8. COOLING SYSTEM

CONTENTS

COOLING SYSTEM

1. GENERAL

Heat generated inside the combustion chamber during combustion and heat generated by friction of moving parts is removed by the cooling system to allow continuous operation in the proper range.

【Coolant flow】

The cooling system cools the engine while it is running to prevent overheating and maintain a proper operating temperature.

Kubota engines are used pressurized forced-circulation type.

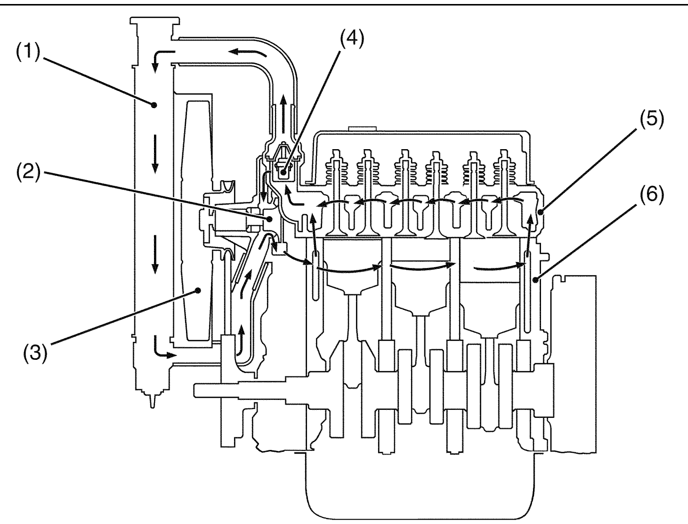
This system consists of a radiator (1), water pump (2), cooling fan (3), thermostat (4) and coolant temperature sensor (some models).

The coolant is cooled through the radiator core, and the fan set behind the radiator pulls cooling air through the core to improve cooling.

When the coolant in the engine is at a low temperature, the thermostat valve is closed so that the coolant is circulated in the engine through the bypass pipe.

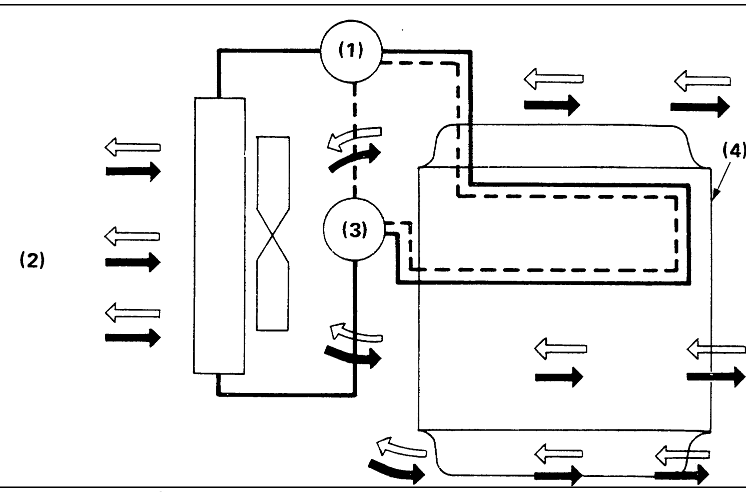
When the temperature of the coolant becomes the valve opening temperature of thermostat (4), the thermostat (4) opens the valve to return the heated coolant to the radiator (1).

The water pump (2) sucks the cooled coolant, forces it into the cylinder block (6) and draws out the hot coolant. 03-M, 07, V3, series engines employ the bottom bypass system to improve the cooling performance of radiator and the three step valve opening type thermostat to reduce thermal shock radically.



(1) Radiator (2) Water pump (3) Fan (4) Thermostat (5) Cylinder head (6) Cylinder block

Fig. 8-1 Cooling system



(1) Thermostat (2) Cooled air (with pusher-fan ⇐) (with suction-fan →) (3) Pump (4) Engine

Fig. 8-2 Cooling air flow

2. RADIATOR

[1] GENERAL

Heated cooling water, passing through the radiator is cooled when the fan causes air to pass through the radiator and disperse the heat. The standard radiator mounted on KUBOTA engine is a tube-and-corrugated-fin type with a superior cooling effect. Radiator capacity is selected according to rated output (at standard condition) of an engine to prevent overheating extended operation.

