Service Bulletin Number	Date
3810340-06	11-MAY-2007

Design Application	Market Application
All	All

Service Bulletin

Cummins® Engine Oil and Oil Analysis Recommendations

Introduction

This Service Bulletin outlines the proper application and maintenance of engine oil for Cummins® engines. The purpose of this Service Bulletin is to update and simplify Cummins Inc. recommendations and guidelines for the end user.

Cummins Inc. recommends the use of a high quality, diesel engine oil such as Valvoline Premium Blue® or Valvoline Premium Blue Extreme Life® or their equivalent, and high quality filters such as Fleetguard® or their equivalent.

Cummins Inc. bases oil drain recommendations on oil performance classifications and duty cycle. Maintaining the correct oil and filter change interval is a vital factor in preserving the integrity of an engine. Consult your Operation and Maintenance manual for detailed instructions on determining the oil change interval for your engine.

SECTION 1: DIESEL ENGINE OIL RECOMMENDATIONS

> CAUTION
>
> Use of CES 20081 oil in off-road engines operating on off-road fuel with higher sulfur content can result in severe engine damage if the applicable drain intervals and recommendations are not followed. See Table 3 for compatible fuel and oil combinations.

> CAUTION
>
> Failure to follow applicable drain intervals and recommendations in this Service Bulletin and the Operation and Maintenance Manual can result in severe engine damage that might not be covered under warranty.

Cummins Inc. has established a number of Cummins Engineering Standards (CES) which describe the performance levels of engine oils that **must** be used in various engines. In addition, Cummins Inc. works through the Engine Manufacturers Association (EMA) and with the many technical and marketing organizations responsible for lubricant quality around the world, to develop industry specifications that meet Cummins Inc. requirements. Table 1 lists the Cummins Engineering Standards and those North American and international performance classifications which most closely satisfy them.

Table 1: Cummins Engineering Standards (CES) for Lubricants:

CES	Application	North American Classification	International Classification[2]
20081	Heavy Duty and MidRange Engines with Exhaust Aftertreatment and 15 ppm Sulfur Diesel Fuel	API-4 CJ-4	
20078	Heavy Duty and MidRange Engines with EGR	API[1] CI-4	
20077	Premium Oil for Heavy Duty and High Horsepower Engines outside North America without EGR		See note 7
20076	Premium Oil for Heavy Duty and High Horsepower Engines without EGR in North America	See note 6	
20075	Minimum quality oil for MidRange engines without EGR in applications outside North America	API[1] CF-4/SG	ACEA[3] E-2 / E-3 JAMA [4] DH-1
20072	Standard oil for engines without EGR in all parts	API[1] CH-4	Global DHD-1[2]

	of the world		ACEA[3] E-5
20071	Standard oil for engines without EGR in all parts of the world	API[1] CH-4 API[1] CH-4/SJ	Global DHD-1[2]
	Categories **not** recommended [5] Do **NOT** Use	API[1] CA CB CC CD CE CG-4	ACEA[3] E-1

[1] American Petroleum Institute.

[2] Developed by EMA, ACEA, JAMA.

[3] ACEA = Association des Constructeurs European d' Association.

[4] JAMA = Japanese Automobile Manufacturers Association.

[5] Use of oils with **only** these designations poses an undue risk of engine damage for engines designed to use more advanced oils, even when drastically shortened oil change intervals are followed.

[6] CES 20076 adds the requirement of a 300 hour Cummins M11 test to API CH-4.

[7] CES 20077 Adds the requirement of a 300 hour test to ACEA E-5.

Engines with EGR and Aftertreatment

Engines using Exhaust Gas Recirculation (EGR) and Exhaust Aftertreatment must operate on Ultra-low Sulfur Diesel (15 ppm Sulfur). Use of oils meeting the requirements of CES-20081 will provide the longest maintenance intervals for the aftertreatment system. For drain interval and maintenance interval recommendations, consult the Operation and Maintenance Manual for the particular engine model and duty cycle.

Engines with EGR, but without Aftertreatment

Engines with Exhaust Gas Recirculation (EGR) can use lubricants meeting CES 20078 (API CI-4). For drain interval recommendations, consult the Operation and Maintenance Manual for the particular engine model and duty cycle. CES 20081 (API Cj-4) can be used when 15 ppm sulfur fuel is also used.

If oils meeting CES 20078 are **not** available, CES 20071, 20072, 20076 or 20077 can be used in EGR equipped engines at reduced drain intervals. Consult the Operation and Maintenance Manual for the particular engine model and duty cycle for the detailed recommendations.

Engines without EGR

Oils meeting CES 20078 (API CI-4) are compatible with CES 20071, 20072, 20075, 20076, or 20077, and can be used where those oils are recommended. Where they are available, oils meeting CES 20071, 20072, 20075, 20076 or 20077 can continue to be used in engines without EGR, as described in Table 1 above.

