SERVICE REPAIR

MANUAL

Hyster K007 (H190HD2, H210HD2, H230HD2, H230HDS2, H250HD2, H280HD2) Forklift Service Repair Manual

HYSTER

COOLING SYSTEM

H8-12XM-6, H10XMS-6 (H190-280HD$_2$, H230HDS) [K007]; H13-16XM-6, H10-12XM-12EC (H300-360HD$_2$, H360HD$_2$-EC) [J019]; H16XM-9, H16XM-12, H18XM-7.5, H18XM-9 (H360-36HD, H360-48HD) [A238]

HYSTER

PART NO. 4059554 0700 SRM 1595

SAFETY PRECAUTIONS
MAINTENANCE AND REPAIR

- The Service Manuals are updated on a regular basis, but may not reflect recent design changes to the product. Updated technical service information may be available from your local authorized Hyster® dealer. Service Manuals provide general guidelines for maintenance and service and are intended for use by trained and experienced technicians. Failure to properly maintain equipment or to follow instructions contained in the Service Manual could result in damage to the products, personal injury, property damage or death.
- When lifting parts or assemblies, make sure all slings, chains, or cables are correctly fastened, and that the load being lifted is balanced. Make sure the crane, cables, and chains have the capacity to support the weight of the load.
- Do not lift heavy parts by hand, use a lifting mechanism.
- Wear safety glasses.
- DISCONNECT THE BATTERY CONNECTOR before doing any maintenance or repair on electric lift trucks. Disconnect the battery ground cable on internal combustion lift trucks.
- Always use correct blocks to prevent the unit from rolling or falling. See HOW TO PUT THE LIFT TRUCK ON BLOCKS in the **Operating Manual** or the **Periodic Maintenance** section.
- Keep the unit clean and the working area clean and orderly.
- Use the correct tools for the job.
- Keep the tools clean and in good condition.
- Always use **HYSTER APPROVED** parts when making repairs. Replacement parts must meet or exceed the specifications of the original equipment manufacturer.
- Make sure all nuts, bolts, snap rings, and other fastening devices are removed before using force to remove parts.
- Always fasten a DO NOT OPERATE tag to the controls of the unit when making repairs, or if the unit needs repairs.
- Be sure to follow the **WARNING** and **CAUTION** notes in the instructions.
- Gasoline, Liquid Petroleum Gas (LPG), Compressed Natural Gas (CNG), and Diesel fuel are flammable. Be sure to follow the necessary safety precautions when handling these fuels and when working on these fuel systems.
- Batteries generate flammable gas when they are being charged. Keep fire and sparks away from the area. Make sure the area is well ventilated.

NOTE: The following symbols and words indicate safety information in this manual:

WARNING

Indicates a hazardous situation which, if not avoided, could result in death or serious injury.

CAUTION

Indicates a hazardous situation which, if not avoided, could result in minor or moderate injury and property damage.

On the lift truck, the WARNING symbol and word are on orange background. The CAUTION symbol and word are on yellow background.

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This section is for the following models:

H8-12XM-6, H10XMS-6 (H190-280HD2, H230HDS) [K007];
H13-16XM-6, H10-12XM-12EC (H300-360HD2, H360HD2-EC) [J019];
H16XM-9, H16XM-12, H18XM-7.5, H18XM-9 (H360-36HD, H360-48HD) [A238]

General

This manual describes the cooling system and the removal and replacement procedures for its main components.

The cooling system for the transmission is described in **Transmission** 1300SRM1455.

The hydraulic control system for the K007, J019, and A238 truck is described in **Hydraulic Control System** 2200SRM1481.

COOLING SYSTEM DESCRIPTION

When the truck operates, heat is generated in various truck components. Most of these components can sufficiently dissipate the generated heat to the surrounding air. A cooling system is required for the engine, hydraulic system and the transmission, because of the big and fluctuating volume of heat to be dissipated and the need for a controlled operating temperature. Each of these systems has its own cooling core.

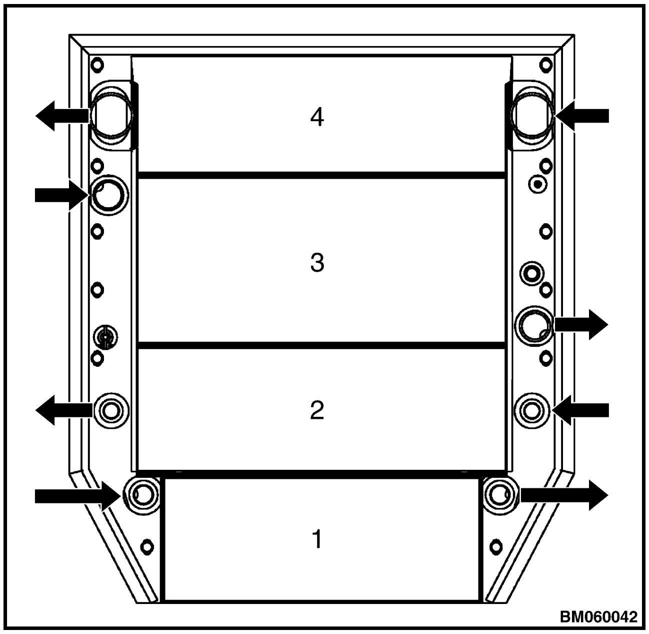
The cores are mounted in a cooling core assembly (together with the charge air cooler). In this assembly, the heat is dissipated by an airflow which is pulled through the cooling cores by a belt-driven fan.

Cooling Cores

The cooling cores transfer the heat from the fluid inside to the air outside. The fluid (coolant or oil) or charge air is in contact with the core, which transfers its heat to the air that is pulled through the cooling core by the fan. Depending on how much heat is dissipated, depends on the size and design of the core, but also on the following factors:

- Temperature difference between the air pulled through the cooling core and the cooling core itself.
- Volume of air pulled through the cooling core, which depends on fan speed. Environmental debris such as paper, straw or lint can restrict air flow. Operating conditions determine the necessary core cleaning frequency.
- Core external insulation, which results from (dust) particles forming an insulating deposit on the outside of the core. The deposit impedes heat transfer from the core to the air. Operating conditions determine the necessary core cleaning frequency.
- Volume of fluid passing through the core. Generally, more fluid passes at higher engine speeds when thermostats are fully open. The flow of charge air increases when more engine power is delivered.
- Core internal insulation, which results from deposits inside the cooling core, which impede heat transfer from the fluid to the core. The hydraulic and transmission oil coolers are unlikely to contain internal deposits because of the properties of oil and the oil filtration system. The charge air cooler may collect dust that has reached the core over time due to imperfect air filtration. Normally, internal cleaning of the charge air cooler is not required until engine overhaul.

For the location of core entry and exit ports, see Figure 1.



1. TRANSMISSION OIL COOLER
2. HYDRAULIC OIL COOLER
3. ENGINE RADIATOR
4. CHARGE AIR COOLER

Figure 1. Cooling Cores, K007/J019

Fan

The fan pulls air through the cooling core assembly. On trucks with Tier 3/Stage III A engines, the fan is directly connected with the fan pulley and turns proportional to engine speed.

Trucks with Tier 4i/Stage III B engines have a fan clutch that reduces fan speed when circumstances allow a lower cooling capacity. The advantage is in reduced power consumption and a reduced noise level of the fan.

Fan Clutch

The fan clutch is mounted between fan pulley and fan. The fan clutch is a viscous coupling that varies clutch engagement between 30% and 95%, depending on engine speed and an electrical Pulse Width Modulation (PWM) signal from the Engine Control Module (ECM).

Fan Clutch Engagement

The fan clutch consists of a rotor that is connected with the engine pulley and a housing that carries the fan. Engagement of the rotor and the housing is obtained by viscous oil that is present between rotor and housing.

At higher rotation speeds of the rotor, viscous oil is centrifuged away from the space between rotor and housing and returns through a bore into an oil chamber. From this oil chamber, oil returns through a valve to the space between rotor and housing.

