (2,438) **or $81 per vehicle per month**

SAVINGS each year thereafter **$ 29,316** ***Plus Longer Engine Life with better lubrication***

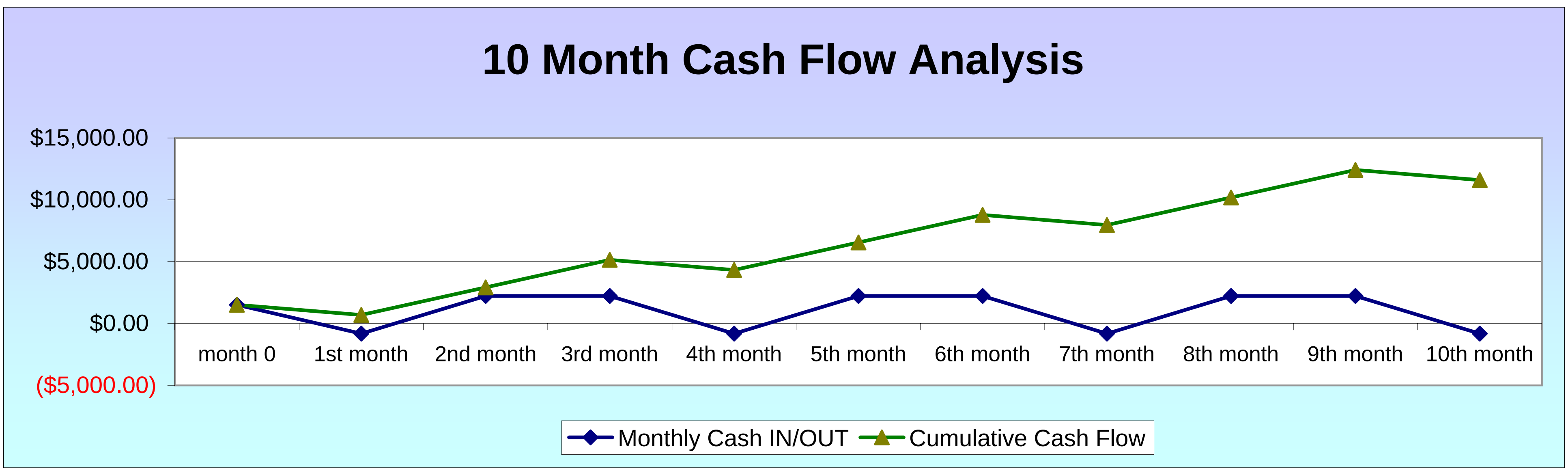
Lease Plan with Option to Purchase

$12,180.00	**Cost of By-pass Filters**
($1,218.00)	**10% down payment**
$10,962.00	**Balance to be leased**
($516.02)	**24 month lease payment per month (at 12% interest)**
($17.20)	**Average cost ver vehicle per month**
($300.00)	**Amount to convert to purchase at end of lease**
($13,902.47)	**Total cost over lease period to own filters**

Methodology:
» Annual Power Up bought in 4 batches
» Annual Savings are distributed evenly throughout the year
» Labor savings not illustrated because hours used for more productive work
» Value of longer useful life and parts savings not illustrated
» Difference in cost of oil analysis not illustrated

