CHAPTER 12

NATEF Tasks

Engine Repair
Lubrication and Cooling Systems

Task		Page
■ Perform oil and filter change.	MLR AST MAST	1574–1581

Knowledge Objectives

After reading this chapter, you will be able to:

1. Describe the components of lubricating oil. (p 1556)
2. Describe the functions of lubricating oil. (p 1557)
3. Describe the types of common additives added to lubricating oil. (p 1558)
4. Describe the three types of oil. (pp 1561–1562)
5. Identify the components of the lubrication system. (pp 1562–1570)
6. Describe the operation of the lubrication system. (pp 1570–1572)
7. Describe the types of lubrication systems and how they operate. (pp 1570–1572)

Engine Lubrication

Skills Objectives

After reading this chapter, you will be able to:

1. Check the engine oil. (pp 1572–1574)
2. Drain the engine oil. (pp 1574–1576)
3. Replace a spin-on filter. (pp 1577–1578)
4. Replace a cartridge filter (replaceable element). (pp 1578–1579)
5. Refill the engine oil. (pp 1579–1581)

Introduction

Machinery, like our automobiles, relies on lubrication to keep the moving parts from wearing out quickly. Lubricating oil is processed from crude oil in a refinery with gasoline and diesel, along with many other beneficial and useful products. Oil is much more than simply crude oil dumped into our engine's crankcase; it is heavily processed to remove impurities, and many additives are put into the processed oil by scientists in a lab to enhance its lubricating qualities.

Each moving part in the engine needs lubricating oil. The system that moves the oil through the engine is called the lubrication system. This chapter will cover the theory of lubrication systems and the methods and specialized tools involved to ensure that you can properly diagnose and correct common problems associated with this system.

Oil

Oil originates from the ground as **crude oil** FIGURE 12-1. Crude oil varies in color from a dirty yellow to dark brown to black. It can be thin like gasoline or a thick oil- or tarlike substance. Crude oil is pumped from the ground and processed into many products such as fuel for use in diesel and gasoline vehicles. Crude oil is also broken down into other products, which are used in plastics manufacturing as well as in kerosene, aviation fuel, asphalt, cosmetics, pharmaceuticals, and many other products. Many of the products refined from crude oil are used in the transportation industry. For example, **lubricating oil** is distilled from the crude oil and used as a base stock. Additives are added to the base stock to make the lubricating oil useful in engines. Other additives, such as thickening agents, are added to the base stocks and used as lubricating grease in bearings. The additives that are added to the base stock perform a variety of tasks such as keeping acids from forming, cutting down on oxidation, and maintaining the correct viscosity over a broader temperature range.

FIGURE 12-1 Crude oil straight from the ground.

You Are the Automotive Technician

A customer brings his 5-year-old vehicle into your shop for an oil and filter change. The vehicle is right at the recommended 7,500 mile interval. He said he has noticed some oil spots on his garage floor, and the oil level was a bit below the "add" mark this morning when he checked it. He is concerned that he has an oil leak, and he would like to know why the oil pressure light on the dash didn't indicate that his oil level was low. You pull the vehicle onto the hoist. The oil light comes on when the key is turned to "run" and goes off once the engine starts, proving that the oil pressure warning light circuit is working. With the engine running, you find a that a drop of oil forms every so often on the end of the oil pressure switch, indicating it is leaking and needs to be replaced. None of the engine seals and gaskets show any signs of leakage.

1. What are the functions that oil performs inside an engine?
2. Why didn't the oil pressure light indicate that the oil was below the "add" line?
3. How often should the oil and filter be changed?

TECHNICIAN TIP

Lubricating oil has been used since the invention of machinery. When metal moves on another piece of metal, the parts wear quickly without lubrication. Lubricating oil also helps to quiet the moving parts and remove heat from metal surfaces.

Functions of Lubricating Oil

Lubricating oil performs five main functions: lubricates, cushions, cools, cleans, and seals. Lubrication involves reducing friction, protecting against corrosion, and preventing metal-to-metal contact between the moving surfaces. Friction occurs between all surfaces that come into contact with each other. When moving surfaces come together, friction tends to slow them down. Friction can be useful, as in a brake system. In the moving parts of engines, friction is a bad thing and will lead to serious damage. Friction can make metal parts so hot they melt and fuse together. When this happens, an engine is said to have seized.

Lubrication reduces unwanted friction and reduces wear on moving parts. Clearances, such as those between the crankshaft journal and crankshaft bearing, fill with lubricating oil so that engine parts move or float on layers of oil instead of directly on each other **FIGURE 12-2**. By reducing friction, less power is needed to move these components and more of the engine's power can be used to turn the crankshaft instead of wasted as heat; the result is increased power to move the vehicle and better fuel economy.

How long an engine lasts depends mostly on how well it is lubricated, especially at the points of **extreme loading**, or high-wear areas, such as between the cam lobe and cam follower. At the same time, the connecting rod and crankshaft bearings take large amounts of stress as the piston tries to drive through the crankshaft each time the cylinder fires. A power stroke can put as much as 2 tons of force on the main bearings. The lubricating oil between the surfaces helps to cushion these shock loads, similar to the way a shock absorber absorbs a bump in the road.

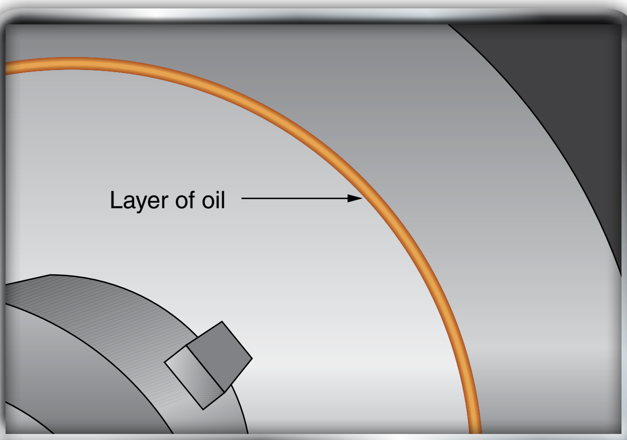


FIGURE 12-2 Clearances fill with lubricating oil so that engine parts move or float on layers of oil instead of directly on each other.

Lubricating oil also helps cool an engine. The lubricating oil collects heat from the engine's components and then returns to the sump, where it cools. The heat from the lubricating oil is picked up by the air moving over the oil sump. Many heavy-duty and high-performance vehicles have cooling fins on their oil pan or even a separate oil cooler to help the oil do its job of cooling critical engine components.

Lubricating oil also works as a cleaning agent. There are additives in the lubricating oil that allow it to collect particles of metal and carbon and carry them back to the oil sump. Larger pieces fall to the bottom of the oil sump, while smaller pieces are suspended in the oil and are removed when the oil moves through the oil filter. When oil is changed, most of the particles are removed with the oil filter and old oil.

The last function of oil is that it seals. It plays a key role in sealing the piston rings to the cylinder walls. Without a small film of oil between the rings and cylinder walls, blow-by gases would be much higher, resulting in diluted oil, lower compression, lower power, and lower fuel economy.

Corrosion Protection

Acids build up in the engine due to the accumulation of combustion by-products and moisture. Blow-by gases contain chemicals that are trapped in the oil. The chemicals react and form acids. When the engine is turned off, it begins to cool. The cooling process creates moisture that then condenses into droplets that fall into the oil and form acids. The acids attack the internal components causing unnecessary damage. The oil contains anticorrosion additives that coat the engine surfaces, helping to protect them from the effects of the acid.

Viscosity

For oil to do all of the work that is expected of it, it must have special properties. Its viscosity is crucial. **Viscosity** is a measure of how easily a liquid flows. Low-viscosity liquid is thin and flows easily. High-viscosity liquid is thick and flows slowly. Lubricating oil must be thin enough to circulate easily between moving parts, but not so thin that it will be squeezed out easily. If it is too viscous, it moves too slowly to protect the moving parts, especially in a cold engine. As engine machining and metal technology have become more advanced, the clearances between lubricated parts have decreased. As a result, engine manufacturers have specified thinner oils for their engines so that oil can flow into the smaller clearances. The thinner oil also flows more easily, which increases fuel economy.

Applied Science

AS-25 Inhibitors: The technician can explain the need for additives in automobile lubricants.

Automotive lubricants are composed of base stock plus an additive package. In addition to engine oil, additives are used in lubricants for manual and automatic transmissions, as well as differentials.

Oil additives are a very necessary part of modern lubricants. The improvements in modern automotive lubricants are one of the factors that enable vehicles to last longer than ever before. Oil additives consist of chemical compounds that have many beneficial functions.

Detergents are additives that help keep the oil clean. Corrosion (or rust) inhibiting additives work to prevent oxidation of engine parts. According to Wikipedia, a corrosion inhibitor is a chemical compound that, when added to a liquid or gas, decreases the corrosion rates of a material, typically a metal or an alloy.

Oil Additives

Special chemicals called additives are added to the base oil by the oil companies. Different combinations of these additives allow the oil to do different jobs in an engine. A description of common additives follows:

- **Extreme-pressure additives** coat parts with a protective layer so that the oil resists being forced out under heavy load.
- **Oxidation inhibitors** stop very hot oil from combining with oxygen in the air to produce a sticky tarlike material, which coats parts and clogs the oil **galleries** and drain-back passages. Oil galleries are the passageways that carry oil through the engine. They are either cast or drilled into the engine block and head(s).
- **Corrosion inhibitors** help stop acids from forming that cause corrosion, especially on bearing surfaces. Corrosion due to acid etches into bearing surfaces and causes premature wear of the bearings.
- **Antifoaming agents** reduce the effect of oil churning in the crankcase and minimize foaming. Foaming allows air bubbles to form in the engine oil, reducing the lubrication quality of oil and contributing to breakdown of the oil due to oxidation. Since air is compressible, oil with foam reduces the ability of the oil to keep the moving parts separated, causing more wear and friction. The antifoaming additives keep these conditions from occurring.
- **Detergents** reduce carbon deposits on parts such as piston rings and valves.
- **Dispersants** collect particles that can block the system, separate them from each other, and keep them moving. They will be removed when the oil is changed.
- **Pour point depressants** keep oil from forming wax particles under cold temperature operation. When wax crystals form, they result in the **gelling** of the oil and keep oil from flowing during cold start-up conditions. Gelling is the thickening of oil to a point that it will not flow through the engine; it becomes close to a solid in extreme cold temperatures.
- Base stock derived from crude oil will not retain its viscosity if the temperature gets cold enough, so viscosity improvers are added to the stock. A **viscosity index improver** is an additive that helps to reduce the change in viscosity as the temperature of the oil changes. Viscosity index improvers also keep the engine oil from becoming too thin during hot operation.