When the valve closes, oil will **NOT** return to the rotor. Existing oil at the rotor will be centrifuged away, reducing clutch engagement.

By varying the valve opening, the clutch engagement will change.

Maximum engagement is 95%. Lowest engagement is 30% of engine (pulley) speed.

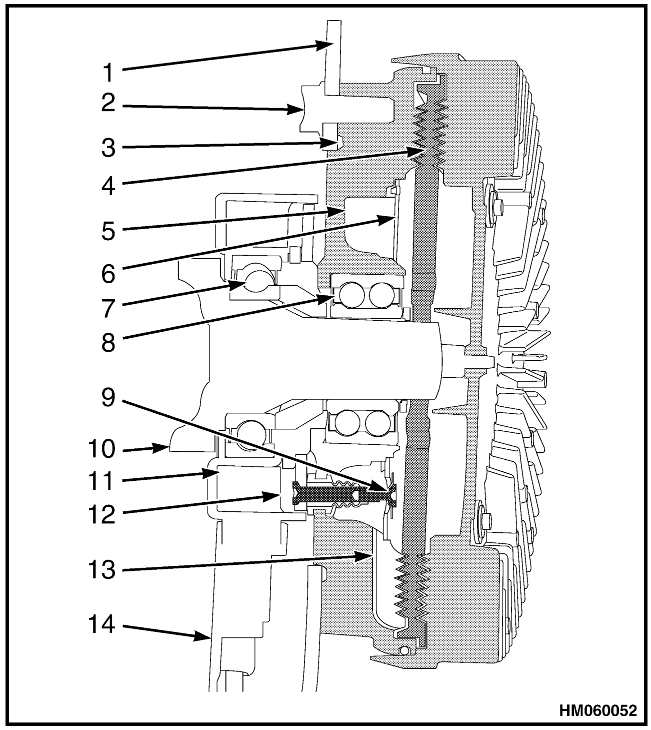
The valve in the clutch closes against spring force, when activating the magnet coil in the anti-rotation bracket. The activated magnet coil attracts the actuator ring which is connected with the valve through a pin. The resulting flow of oil changes fan speed, which is measured by a speed sensor in the anti-rotation bracket and communicated to the ECM. Depending on the difference between actual and required fan speed, the ECM will change activation of the magnet coil. See Figure 2.

The PWM signal to the magnet coil depends on the temperature inputs for engine coolant, intake air, and transmission oil. These inputs are received by the ECM and result in a programmed signal to the magnet coil. The actual engagement can be checked with a laptop through the Cummins programme called Insite'.

When the magnet coil is de-activated, spring force will open the valve. This means that in case of an electric failure, the engagement of the clutch will be at maximum.

Clutch engagement is also influenced by actual viscosity of the viscous oil. Engagement is higher at lower temperatures. Engagement is lower at higher temperatures. The ECM compensates for differences in engagement, but at extremely cold temperatures the normally lowest engagement of 30% may remain at a higher level because of the higher viscosity.

The reaction time for a changed engagement depends on actual viscosity and rotor speed (engine speed). This is particularly noticeable when comparing the start of a cold engine and a warm engine. After cold starting the engine, it will take at least 30 seconds at high idle before the oil at the rotor has disappeared, disengaging the clutch. The fan clutch of a warm engine will disengage in less than 20 seconds after the engine has been started.



1. FAN FLANGE
2. FAN RETAINER BOLT
3. FAN CLUTCH HOUSING
4. ROTOR
5. OIL CHAMBER
6. SEPARATING WALL
7. COIL BRACKET BEARING
8. CLUTCH HOUSING BEARING
9. VALVE
10. HEXAGON NUT
11. MAGNET COIL
12. ACTUATOR RING
13. RETURN BORE
14. ANTI-ROTATION BRACKET

Figure 2. Fan Clutch

Shroud

The shroud on the cooling core assembly raises the efficiency of the fan and ensures that air is pulled through the cooling cores only. Fan efficiency is raised by a narrow clearance between fan and shroud. One third of the fan is outside the shroud, to allow centrifuged air to escape. This increases the propelled air volume.

The warmed air flows away underneath and at the front of the truck. Seals between the frame and the core assembly prevent the recirculation of warmed air to the suction side of the core assembly.

Engine Cooling System

During operation of the truck, heat is generated in the engine. The engine cooling system regulates the dissipation of this heat in order to maintain the engine at the desired operating temperature. The coolant is pumped in a closed circuit, where it absorbs heat from the engine and dissipates heat in the cooling core. The cooling capacity of the radiator and the fan is sufficient to keep coolant temperature well below the maximum temperature, even at ambient temperatures reaching 50°C (122°F).

The main components of the engine cooling system are:

- Water Pump
- Thermostat
- Expansion Tank And Radiator Cap
- Cooling Core
- Cab Heater
- Coolant

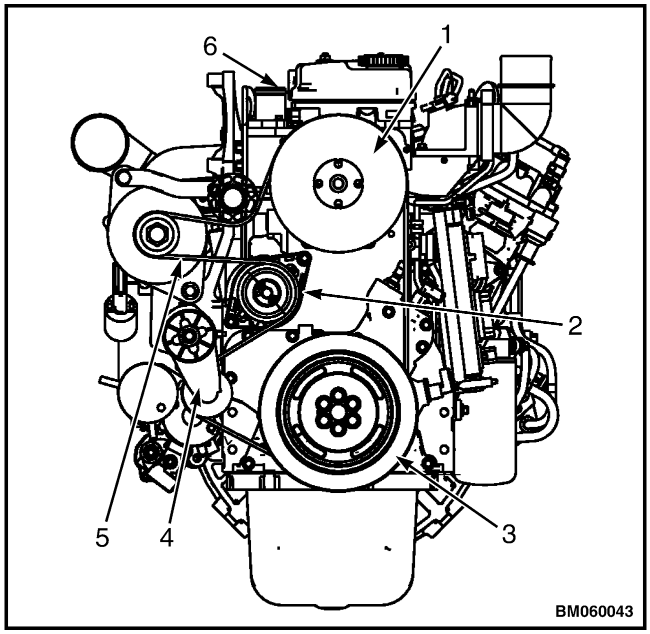
The functional description of these components is below.

Water Pump

The water pump circulates the coolant through the engine cooling system and the (optional) cab heater. The pump is belt driven by the crankshaft pulley. See Figure 3.

Pump supply relates to engine speed but does not increase proportionally with engine speed.

It is essential that the suction side of the pump is completely filled with coolant. Any vapor at the suction side of the pump would reduce pump supply and cause damage through cavitation. To prevent the formation of vapor, the cooling system is kept at a higher pressure by the radiator cap.



1. FAN PULLEY
2. WATER PUMP
3. CRANKSHAFT PULLEY
4. BELT TENSIONER
5. DRIVE BELT
6. COOLANT OUTLET

Figure 3. Drive Belt

Thermostat

CAUTION

DO NOT operate the engine without a thermostat. Without a thermostat, coolant at the outlet flange will partially recirculate through the bypass, causing the engine to overheat.

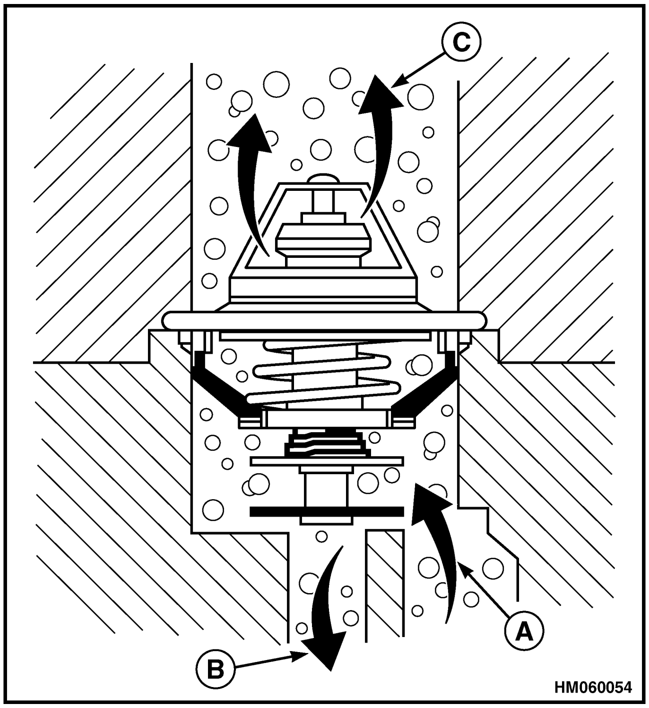
The thermostat controls coolant flow to the cooling core.

