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AIRCRAFT GENERAL KNOWLEDGE

CHAPTER 6 – LUBRICATION

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LUBRICATION

6.1 Types of Aviation Oils

In aviation there are generally three types of engine oil used:

6.1.1 Straight Mineral Oil

Straight mineral aviation oils are designed primarily for use in the break-in period for new or rebuilt engines. The primary reason for breaking-in an engine on mineral oils is that they do not contain any cleanliness or anti-frictional additives. This allows wear particles to remain in the ring belt area which then acts as a lapping compound. Due to these actions an increased wear rate in the compression ring/cylinder wall surface develops; this promotes a mechanical mating or “seating” of the rings. It is common practice to use this oil for the first 50 hours on new and overhauled engines.

6.2.1 Ashless Dispersant Oil

These are mineral oils with additives, designed to keep wear and combustion by-products dissolved and/or suspended, so that they drain out of the engine during an oil change. "Dispersant" is the cleaning/suspension agent, and "Ashless" describes the fact that the particular additive used will not create any ash, which may tend to glow in the combustion chamber and cause premature ignition or detonation.

The majority of piston engine manufacturers recommend ashless dispersant additive oils for general use, in preference to straight mineral oils because of their enhanced oxidation and thermal stability properties. Their characteristics reduce waste deposit (known as sludge) formation in the engine oil system, which could ultimately block the engine oil galleries and lead to premature wear or failure.

6.3.1 Synthetic Oil

A synthetic lubricant is a product that is made from a chemical reaction (synthesis) of two or more simpler chemical compounds, also containing the necessary performance additives. The base stocks that form a synthetic lubricant are tailored through molecular restructuring in order to meet specific physical and chemical characteristics.

Synthetics are good at lubrication, and flow well at lower temperatures. Synthetic oil pumps easily, and quickly reaches the areas in the engine where it is required. It's especially suited for close tolerance parts running at high speed and that aren’t subject to combustion by-product wastes, such as in a gas turbine engine.

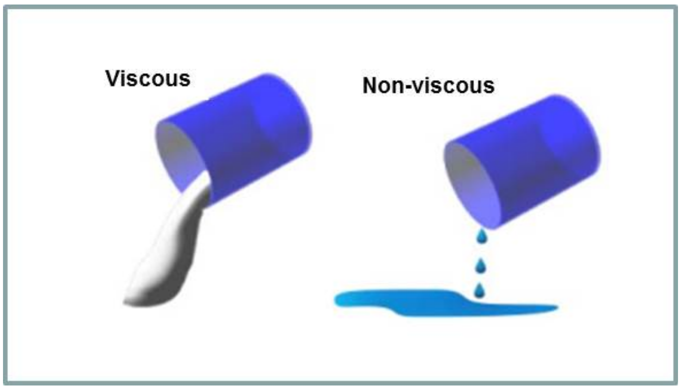
Synthetic oils don't break down easily due to mechanical wear action, so they can have a longer life if kept clean.

Unfortunately, piston engines create too many contaminants for synthetics to have much advantage in this area. Synthetics also have a shortcoming in that they don't dissolve contaminants or suspend them very well, and tend to let impurities either stay where they are, or drop out into the sump where they add to sludge formation.

6.2 Properties of Oil

6.1.2 Viscosity

The resistance of oil to flow (known as viscosity), is affected mainly by temperature. In cold weather viscosity is at its highest, and the circulation of oil is difficult. On the other hand, at high temperatures, viscosity is so low, and the oil so thin, that the lubrication function is reduced, and moving parts start to wear.



6.2.2 Measuring Viscosity

Aviation oil grades are classified numerically (80,100,140 etc). The approximation of their viscosity (grade) is measured using a device known as the Saybolt Universal Viscosimeter. A tube filled with 60 cubic centimetres of oil, heated to 5ºC (130ºF) or 99ºC (210ºF) is passed through a hole of known dimensions. The time taken to complete this test is a measure of the viscosity. This means the higher the number the thicker the oil (an 80 grade is thinner than a 100 grade).

6.3.2 Multi-Grade Oils

Multi-grade oils such as 20W-50 are new generation oils made possible by adding polymers to the oil. The polymers allow the oil to have different grades at different temperatures.