10 Month Cash Flow Analysis:

	month 0	1st month	2nd month	3rd month	4th month	5th month	6th month	7th month	8th month	9th month	10th month
Down Payment	($1,218.00)										
Monthly Payment		($516.02)	($516.02)	($516.02)	($516.02)	($516.02)	($516.02)	($516.02)	($516.02)	($516.02)	($516.02)
Power Up		($3,045.00)			($3,045.00)			($3,045.00)			($3,045.00)
Oil savings	$566.67	$566.67	$566.67	$566.67	$566.67	$566.67	$566.67	$566.67	$566.67	$566.67	$566.67
Full-flow filter savings	$311.67	$311.67	$311.67	$311.67	$311.67	$311.67	$311.67	$311.67	$311.67	$311.67	$311.67
Waste Oil savings	$23.61	$23.61	$23.61	$23.61	$23.61	$23.61	$23.61	$23.61	$23.61	$23.61	$23.61
Diesel fuel savings at 2%	$1,838.94	$1,838.94	$1,838.94	$1,838.94	$1,838.94	$1,838.94	$1,838.94	$1,838.94	$1,838.94	$1,838.94	$1,838.94
Monthly Cash IN/OUT	$1,522.89	($820.13)	$2,224.87	$2,224.87	($820.13)	$2,224.87	$2,224.87	($820.13)	$2,224.87	$2,224.87	($820.13)
Cumulative Cash Flow	$1,522.89	$702.75	$2,927.62	$5,152.49	$4,332.36	$6,557.22	$8,782.09	$7,961.96	$10,186.83	$12,411.69	$11,591.56



Clean Oil Reduces Engine Fuel Consumption

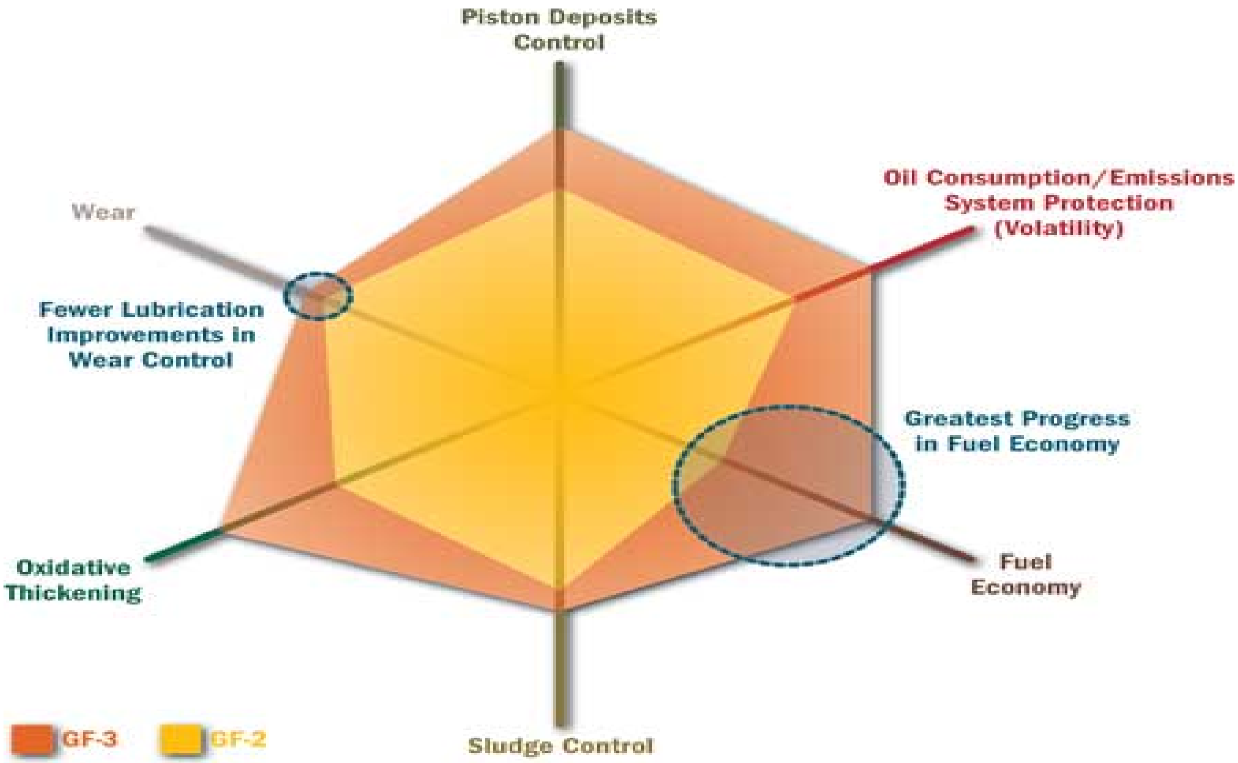
by Jim Fitch

In the July-August issue of Machinery Lubrication magazine, my column discussed the important role of lubrication on energy conservation and environmental protection. The more I delve into this subject, the more I discover the pronounced impact lubrication has on energy and the environment. A case in point is the impact of clean oil on fuel consumption and emission in engines.

