



3 • Lube Filtration

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Something in the Oil

Engine oil contacts more critical components of the engine than any other fluid. Modern diesel engines, designed to meet stringent emissions regulations and achieve long service life, utilize precise fits and clearances to accomplish these goals. Therefore, it is of paramount importance to keep the engine oil as clean as possible. This is particularly important if there is any interest in extending engine oil change intervals. Since the oil can carry harmful abrasive particles and since the oil creates harmful sludge as it degrades, it is necessary to remove these contaminants. In many engine applications, and especially severe service vocations, a standard full-flow oil filter cannot remove all of the harmful contaminants and still provide adequate filter life. Fleetguard® Centriguard™ Centrifugal Filters can be the difference between healthy engine life and premature death.



Don't Compromise on Oil Filtration



The Centriguard with patented SpiraTec™ technology collects soot up to two and a half times (2.5x) faster than conventional empty rotor designs. That translates to a significant reduction in wear rates of key engine components and a significant reduction in the amount of soot the oil must keep in suspension. That means that while competitive designs will allow your filters to plug, engine components to wear, and oil viscosity to increase, the Fleetguard Centriguard with patented SpiraTec technology will be protecting your engine, saving you money.

From Combination Full-Flow and By-Pass Filtration to Centriguard

Fleetguard oil filtration products are the most advanced in the industry, covering all brands of engines. Particularly effective is the combination full-flow & by-pass oil filter, referred to as the Combo Filter. These filters are standard equipment on many modern diesel engines and are very effective at removing harmful particles and sludge from the oil. The Combo Filters provide a perfect balance between efficiency, real-world life and low restriction to oil flow. However, some combinations of engines, oils, duty cycles and oil change intervals will require more protection. These applications are where the Centriguard can provide the additional oil conditioning required to prolong oil life and help your engine deliver the performance and longevity that you require. Refer to the application charts and physical dimensions on the following pages to determine which remote-mount Centriguard Centrifuge is appropriate for your application. Also note that the Fleetguard Centrifuge product line includes service rotors that will enhance the performance of other centrifuge products. Pick the one that is right for you or contact Cummins Filtration® Technical Assistance at 800-22-FILTER for more information.

Specifying the Right Centriguard for the Job

Every technician knows that the right tool makes the job much easier and makes him/her more efficient. The same holds true for a centrifugal oil filter. The proper selection of a Fleetguard centrifuge assembly or service rotor will ensure that the product provides the most cost effective engine protection in the smallest package size. Use the following criteria for selecting the right tool for your engine:

- 1. Available engine oil flow for a by-pass oil filter** – The Fleetguard centrifuge rotors are designed to operate with a maximum oil flow rate, which is controlled by the oil jet orifice size. Some engines can only provide up to 1 gal/min (3.8 L/min) oil flow, whereas other engines can accommodate 2 gal/min (7.6 L/min) oil flow or more for a by-pass oil filter. It is imperative that you confirm the oil flow rate that can be furnished by your engine at all operating conditions. For example, idling with oil at normal operating temperature must not create any concern about oil starvation (oil pressure/flow drops too low) for other engine components. If potential oil starvation could occur under particular engine operating conditions, a check valve with a pressure setting to shut off oil supply to the centrifuge may be necessary.
- 2. Centrifuge rotor capacity to match the oil change interval and typical soot/contaminant generation rate** – The application chart on the page following this introduction provides an initial indication of the engine size that can be supported by one centrifuge assembly. The "Specifications" tables provide a recommended engine oil sump size as another means for selecting the appropriate centrifuge. If details such as oil analysis trends are known and can document the rate of soot generation during a typical oil change interval, this information can be used to better match the centrifuge to the application. Please contact a Technical Assistance Specialist if you have oil analysis trend data to help select a centrifuge.

Introduction

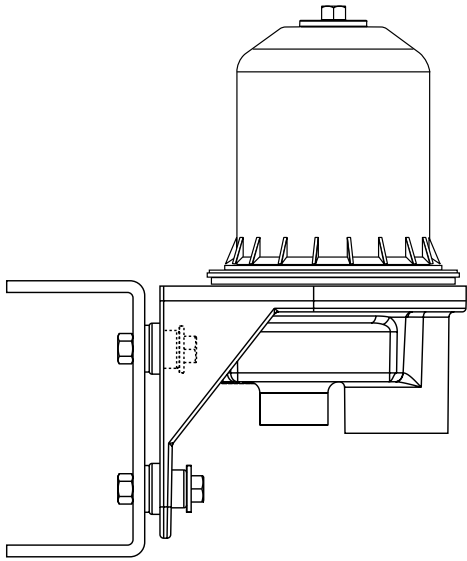
3. **Physical space constraints** – Unless the centrifuge assembly is already installed in your engine or vehicle, you must find space for an on-engine or on-vehicle/equipment installation of a Centriguard™ centrifuge assembly. Consider not only the physical size of the centrifuge assembly but also the service space requirements.
4. **Physical space constraints for rotor service access** – New installations of Centriguard centrifuge assemblies will require a clear space envelope above the unit for servicing the rotor. While the most desirable installation will provide a continuously clear service area, some installations may require the removal of other engine/vehicle components to achieve the necessary clearance. Please note that the CH41100, CH41101, and CH41102 family of centrifuge units have a different service envelope requirement than do the CH41111 – CH41114 family of centrifuge assemblies.
5. **Plumbing requirements** – The by-pass centrifuge requires hot oil at sufficient pressure for efficient operation and oil filtration. The “Specifications” tables reflect the temperature, pressure and inlet plumbing connections recommended for proper plumbing of the centrifuge. Similarly important is the oil drain plumbing. The oil must exit the centrifuge housing and return to the engine oil sump in an unobstructed manner. Depending upon the centrifuge installation and the relationship of the centrifuge to the engine oil sump, a centrifuge with an air-assisted drain feature may be required. Only the CH41101, CH41112, and CH41114 units include the air-assisted drain feature. Centriguard units with the air-assisted drain require air plumbing. The air line connection sizes are listed in the Specifications tables, as well.

IMPORTANT NOTE: The Fleetguard® centrifuge assemblies are installed as by-pass oil filtration systems. The centrifuge is intended as a supplemental filtration system to the on-engine oil filter(s). The on-engine filtration must not be removed or deactivated at the time of the centrifuge installation unless approval has been received from a Technical Assistance Specialist by calling 800-22-FILTER.

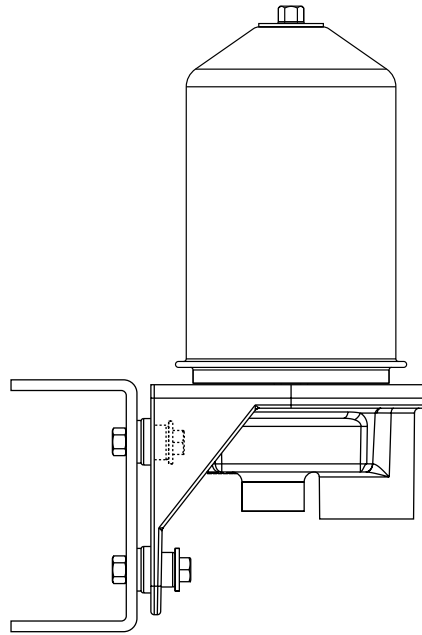


Centriguard™ Centrifugal Separators

CH41100 • CH41101
CH41102



CH41111 • CH41112
CH41113 • CH41114

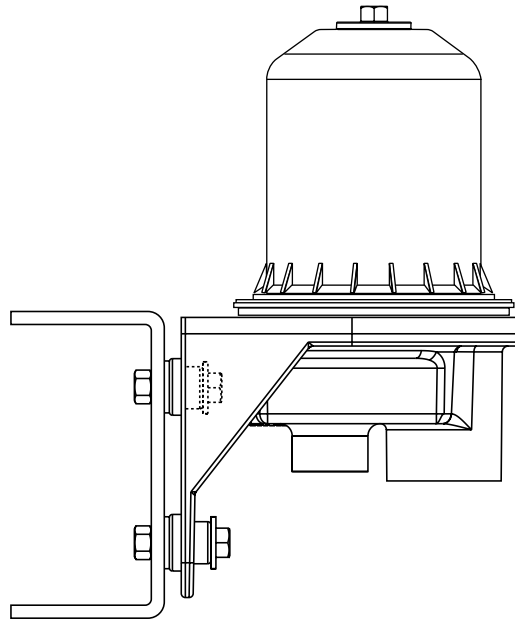


Remote Mount Centrifuge Assembly Package Application Coverage

Centrifuge Assembly		CH41111	CH41112	CH41113	CH41114	CH41100	CH41101	CH41102
Service Rotor and Gasket		CS41011	CS41011	CS41016	CS41016	CS41005	CS41007	CS41007
Engine Displacement	5 L							
	8 L	■	■			■	■	■
	11 L			■	■		■	■
	14 L					■	■	■
	17 L						■	■
	20 L							
	23 L							
	26 L							

Note: Targeted engine size is for one centrifuge unit. For larger engines, it may be necessary to use multiple units to increase collection capacity during single service interval – provided the necessary oil flow is available.





Specifications

Specification	CH41100	CH41101	CH41102
Required Flowrate* @60 in ² (4 bar)	2 gal/min (7.6 L/min)	1 gal/min (3.8 L/min)	1 gal/min (3.8 L/min)
Recommended Temperature	230 °F (110 °C)	230 °F (110 °C)	230 °F (110 °C)
Recommended Pressure	44 - 87 lb/in ² (3 - 6 bar)	44 - 87 lb/in ² (3 - 6 bar)	44 - 87 lb/in ² (3 - 6 bar)
Drain Hose and Attachment Fitting Minimum ID *	1-1/4" (32 mm)	3/8" (10 mm)	3/4" (19 mm)
Recommended Sump Size *	5 - 30 gal (18 - 113 L)	5 - 30 gal (18 - 113 L)	5 - 30 gal (18 - 113 L)
Air Supply Connection Needed**	N/A	1/4" NPT	N/A
Volumetric Capacity (weight depends on density of contaminant)	0.15 gal (0.57 L)	0.15 gal (0.57 L)	0.15 gal (0.57 L)
Overall Height of Assembly	11.2" (285 mm)	11.2" (285 mm)	11.2" (285 mm)
Depth of Assembly	6.55" (167 mm)	6.55" (167 mm)	6.55" (167 mm)
Width of Assembly	6.53" (166 mm)	6.53" (166 mm)	6.53" (166 mm)
Assembly Weight (dry)	5.5 lb (2.5 kg)	5.5 lb (2.5 kg)	5.5 lb (2.5 kg)
Rotor Weight (dry)	0.73 lb (330 g)	0.73 lb (330 g)	0.73 lb (330 g)
Clearance Above Assembly Needed for Service of Rotor	5.7" (145 mm)***	5.7" (145 mm)***	5.7" (145 mm)***

* Indicates engine supply parameters needed for EACH centrifuge used. In the event of multiple units used on the same engine/ application, contact your Fleetguard® representative.

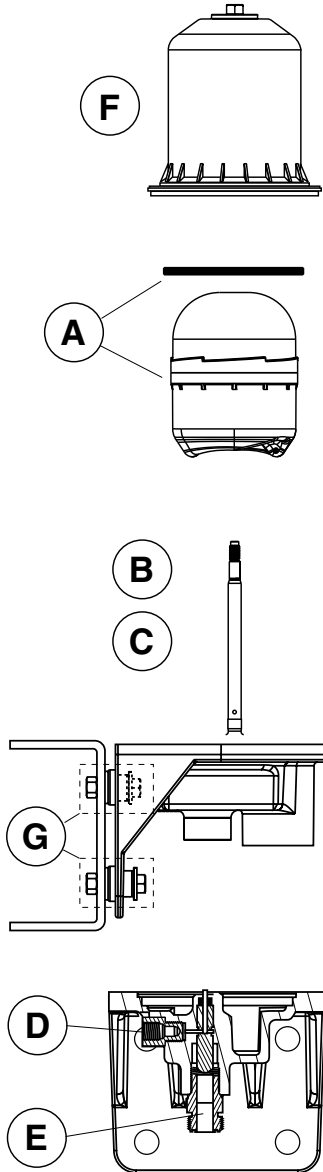
** Air system requirements (for CH41101 only)

When possible, the air connection should be sourced from system operating pressure - 100 lb/in² (6.8 bar) to 125 lb/in² (8.6 bar). Air pressure should be equal to or greater than the oil operating pressure.

***In order to achieve minimal removal height, the rotor and shell should be removed together.

Specifications subject to change without notice.