Outside North America, where oils meeting CES 20076 or CES 20077 might **not** be available, Cummins Inc. primary recommendation is for an oil meeting Global DHD-1, as jointly developed by EMA, ACEA, and JAMA.

The oil suppliers are responsible for the quality and performance of their products.

Cummins Inc. recommends engine oil with a normal ash content of 0.8 to 1.5 percent mass. Oils with higher ash contents, up to 1.85 percent mass, can be used in areas where the sulfur content of the fuel is over 0.5 percent mass. Limiting ash content is critical to prevention of valve and piston deposit formation. See to Fuels for Cummins® Engines, Bulletin Number 3379001, for more information regarding fuel sulfur content.

The values listed in the table below are guidelines **only**. The absolute value of these numbers will vary with the situation.

CES 20078 and CES 20081 Oil Compatibility with 500 PPM and 15 PPM Sulfur Fuel		
Fuel Type	Oil Type	
	CES 20078 (CI-4)	CES 20081 (CJ-4)
350 to 500 PPM Sulfur Fuel	Yes	No or reduced oil drain internal
15 PPM Sulfur Fuel	Yes	Yes

Minimum Requirements

For Heavy Duty engines (L, M, N, ISX and Signature) and high horsepower engines (QSK, QST series), API CF-4 oils can be used, but the drain interval **must** be reduced to 250 hours / 15,000 km (10,000 miles).

For mid range engines (B, ISB, C, and ISC series) oil meeting CES 20075 can be used, but the drain interval **must** be reduced to 250 hours / 15,000 km (10,000 miles).

Cummins Inc. Recommended SAE Oil Viscosity Grades

Cummins Inc. primary recommendation is for the use of 15W40 multigrade for normal operation at ambient temperatures above -15°C [5°F]. The use of multigrade oil reduces deposit formation, improves engine cranking in low temperature conditions, and increases engine durability by maintaining lubrication during high temperature operating conditions. Since multigrade oils have been shown to provide approximately 30 percent lower oil consumption, compared with monograde oils, it is important to use multigrade oils to be certain your engine will meet applicable emissions requirements. While the preferred viscosity grade is 15W-40, lower viscosity multigrades can be used in colder climates. See Figure 1: Recommended SAE Oil Viscosity Grades at Ambient Temperatures.

Oils meeting API CI-4 and CJ-4 and a 10W30 viscosity grade, **must** meet a minimum High Temperature / High Shear viscosity of 3.5 cSt., and ring wear / liner wear requirements of Cummins Inc. and Mack tests. Thus, they can by be used over a wider temperature range than 10W30 oils meeting older API performance classifications. As these oils will have directionally thinner oil films than 15W40 oils, top quality Fleetguard® filters **must** be used above 20°C [70°F]. Some oil suppliers might claim better fuel economy for these oils. Cummins Inc. can neither approve nor disapprove any product **not** manufactured by Cummins Inc. These claims are between the customer and the oil supplier. Obtain the oil supplier's commitment that the oil will give satisfactory performance in Cummins® engines, or do **not** use the oil.

WARNING

An SAE 10W30 designation on a product is a viscosity designation only. This designation alone does not imply that the product meets Cummins Inc. requirements. Only 10W30 oils with diesel performance credentials listed in table 1 can be used in Cummins® Engines if the reduced ambient temperature indicated in Figure 1 is observed. Only 10W30 oils meeting CES 20078 (API CI-4) and CES 20081 (API CJ-4) can be used in the ambient temperature range similar to 15W40 oils.

Figure 1: Recommended SAE Oil Viscosity Grades vs. Ambient Temperatures

Synthetic Oils

Use of “synthetic engine oils” (those made with API group 3 or group 4 base stocks) is permitted subject to the same performance and viscosity limitations of petroleum (mineral) based engine oils. The same oil change intervals **must** be applied to synthetic oils that are applied to petroleum (mineral) based engine oils.

Re-refined Oils

Re-refined lubricating oils can be used in Cummins® engines, if they have an API license signifying they have been tested and meet the minimum standards for that quality level. It is important to be certain these oils are actually re-refined and **not** just reclaimed. Re-refined oils have been treated to remove additives and wear debris, distilled, and refortified with additives.

Friction Modifiers

Do **not** use oils containing supplemental friction modifiers in Cummins® diesel engines unless the oil supplier can provide evidence of satisfactory performance in Cummins® engines. Obtain the oil supplier's commitment that they will make sure the oil is satisfactory, or do **not** use the product.

Break-in Oils

Special “break-in” oils are **not** recommended for use in new or rebuilt Cummins® engines. Use the same lubricating oil that will be used during normal engine operation.