The thermostat is located at the top of the cylinder block, and is held in place by the coolant outlet flange.

When coolant is cold, the thermostat closes the connection with the radiator and forces coolant from the engine to return to the suction side of the water pump through a bypass.

When coolant temperature reaches 82°C (179°F), the thermostat starts opening the connection to the cooling core, while closing the bypass between engine and water pump.

At 91°C (196°F), the connection to the cooling core is completely open and the bypass is completely closed. At that temperature, all coolant passes through the cooling core before re-entering the engine. See Figure 4.



A. COOLANT FLOW FROM ENGINE
B. BYPASS FLOW TO WATER PUMP
C. COOLANT FLOW TOWARDS COOLING CORE

Figure 4. Coolant Thermostat

Expansion Tank And Radiator Cap

The function of the expansion tank is:

- To allow expansion of the engine coolant when the engine warms up.
- To regulate pressure in the engine cooling system.
- To allow the removal of gasses that may have formed in the coolant.

Coolant expands as it warms up. The increased volume of coolant flows through the expansion hose to the expansion tank, where it compresses the contained air, causing cooling system pressure to rise.

The rising system pressure raises the boiling point of the coolant. A higher boiling point is required for circumstances when coolant flow is limited. For instance when returning to idle after full power operation, or when turning off a warm engine. If the coolant were to boil in those circumstances, it would form gas bubbles. Those bubbles would reduce the contact area of the coolant with the engine. The bubbles would also restrict coolant flow through the engine. As a result, temperature in the affected part of the engine would rise even further, which might lead to component failure.

For a sufficiently quick pressure increase, the air volume in the expansion tank must be limited. For this reason, the expansion tank must be filled to at least the minimum level mark “MIN”.

The pressure in the cooling system is regulated by the cap on the expansion tank, the so-called “radiator cap”. This cap houses a pressure valve, which releases pressure from the expansion tank between 90 kPa (13 psi) and 110 kPa (16 psi).

The valve admits outside air, when vacuum in the expansion tank is between 2 kPa (0.3 psi) and 7 kPa (1 psi).

A bigger diameter hose connects the cooling core to the bottom of the expansion tank to provide some compensation for pressure surges caused by engine speed changes.

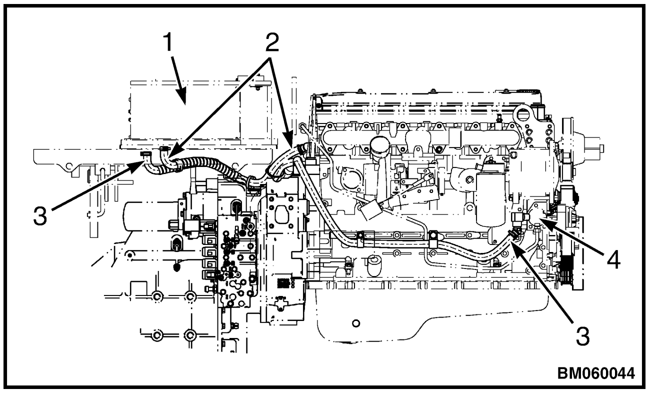
To allow de-aeration when the engine cooling system is filled, the cylinder head and the engine cooling core are both connected to the expansion tank by a de-aeration hose.

A fluid level sensor in the expansion tank sends a signal to the ECM (Engine Control Module) when the minimum coolant level has been reached. In that case, the ECM will switch the engine off within 30 seconds.

Cab Heater

The cab heater is located under the cab floor, underneath the seat. Heated coolant flows from the cylinder head through a hose to the heater. Coolant flow is controlled by the water valve in the heater assembly. Coolant leaves the heater through a hose which is connected to the suction side of the water pump.

The cab heater is described in **Cab Heater** 0100SRM1459. See Figure 5.



1. CAB HEATER
2. HOT COOLANT HOSE (TOWARDS HEATER)
3. COLD COOLANT HOSE (FROM HEATER)
4. ENGINE COOLANT INLET

Figure 5. Cab Heater

Coolant

Coolant is a mixture of water (48%), ethylene glycol (48%), and some additives (4%). Water is a fluid with the highest heat capacity and the lowest cost. However, water has only limited thermal usage and tends to enhance corrosion.

This limited thermal usage is extended by the addition of ethylene glycol. The tendency to enhance corrosion is suppressed by additives. These additives are not available for replenishment. This implies that the entire coolant system has to be drained and refilled when the additives are depleted. Water and/or ethylene glycol can be added separately to correct their relative contents.

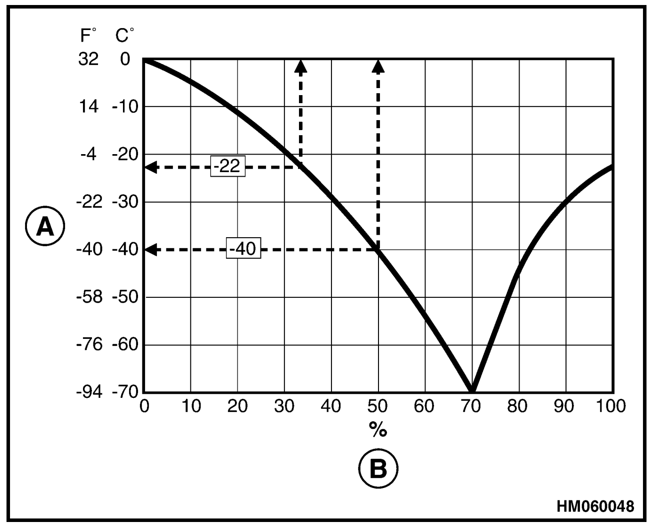
Ethylene Glycol

The mixing ratio of water and ethylene glycol for optimum thermal capacity and boiling point elevation is normally 50/50. Other mixing ratios influence the freezing point, boiling point and fluidity of the mixtures. See Figure 6.

Higher concentrations of ethylene glycol reduce fluidity and heat capacity, but raise the boiling point. Operation of the lift truck in arctic conditions justifies ethylene glycol contents of 50% or more. See Figure 6.

Ethylene glycol content can be established with a portable refractometer. This content can be raised by adding pure ethylene glycol or can be lowered by adding distilled water to the cooling system. Ethylene glycol degrades over time, but degrades more rapidly with a pH below 7.0. When ethylene glycol degrades, acidic components are formed, which rapidly lower the pH. Additives in the coolant compensate for the negative effects of degrading ethylene glycol.

Remark: pH is a measure of acidity or alkalinity. A pH lower than 7.0 indicates an acidic environment, which promotes corrosion. A pH higher than 7.0 indicates an alkaline or basic environment, which reduces corrosion.



A. FREEZE POINT TEMPERATURE
B. PERCENTAGE OF ETHYLENE GLYCOL IN COOLANT

Figure 6. Coolant Mixture Ratios

Water

The water quality requirement for coolant is distilled or deionized water, with little or no minerals. Minerals increase corrosion, form deposits and deplete some of the additives. If distilled or deionized water is not available, test strips must be used to establish the water quality. For limiting values, see Table 1.

