Diesel Engine Lubrication Systems

The movement of various engine parts under high speed and load conditions creates the requirement for an engine lubrication system. Without some lubricant, friction between parts would quickly wear and generate heat causing severe engine damage and eventually seizure. A number of other lubrication system functions, while not obvious, are critical to good engine operation and durability. Lubrication systems in a diesel engine accomplish the following tasks:

1. Reduce friction between moving parts, which minimizes engine wear, and the creation of heat.
2. Cools a variety of internal engine parts and removes some heat from the engine.
3. Removes dirt, abrasives and contaminants from inside the engine.
4. Assists sealing of the combustion chamber by forming a film between the piston rings and the cylinder wall.
5. Absorbs shock loads between bearings and gears thus, cushioning and protecting engine parts while minimizing engine noise production.
6. Stores an adequate supply of oil for lubricating internal engine parts.
7. Minimizes corrosion of internal engine components
How the lubrication system accomplishes some of the above tasks is a function of a number of lubrication system components.

- Engine oil
- Oil pump
- Oil pan
- Oil cooler
- Oil filter(s)
- Pressure regulating and relief valves
- Oil level dipstick

**Engine oil**
Of all the components of a lubrication system, engine oil is the most critical given the functions it accomplishes. Lubricating oil is primarily a product of petroleum, commonly called mineral oil. Mineral oils will contain a variety of different hydrocarbon molecules that have different sizes, shapes and lubricating qualities. This means they will perform and respond differently to heat, pressure and other engine operating factors.

Given the variations of potentially different oil characteristics and qualities, the American Petroleum Institute (API) has developed specifications to define what engine oil performance standards are. Two distinct classifications of oils are recognized by API performance specifications. **S-series oils** are designed to meet performance standards for spark ignition systems while **C-series oils** meet compression ignition engine performance requirements.

These API standards have progressively evolved since first conceived during the 1940’s to meet advances to engine technology and engine manufacturers’ performance requirements. Today’s oils are a highly refined petroleum product with a package of chemicals called additives to permit lubricating oil to meet engine operational requirements.
The **API service symbol**

The API service symbol designates the performance standards oil meets according API specifications. Engine oil carrying the API designations must be certified after specialized testing to determine whether they meet minimum API standards. Oils meeting minimum API criteria are permitted to carry the API service symbol. The donut symbol is divided into three parts:

The top half designates the oil's performance standard.

The center identifies the oil's viscosity which is a standard defined by the Society of Automotive Engineers (SAE). Viscosity is a measure of an oil's flow characteristics, or thickness.

The bottom half indicates whether the oil has demonstrated energy-conserving properties in a standard test in comparison to reference oil. Widespread use of energy conserving oils is expected to result in improved fuel economy in the vehicle fleet. However, a particular vehicle or operator may not always have fuel savings when using these oils. The use of friction reducing additives such as graphite, molybdenum disulfide, or other suspended materials provide energy saving enhancements to the oils.

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1. **Performance Level:**
   - **Gasoline engine oil categories** (for cars, vans, and light trucks with gasoline engines): Oils designed for gasoline-engine service fall under API's “S” (Service) categories. Look for current service categories SL and SJ. See reverse for descriptions of current and obsolete API service categories.
   - **Diesel engine oil categories** (for heavy-duty trucks and vehicles with diesel engines): Oils designed for diesel-engine service fall under API’s “C” (Commercial) categories. Look for current categories CI-4, CH-4, CG-4, CF-4, CF-2, and CF.

2. **Viscosity:** The measure of an oil’s thickness and ability to flow at certain temperatures.

3. **Fuel Economy Rating:** The “Energy Conserving” rating applies to oils intended for gasoline-engine cars, vans, and light trucks. Widespread use of “Energy Conserving” oils may result in an overall savings of fuel in the vehicle fleet as a whole.