TECHNICIAN TIP

Before multiviscosity oils, it was a normal practice for engines to need one grade of lubricating oil for summer and another for winter.

Oil Rating Standards

There are several certifying bodies for engine oil, each with its own standards. The three most common are the American Petroleum Institute (API), the American Society of Automotive Engineers (SAE), and the International Lubricant Standardization and Approval Committee (ILSAC). However, there are three others that technicians must be aware of: the Japanese Automotive Standards

Organization (JASO), the Association des Constructeurs Européens d'Automobiles (ACEA), also called the European Automobile Manufacturers Association, and the vehicle manufacturers' (OEM) own standards. Let's look at them one at a time.

American Petroleum Institute (API)

The API sets minimum performance standards for lubricants including engine oils. The API has a two-part classification: service class and service standard. The API service class has two general classifications: S for spark ignition engines and C for compression ignition engines, also referred to as "commercial." Engine oil that meets the API standards may display the API Service Symbol, which is also known as the API "donut." This protocol is important to understand because oil rated S only cannot be used in compression ignition engines unless they also carry the C rating and vice versa. Be careful that the wrong oil is not used in a particular engine.

The API service standard (SA) was used in engines up to 1930, which means pure mineral oil without any additives. As engine manufacturers improved engine technology—or as government regulations changed, such as requiring reduced amounts of phosphorus—engine oil with new qualities was required, and the API would introduce a new rating level. The API SN level was added in October 2010 for 2011 gasoline vehicles. API CJ-4 was added in 2010 to meet four-stroke diesel engine requirements.

The API symbol is the donut symbol located on the back of the oil bottle **FIGURE 12-3**. In the top half of the symbol is the service class—S or C—and the service standard that the oil meets. The center part carries the SAE viscosity rating for the oil. The API symbol may also carry an energy saving designation if it is a fuel-saving oil. Be sure to use oil that has a correct API rating and also an energy-conserving designation in all North American vehicles.

TECHNICIAN TIP

In most cases, higher rated engine oils are backward compatible. This means you can use SM oil in a vehicle that requires SL. But there is one exception that some technicians have found. SN-rated oil has very low levels of phosphorus and zinc, which aids in flat tappet camshaft lubrication. So if you are working on an older engine that uses flat tappets, you probably do not want to use SN-rated oil, but SM instead.

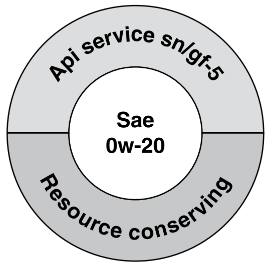


FIGURE 12-3 The API donut shows the API service class and service standard, the viscosity, the ILSAC performance rating, and the energy-conserving designation.

American Society of Automotive Engineers (SAE)

Engine oil producers must also meet the SAE viscosity rating for each particular oil. Engine oil with an SAE number of 50 has a higher viscosity, or is thicker, than an SAE 20 oil. Oils with low viscosity ratings, such as SAE 0W, 5W, and 10W (the "W" stands for winter viscosity), are tested at a low temperature—around 0°F (–17.8°C). These ratings indicate how the oil will flow when started cold in cold climate conditions. Oils with high viscosity ratings, such as SAE 20, 30, 40, and 50, are tested at a high temperature—around 210°F (98.9°C). These ratings indicate how the oil will flow when the engine is being used under loaded conditions in hotter conditions.

Modern oils are blends of oils that combine these properties. The oils are blended with viscosity index improvers to form multigrade, or multiviscosity, oils. They provide better lubrication over a wider range of climatic conditions than monograde oils. These oils are classified by a two-part designation, such as SAE 0W-20. In this example, when the oil was tested at 0°F (–17.8°C), it met the specifications for a viscosity of 0W weight oil, and when the same oil was tested at 210°F (98.9°C), it met the viscosity specifications for 20 weight oil. Multiviscosity oils flow easily during cold engine start-up but do not thin out as much as the engine and oil come up to operating temperature. These properties allow the oil to get to the components quicker during start-up while maintaining its ability to cushion components when it is hot. While multiviscosity oils extend the operating temperature range of the engine, always refer to the vehicle's service information to determine the correct oil viscosity to use for the climate the engine will be operated in.

Applied Science

AS-103: Viscosity: The technician can demonstrate an understanding of fluid viscosity as a measurement and explain how it impacts engine performance.

Viscosity is the measurement of a liquid's resistance to flow. This concept is often best understood by example. Imagine you have a small funnel that you fill with honey. You will find that the funnel drains quite slowly. If you filled the funnel with water, it would drain almost instantly. The difference is because honey has a higher viscosity than water.

Late-model engines are assembled with tighter clearances between moving parts to maximize efficiency and minimize mechanical noise. High-viscosity oil, as used in older vehicles, will not move quickly enough to protect crucial parts in late-model engines, especially on a cold start. Low-viscosity oils, used in older engines, will flow too rapidly past components with large clearances and will provide insufficient lubrication and insufficient oil pressure. The result in both cases is excessive mechanical noise and premature failure with continued operation.

International Lubricant Standardization and Approval Committee (ILSAC)

ILSAC works in conjunction with the API in creating new specifications for gasoline engine oil. However, ILSAC requires that the oil provide increased fuel economy over a base lubricant. These oils should reduce vehicle owners' fuel costs a small amount compared to an oil that does not meet the ILSAC standard. Like the API standard, ILSAC issues sequentially higher rating levels each time the standards are changed. ILSAC GF-5 replaced GF-4 and became the standard in September 2011. Engine oils that meet the GF-4 and GF-5 standard can display the API starburst symbol, which the API created to verify that the oil meets the highest ILSAC standard.

Association des Constructeurs Européens d'Automobiles (ACEA)

The ACEA classifications formulated for engine oils used in European vehicles are much more stringent than the API and ILSAC standards. Some of the characteristics the ACEA-rated oil must score high on are soot thickening, water, sludge, piston deposits, oxidative thickening, fuel economy, and after-treatment compatibility. While some of these may be tested by the API and ILSAC, the standards are set high to achieve ACEA certification ratings. This means that the engine oil provides additional protection or characteristics that API- or ILSAC-rated oils may not match. If you are servicing a European vehicle, it is advised that you do not go by any API recommendations; instead, make sure the oil meets the recommended ACEA rating specified by the manufacturer or the manufacturer's own specification rating.

Japanese Automotive Standards Organization (JASO)

The JASO standards set the classification for motorcycle engines, both two-stroke and four-stroke, as well as Japanese automotive diesel engines. For four-cycle motorcycle engines, the JASO T 903:2011 came into effect in October 2011 and designates different ratings for wet clutch (MA) and dry clutch (MB). For two-stroke motorcycles, JASO M 34:2003 came into effect in October 2003. And for automotive diesel engines, JASO M355:2008 came into effect in August 2008.

OEM-Specific Standards

As engine manufacturers continued to design new features or longer drain intervals into their engines, faster than some of the oil rating organizations could (or would) change their standards, engine manufacturers came up with their own standards. These standards are specific to individual manufacturers or even individual engines of a particular manufacturer. A few examples follow: Oil meeting Volkswagon's VW 506.00 standard are suitable for use on diesel engines (not with single injector pump) with an extended service interval of up to 31,000 miles or 2 years. Oil meeting General Motor's Dexos1™ is specified for use in all 2011 GM vehicles except those equipped with Duramax diesel engines and is backward compatible in all older GM vehicles. Its viscosity is SAE 5W-30 and meets the ACEA A3/B3 standard. It has a service interval of up to 18,600 miles. Oil meeting BMW's Longlife-04 standard is approved for fully synthetic long-life oil and is usually required for BMWs equipped with a diesel particulate filter.

As you can see, it is important to understand the oil requirements for the vehicle you are working on and only use the specified oil. Using the wrong oil can result in severe damage to the engine. Furthermore, using the wrong oil can void the customer's warranty, leaving the customer, or your shop, responsible for repairs. Long gone are the days of grabbing five bottles of any 10W-30 oil off the shelf and putting it into any car that rolls through the door.

TECHNICIAN TIP

Be sure to check the owner's manual or service manual of the vehicle to ensure that you are using the correct oil rating and viscosity for the engine. Do not use just any oil that is sitting on the parts shelf.

American Petroleum Institute Classifications

The API classifies oils into five groups:

1. Group 1 oils are produced by simple distillation of crude oil, which separates the components of the oil by their boiling point, and by the use of solvents to extract sulfur, nitrogen, and oxygen compounds. This method was the only commercial refinement process until the early 1970s, and the bulk of commercial oil products on the market are still produced by this process, such as conventional engine oils.
2. Group 2 and group 3 oils are refined with hydrogen at much higher temperatures and pressures, in a process known as **hydro-cracking**. This process results in a base mineral oil with many of the higher performance characteristics of synthetic oils.
3. The more heavily hydro-cracked group 3 oils have a very high viscosity index (above 120) and many, but not all, of the higher performance characteristics of a full polyalphaolefin (PAO) synthetic oil. Although not fully synthetic, these oils can be sold as synthetic oil in North America.
4. Group 4 oils are all of the full synthetic PAO group (most common true synthetic).
5. Group 5 includes all other types of synthetic oil.

TECHNICIAN TIP

Over time, lubricating oil breaks down by reacting with dissolved atmospheric oxygen. In most refineries, impurities are removed by using solvent. **Hydrogenating** is a newer process that is more effective at removing impurities. Hydrogenation is the use of hydrogen during refining to assist with removing impurities. By hydrogenating the oil, and with the use of oxidation-inhibiting additives, this deterioration rate can be slowed by more than a hundredfold. Hydrogenating also reduces the presence of aromatic hydrocarbons, thereby giving more effective oxidation inhibitor action, minimizing sludge and varnish deposits, and generally avoiding other related machinery problems.

Types of Oil

There are three types of oils sold by oil manufacturers: conventional, synthetic, and synthetic blend. **Conventional oil** is processed from petroleum and uses additives to help the oil work properly in today's high-tech engines. **Synthetic oil** can be man-made or highly processed petroleum. Synthetic oil has fewer impurities since it either is made in a lab, rather than pumped from the ground, or, if it is pumped from the ground, is more highly refined and processed. Synthetic blends are used because they are cheaper to purchase and give the benefit of half synthetic. Manufacturers publish the required oil for each vehicle in the owner's manual.