Parts List

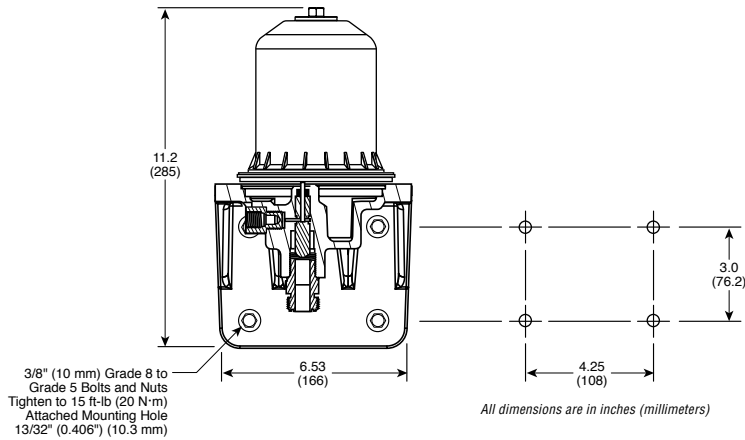


Part	Description	CH41100	CH41101	CH41102	Service Frequency
A	Service Rotor and Gasket	CS41005	CS41007	CS41007	Every Oil and Filter Change
B	Gravity Drain Base Casting and Shaft (Includes vibration isolators, nuts, bolts, and washers)	3935262 S	N/A	3935262 S	Only If Damaged
C	Air Assist Base Casting and Shaft (Includes vibration isolators, plunger assembly, air control fitting, nuts, bolts, and washers)	N/A	3940750 S	N/A	Only If Damaged
D	Air Control Fitting (1/4" NPT)	N/A	3941519 S	N/A	Only If Damaged
E	Oil Shutoff/Air Flow Plunger Assembly (Includes plunger, spring and O-Rings)	N/A	3943071 S	N/A	Only If Damaged
F	Cover Housing with Label (Includes nut, O-Ring and retaining ring)	3935261 S	3940756 S	3944520 S	Only If Damaged
G	Vibration Isolator Kit (Includes 4 vibration isolators, 4 bolts, 8 washers, and 4 nuts)	3935263 S	3935263 S	3935263 S	Every Three Years

Ordering Information

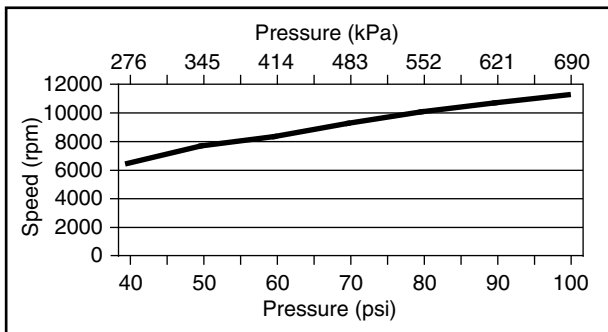
Part Number	Description
CH41100	Centrifugal Separator with Gravity Drain Base
CS41005	2 gal/min (7.6 L/min) Service Rotor and Gasket

Mounting/Dimensions

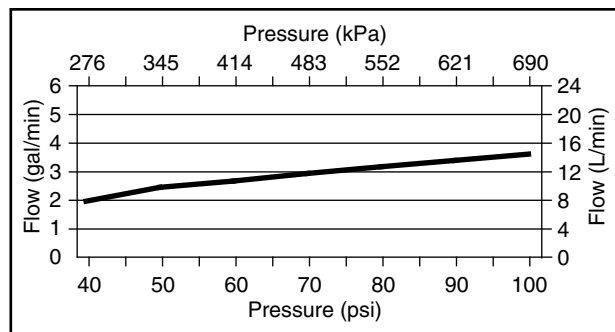


Performance

Speed vs Pressure



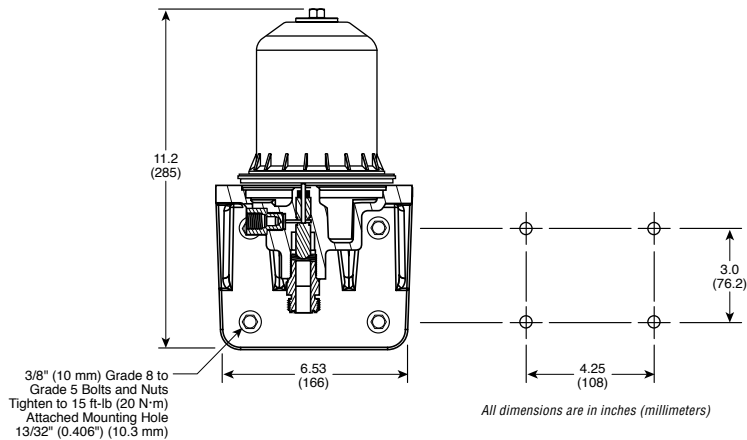
Flow vs Pressure



Ordering Information

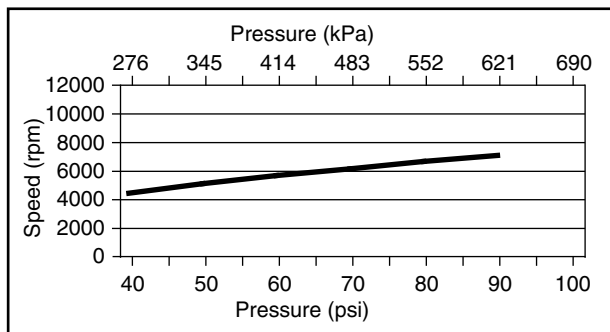
Part Number	Description
CH41101	Centrifugal Separator with Air Assist Base
CH41102	Centrifugal Separator with Gravity Drain Base
CS41007	1 gal/min (3.8 L/min) Service Rotor and Gasket

Mounting/Dimensions

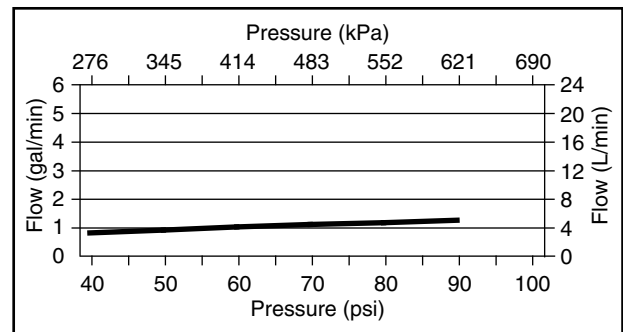


Performance

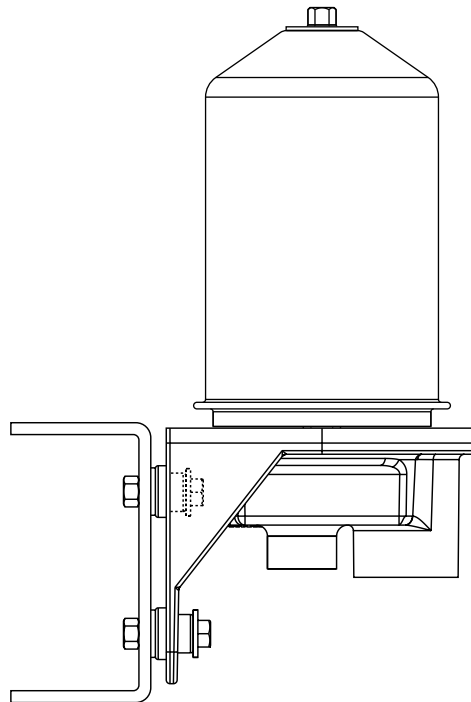
Speed vs Pressure



Flow vs Pressure



CH41111 • CH41112 • CH41113 • CH41114 Centriguard™ Separators



Specifications

Specification	CH41111	CH41112	CH41113	CH41114
Required Oil Flowrate* @60 lb/in ² (4.1 bar) and 230 °F (110 °C)	2 gal/min (7.6 L/min)	2 gal/min (7.6 L/min)	1 gal/min (3.8 L/min)	1 gal/min (3.8 L/min)
Drain Hose and Attachment Fitting Minimum ID into Sump*	1-1/4" (32 mm)	1/2" (13 mm)	3/4" (19 mm)	3/8" (10 mm)
Recommended Sump Size*	5-30 gal (18-113 L)	5-30 gal (18-113 L)	5-30 gal (18-113 L)	5-30 gal (18-113 L)
Air Supply Connection Needed**	N/A	1/4" NPT	N/A	1/4" NPT
Volumetric Capacity (weight depends on density of contaminant)	0.26 gal (1.0 L)	0.26 gal (1.0 L)	0.26 gal (1.0 L)	0.26 gal (1.0 L)
Overall Height of Assembly	14.3" (363 mm)	14.3" (363 mm)	14.3" (363 mm)	14.3" (363 mm)
Depth of Assembly	6.5" (167 mm)	6.5" (167 mm)	6.5" (167 mm)	6.5" (167 mm)
Width of Assembly	6.5" (166 mm)	6.5" (166 mm)	6.5" (166 mm)	6.5" (166 mm)
Assembly Weight (dry)	8.1 lb (3.7 kg)	8.3 lb (3.8 kg)	8.1 lb (3.7 kg)	8.3 lb (3.8 kg)
Rotor Weight (dry)	1.1 lb (510 g)	1.1 lb (510 g)	1.1 lb (510 g)	1.1 lb (510 g)
Clearance Above Assembly Needed for Service of Rotor***	4.5" (115 mm)	4.5" (115 mm)	4.5" (115 mm)	4.5" (115 mm)

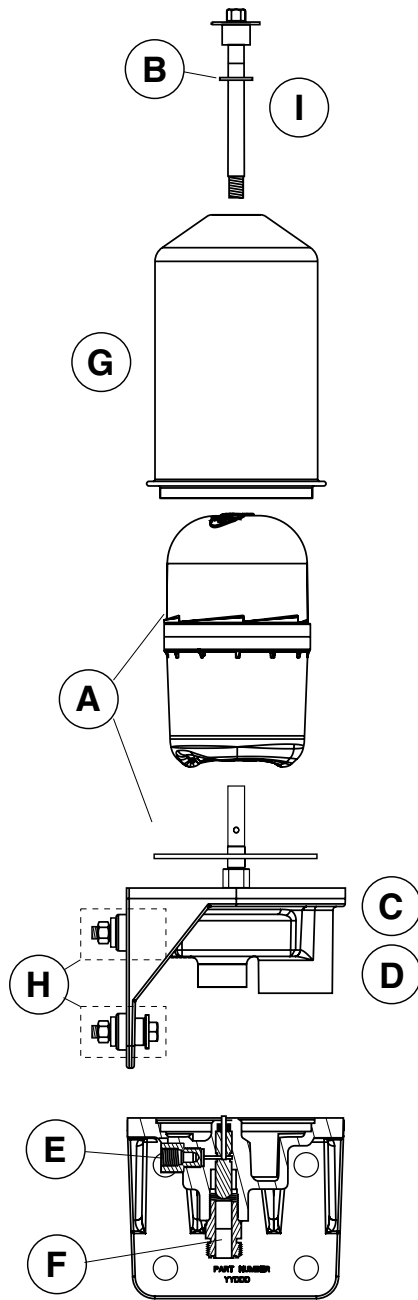
* Indicates engine supply parameters needed for EACH centrifuge used. In the event of multiple units used on the same engine/application, contact your Fleetguard® representative.

** Air system requirements (for **CH41112** and **CH41114**).

When possible, air connection should be sourced from system operating pressure - 100 lb/in² (6.8 bar) to 125 lb/in² (8.6 bar). Air pressure should be equal to or greater than the oil operating pressure.

*** In order to achieve minimal removal height, the rotor and shell should be removed together.

Specifications subject to change without notice.