There are many ways that a lubricant could fail to deliver fuel-efficient engine performance. Many of these are due to formulation issues as opposed to transient properties of the lubricant in service. For instance, there were significant advances in energy conservation when switching from GF-2 to GF-3 (international quality designation for gasoline engine lubricants) in 2001 (Figure 1).

Figure 1. GF-3 and GF-2 Comparison Diagram

When a lubricant degrades, it forms reaction products that become insoluble and corrosive. So too, the original properties of lubricity and dispersancy can become impaired as the lubricant ages and additives deplete. Much has been published about the risks associated with overextended oil drains and the buildup of carbon insolubles from combustion blow-by.



However, surprisingly little has been said about the impact of fine abrasives in a lube oil as it relates to fuel economy over the engine's life. One can imagine numerous scenarios in which solid abrasives suspended in the oil could diminish optimum energy performance. Below is a list of several scenarios:

Antiwear Additive Depletion. High soot load of crankcase lubricants has been reported to impair the performance of ZDDP antiwear additives. Some researchers believe that soot and dust particles exhibit polar absorbencies, and as such, can tie-up the AW additive and diminish its ability to control friction in boundary contacts (cam nose, ring/ liner, etc.).

Combustion Efficiency Losses. Sooner or later, wear from abrasive particles and deposits from carbon and oxide insolubles will interfere with efficient combustion in an engine. Valve train wear (cams, valve guides, etc.) can impact timing and valve movement. Wear of rings, pistons and liners influences volumetric compression efficiency and combustion blow-by resulting in power loss. As has been previously reported in this magazine, particle-induced wear is greatest when the particle sizes are in the same range as the oil film thickness (Figure 2). For diesel and gasoline engines, there are a surprising number of laboratory and field studies that report the need to control particles below ten microns. One such study by GM concluded that, “controlling

Frictional Losses. When hard clearance-size particles disrupt oil films, including boundary chemical films, increased friction and wear will occur. One researcher reports that 40 to 50 percent of the friction losses of an engine are attributable to the ring/cylinder contacts, with two-thirds of the loss assigned to the upper compression ring.[2] It has been documented that there is an extremely high level of sensitivity at the ring-to-cylinder zone of the engine to both oil- and air-borne contaminants. Hence, abrasive wear of the ring/cylinder area of the engine translates directly to increased friction, blow-by, compression losses and reduced fuel economy.