The first number indicates the viscosity of the oil at a cold temperature, while the second number indicates the viscosity at operating temperature. Multi grade oils are designed to change their viscosity with temperature changes, thus maintaining relatively constant lubrication capabilities throughout an engines temperature operating range .

The result is that at 100ºC, the oil has thinned only as much as the higher viscosity number indicates; so a 20W-50 oil has a 20 grade oil that will have the characteristics of a 50 grade oil when hot, but a 20 grade oil when cold.

6.3 Desired characteristics of oil

In order to ensure the best possible service from engine oil, manufactures characterise oil according to the following criteria:

- Flash point (temperature at which it ignites). **Should be high**.
- Cloud point (point at which the suspended wax begins to solidify, and crystallise giving the oil a cloudy appearance**). Should be high**.
- Pour point (temperature to which the oil can be cooled before it resists flow). **Should be low**.
- Specific Gravity**. Should be low**.

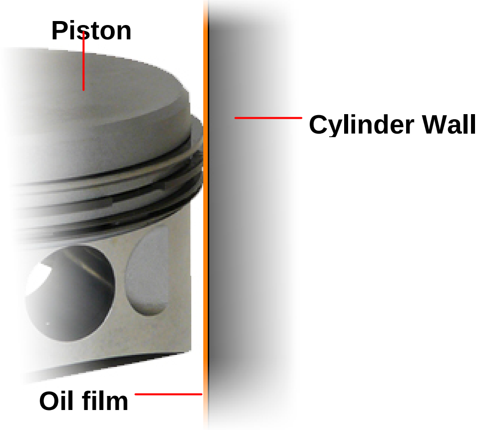
6.4 Desired qualities of lubricating oil

In order to achieve its purpose, lubricating oil should possess the following properties:

- Have the correct viscosity
- Have high anti-friction characteristics
- Have maximum fluidity at low temperatures
- Maintain its viscosity qualities even with changes in temperature
- Possess maximum cooling abilities
- Resistance to oxidisation
- Be non-corrosive

6.5 Function of Lubricating Oils

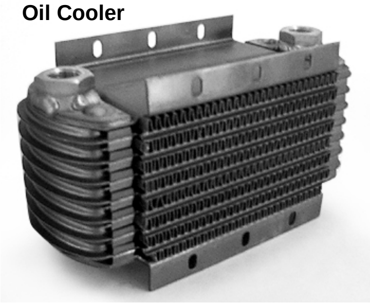
The engines oil system has two very important roles in the operation of the engine, namely lubrication of the moving parts, and aiding the cooling of the engine by reducing friction and therefore some of the heat from the cylinders.



6.1.5 Lubrication

A film of oil is provided between the moving parts of an engine. This oil wets the surfaces, fills in the slightly irregular metal surfaces and keeps those surfaces apart. The movement is now between layers of the oil, which slide over each other with very little friction.

6.2.5 Cooling



The oil is in contact with the moving parts of an aircraft engine, and it absorbs much of the heat from the combustion process. This heated oil then flows through the system into the oil cooler (heat exchanger), where the heat is given up to the outside air passing through the core of the cooler.

6.3.5 Cleaning

During normal engine operations metal particles, carbon and water can enter the oil. The ability of oil to hold these contaminates until they can be trapped in the filter helps keep the inside of the engine clean.

6.4.5 Protection

When metal is allowed to remain uncovered in the presence of moisture or some of the chemicals that contaminate the air, rust or other surface corrosion will form. This is especially true of metals surfaces such as cylinder walls or crankshaft, which have been hardened by the process of nitriding. A thin film of oil covering these surfaces will prevent the oxygen reacting with the metal and forming corrosion.

6.5.5 Sealing and cushioning

The viscous nature of oil, that is, its ability to wet the surface it contacts, makes oil a good sealing agent between the moving parts. The oil film on the cylinder walls and around the piston increases its ability to form a tight seal in the cylinder and the thin film of oil between the rocker arm and its bushing takes up much of the hammering shock from the valve action.

6.6 Lubrication System

A typical oil system includes the following components:

- Sump or tank holding the unpressurised oil
- Oil pump circulating the oil
- Pressure regulator controlling upper and lower limits of oil pressure
- Filters removing foreign matter
- Oil cooler shedding excess heat from the oil
- Oil pressure and temperature gauges displaying system pressure and temperature.