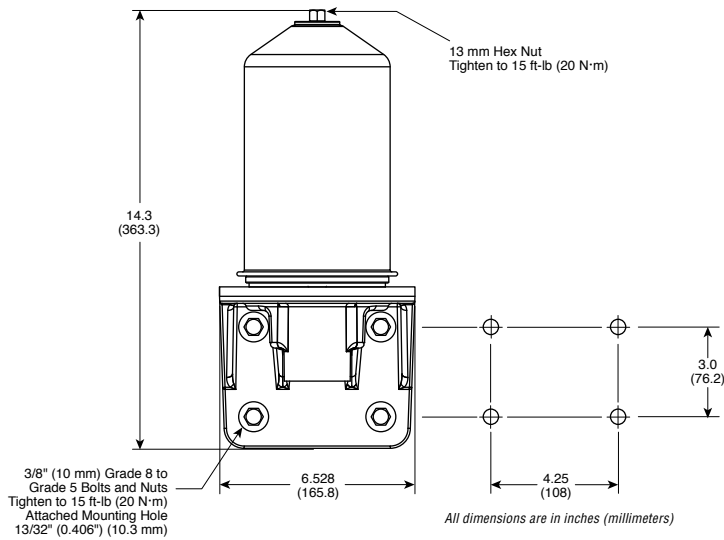
Parts List

	Part	CH41111	CH44412	CH41113	CH41114	Service Frequency
A	Service Rotor and Gasket	CS41011	CS41011	CS41016	CS41016	Every Oil and Filter Change
B	Top Shaft O-Ring	3923049 S	3923049 S	3923049 S	3923049 S	Only If Damaged
C	Gravity Drain Base Casting and Shaft (Includes vibration isolators, nuts, bolts, and washers)	3950689 S	N/A	3950689 S	N/A	Only If Damaged
D	Air Assist Base Casting and Shaft (Includes vibration isolators, plunger assembly, air control fitting, nuts, bolts and washers)	N/A	3950690 S	N/A	3950690 S	Only If Damaged
E	Air Control Fitting (1/4" NPT)	N/A	3941519 S	N/A	3941519 S	Only If Damaged
F	Oil Shutoff/Air Flow Plunger Assembly (Includes plunger, spring and O-Rings)	N/A	3943071 S	N/A	3943071 S	Only If Damaged
G	Cover Housing with Label	3951366 S	3951367 S	3955640 S	3955641 S	Only If Damaged
H	Vibration Isolator Kit (Includes 4 vibration isolators, 4 bolts, 8 washers, and 4 nuts)	3935263 S	3935263 S	3935263 S	3935263 S	Every Three Years
I	Top Shaft Assembly (includes nut, top shaft and O-Ring)	3943871 S	3943871 S	3943871 S	3943871 S	Only If Damaged

Ordering Information

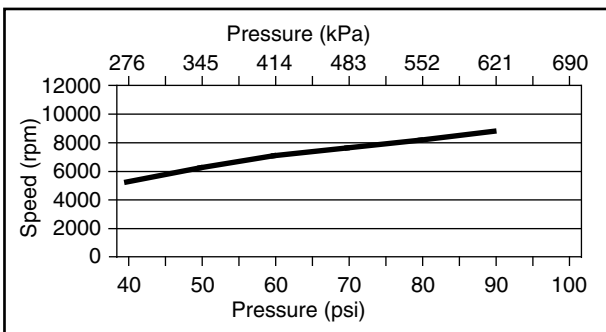
Part Number	Description
CH41111	Centrifugal Separator with Gravity Drain Base
CH41112	Centrifugal Separator with Air Assist Base
CS41011	2 gal/min (7.6 L/min) Service Rotor and Gasket

Mounting/Dimensions

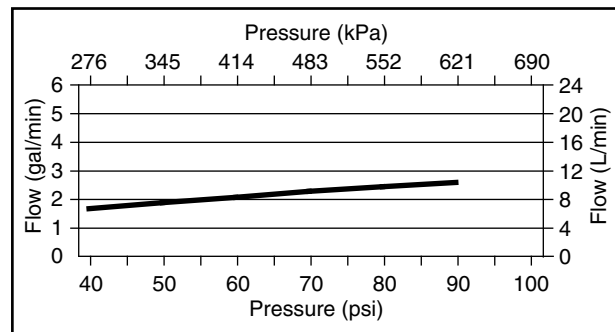


Performance

Speed vs Pressure



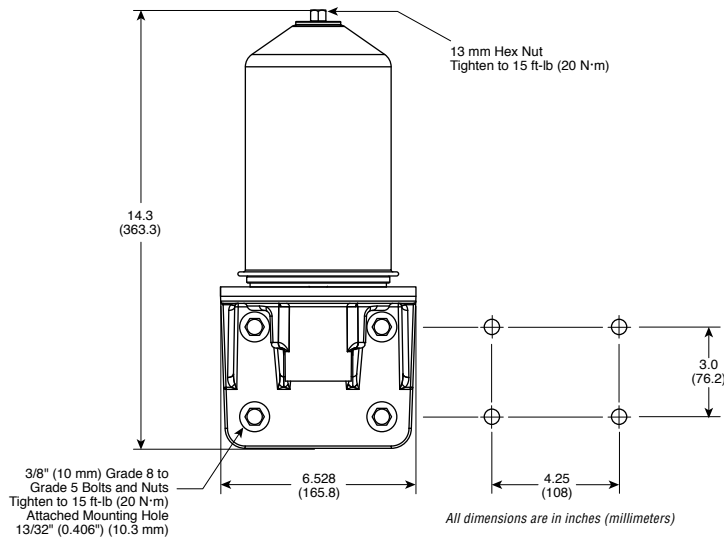
Flow vs Pressure



Ordering Information

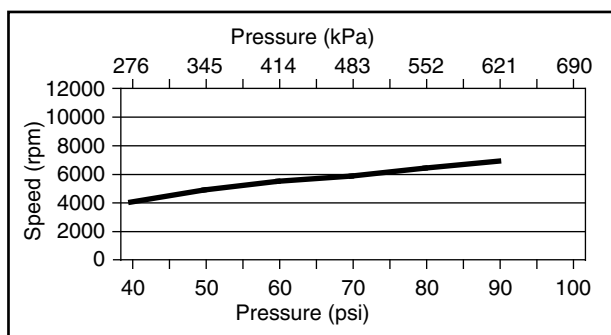
Part Number	Description
CH41113	Centrifugal Separator with Gravity Drain Base
CH41114	Centrifugal Separator with Air Assist Base
CS41016	1 gal/min (3.8 L/min) Service Rotor and Gasket

Mounting/Dimensions

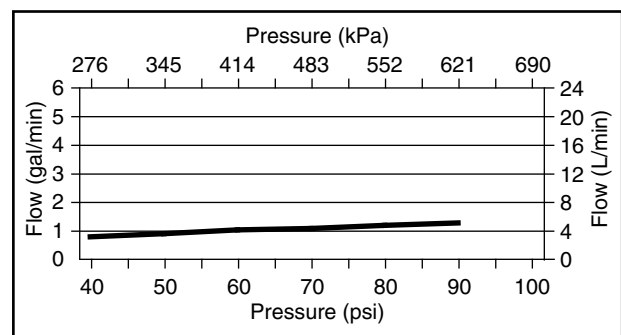


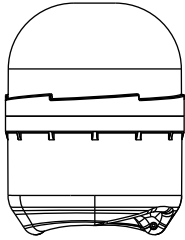
Performance

Speed vs Pressure

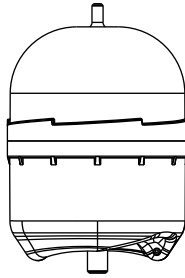


Flow vs Pressure

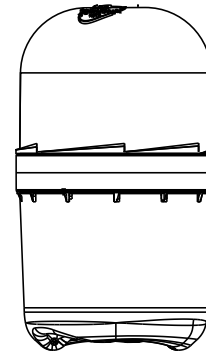




**CS41000 • CS41001
CS41002 • CS41003
CS41004 • CS41005
CS41007**



CS41008

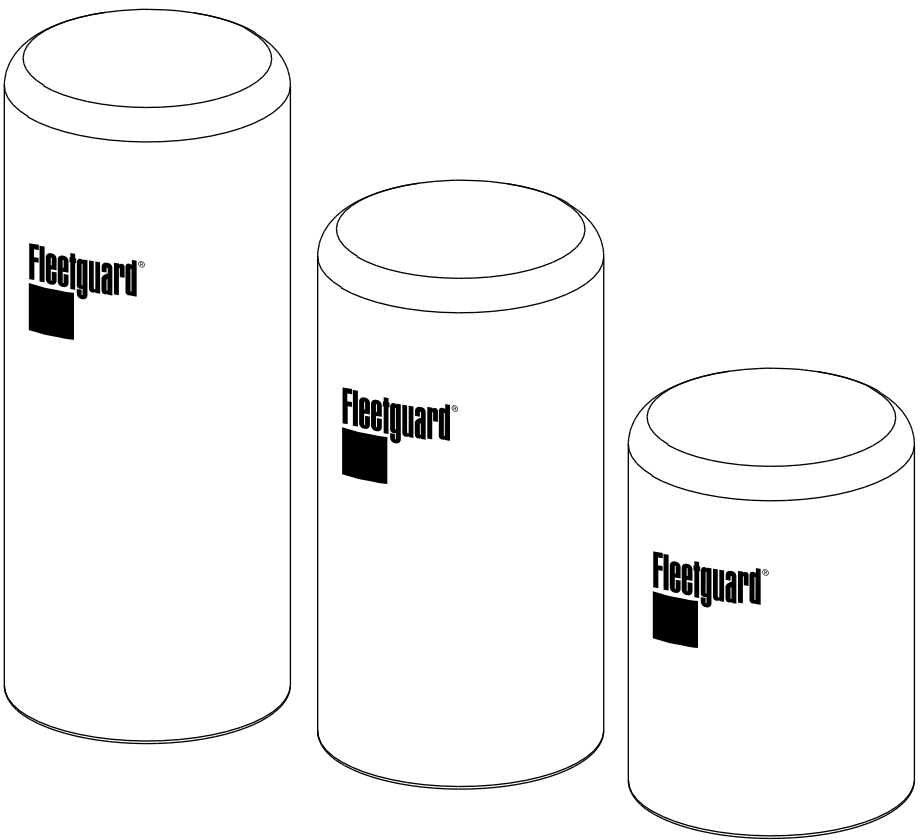


**CS41010 • CS41011
CS41013 • CS41016**

Ordering Information

Rotor Part Number	Cross Reference	Required Flow Rate @ 60 in ² gal/min (L/min)	Recommended Temperature °F (°C)	Capacity gal (L)	Rotor Weight (dry) lb (g)
CS41000	Note: Supersedes LF3416 Mack Centrimax 236GB244A (Kit 57GC2134)	2 (7.6)	230 (110)	0.15 (0.57)	0.73 (330)
CS41001	DAF 1310891	2 (7.6)	230 (110)	0.15 (0.57)	0.73 (330)
CS41002	Perkins OE45353	2 (7.6)	230 (110)	0.15 (0.57)	0.73 (330)
CS41003	Renault 5010412645 (Kit 5010437143)	2 (7.6)	230 (110)	0.15 (0.57)	0.73 (330)
CS41004	Renault 5001846545 (Kit 5001853256)	2 (7.6)	230 (110)	0.15 (0.57)	0.73 (330)
CS41005	Mack Centrimax Plus 236GB245M (Kit 57GC2187), Renault 5010412645 (Kit 5010437356)	2 (7.6)	230 (110)	0.15 (0.57)	0.73 (330)
CS41007	Rotor Used in Fleetguard® CH41101 and CH41102 Remote Mount Assemblies	1 (3.8)	230 (110)	0.15 (0.57)	0.73 (330)
CS41008	DAF 1643072, Mercedes Benz A 906 181 00 86 for Freightliner Applications	2 (7.6)	230 (110)	0.15 (0.57)	0.67 (306)
CS41010	Mack Centrimax Ultra Rotor 236GB41M (Kit 57GC2206)	2 (7.6)	230 (110)	0.26 (1.0)	1.1 (495)
CS41011	Mack Centrimax Plus Ultra Plus 236GB42M (Kit 57GC2231)	2 (7.6)	230 (110)	0.26 (1.0)	1.1 (510)
CS41013	International Truck and Engine Corporation 1842825C91	2 (7.6)	230 (110)	0.26 (1.0)	1.1 (510)
CS41016	Rotor Used in Fleetguard CH41113 and CH41114 Remote- Mount Assemblies	1 (3.8)	230 (110)	0.26 (1.0)	1.1 (510)

Venturi™ Lube Oil Filters



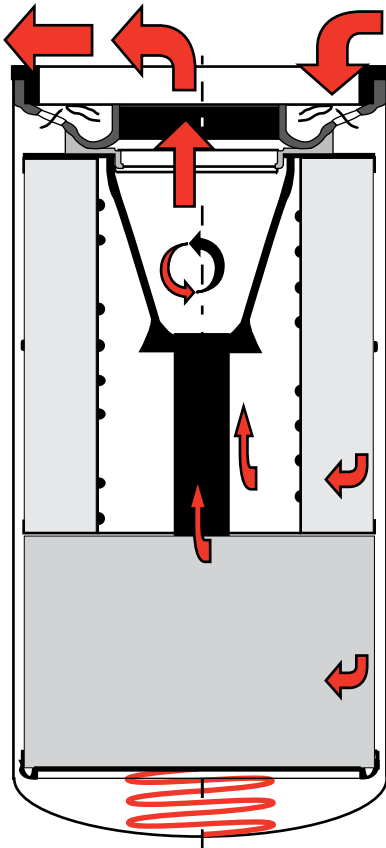
Something in the Oil

Engine oil contacts more critical components of the engine than any other fluid. Modern diesel engines, designed to meet stringent emissions regulations and achieve long service life, utilize precise fits and clearances to accomplish these goals. Therefore, it is of paramount importance to keep the engine oil as clean as possible and it is particularly critical if there is any interest in extending engine oil drain intervals. Since the oil can carry harmful abrasive particles and since the combustion process blows sludge-forming materials into the oil, it is necessary to remove these contaminants. In many engine applications, and especially severe service vocations, a standard full-flow oil filter cannot remove all of the harmful contaminants and still provide adequate filter life. Fleetguard® Venturi™ Lube Oil Filters can be the difference between a healthy engine and premature overhaul.