Conventional Oil

Conventional oil is processed from crude oil pumped from the ground FIGURE 12-4. The crude oil contains many impurities that are removed during the refining process. One of the impurities found in all crude oil is wax. This wax is removed during refining and is used for candle wax; it also serves as an additive in some food and candy. Wax is not a good thing in oil since it creates a thickening effect when it gets cold, becoming too thick to flow through the engine. Crude is broken down into mineral oil, which is then combined with additives to enhance the lubricating qualities. Without the additives, conventional oil would not work well. It would foam easily, break down quickly, and corrode the engine parts after being in the engine for a short time.

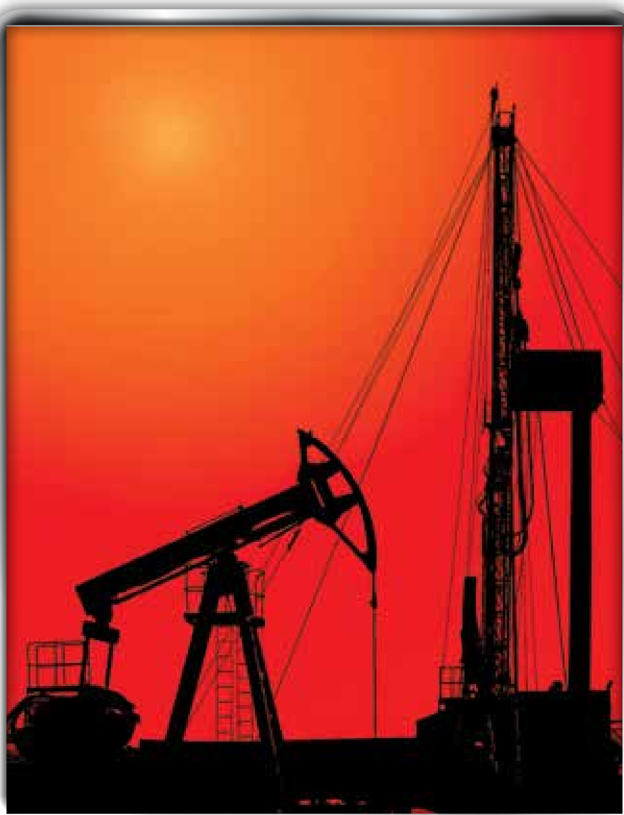


FIGURE 12-4 Conventional oil is processed from crude oil pumped from the ground.

Synthetic Oil

There are two main categories of synthetic lubricating oils: type 3, which is not a true synthetic, and type 4 (PAO), which is a true synthetic. Both types of synthetics are more costly to manufacture, since the base stocks are more highly refined or are developed in a lab, and are therefore more costly to the customer. Synthetic lubricants have a number of advantages over conventional oils. They offer better protection against engine wear and can operate at the higher temperatures needed by performance engines. Synthetic oils have better low temperature viscosity, which allows the oil to be circulated through the engine more quickly during low temperature engine start-ups. Synthetics have fewer wax impurities that coagulate at low temperatures, they are chemically more stable, and they are generally thinner so they allow for closer tolerances in engine components without loss of lubrication. Modern high-performance engines run much tighter tolerances, so the need for a thinner oil that is able to hold up under higher temperatures is desirable. Some synthetics also last considerably longer, extending oil change intervals to 20,000 miles (30,000 kilometers [km]) or more, which benefits the environment by reducing the used oil stream and reducing the need for finding new sources of oil.

True synthetic oils are based on man-made hydrocarbons, commonly **polyalphaolefin (PAO)** oil, which is a man-made oil base stock—meaning it is not refined from crude oil. Synthetic oils were developed in Germany during World War II due to the lack of crude oil. Synthetic oil was used primarily in jet engines due to the high heat demands of these engines. Normal conventional oil would create heavy carbon deposits on bearings due to the extreme heat, which led to failures. Amsoil was the first synthetic to be approved by the API in 1972. Many companies now offer synthetic oils. Very few synthetic oils on the market are full PAO oils. Many of the oils allowed to be labeled as synthetic are in fact blends of processed **mineral oil** (highly refined base stock refined from crude oil) and PAO, or even just highly refined base stock, that possess lubrication qualities similar to PAOs.

Synthetic Blends

Synthetic blends give some of the benefit of the full synthetic with the cost effectiveness of conventional oil. These oils are a mix of conventional high-quality oil and full synthetic oil. They need to be changed sooner than a full synthetic but less frequently than conventional oil. The more pure the base stock is after the refinement process, the longer the oil will last in the engine. Some manufacturers are now recommending synthetic blend oil over conventional oil due to the better protection and performance of these types of oils. Because it is half synthetic, half conventional, the full benefit of the thinner, higher performance pure synthetic is diluted, but in turn the conventional half is improved by adding oil that has no impurities. If the vehicle will be used hard, such as for hauling or towing, synthetic blends will perform better than conventional oil because of the ability of the synthetic oil to stand up to the higher heat and heavier load placed on the engine.

> **TECHNICIAN TIP**
>
> Be sure to use at least the minimum recommended oil by the manufacturer. Manufacturers of engines spend a lot of money and time designing engines that are efficient and long lasting. Always follow the manufacturer's recommendations.

Lubrication Systems

The **lubrication system** is a series of engine components that work together to keep the moving parts inside an engine lubricated FIGURE 12-5. Proper lubrication ensures that the engine runs cooler, produces maximum power, and gets maximum fuel efficiency. Lubrication also ensures that the engine will last for a long time. The lubrication system has many components that work together to deliver the oil to the correct locations in the engine. A typical lubrication system consists of an **oil sump**, an oil pump strainer (also called a pickup tube), an **oil pump**, a pressure regulator, **oil galleries**, an oil filter, and a low pressure warning system.

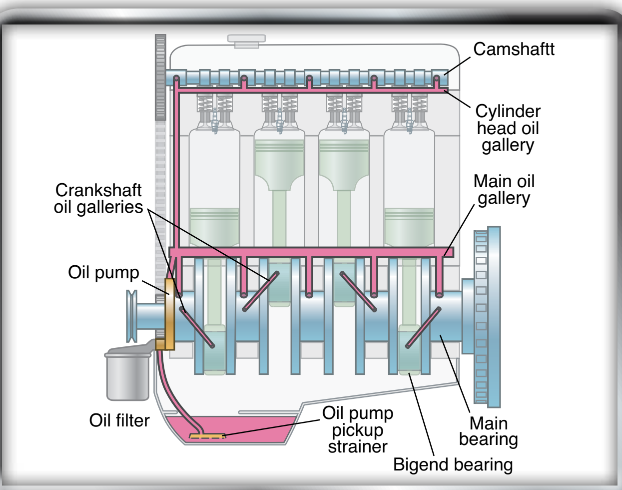


FIGURE 12-5 The lubrication system.

The oil is stored in the oil sump. Oil is drawn through the oil pump strainer from the oil sump by an oil pump. The oil travels from the oil pump to the oil filter, which removes particles of dirt from the oil. Oil moves from the filter to the oil galleries. Oil galleries are small passages in the cylinder block and head(s) that direct oil to the moving parts. Oil that has been pumped to the crankshaft main bearings travels through oil-ways to the connecting rods. Oil may also be splashed from the connecting rods onto the cylinder walls, and the circulation of the oil assists with the cooling of the internal parts.

Oil Pan

The **oil pan** is located at the bottom of the engine **FIGURE 12-6**. On a wet sump lubricating system, the oil pan holds the entire volume of the oil required to lubricate the engine. The lowest point of the oil pan is the oil sump. This is where the **oil pump strainer** is located. The deep point in the oil pan ensures that there should never be a shortage of oil for the oil pump to pick up if the correct amount of oil is in the engine. The oil pan is sealed to the engine with silicone or an oil pan gasket. The sump is equipped with a drain plug that allows the oil to be drained from the engine during oil changes **FIGURE 12-7**.

Pickup Tube

Between the oil sump and oil pump is a **pickup tube** with a flat cup and a wire mesh strainer immersed in the oil. The pickup tube pulls oil from the oil sump by suction of the oil pump and atmospheric pressure. A strainer on the pickup tube stops large particles of debris from entering the oil pump and damaging it. The pickup tube leads to the inlet of the oil pump, on the low-pressure side of the oil pump. The pickup tube fits tightly into the oil pump and is usually bolted in place by a bracket to ensure that it does not fall out due to vibration. If the pickup tube were to fall out, the engine would not receive oil, since the pump would not reach down into the sump from which oil is drawn.

FIGURE 12-6 The oil pan.

FIGURE 12-7 A drain plug allows oil to be drained during oil changes.

Oil Pump

Oil pumps move oil from one side of the pump to the other. Most oil pumps are of the positive displacement type. This means that they move a given amount of oil from the inlet to the outlet each revolution. The faster the pump turns, the more oil that is pumped. Oil pressure is determined by two factors: (1) the size of the leaks in the system, which in the case of an engine means the amount of clearance between the bearings and the journals and the diameter of any spurt holes, and (2) the amount of oil flowing in the system. As you can imagine, an engine has a fairly consistent set of leaks. When the engine is new, the leaks are fairly small. When the engine has acquired many miles, the leaks are larger. This is why engine oil pressure falls over the life of the engine. In fact, low oil pressure can mean one of three things (other than a bad oil pressure gauge). Either the oil leaks inside the engine have gotten excessive (e.g., worn bearings), the oil pump is worn out and not creating as much flow as it needs to, or the oil is thinner than it should be (e.g., saturated with gasoline from a leaky fuel injector), which causes it to drain from the leaks faster than it should.

Oil pumps may be driven from the camshaft or the crankshaft. In a **rotor-type oil pump**, an inner rotor drives an outer one; as they turn, the volume between them increases **FIGURE 12-8A**. The larger volume created between the rotors lowers the pressure at the pump inlet, creating a vacuum. Outside atmospheric pressure, which is higher, forces oil into the pump, and the oil fills the spaces between the **rotor lobes**. As the lobes of the inner rotor move into the spaces in the outer rotor, oil is squeezed out through the outlet. In other words, oil is drawn into the spaces between the lobes on the inlet side and travels around with the lobes. The oil cannot get back to the inlet side because the lobes come together, and it is therefore forced out of the pump outlet.

The **crescent pump** uses a similar principle FIGURE 12-8B. It is usually mounted on the front of the cylinder block and straddles the front of the crankshaft.

Applied Math

AM-29: Volume: The technician can use various measurement techniques to determine the volume as applicable.

Two technicians are examining an engine oil pan as it is being cleaned. It is a standard automotive pan from a V6 engine and has a rectangular shape. Randy says that the volume of the pan could be calculated by multiplying the area of the base times the height. Tom agrees with this and adds that in the U.S. system of measurement the result would be in cubic inches which can be converted into quarts.