Pressurized cooling water inside the radiator is kept less than 88 kPa (0.9 kgf/cm^2, 12.8 psi) by the radiator cap to prevent deformation of radiator due to excessive pressure. Generally, corrugated-fin types come with louver or without louver and with various fin pitches. When selecting a radiator, dust conditions, ambient temperature, load etc. must be considered carefully.

A radiator has many thin copper, brass or aluminium components and requires special care and handling.

Radiators should be installed where they are not subjected to impacts and vibration. Measures should also be taken to prevent engine parts or other objects from contacting radiator.

A coolant recovery tank should be installed for all applications.

This helps prevent loss of coolant and overheating resulting from coolant level.

[2] TYPE

In general, there are two kinds of radiators. One is a down flow radiator. The other is a cross flow radiator.

★ Down flow radiator (Conventional)

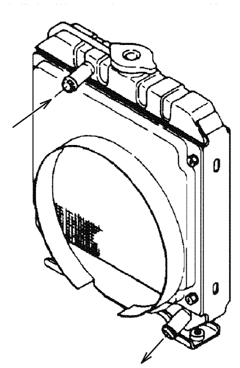


Fig. 8-3

★ Cross-flow radiator

In a cross-flow radiator the coolant passageways travel horizontally rather than vertically. Another feature of the cross-flow radiator is that the inlet and outlet tanks are located on the sides of the radiator, rather than on top and bottom. This allows for a “low profile” cooling system.

These radiators offer a compact cooling system, but special attention must be given to key issues associated with a cross-flow radiator.

1) Cooling system fill

a) A cooling system should be designed to provide complete filling of the engine, piping, and radiator without air pockets in the system. Due to the nature of the cross-flow radiator design, this can be very difficult.
b) Even with a standard coolant recovery bottle, removing this air can require several warm-up and cool-down cycles.
c) Only cooling system with a pressurized recovery tank will allow proper and quick de-aeration.

2) De-aeration capability

a) De-aeration capability is the ability of a cooling system to get rid of air and gasses entrapped in the cooling system. Air can be introduced into the system during fill or during normal operation.
b) A properly designed down-flow radiator has a top tank with a baffle. The area above the baffle serves as space to isolate entrapped air from the coolant.
c) A cross-flow radiator has no method of separating the entrapped air from the coolant causing the air to constantly be drawn back into the system. Constant splashing as coolant enters the tank causes air and coolant to mix, allowing the cooling system to draw the air in.

* Air retained in the cooling system can cause “hot spots” in the engine, particularly the cylinder head. It can also reduce cooling capacity and possibly cause cavitations of the water pump.

3) Drawdown capability

a) Drawdown capability is the ability of a cooling system to correctly function with a given amount of coolant loss.

b) Cross-flow radiators do not provide drawdown capability during operation, Even With A Standard Coolant Recovery Bottle.

* Only at cool-down will coolant from the recovery bottle be allowed back into the radiator.

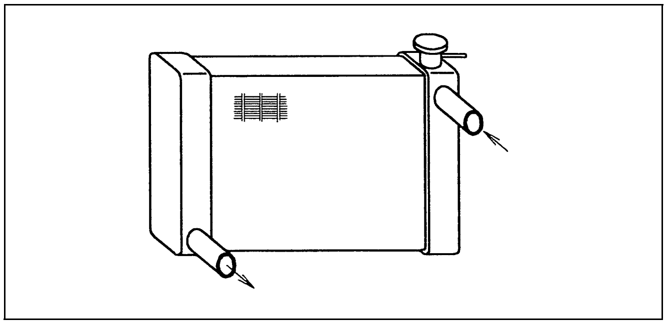


Fig. 8-4

[3] RADIATOR POSITION

In case of mounting a radiator parallel to the crankshaft, positioning of other components, such as the fan belt drive system, becomes complicated. Non-standard positioning should be avoided as much as possible.

(1) Basic arrangement

Basically a fan is installed on the water pump shaft, and a radiator position is shown below.