Don't Compromise On Oil Filtration

Fleetguard filters are some of the most advanced full-flow oil filters in the industry, with both cellulose and synthetic filter media and covering all brands of engines. However, when demands for maximum equipment utilization and extended oil drain intervals prevail, the situation may require a step up to the Venturi oil filter. The Venturi, a combination full-flow and by-pass oil filter referred to as the Combo filter, is a unique arrangement of filtration functions in one single filter. These filters are standard equipment on several modern diesel engines and are very effective at removing harmful particles and sludge from the oil. Using StrataPore™ synthetic filter media, the Venturi Combo filters provide a perfect balance between efficiency, real-world life and low restriction to oil flow.



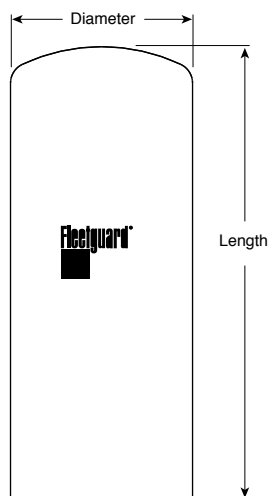
From Full-Flow Only Oil Filtration to a Combination of Full-Flow and By-Pass Filtration

Full-flow oil filtration for internal combustion engines began over 50 years ago. The full-flow oil filter technology has evolved from a cotton bag fastened around a steel support structure to pleated cellulose media cartridges and on to a variety of filter media packaged in spin-on filters. The basic premise of full-flow filtration has remained consistent through the years – to filter abrasive contaminants from the engine oil at an efficiency level that would not starve the engine of oil due to high filter restriction. This approach has always been a compromise among efficiency, life and oil flow.

Engine manufacturers have long known the benefits of improved oil filtration efficiency on improved engine component life. So by-pass filtration was born. By diverting a small portion of the oil flow away from the lubricated engine components, a steady stream of oil could be super-cleaned and returned directly to the engine sump. Over time and through turn-over of the engine sump, the super-clean oil would contribute to improved oil cleanliness. The result was reduced engine wear rates and longer operation at peak performance levels.

Engine oil by-pass filtration is required by some engine manufacturers and is frequently an option by the OEMs. Many aftermarket by-pass oil filtration systems are commercially available. Most of these systems are hindered by the need to mount a separate filtration device on the engine/equipment plus the need to route plumbing from the engine to the by-pass filter and back to the engine. The Fleetguard Venturi Combo filter eliminates this aggravation. The Venturi filter combines full-flow and by-pass filtration in one filter unit. All of the plumbing is contained within the filter with no extra plumbing required. There are no opportunities for hose issues and fitting leaks. Additionally, the Venturi filter does not rob oil flow from the engine and divert it to the engine sump. The super-clean oil is combined with the oil from the full-flow portion of the filter. So all of the oil is sent directly to the lubricated engine components.

The Fleetguard Venturi Combo filter utilizes the proprietary StrataPore synthetic filter media plus the patented stacked-disk by-pass filter media. Both materials have proven to be robust for extended oil drain intervals. Most importantly, the stacked-disk by-pass filter has demonstrated the ability to remove a large quantity of sludge that would normally plug the full-flow filter. This combination system enables the Venturi filter to provide outstanding performance and life.



Ordering Information

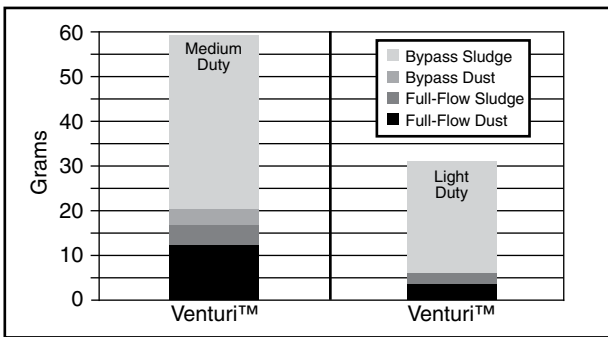
Part Number	Typical Application	Diameter in (mm)	Length in (mm)	Thread Size
LF9000	Cummins®	4.7 (119)	13.9 (353)	M95 x 2.5-7H
LF9001	Cummins	4.7 (119)	11.6 (295)	M95 x 2.5-7H
LF9008	Hitachi®	4.8 (122)	9.9 (252)	1-1/2-12 UNS-2B
LF9009	Cummins	4.7 (119)	11.9 (302)	2-1/4-12 UNS-2B
LF9010	John Deere®	4.7 (119)	11.6 (295)	M52 x 1.5-6H
LF9018	Komatsu®	4.7 (119)	13.0 (330)	M95 x 2.5-7H
LF9024	Cummins and Komatsu	4.7 (119)	11.9 (301)	M90 x 2.0-7H
LF9025	International Truck and Engine Corporation®	4.7 (119)	13.9 (353)	M95 x 2.5-7H
LF9026	International Truck and Engine Corporation (pre 2004)	5.4 (137)	12.2 (310)	M36 x 1.5-5H
LF9027	Ford® Powerstroke 7.3 L	4.2 (108)	8.1 (206)	1-1/2-16 UNS-2B
LF9028	Kubota®	3.7 (94)	6.9 (176)	1-16 UN-2B
LF9031	Cummins	4.7 (119)	11.8 (300)	M95 x 2.5-7H
LF9032	John Deere®	4.7 (119)	13.9 (353)	M52 x 1.5-6H
LF9034	Cummins	4.7 (119)	11.9 (301)	M90 x 2.0-7H
LF9035	International Truck and Engine Corporation	4.7 (119)	10.5 (267)	M92 x 2.0-7H
LF9039	Cummins	4.7 (119)	11.8 (300)	2-1/4-12 UNS-2B
LF9325	Cummins	4.7 (119)	11.3 (287)	1-1/2-12 UNS-2B
LF9333	Detroit Diesel®	4.7 (119)	10.3 (262)	2-1/2-12 UNS-2B
LF9548	Case®	4.7 (119)	9.4 (238)	2-1/4-12 UNS-2B
LF9620	Detroit Diesel	4.7 (119)	10.3 (262)	1-5/8-12 UNS-2B
LF9667	Caterpillar and Mack®	4.2 (108)	10.4 (264)	1-1/18-16 UN-2B
LF9691	Caterpillar	4.7 (119)	11.3 (287)	1-1/2-16 UNS-2B
LF9691A	Caterpillar	5.4 (137)	12.2 (310)	1-1/2-16 UNS-2B
LF9747	Komatsu	4.7 (119)	11.3 (287)	1-1/2-12 UNS-2B
LF9931	GMC®	5.4 (137)	12.2 (310)	M45 x 1.5-6H

Performance

Cummins Filtration® utilizes a comprehensive battery of laboratory and real world product development tests for its Fleetguard® filters. The Venturi™ product line was established using this approach. The following graphs represent typical performance for the Venturi products. While the various filter part numbers may be of different size, the ratio of full-flow to by-pass filtration has been optimized for the particular engine applications.

The basic performance premise behind the Venturi Lube Oil Filters is centered around the fact that engine oil contaminants are comprised of both organic (carbon-containing compounds) and inorganic (dust, wear metals, etc.) materials. Engines generate combustion by-products and contaminate the engine oil at different rates throughout the typical oil drain interval. The normal used oil filter will end up with approximately 80% organic and 20% inorganic make-up of the contaminants trapped in the filter. Managing these two contaminant types is what makes the Fleetguard Venturi Oil Filters unique and able to support the maximum achievable engine oil drain intervals. Laboratory test results, with test dust, do not tell the whole story about the performance of an optimized oil filter.

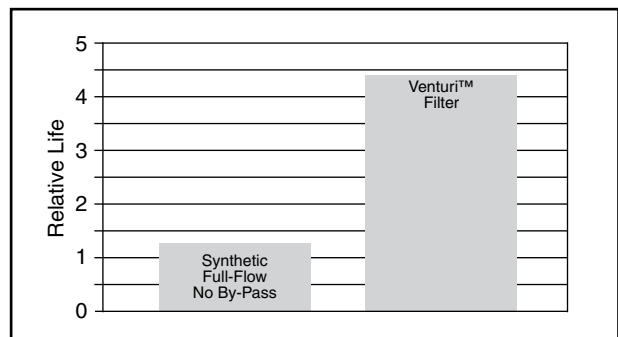
Captured Contaminant



Notes:

- Obtained from actual field-returned filters.
- Sludge is primarily organic contaminant.
- Dust is primarily inorganic contaminant.
- Optimum engine protection is obtained by removing both organic and inorganic contaminant.

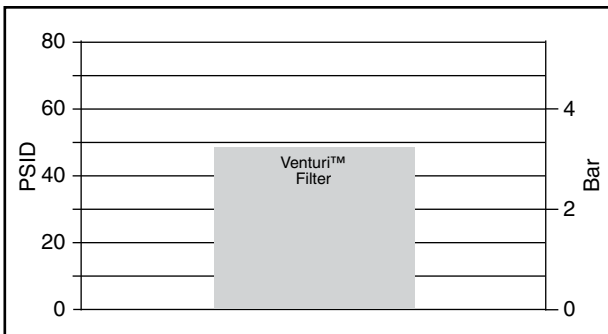
M-11 High-Soot Filter Plugging Engine Test



Notes:

- The M-11 High Soot Test is an actual operating engine.
- The synthetic full-flow, no by-pass filter is an ASTM reference filter.
- Greater relative life translates to longer real world filter life.
- On-engine relative life is more relevant to actual engine utilization than laboratory test dust capacity.

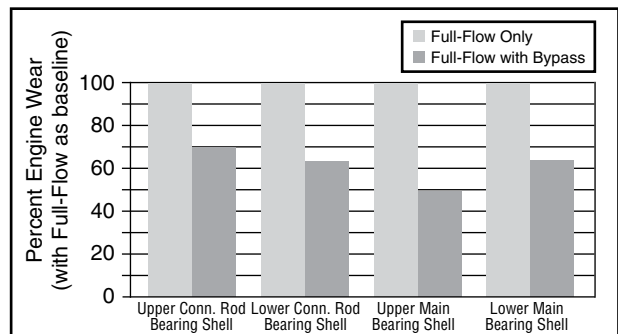
Cold Flow Restriction



Notes:

- Oil flow test conducted at 14 °f (-10 °C) and 6 gal/min (23 L/min) oil flow.
- Test oil was 15W40.
- Higher oil flow restriction results in delayed oil flow to critical engine components.
- Delayed engine oil results in opportunities for increased engine wear.

Engine Wear



Notes:

- Data taken from Society of Automotive Engineers (SAE) technical papers no. 710813 and 790089.
- Wear rates using a full-flow-only filter were established as the "baseline" 100% wear rate.
- Wear rates for the full-flow and by-pass oil filter combination are a percentage of the baseline.
- Reduced engine component wear yields longer engine life and improved engine up time.



Technical Notes

SPECTROMETRIC METALS

There are any number of metallic elements to be found in used lubes, but they can be generally grouped into four basic categories.