4. **API Certification Mark:** An oil displaying this mark meets the current engine protection standard and fuel economy requirements of the International Lubricant Standardization and Approval Committee (ILSAC), a joint effort of U.S. and Japanese automobile manufacturers. Most automobile manufacturers recommend oils that carry the API Certification Mark.
The API certification symbol
The API certification mark or starburst symbol identifies an engine oil as recommended for a specific application such as diesel or gasoline service. Oil qualifies to display the starburst symbol only if it meets the most current requirements for minimum performance standards and is licensed by the API. Currently diesel engine oils meeting the API CI-4 standard are permitted to carry this symbol. CI-4 was developed for 2002 model year for engines using exhaust gas recirculation (EGR). The PLUS suffix (CI-4PLUS) indicates a diesel engine oil with energy conserving properties. Another change to performance specifications is expected for 2007 model year diesels. Tentatively designated PC-10, this 2007 oil is formulated for diesel engine applications burning ultra-low-sulphur diesel fuel (ULSD) and using exhaust after-treatment devices such as N0x adsorbers, and catalyzed particulate traps.

Global oil standards
Global DHD-1, introduced in 2001, is a performance specification for engine oils used in high-speed, four stroke-cycle heavy-duty diesel engines designed to meet 1998 and newer exhaust. Japanese and European manufacturer associations have develop specifications for this global oil. DHD-2 is expected to be implemented for 2005 model year engines.

Oil Viscosity
Oil viscosity is a performance criteria defined by the society of automotive engineers and not the API. Until API standards were first developed in 1947, viscosity was the only way oil was rated. The term viscosity refers to a liquids resistance to flow. A numerical designation indicates whether oil flows easily or slowly. For example, engine oils having a viscosity with low numbers such as 0, 5 or 10 flow easier than viscosities of 20, 30 or 50. In other words, the higher the number the thicker the viscosity.

Oil gets thinner and its viscosity decreases when hot. Likewise, oil thickens and the viscosity increases as its temperature decreases. Oil viscosity measured at 0F (-18C) are given a W for a suffix which is short form for winter viscosity rating. Oils tested at 212F (100C) are referred to as a hot or summer viscosity and no letter accompanies the viscosity grade. Oils with a single number are called a straight grade or single grade.

Multi-weight oils
Oils with two numbers (i.e.15w-40) have their viscosity measured under both hot and cold conditions. Referred to as multi-grade or multi-weight viscosity oils, these oils are a blend of a several different oils with different viscosities. The numbers provide viscosity
information about the oils performance under a wide range of operating conditions. The low-temperature viscosity (the first number, 15W in 15W-40 oil) helps predict how well an engine might crank in cold temperatures when resistance to cranking is high due to thick oil. Generally, the lower number means the engine will start easier in cold weather. In addition, the low temperature or winter number indicates how well the oil will flow to lubricate critical engine parts at cold temperatures.

The high-temperature viscosity (the second number, 40 in a 15W-40 oil) provides information about the oils thickness or body, for good lubrication and load bearing characteristics at normal engine operating temperatures. Multi-grade oils main advantage is improved cold starting characteristics with less engine drag.

**Viscosity change and VI improver**

Looking at the viscosity numbers of multi-grade oil, 15w-40 for example, it appears that the oil is thicker when hot and thinner when cold. However, this grade of oil is still thicker when cold than when hot, because a cold 15w weight is still thicker than a hot 40 weight. However, another feature is built into multi-weight oils to control viscosity change. Since oil is made of a variety of hydrocarbon molecules, some light and thin while others are thick and tar like, changes to viscosity with temperature can occur more dramatically with some oils in comparison to others. To measure this change, the viscosity index (VI) of oil refers to the change in oil viscosity with temperature. Oil with a high viscosity index will change viscosity faster than oil with a low viscosity index. It is not desirable to use oil with a high VI since it will thicken and thin too much with temperature giving uneven lubrication performance. To control the VI properties of lubrication oil another ingredient is added to oil called viscosity index improver. The viscosity improver is a special hydrocarbon polymer or, more simply, a chain of atoms.

The unique property of the VI polymer molecule is when cold, it coils into a ball like shape. When heated, the polymer molecule stretches into a long rod. When added to oil, VI will counteract the tendency of oil to thin when hot and thicken when cold. In other words, viscosity index improver causes the oil to thicken when hot and thin when cold. This also helps to explains why multi-weight oil has a lower viscosity grade when cold than when hot.