Drain Intervals

Correct oil and filter change intervals **must** be maintained for each specific Cummins® engine model. A sharp increase in component wear and damage can occur if excessive drain intervals are followed. See the appropriate Operation and Maintenance manual to determine the appropriate drain interval for your engine and application.

Monograde Oils

Use of monograde oils can affect engine oil control. Shortened drain intervals might be required with monograde oils, as determined by close monitoring of the oil condition with scheduled oil sampling.

Non-Classified Oils

In some parts of the world, oils meeting current Global DHD-1 or API, ACEA, or JAMA classifications might **not** be available. Advice can be required when using non-classified oils. Oil suitability and service intervals can be determined by close monitoring of the oil condition with scheduled oil sampling.

SECTION 2: NATURAL GAS ENGINE OIL RECOMMENDATIONS

The use of quality engine oils combined with appropriate oil and filter change intervals are critical factors in maintaining engine performance and durability.

Cummins Inc. recommends the use of a high quality SAE 15W40 and SAE 40 engine oil for natural gas and propane engines. The specific performance category of oil recommended is a function of the design of the natural gas engine as outlined below.

Requirement for natural gas engines using High Pressure Direct Injection:

CES 20078 or CES 20076 (API CI-4 or API CH-4) in North America

CES 20077 (Global DHD-1 or ACEA E-5) outside North America

SAE 15W40 oil Viscosity.

Requirements for L10G* and QSK19G, K19G, G19, G38, G50, G28, G855, and G14 Series natural gas engines:

SAE 15W40 Viscosity

Less than 0.6 percent Sulfated Ash

TBN (ASTM D4739) -5.0 min

250 / 350 PPM Phosphorous

250 / 350 PPM Zinc

1200 PPM Calcium.

Requirements for B*, C*, G5.9, G8.3, L Gas Plus and ISL G Series natural gas engines:

CES 20074

SAE 15W40 Viscosity

Less than 0.6 percent Sulfated Ash

TBN (ASTM D4739) -5.0 min

600/800 PPM Phosphorous

600/850 PPM Zinc

1200 PPM Calcium.

Requirements for QSK45G, QSK60G, QSV81G, and QSV91G Series natural gas engines:

Use high quality SAE40 CNG engine oil such as Valvoline® GEO LA..

For a list of approved oils, contact Cummins Energy Solutions Business.

For oil analysis and oil change intervals, see the engine Operations and Maintenance Manual or contact your local distributor.

*A sulfated ash limit of 0.6 percent mass has been placed on all engine lubricating oils recommended for use in Cummins® B, C, and L10, natural gas engines. Higher ash oils can cause valve and/or piston damage, spark plug fouling, and lead to excessive oil consumption and degradation of the catalyst.

SECTION 3: FUNCTIONS OF ENGINE OIL

The following sections are provided for general information. If engine oil is to perform adequately, it **must** perform the following functions:

Lubrication

The primary function of the engine oil is to lubricate moving parts. The oil forms a hydrodynamic film between metal surfaces, preventing metal-to-metal contact and reducing friction. When the oil film is **not** sufficient to prevent metal-to-metal contact, the following occurs:

- Heat is generated through friction
- Local welding occurs
- Metal transfer results in scuffing or seizing.

Extreme Pressure Wear Control

Modern lubricants contain Extreme Pressure (EP) anti-wear additives. These additives form a chemically bonded molecular film on the metal surfaces at high pressures to prevent direct contact and wear when the load on the parts is high enough to eliminate the hydrodynamic oil film.

Cleaning

Oil acts as a cleaning agent in the engine by flushing contaminants from critical components. Sludge, varnish, and oxidation buildup on the pistons, rings, valve stems, and seals will lead to severe engine damage if **not** controlled by the oil. Oil formulated with the optimal additives will hold these contaminants in suspension until they are removed by the oil filtration system or during the course of an oil change.

Protection

Oil provides a protective barrier, isolating non-like metals to prevent corrosion. Corrosion, like wear, results in the removal of metal from engine parts. Corrosion works like a slow acting wear mechanism.

Cooling

Engines require the cooling of internal components that the primary cooling system can **not** provide. The lubricating oil provides an excellent heat transfer medium. Heat is transferred to the oil through contact with various components, which is then transferred to the primary cooling system at the oil cooler.

Sealing

Oil acts as a combustion seal filling the uneven surfaces of the cylinder liner, piston, valve stem, and other internal engine components.

Shock-Damping

The oil film between contacting surfaces provides cushioning and shock-damping. The damping effect is essential to highly loaded areas such as the bearings, pistons, connecting rods, and the gear train.

Hydraulic Action

Oil acts as a working hydraulic media within the engine. Examples of this are the use of oil to operate engine brakes and STC injector tappets.