Wear Metals: The product of friction, corrosion, and/or deterioration of components within a given unit:

Metal	Engines	Transmissions	Gears	Hydraulics
Iron	Cylinder liners, rings, gears, crankshaft, camshaft, valve train, oil pump gear, wrist pins	Gears, disks, housing, bearings, brake bands, shaft	Gears, bearings, shaft, housing	Rods, cylinders, gears
Chrome	Rings, liners, exhaust valves, shaft plating, stainless steel alloy	Roller bearings	Roller bearings	Shaft
Aluminum	Pistons, thrust bearings, turbo bearings (Cat)	Pumps, Thrust washers	Pumps Thrust washers	Bushings, thrust plates
Nickel	Valve plating, steel alloy from crankshaft, camshaft, gears from heavy bunker type diesel fuels	Steel alloy from roller bearings and shafts	Steel alloy from roller bearings and shafts	
Copper	Lube coolers, main and rod bearings, bushings, turbo bearings, lube additive	Bushings, clutch plate (auto/powershift) lube coolers	Bushings, thrust plates	Bushings, thrust plates, lube cooler
Lead	Main and rod bearings, busings, lead solder	Bushings (bronze alloy), lube additive supplement	Busings (bronze alloy), grease contamination	Busings (bronze alloy)
Tin	Piston flashing, bearing overlay, bronze alloy, babbitt metal along with copper and lead	Bearing cage metal	Bearing cage metal, lube additive	
Cadmium	N/A	N/A	N/A	N/A
Silver	Wrist pin busing (EMDs), silver solder (from lube coolers)	Torrington needle bearings (Allison transmissions)	N/A	Silver solder from lube coolers
Titanium	Gas turbine bearings/hubs/blades, paint (white lead)	N/A	N/A	N/A
Vanadium	From heavy bunker type diesel fuel	N/A	N/A	N/A

Technical Notes

Contaminant Metals: Abrasives, dirt; contaminated lube storage; casting sand or metal from manufacture; coolant additive metals, etc.:

Metal	Engines	Transmissions	Gears	Hydraulics
Silicon	Dirt, seals and sealants, coolant inhibitor, lube additive (15 ppm or less)	Dirt, seals and sealants, coolant inhibitor, lube additive (15 ppm or less)	Dirt, seals and sealants, coolant inhibitor, lube additive (15 ppm or less)	Dirt, seals and sealants, coolant inhibitor, lube additive (15 ppm or less)
Sodium	Lube additive, coolant inhibitor, salt water contamination, wash detergents	Lube additive, coolant inhibitor, salt water contamination, wash detergents	Lube additive, coolant inhibitor, salt water contamination, airborne contaminant	Lube additive, coolant inhibitor, salt water contamination, airborne contaminant
Lithium	Coolant inhibitor, airborne contaminant	Coolant inhibitor, airborne contaminant	Coolant inhibitor, airborne contaminant	Coolant inhibitor, airborne contaminant

Multi-Source Metals:

Metal	Engines	Transmissions	Gears	Hydraulics
Boron	Ring plating, lube additive, coolant inhibitor	Lube additive, coolant inhibitor	Lube additive, coolant inhibitor, grease additive	Lube additive, coolant inhibitor
Antimony	Lube additive	Lube additive	Lube additive	Lube additive
Maganese	Steel alloy	Steel alloy	Steel alloy	Steel alloy
Lithium	N/A	Lithium complex grease	Lithium complex grease	Lithium complex grease

Additive Metals: Metals placed in the lubricant by the blender to achieve beneficial effects:

Metal	Engines	Transmissions	Gears	Hydraulics
Magnesium	Detergent dispersant additive, airborne contaminant	Detergent dispersant additive, airborne contaminant	Detergent dispersant additive, airborne contaminant	Detergent dispersant additive, airborne contaminant
Calcium	Detergent dispersant additive, airborne contaminant, contaminant from water	Detergent dispersant additive, airborne contaminant, contaminant from water	Detergent dispersant additive, airborne contaminant, contaminant from water	Detergent dispersant additive, airborne contaminant, contaminant from water
Barium	Lube additive	Lube additive (rare)	Lube additive (rare)	Lube additive (rare)
Phosphorus	Anti-wear additive (ZDP)	Anti-wear additive (ZDP), EP additive (extreme pressure)	Anti-wear additive (ZDP), EP additive (extreme pressure)	Anti-wear additive (ZDP)
Zinc	Anti-wear additive (ZDP)	Anti-wear additive (ZDP)	Anti-wear additive (ZDP)	Anti-wear additive (ZDP)

It is necessary to monitor all of these metal types to fully evaluate a system.

The situation is far from this simple, however, because every metal can at least fit into two or three categories, some into all four. Furthermore, there are not only engines to consider, but gears, compressors, and hydraulics; the same metals have different meanings in each of these subcategories. Even further complexities exist because different manufacturers utilize different metallurgies, oil companies different additives, and coolant additive manufacturers different materials.

The case of SILICON is perhaps the most complex and interesting. It first may be found up to 15 ppm as silicone polymer defoamant. It may also be found as a major constituent of certain synthetic lubes. It is, of course, found as "dirt" or abrasives. It can be found as a constituent in certain preparatory agents used to lubricate or seal at manufacture. It can be found as a constituent in silicon rubber gaskets or seals. Finally, it can also be found in certain coolant additives - its presence in the lubricant might, therefore, be indicative of a coolant leak. In most situations, an experienced consultant can pin down the source of silicon to a single possibility by evaluating the remaining test data.

Nearly everyone would like to know "limits" for metals, particularly the WEAR variety. It is the WEAR metals, in particular, however, which cannot be assigned GENERIC limits because every piece of equipment develops its own unique wear rate. For this reason chronological, cumulative histories are kept on each individual piece of equipment. In this way we can monitor WEAR RATE or, more precisely, the CHANGE IN WEAR RATE from sample to sample. We do use formulae for monitoring change in wear rates, but these are proprietary. They vary according to manufacturer, model and application among several other items. Make-up lube addition also plays a role in the wear metals concentrations derived.

CONTAMINANT metals can be assigned loosely defined "rule-of-thumb" limits, but, once again, manufacturer and application influence our tolerances.

ADDITIVE metals let us know a great deal about the nature of the additive package placed in the lube. We can usually identify the type of product in use and continue to monitor the quality control of that product as new batches are received.

Note: It is recommended that each batch of new lube be tested for spectrometric metals for a baseline. We then monitor the additive metals for relative consistency from sample to sample, assuring customers that the correct lube is being utilized. Such baseline testing is recommended a minimum of every six months.

Other References

SAE Paper #740535
Heavy Duty Equipment Maintenance/Management
(June, July, August 1978)

FUEL CONTAMINATION

FUEL CONTAMINATION is a measurement of unburned fuel found in the crankcase/sump of liquid-fueled reciprocating engines (LFREs), although there are some specialized applications for "fuel" detection. One example might be the desire to measure solvent thinning of hydraulic fluids. Another example would be to spot saturated ("wet") gas engine fuel.

Every LFRE will have a certain amount of raw fuel in its blow-by. Usually the heat of the engine evaporates volatile portions of this fuel at a rate producing an equilibrium (a stable level of fuel contamination). If an equilibrium is not reached, or too high an equilibrium percentage is maintained, there is a problem: leaking injectors, faulty carburetor floats, leaking injector seals, pumps or jumper lines, worn rings, etc.

In over-the-road (OTR) diesel applications, 1.5 to 2.0% or lower is typical. A pick-up and delivery (P&D) application features a much higher percentage of idle time, consequently the engine lube tends to remain too cool to evaporate fuel properly. Further, and particularly true of carbureted fuel systems, there is a distinct over-fueling condition at low idle speeds, which could also contribute to a higher fuel contamination level. In diesels, however, such contribution is usually negligible since fuel is more proportionately metered with injected versus carbureted systems.

Occasionally there will be units which consistently show fuel contamination levels above 4.0% owing to extremely concentrated P&D work. Under these circumstances no corrective action, short of altering the application in which the engine is used, will prevent such results.

Excessive fuel contamination must be controlled because lube film strength decreases, adding to the risk of abnormal wear, particularly in the ring/cylinder region. There is also the distinct danger of a crankcase explosion at levels beyond 7%. The independent laboratory utilizes an FTIR (Fourier-Transform Infrared) Spectrometer to measure fuel contamination.

Technical Notes

Technical Point

Lubes and fuels both emanate from the same source: crude oil. Fuels are the more volatile portion of the crude product. It is important to understand that fuel does not possess a distinct boiling temperature as does, for example, water, ethyl alcohol, acetone, for it is not a “pure” product or compound. It is a mixture of petroleum products within a boiling RANGE.

A typical ASTM #2D diesel fuel might have an initial boiling temperature of 302 °F (150° C) at standard sea level atmospheric conditions, but as the product is carried over to the distilling receiver, the temperature required to boil the fuel continually increases. A typical ending temperature might be well over 572 °F (300° C).

ALL fuel contamination detection methods must necessarily be estimates of the TRUE fuel level.

Other References

SAE paper #740535
Heavy Duty Equipment Maintenance/Management
(June, July, August 1978)

SOOT CONTAMINATION

SOOT represents a measurement of carbon combustion by-products in the lube system.

Diesel Engine

Soot develops from incomplete combustion and is blown past rings and valve guides as a normal operational process. It is finely divided carbon, oftentimes less than a micrometer in size and is the cause of routine lube blackening. Lube additive dispersants also play a role in lube blackening as they maintain much of the generated fuel soot in suspension rather than allow it to be filtered.

Proper filtration helps control fuel soot, especially when particles combine with themselves (agglomerate) to form larger particles.

Sources of excessive soot in diesel systems include:

- Over-fueling or restricted air intake
- Poor injector spray pattern (plugged nozzle, etc.)
- Worn rings, valve guides, turbocharger or supercharger seals
- Oxidized fuel and lube products (poor timing, poor fuel or lube)
- Plugged or inoperative lube filters

Usually recommendations are for corrective action or drains at or near 3.0% soot in most diesel systems, but the decision to render advice is also based on the unit's pattern on an individual basis as well.

WATER CONTAMINATION

It is recommended that samples be taken when a unit is at operating temperature, or has been shut down for only a short while. As well as providing the most representative sample, it minimizes chances of obtaining samples with condensate water (unless there is a problem with systems using water traps).

Water should not normally be found in most systems at levels above 0.1% (1000 ppm), provided samples are taken correctly. Oftentimes, the laboratory detects metallic coolant additives rather than water because the water is continually evaporated by a unit's heat. When water is detected, these same metals aid in qualifying the source (coolant/condensate/etc.; salt or fresh water in marine situation).

Exemplary Metals Combinations

Chromium	Silicon	Sodium	Boron	Magnesium	Phosphorus	Possible Evaluation
		X	X	OR	X	Washing compound (e.g. truck washrack)
		X				Salt water or coolant
		X		X		Sea water
X		X				Chromate coolant treatment
		X	X			Coolant/glycol
	X	X	X			Coolant/glycol
	X	X				Coolant/glycol

Other References:

SAE Paper #740535
 Heavy Duty Equipment Maintenance/Management
 (June, July, August 1978)

VISCOSITY

VISCOSITY OF A LUBRICANT IS A MEASURE OF ITS RESISTANCE TO FLOW WITH RESPECT TO TEMPERATURE. Two things are therefore necessary in reporting viscosity: a) temperature at which the viscosity is measured; b) the amount of time units for a given amount of the flow through a given passage.

The two most common temperatures for motor oil viscosity are 100 °F (40 °C) and 210 °F (100 °C). The units reported are mm²/s. The change in viscosity temperatures is the result of an effort to standardize to a common world system; essentially it is metrication of the viscosity reporting system.

VISCOSITY INDEX IS THE CHANGE IN RESISTANCE TO FLOW OF A LUBRICANT WITH RESPECT TO TEMPERATURE. As a lube is heated it will get “thinner” (its viscosity will decrease). The amount of thinning which takes place over a given temperature span can be expressed as VISCOSITY INDEX (VI), a term expressed as a number without units. The less tendency a lube has to thin with temperature increase, the greater is VI. Determination of VI requires two viscosities at different temperatures (usually 100 °F (40 °C) and 210 °F (100 °C)).

SIGNIFICANCE OF VISCOSITY: There are numerous references which cite that the viscosity of a lube is its most important single property, and perhaps this is true, at least when the lube is new. By itself, however, a viscosity does not nearly qualify a lube. It basically defines the film thickness the lube will have for a given application. New lubes placed in engines or other machinery should be inspected for correct initial viscosity. Assuming no errors are made with the initial fill, the following factors can influence viscosity:

Downward:

- Liquid fuel contamination
- Non-emulsified water contamination
- Shearing of VI-improving polymers
- Wrong make-up lube addition

Upward:

- Soot contamination
- Certain emulsions with water
- Lube oxidation/degradation
- Wrong make-up addition

Most modern lubes, particularly engine lubes, are “oxidation-stable” under standard drain intervals so that, unless extended drains are contemplated, it is better to observe the contamination which influences viscosity rather than the viscosity itself. It is possible to have combined contamination such that viscosity remains stable, but an abnormal situation exists (e.g. high fuel and solids). For this reason, the laboratory DOES NOT ROUTINELY DETERMINE VISCOSITY UNLESS EXTENDED DRAINS ARE CONTEMPLATED, for it has limited value in detecting fuel contamination and is oftentimes misleading.

On the other hand, INCREASED VISCOSITY, IN THE ABSENCE OF FUEL OR OTHER CONTAMINATION, WILL USUALLY INDICATE LUBE OXIDATION/DEGRADATION, and the viscosity is the most convenient means to measure this with reasonable effectiveness. VISCOSITY, along with neutralization number, SHOULD ALWAYS BE REQUIRED BY CUSTOMERS WISHING TO SAFELY EVALUATE EXTENDED LUBE DRAINS.