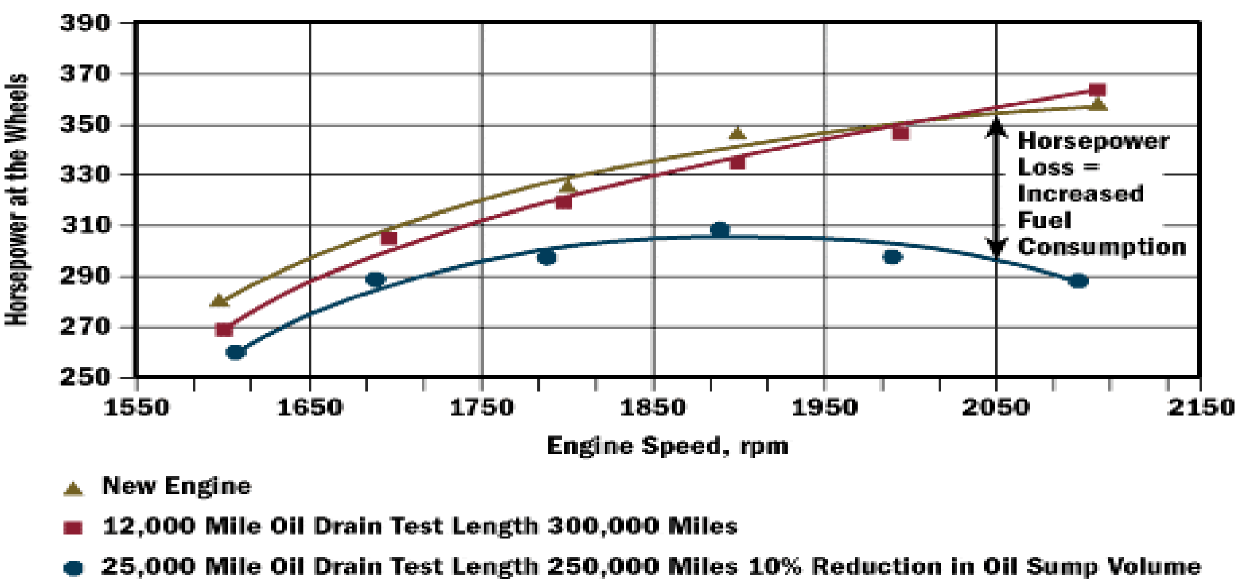
Viscosity Churning Losses. Wear particles contribute to oxidative thickening of aged oil. High soot load and/or lack of soot dispersancy can also have a large impact on oil viscosity increases. Viscosity-related internal fluid friction not only increases fuel consumption but also generates more heat that can lead to premature degradation of additives and base oil oxidation.

Stiction Losses. Deposits in the combustion chamber and valve area can lead to restriction movements in rings and valve control. When hard particle contamination agglomerates with soot and sludge to form adherent deposits between valves and guides, a tenacious interference, called stiction, results. Stiction causes power loss. It causes the timing of the port openings and closings to vary, leading to incomplete combustion and risk of backfiring. Advanced phases of this problem can lead to a burned valve seat.[2]

Diesel Engine Oil Film Thickness

Component	Oil Film Thickness (microns)
Ring-to cylinder	3.0 - 7
Rod bearings	0.5 - 20
Main shaft bearings	0.8 - 50
Turbocharger bearings	0.5 - 20
Piston pin bushing	0.5 - 15
Valve train	0 - 1.0
Gearing	0 - 1.5

Figure 2. Particle-induced Wear is Greatest when the Particle Sizes are in the Same Range as the Oil Film Thickness