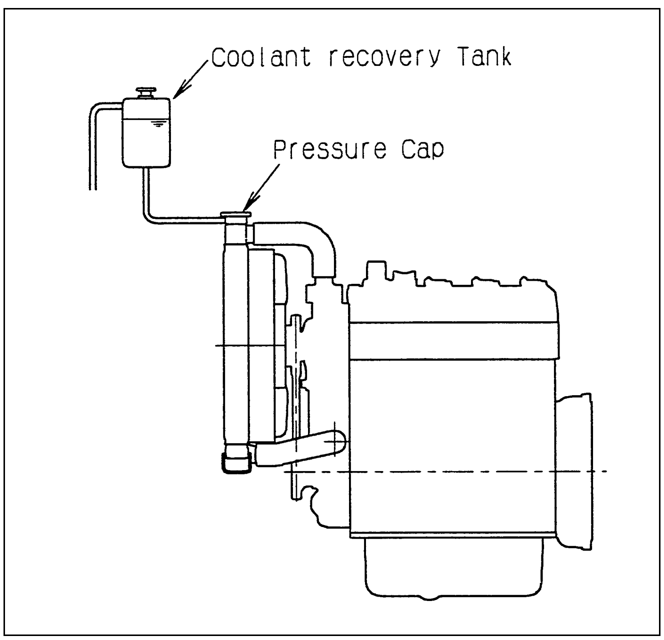


Fig. 8-5

(2) Top of radiator below engine water outlet

Sometimes a radiator is positioned at a lower level and the pressure cap may be positioned at a lower level than the rest of system. In this case, a special venting/bleed line arrangement is required.
Below are examples.