Oil Additives

Lubricating oil is formulated with additives designed to combat specific contaminants (listed in Section 6) throughout its usable life. The additives used are more important to overall engine performance than the oil itself. Without additives, even the highest quality oil will **not** be able to satisfy engine requirements. Additives include:

1. Detergents or dispersants, which keep insoluble matter in suspension until the oil is changed. These suspended materials are **not** removed by the oil filtration system. Excessively long oil drain intervals result in deposit formation in the engine.
2. Inhibitors that maintain the stability of the oil, prevent acids from attacking metal surfaces, and prevent rust formation when the engine is **not** in operation.
3. Other lubricating oil additives assist the oil in lubricating highly loaded areas of the engine (such as valves and the injector train), prevent scuffing and seizing, control foaming, and prevent air retention in the oil.

Engine oil **must** be formulated in such a manner that it does **not** foam as a result of the mechanical agitation process associated with its many functions. Foamed oil results in engine damage similar to oil starvation, because of insufficient oil film protection.

SECTION 4: VISCOSITY

Viscosity is a measure of the resistance to flow offered when one layer of oil molecules move relative to an adjacent layer. This resistance comes from the friction generated by the oil molecules as they move past each other. This shearing action occurs constantly in the oil films lubricating all moving parts of an engine.

The viscosity characteristics of all fluids are affected by temperature. Multigrade oil viscosities tend to be less sensitive to temperature changes because of the addition of viscosity improvers in their formulation. The viscosity of multigrade oils is also a function of their rate of shear, or the relative speed of moving parts. The lower the relative speed, the greater the apparent viscosity of most multigrade oils.

Most of the wear an engine ordinarily experiences occurs at initial startup in some applications before oil has time to fully circulate. The correctly formulated multigrade oil is the ideal engine lubricant for a Cummins® engine. Relatively thin oil is available for rapid lubrication and easy cranking while starting.

Oil Viscosity and Engine Performance

The selection of oil of the correct viscosity is extremely important for optimum performance and for maximum engine life. If the oil is too viscous, engine drag is increased with the following effects:

Engine is difficult to start

Engine power output is reduced

Engine cooling is reduced

Internal wear is increased

Engine parts run hotter

Fuel consumption is increased.

If the oil viscosity is too low, the engine experiences:

Increased wear from metal-to-metal contact

Increased oil consumption and leakage

Increased engine noise.

Some oil suppliers might claim better fuel economy for the lower viscosity oils. Lower viscosity results in lower oil film thickness. Therefore, Cummins Inc. has required that all multi-viscosity 30 weight (xW30) oils registered under CES 20078 (API CI-4) **must** meet the minimum High Temperature / High Shear viscosity of 3.5 cSt. These can be used over a wider temperature range than other 10W30 or 5W30 oils. As these oils will have directionally thinner oil films than 15W40 oils, top quality Fleetguard® filters **must** be used above 20°C [70°F]. See Figure 1 for viscosity recommendations.

As Cummins Inc. can neither approve nor disapprove any product **not** manufactured by Cummins Inc., these claims are between the customer and the oil supplier. Obtain the oil supplier's commitment that the oil will give satisfactory performance in Cummins® engines, or do **not** use the oil.

Viscosity Recommendations

Cummins Inc. recommends the use of multigrade lubricating oils with viscosity grades shown in Figure 1 for the ambient temperatures indicated. **Only** the preferred oil grades are shown in the figure.

If monograde oils are substituted for multigrade oils in the areas where multigrades are **not** currently available, shortened drain intervals might be required, as determined by close monitoring of the oil condition with scheduled oil sampling. Use of monograde oils can affect engine oil control.

Section 5: Oil Performance Classification

Cummins Engineering Standards (CES)

Cummins Inc. has established a number of Cummins Engineering Standards (CES) which describe the performance levels that **must** be used in various engines. The CES documents are the primary definition of lubricant performance for Cummins® Engines. In addition, Cummins Inc. works through the Engine Manufacturer's Association (EMA) and with the many technical and marketing organizations responsible for lubricant quality around the world. Heavy Duty Engine Oil Recommended Guidelines in Global DHD-1 provide international users guidance in choosing oils in all parts of the world.

Table 1 in Section 1 lists the Cummins Engineering Standards that are applicable to all Cummins® engines and those North American and international performance classifications, which most closely satisfy them.

Supplemental Friction Modifiers and Other Additives

Addition of supplemental additives can alter the balance that the original formulator established in the fluid.

Cummins Inc. neither approves nor disapproves of any additives **not** manufactured or sold by Cummins Inc. or its subsidiaries. Engine failure or performance problems, which result from the use of such additives, are **not** warrantable by Cummins Inc.