Eventually VI additives wear out as the polymer chains are broken through shearing. It may be observed that some engines will start to use more oil at about 15,000 miles (24,140kms). Increased oil consumptions is due to the thinning of the oil caused by viscosity improver additive shearing and wearing out.
**Synthetic oils**

Synthetic-base lubricants have been used in aviation and special-purpose engines since the late 1970's. Most lubrication oils referred to as synthetic are at least partly derived from mineral oil. Out of the four major classes of synthetic oil base stocks, two are 100-percent petroleum based, one is approximately 75-percent derived from a petroleum base and the fourth uses petroleum molecules for ten to thirty-percent of its formulation. The differences between conventional and synthetic lubrication oils is in the additives and refining process used to select the molecular composition of the oil. During refining of conventional engine oil, the molecular structure of oil is not changed. However, for synthetic oils, molecules of oil are carefully selected and formed into polymers. These molecules can originate from a variety of sources other than petroleum. The lubrication characteristics of the can be adjusted by changing the composition of these chains of molecules. Generally, the molecules are selected to make oil slipperier or having a smaller coefficient of friction.

Chemical additives are blended with the synthetic oil base stock, similar to the process of making conventional oils. However, synthetic oils usually have more additives than conventional oils. No API or SAE standards exist yet for defining what synthetic oil is but they do need to meet minimum API and SAE criteria if they carry the API symbols.

![Image](image.jpg)

**Benefits**

Manufacturers claim the following benefits for synthetic oils:

- Improved low temperature viscosities. Conventional oils tend to include wax molecules that thicken oil at lower temperatures. For example, typical synthetic 15W-40 oil remains liquid at -50C
• Improved high temperature performance. Synthetic oils have few light or thin hydrocarbon molecules which tend to evaporate at high temperatures.

• Resistance to chemical break-down, oxidation, coking and deposit formation.

• Decreased oil consumption due to less evaporation and resistance to deposit formation.

• Fewer chemical impurities

• Reduced friction and engine wear because of a lower coefficient of friction.

• Improved fuel consumption, through better engine lubrication.

• Longer intervals between oil changes due to higher resistance to oxidation.

**Disadvantages of synthetics**

The primary disadvantage of synthetic oils is that they cost significantly more than mineral oils. However, synthetic oil manufacturers suggest this problem is offset by a long service life and improved performance. Another problem with synthetics is they are liquidier thus, more likely to leak or weep through worn seals and lose gaskets. This explains why it is observed that when changing over to synthetic oil after using conventional engine oils, more engine oil leaks are observed.

Synthetics best application is in extreme operating conditions such as heat and cold. Equipment with high initial cost and long chassis life such as farming and off-road machinery can also benefit from the extended engine longevity that can result from using synthetics. In other words, synthetics would protect investments of $100K or more better over the 20 and 30-year equipment life. The other advantageous application for synthetic oils are only likely to be relevant in high performance applications such as motor racing and aviation or for general lubrication in extreme environments.

**Limiting factors to engine oil life**

Today’s diesel engine technology requires lubrication oils to meet a variety of operating conditions and provide for long service intervals. To understand what additives are needed to provide acceptable service, and when oil should be changed, it is helpful to consider what are the main factors that can limit oil life.

**The percentage of solids**

The percentage of solids refers to the total amount of particles that are suspended in the oil. Combustion soot, dirt, and oxidized oil are typically the major solids found in oil. The percentage of solids becomes a limiting factor to oil life when the particles interfere
with lubricating abilities of the oil. Engine manufacturers suggest an oil change to remove dissolved solids should occur before they rise above 5% by weight. However, improvements in wear reduction are best achieved if the solids are kept below 2%.

Detergents are added to the oil to prevent the solids from clumping and forming damaging deposits inside the engine. Like hand cleaner, these detergents surround the particles and suspend them in the oil until it is drained or, the filter removes the particles. It is normal for high detergent oil to appear dirty after a short time. Just like dishwashing soap will clean dishes and keeps dirt suspended in the water, so oil detergent additives will hold solids in suspension. Chemical dispersants are also added with detergent to oil to keep these particles in suspension throughout the oil to avoid clumping, plugging and sludging in engine passageways. Since combustion formed soot will stick to combustion chamber walls and scrape into the oil pan by the piston rings, high detergent-dispersant oils are required on EGR equipped engines to hold more of the soot produced from the use of EGR and retarded injection timing. . Better filtration of oil will remove more solids.
Synthetic oils will require change intervals just like conventional oils if the percentage of solids is the limiting factor to engine oil life.