At break time, they decide to measure the pan and calculate its volume in quarts. The pan measures 6 inches wide, 9 inches long, and 5.35 inches deep. The area of the base is 6×9, which is 54 square inches. Next, they multiply times the height of 5.35 inches for 288.9 square inches. This is approximately 5 quarts (considering one quart is equal to 57.750 cubic inches).

To calculate the example in metric units the process would be very similar except that we would be using metric units. Centimeters would be used for the linear units to determine the base $\times$ height. There would be cubic centimeters to convert to liters.

The inner gear is then driven by the crankshaft directly. An external toothed gear meshes with the inner one. Some gear teeth are meshed but others are separated by the crescent-shaped part of the pump housing. The increasing volume between gear teeth causes pressure to fall, creating a vacuum, and atmospheric pressure pushes oil into the pump. Oil is then carried around between the gears and crescent before being discharged to the outlet port.

In a **geared oil pump**, the driving gear meshes with a second gear FIGURE 12-8C. As both gears turn, their teeth separate, creating a low-pressure area. Higher atmospheric pressure outside forces the oil up into the inlet, which fills the spaces between the gear teeth. As the gears rotate, they carry oil around the chamber. As the teeth mesh again, oil is forced from the outlet into the oil gallery and toward the oil filter where it is filtered of any particles.

Oil Pressure Relief Valve

A normal oil pump is capable of delivering more oil than an engine needs. Extra volume provides a safety measure to ensure the engine is never starved for oil. As the oil pump rotates, and engine speed increases, the volume of oil delivered also increases. The fixed clearances between the moving parts of the engine slow the escaping of oil back to the oil sump, and pressure builds up in the lubrication system. An **oil pressure relief valve** stops excess pressure from developing. It is like a controlled leak, releasing just enough oil back to the oil sump to regulate the pressure in the whole system. The oil pressure relief valve contains a spring that is calibrated to a specific pressure. When the pressure is

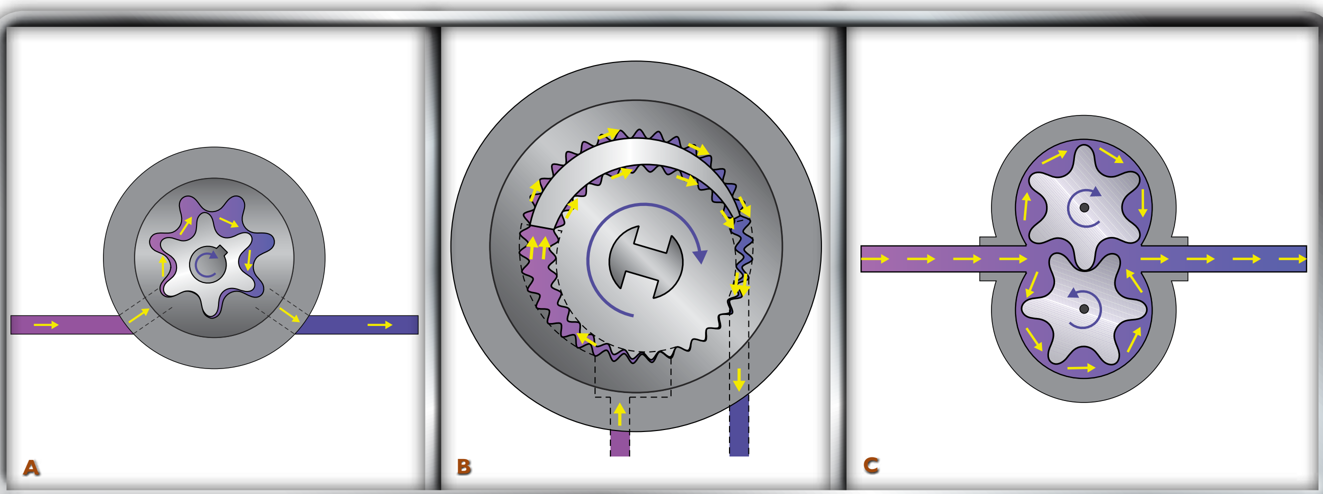


FIGURE 12-9 **A.** Rotor-type oil pump. **B.** Crescent pump. **C.** Geared oil pump.

reached, the oil pressure relief valve slides open just enough to bleed sufficient oil back to the pan to maintain the preset maximum relief pressure. If the engine speed and oil flow increase, the pressure relief valve will open farther and allow more oil to escape back to the sump. If the engine speed and oil flow decrease, the pressure relief valve will close an appropriate amount.

TECHNICIAN TIP

So what is the difference between a high-pressure oil pump and a high-volume oil pump? A high-pressure pump has a stiffer pressure relief spring, which allows the pump to create higher oil pressure. A high-volume pump has greater volume between the rotor or gear teeth, usually accomplished by making both the rotor/gear and the oil pump housing deeper. This design causes more oil to be drawn into the pump during each revolution, and therefore more oil is forced out of the pump each revolution. Generally speaking, a high-volume pump is more beneficial; because it can pump more oil, the pressure will not fall as quickly as the engine experiences wear and tear.

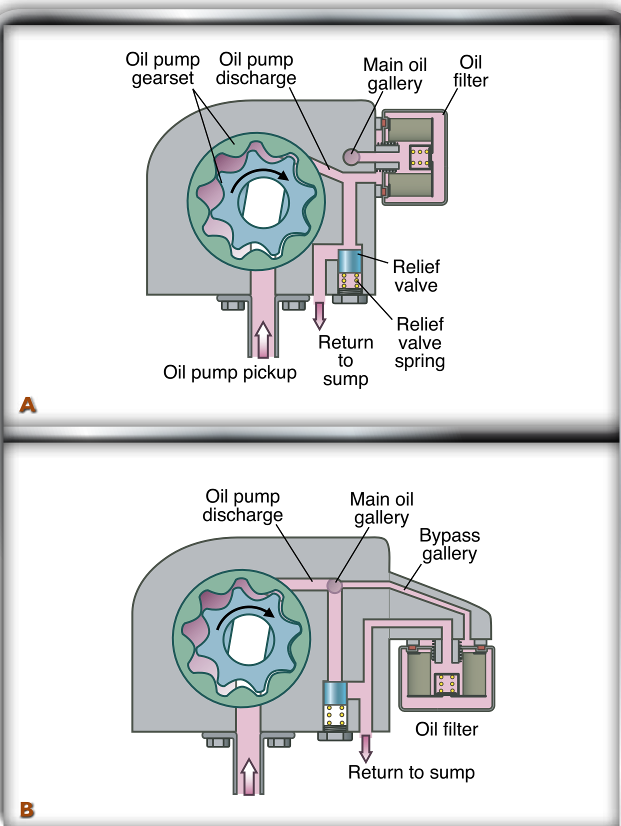


FIGURE 12-9 **A.** Full-flow filtering system. **B.** Bypass filtering system.

FIGURE 12-10 Pleated oil filter paper.

Oil Filters

There are two basic oil-filtering systems: full-flow and bypass **FIGURE 12-9**. The most common, **full-flow filters**, are designed to filter all of the oil before delivering it to the engine. The location of the filter right after the oil pump ensures that all of the oil is filtered before it is sent to the lubricated components. The bypass filtering system is more common on diesel engines and is used in conjunction with a full-flow filtering system. The **bypass filter** is discussed later in this section.

Oil filters use a pleated filter paper for the filtering medium **FIGURE 12-10**. Oil flows through the paper and as it does so, it filters out particles in the oil. Most full-flow oil filters will catch particles down to 30 microns. A micron is 0.000039" (0.001 mm)—a very small particle. A human hair's thickness can be as small as 50 microns, for example. As the oil filter catches these fine particles, the paper filter element will begin to clog, making it harder for the oil to flow through. As the engine is initially started cold for a few seconds, or if the filter becomes clogged, the bypass valve will open to let unfiltered oil flow to the lubricated components. The manufacturers believe it is better to have unfiltered oil flow to components than no oil at all. To prevent excessive engine wear, it is critical to change the oil filter at the manufacturer's recommended interval.

There are two common types of oil filters: spin-on and cartridge **FIGURE 12-11**. The spin-on type is the most common. It uses a one-piece filter assembly with a crimped housing and threaded base. The pleated paper filter element is formed into the inside of the crimped housing. This kind of filter spins off with the use of an oil filter wrench and tightens by hand force only. A square-cut rubber O-ring fits into a groove in the base of the filter

FIGURE 12-11 **A.** Spin-on filter and O-ring. **B.** Cartridge paper filter, housing, and bolt.

Applied Math

AM-30: Volume: The technician can determine if the existing volume is within the manufacturer's recommended tolerance.

A technician was instructed to change the engine oil and filter on a late model automobile. In addition to this, he was also to change the automatic transmission fluid and filter. The technician has access to manufacturer's service information, which he consulted before starting the tasks. The service information stated that 5.5 quarts of oil would be needed for an engine oil change with filter replacement. Concerning the automatic transmission fluid and filter change, the manual stated 9.5 quarts are needed for this service.

The technician begins working by draining the engine oil and filter. As he puts the new oil into the engine, the technician counts the number of quart containers. He discovers that after the engine was started, to fill the oil filter and shut off, it takes a total of 5.5 quarts to bring the oil level to the exact full mark on the dipstick. By this method, the technician was able to determine that the existing volume is within the manufacturer's tolerance.

At this point, the technician goes on to the transmission fluid and filter change. He drains the fluid and changes the filter. As before, the technician counts the number of quart containers necessary for filling the system properly. He pours in one quart at a time, in order to take an accurate count. The technician observes that it takes 9.5 quarts to fill the system to the full line on the dipstick, with the engine running in park. By this method, the technician is able to verify that the existing volume is within the manufacturer's tolerance.

and seals the base of the filter to the engine block. A new O-ring comes with the filter, so it gets replaced with the filter. Be aware, though, that the old O-ring may stick to the filter adapter on the engine block. If you do not notice this and leave the old O-ring on along with the new O-ring, the old one will not be able to stay in place because it is not in any groove. As a result, it will get pushed out of place when the engine is started and most, if not all, of the engine oil will be pumped out onto the ground. Always check for the old O-ring when removing the oil filter.

The cartridge style of oil filter uses a separate reuseable metal or plastic housing and a replaceable filter cartridge. It is typically held together in one of two ways: threaded center bolt or screw-on housing. If it uses a center bolt, it will have a sealing washer between the bolt and the housing to prevent oil from leaking out. There is also a seal that fits either between the cylindrical housing and the filter adapter on the block or between the cylindrical housing and the end cap, depending on the design. Cartridge filters must be disassembled, the housing cleaned, and the paper filter element and any O-rings or seals replaced with new ones.