6.1.6 Types of Lubrication Systems

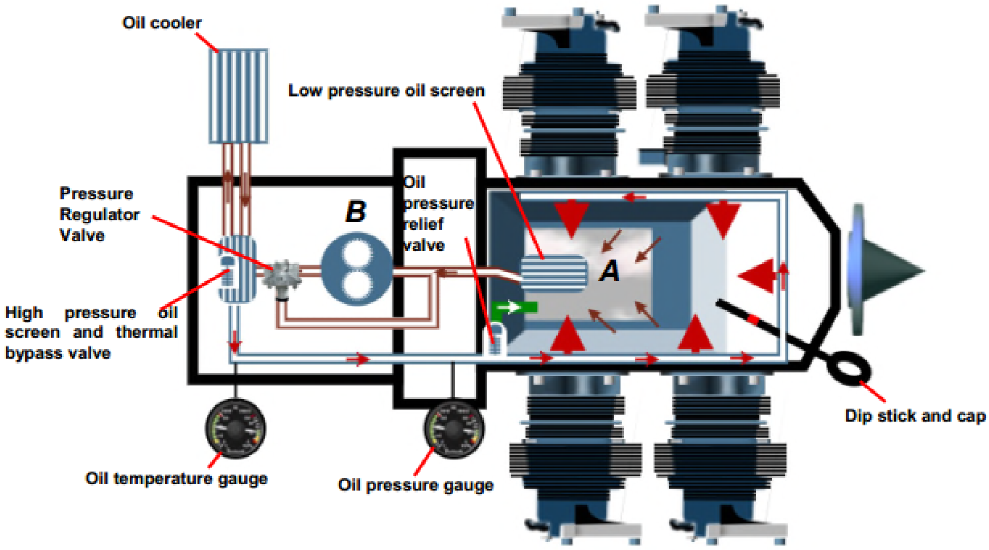
There are two commonly used lubrication systems in aircraft engines, they are known as:

- The wet sump system (generally used by horizontally opposed engines).
- The dry sump system (generally used by inverted, radial and high powered horizontally opposed engines).

Horizontally opposed
Typically Wet Sump

Radial
Typically Dry Sump

6.1.6.1 Wet Sump Lubrication System



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Most modern aircraft engines use a wet sump system, in which all of the *oil is carried in a sump*, which is attached to the crankcase. A dipstick is located in the sump to check the oil quantity.

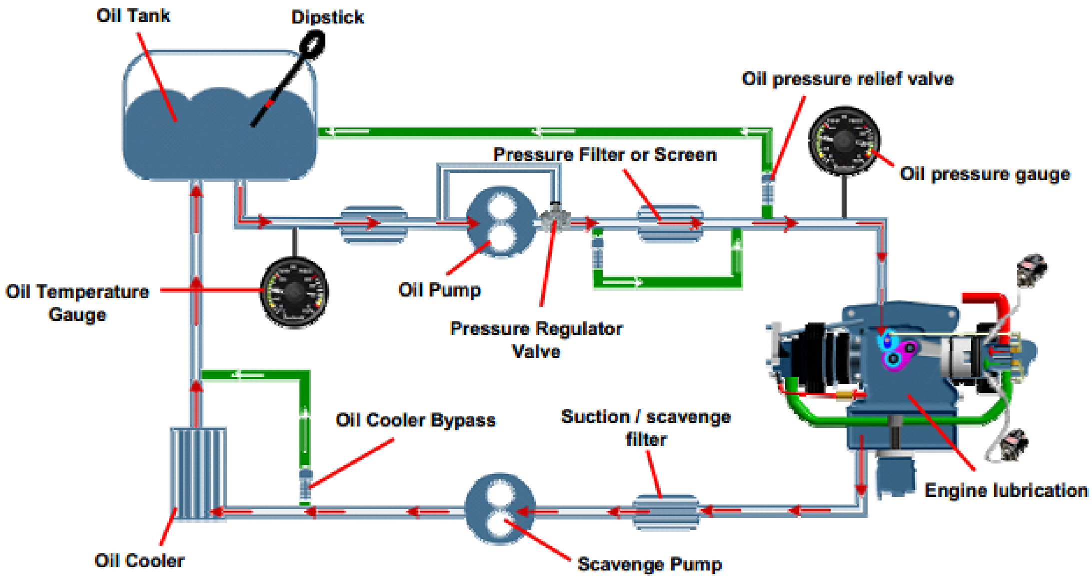
The oil is picked up through an oil suction screen by the pressure oil pump. From the pump exit, the oil is directed to the oil filter chamber, and if the filter should become clogged, a spring-loaded by-pass valve will open, permitting oil to flow directly from the pump to the oil filter outlet. From here, a passage leads to the adjustable oil pressure relief valve, and *any time the pressure exceeds that for which the valve is set, the excess will bypass back into the sump.*