Table 1. Limiting Values

Total Solids	340 ppm maximum
Total Hardness ($CaCO_3$, $MgCO_3$)	170 ppm maximum
Chloride (Cl)	40 ppm maximum
Sulfate (SO_4)	100 ppm maximum

Table 1. Limiting Values (Continued)

pH	7.0 to 8.0

Additives

The additives package in the coolant contains several components, each with a different function. The most important function is corrosion protection and maintaining a predetermined acidity (pH). Other functions are scale inhibition, de-foaming, and liner pitting protection.

The acidity (pH) of coolant in this truck is maintained by chemicals that are categorized as Organic Acid Technology (OAT). One of the characteristics of OAT type coolant is that the pH remains stable for up to 5 years, provided it passes the 6-month quality checks.

Once the additives are depleted, the pH will drop. When the pH is 7.7 or lower, the coolant must be replaced.

Do not mix coolant with different coolants or additives, as that may have consequences for coolant quality, such as:

- De-activation of some of the protecting additives
- Formation of gel, which blocks coolant flow
- Formation of deposits, which impede heat transfer in the engine block and the cooling core.

The factory filled coolant allows mixing with other OAT type coolants to a maximum of 25%, provided the added coolant meets the coolant quality requirements. Do not use or mix with conventional coolants or coolants based on Supplemental Cooling Additives (SCAs).

Coolant Quality Requirements

When replacing the entire coolant volume, refill with an Organic Acid Technology (OAT) based product, which meets Cummins requirement CES 14603 and Cummins bulletin 3666132.

Essential properties of these OAT type coolants are:

- Acidity (pH) between 8.0 and 9.0
  Reserve alkalinity at least 2.5
  Total of dissolved solids maximum 3,000 ppm.
- Chemicals to be included:
  Nitrite with a minimum of 2,000 ppm, or alternatively: nitrite in combination with molybdate with a minimum of 1,300 ppm.
- Chemicals to be excluded:
  Chromates
  Borates
  Silicates
  Phosphates
  Amines

Examples of acceptable products are:

Shell Rotella ELC

Eurol Coolant XL-NM

Shell HD Premium Coolant

Table 2. Coolant Fill Quantities

K007 Engine, Tier 3/ Stage III A	25.5 liter (6.7 gal)
K007 Engine, Tier 4i/ Stage III B	19 liter (5 gal)
J019 Engine, Tier 3/ Stage III A	25.5 liter (6.7 gal)
J019 Engine, Tier 4i/ Stage III B	22 liter (5.8 gal)
A238 Engine, Tier 4i/ Stage III B	24 liter (6.3 gal)

Charge Air Cooling System

The turbocharger uses the energy from the exhaust gas stream to compress the intake air, which can heat up to well over 100 to 160°C (212 to 320°F). Compressed intake air is cooled by leading it through the charge air cooler before it enters the engine. Cooling the intake air improves engine performance and lowers emission values.

Transmission Oil Cooling System

The cooling system for the transmission is described in **Transmission** 1300SRM1455.

The transmission oil cooling system contains a thermostat valve, which is installed between the torque converter outlet port and the transmission cooling core. This thermostat starts opening at 87°C (189°F) and is completely opened at 102°C (216°F). At temperatures below 87°C (189°F), oil flow is directly returned to the transmission. At temperatures above 102°C (216°F), the entire oil flow from the outlet port passes through the transmission cooling core before it is returned to the transmission.

Hydraulic Oil Cooling System

General

Heat generated in the various hydraulic components is absorbed by the hydraulic oil, which returns to the hydraulic tank.

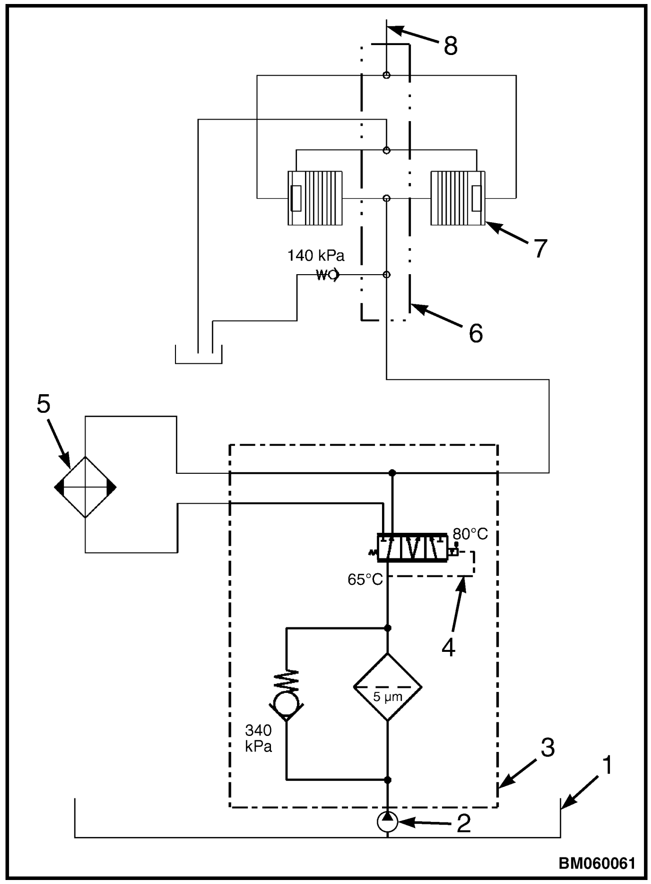
Hydraulic Oil Cooling

A separate gear pump provides an oil flow through the in series connected systems for oil filtration, oil cooling and brake cooling. See Figure 7.

The hydraulic control system signals and provides some protection when extreme temperatures are reached.

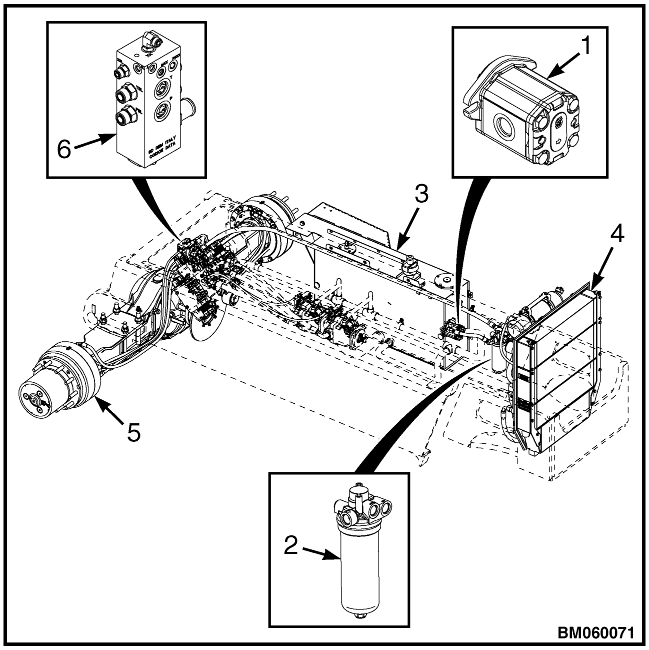
Below is a short description for these subsystems in the hydraulic cooling system.

A component location overview is shown on Figure 8.



1. HYDRAULIC OIL TANK
2. GEAR PUMP
3. FILTER ADAPTER
4. THERMOSTAT
5. HYDRAULIC COOLING CORE
6. WET BRAKE MANIFOLD
7. DRIVE AXLE
8. SERVICE BRAKE CONNECTION

Figure 7. Hydraulic Cooling System



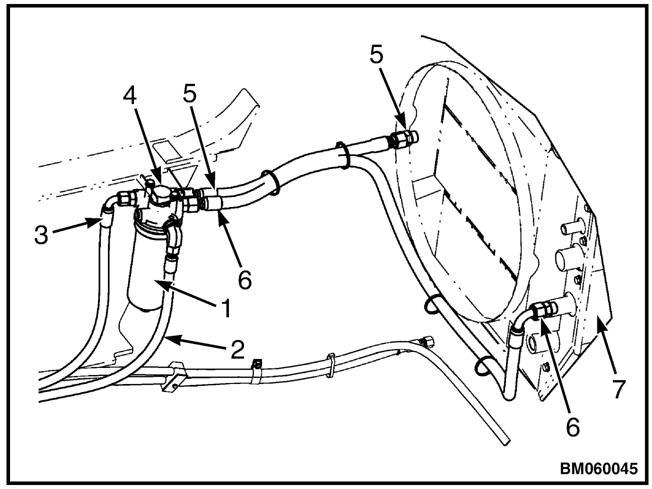
1. GEAR PUMP
2. HYDRAULIC FILTER
3. HYDRAULIC TANK
4. COOLER
5. SERVICE BRAKES
6. BRAKE FLOW DISTRIBUTION MANIFOLD

Figure 8. Hydraulic Oil Cooling System Components

Oil Filtration and Oil Cooling

Pump supply is filtered by a 5 micron filter element which is mounted on a filter adapter. The filter is protected by a 340 kPa (49 psi) bypass valve.