Most oil filters on diesel engines are larger than those on similar gasoline engines, and some diesel engines

TECHNICIAN TIP

Magnets are also used as a type of filter. They attract ferrous metal particles and hold them in place until they can be cleaned off. Some manufacturers use magnetic drain plugs, which then need to be inspected and cleaned off as part of an oil change. Others place a magnet to the inside or outside of the oil pan. Although this style cannot readily be cleaned, it does hold the magnetic particles in place so they cannot travel freely.

have two oil filters. Diesel engines produce more carbon particles than gasoline engines, so the oil filter can have a full-flow element to trap larger impurities and a bypass element to collect sludge and carbon soot. In a bypass system, the bypass element filters only some of the oil from the oil pump by tapping an oil line into the oil gallery. It collects finer particles than a full-flow filter. After this oil is filtered, it is returned to the oil sump. If the bypass filter were to clog and stop oil flow, the flow of oil lubricating the engine components would not be affected.

Spurt Holes and Galleries

Pistons, rings, and pins are lubricated by oil thrown onto the cylinder walls from the connecting rod bearings. Some connecting rods have **oil spurt holes** that are positioned to receive oil from similar holes in the crankshaft FIGURE 12-12. Oil can then spurt out at the point in the engine cycle when the largest area of cylinder wall is exposed. This oil sprays from the connecting rod holes and lubricates the cylinder walls and piston wrist pin, and may help cool the underside of the piston.

Oil is fed to the cylinder head through oil galleries and on to the camshaft bearings and valve train. When oil reaches the top of the cylinder head and lubricates the valve train, it has completed its pressurized journey. The oil drains back to the oil sump through oil drain-back holes located in the cylinder head and engine block.

TECHNICIAN TIP

In many cases, the ends of the oil galleries are plugged with a threaded pipe plug or a small soft plug. During an engine rebuild, these plugs are normally removed and the galleries cleaned with stiff wire brushes. It is very important to make sure the plugs have been reinstalled with a sealer and tightened properly so that they do not leak. Many a technician has started up a newly rebuilt engine and had oil pour out of the bell housing, all because one or more of the oil gallery plugs were missing.

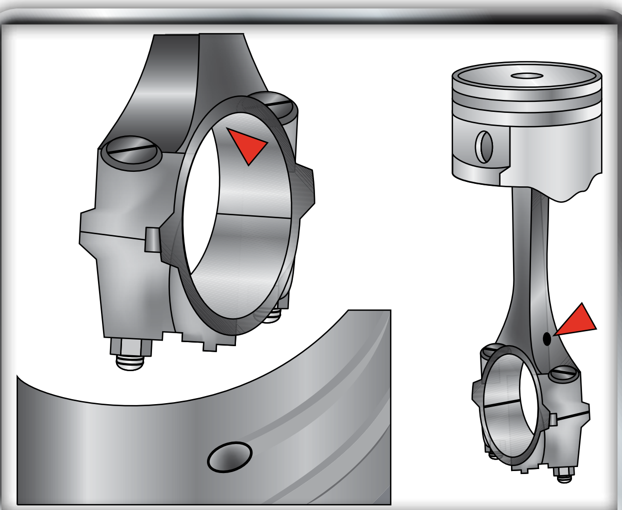


FIGURE 12-12 Some connecting rods have oil spurt holes, which are positioned to receive oil from similar holes in the crankshaft.

Oil Indicators

A lubrication system failure can be catastrophic to the engine. Because of the damage that would happen if the lubrication system failed, a warning system is installed to let the driver know the system has failed. If oil pressure falls too low, a pressure sensor threaded into a gallery can activate a low oil pressure warning light, register pressure on a gauge, or turn on a low oil pressure warning message FIGURE 12-13. The pressure sensor is also commonly called a sending unit since it sends a signal to the light, gauge, or message center in the dash. If the sending unit is designed as part of a warning lamp system, it is made up of a spring-loaded diaphragm and a set of switch contacts and is commonly called a pressure switch. Oil pressure is on the engine side of the diaphragm and a spring is on the other. With the engine off and the ignition switch in the run position, the oil pressure is zero, so the spring holds the diaphragm toward the engine and the switch contacts are closed (i.e., making contact with each other). This causes current to flow from the warning lamp in the dash through the closed switch contacts in the sending unit to ground, which turns on the warning light. When the engine is started, oil pressure increases above spring pressure and the diaphragm is pushed away from the engine, opening the switch contacts and turning off the warning light. In some vehicles, the sending unit sends the electrical signal to the BCM, which is programmed to turn the light on below a certain pressure. This is how the system should work when everything is working normally. If the oil pressure drops below spring pressure while the engine is running, the light will come on, warning the driver of the low oil pressure condition.

If the sending unit is part of an oil pressure gauge system, it usually uses a variable resistor within the sending unit. The variable resistor is moved by the oil pressure moving the diaphragm against the spring pressure. As the pressure increases, the diaphragm is forced against spring pressure and changing the resistance of the variable resistor. This changes the amount of current flowing through the oil pressure gauge and causes it to read higher. If the engine oil pressure drops, then the spring pushes

FIGURE 12-13 If oil pressure falls too low, a pressure sensor in a gallery can **(A)** activate a warning light, **(B)** register on a gauge, or **(C)** turn on a warning message.

the diaphragm toward the engine, again changing the resistance of the variable resistor and the current flowing through the oil pressure gauge, decreasing the pressure reading on the gauge. Some factory-installed oil pressure gauges include a warning light to warn the driver of low oil pressure. In many instances, a driver may not notice that the oil pressure gauge reading has dropped and will keep driving the vehicle, leading to engine damage. But the warning light is designed to catch the driver's attention

TECHNICIAN TIP

Some people erroneously refer to the low oil pressure warning system as a low oil level warning system. They think this because, if the oil level gets really low, then the oil pump will draw air into the lubrication system and the oil pressure will fall, turning on the low oil pressure warning light. Unfortunately, if the oil is allowed to get that low, it is doing damage to the engine. A true low oil level warning system is designed to alert the driver when the oil level approaches the "add" mark, which is well before engine damage is being done.

TECHNICIAN TIP

Many vehicle manufacturers have moved to using a switch type sending unit with a gauge. The switch is spring loaded so that it will come on below a predetermined pressure. But it also allows current to flow through a resistance that is in series with the switch. When the oil pressure is above the spring pressure, the resistor causes the oil pressure gauge to stay mid-scale. When oil pressure falls below this setting, the contacts open and the gauge reads low. This can confuse drivers since the oil pressure remains very steady for many years, and all of a sudden, it drops to zero. As the engine clearances become larger, or if oil becomes thin, oil pressure drops. Once it falls low enough that spring pressure overcomes oil pressure, the gauge will read low or zero.

so that he or she can stop the vehicle and investigate the cause of the low oil pressure.

If the sending unit is part of a driver information system, then the sending unit could be of the switch type or the variable resistance type. It usually also would include a sensor for low oil level monitoring and maybe even an oil temperature monitor. You will need to investigate various manufacturers' driver information systems to familiarize yourself with the different systems and strategies each manufacturer uses.

Oil Analysis

Oil will suspend particles as the engine wears. Analysis of the engine oil is a useful way to see what parts are wearing in the engine. The military as well as many companies use oil analysis to ensure that the engine oil is changed at the appropriate interval. A small tube is slipped down the oil dipstick tube all the way to the oil pan sump. A vacuum device is hooked to this tube to pull a sample of oil from the pan to a collection container. This sample is labeled with the vehicle information and sent to a lab. The lab thoroughly analyzes the oil and reports the findings back to the shop. The report lists physical properties such as viscosity, condensed water, fuel dilution, anti-freeze, acids, metal content, and oil additives. Each of these attributes can be used to determine the condition of the oil as well as the engine. When oil analysis is performed for a particular engine on a regular basis, issues can usually be addressed before they become catastrophic. Oil analysis is typically used in heavy vehicle applications that may use 3 or more gallons (11.4 or more liters) of engine oil. Some race teams will analyze the engine oil to ensure that the engine is not being damaged.

As a technician, a simple test to check for excessive engine wear is to take a white paper towel and wipe the oil from the dipstick on it. Hold the towel to the light and move it back and forth to see if light reflects from metal. If metal is in the oil, there is substantial wear happening inside the engine.

Oil Monitoring Systems

Oil monitoring systems are used to inform the driver when the oil needs to be changed. There are several types of **oil monitoring systems**. Some oil systems are simply timers that keep track of mileage and will activate a warning light to notify the driver when it is time to change the engine oil. Other systems are very sophisticated, analyzing the conductivity of the oil through a sensor in the oil pan and monitoring changes that indicate it is time to change the oil. Depending upon the feedback from the sensor, the monitoring system computer will activate the change oil light or message to warn the driver that it is time to change the oil.

Another monitoring system, called an oil-life monitor, calculates the expected life of the oil and displays it to the driver. The computer receives inputs from several sensors that take into account the number of start-ups, mileage, driving habits/conditions, temperature, length of run time, and other data to calculate the remaining life of the oil, which is displayed as a percentage. When the oil is freshly changed and the oil-life monitor is reset, it will say the oil life is 100%. As the oil life wears out, the monitor will read closer to 0% oil life, informing the driver of the need to change the oil. Since it monitors the conditions the oil is operating under, the life of the oil can change drastically depending on the conditions. For example, if the vehicle were only driven in moderate temperatures for long distances, the oil would be good thousands of miles longer than a vehicle driven in stop-and-go traffic and with long periods of idling. Each vehicle equipped with an oil monitoring system has a specific reset procedure to turn the light or message off after an oil change.

TECHNICIAN TIP

As a technician, you will have to be able to find the procedure to turn the light off and reset the oil monitoring system. Refer to the service manual or owner's manual for resetting procedures. The reset procedures range from something as simple as pushing a button, to having to go through a set of steps, to having to use a dedicated tool.

Types of Lubrication Methods

Pressure System

Modern vehicle engines use a **pressure, or force-feed, lubrication system** where the oil is forced throughout the engine under pressure FIGURE 12-14. In gasoline engines, oil will not flow up into the engine by itself so the oil pump collects it through a pickup tube and strainer and forces it through an oil filter, then into passageways, called galleries, in the engine block. The galleries allow oil to be fed to the crankshaft bearings first, then through holes drilled in the crankshaft to the connecting rods. The oil also moves from the galleries onto the camshaft bearings and the valve mechanism. After circulating through the engine, the oil falls back to the oil sump to cool. This design is called a wet sump lubrication system.