On engines with thermostatically controlled oil coolers; if the temperature of the oil is below that for which the oil cooler by-pass valve is set, the oil goes directly into the oil gallery in the engine crankcase. If it is hotter than it should be, it must pass through the core of the cooler.

From this point, the oil lubricates the engine as in the dry sump system, and drains internally back into the sump for recirculation.

6.1.6.2 Dry Sump Lubrication System

In the dry sump lubrication system, *oil is stored in a separate tank*, circulated through the engine, and then returned to the oil storage tank. A dry sump system also requires a pump to return the oil to the oil tank. This is called a scavenge pump. To prevent oil pooling in the engine the scavenge pump is at least twice the capacity of the pressure pump



6.1.6.3 Oil Tank

The oil tanks are situated near to the engine, slightly above the oil pump inlet to ensure gravitational feed, and are generally constructed from aluminium or stainless steel. The tank provides sufficient space for oil expansion and foaming. The neck of the tank is fitted with a filter to prevent foreign objects entering the tank during filling.

The level of the oil is generally measured using a dipstick or a sight gauge, and on some aircraft electronic indicators (float type) provide a reading in the cockpit on a suitable gauge.

Important !!!

As part of a pre flight inspection, the oil quantity must be checked. If the check is via a dipstick, care must be taken that it is securely reinstalled and any refill caps are likewise secured.

6.1.6.4 Oil Pump

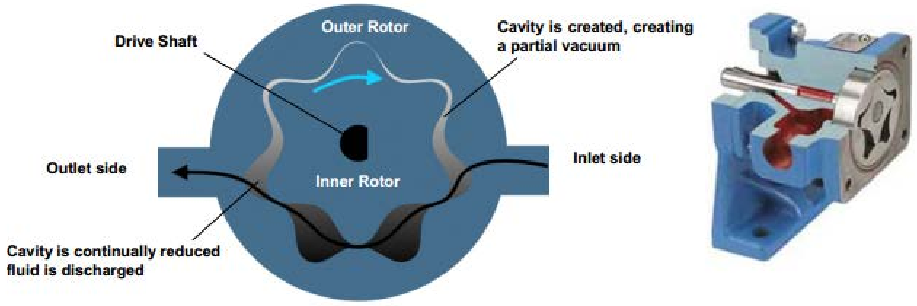
Oil is drawn from the tank by means of a positive displacement pump. The oil is routed through the pump then to a high-pressure oil screen or filter; the oil pump is driven by the accessory drive from the engine.

6.1.6.5 Scavenge Pump

Once the oil has circulated through the engine, it drains back into the crankcase, from where it is recovered by the scavenge pump. ***The scavenge pump has a greater pumping capacity than the oil supply pump***, to ensure that all the oil is scavenged from the engine. Before reaching the pump, the oil is passed through the scavenge filter or screen, in order to remove any wear particles which may have dislodged, and been picked up by the oil.

GEROTOR PUMP OPERATION

Gerotor elements utilize a drive shaft with an inner and outer rotor. As the inner rotor rotates, a cavity is created within the element. This cavity creates a partial vacuum between the inner and outer rotor and fluid is drawn in through the inlet side of the element. As the inner rotor continues to rotate, the cavity is progressively reduced in size and the fluid is discharged under pressure on the outlet side of the element.



6.1.6.6 Pressure filter or screen

Oil from the pressure pump is fed into the pressure screen or filter, to ensure that clean oil enters the lubrication system. However, should the pressure screen become clogged, the system is fitted with a **by-pass valve,** which allows the unfiltered oil to enter the system. The valve is configured to allow the oil to by-pass the pressure filter to ensure an uninterrupted oil supply.

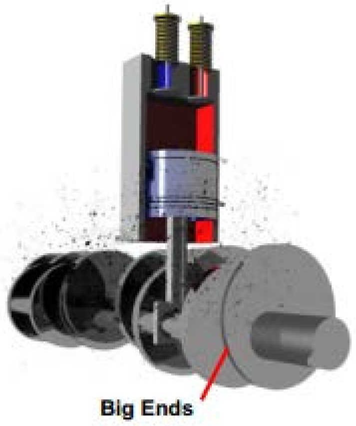
6.1.6.7 Oil pressure regulator/relief valve

The oil pump output is designed to maintain a desired pressure. The pressure of the oil should be high enough to ensure that the all the components are adequately lubricated; but too high a pressure could result in the system developing leaks. The valve, located on the output side of a pressure pump, is set *to relieve excess pressure* and to return this oil to the inlet side of the oil pump. Often these valves are adjustable, to allow for variations in engine oil pressures throughout the service life of an engine.

6.2.6 Engine Lubrication

6.2.6.1 Crankshaft cylinders and pistons

As the high-pressure oil enters the engine, it is fed into the main bearings by internal passages (oil galleries), and then into the hollow crankshaft. Lubricating the rotating assemblies, it escapes as a fine mist or spray and as a result of the centrifugal force of the rotating crankshaft thrown onto the cylinder walls.



Splash lubrication is not effective on its own, and is usually combined with pressure lubrication, which ensures:

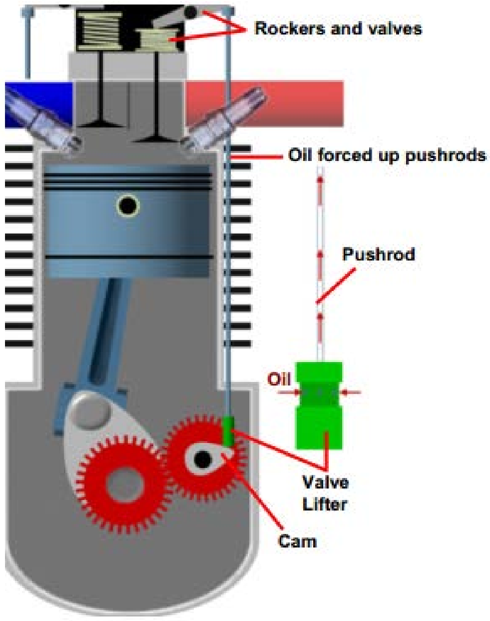
- Positive oil pressure into the bearings
- Greater cooling effect as more oil is circulated
- Positive lubrication in all flight attitudes

6.2.6.2 Cams, Camshafts

The cams, camshafts and other valve gear components are lubricated by directing high-pressure oil through a reducer valve.

6.2.6.3 Overhead valves

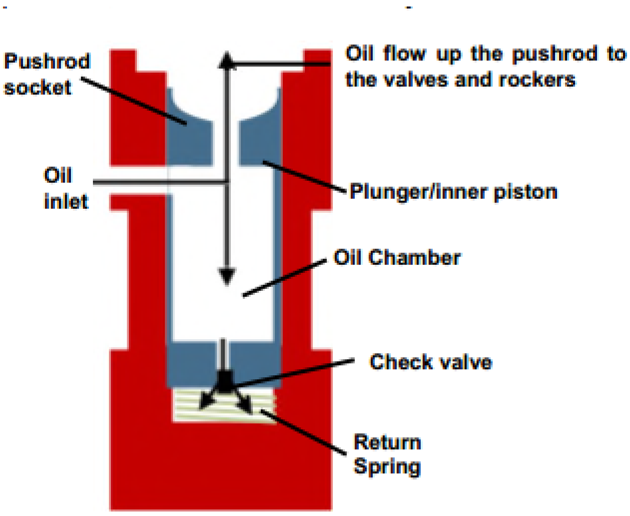
The overhead valve system is fed with oil via the centre of the pushrods. Oil under pressure enters the valve lifters via small holes, and is directed from here via the push rod to the valves and rockers. Drain lines return the oil to the engine sump from the rocker area.