Section 6: OIL CONTAMINATION

The engine oil **must** be changed just before it can no longer adequately perform its intended functions within an engine. Technically, oil does **not** wear out, but it does become contaminated. Additives deplete to the point that the oil and additive combination can no longer satisfactorily protect the engine. Progressive contamination of the oil between drain intervals is normal, and can vary as a function of engine operation and load factor.

Oil Contaminants

In normal diesel engine operation a wide variety of contaminants are introduced to the lubricating oil.

1. Combustion by-products:

   Exhaust gases (blowby gases) that leak past the piston rings, valve guides and turbocharger seals into the crankcase. These gases contain particles of carbon, water, acids, partially burned fuels, varnish, and lacquers. All of these particles contaminate the oil.

2. Acids, varnish, and sludge:

   As the lubricating oil comes in contact with hot engine components, or when heated oil comes in contact with entrapped air, oxidation and decomposition occur, creating contaminants such as acids, varnish, and sludge.

3. Abrasives or foreign material:

   These contaminants can enter the engine through the combustion air, fuel, worn engine parts, and inadequate service practices. They find their way to the crankcase with the combustion by-products.

4. Fuel or coolant:

   These contaminants are generally associated with engine malfunction. Fuel dilution, however, can also be caused by excessive engine idling or stop-and-go operation.

5. Soot:

This contaminant is caused by retarded injection timing and burning fuel mixing with oil on the cylinder liner(s). Excessive soot causes abnormal valve and injector train wear.

6. Environmental:

   The specific operating environment introduces other contaminants. Examples are dust and abrasives such as grit and road salt.

Section 7: OIL FILTRATION

Oil Filter Design, Use and Function

Maximum engine life is dependent on the correct use and maintenance of full flow, bypass, or combination lubricating oil filters that protect vital engine components from the abrasive contaminant, which are held in suspension in the lubricating oil. Cummins Inc. requires the use of full flow filters on all of its engine models. In addition, except for the B Series model, all turbocharged Cummins® engines **must** use bypass filtration, bypass filtration is strongly recommended for use on all naturally aspirated engines.

The full flow filter will remove contaminant particles of 30 microns and larger that are suspended in the engine oil. Particles of this size can cause immediate bearing damage.

The bypass filter (or filter section if using a combination filter) receives approximately ten percent of the total pump output and filters it to remove smaller particles, down to 10 microns, which the full flow filter does **not** capture. This maintains the oil contaminant concentration at a level low enough to prevent engine wear.

Cummins® engines are fitted at the factory with a quality Fleetguard® combination lubricating oil filter, which contains both a full flow and bypass filter in one filter can. Many of them are a Venturi® design which directs all of the oil flow to vital engine parts, instead or returning a portion of it to the pan. These filters provide the optimum balance of fine filtration for protection and rugged construction designed for long filter life.

Some Cummins® engines are being supplied with a Fleetguard Centriguard™ centrifugal filter using ConeStaC™ technology. These are the **only** centrifugal filters demonstrated in laboratory testing to surpass Fleetguard's stacked disk bypass filters. Any add-on filtration system **must** meet all applicable application guidelines.

Oil Filter Plugging

During normal engine operation, the engine oil becomes contaminated from combustion, as well as from wear debris and oxidation products. Engine oil filters do **not** plug during the normal oil drain interval as long as the engine oil remains suitable for use in an engine. A filter that plugs is performing its intended function of removing particulate matter and sludge from the oil. Filter plugging is the result, **not** the cause, of an engine or lubricating oil problem.

Causes of filter plugging **must** be investigated, as a plugged filter can indicate a serious engine problem that **must** be corrected. The most frequently observed causes of filter plugging are outlined below:

Excessive Oil Contamination

This occurs when the oil's limit for handling combustion contaminants is exceeded. Filters plugged in this way have a heavy buildup of organic sludge. This kind of contamination is caused by fuel soot, oxidation products, and products of combustion which have accumulated in the oil to the point that the filter is no longer able to function. Causes of this kind of plugging include excessive oil change intervals, poor maintenance practices, and high blow-by.

Impaired Dispersancy

This is caused by coolant leaks into the crankcase or a buildup of condensed moisture. This moisture impairs the operation of the oil's dispersant, so fuel soot and carbon cling together and dropout takes place. Coolant or moisture in the crankcase can also cause part of the oil's additive package to precipitate from the oil and plug the filter.

Gel or Emulsion Formation

This is a form of plugging caused when water or coolant contaminates oil. It often occurs when oil in a bulk storage tank contains a small amount of water, less than 0.5 percent. Filter plugging can take place rapidly after such oil has been added to the engine.