The hydraulic filter adapter includes a thermostatic valve which starts opening at 65°C (149°F). When this valve is fully open at 80°C (176°F), all oil flowing through the filter assembly is directed to the hydraulic oil cooling core. Oil from the cooling core returns to the filter adapter, and flows further to the brake manifold. See Figure 9.



1. FILTER ELEMENT
2. PUMP SUPPLY HOSE TO FILTER ADAPTER
3. RETURN HOSE FROM FILTER ADAPTER
4. FILTER ADAPTER
5. COOLING CORE RETURN HOSE TO FILTER ADAPTER
6. COOLING CORE SUPPLY HOSE FROM FILTER ADAPTER
7. HYDRAULIC OIL COOLING CORE

Figure 9. Hydraulic Filter and Connecting Hoses

Brake Cooling

The brake manifold connects the supply and return hoses for the service brake system and the wet brake cooling system. The manifold includes a 140 kPa (20 psi) relief valve, which protects the seals in the brake housing.

None of the components of the brake manifold are serviced separately.

Hydraulic Control System

The hydraulic control system activates a fault code and may also reduce engine or vehicle speed when extreme hydraulic oil temperatures are detected.

h-hot is displayed when oil temperature in the tank exceeds 90°C (194°F). In addition, the optionally available High Temperature Protection limits vehicle speed to 10 km/h to reduce the heat generated during braking.

h-cold is displayed when oil temperature in the tank is below -5°C (23°F). Depending on the hydraulic temperature, engine speed is reduced proportionally to protect the hydraulic pumps against cavitation.

Service and Repair

COOLING SYSTEM CHECKS

WARNING

DO NOT operate a lift truck that needs repairs. Report the need for repairs immediately. If repair is necessary, put a DO NOT OPERATE tag in the operators area. Remove the key from the key switch.

During engine operation, stay clear of the fan, pulleys, and drive belts. Contact with these parts can cause serious injury.

Compressed air can move particles so they cause injury to the user or to other personnel. Make sure the path of the compressed air is away from all personnel. Wear protective goggles or a face shield to prevent injury to the eyes.

Do not try to locate hydraulic leaks by putting hands on pressurized hydraulic components. Hydraulic oil can be injected into the body by pressure.

Basic Checks

Perform the checks listed below in the sequence shown to find the cause of a cooling problem. Before starting a repair, try to find additional symptoms that confirm the suspected cause of failure.

Put the lift truck on a level surface. Lower the carriage and forks, stop the engine, and apply the parking brake.

1. **Cooling cores:**
   Make sure the outside of the cooling core assembly is clean. Use compressed air to remove dust and debris that may have accumulated on the exterior of the cores. Check for signs of moisture and oil on the cooling cores.
   If any leakage is found, the leaking cooling core(s) must be replaced. See Cooling Core Replacement.
2. **Coolant level:**
   Coolant level must be above the "MIN" mark in the expansion tank when the engine is cold. Follow the procedures under External Leak Test if more than 1 liter (0.26 gal) per 1,000 hours must be added.
3. **Drive belt:**
   Check the belt for excessive wear and damage and for hardening, and check the belt tension. For replacement instructions, see Drive Belt Replacement.
4. **Fan condition:**
   Check the fan blades for wear and damage. Replace the fan if necessary.
5. **Collapsed hoses:**
   Check if one or more coolant hoses are collapsed when the engine is cold. Collapsed hoses indicate a defective vacuum valve in the radiator cap. See External Leak Test.

Coolant Quality Checks

1. **Expansion Tank**
   The inside of the expansion tank should be free of deposits and rust.
   Deposits and rust indicate a serious coolant quality problem that may have caused the buildup of insulating deposits inside the entire cooling system. Do a leak test to establish if a gasket problem caused the coolant to deteriorate. See the section External Leak Test for the procedure.
   Repair any leakage, clean the entire cooling system, flush and refill with new coolant. See Flushing the Engine Cooling System for the procedure.
2. **Visual Test**

Take a small quantity of coolant from the expansion tank and pour it into a sight glass. Coolant should be a clear fluid without cloudiness, floating debris or oil. Oil in the coolant, cloudiness, or floating debris indicates a possible head gasket or cylinder liner defect. Do a leak test and replace the head gasket or cylinder liners if defective. See the section External Leak Test for the procedure. Clean, flush, and refill the system with new coolant. See Flushing the Engine Cooling System for the procedure.

Cloudiness and floating debris can also indicate that additives in the coolant are depleted or that incompatible additives have been mixed. In that case, clean, flush and refill the system with new coolant.

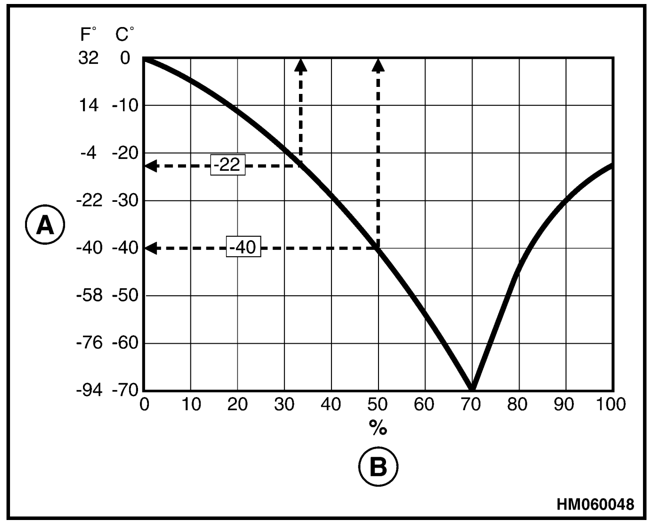
3. **Coolant Acidity (pH) Test**

   Use a test strip to establish the acidity of the coolant. Flush and refill the cooling system with new coolant if the pH is lower than 7.7. See Flushing the Engine Cooling System for the procedure.

   When the pH is lower than 7.7, the additives in the coolant are depleted. Perform a leak test if the pH has dropped below 7.7 within 3 years of service. See External Leak Test for the procedure.

4. **Freeze Protection Test**

   Check the ethylene glycol content with a portable refractometer. Ethylene glycol content must be 40% or more, depending on lowest ambient temperature. An ethylene glycol content of more than 50% affects the cooling capacity of the coolant. Raise the ethylene glycol content by adding ethylene glycol. Lower the ethylene glycol content by adding distilled water. See Figure 10.



A. FREEZE POINT TEMPERATURE
B. PERCENTAGE OF ETHYLENE GLYCOL IN COOLANT

Figure 10. Coolant Mixture Ratios

Coolant Flow Checks

Thermostat

CAUTION

DO NOT operate the engine without a thermostat. Without a thermostat, coolant will not flow to the radiator, and the engine will overheat.

Failure of a thermostat results in either too low or too high operating temperatures.

When a thermostat opens at too high a temperature, the system will overheat, while the cooling core remains relatively cold.

When a thermostat opens at too low a temperature the system will not reach its normal operating temperature. The temperature at core entry is similar to actual system temperature.

If a malfunctioning engine thermostat is suspected, replace it with a new one. See thermostat replacement.