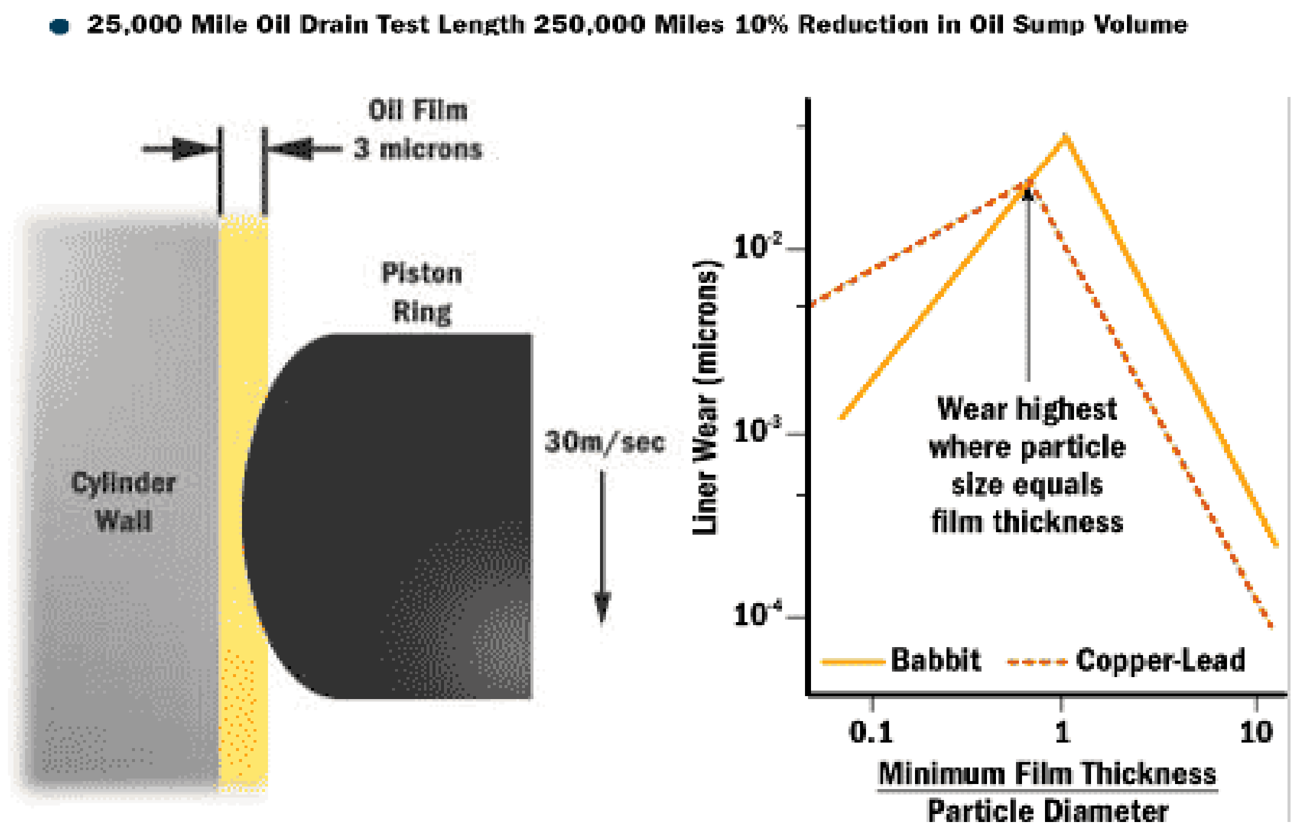


Figure 3 shows an example of how increased engine wear, in this case due to overextended oil drains, contributes to power loss in the engine. At 2100 rpm, the severely worn engine horsepower at the wheels decreased from 365 hp to less than 300 hp (18 percent). **Loss of horsepower translates directly to losses in fuel economy**.[3]

A bus engine fuel consumption study by G. Andrews, et al. of the University of Leeds (Table 1), provides evidence of the benefit associated with cleaner oil on fuel economy in an actual road trial.[4] It was noted that the Cummins engine's **fuel efficiency increased 2 percent to 3 percent** when a six-micron by-pass filter was used along with a full flow filter. The study spanned 50,000 miles of service. The fuel consumption was calculated based on detailed fuelling records from the fleet. In a similar study reported by the same authors using by-pass filtration, a **5 percent to 8 percent reduction in fuel consumption** was achieved on a 1.8 liter Ford passenger car IDI diesel engine.

A study reported by J. Fodor and F. Ling of the Research Institute of Automotive Industry-Budapest and published in Lubrication Engineering magazine (Table 2) found a sharp improvement in fuel economy in a six-cylinder diesel engine fitted with improved filtration. By reducing oil contamination by 98 percent, not only was a nearly **5 percent reduction in fuel consumption** achieved but wear and friction were reduced by 93 percent and 2.9 percent respectively.[5]

Waste Stream Emissions

When the engine consumes oil, due primarily to contaminant-induced wear, oil enters the combustion chamber, burns with the fuel, and is pushed out with exhaust gases as particles and volatile hydrocarbons. New mineral-based lubricants have a more volatile light-end fraction and are more prone to hydrocarbon emissions. The level of exhaust emissions increases considerably over time

Figure 4. Off-road/tractor Particulate Emissions Predictions

Unlike a new engine, the lubricating oil is a dominant contributor to particulate matter (PM) emissions in aged engines. The obvious strategy to control/reduce hydrocarbon emissions is to reduce oil consumption. ...