Standard SAE Grading For Motor Oils

SAE Motor Oil Grade	Number Viscosity @ 210 °F (100 °C)
20	~ 5.6 to 7.2 mm ² /s
20	~ 9.3 to 12.4 mm ² /s
40	~ 12.5 to 16.2 mm ² /s
50	~ 0.3 to 21.8 mm ² /s

It should be noted that 210 °F (100 °C) is the ONLY temperature to be used in classifying motor lube by SAE grade. Also note that there are no MOTOR lube grades below 20 or above 60.

There is also no such legitimate term as “weight” (e.g. “30 weight”). The “W” designations found on certain cans or drums refers to a -0.4 °F (-18° C) viscosity requirement for the particular product, and should always be followed by a number (20, 30, 40, or 50) indicating the grading for 210 °F (100 °C). This grading pertains only to motor lubes. Gear lubes and specialty lubes have other systems for viscosity grading which do not necessarily relate to motor lubes.

It is reasonable to expect a lube to increase at least one grade (e.g. 30 SAE to 40 SAE) during typical drain intervals. This increase occurs because of routine lube oxidation and the evaporation of more volatile constituents in the lube. Solids, of course, also contribute. VI-improving polymers are synthesized materials which artificially thicken lubes as temperature increases. They exhibit this ability due to their physical form at various temperatures. At lower temperatures their molecules are very compressed, offering little resistance to lube flow. At elevated temperatures these molecules spread out to their full physical length, impeding flow, or “thickening” the lube. Shearing of these polymers is the actual cutting of the molecular chain into shorter chains, an action which can occur between two rubbing surfaces in the system. Heat also contributes to this phenomenon. In the shorter state these chains no longer impart a thickening effect to the lube, and the polymer is said to have been “sheared.” The lube, consequently, is more nearly as it was prior to polymer treatment and may then fail to have sufficient viscosity at operating temperature.

Expected Ranges of Other Lubes	Minimum mm ² /s @ 210 °F (100 °C)	Maximum mm ² /s @ 210 °F (100 °C)
ATF (Automatic Transmission Fluid)	5.5	8.5
Hydraulic Fluid (typical tractors)	5.5 to 9.8	7.0 to 13.0
90 SAE Axle/Manual Transmission	13.5	23.9
140 SAE Axle/Manual Transmission	24.0	40.9
250 SAE Axle/Manual Transmission	43.0	77.0

Other References

SAE paper #740535
Heavy Duty Equipment Maintenance/Management
(June, July, August 1978)

Technical Notes

ADDITIVES

A motor lube consists of two major parts: BASE STOCK (or BASE “OIL”) and ADDITIVE. The BASE STOCK is the primary lubricant and can be petroleum or synthetic. The ADDITIVE is usually a laboratory or synthesized product, or combination of products, which enhances the BASE STOCK’S performance.

Together the BASE STOCK and ADDITIVE make up the “finished lubricant.” Usually the ADDITIVE comprises less than 20% of the total lubricant volume, but there are not absolute limitations. A lube is qualified primarily by its performance not its additive quantities. Furthermore, the BASE STOCK is equally important to a lube’s performance.

Its chemical structure, resistance to oxidation, wax content, etc. are all critical factors, as well as its compatibility with the proposed additive package.

Detergents

As the name implies, these compounds help maintain engine cleanliness by preventing deposits on critical areas such as ring lands, or by removing such deposits. They also help maintain deposits such as fuel soot in suspension to be filtered out or drained with the lube. Metallic carriers are generally used (except where “ashless” lubes are required) to bring the non-metallic portion, which is the “detergent” part of the compound, to the lube. The metal, however, is also beneficial in itself for its alkaline properties, acting as a neutralizer for corrosive acids, thus helping to give the lube its Total Base Number (TBN).

Dispersants

Dispersants have overlapping properties with detergents in that they, too, maintain particles in suspension. Many technical people distinguish the two terms by calling metallic particle suspenders “detergents” and totally non-metallic (ashless) particle suspenders “dispersants.” They reduce the tendency of small particles to combine into larger particles, taking some of the burden off the filters, and prevent deposition of these particles on valve covers and moving parts particularly at low temperatures. Monitor™ soot test aids in monitoring the effectiveness of the lube’s dispersants.

Defoamant

This material, usually a silicon polymer, acts in a very complex chemical and physical manner to minimize foaming tendencies of lubes. It has limited solubility in lubricants of a non-silicon nature, and this limited solubility helps its effectiveness in accelerating the formation of large bubbles from small ones which dissipate from the lube much more readily. The larger bubbles rise to the surface quickly and then break.

Antioxidants

There are antioxidants for fuels and lubricants, and most of them are non-metallic. Oxidation is a general term used to describe the combining process with oxygen which a lubricant tends to do. This oxidation, in turn, forms undesirable compounds which are far less suitable as lubricants. A number of metals, most notably copper, tend to aid (catalyze) oxidation. Some types of antioxidants, therefore, react chemically with the offending metal to nullify its catalytic effect. Another way to inhibit oxidation is to break the chemical chain by “sacrificing” the antioxidant. This type of compound has a great affinity for oxygen when it appears in oxidation products and can combine with it to form harmless compounds, while simultaneously stopping the oxidation chain.

Anticorrosives

These materials prevent chemical corrosion from occurring. They can accomplish this by forming a chemical, protective coating on metal surfaces, or they can directly attack and neutralize materials (usually acids) which cause corrosion.

Extreme Pressure (EP) Agents

EP agents increase the load carrying ability or film strength of lubes. This increase in turn prevents or at least minimizes direct metal-to-metal contact. Many gear systems need lubes fortified with EP agents to function properly. Some EP agents include sulfurized sperm oils and molybdenum sulfide.

Anti-Wear Additives

These materials are similar in scope to EP agents; some plate or coat while some combine chemically with metal surfaces, particularly ferrous (iron or steel), to form a protective coating, necessary in the event that the lube film is interrupted.

Viscosity Index (VI) Improvers

VI improvers consist of polymers whose properties change significantly with temperature, such that a lubricant resists “thinning out” as its temperature increases. Polyisobutylenes were among the early compounds used. The latest technology uses copolymer chemistry, which seems to be far more stable, particularly for use in diesel engines. A VI improver’s function is to improve cold starting capabilities while retaining necessary film thickness at operating temperature.

Pour Point Depressants

The pour point of a lube is simply the lowest temperature at which it will still pour. The amount of wax in a lube influences its pour point. Pour point depressants minimize the size of wax crystals formed in the lube. By so doing, they allow the lubricant to achieve its lowest possible pour point, based on its true viscosity characteristics and not on its wax content. Polymethacrylates are the general class of organic compounds used as pour point depressants, also providing some VI improvement.

The fluids listed above are only a portion of the various additives developed for petroleum products, but they represent most of the important ones for automotive use. It should also be noted that several of the above properties can, at times, be fulfilled adequately by a single additive compound.

Note: ADDITIVES, with the exception of solid lubricants, are SOLUBLE in BASE STOCKS and would normally not be susceptible to filtration depletion from typical automotive filters. It is possible, however, that in the course of being consumed, an additive could form an insoluble product capable of being filtered.

Note: The laboratory uses industry-standard terminology for synthetic lubricants: products which consist of base stocks manufactured by chemical synthesis and containing necessary performance additives.

Additive Metals

ICP spectrometers routinely measure five potential additive metals: Magnesium (Mg), Calcium (Ca), Barium (Ba), Phosphorus (P), and Zinc (Zn). **Note:** Boron (B) and Sodium (Na) may also be additives, as well as Molybdenum (Mo), though less frequently.

These metals are detected to aid in verifying the correct product is being used, but detection of metals alone cannot verify their continued effectiveness as an additive. The reason is very simple: when a spectrometer measures Ca, for example, it is measuring Ca in ANY form (additive or contaminant). When the Ca-containing additive is placed in the lubricant, it has a particular chemical structure and one cannot monitor that structure or its effectiveness with metals detection alone. In analyzing a NEW LUBE, however, any Ca measured is fresh, active additive, and this information helps predict the lube’s performance capabilities.

Detergent Carriers

Ca, Mg and Ba, in order of current use frequency, are the most common metals in use as carriers. Typically only one of these three metals is found in a specific brand and type of motor lube, dependent on how the suppliers choose to meet the desired specification. It is possible, however, to find new lubes using a combination of metals to achieve the same purpose. There is no rule.

These metals impart alkaline properties to the lubricant, enabling it to neutralize corrosive acids. Mg has the highest alkalinity per given weight amount, Ba the least. For this reason, Mg and Ca are nearly exclusively found in high performance motor lubes with sulfated ash limitations.

Anti-Wear/Antioxidants

Zinc dithiophosphate, containing P and Zn in roughly equal proportions, is the most common anti-wear/antioxidant compound found in motor lubes and many hydraulic oils, thus is routinely investigated for its presence. There are several types of zinc dithiophosphates, each having its own favorable properties for particular applications.

Zinc dithiophosphate is an additive which provides multi-function capability. In the antioxidant role it can break the oxidation chain of a lubricant; in the anti-wear role it chemically “plates” out on such components as cams and lifters, or gears and serves as a lubricant in the event that metal-to-metal contact takes place.

Some Zn and P plate-out, and a decrease in these elements might be expected, but make-up lube, as with all additives, tends to restore the level and maintain equilibrium.

Technical Notes

It is possible to find lubes having P without Zn used as an anti-wear agent.

There are a number of other metals which are used as additives. Molybdenum (Mo) as molybdenum sulfide is a solid lubricant currently enjoying some popularity as an extreme pressure agent. Unlike most additives, however, it is not dissolved in the base lube but suspended as minute particles less than one micron in size.

It should be pointed out that when Mo is used as an additive, detection of Mo to evaluate Mo-coated rings is not possible, again due to the lack of distinction between one form of a metal and another by emission spectrometric analysis. Similarly if Zn is an additive, Zn from brass or bronze is masked. If leaded gasoline is an engine's fuel, lead cannot be used to evaluate potential bearing wear.

New lubes should be tested for base data to avoid misinterpretation as to the source of a metal.

“Typical” Levels

Most motor oils will have Mg, Ca and/or Ba from 500-3500 ppm, dependent on the specification.* Lubes with high alkaline properties may have anywhere from 5000-8000 ppm Mg+Ca+Ba. Many industrial fluids have no metallic additives.

P and Zn are generally found from 600-1500 ppm. Automotive gasoline and several diesel engines usually require a minimum of 1000 ppm zinc dithiophosphate for valve train protection, as this is the area of highest “unit” loading in such systems.

*Automatic transmission fluids may have similar levels, however, not necessarily normal.

Defoamants

The most common defoamant in use is a silicon polymer. It is usually added at the ppm level, thus it is not unusual to see up to 12 ppm silicon in new lubes, although 7-8 ppm is a typical range. Testing the new lube is important, for additional silicon from the starting level will usually indicate abrasives (“dirt”).

Other Metals

Molybdenum (Mo), usually as a sulfide, is used as a friction reducer or EP agent in certain specialty lubes. Levels of nearly 1% (10,000 ppm) are not unusual. Boron tends to be found coexisting with Mg additives at up to 4% of the Mg value. Similarly, sodium may be found in the presence of Ca or Ba. There are exceptions to these guidelines.

Other References:

SAE Paper #740535
Heavy Duty Equipment Maintenance/Management
(June, July, August 1978)

NEUTRALIZATION NUMBERS

There are a variety of neutralization numbers utilized in the petroleum industry. This discussion is confined to the two most commonly used versions.

Total Acid Number (TAN)

Simply stated, TAN IS THE TOTAL AMOUNT OF ACID AND ACID-ACTING CONSTITUENTS FOUND IN THE LUBE. The term “acid” does not necessarily connote metal-corroding materials themselves. Many chemicals, including necessary lube additives, can have an acid number.

SIGNIFICANCE: Increases in TAN of used lubes from the starting point of the new lube (which may NOT necessarily be zero) usually indicate LUBE OXIDATION or CORROSIVE ACID CONTAMINATION.

“OXIDATION” is a general term used to describe the degradation of the basic lube product as a result of operating temperatures and/or churning with air. Generally, oil thickening is associated with oxidation. Organic acids are formed prior to and during thickening which can be detected by TAN increase. Oxidation of lube is not only significant from the standpoint of thickening, but the lubricating quality (lubricity) of the lube itself can also be reduced.