Cummins Inc developed engine tests, which are a part of the oil performance categories in Europe and North America, to measure an oil's ability to resist filter plugging. In addition, stacked-disk, multi-media filtration is specifically designed to control the organic sludge contamination and provide maximum filter life.

Section 8: OIL CHANGE INTERVALS

Factors Used to Determine Oil Drain Intervals

Cummins Inc. bases its oil drain specifications on duty cycle and oil contamination. This contamination occurs in all engines at varying rates, regardless of design.

Maintaining the correct oil and filter change interval is a vital factor in preserving the integrity of an engine. Filters **must** be changed when the oil is changed.

Oil contamination is the direct result of normal engine operation. The load factor, fuel used, and the environmental conditions all influence the rate of oil contamination. Laboratory and field tests confirm that a positive relationship occurs between the total amount of fuel consumed by an engine and the level of contamination it can absorb and still function as designed. Oil has limitations on the amount of contamination it can absorb and still function as designed. The relationship between fuel consumption and oil contamination forms a basis of establishing the oil change interval.

Acceptable methods for determining lubricating oil and filter change intervals include:

- Fixed Method (Mileage/Hours)
- Duty Cycle Method (Operating Conditions)

The appropriate Operation and Maintenance manual **must** be consulted for detailed instructions and specific tables or charts on oil and filter change intervals.

Centinel™ Continuous Oil Change

Cummins Inc. has developed the Centinel™ system for continuously replacing the used oil in the engine with fresh oil. This system uses a computer to monitor the engine's operation and maintains the condition of oil in the engine well within the acceptable range. Because this system keeps the oil so clean, filter change and oil drain intervals are greatly extended. Fleetguard™ ES oil filters are specifically designed with improved media and seals for this longer service and **must** be used with Centinel™. Contact a Cummins Inc. distributor to determine which Centinel™ system is best for your application.

NOTE: The use of Centinel™ or any type of oil blending is prohibited for engines with aftertreatment.

Section 9: USED OIL ANALYSIS

Oil Sample Collection

Oil sample collection intervals **must** be set in such a manner that trend comparisons can be made. Background data is required if oil analysis is to be utilized correctly. Such data **must** include:

- Engine model/serial number
- Miles/hours of oil use
- Miles/hours on engine since new or since rebuild
- Oil used (brand name, performance category and viscosity grade)
- Date sample was collected
- Engine application
- Amount of new oil added since previous oil change
- Any recent engine maintenance
- Analysis of new (unused) oil.

It is important to conduct oil analysis on new (unused) oil to establish a baseline. New (unused) oil analysis samples should be taken twice a year or each time the oil type is changed at a minimum. Samples should be taken from the bulk supply tanks to determine the makeup of the oil and also to confirm that no contaminants are being introduced by the storage system.

The sample to be used for analysis **must** be representative of the oil in the engine. Use the following guidelines when collecting oil samples:

- Bring the engine to operating temperature prior to sampling. This will make sure representative contaminant levels are in the sampled increment.
- Successive samples **must** be taken in the same manner and from the same location.
- Take the oil sample before adding any new oil to the engine.
- Always collect the oil in a clean, dry container.
- Collect a minimum of 118 ml [4-oz] of oil.

Two methods can be used to collect oil samples:

The recommended method for collecting an oil sample is to take the sample from a pressurized port while the engine is iding and warm. This method makes sure the oil sample is not stagnant and represents the actual homogeneous oil mixture that is flowing through the engine.

1. Clean the outside of the valve by wiping with a clean, dry cloth.
2. Idle the engine and bring to warm temperature.
3. Purge the sample fitting by allowing a small amount of oil to flow through the valve.
4. Collect the sample into a clean dry bottle from the oil stream being pumped by the engine.

NOTE: A recommended location for sampling is a port that allows pre-filtered oil to be collected. See the Operation and Maintenance Manual for component locations.

In cases where the engine is **not** operational an alternative method can be used. This method uses a vacuum to draw the sample out of the oil sump. The sample should be obtained as soon after stopping the engine as possible so the oil is still warm and stratification has **not** occurred.

1. Use the dipstick to determine the oil level in the pan.
2. Hold a new, clean piece of tubing against the dipstick and mark on the tube the location where the dipstick seats.
3. Cut the tubing so it reaches 25 to 50 mm (1 to 2 inches) below the oil level in the pan.
4. Insert the tubing into the dipstick tube so that the mark previously made on the tubing is aligned with the top of the opening for the dipstick tube.
5. Use a hand operated vacuum pump, to pump the sample into a clean dry bottle.

NOTE: Do not allow the tube to draw oil from the bottom of the oil pan because excess debris will be included and will cause an incorrect oil analysis. Do not reuse the sampling tube.