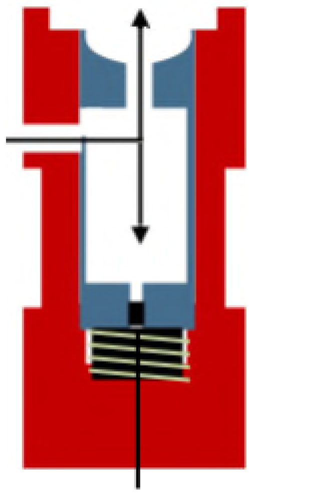


In engines making use of solid valve lifters, regular adjustments have to be made to maintain clearances between valves and rocker arms, to ensure correct valve operation. Component wear and different expansion rates of materials in the valve train are the reasons for these adjustments.

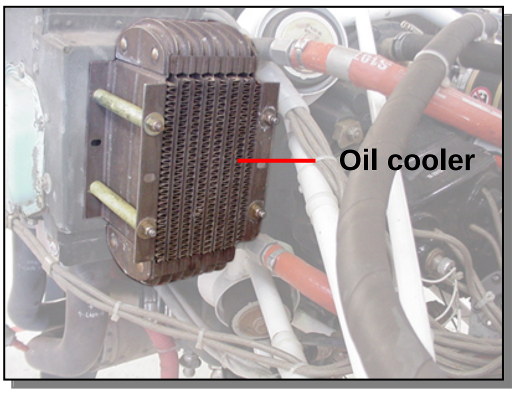
In order to overcome the constant need to adjust clearance on the valves and rockers, a hydraulic lifter system was introduced in some engines. These operate using high-pressure engine oil to maintain the correct settings. These hydraulic lifters have two roles, one to maintain clearance, and the other to supply oil via the push rods to the valves and rockers.

Upon entry into the lifter, pressurised oil flows in two directions. One direction is downward through the check valve at the bottom of the plunger to maintain rocker / valve clearance, and simultaneously, pressurised oil also flows upwards through the pushrod socket and into the pushrod, which carries it directly to the rocker area for lubrication.





6.2.6.4 Oil Cooler



As the lubrication system has an important role in removing heat from the engine, oil returning to the tank passes through a oil cooler. Airflow through the cooler disposes the heat to atmosphere.

Depending on the design of the lubricating system, the cooler may be situated either between the oil filter and the bearings, or in the return line between the scavenge pump and the oil.

Many oil coolers are fitted with a thermostat control valve; this valve keeps the oil temperature within the range specified for the engine operation.

6.3.6 Oil Pressure and Temperature Gauge Indications

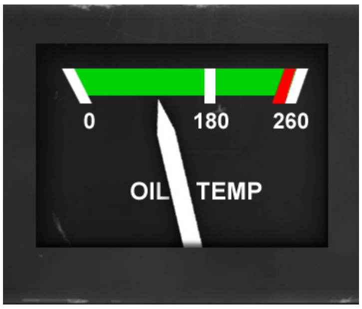
6.3.6.1 Oil pressure gauge

An oil pressure sensor is usually installed in an oil gallery after the pressure regulator valve.

The oil pressure gauge provides a direct indication of the oil system operation. It measures the pressure in pounds per square inch (p.s.i.) of the oil supplied to the engine. Green indicates the normal operating range, while red indicates the minimum and maximum pressures. There should be an indication of oil pressure within 30 seconds of engine start; it is recommended the engine be immediately shut down if this does not occur.

A below normal pressure reading is generally an indication that the oil pump is not providing sufficient pressure to circulate the oil through the engine, while a higher than normal oil pressure may indicate that the oil lines are blocked, or there is a fault with the pressure regulator valve. In either case, the pilot should assume that vital parts of the engine are not receiving oil, and follow the instructions in the aircraft-operating manual.

6.3.6.2 Oil temperature gauge



The oil temperature gauge measures the temperature of oil; *a temperature sensor is usually installed at a position before the oil enters the engine*. A green area shows the normal operating range and the red line indicates the maximum allowable temperature. Unlike oil pressure, changes in oil temperature occur more slowly. This is particularly noticeable after starting a cold engine, when it may take several minutes or longer for the gauge to show any increase in oil temperature.

Check oil temperature periodically during flight especially when operating in high or low ambient air temperature. *High temperature indications may indicate a plugged oil line, a low oil quantity, a blocked oil cooler, or a defective temperature gauge*. Low temperature indications may indicate improper oil viscosity during cold weather operations