CORROSIVE ACID is formed primarily from sulfur blow-by products in the combustion process. Any amount of water contributes toward activating this acid to the point of parts corrosion. The formation of corrosive acids in engines is unavoidable, but alkaline (basic) materials are added to motor lubes to counteract the acid upon entry into the crankcase. Corrosive acid in non-engine systems is usually an environmental problem. One exception is the formation of corrosive hydrochloric acid in refrigeration systems, where freon deterioration may occur in the presence of moisture.

There are no “typical” TANs, but it is fairly unusual to observe one above 10.0 – an increase of 2-3 above starting point may be unacceptable. The change in TAN is the concept to monitor.

Total Base Number (TBN)

TBN IS THE AMOUNT OF ALKALINE MATERIAL (generally as corrosive acid neutralizers) IN THE LUBE, commonly referred to as ALKALINE RESERVE.

SIGNIFICANCE: TBN IS OF PRIMARY CONCERN IN MOTOR LUBES, as additives are placed in the lube when it is blended to neutralize corrosive sulfur acids formed in the crankcase in the normal process of combustion. Measurement of TBN allows one to know if the starting additive package is still capable of counteracting combustion acids. Therefore, TBN IS AN ESSENTIAL ELEMENT TO THE SAFE EVALUATION OF LUBE DRAIN INTERVALS.

Generally a new lube starts with the highest TBN it will exhibit. From that point TBN will tend to decrease as acids consume its alkaline properties. The addition of fresh make-up lube, however, helps forestall the decline in TBN, oftentimes allowing (all other factors being equal) extension of lube drains in properly maintained engines. This decline will naturally vary from unit to unit depending upon individual conditions.

Typical motor lubes have TBNs of 5-7. “Highly-compounded” oils may have TBNs of 12-15. Marine oils using high-sulfur fuel may have TBNs of 35-40, while upper cylinder lubricants in those same engines may exceed 70 TBN.

Note: TBN alone is not a relative indicator of lube quality, only its ability to neutralize corrosive acids. A higher TBN clearly demonstrates better capability to counteract acids but does not mean the higher TBN lube is better than, or even equal to, a lower TBN lube with respect to other important properties.

It should also be noted that most motor lubes can have both a TAN and TBN in the new and used state. If one regards these terms as two distinctly different properties, there is no difficulty in explaining their simultaneous presence. Ideally one would perform analyses for both terms in the inspection of motor lubes, but TBN is by far the more important property of the two for motor lubes. TAN is usually acceptable when TBN is sufficient.

TAN is almost exclusively used for non-engine systems because there is no combustion process taking place and because many non-alkaline lubes are in use in such systems, making the analysis for TBN pointless.

TAN also applies for large stationary 2-cycle gas engines using “mineral oil” type lube.

A WORD ABOUT pH – pH and TAN are oftentimes confused. The concepts are quite involved but, succinctly, pH is relative acid strength while TAN is total amount with no regard for strength. Weak acids, such as lube oxidation products, do not significantly affect pH.

Other References:

SAE paper #740535
Heavy Duty Equipment Maintenance/Management
(June, July, August 1978)

DRAIN INTERVAL EVALUATION

Today nearly every lubricant's user is concerned about costs and availability of product and disposal of used product.

The lube analysis consulting industry is ideally situated to evaluate drain intervals, enabling one to minimize lubes consumption but with reasonable safety, as opposed to arbitrary drain interval, which can lead to problems whose costs far exceed the lube's “savings.”

Monitor™ lab introduced the “HYBRID” concept in evaluating drain intervals. The principle of the “HYBRID” concept is to place the units to be evaluated on a drain interval analytical program, monitoring lube DEGRADATION, as opposed to only WEAR and CONTAMINATION.

Once the safe lube drain limit is determined, one can then abandon the drain interval analytical program, returning to the more economical wear/contamination. The purpose of this approach is twofold: 1) Arrive at a maximum SAFE drain interval ECONOMICALLY for a given lube, system type and application; 2) Monitor the unit to be certain no excessive contamination (and subsequent wear) develops within the system prior to lube change.

The “HYBRID” system presupposes that a uniform lube change interval will be adopted for a given class of units. It is important to understand that varying “SAFE” drain intervals are attainable dependent upon the equipment manufacturer. (For discussion purpose, use of a specific lube product will be assumed.)

If one has a “mixed” equipment set, be it engines, gears, hydraulics or other, one should consider each manufacturer separately. Generally at least half a dozen units of each manufacturer and application should be evaluated thoroughly prior to adopting a drain interval “across-the-board.” Naturally, the larger the test group used, the greater will be the confidence level of the drain interval projections.

The Ultimate Approach to Conservation

The concept of extending drain intervals to achieve optimum oil drain intervals is only viable using a fluid and unit condition monitoring program such as the Monitor™ Oil Analysis Kit (part number **CC2543**). By monitoring both the fluid condition and the unit's condition, it is possible to determine at what hour/mileage interval you can extend the oil life to without sacrificing life expectancy.

This determination can be made by monitoring the oil's TBN (Total Base Number or Reserve Alkalinity). Typical engine oil's TBN will start around 8.0 to 10.0. As the oil ages, the TBN decreases to a point where the oil no longer has the alkalinity to neutralize acids that form from the combustion process. Through testing you can determine how far to let the TBN drop before the wear metals start to increase.

The scattergram graph on the following page depicts the typical decline of the TBN as the hours/miles increase. Using the graph and monitoring and comparing the wear metals patterns of the engine will give the analyst the information needed to determine the “Optimum Oil Drain Interval.”

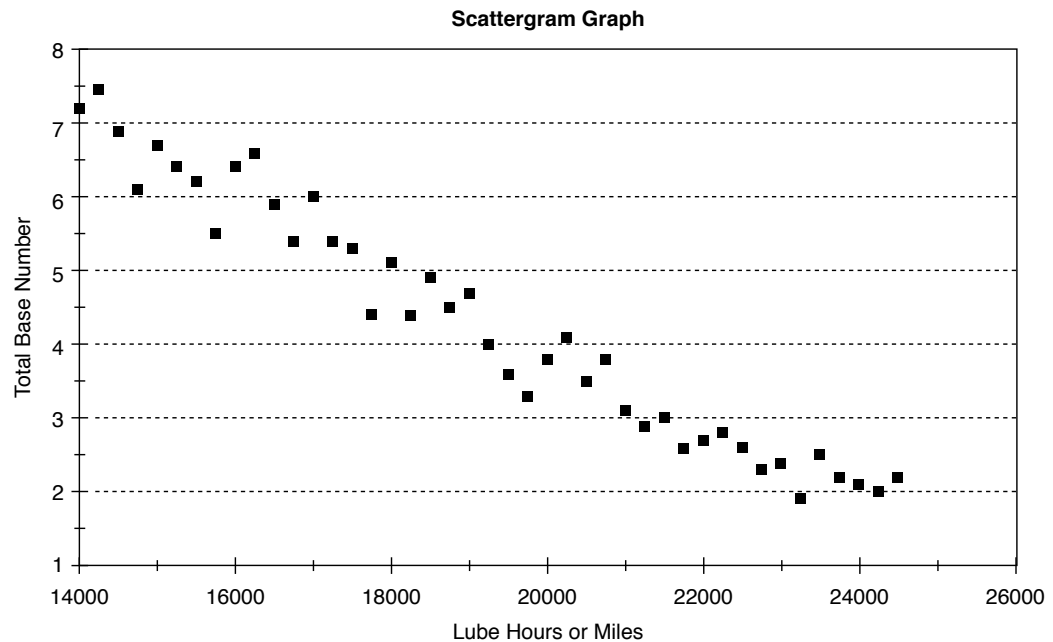
This determination could only be proved if every unit in the system were sampled (once again manufacturer and application may dictate a sub-system approach). Because scheduling of routine maintenance becomes far more complex when there is a variety of manufacturers and applications, some firms change lubes purely “on condition,” i.e., only when lab analysis suggests it. This situation would further require that every unit be regularly tested using a drain interval evaluation analytical package.

The minimum drain interval evaluation test recommended is:

SPECTRO METALS
FUEL CONTAMINATION (liquid-fueled recip only)
FUEL SOOT (LFRE)
WATER
VISCOSITY
NEUTRALIZATION NUMBER

If pure SYNTHETICS are in use, infrared analysis is also useful to detect standard petroleum product contamination of the synthetic.

Monitor™ Oil Analysis Kit (part number **CC2543**) includes these tests.



Technical Notes

Factors Influencing Drain Intervals*

1. LUBE CONSUMPTION: All other things being equal, the greater the lube consumption, the better the chances for extended drain. In effect, the lube is being renewed or “sweetened,” including beneficial additives.
2. LUBE QUALITY: Some lubes are simply more effective than others for particular applications, whether due to better base stock or to superior additives.
3. FUEL ECONOMY: Fuel economy is a direct indicator of how much acid, unburnt fuel, fuel dilution, soot and other contaminants are developed and placed into the oil. Most engine manufacturers have information that uses fuel economy to indicate what sort of duty cycle the engine is operating and therefore what potential there is for Oil Drain Interval extension.
4. DUTY CYCLE: Duty Cycle is a combination of a number of factors which basically indicates how hard the engine is working. The harder an engine works, or the more severe the duty cycle, the less opportunity there is for Oil Drain Extensions.
5. HEAT: Excessive temperature is an enemy of all lubes, promoting oxidation and other forms of lube degradation.
6. CONTAMINATION: Excessive contaminants will ultimately render a product ineffective as a lubricant. Type and degree of filtration can influence this area, depending on the nature and cause of the contamination.
7. EQUIPMENT USAGE: How a particular piece of equipment is used plays an important role in lube drain interval and affects all of the above parameters.

*This list excludes the situations where a unit has a serious mechanical problem.

Other References

SAE paper #740535
Heavy Duty Equipment Maintenance/Management
(June, July, August 1978)

PARTICLE COUNTING

“Particle Counting” is a term denoting the detection of a particulate matter in a fluid with respect to size range and quantity. There are a number of methods for particle counting. The earliest counts were centered around microscopy, wherein filter patch samples were prepared and then viewed under a microscope with a calibrated grid for sizing. A manual count within grids was then conducted. The process, while certainly useful, is nevertheless tedious and relatively slow by today’s standards.

Particle counting instrumentation includes techniques like light scattering, which is currently the most popular method for inspecting petroleum products. One instrument type causes a thin diameter flow through a sensor-monitored light path. Another utilizes a laser that is rotated to describe a one milliliter cylinder in a static sample in the path of the last beam and its sensor.

Particle counting is becoming a popular analytical method for particulate monitoring in non-opaque fluids. Some of the specific applications include:

- Automatic Transmissions
- Coolants
- Compressors
- Diesel Fuels
- Filter Evaluation
- Gas Reciprocating Engines
- Gas Turbines
- Hydraulics
- New Lube QC
- Refrigeration Systems

Note: IF A PRODUCT SAMPLE OF TWO INCH THICKNESS WILL NOT PASS LIGHT TO THE NAKED EYE TO ANY REASONABLE DETECTABLE SIGNIFICANCE, IT IS PROBABLY TOO OPAQUE TO YIELD A RELIABLE PARTICLE COUNT BY LIGHT SCATTERING METHODS.

The micrometer (also called “micron”) is the particle measurement standard unit. It is one-millionth of a meter. Results are usually expressed in particles per milliliter, or particles per 100 milliliters.

Commonly requested ranges:

A	B
Greater than 25 microns	5 to 10 microns
Greater than 15 microns	10 to 25 microns
Greater than 30 microns	25 to 50 microns
Greater than 50 microns	50 to 100 microns
	100+ microns

Note: 40 MICRONS IS THE THRESHOLD OF PARTICLE DETECTION IN THE AVERAGE NAKED EYE. IT IS DOUBTFUL WHETHER MEASUREMENT OF METALLIC PARTICLES ABOVE 100 MICRONS IS USEFUL, FOR THEY TEND TO SETTLE QUITE RAPIDLY DUE TO THEIR DENSITY, AND RELIABLE COUNTS ARE DIFFICULT TO ACHIEVE.

Sampling

There are some sophisticated techniques for taking lube samples for particle counting, but these techniques are almost impossible to achieve in a field environment. For field monitoring, therefore, we recommend VERY CONSISTENT observation of the standard sampling methods one would use for lube. The laboratory’s regular sampling jars are “reasonably clean” and are factory-capped to minimize contamination from the container.

Some Limitations of Particle Counting

1. As mentioned earlier, samples too opaque will simply not pass enough light to allow the sensor to react.
2. Water oftentimes is not differentiated from true particulates, particularly when the water is finely dispersed. Samples with known water, therefore, are normally not amenable to particle counting.
3. Samples which are too “dirty” tend to interfere with the ability of the sensor to properly discriminate. The result is unreliable data. Certainly it is always possible to dilute “dirty” samples with filtered solvent until a count is technically feasible, but extremely high dilution can lead to significant errors once the dilution factor is applied.
4. Particle counters do not care about the compositional nature of particles – only their size and quantity. Unless one is simply making counts for relative purposes, therefore, one will need other tests to help suggest the composition/source of the particulates.

Evaluation Particle Counts

While samples are not always representative, the following discussion is conducted on the premise one is evaluating reasonably good data.

Particle counts are best viewed on a relative basis just like the rest of the tests run on lubes for maintenance diagnostics. They should also be viewed in conjunction with other test data, again on a relative basis.

As an example, if wear metals rise with particle count, there is an obvious connection. The question might be, however, is the apparent wear FROM the particles, or do the particles simply REFLECT the increased wear metals? One way to answer this question is to watch the particles above 20 microns, which is beyond the threshold of most spectrometers to “see.” (The particles are too large to be completely ionized by the spectrometer’s excitation source, consequently only surface atoms are “seen.”)

If particles above 40 microns begin to increase significantly, but wear metals do not, component fatigue may be taking place, and a qualitative microscopic examination may help pinpoint the nature of the particulates generation. General increases in all ranges are the most typical patterns noted, but unnecessarily high levels (even though tolerable) may be avoidable by judicious filter changes. Certainly, as particulates increase regardless of initial cause, they will eventually contribute to wear, even if they are themselves wear particles.

Note: CARELESSNESS IN CHANGING LUBE AND FILTERS IS ONE OF THE VERY COMMON WAYS IN WHICH EXCESSIVE PARTICULATES ARE INTRODUCED INTO A SYSTEM. LUBE AND FILTER STORAGE FACILITIES ARE ALSO PRONE TO PARTICULATE PROBLEMS IF NOT PROPERLY MAINTAINED.

New Product

We have seen numerous instances where new lubes are, in fact, “dirtier” than used product. This phenomenon is apparently due to the effects of filtration equipment placed in the unit’s lube flow stream, removing particles from the new lube. In most cases this “dirtiness” in new lubes is more apparent in particle size about 20 microns, but it need not necessarily be confined to larger particles. The phenomenon simply emphasizes further the need to be diligent with respect to lube handling and storage cleanliness.

INFRARED ANALYSIS

Infrared (IR) analysis is one of numerous spectrometric techniques for analyzing the chemistry of materials (more familiar spectro techniques to the used lube analysis world are ATOMIC ABSORPTION or ATOMIC EMISSION spectrometric analysis). In all cases “spectrometric” analysis implies a measurement of very specific wavelengths* of light energy, either in terms of amount absorbed by the sample in question, or the amount given off (emitted) from the sample when suitably energized.

IR is an absorption form of spectrometric analysis. Unlike atomic emission or atomic absorption, IR is not concerned with specific elements (such as iron, copper, etc.) but, rather, with groupings of atoms in specific combinations to form what are often called “functional groups.” These various functional groups help determine a material’s properties or expected behavior, i.e., its chemistry, and most of these functional groups respond to infrared waves.

By knowing (through established research) which wavelengths are absorbed by each functional group of interest, one can cause the appropriate wavelength to be directed at the sample being analyzed, then measure the amount of energy (or “light”) absorbed by the sample. The more energy absorbed, the more of that particular functional group is existent in the sample. Results can therefore be numerically quantified. Not surprisingly, the units of measurement are usually expressed as “ABSORBANCE UNITS.”

*Wavelength, as used here, may be thought of in the same way as radio waves, wherein one “tunes in” a particular radio station by selecting a certain frequency, while simultaneously “tuning out” all the other competing frequencies (other stations).

How Does IR Apply to Lube Analysis Consulting?

While this notion is a definite distortion, it is probably useful for the layperson to treat infrared analysis as (primarily) the chemistry of:

CARBON HYDROGEN OXYGEN NITROGEN SULFUR

and the various combinations in which these elements configure or attach themselves, at least for most purposes that used lube analysis attempts to address.

By identifying and (hopefully) quantifying certain functional groups, one can derive highly dependable information about the lube (whether new or used) including, but not limited to:

1. Basic Physical Composition (Stock)

- a) Is it a mineral oil? If so, what kind?*
- b) Is it a synthetic lube? If so, what kind?
- c) Is it a mixture of mineral and synthetic? Most lubes consist of two major components: "BASE STOCK" and "ADDITIVE".

*As the term implies, base stock is the foundation from which the lubricant is built (by inserting additives), and it is possible many times to distinguish between differing base stocks with infrared for the purpose of quality control. This feature is particularly useful for assurance that a synthetic lube is not being inadvertently contaminated with mineral oil, thereby impairing the synthetic's beneficial properties.

2. Additive Chemistry

- a) Does it contain "additives"? If so, what type?*
- b) Are the additives yet effective?

*Although not a part of "routine" infrared inspection, an inspection for chemistry (additives) is not difficult, provided one is familiar with the product being analyzed. In a number of instances, the question of specific additive depletion can be answered.

3. Is the Lube Contaminated?

- a) with water?
- b) with glycol?
- c) with mineral oil (if a synthetic is in use)?
- d) with oxidation products?

IR is particularly useful for detecting oxidation products, from liquid to semi-solid state. Such products, of course, are detrimental to good lubrication, if present in significant quantity. It is also sensitive to coolants (water or glycol), although metallic coolant additives in the lube (through the well-known metallic "SPECTRO-ANALYSIS") are usually sufficient for this function, and generally preferable, as there is a higher degree of sensitivity when monitoring internal coolant leakage.

As mentioned earlier, IR is excellent for monitoring synthetic lube contamination. It would also be very applicable if, as an example, a manufacturing plant produced certain types of chemicals which were potential contaminant problems to the lube or machinery being lubricated, such that IR could detect chemicals' presence as they accumulated in the lube.

4. Is the Lube Degraded?

- a) from "oxidation" (undesirable inclusion of oxygen in the lube's molecular structure)?
- b) from "nitration" (undesirable inclusion of nitrogen in the lube's molecular structure, or formation of nitro compounds which degrade the lube)?

* These questions are difficult to answer at times, even with a new lube reference, unless one is familiar with the product in varying degrees of degradation.

Oxidation is developed from varying combinations of heat, air (which contains oxygen) and lube agitation (which promotes entrainment) and is characterized by lube thickening.

Whenever a lube thickens, oxidation is usually suspected, but while this is more often than not the case, it is not the only cause of lube thickening.

Nitration is a chemistry phenomenon similar to oxidation, but with nitrogen (found in even greater abundance than oxygen in air) as the offender along with oxygen. It, too, promotes lube thickening. Nitration is a particular problem where gas reciprocating engines are used, influenced by air/fuel ratio, as well as heat and agitation.

Once nitrates exist, there is also the potential for corrosive nitric acid to form, to go along with the problem of lube thickening. Therefore, IR is a highly useful tool for monitoring this potentiality and for making the distinction between oxidation and nitration when viscosity increases (comparison of acid # and viscosity is also useful).

Technical Notes

Brief Synopsis of IR For Routine Used Lube Analysis

Oxidation – Measurement of keto, carbonyl and carboxylic functional groups from base line (mineral lube only).

Nitration – Measurement of nitro type functional groups from base line.

IR Application Summary For Routine Used Lube Analysis

Extended Drains – IR is certainly useful in terms of investigating extended drains in any lube -wetted system, and its use should be strongly considered in that circumstance.

Gas Recip - In the analysis of lubes from reciprocating gas engines, from small fork lift size to pipeline transmission size, IR may well be a “necessary” test, in conjunction with other analyses.

HOW DO I INTERPRET THE DATA?

This question is frequently asked by customers. Normally one should not have to interpret test data as the laboratory provides this important function. The data are presented primarily to let the customer know which, if any, of the values triggered maintenance recommendations. These values are usually flagged. Following are some of the laboratory’s considerations.

Wear Metals

One of the least understood concepts to the layperson is “wear metals.” They are the first 11 metals listed on the report (and occasionally Zinc or Magnesium), and they simply represent the amount of each metal detected in the lube at sampling time, though NOT its chemical form. As an example, when iron is reported from the ICP spectrometer (the instrument used to detect and quantify metallic elements), it is not known if it is in an oxide form (rust, e.g.) or if it represents relatively recent erosion of an iron-containing part in the system.

Additive Metals (Magnesium, Calcium, Barium, Phosphorous, Zinc)

Within reason, the amount of each metal detected is irrelevant as long as the amount deposited in the lube remains at a constant, stable rate with respect to time or mileage on the lube from sample to sample, i.e. it is possible that metal quantities will climb the longer a lube remains in the crankcase/sump. Under extended drains, the values may become further magnified, but may still be indicating a “normal” wear rate pattern for that particular unit. It is WHEN THE WEAR RATE ESTABLISHED FOR A GIVEN UNIT INCREASES SIGNIFICANTLY THAT CORRECTIVE ACTION OR INSPECTION MAY BE ADVISABLE.

Each engine (or other machine) make exhibits particular tendencies. Some tend to show metal increases at a constant rate, others tend to stabilize after various time or mileage plateaus. There are numerous reasons why this is so, even between models of the same manufacturer, among them: LUBE CONSUMPTION RATE (probably the most significant), SUMP CAPACITY RELATIVE TO SURFACES LUBRICATED, STANDARD ORIGINAL EQUIPMENT FILTRATION, UNIT SUPERCHARGED OR NOT, BMEP RATING. Even identical units may show quite a variance from: AGE DIFFERENCE (lube consumption), SPECIAL AFTER-MARKET FILTRATION, APPLICATION, TYPE OF LUBE. DON'T ASSUME THAT A GIVEN UNIT MUST HAVE A PRE-DETERMINED THRESHOLD VALUE FOR WEAR METALS, EVEN FOR A SPECIFIC INTERVAL - LET ITS TREND SERVE AS AN INDICATOR.

Contaminant Metals (Silicon, Sodium)

These metals tend to remain fairly stable but can easily fluctuate +20% -20% as a normal circumstance. Drastic changes, or the elimination or emergence of an element that was or was not present prior, indicates the addition of make-up lube whose additives differ from the prime supplier's. It could also indicate (if the change remains) that one's supplier has changed formulation. Remember, it is possible for a wide variety and quantity of additives to be used to meet the SAME spec, and remember, too, the level of additives detected is not necessarily an indication of the useful life of such additives.

These metals CAN have pre-determined limits, once one has tested the NEW LUBE for initial base line data. Increases in silicon alone usually mean the entrance of abrasives ("dirt"). The effect, if any, is easily noted by observing the change in wear metals. An increase in all three contaminant metals, or Sodium and/or Potassium, may indicate coolant leakage (as these are elements from chemicals typically placed in coolants). Once again we must note the starting concentration of each metal in the NEW LUBE. If glycol antifreeze is in use, we can confirm its presence with a test.

Other Physical Contamination (Fuel, Soot, Water)

These products, when found in excess of their norms, usually indicate a need for corrective action as well as a lube drain. The exception is when solids build up over an extended drain interval, in which case they just show a need to drain lube and/or change filters. Here again, age of the unit, make-up lube rate, application, lube type and BMEP (Brake Mean Effective Pressure; applicable to recip engines) play a major role.

Lube Condition Indicators

Like wear metals, these values have tolerances. It is very important to have NEW LUBE base data on these parameters before attempting to diagnose changes and trends. The laboratory has a wealth of such data in its files. Such data have a habit of becoming obsolete over extended time periods, as oil companies find improved ways to meet particular specs and, thus, change their formulation for a product whose trade name remains the same. For this reason, one should periodically have the laboratory test incoming NEW LUBE batches, certainly not every time, but for example, every six months. If one is already on the program, it will probably tell you if and when this occurrence takes place. Change for the better is GOOD - not knowing about it could be confusing. "So now, why can't I start evaluating my own reports?" You can, and you will eventually become competent at it for your own operation, depending on individual background, BUT analyzing trends is a complicated process (and this approach is proprietary) and involves the interplay of ALL the test data, not just wear metals or contamination separately. That's why it is usually best to leave the primary interpretation to the laboratory. YOUR help is needed in providing a "current" evaluation of a troubled unit, for you may have information which can aid in pinpointing problems. This exchange, which occurs when data analysts contact you with a problem result, might be called a "follow-up" or secondary interpretation.

Advising the laboratory of action taken and FINDINGS is equally important to program success. In the first place, NO consulting firm of this type can be 100% right, but with RARE exception, an abnormal finding means a problem, even if not what initially suspected. Your feedback enables the approach to be altered in a positive manner, to improve precision, all of which ultimately benefits YOU.

Other References

SAE #740535
Heavy Duty Equipment Maintenance/Management
(June, July, August 1978)