... This, of course, points to a strategy of reducing abrasion and wear. According to projections by Barris of Donaldson Co. (Figure 4), after **12,000 hours of service, an off-road diesel engine can produce nearly six times more exhaust emissions due to wear associated with particles and other causes.**[6]

Crankcase Oil Particle Counts

Good environmental stewardship is everyone's responsibility. We all benefit from cleaner air and a safer environment. In addition, the financial impact that comes from reduced fuel consumption alone can be substantial. Perhaps it's time for OEMs and users alike to begin revisiting contamination control practices, including filtration, associated with internal combustion engines.

If clean oil is important to control wear, reduce fuel consumption and emissions, perhaps it's also time for users to begin asking their laboratories to begin reporting particle counts and ISO Codes of used crankcase oils. **Remember, if it's important, we measure it - correctly. What gets measured gets done.**

Jim Fitch

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3. McGeehan, J. (2001, September-October). Uncovering the Problems with Extended Oil Drains. Machinery Lubrication magazine (www.machinerylubrication.com), pp. 24-29.

4. Andrews, G.E., Li, H., Jones, M.H., Hall, J. Rahman, A.A. and Saydali, S. (2000). "The Influence of an Oil Recycler on Lubricating Oil Quality with Oil Age for a Bus Using In-Service Testing". SAE 2000 World Congress (Paper 2000-01-0234).

5. Foder, J. and Ling, F.F. (1985, October). Friction Reduction in an IC Engine through Improved Filtration and a New Lubricant Additive. "Lubrication Engineering". pp. 614-618.

6. Barris, M.A. (1995). "Total Filtration: The Influence of Filter Selection on Engine Wear, Emissions and Performance". SAE Fuels and Lubricants (Paper 952557).

Please reference this article as:

Jim Fitch, "Clean Oil Reduces Engine Fuel Consumption". *Practicing Oil Analysis* Magazine. November 2002

Fuel Economy Data

(using an On-board-Computer)

Test Status		Before Power Up April 29th		With Power Up August 17th		Improvement
Distance via computer log		10,647		25,517		
Fuel Used		1,844.5		3,995.5		
Idle Time		17.6%		13.6%		
Avg. Mileage		5.77 mpg		6.39 mpg		+ 10.7%
Avg. Mileage (while moving)		5.94 mpg		6.45 mpg		+ 8.6%

Dynometer Load Tests

Test Status		Wheel HP		% of Change in Wheel HP		Turbo Boost Pressure (in-H_2O)		Coolant Temp (°F)
Before Power Up		395				56		214° (and climbing)
After Power Up (Load test #1)		397		+ 0.8%		54		198°
After Power Up (Load test #2)		400		+ 1.3%		54		198°

Sample ID:	20765
Equipment Code:	785-MINING CYLINDER
Equipment Name:	785-MINING CYLINDER
Equipment Area:	CCECO
Lubricant:	CHEVRON RYKON 32
Total Hours:	0.0
Hours On Oil:	0.0. On Filter: 0.0

CCECO LAB AND FILTRATION
701 North Levee Road
Puyallup, WA 98371
Ph: (253)845-2900, Fax: (253)845-2490

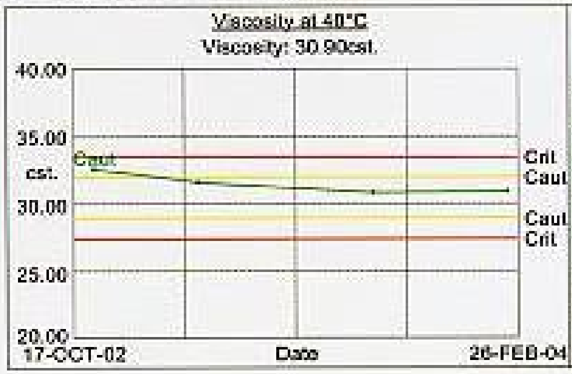
FLUID ANALYSIS REPORT

NORMAL

Sampled: 15-FEB-04, 03:44 pm
Tested: 23-SEP-04
Reported: 23-SEP-04

Sample Comments

Particle Count ISO Code is 14/12.
Particles > 5µm (121.40) is in the NORMAL range.
Particles > 15µm (21.10) is in the NORMAL range.
The viscosity at 40 deg. Celsius (30.90cst.) is within the NORMAL range.
Water Y or N: Water Present is NO.
Sample contains clear material, silica, and metal.
ISO Target Level has been met.