**Sulphur and combustion acids**

Sulphur acids are present in engine oil because there is sulphur in the diesel fuel and corrosive acids produced using recirculated exhaust gas in the cylinders. Since sulphur combines with water produced during combustion, highly corrosive acids are formed in the oil. To counteract this condition, oil manufacturers add alkali or base substances to the oil to neutralize the effect of sulphuric acids. This property distinguishes oils used in spark ignition engines from compression ignition engines. The total base number (TBN) is the measure of engine oils acid neutralizing ability. Diesel engines will use a TBN of between 6 and 10 points. When the TBN is below half its new value, the engine oil should be changed.

**Oxidized oil**

Oil is oxidized when it is exposed to air and the oxygen joins the oil. Conventional oils generally turn brown during if highly oxidized. This process occurs more rapidly at high temperatures. The problem with oxidation is oil loses some of its lubricating properties as it oxidizes thus, causing accelerated engine wear. Synthetic oils are at an advantage since synthetic oils do not oxidize as fast as conventional oils. This means if oil oxidation due to high engine operating temperatures is the limiting factor on lube oil life, the use of synthetic oil could extend the oil change interval.

**Other limiting factors**

Engine problems such as liner o-ring and head gasket leaks sending coolant into the oil require oil change after a repair. Defective air filter which permit dirt to enter the engine, fuel leaking into the oil, wrong fuel (i.e. gasoline contamination of diesel fuel) water in the oil, or a mechanical failure producing internal debris are all are circumstances require an oil change subsequent to engine repair. Many engines have experienced catastrophic failures subsequent to seemingly minor repair shortly after returning to service when the oil has not been changed.

Oil that has turned milky white or grey usually has coolant leaking into it. Minor internal coolant leaks are not easily detected and an oil sample should be obtained for analysis. Conventional antifreeze will leaks will show-up on a oil analysis as having high silicate levels in the oil. Fuel contamination of oil can often be detected by simply smelling the fuel in the oil or performing an oil analysis.

**Oil pan**

The function of the oil pan is to store an adequate supply of oil for the lubrication system. While more than enough oil is available in the oil pan to supply the lubrication requirements of the engine, excess oil is needed to distribute contaminant loading, and compensate for oil consumption. The location of the oil pan provides some cooling of engine oil which normally is at temperatures above coolant operating temperature.
The sump is the deepest part of the oil pan where the oil pump pick-up tube is located. Depending on the chassis configuration, the sump may be located at the rear, front or middle of the engine to accommodate suspension of frame component clearances.

A windage tray may also be incorporated into the oil pan. Windage trays separate the crankcase from the oil pan reservoir to prevent the crankshaft from whipping engine oil stored in the pan. The primary advantage of the tray is it increases fuel economy by as much as two or three percent. Additionally, the tray prevents drivability complaints such as engine thumping and stumbling during cornering or braking when oil can surge up into the crankcase.

**Oil pumps**

Oil pumps are used to pressurize the lubrication system of a diesel engine. Pumps are positive displacement type, usually a closed gear or gerotor design. The lube is supplied under pressure to moving parts through drilled passageways in the engine called oil galleries. Most moving parts are supplied pressurized oil for lubrication. However, cylinder walls are lubricated by splash lubrication from oil thrown-off engine bearings.

Oil is drawn into the pump through a pick-up tube and screen located in the oil pan sump. When replacing oil pumps, they should be primed to shorten the time required to develop engine oil pressure. Wear in an oil pump is often evaluated by measuring clearances between gears or pump bodies using feeler blades.

**Oil coolers**

Oil coolers are heat exchangers used to remove excess heat from engine oil. Virtually all diesel engines use oil coolers since cooling of pistons and other internal engine parts is
performed using lubrication oil. Engine oil can easily become overheated while absorbing heat from internal parts and turbochargers. Piston cooling by lubrication oil is a point where engine oil picks-up considerable heat. Nozzles or drilled passageways in the connecting rods direct oil to the underside of the piston crown to prevent piston crown heat damage and ring seizure. Engine oil should never exceed 250F (139C). Many electronic engines use oil temperature sensors to shut-down or de-rate engine power if oil temperatures exceed 250 - 260F (139 - 143C). Normal engine oil temperature is usually maintained at 30 - 40F (16 - 22C) above the temperature of the coolant. This means an engine operating between 190 – 205 F will have an oil temperature of 220 F – 245 F (122 - 136C).
Often a cooler has a thermostatically controlled inlet that will not allow oil to flow through it until the engine is to operating temperature. This helps hasten the warm-up of engine oil.

The cooler may also be equipped with a pressure relief valve allowing oil to bypass the cooler if it becomes plugged. The bypass valve will open if a substantial pressure drop occurs across the cooler.

Engine coolant will remove heat from and oil cooler. Plate and tube type oil coolers are the most commonly used. Defective coolers or poor maintenance of the cooling system can lead to cooler corrosion causing oil to enter the engine coolant. A suspected leaking cooler can be removed from the engine and pressurized with air to check for leaks.

**Oil viscosity valve**

Some engines may be equipped with a viscosity valve that allows oil to bypass the oil cooler if oil pressure is too high, regardless of oil temperature. The idea of the valve is that cold, highly viscous, will cause higher lubrication system pressures. The raised oil pressure pushes back a spring in the valve, opening a bypass passageway, permitting oil to flow past the cooler.

As the oil temperature rises and the viscosity drops, the oil pressure simultaneously drops. This allows the bypass valve spring to close forcing more oil through the cooler. The result is engine oil temperature rises while viscosity falls.

**Pressure regulating and pressure relief valves**

Since the oil pump can produce more oil flow than the engine can use, an oil pressure-regulating valve is used to control oil pressure. Oil pressure that is too high can blow gaskets on the spin-on oil filter and swell the oil filter into a pumpkin. Excessively high oil pressure can also lead to engine bearing erosion. Keeping the oil pressure regulated to between 20 and 40-psi when the engine oil is warm can reduce parasitic power loss caused from regulating higher oil pressure. The oil pressure-regulating valve is usually located in the main oil gallery or at the outlet of an oil pump. Using a conventional spring-loaded bypass valve arrangement permits maximum oil pressure control by the valve. When oil pressure reaches a value equal to spring tension of a pressure-regulating valve, spring pressure is overcome by oil pressure moving a spool valve to a bypass position. Oil will return to the sump in quantities proportional to the excess volume produced by the oil pump. As long as clearances between engine bearings and other components using oil remain close, adequate oil pressure is maintained by the oil pump and pressure regulating valve. If an engine has excessive wear, or internal oil leaks, oil pressure will drop.

In the event the pressure-regulating valve cannot relieve oil pressure fast enough such as when the oil is cold and thick or the regulator is not properly working, a pressure relief valve is connected in series with the pressure regulator. This valve will open at typically 100 psi and return oil to the sump.
Above: Engine oil lubrications systems will have a minimum of a pressure regulating valve and a high pressure relief valve.

Below: Engines with thermostatic bypass of oil coolers allow oil to bypass the cooler until the oil warms-up. This improves the warm-up speed of the oil and engine efficiency (Minimizes drag and negative effects of high oil viscosity).
The regulator spool valve is held on its seat by spring pressure. Oil from the signal line flows through the viscosity sensor into the chamber above the spool valve and then exits through the balance orifice. Since the balance orifice is smaller than the orifice in the viscosity sensor, pressure will build in the chamber above the spool valve. The pressure in this chamber controls the position of the spool.

The viscosity sensor regulates the flow of oil delivered to the regulator valve to better control oil pressure when the oil is cold. This sensor increases the oil flow to engine components during start-up and warm-up conditions.

2. Let's take a closer look at how the viscosity sensor works. Once the engine has been shut down, oil drains from the upper cavity of the pressure regulator valve, though the balance orifice.

At start-up, when the engine is cold, the oil will be viscous and will not flow through the viscosity sensor freely. Oil entering the valve chamber will escape through the balance orifice at a quick enough rate to prevent significant pressure from building in the valve chamber. With an absence of pressure in the chamber, the valve will remain on its seat and not relieve oil pressure.

84. As the oil pressure and temperature increase, more oil will flow through the viscosity sensor into the valve chamber. At a certain point, the flow entering the chamber will be greater than can escape through the balance orifice and pressure will start to build in the chamber. This pressure in the chamber will force the spool valve off its seat and start the system pressure regulation.
**Oil filter bypass valve**

A oil filter bypass relief valve is often found in the oil filter header of many engine which allows pressurized oil to bypass a plugged filter. It operates on principles of pressure differential. Usually, when a new oil filter is used, very little pressure drop occurs across the filter media. With increasing contamination, the filter will become restrictive and a pressure drop across the filter occurs. When the pressure drop exceeds more than usually 3-psi, the bypass valve will open allowing unfiltered oil to move through the main oil gallery. The operation of the filter bypass valve is performed in addition to the normal bypass relief feature incorporated into most oil filters.

![Diagram of full-flow lubrication system with bypass valve](image_url)

**Fig. 20-6** A full-flow oil filtration system. *(Deere and Co.)*

**Above:** Full flow lubrication system with bypass valve located inside (integral) to the oil filter.
Lubrication Systems Valves a Typical Lubrication System
**Oil filters**
The purpose of lubrication oil filtration is contamination removal. Oil contamination will can cause abrasive wear to engine components if not properly controlled. Soot, sludge and dirt are the most common contaminants removed by the filtration system. The choice of filter capacity and type of filter media are determined by the degree of cleanliness desired for the lubrication oil.

**Filter media**
The choice of filter media used inside the oil filter depends on a number of variables such as particle removal efficiency, contaminant holding capacity, the resistance to flow, through the filter and corresponding pressure drop. There are between 50 and 75 different media grades designed for oil filtration available to filter manufacturers. Media used for air, coolant and oil filtration cannot be used interchangeably. Types of media range from mesh like screens to depth style filters using thread or chopped paper to 100% natural cellulose and 100% synthetic microfibers.

When only large particles are to be removed, is a cellulose or paper media is used. To remove progressively smaller sizes of particles the type of media changes from complex cellulose to blended media where cellulose and microfiber materials are blended together. Cellulose or paper provides filtration to 15-20 microns. Glass micro-fiber or micro-glass will provide the most efficient filtration with the least amount of restriction but usually is the most expensive to manufacture. Micro-glass filtration is capable of removing particles down to 2-5 microns in size.
Pleated filters provide greater surface for holding contaminant. However, too many pleats can prevent oil flow by not allowing enough oil between the pleats.

**Anti-drain back valve**

Many cartridge type filters have anti-drain back valve built into the filter element. The purpose of the anti-drain back valve is to prevent the oil in the engine from returning to the crankcase when the engine is shutdown. This permits the instantaneous build-up of oil pressure and oil supply to the engine after start-up. This valve usually consists of a one way flow valve in the center tube of the filter. Many drain back valves are made of nitrile rubber. However, nitrile rubber diaphragms get stiff in extreme cold and may fail to seal in those conditions. Silicone rubber seals or steel valves are not prone to this problem.

![Anti drain back. The outer edge of the red membrane seals against the top of the filter. It is forced aside by oil pressure when the engine starts and oil enters via the small holes](image)

**Filter bypass valve**

The bypass valve is a feature incorporated into the filter to allow oil to pass from the dirty to clean side of the filter if resistance or restriction is excessive across the filter. This prevents oil starvation to the engine in the event of a plugged filter. The simplest design uses a spring loaded filter element which will cause the spring located beneath the element to compress if the oil pressure differential across the filter element becomes too high. This design permits oil to move through the outside dirty side of the filter straight through to the center filtered side of the element without passing through the filter media.
**Filtration systems**

Almost all diesel engine lubrication systems use full flow lubrication. This means any oil reaching the oil filters has passed through an oil filter. Some lubrication system on heavy-duty diesel engines will have a supplemental, partial flow or bypass lubrication system which filters oil through a bypass filter and returns the filtered oil to the sump. No oil passing through the filter actually reaches moving engine parts. This system is not like very old filtration bypass systems which allowed some amount of unfiltered oil to regularly lubricate moving engine parts.

![Diagram of a bypass oil filtration system](image)

*Fig. 20-5  A bypass oil filtration system. (Deere and Co.)*

Above: The LF-3000 filter provides both full-flow (30 microns) and bypass filtration (10 microns). Bypass is controlled by an orifice in the center of the filter housing.
Types of oil filters

Spin-on oil filters introduced during the 1950’s made changing oil easier and less messy. Since the late 1980’s however, European and now North American engine manufacturers are reverting to the cartridge style filter because the use of spin-on type filters has caused a number of problems. One problem is the availability of engine compartment space for filters. Because space is at a premium in the engine compartment of today’s vehicle, the oil filter can be very difficult to locate and change. New style cartridge filter housing are usually conveniently located on the top or side of the engine compartment making them accessible from beneath the hood without the requirement to raise the vehicle. Cartridge type filter housings are typically designed with a screw on type cap and a single sealing gasket. The housings are ventilated when opened and the oil flows out of the filter back to the sump through a separate drain system. Messy spills associated with spin-on filters are minimized this way.

Oil system module and secondary filter assembly

1. Oil system module assembly
2. Bolt, M8 x 30 (8)
3. Hose, 1 in O.D.
4. Hose clamp (2)
5. O-ring (2)
6. Secondary filtration filter assembly
7. Bolt, M8 x 25 (6)
8. Oil cooler drain tube
9. Support bracket bolt, M8 x 16
10. Bolt, M8 x 20 (8)
11. Oil filter (spin-on)

7. Remove oil cooler drain tube support bracket bolt (M8 x 16) at lower end.
8. Pull oil cooler drain tube (lower end) out of oil cooler module and discard O-ring.
9. Remove eight oil system module assembly bolts (M8 x 30).
10. Remove the complete oil system module including the oil cooler and filter header as a unit (less oil filter) and place onto a clean workbench.
Another advantage of the cartridge type filter is the cost of a cartridge filter is less than a spin-on. It is reported that almost 80% of the cost of a spin-on filter is in the steel canister and valves. With a cartridge filter, only the pleated media and a gasket are replaced during filter service. Not only does this reduce the cost but also unnecessary waste of natural resources is eliminated. OEM manufacturers are better able to establish standardized oil filter cartridge sizes, thus eliminating the number of different cartridges required to service a particular brand of vehicle or engine.

The most important reason for the change from spin-on to cartridge filters is the problems of spin-on filter disposal. Disposal of the filter element with the smallest quantity of oil is not only environmentally-friendly but now required by law in many jurisdictions in North America. The disposal cost of a cartridge filter is far less than that of a spin-on filter which requires special handling procedures to be exempt from EPA regulations regarding hazardous waste.

Currently, U.S. manufactured oil filters are exempt from hazardous waste regulation if the oil filter is:

- Punctured through the dome end or anti-drain back valve and hot-drained. (The anti-drain back valve usually prevents sludge from draining out of the filter).
- Hot-drained and crushed
- Hot-drained and dismantled
- Hot-drained using an equivalent method to remove used oil

Hot-draining is defined as draining the oil filter at or near-engine operating temperature. This means the filter is removed from the engine while it is still warm, then punctured or crushed and drained. Most of the oil is removed from the filter during hot-draining. The EPA further recommends hot-draining for a minimum of 12-hours.

(Remember, hot engine oil can scald and extreme care is needed to prevent injury when changing oil.)

**Engine oil quality sensor**

Sensors are now available to measure the condition of lubrication oil to determine the correct oil change interval. Such a sensor also helps alert the operator when oil quality falls outside specified parameters, which could be due either to the oil exceeding its useful life or, a symptom of an engine problem. In addition, oil change interval schedules can be extended, which assists in reducing the negative environmental effects of used oil and oil filter disposal. One such sensor made by Delphi provides real-time on-engine sensing of oil condition to accurately measure soot, which absorbs oil additives and contributes to engine wear. The sensor operates like a variable capacitor using oil as the dielectric element. By measuring AC conductivity across the sensor at frequencies between 2-5 MHz, the sensor evaluates the dielectric strength of oil. This variable will change in proportion to oil quality. Threshold levels for oil quality can be configured to measure oil contamination based on individual customer requirements.
Lubrication system service

Oil change interval
Oil changes intervals are based on the type of operating conditions an engine encounters and the amount of fuel consumed. As a general rule, every 45 gallons of fuel consumed by the diesel engine produces enough contaminants to use up one quart of oil. If the quantity of oil in the oil pan is multiplied by the number of barrels of fuel burned (45 gallons), the oil recommended oil change interval is calculated. Extended service intervals can be achieved using good quality lubricating oil and filters which minimize the effects of oil life limiting factors such as soot loading of the oil, oxidation, acid formation and others things.

Operating an engine in stop and go conditions, heavily loaded, cold weather, with extended idle and so on are severe operating conditions which shorten the oil service interval. The best practice to extend oil change intervals is to use engine oil sampling analysis to determine levels of solids, the TBN and limits of oil oxidation.

Low and high oil pressure
Operation of the valves and oil pump are evaluated using a pressure gauge in the main oil gallery. Complaints about low oil pressure should be verified when the engine is at operating temperature. Idle oil pressure and high idle oil pressure can be compared against manufactures specifications. (See flow charts for low oil pressure diagnostics)

High oil consumption
High oil consumption complaints need to be verified by actual measurement of oil used for a given distance. Usually, the technician diagnosing the complaint will add oil to engine and not the customer to provide accurate record for oil consumption. (See flow charts for high oil consumption analysis).
Oil in the cooling system can be the result of a perforated/corroded oil cooler.
Below – testing and oil cooler for leaks.

Checking the oil cooler for external

1. Test plate set
2. Air pressure regulator
3. Coolant port (closed)
4. Oil port
Low Oil Pressure

On electronic fuel injected engines, check for a steady or intermittent "check engine" light

Use the diagnostic data reader to access any stored fault or trouble codes, then refer to the engine manufacturer's diagnostic/test information

Probable causes when no codes are displayed

Lubricating oil

- Check for
  1. Check engine oil
  2. Lubricating oil viscosity
  3. Fuel or coolant dilution

Pressure gauge

- Check for
  10. Faulty gauge
  11. Gauge or line obstructed

Poor circulation

- Check for
  4. Cooler partially restricted
  5. Filter bypass valve not functioning properly
  6. Pressure regulating valve not functioning properly
  7. Rocker arm shaft plugs missing
  8. Oil suction loss
  9. Excessive main bearing clearance/wear

Oil pump

- Check for
  8. Oil suction loss
  12. Relief valve not functioning
  13. Flange leak (pressure side)
  14. Worn or damaged oil pump
High Lubricating Oil Consumption

On electronic fuel injected engines, check for a steady or intermittent "check engine" light

Use the diagnostic data reader to access any stored fault or trouble codes, then refer to the engine manufacturer's diagnostic/test information

Probable causes when no codes are displayed

External leaks

Check for

1. Overfilled crankcase
2. Oil in the air tanks
3. Leaks at lines, connections, mating joints, seals, or gaskets
4. Plugged breather

Internal leaks

Check for

5. Turbo oil seal leaking
6. Worn valve guides or seals
7. Oil cooler core leaking

Oil control at cylinder

Check for

1. Overfilled crankcase
8. Worn or damaged cylinder components
9. Dirt in intake system
## Appendix: API service classification

<table>
<thead>
<tr>
<th>Category</th>
<th>Status</th>
<th>Service</th>
</tr>
</thead>
</table>
| CI-4     | Current | Introduced September 5\textsuperscript{th} 2005 for high speed four stroke cycle diesel engines to meet 2004 exhaust emission standards implemented in 2002.

CI-4 oils are formulated to sustain engine durability where exhaust gas recirculation (EGR) is used and are intended for use with diesel fuels ranging in sulfur content up to 0.5% weight.

Can be used in place of CD, CE, CF-4, CG-4, and CH-4 oils. |
| CH-4     | Current | Introduced in 1998. For high-speed, four-stroke engines designed to meet 1998 exhaust emission standards.

CH-4 oils are specifically compounded for use with diesel fuels ranging in sulfur content up to 0.5% weight.

Can be used in place of CD, CE, CF-4, and CG-4 oils. |
<p>| CG-4     | Current | Introduced in 1995. For severe duty, highspeed, four-stroke engines using fuel with less than 0.5% weight sulfur. |</p>
<table>
<thead>
<tr>
<th>Oil</th>
<th>Status</th>
<th>Introduced</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>CG-4</td>
<td></td>
<td></td>
<td>CG-4 oils are required for engines meeting 1994 emission standards. Can be used in place of CD, CE, and CF-4</td>
</tr>
<tr>
<td>CF-4</td>
<td>Current</td>
<td>1990</td>
<td>Introduced in 1990. For high-speed, four-stroke, naturally aspirated and turbocharged engines. Can be used in place of CD and CE oils.</td>
</tr>
<tr>
<td>CF</td>
<td>Current</td>
<td>1994</td>
<td>Introduced in 1994. For off-road, indirect injected and other diesel engines including those using fuel with over 0.5% weight sulfur. Can be used in place of CD oils.</td>
</tr>
<tr>
<td>CE</td>
<td>Obsolete</td>
<td>1987</td>
<td>Introduced in 1987. For high-speed, four-stroke, naturally aspirated and turbocharged engines. Can be used in place of CC and CD oils.</td>
</tr>
</tbody>
</table>