The thermostats for transmission and hydraulics are not serviced separately. For a replacement, the entire assembly needs to be exchanged. Make sure to have established that a thermostat malfunctions, before replacing the transmission bypass valve or the hydraulic filter assembly.

See Table 3 which lists the temperatures at which the thermostats should start opening and at which they should be completely open.

Table 3. Thermostat Operating Temperatures

Thermostat	Starts to open at	Is fully open at
Engine	82°C (180°F)	91°C (196°F)
Transmission	87°C (189°F)	102°C (216°F)
Hydraulic	65°C (149°F)	80°C (176°F)

Water Pump

WARNING

During engine operation, stay clear of the fan, pulleys, and drive belts. Contact with these parts can cause serious injury.

The radiator core or other parts of the cooling system may be hot or under pressure and can cause serious injury.

To find the cause of a sudden coolant flow problem, perform the following tests in the sequence shown:

1. Run the engine until the coolant temperature reaches 91 to 103°C (196 to 218°F). At this temperature, the thermostat should be completely open.
2. Put on an insulated leather glove and squeeze the upper radiator hose, while an assistant revs the engine several times. For the location of the upper radiator hose, see Figure 13.
3. When pressure surges can be felt, the water pump functions sufficiently.
4. If no pressure surges can be felt, remove the water pump for inspection. For instructions, see Water Pump, Inspect, and Install.

Cooling Core Efficiency

Table 4 shows the temperature difference to be obtained between core entry and core exit, under the following conditions:

- Fluids and air have reached the tabled core entry temperatures. Lower entry temperatures result in smaller temperature differences.
- Fan and engine run at maximum speed.
- Results are for an ambient temperature of 50°C (122°F). Temperature differences improve with 3% for every 10°C (18°F) that ambient temperature is lower than 50°C (122°F).

If the required temperature difference cannot be obtained, clean and flush the cooling core. See Cleaning the Engine Cooling System and Flushing the Engine Cooling System.

Table 4. Temperature Differences Between Core Entry and Core Exit

	Charge Air	Engine Coolant	Hydraulic Oil	Transmission Oil
Core Entry Temperature	200°C (360°F)	105°C (190°F)	90°C (160°F)	120°C (215°F)
Temperature Difference				

Table 4. Temperature Differences Between Core Entry and Core Exit (Continued)

	Charge Air	Engine Coolant	Hydraulic Oil	Transmission Oil
K007/J019 Tier 3/ Stage III A	90°C (160°F)	6°C (11°F)	18°C (64°F)	11°C (20°F)
K007 Tier 4i/Stage III B	90°C (160°F)	6°C (11°F)	18°C (64°F)	11°C (20°F)
J019 Tier 4i/Stage III B	75°C (135°F)	7°C (13°F)	18°C (64°F)	11°C (20°F)
A238 Tier 4i/Stage III B	75°C (135°F)	7°C (13°F)	18°C (64°F)	11°C (20°F)

Cooling Core Flow Restrictions

This test helps to find out if any fins in the cooling core have restricted flow. Use a digital thermometer or an infrared thermometer to measure temperatures.

1. Run the engine until the engine cooling core is warm.
2. Switch **OFF** the engine.
3. Open the rear cover to access the radiator.
4. Measure the outside temperature of the core from top to bottom and search for temperature differences. Relatively cold spots indicate a restricted coolant flow.
5. If flow restrictions have been found, clean and flush the radiator. See Cleaning the Engine Cooling System and Flushing the Engine Cooling System.

Engine Leak Tests

Perform a leak test if one of the following observations has been made:

- More than 1 liter (0.25 gal) of coolant had to be added during the past 3,000 running hours.
- Coolant quality failed the visual test.
- Coolant pH has dropped below 7.7 within 3 years of service.
- Coolant is present in the engine oil.
- Excessive steam emission from the exhaust, possibly accompanied by difficult starting.

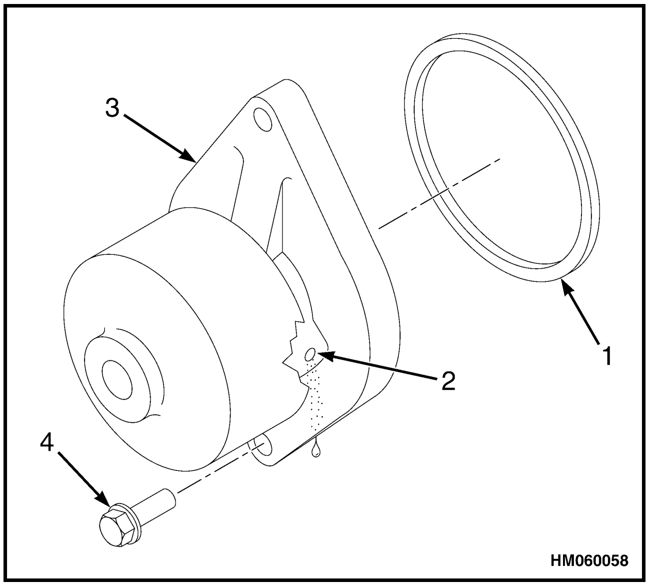
External Leak Test

NOTE: : If the pressure tester has no cap that fits the thread on the expansion tank, disconnect the radiator de-aeration hose from the expansion tank. Connect the hose of the tester to the now open tank connection flange. Before testing, securely plug the free end of the radiator de-aeration hose. Connect a piece of hose to the overflow tube on the radiator cap and plug this hose to prevent pressure release through the radiator cap.

After testing, remove all tools and materials used. In particular, remove the plugs from the radiator de-aeration hose and from the overflow tube.

1. Make sure the engine and components of the cooling system are dry on the outside. Also clean and dry the weephole, which is situated just below the water pump's impeller shaft. Attach a pressure tester to the expansion tank and apply 140 kPa (20 psi) for 5 minutes. Any drop in pressure indicates a leak.

   If pressure drops, check for coolant leaks at connections, hoses, water pump, cooler core, and engine. Repair leaking components as necessary. Replace the water pump if any coolant escapes from the weephole of the water pump during the pressure test. Remove the pressure tester from the expansion tank and reinstall the radiator cap. Perform an internal leak test if no external leak was found. See Figure 11.

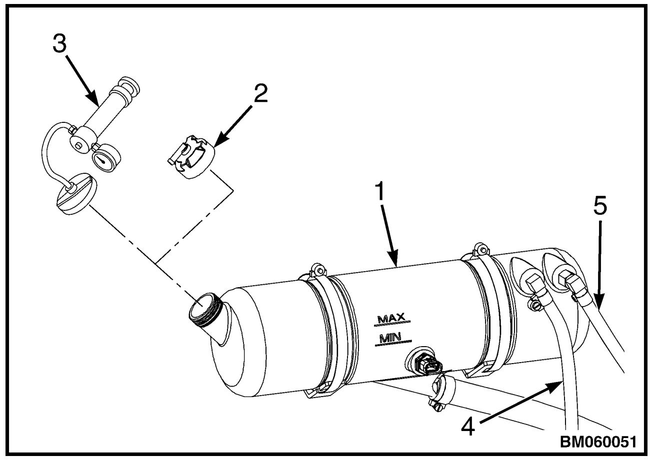


1. O-RING
2. WEEP HOLE
3. WATER PUMP
4. CAPSCREWS

Figure 11. Water Pump

2. Check the functionality of the radiator cap.

- Measure the relief pressure of the cap by pressurizing the tank side of the radiator cap. Disconnect the cooling core de-aeration hose from the expansion tank. Connect the hose of the tester to the now open tank connection tube. Before testing, securely plug the free end of the radiator de-aeration hose. The radiator cap should release pressure at 103 kPa (15 psi). If the relief pressure is too low, it will lead to coolant loss through the radiator cap and a lowered boiling point of the coolant, which will reduce cooling capacity. If the cooling system pressure is too high, it can result in gasket failures at the water pump, cylinder liners, and cylinder head.
- Measure the opening pressure of the vacuum valve. Release pressure from the cooling system and reinstall the radiator cap. Connect the hose of the pressure tester to the overflow tube. To measure the opening pressure of the vacuum valve, pressurize the overflow tube.
This valve should open and allow air into the system when 7 to 12 kPa (1.0 to 1.7 psi) is applied. A malfunctioning vacuum valve causes a slow buildup of pressure, which promotes corrosion in the water pump and at the cylinder liners. See Figure 12.



1. EXPANSION TANK
2. RADIATOR CAP
3. PRESSURE TESTER
4. CYLINDER HEAD DE-AERATION HOSE
5. COOLING CORE DE-AERATION HOSE

Figure 12. Radiator Cap and Expansion Tank Test

Check for Coolant Leak Into The Engine Oil Sump

1. Take out the oil gauge and insert a small diameter hose, attached to a suction pump. Be sure to take an oil sample from the bottom of the oil pan, where any coolant will collect.

2. Have the sample examined in a laboratory and repair the engine if coolant is present in the oil sample.
   - Coolant contamination is recognized by abnormal levels of a corrosion inhibitor in the engine oil, originating from the coolant.
   - Presence of ethylene glycol in the sample does indicate coolant contamination. However, absence of ethylene glycol does NOT exclude that coolant has leaked into the engine oil. The reason is that ethylene glycol can react with certain additives in the engine oil, become volatile, and boil off at sump temperatures. Secondly, deteriorated ethylene glycol reacts with bearing and bushing materials to form elevated levels of lead in the oil.
   - Water in the oil may be the result of condensation. Investigate if the operating conditions, e.g. short running times, have promoted condensation.

Combustion Leak Test

Use a combustion leak test kit to check if combustion gases leak into the cooling system. Note that test kits which react to the presence of sulfur may not be reliable, when low-sulfur diesel fuel is used. Follow the manufacturer's instructions when doing the test. Repair the engine if exhaust gases are leaking into the cooling system.

If no combustion leak test kit is available, perform the following steps to find indications of a combustion gas leak.

CAUTION

If a combustion leak is present, pressure may build up quickly and exceed the maximum allowable pressure. Immediately release cooling system pressure if pressure reaches 140 kPa (20 psi) during this test.

- Attach a pressure tester to the expansion tank. Observe the pressure gauge, while your assistant starts the engine. If pressure builds up quickly, there is a serious combustion leak. Immediately stop the engine. Repair the engine if pressure in the expansion tank builds up quickly. See Figure 12.
- If there is a slow pressure buildup, apply 103 kPa (15 psi) of pressure to the cooling system. Make sure the coolant temperature is 80°C (176°F) or lower. Observe the pressure gauge, while your assistant starts the engine and rapidly accelerates the engine three times to 2000 rpm, each time followed by 1 minute of idling. Stop the engine. Repair the engine if pressure in the cooling system rose rapidly and (almost) simultaneously with revving.

Engine Cooling System Maintenance

WARNING

DO NOT operate a lift truck that needs repairs. Report the need for repairs immediately. If repair is necessary, put a DO NOT OPERATE tag in the operators area. Remove the key from the key switch.

Safety labels are installed on the lift truck to give information about operation and possible hazards. It is important that all safety labels are installed on the lift truck and can be read.

Put the lift truck on a level surface. Lower the carriage and forks, stop the engine, and apply the parking brake.

Draining the Engine Cooling System

WARNING

DO NOT remove the radiator cap from the expansion tank when the engine is hot. When the radiator cap is removed, the pressure is released from the system. If the system is hot, the steam and boiling coolant can cause burns.

CAUTION

Disposal of lubricants and fluids must meet local environmental regulations.

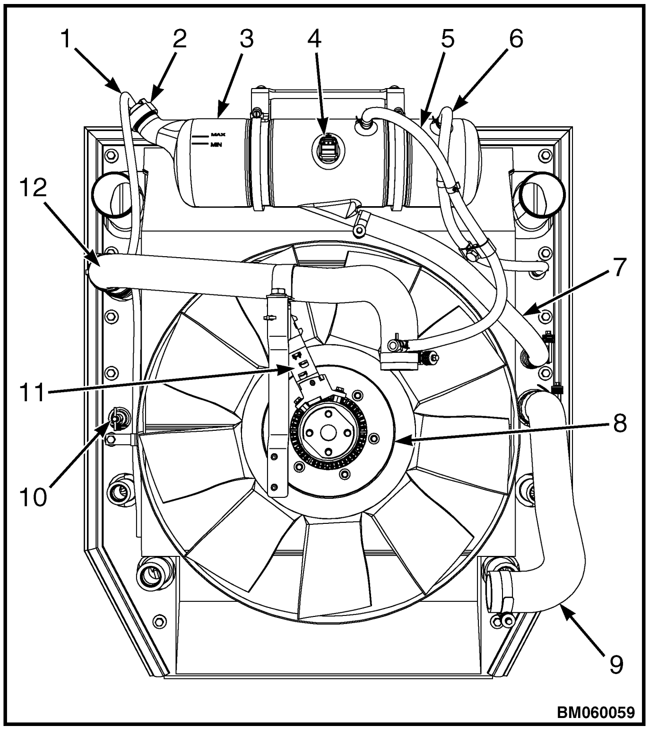
1. Turn the switch of the operator cabin heating to its hottest setting.
2. Let the coolant cool to room temperature.
3. Remove the radiator cap from the expansion tank.

NOTE: Use drain pans large enough to catch all coolant. For coolant volume, see Table 2.

4. Open the coolant drain valve at the lower end of the engine cooling core.

5. Alternatively, to speed up the draining process, loosen the clamp on the coolant return hose at the water pump. Remove the hose from the water pump. Attention: the coolant will now flow out of the cooling core very rapidly. Use a drain pan large enough to catch all coolant.

For the location of coolant hoses, see Figure 13.



1. EXPANSION TANK OVERFLOW HOSE
2. RADIATOR CAP
3. EXPANSION TANK
4. COOLANT LEVEL SENSOR
5. ENGINE DE-AERATION HOSE
6. ENGINE CORE DE-AERATION HOSE
7. ENGINE CORE EXPANSION HOSE
8. VISCOUS FAN CLUTCH ASSEMBLY
9. ENGINE CORE RETURN HOSE
10. ENGINE CORE DRAIN VALVE
11. ANTI-ROTATION BRACKET FOR FAN CLUTCH
12. ENGINE CORE SUPPLY HOSE

Figure 13. Cooling Core Assembly, Tier 4i/Stage III B shown

Filling the Engine Cooling System

1. Close the coolant drain valve at the right side of the engine cooling core.

2. Reinstall the coolant return hose to the water pump and tighten the clamp.

3. Turn the heater knob in the operator cabin to its hottest setting.

4. Fill the cooling system through the radiator cap opening in the expansion tank. When refilling with coolant, use a product which meets the specifications as listed in the Periodic Maintenance SRM. Fill until coolant level has stabilized at the "MAX" mark. For coolant volume, see Table 2.

5. Reinstall the radiator cap on the expansion tank.

6. Start the engine and rev it a few times.

7. Switch off the engine and check if the coolant level in the expansion tank remains between the MIN and MAX mark on the expansion tank.

8. If coolant level in the expansion tank has dropped beneath the MIN mark, repeat the procedure from Step 3 through Step 7.

Flushing the Engine Cooling System

WARNING

DO NOT remove the radiator cap from the expansion tank when the engine is hot. When the radiator cap is removed, the pressure is released from the system. If the system is hot, the steam and boiling coolant can cause burns.

CAUTION

Disposal of lubricants and fluids must meet local environmental regulations.

NOTE: Use drain pans large enough to catch all coolant. For coolant volume, see Table 2.

1. Drain the engine cooling system. See Draining the Engine Cooling System.

2. Close the coolant drain valve at the right side of the engine cooling core.

3. Reinstall the coolant return hose to the water pump and tighten the clamp.

4. Make sure the heater knob in the operator cabin is turned to its hottest setting.

5. Fill the cooling system with clean water through the radiator cap opening in the expansion tank. Fill until the water level has stabilized at the "MAX" mark.

6. Reinstall the radiator cap on the expansion tank.

7. Run the engine until the top radiator hose is hot.

8. Drain the engine cooling system. See Draining the Engine Cooling System.

9. Check the drained water for the following:
   - If it is dirty, repeat Step 2 through Step 9, until the water is clean.
   - If it is clean, refill the engine cooling system with coolant. See Filling the Engine Cooling System.

Cleaning the Engine Cooling System

CAUTION

Maximum recommended time with any type of cleaner is 3 hours. Any prolonged usage may cause damage to system elastomers and corrode system soft metals.

1. Drain the engine cooling system and flush it once. Go to Draining the Engine Cooling System and Flushing the Engine Cooling System.

2. Refill the cooling system with cleaner and follow the cleaner manufacturer's instructions. See Filling the Engine Cooling System.

3. Flush the system twice before refilling with coolant, see Flushing the Engine Cooling System.

4. Refill the engine cooling system with coolant, see Filling the Engine Cooling System.

Remove and Replace Procedures

DRIVE BELT

Remove

NOTE: Notice the routing of the drive belt for easier installation.

1. Use a tool to pivot the belt tensioner counterclockwise.

2. Slip the drive belt off the water pump pulley and release the belt tensioner.

3. On trucks with Tier 4i/Stage III B engines:
   - Disconnect the electric connector of the fan clutch assembly.
   - Remove the bolt that retains the anti-rotation bracket to the support bracket.
   - Guide the belt upwards between the anti-rotation bracket and the support bracket.

4. Guide the belt over the fan for a complete removal of the belt. See Figure 14.

Install

1. Guide the drive belt over the fan.

2. On trucks with Tier 4i/Stage III B engines:

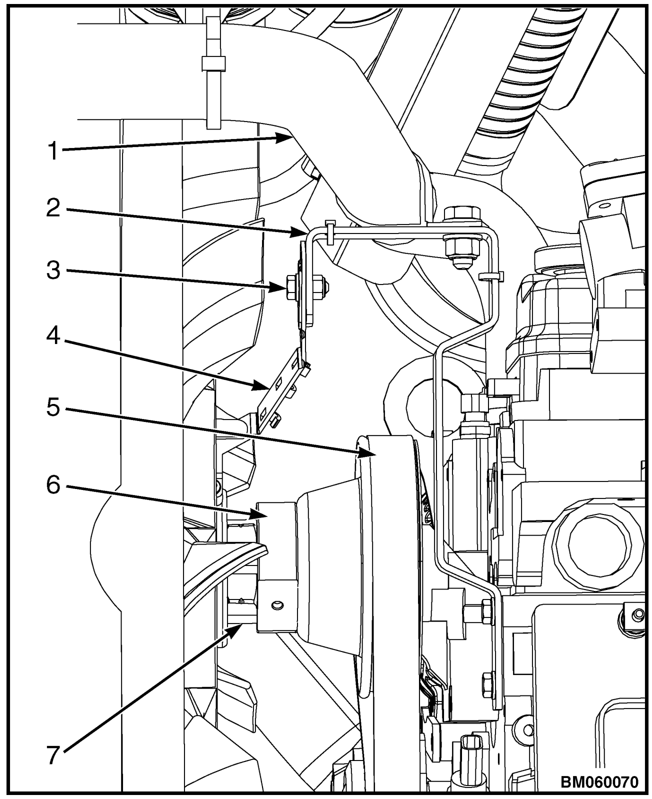
- Guide the belt downwards between the anti-rotation bracket and the support bracket.
- Install the bolt that retains the anti-rotation bracket to the support bracket.
- Connect the electric connector of the fan clutch assembly.

3. Route the drive belt over the pulleys except for the pulley for the water pump.

4. Use a tool to pivot the belt tensioner counterclockwise.

5. Slip the drive belt onto the water pump pulley and release the belt tensioner.

6. Check correct alignment of the belt.



1. ENGINE CORE SUPPLY HOSE
2. SUPPORT BRACKET
3. BOLT
4. ANTI-ROTATION BRACKET
5. FAN PULLEY
6. FAN SPACER
7. HEXAGON NUT

Figure 14. Fan Clutch Assembly, Tier 4i/Stage III B only

BELT TENSIONER

Inspect

1. Look for signs of slippage at the alternator pulley.

2. Put a spanner on the nut at the alternator pulley and try to rotate the alternator clockwise.

If the alternator pulley slips, judge whether the spring force of the belt tensioner is still sufficient.

3. Use a tool to pivot the belt tensioner counterclockwise.

4. Remove the belt from the water pump pulley and tensioner pulley.

Inspect the tensioner pulley for play and smooth rotation.

Inspect the pivot of the tensioner for play.

5. Install a new tensioner if it fails the inspection for the spring, pulley, or pivot.

Remove

1. Remove the drive belt. See Drive Belt.
2. Remove the mounting bolt for the tensioner, and the tensioner.

Install

1. Install the tensioner and lock it in position on the engine block.
2. Install the capscrew and tighten to 43 N•m (32 lbf ft).
3. Install the drive belt. See Drive Belt.

WATER PUMP

Inspect

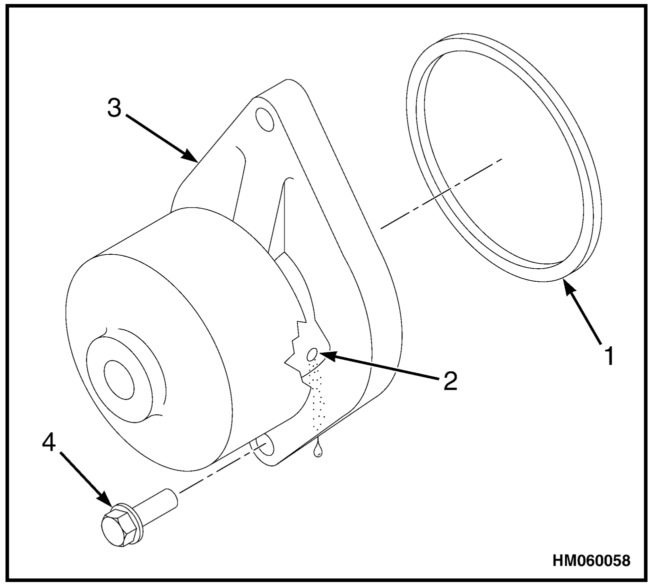
1. Pivot the belt tensioner counterclockwise to release the tension in the drive belt, and remove the belt.
2. Perform the following checks:
   - Pressurize the cooling system and verify if the water pump leaks at the weep hole. An existing droplet at the weep hole is acceptable. Continuously escaping droplets are not acceptable. See Figure 15.
   - Rotate the water pump pulley and verify its smooth rotation.
   - Establish that the water pump bearings have no play.
3. Replace the water pump if it fails any of the above tests. The water pump is serviced as an assembly only.
4. Re-install the drive belt if the pump still functions properly. See Drive Belt.

Remove

1. Drain the engine cooling system. See Draining the Engine Cooling System.
2. Remove the drive belt. See Drive Belt.
3. Remove the two capscrews that retain the water pump, and remove the water pump. Discard O-ring.

Install

1. Install a new O-ring in the water pump housing.
2. Install the water pump on the engine. Make sure the weephole is below the shaft.
3. Install the two capscrews for the pump and torque to 24 N•m (18 lbf ft).



1. O-RING
2. WEEP HOLE
3. WATER PUMP
4. CAPSCREWS

Figure 15. Water Pump

4. Guide the drive belt over the fan and route it over the pulleys except for the pulley for the water pump. See Drive Belt.
5. Pivot the tensioner and slip the drive belt over the water pump pulley.
6. Refill the cooling system. See Filling the Engine Cooling System.
7. Operate the engine and check for leaks. Verify correct coolant level.