Generally Recommended ISO Code Range

Pressure (PSI)	Up to 3000	Over 3000
Gear pumps	17/15	16/14
Gear motors	18/15	17/14
Vane pumps	17/14	16/13
Vane motors	17/14	16/13
Variable vane pumps	15/13	N/A
Piston pumps	15/13	14/12
Piston motors	16/13	15/12
Radial piston motors	17/13	16/12
Cam wave motors	15/13	14/12
Sol. Dir. valves	18/15	17/14
Prop. Dir. valves	15/12	13/11
Servo valves	14/11	13/10
Press. comp. flow cntrl.	15/13	15/13
Hydrostatic trans.	14/12	14/11
Cylinders	18/15	17/14

These codes are only recommended as a general guideline. Individual conditions will vary depending on circumstances such as duration of pressure, temperature, type of oil, safety, critical nature of machine use, hours of service per day, life expectancy of machinery, and manufacturers recommendations. Please consult the manufacturer of your machinery for further recommendations.

The test results are for customer evaluation only, CCECO Lab & Filtration assumes no responsibility for use of information gained from any test result.

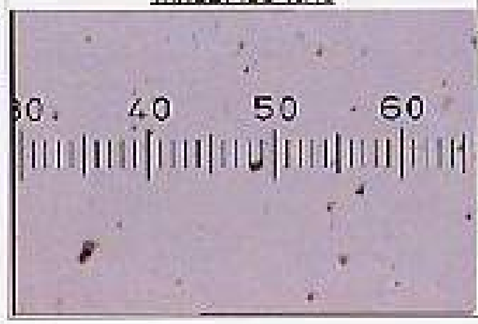
ISO Particle Count - Table

Sample	Date	Hours	ISO Code	>2µm	>3µm	>5µm	>10µm	>15µm	>25µm	>50µm	>100µm
20765	15-FEB-04	0.0	14/12	1218.10	371.50	121.40	36.90	21.10	7.10	0.80	0.20
20615	17-SEP-03	0.0	16/13	1672.00	1491.10	618.00	172.30	68.40	16.05	2.10	0.00
20592	06-MAR-03	0.0	18/15	8022.80	4629.10	**2443.30	756.30	**279.00	59.75	5.20	0.00
20437	09-NOV-02	0.0	22/18	38527.00	32559.00	**22494.00	7042.10	**1772.70	192.40	20.40	0.60

Water Y or N - Table

Sample	Date	Hours	Water Present
20765	15-FEB-04	0.0	NO
20615	17-SEP-03	0.0	NO
20592	06-MAR-03	0.0	NO
20437	09-NOV-02	0.0	NO

TARGET ISO 16/13



Photographic Image - History

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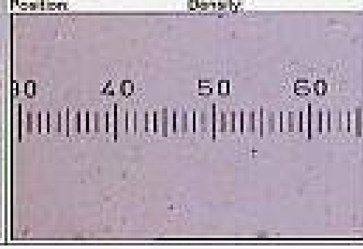
Position: Density:



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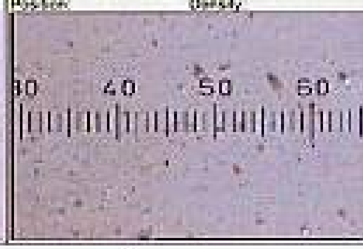
Position: Density:



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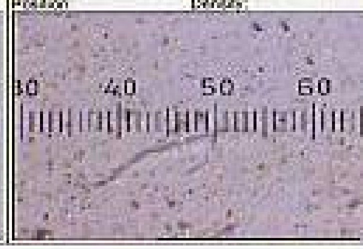

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Position: Density: