Chapter 22

ENGINE LUBRICATION & COOLING SYSTEMS

ENGINE LUBRICATION SYSTEMS
(Excluding 2-stroke petrol outboards)

Fig 22.1: OLD STYLE LUBRICATION SYSTEMS
1. Suction strainer
2. Lube oil pump
3. Pressure relief valve (Crankcase breather)
4. Lube oil cooler
5. Lube oil filter
6. Engine block
7. Dipstick

Fig 22.2: MODERN LUBRICATION SYSTEM – INTERNAL (WET-SUMP) (Volvo Petrol Engine)
1. Lube oil strainer
2. Lube oil pump & Relief valve (Crankcase breather)
3. Lube oil filter
4. Hydraulic valve lifters (Not always fitted)
5. Lube oil gallery in engine
6. Drive for lube oil pump
ENGINE LUBRICATION IS NECESSARY FOR THE FOLLOWING REASONS:

- It reduces wear and prevents metal-to-metal contact between moving parts. This minimises friction and allows an engine to run smoothly without becoming too hot.
- It acts as a secondary engine cooling system with excess heat being extracted via the oil cooler.
- It removes grit and other contaminants from machine surfaces, accumulating them in the oil filter.
- It cushions the engine's bearings from shock of cylinder firing.
It neutralises the corrosive combustion products.
> It seals the engine’s metal surfaces from rust.

THE CLASSIC SYMPTOMS OF OIL RELATED ENGINE FAILURE ARE:
- Bearing failure
- Piston ring sticking
- Excessive oil consumption

HOW LUBRICATION OPERATES

In today’s engines (other than in 2-stroke petrol outboards), lubricating oil is circulated from the sump. It is known as the internal or wet-sump lubrication system. The oil is forced through pipe lines, drilled passages and splash feeds or is pressure fed through galleries in the crankcase, hence the term force-feed lubrication system. In some older engines, the oil reservoir is an external tank. They are said to have the dry-sump lubrication system.

Lube oil pumps are provided with a relief valve to cope with build up of high pressure. And, the filtration system incorporates a bypass valve. This allows unfiltered oil to reach the engine should the filter become blocked. However, when the bypass valve remains open, the debris from the filter may also be flushed into it. Filter plugging can also lead to distortion and cracks in the filter element due to increase in the pressure difference between outside and inside the element. This too would allow debris to flow into the engine.

As discussed in Parts & Components of an Engine, the sump (crankcase) is vented to the atmosphere in order to prevent vacuum build up due to movement of pistons or pressure created by heat.

The oil thickness (its resistance to flow) is known as VISCOSITY. The more viscous (thicker) oil is, the stronger the film it will provide. The thicker the oil film, the more resistant it will be to being wiped or rubbed from lubricated surfaces. On the other hand, too thick oil will have excess resistance to flow quickly to those parts in need of lubrication. Oil supply to all parts must be adequate regardless of the temperature.

For the maximum protection of an engine, a multigrade marine oil of the maker’s specifications should be used. Commonly, 20-grade oil is used in cold regions, 40-grade in the tropics, and 30-grade being the best all-rounder. It must be maintained to the correct sump level, and changed, along with its filters, as per the maker’s recommendation, to prevent build up of acids and contaminants in the oil.

PRELUBRICATION (AFTER LONG PERIODS OF ENGINE IDLENESS)

The Caterpillar prelubrication system provides the capability to prelubricate all critical bearing and journals before starting the engine. It is designed to minimise the sometimes-severe engine wear associated with starting an engine after periods of idleness.

The automatic system utilizes a small pump that fills the engine oil galleries from the sump until the presence of oil is sensed at the upper portion of the lubrication system. The starter motors are automatically energised only after the engine has been prelubricated.

The manual system uses the engine’s manually operated sump pump and allows the engine operator to fill all engine oil passages after oil changes, filter changes, periods of idleness, and before activating the starter motors.

LUBE OIL CHECKS

Check the oil level daily with the engine stopped. If necessary, add sufficient oil to raise the level to the proper mark on the dipstick. Make sure the dipstick marking has been adjusted if the engine is installed in a tilted position. All diesel engines are designed to use some oil, so the periodic addition of oil is normal. Never overfill the sump. The pressure created by too much oil can force it to seep past the main bearing seals.

If the oil level is constantly above normal, and excess lube oil has not been added to the crankcase, seek expert advice for the cause. Fuel or coolant dilution of lube oil can result in serious engine damage.

Check for normal operating pressure and temperature. Too much oil pressure will scour the bearings and too little seize them. Generally speaking, an average diesel engine will start cold at 450 KPa (65 psi) then drop back to around 240 KPa (35 psi) at a cruising speed producing optimum temperature.

Proper gauges are superior to Low Pressure Alarms. They usually do not switch on until the pressure is down to 48 KPa (7 psi). A combination of the two is an ideal solution.

On starting the engine, the Low Oil Pressure Alarm may sound for a few seconds. If the oil pressure does not rise within a few seconds, stop the engine and check the oil level, filter and breather.
Figure 22.6 shows an Oil Pressure Switch on a Caterpillar engine, which triggers the alarm when the oil pressure is below the rated pressure. It may be fitted with an Override Button, which is pushed to permit the engine to start without sounding the alarm. As the oil pressure increases, the button automatically comes out to RUN position.

Fig 22.7: OIL FILTER & REPLACING THE FILTER ELEMENT (A Caterpillar Engine)

Left: A crankcase breather valve with a vapour collector (Caterpillar)
Right: A vapour collector on a crankcase breather connected to air cleaner (Perkins showing securing clips)
COOLING SYSTEMS – INBOARD ENGINES

The marine internal combustion engines must be operated at a specific working temperature. Overheating causes excessive expansion, which can cause an engine to seize. Most marine engines are water-cooled. Their cylinders are surrounded by cooling water spaces known as a Water-jacket. With a few exceptions, the transmission oil too is cooled by either the engine’s water-jacket or a water jacket of its own.

On rare occasions, you may come across an AIR-COOLED marine engine or an OPEN CIRCUIT seawater cooling system. The latter is a direct seawater (raw water) cooling system.

Most marine engines are cooled by a closed-circuit fresh water system. The fresh water carrying the engine heat is circulated through an outboard mounted Keel Cooler or an inboard mounted Heat Exchanger (tube-nest cooler), where it is cooled by seawater. Seawater does not enter the Keel or Skin Cooler. It makes contact on the outside. In the case of the heat exchanger, the seawater is pumped in and circulated through it. It is then discharged overboard either through the exhaust or directly over the side. If discharged through the exhaust, it is known as the "Wet Exhaust" system. The keel cooling system has only a "Dry Exhaust".

HEAT EXCHANGER COOLING SYSTEM (OPEN CIRCUIT/CLOSED CIRCUIT)

Fig 22.9: HEAT EXCHANGER COOLING SYSTEM (Volvo Penta)
(Anti-siphon/vacuum valve is fitted where engine is fitted below the waterline. See also wet-exhaust system)

The heat-exchanger system is the most common form of cooling system employed in marine engines. The heat exchanger can be engine-mounted or remote from the engine. It has two water circuits: the closed circuit, which circulates through the engine block, and the open (or exchange) circuit. The latter uses raw water which, having been once used, is rejected. Two pumps are needed; one to circulate the fresh water through the engine and the heat exchanger, and the other to feed raw water to the heat exchanger.
The advantages of the Heat-Exchanger System are:

- The raw water only comes into contact with parts intended to withstand it. These parts are resistant to corrosion.
- A sufficient flow of water is available for cooling the exhaust pipe and exhaust gas.
- The amount of water in the sealed circuit is relatively small. This means that the engine will warm up fairly rapidly. The flow of water is easy to control with a thermostat.
- Addition of anti-freeze to protect the block in the winter.

AFTERCOOLING

The term Aftercooling is used in turbocharged engines where compressed air blown by the turbocharger is also cooled by a heat exchanger before entering the combustion chamber. Cooler air is denser and allows more fuel to burn.

JACKET WATER AFTERCOOLED

Heat Exchanger

1. Turbocharger
2. Aftercooler, jacket water cooled
3. Jacket water outlet connection
4. Jacket water inlet connection
5. Expansion tank
6. Jacket water pump
7. Auxiliary pump, seawater
8. Seawater inlet connection
9. Seawater outlet connection
10. Pressure cap
11. Duplex full-flow strainer
12. Heat exchanger
13. Shut-off valve
14. Seawater intake

KEEL COOLING SYSTEM
(CLOSED CIRCUIT)

In this system, closed circuit fresh water is cooled by passing it through pipes or, in steel hulls, a tank fitted beneath the hull. The former is known as keel cooling and the latter skin tank cooling. A pump circulates the fresh water through the engine as well as through the pipes or the skin tank. The cooler components in contact with the outside water should be of highly corrosion resistant material, such as copper-nickel or equivalent.

Fig 22.10: HEAT EXCHANGER COOLING SYSTEM
(Aftercooler is jacket-water cooled) (Caterpillar)

Fig 22.11: KEEL COOLING
(Closed circuit fresh water is cooled by passing it through pipes or, in steel hulls, a tank fitted beneath the hull.) (Caterpillar)
REGULATING THE TEMPERATURE

A thermostat and a bypass (at "ABC" in the illustration) regulate the jacket-water temperature. Depending on the temperature of the water discharged by the engine jacket, the thermostat closes and opens as necessary in order to direct all or a part of the discharged water to the cooler (through "Outlet" in the illustration). The remainder is bypassed to the expansion tank for mixing with water from the cooler. The following illustration shows the thermostat directing jacket water into the expansion tank and the cooler's inlet. It is known as the Controlled Inlet Thermostat. In some engines, thermostats are configured to direct jacket water into the cooler's outlet. They are known as Controlled Outlet Thermostats. Regardless of whether it is the inlet or the outlet control system, the thermostat is always placed at the jacket water outlet.