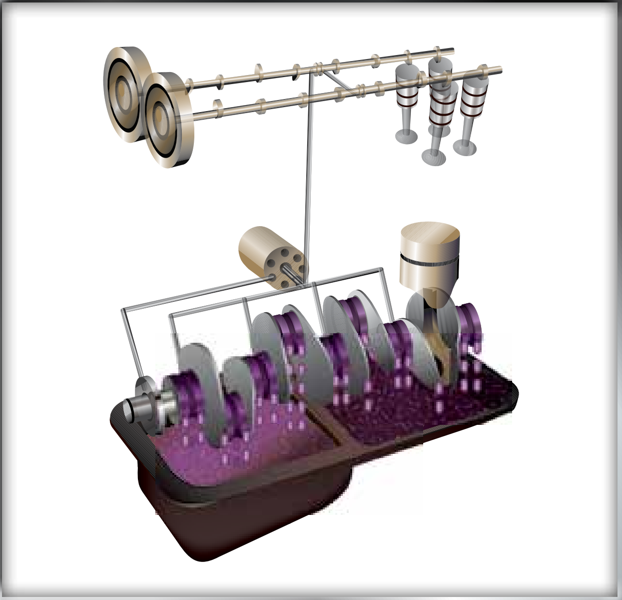


FIGURE 12-14 A pressure, or force-feed, lubrication system.

Some engines use a dry sump lubrication system. It uses all of the parts that make up a wet sump system and it lubricates the engine in the same way. It differs from the wet sump system in the way the oil is collected and stored. In a dry sump system, the oil falls to the bottom of the engine into an oil collection pan. A **scavenge pump** then pumps it to an oil tank where it is stored until the normal oil pump collects it and pumps it through the filter and engine in the normal way. Because there is no oil storage sump under the engine, the engine can be mounted much lower than in a wet sump system, which allows the vehicle to have a much lower center of gravity. The oil tank can be positioned away from the engine where it can get best cooling and the amount of oil in the system can be much greater than in the wet sump system since space is less of an issue.

Diesel engines are lubricated in much the same way as gasoline engines, but there are a few differences. Diesel engines typically operate at the top end of their power range, so their internal operating temperatures are usually higher than those in similar gasoline engines. Thus, the parts in diesel engines are usually more stressed. Since diesel fuel is ignited by the heat of compression, the compression pressures (and compression ratio) are much higher than in gasoline engines. Diesel fuel has more British thermal units (BTUs) of heat energy than gasoline, so it produces more heat when it is ignited, placing more stress on the engine's moving parts. Because of stress from the higher compression and combustion pressures/temperatures, parts have to be much heavier, and with heavier parts, oil must be able to handle higher shear forces. As a result, diesel oils need a different range of properties and are classified differently, usually with a C rating in the API system. It is also common for many diesel engines to use an oil-to-water cooler to cool the oil in the engine. The cooler and oil filter are usually on the same mounting on the cylinder block.

Applied Science

AS-92: Friction: The technician can explain the need for lubrication to minimize friction.

Oil is a good lubricant in an engine because it has a low coefficient of friction. It creates a protective layer between two metal components, which both have a high coefficient of friction. The high coefficient of friction produces heat, causing the metal to expand, potentially creating engine wear and damage. Oil keeps the two metal components from rubbing against each other, thus preventing damage.

Splash Lubrication

Not all lubricated engine components are lubricated by the pressure-fed system. Some are lubricated by the **splash lubrication** method FIGURE 12-15. In this method, the oil is thrown around and gets into spaces that need lubrication. Automotive and diesel engines use splash lubrication for lubricating the cylinder walls, pistons, wrist pin, valve guides, and sometimes the timing chain. The oil that is splashed around usually comes from moving parts that are pressure-fed; as the oil leaks out of those parts as designed, it is thrown around and provides splash lubrication to the needed components.

Most small four-stroke gasoline engines use only splash lubrication to lubricate all of the parts on the engine including the crankshaft bearing, camshaft, and lifters. On horizontal-crankshaft engines, a **dipper** on the bottom of the connecting rod scoops up oil from the crankcase for the bearings. The dipper is also able to splash oil up to the valve mechanism. Alternatively, an **oil slinger** can be driven by the crankshaft or camshaft. A slinger is a device that runs half-submerged in the engine oil. The oil is slung from the slinger upward by centrifugal force to lubricate moving parts. A similar system is used in most small vertical-crankshaft engines. Oil is also splashed up to the valve mechanism from the centrifugal force of the slinger spinning at engine speed.

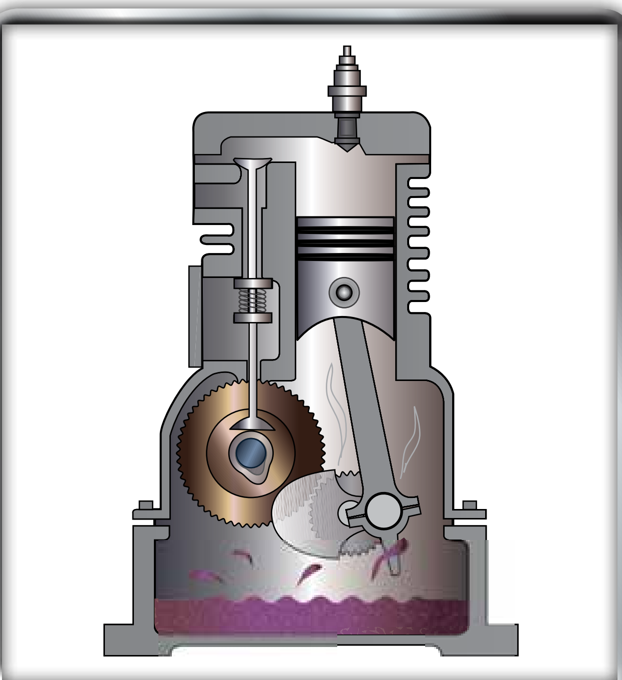


FIGURE 12-15 A splash lubrication method.

Maintenance and Repair

Tools

The tools for lubrication repair include **FIGURE 12-16**:

- A variety of oil filter wrenches to remove the oil filter
- A set of wrenches and a socket set to remove the oil drain plug and any engine covers
- A mirror and a quality light for leak testing
- A special socket to remove many of the oil pressure switches or sensors

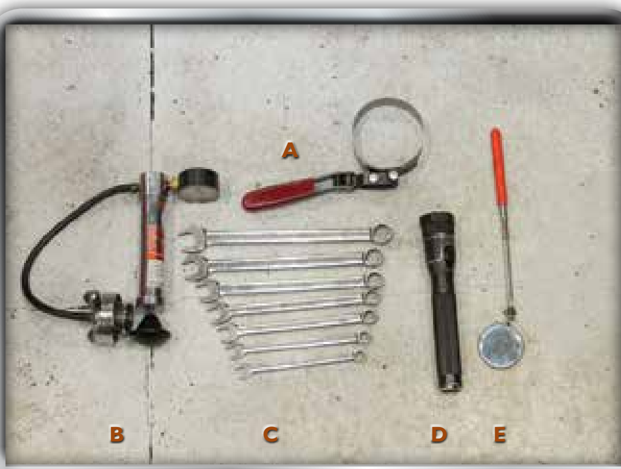


FIGURE 12-16 Tools for lubrication repair. **A.** Oil filter wrench. **B.** Coolant pressure tester. **C.** Set of wrenches. **D.** Light. **E.** Mirror.

Checking the Engine Oil

Checking the engine oil level regularly is necessary and should be performed during every fuel fill-up or every other fuel fill-up, depending on the age and condition of the vehicle. There is a danger of damaging the engine if the engine oil drops too low in the oil sump. The oil level can be low either because there is an oil leak or because the engine is consuming oil by burning it. Burning engine oil could be due to worn piston rings, worn valve guides, or a malfunction with the positive crankcase ventilation (PCV) system. Checking oil level should also be part of any pretrip check or part of a predelivery inspection on a new car at the dealership. Predelivery inspections are performed on new vehicles before delivering to the purchaser and help to ensure that the vehicle is being delivered in the condition the manufacturer specifies and without any known faults or defects that would reflect negatively on the customer satisfaction index for the manufacturer or dealer.

Always make sure the vehicle is on a level surface and the engine is off before taking a reading. If you do not, you will get inaccurate readings. Also wipe the dipstick off and reinsert it fully before removing it and reading it. When reading it, hold the dipstick horizontal so the oil will not run down the stick. Typically, the amount of oil needed to raise the oil level from the bottom of the "safe" mark on the dipstick to the "full" mark is about a quart. This amount may vary, so always check the service manual to determine the correct quantity. Always install the recommended amount and type of oil given in the service manual. Although fresh oil is translucent and oil that needs to be replaced often looks black and dirty, it is usually difficult to assess the condition of engine oil simply by its color. Oil loses its clean, fresh look very quickly but may still have a lot of life left in it.

The best guide to knowing when to change the oil is the vehicle's oil-life monitor, if equipped. It will tell you the percentage of oil-life remaining before a change is needed. If the vehicle is not equipped with an oil-life monitor, check the oil change sticker on the windshield or ask the owner for oil change records to determine if the oil needs to be changed. This can ensure that the oil is not changed too often, which would be an unnecessary expense for the customer. Our job as technicians is to provide high-quality work only when it is truly needed by the customer. Part of being a professional is letting customers know when they do and when they do *not* need a service performed. Informing the customer of what needs to be done and what does not, along with an explanation, helps to build trust with the customer and often results in the customer returning to your shop for future repairs.

If the oil on the dipstick is not blackish in color but looks milky gray, it is possible that there is water (or coolant) being mixed into the oil. This could indicate a serious problem somewhere inside the engine, such as a leaking head gasket or a cracked head, and you should report this to your supervisor immediately. Engine operating conditions can also influence the oil's condition. For instance, continuously stopping and starting the engine with very short operating cycles can cause condensation to build up inside the engine. An extreme case of this will cause very rapid oil deterioration and will require frequent oil changes. The oil of a vehicle that is running too rich or that has a leaking fuel injector will smell like fuel and will be very thin. These problems can ruin an engine quickly, as oil will not adequately lubricate the moving surfaces in the engine. If you had to add oil to the engine, do not forget to reinstall the filler cap after topping off the oil.

To check the engine oil, follow the steps in **SKILL DRILL 12-1**.

SKILL DRILL 12-1 Checking the Engine Oil

1. Locate the dipstick. With the engine off, remove the dipstick, catching any drops of oil on a rag, and wipe it clean. Observe the markings on the lower end of the stick, which indicate the "full" and "add" marks or specify the "safe" zone.

2. Replace the dipstick and push it back down into the sump as far as it will go. Remove it again, and hold it level while checking the level indicated on the bottom of the stick. If the level is near or below the "add" mark, then you will need to determine if the engine just needs topped up to the full level with fresh oil or replaced with new oil and oil filter.

3. Check the oil for any conditions such as unusual color or texture. Report these to your supervisor. Check the oil monitoring system, oil sticker, or service record to determine if the oil needs changed. (Some oil monitoring systems show the percentage of life left in the oil.)

4. If additional oil is needed, estimate the amount by checking the service manual guide to the dipstick markings. Unscrew the filler cap at the top of the engine, and using a funnel to avoid spillage, turn the oil bottle so the spout is on the high side of the bottle and gently pour the oil into the engine. Recheck the oil level.

5. Replace the oil filler cap, and check the dipstick again to make sure the oil level is now correct.

Safety

If the engine has been running, be careful not to burn your hand or arm on the exhaust manifold or any other hot part of the engine when reaching for the dipstick. Remember, the dipstick and the oil on it will also be hot. Dripping oil from the dipstick will smoke or burn if it falls on any hot engine surfaces.

TECHNICIAN TIP

Make sure the hood is secure with a hood prop rod, if necessary. Always make sure you wear the appropriate personal protection equipment before starting the job. It is very easy to think that nothing can happen on a basic job like checking the oil level.

Draining the Engine Oil

Draining the engine oil is a necessary task any time the oil and filter are to be changed or whenever the oil pan needs to be removed for service work. Draining the engine oil for an oil change is necessary after a certain time or mileage interval to remove the dirt and particulates that are suspended in the oil. As the engine wears, the very small pieces of metal will get suspended in the oil. Removing the old contaminated oil helps to make the engine last longer. Always follow the manufacturer's oil change interval, and remember that normal use and severe use have different oil change intervals.

When draining the oil, several precautions are necessary. First, the engine oil is normally changed after the engine is fully warmed up. This helps to stir up any contaminants, making them easier to flush out with the draining of the oil. However, that means that the oil can be 200–300°F (93–149°C), so use disposable gloves and don't burn yourself.

Second, make sure you locate the correct drain plug—or in some cases, the correct *two* drain plugs. Some vehicles have a drain plug on the transmission/transaxle that can be mistaken for the oil drain plug. If in doubt, look it up or ask your supervisor to point it out.

Third, many drain plugs are either angled off of the bottom radius of the oil pan or almost sideways at the bottom side of the pan. This means when the drain plug is removed, hot oil will want to spray sideways. Always make sure you take into consideration what path the oil will take. Oil can shoot out pretty far. The lower the drain pan is compared to the drain plug, the harder it will be to judge the distance the oil will spray.

Fourth, the drain plug gasket can be of the integrated silicone, long-life style that rarely needs to be replaced. The gasket can also be a one-time-use gasket made of plastic, aluminum, or fiber. This type of gasket should be replaced during every oil change since it is crushed to conform to any irregularities of the pan and drain plug. Because it is crushed, it will not conform as easily the next time it is tightened. This means that someone may think it needs to be tightened excessively to prevent seepage. Overtightening can strip the threads on the oil pan, especially if it is made of aluminum, or can strip the threads on the drain plug itself. Replace a non-silicone drain plug gasket every time it is removed.

To drain the engine oil, follow the steps in **SKILL DRILL 12-2**.

> **TECHNICIAN TIP**
>
> When removing the drain plug, be sure to use the proper-sized wrench or socket. Always inspect the drain plug gasket for damage before reusing; some manufacturers require the use of a new drain plug gasket each time the drain plug is removed. Always look up and torque the drain plug to proper specifications, as overtightening could damage the threads of the plug and oil pan, and undertightening could cause an oil leak or the plug to vibrate loose and fall out, resulting in the loss of all the engine oil.

> **TECHNICIAN TIP**
>
> Refer the customer to the owner's manual to determine when the oil should be changed. That could be based on a mileage interval, time interval, or oil-life monitor. You may also need to verify whether the vehicle is operated under normal or severe conditions. Severe conditions may include driving in low temperatures, stop-and-go driving, dusty conditions, short trips, towing, etc. Intervals for severe driving conditions are sooner than normal driving intervals.

Replacing Oil Filters

Oil filters are designed to filter out particles that find their way into the oil. The filter will catch particles that result from carbon from the combustion process that leaks past piston rings or small metal flakes that result from normal engine wear. The engine oil will suspend some of the particles while the heavier particles will fall to the bottom of the oil pan. The oil filter is designed to catch the particles and let the oil flow through. It is critical to change the oil filter at the manufacturer's recommended mileage to help ensure that it does not become clogged.

When changing a spin-on oil filter, be careful of a few things. First, an oil filter wrench is only used to remove an oil filter. It is never used to install an oil filter. Installation must be performed by hand.

Second, the O-ring that seals the spin-on oil filter to the block tends to stick on the engine block when the filter is being removed. This can lead to double-gasketing, which occurs when the new O-ring in the new filter is installed over the old O-ring. Since the groove in the filter is only deep enough to hold the new O-ring, the old one is not held in place. Once the engine is started, the oil pressure pushes it out of place and oil is pumped very quickly out of the engine and onto the floor. This not only makes a huge mess and wastes good oil, but if you don't realize it has happened, the engine could be damaged in

SKILL DRILL 12-2 Draining the Engine Oil

1 Before you begin, clean up any oil spills, obtain the oil drain container (and make sure it has enough room for the oil to be drained), have enough new oil of the correct type to refill the engine, have the correct oil filter, and ensure that the engine oil is up to operating temperature before starting the oil change.

2 Identify the location of the oil drain plug. Some vehicles have two drain plugs, draining separate sump areas. If the drain plug is leaking, damaged, or does not look right, inform your supervisor. Use a box wrench or socket to remove and replace the drain bolt. Be careful that you do not remove the transmission drain plug by mistake.

3 Position the drain pan so it will catch the oil. Remove and inspect the drain plug and gasket; replace as necessary.

4 Allow the oil to drain while you are dealing with the drain plug, gasket, and oil filter (see Skill Drill 12-3).

5 Screw in the drain plug all the way by hand and then tighten it to the torque specified by the manufacturer. Wipe any drips from the underside of the engine.

6 Safely dispose of the drained oil according to all local regulations.

only a minute or two of running. Always check that the old O-ring was removed with the filter. If it was not, reach up and peel it off of the filter mounting.

Third, when installing the spin-on oil filter, smear a bit of oil on the surface of the O-ring. Doing so lubricates it so that it will spin with the oil filter as it is being tightened. Failure to lube the O-ring can cause it to bind and roll out of the oil filter groove when the filter is being tightened.

Last, when installing the spin-on oil filter, it can be hard to see how it is going on the threaded filter adapter. If you get it cross-threaded, it will leak just like a double-gasketed O-ring. Plus you are likely to damage the threads

TECHNICIAN TIP

To help judge how far to turn the filter to tighten it, mark the outside of the filter with a marker or a dab of oil (but remember to wipe the oil off when you have finished). Do not overtighten the filter. Typically, three-quarters to a full turn is adequate torque for a seal that will not leak, but make sure to follow the tightening instructions for the filter, which are on the filter and/or the box it came in. Be careful not to cross-thread the oil filter on the threaded adapter fitting.

on the adapter, making it harder to install the filter in the future. To prevent this problem, always start the filter by turning it with your fingers. Once you suspect it is started, stop and try to lift the filter off of the adapter. If it comes off, it has not started. Try to start it by finger again; then try to lift it off. If it does not lift off, then it has started onto the threads. Now count the turns that the filter spins on. It should go on at least five full turns before the gasket contacts the filter mounting surface if it is not cross-threaded. You can then tighten it by hand the appropriate amount as specified by the filter manufacturer, typically about three-quarters to one turn.

Manufacturers are returning to using cartridge filters more and more because it is easier to properly dispose of the oil. It also reduces the amount of waste generated from used spin-on filters. When changing a cartridge filter, be aware of the following situations. First, the only parts that get replaced are the paper filter cartridge and the O-rings or seals. All of the other parts are reused, so do not damage them or throw them away during disassembly.

Second, some cartridge filters are near the bottom of the engine, while others are on top. Use the service information to help you locate the filter. If the filter is on the top of the engine, there is a good chance that you will need to prefill the cartridge before installing the filter end cap. Again, check the service information for the vehicle you are working on.

Third, be careful with tightening a cartridge filter, as it is easy to crack or damage the housing—especially if it is plastic. Always follow the manufacturer's torque procedure.

SKILL DRILL 12-3 Replacing a Spin-on Filter

1 Check for new filter availability. Locate the filter being changed. It will usually be located on the side of the engine block or at an angle underneath the engine. Select the proper oil filter wrench.

2 Position a drain pan to catch any oil that will leak from the filter.

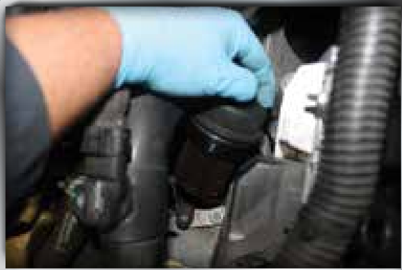
3 Remove the filter. Clean the seating area on the engine so that its surface and the surface of the new filter can seal properly. Make sure the O-ring from the removed filter is not still stuck to the filter mounting surface.

4 Confirm you have the correct replacement filter. Smear a little oil on the surface of the new O-ring.

5 Screw in the filter until the filter just starts and ensure that it cannot be pulled off. Then turn the filter by hand until the filter lightly contacts the base. Be careful not to cross-thread the oil filter.

SKILL DRILL 12-4 Replacing a Cartridge Filter (Replaceable Element)

1. Before removing a cartridge-style oil filter, make sure a suitable replacement filter is available. The filter may be located on the side of the engine block, at an angle underneath the engine, or on the top of the engine. If the filter is located in a plastic end cap housing, be sure to use the special tool that the service information calls for.



2. Position a drain pan to catch any oil that will leak from the filter. Unscrew the filter cartridge retaining bolt or oil filter cap, and remove the cartridge filter and housing or end cap.

3. Remove the filter and clean the housing or end cap as necessary, and replace any O-rings or gaskets on the assembly.

4. Smear a little oil on the surface of any new O-rings. Install the new filter cartridge back into its housing.

5. If the cartridge is on the top of the engine, the service information may direct you to pour a specified amount of oil into the filter cavity before the end cap is installed. Screw the cartridge bolt or end cap back in place and tighten to the specified torque. Be careful not to cross-thread the oil filter bolt or end cap.