Contamination Check

Used oil analysis can be employed to monitor engine contaminant levels, which can provide evidence of system weakness or malfunction such as faulty air filtration, coolant leaks, fuel dilution, and wear metals that can suggest engine damage.

This technique requires the comparison of the used oil analysis data to that obtained from the oil in its new condition. The extent of the used oil degradation from the new condition provides the indicators needed to monitor the system. The primary oil characteristics that will function as warning signals are the level of contamination (fuel, soot, silicon, boron, sodium, potassium) and the oil's viscosity and flash point. General contamination check guidelines are listed in Table 2.

Table 2: Oil Contamination Guidelines

Property	Guideline
Viscosity change at 100°C (ASTM-D445)	±1 SAE Viscosity grade or 5 cSt from the new oil
Fuel Dilution	5 percent
Total base number (TBN) (ASTM D-4739)	2.5 number minimum or half new oil value or equal to total acid number (TAN)
Water content ASTM (D-95)	0.5 percent maximum
Potential Contaminants:	
Silicone (SI)	15 ppm increase over new oil
Sodium (Na)	20 ppm increase over new oil
Boron (B)	25 ppm increase over new oil
Potassium (K)	20 ppm increase over new oil

Soot (weight/percent)	MidRange B and C	All Other Engines
CES 20078 and 20081	3.0 percent	7.5 percent
CES 20076	3.0 percent	6.3 percent
CES 20072	3.0 percent	5.0 percent
CES 20075	1.5 percent	1.5 percent

The contamination guidelines presented above are guidelines **only**. This does **not** mean values that fall on the acceptable side of these guidelines can be interpreted as indicating the oil is suitable for further service.

The ASTM publishes testing methods in their `Annual Book of Standards'.

Elemental analysis can be made using several different techniques such as Atomic Emission Spectroscopy (AES), Atomic Absorption Spectroscopy (AAS), and Ion Coupled Plasma (ICP). These are **not** standard ASTM methods; however, most used oil analysis laboratories are capable of determining additive metal concentration by one of these methods. Sample results determined by the same laboratory using the same technique can be safely compared.

The guideline numbers presented above are representative of those which will be considered sufficient to justify investigation of the engine, maintenance practices, or operating procedure to identify the reason for the contaminant or oil property change. However, an engine **must not** be disassembled solely on the basis of oil analysis results. Along with further investigation, an oil change is also usually justified. The absolute values of the above items vary with miles or hours on the engine, engine oil capacity, and the engine oil consumption rate.

If there are any additional questions, which can **not** be answered from material in this bulletin, please contact your Cummins Inc. distributor or call 1-800-DIESELS.

APPENDIX A - Used Oil Analysis Applications

For the diesel engine operator, used oil analysis has two distinctly different applications:

1. Contamination Checks

Used oil analysis can monitor engine oil contaminant levels and provides evidence of dirt ingress, excessive fuel contamination (dilution), coolant leaks, excessive soot accumulation, and abnormal wear. General contamination check guidelines are listed in Table 2. These are **only** guidelines. This does **not** mean values that fall on the acceptable side of these guidelines can be interpreted as an indication that the oil is suitable for further use. Used oil analysis is **not** a sole criteria in determining oil and filter change intervals.

Elevated levels of silicon in the used oil indicate dirt contamination of the oil, usually caused by faulty intake filtration. At times, dirt contamination occurs through the oil side of the engine from contaminated engine oil. The used oil can also contain abnormal levels of copper and lead from bearing material wear, without extremely elevated levels of chromium and iron.

The percent fuel in the used engine oil determines excessive fuel contamination (dilution). This can also be reflected in a viscosity decrease of more than a SAE grade and significantly lowered flash point compared to new oil properties. The poor thermal stability of fuel results in oxidation of the fuel at oil pan temperatures. Subsequent accumulation of elevated levels of lead in the used oil can occur from the interaction of the deteriorated fuel with bearing and bushing material.

Coolant contamination is identified from abnormal levels of the corrosion inhibitor in the coolant leaking into the oil. This results in elevated levels of sodium, potassium, boron, and silicon in the used oil. Sodium and potassium contents will depend on which is used for the corrosion inhibitor. Additionally, glycol components from antifreeze can be present in the oil. Elevated levels of glycol components are **not** always present with coolant leaks because these components can react with certain additive components in the oil, become volatile, and boil off at sump temperatures. Deteriorated glycol, which forms at oil sump temperatures, reacts with bearing and bushing materials to form elevated levels of lead in the oil.