As illustrated, the inlet control system uses the expansion tank for mixing water from the engine with water from the cooler. The water returning to the engine is therefore less subject to temperature variations. In the outlet control system, water mixing is done at the water pump inlet. This can cause serious temperature variations in the engine when the sea is very cold.

EXAMPLES OF AFTERCOOLER ARRANGEMENTS

Sep22.13
SEPARATE CIRCUIT AFTERCOOLED
(Auxiliary seawater-cooled aftercooler on keel-cooled engine) (Caterpillar)

1. Turbocharger
2. Aftercooler, auxiliary water cooled
3. Jacket water outlet connection
4. Jacket water inlet connection
5. Expansion tank
6. Jacket water pump
7. Auxiliary water pump
8. Auxiliary water inlet connection
9. Auxiliary water outlet connection
10. Lines to aftercooler cooler
11. Lines to jacket watercooler
Fig 22.14
SEPARATE CIRCUIT AFTEROOLED
(Auxiliary seawater-cooled aftercooler on heat-exchanger cooled engine)
(Caterpillar)

1. Turbocharger
2. Aftercooler, seawater cooled
3. Jacket water outlet connection
4. Jacket water inlet connection
5. Expansion tank
6. Jacket water pump
7. Auxiliary seawater pump
8. Auxiliary seawater inlet connection
9. Aftercooler outlet connection
10. Pressure cap
11. Duplex full-flow strainer
12. Heat Exchanger
13. Shut-off valves
14. Seawater intake
15. Seawater discharge

Fig 22.15
SEPARATE CIRCUIT AFTEROOLED
(Two keel coolers)
(Caterpillar)

1. Turbocharger
2. Aftercooler, keel cooled
3. Jacket water outlet connection
4. Jacket water inlet connection
5. Expansion tank
6. Jacket water pump
7. Auxiliary fresh water pump
8. Auxiliary fresh water inlet connection
9. Aftercooler outlet connection
10. Bypass filter
11. Shut-off valve
12. Duplex full-flow strainer
13. Keel cooler for aftercooler
14. Keel cooler for jacket water
15. Expansion tank for aftercooler circuit
16. Vent line for aftercooler circuit
17. Auxiliary expansion tank
18. Flexible connection
Fig 22.16
SEPARATE CIRCUIT AFTERCOOLED
(Two heat exchangers)
(Caterpillar)

HEAT EXCHANGER & TEMPERATURE GAUGE

Fig 22.17 (A), (B)
HEAT EXCHANGER AND ITS CORE (Caterpillar)
The core (tube-nest) must be inspected and cleaned for scale and debris inside and outside the tubes. Use a 3 mm diameter brazing-rod to clean the tubes. A mechanic can pressure test the Heat Exchanger for leaks.
HOW TO CHECK THE RAW WATER PUMP IMPELLER  
(*Perkins engine*)

When the cover of the raw water pump is removed, raw water will flow from the pump. Ensure that the seacock is closed. If necessary, disconnect the hose connection at the pump. Remove the end plate of the pump. Inspect the rubber impeller for excessive wear or damage and renew, if necessary. Apply grease to the blades of the new impeller before fitting it as per the instruction manual. Replace the gasket and re-secure the end plate. Connect the hose connections at the pump and open the seacock. See also “Pumps”.

Fig 22.24  
CHECKING PUMP IMPELLER

POSSIBLE PROBLEMS WITH WATER COOLING SYSTEMS

- Blockage of seawater inlet.
- An obstruction blocking flow of water around underwater pipes.
- Salt deposits in sea water pipes, reducing their internal diameter.
- Damage due to corrosion.
- Air trapped inside the cooling system.
- Pump drive belt slipping.
- Pump impeller failure.
- Marine growth on the keel cooling system.

As discussed in the fuel system, plastic or other non-metallic hoses should also not be used in the cooling system. They are liable to fail under pressure and collapse under suction. They can be easily damaged and restrict flow, become soft and detached from clips when heated. They also melt easily in a fire. All flexible hoses on an engine must be made of woven wire casings with screwed hose fittings. They should have as few joints as possible, and routed to avoid sharp bends and edges.

Even a slight fall in the amount of cooling water discharge could indicate a problem. The pump impeller could be slowly failing or the raw water intake could be slightly blocked. If it is not a problem at low revs, it will become one when you increase speed.

CHECKING THE WATER COOLING SYSTEM

A) ITEMS TO CHECK BEFORE STARTING

- Fresh water strainer and filter clean
- Zinc anode protection in place
- Trapped air bled through vent plugs
- (Vents are fitted in the higher parts of the cooling system)
- Raw water grill (underwater) clear of obstructions
- Pumps operational
- Pressure cap fitted and sealing

B) ITEMS TO CHECK WHEN RUNNING

- Seawater overboard discharge evident
- Water level in expansion tank correct
- Operating temperature normal.