Last, since the filter housing is being reused, it is important that it is clean before being reinstalled. You may need to wash it out in a clean solvent tank. Just be sure that you also remove any solvent residue before reinstalling it.

To replace a spin-on filter, follow the steps in SKILL DRILL 12-3.

To replace a cartridge filter (replaceable element), follow the steps in SKILL DRILL 12-4.

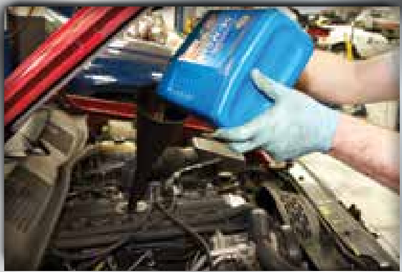
Before removing either type of oil filter, refer to the service information for the vehicle and identify the type of filter required. Make sure a suitable replacement filter is available.

Refilling Engine Oil

Refilling an engine's oil supply is necessary when performing an oil and filter change. It may also be necessary to refill the engine oil after a lubrication system part has been replaced, if the oil was drained. Always add the recommended amount of oil and grade of oil listed in the service information. After adding the required amount of oil, be sure to start the engine to build oil pressure and fill the oil filter, and then shut the engine off to check for leaks and the level on the dipstick. Fill the oil to the max line and no farther.

To refill the engine oil, follow the steps in SKILL DRILL 12-5.

SKILL DRILL 12-5 Refilling the Engine Oil



1. Using the service information, research the correct grade and the quantity of oil you will need to fill the engine. Turn the container of oil so that the spout is on the high side of the bottle. Pour the oil into the funnel carefully so that no oil is spilled onto the outside of the engine, and pour slowly enough to avoid the risk of blowback or overflow. Fill the engine only to the level indicated on the engine dipstick. Replace the filler cap.

2. Start the engine and check the oil pressure indicator on the dash. If the oil pressure is inadequate, stop. Do not continue to run the engine.

3. If the oil pressure is good, turn the engine off and check underneath the vehicle to make sure no oil is leaking from the oil filter or drain plug.

4. With a level vehicle, check the oil level again with the dipstick. It may be necessary to top off the engine by adding a small quantity of oil to compensate for the amount absorbed by the new filter. Do not overfill.

5. Refer to the owner's manual or the service information, and install a static sticker.

6. Reset the maintenance reminder system to remind the owner when the next oil change is due.

Wrap-up

Ready for Review

- Lubrication oil is distilled from crude oil and has additives to prevent acid formation, reduce oxidation, and maintain correct viscosity.
- Functions of oil include reduces friction, cushions, cleans, cools, and seals.
- Viscosity refers to how easily a liquid flows.
- Oil additives include: extreme pressure additives, oxidation inhibitors, corrosion inhibitors, anti-foaming agents, detergents, dispersants, pour point depressants, and viscosity index improvers.
- Engine oil also works to suppress engine noise and protect against corrosion.
- The three types of oils are: conventional, synthetic, and synthetic blend.
- Conventional oil is refined from crude oil and requires additives to function effectively.
- Synthetic oil is developed in a lab, is longer lasting, operates at higher temperatures, protects better against engine wear, and is more costly to manufacture.
- Synthetic blends combine conventional and synthetic oils.
- The American Petroleum Institute classifies oil into groups 1–5.
- Components of a lubrication system include: oil pan, oil sump, pick-up tube, oil pump, oil pressure relief valve, oil filter, spurt holes, and gallery.
- Types of oil pumps are: rotor type, crescent pump, and geared oil pump.
- The two most basic oil filtering systems are full-flow filters (most common) and bypass filters.
- Vehicles are equipped with oil indicators, oil monitoring systems, and some with an oil cooler.
- Types of lubrication systems are: splash and pressure (or force feed).
- Common lubrication system issues are infrequent oil changes, oil leaks, and valve train noise due to low oil pressure.
- Always check a vehicle's service manual when changing engine oil to determine the correct quantity.
- Lubrication repair tools include: oil filter wrench, wrenches and socket set, mirror, good quality light, digital volt ohm meter, and a special socket for removing oil pressure switches or sensors.
- Maintenance and repair procedures include: draining the engine oil; replacing the oil filter; refilling engine oil; and inspecting, testing, and replacing oil pressure and temperature switches.

Key Terms

antifoaming agents Oil additives that keep oil from foaming as it moves through the engine.

bypass filter An oil filter system that only filters some of the oil.

conventional oil Oil that is processed from crude oil; about 20% of oil is additives.

corrosion inhibitors Oil additives that keep acid from forming in the oil.

crescent pump An oil pump that uses a crescent-shaped part to separate the oil pump gears from each other, allowing oil to be moved from one side of the pump to the other.

crude oil Material pulled from the earth, originating from organic compounds broken down over time and formed into petroleum. This material is processed in a refinery to break down into various hydrocarbon substances such as diesel, gasoline, and mineral oil, among others.

detergents Oil additives that help to keep carbon from sticking to engine components.

dipper A type of splash lubricating system used in small engines. It works like a spoon scooping up oil and throwing it upward onto the crankshaft and other wear surfaces.

dispersants Oil additives that keep contaminants held in suspension in the oil, to be removed by the filter or when the oil is changed.

extreme loading Large pressure placed on two bearing surfaces. Extreme loading will try to press oil from between bearing surfaces.

extreme-pressure additive An oil additive that ensures that a protective coating is given to moving engine parts and that keeps oil from being forced out under extreme pressure. Helps oil to cushion components.

full-flow filter An oil filter installed on production cars. This oil filter cleans all oil coming from the oil pump on its way to the lubricated components.

galleries Passageways drilled or cast into the engine block or head(s), which carry pressurized lubricating oil to various moving parts in the engine, such as the camshaft bearings.

geared oil pump An oil pump that has two gears running side by side together to move oil from one side of the pump gears to the other.

gelling A thickening effect of oil in cold weather. This is not a desirable trait for lubricating oil, as it will not flow when it is gelling. Wax content in base stock mineral oil makes gelling worse.

hydro-cracking A process in which group 2 and group 3 oils are refined with hydrogen at much higher temperatures and pressures. This process results in a base mineral oil with many of the higher performance characteristics of synthetic oils.

hydrogenating A process used during refining of crude oil. Hydrogen is added to crude oil to create a chemical reaction to take out impurities such as sulfur.

lubricating oil Processed crude oil with additives to help it perform well in the engine.

lubrication system A system of parts that work together to deliver lubricating oil to the various moving parts of the engine.

mineral oil Base stock processed from crude oil in a refinery, used as the base material of all conventional oil.

oil cooler A device that takes heat away from engine oil by passing it near either engine coolant or outside air. Cooling the engine oil helps to keep it from overheating and breaking down.

oil galleries Oil passages that are drilled into the engine block and cylinder head(s). These passageways carry oil from the oil pump to critical moving parts.

oil monitoring system A system that alerts the driver when it is time to change engine oil. These systems will need to be reset for the customer after an oil change is performed.

oil pan The metal pan that covers the bottom of the engine, contains oil sump where engine oil is held.

oil pressure relief valve A valve usually located in the oil pump that limits the oil pressure. When oil pressure is reached, excessive pressure is bled back to the sump.

oil pump A device that pumps lubricating oil through the engine.

oil pump strainer A screen located on the oil pump pickup that keeps debris from being picked up by the oil pump.

oil slinger A device used on small engines, located on the crankshaft or driven by the camshaft. It works to fling oil up onto moving engine parts.

oil spurt holes Holes drilled into the connecting rod that spray oil up onto the cylinder walls and the piston wrist pins.

oil sump The lower part of the oil pan that holds lubricating oil for the engine. The oil pickup screen sits in this low point.

oxidation inhibitor An oil additive that helps keep hot oil from combining with oxygen to produce sludge or tar.

pickup tube A tube connected to the oil pump that acts like a straw for the oil pump to pull oil from the sump of the oil pan.

polyalphaolefin (PAO) A man-made base stock (synthetic) used in place of mineral oil. Oil molecules are more consistent in size and no impurities are found in this oil since it is made in a lab.

pour point depressants Oil additives that keep wax crystals from forming and causing the oil to gel during cold operation.

pressure, or force-feed, lubrication system A lubrication system that has a pump to pressurize the lubricating oil and push it through the engine to moving parts.

rotor lobes Lobes or rounded edges on rotors that squeeze oil and create pressure.

rotor-type oil pump An oil pump that uses rounded gears to squeeze oil through.

scavenge pump A pump used with a dry sump oiling system to pull oil from the dry sump pan and move it to an oil tank outside the engine.

splash lubrication A lubrication system that relies on oil being splashed onto moving parts by rotating engine parts striking the oil. These systems are typically used in small engines.

synthetic blend A blend of conventional engine oil and pure synthetic oil.

synthetic oil Synthetic oil that, in its pure form, uses man-made base stocks and is not derived from crude oil. This oil lasts longer and performs better than normal oil. The base stock additives are similar to those in conventional oils.

viscosity The ability of a liquid to flow.

viscosity index improver An oil additive that resists a change in viscosity over a range of temperatures.

ASE-Type Questions

1. Tech A says that one function of oil is to clean. Tech B says that one function of oil is to cushion. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
2. Two techs are discussing 5W20 oil. Tech A says the W stands for "weight". Tech B says the W stands for "Winter." Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
3. Tech A says that the higher the viscosity number, the thicker the oil. Tech B says that most modern vehicles use single weight oil. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
4. Tech A says that spin-on oil filters need RTV gasket sealer to seal the gasket. Tech B says that some oil filters use a replaceable paper filter cartridge. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
5. Tech A says that the oil pressure will typically be low if the oil level is at the "add" line on the dipstick. Tech B says that a cracked pickup tube could cause low oil pressure. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
6. Tech A says that most oil pumps are of the positive displacement style. Tech B says that oil pumps are designed to deliver more oil than is needed for an engine. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
7. Tech A says that it takes about 1 pint of oil to raise the oil level from "add" to "full." Tech B says that it takes about 1 quart to raise it that much. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
8. Tech A says that oil pressure is reduced when bearing clearances increase. Tech B says that oil pressure is regulated by the pressure relief valve. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
9. Tech A says that a full-flow oil filter filters all of the oil going to the bearings. Tech B says that a bypass filter bypasses the pump, so that any particles in the oil won't damage the pump. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
10. Tech A says that it is better to use two O-ring gaskets than just one on an oil filter. Tech B says that it is good practice to replace plastic, fiber or aluminum drain plug gaskets during every oil change. Who is correct?
    a. Tech A
    b. Tech B
    c. Both A and B
    d. Neither A nor B