Excessive soot contamination of engine oil is identified as weight percent soot, and is measured by thermogravimetric or infrared analysis. Soot is captured in the oil and harmlessly suspended until active additive components become depleted. It then agglomerates into larger particles. Valve and injector train wear occurs at an accelerated rate, resulting in an increased soot generation rate and further accelerated wear. Valve and injector train wear result in elevated levels of iron in the used oil. Unresolved, excessive soot accumulation and wear create sludge in the engine. Newer oil formulations meeting CES-20081, CES 20078, and CES 20076 (API CJ-4 , CI—4 and CH-4+) have been formulated to safely suspend more soot than older oil formulations. Therefore, the guideline for soot has been increased to 5.0 weight percent.

Abnormal wear causes abnormal accumulation of wear metals in the used oil. Condemnation limits are **not** possible except for engines in an application operating at one site on a single engine oil. The wear metal content of an oil sample depends on the engine, the load factor, the capacity of the lubricating system, the miles or hours on the oil, the engine oil consumption rate and so on. Engines with large oil capacities result in lower wear metal levels than engines with smaller oil capacities because the particles are suspended in a larger volume of oil. Low oil consumption engines exhibit higher wear metal levels than high oil consumption engines because of the absence of dilution by new oil between oil changes. Engine oil consumption rate can change the wear metal content of the used oil by a factor of two and mask doubling wear rates which can indicate engine damage. Wear rates are unknown unless the engine oil consumption is known. Wear metal levels vary nearly linearly with the miles or hours on an oil sample. Doubling the miles or hours on an oil sample nearly doubles the wear metal content of a used oil sample. Wear metal content of a used oil sample is almost meaningless information without the engine oil consumption rate, the miles or hours on the oil sample, and a new oil analysis.

Abnormal wear, which can indicate a problem, usually **only** involves elevated levels of one or two metals. Detection of elevated levels of a wear metal is best performed by comparing the levels in the used oil sample to the levels in previous oil samples from the same engine. Engine components containing copper and lead can become chemically active with a change in the additive chemicals in the oil that is often accompanied by switching to a different brand of oil. This often results in dramatically increased levels, often ten times, of copper or lead in used oil. Increased levels from this source is **not** reason for excessive concern. These components will become passive after a few oil changes with different oil. Wear metal levels will then slowly decline back into the normal range for the engine.

Never disassemble an engine based solely on used oil analysis. Perform additional troubleshooting to determine if a problem exists. If a problem is suspected based on oil analysis, cut open the full flow oil filter and look for wear metal particles that are trapped by the filter and easily visible.

2. Evaluating Operating and Maintenance Intervals

Cummins Inc. does **not** recommend that oil analysis be used to determine maintenance intervals. Oil analysis **only** permits maintenance intervals to be estimated. Engines **must** be operated at the estimated interval for 800,000 to 1,100,000 km [500,00 to 700,000 mi] or 10,000 to 15,000 hours to determine if the estimated maintenance interval based on oil analysis was correct. If the interval is estimated correctly, the engine will remain in an acceptable condition for its operating environment. If an extended maintenance interval is guessed incorrectly, up to 50 percent of the potential engine life to rebuild can be sacrificed for the longer maintenance interval.

The use of oil analysis to estimate maintenance intervals is complicated, time consuming, and expensive. It can cost up to several hundred dollars an engine to create baseline data from which maintenance intervals are derived. This is because of the need to analyze samples by more detailed and expensive analytical procedures than that required for contamination monitoring. Record keeping on oil consumption is required during the baseline period because oil consumption data is necessary to convert the ppm of metals in the used oil into wear rates. Often oil consumption rates increase by two to four times toward the end of a long maintenance interval.

For example, an engine with 3220 km [2,000 mi] per quart oil consumption during the first 8050 km [5,000 mi] of an interval can consume oil at 805 km [500 mi] per quart with 32,200 km [20,000 mi] on the oil. Slow accumulation of wear metals can reflect increased oil consumption, **not** low wear rates because of dilution by more new oil. Low wear rates on engines operating toward the end of the maintenance interval are required to prevent a large loss in engine life to overhaul.

Many used oil testing procedures have been developed from quality control tests for new engine oil. In new engine oil, these tests reflect chemically active additives in the oil. They make sure that each time the oil is blended it contains the correct amount of additives. When these test procedures are applied to contaminated and deteriorated used oil, the data will **not** be meaningful. Additives take a different chemical form in used oil.

Commercially available oil testing techniques do **not** measure depletion of all the chemical additives in the oil, or determine when these additives stop protecting engine parts from wear and deposits. Low wear metal levels in used oil samples can reflect high oil consumption rates and dilution with new oil added to replace that consumed. Low wear metal levels in used oil samples can also reflect additional contamination and wear debris. Engine oil operated beyond this saturation point often drops contamination and wear debris out as sludge. This results in declining wear metal levels at increasing kilometers [miles] or hours on the oil. This does **not** mean that wear rates are decreasing and oil condition is improving. It means that oil analysis becomes meaningless after the engine oil is excessively contaminated.