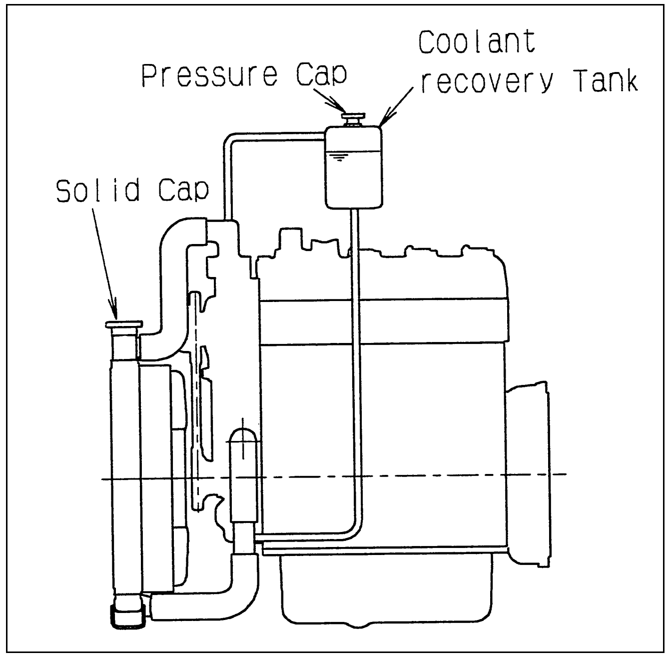


Fig. 8-6

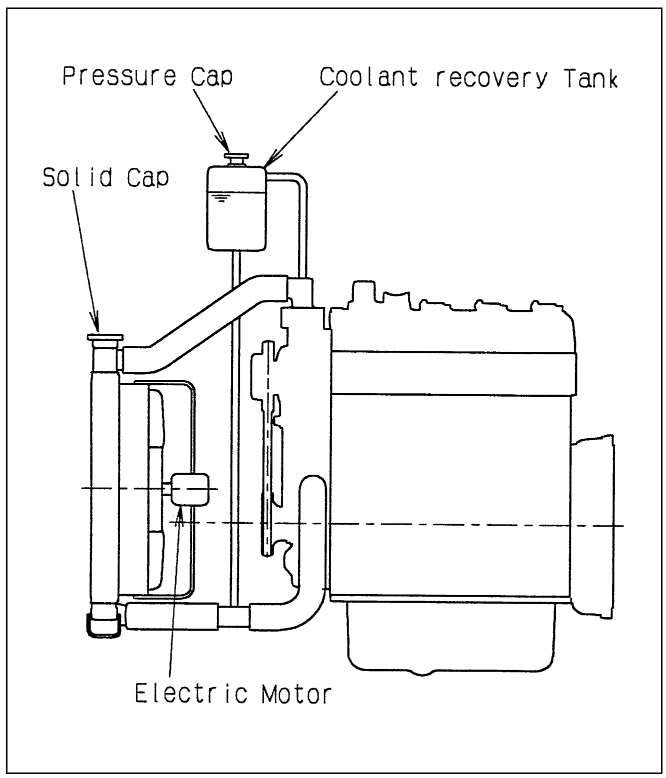


Fig. 8-7

(3) Distance between fan and radiator core

Clearance between fan and radiator core should be kept as far as possible, within the space limitation in radiator mounting.

If the clearance between fan and radiator core cannot be maximized due to lack of space, it should be more than 25 mm (1 in.).

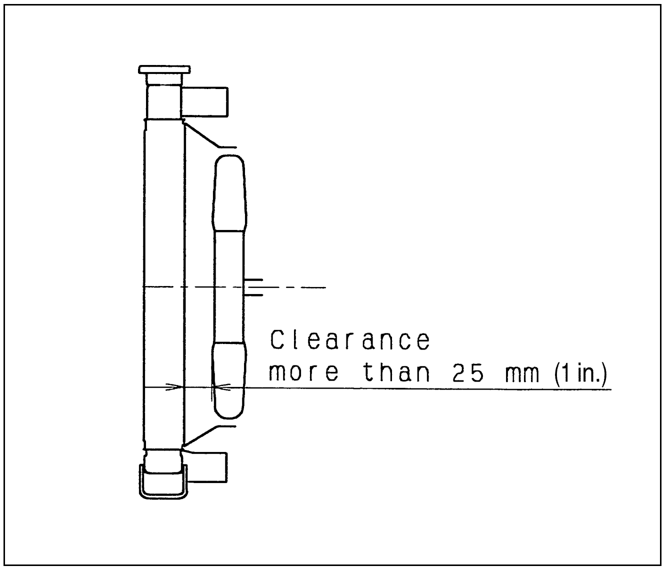
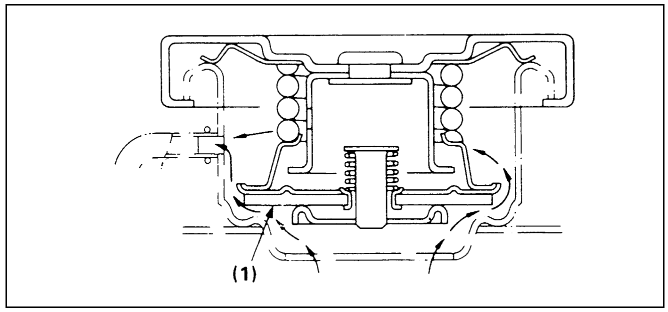


Fig. 8-8

[4] RADIATOR CAP

Pressure inside a radiator is slightly higher than atmospheric pressure and is regulated by the radiator cap.
[less than 88 kPa (0.9 kgf/cm^2,12.8 psi)]

【Function of Radiator Cap】
(1) When internal pressure is high

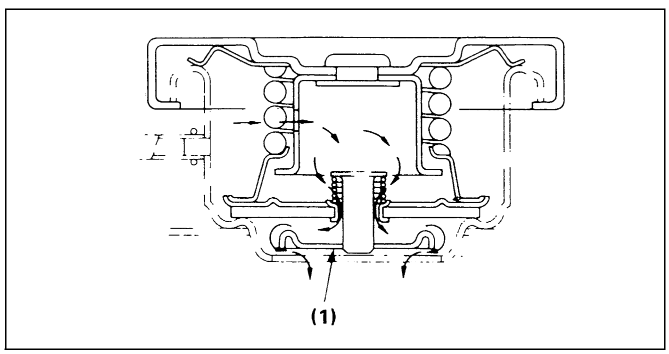


(1) Pressure valve

Fig. 8-9 When radiator internal pressure is greater than 88 kPa (0.9 kgf/cm^2, 12.8 psi)

When temperature in the radiator increases, the coolant volume increases proportionally. This, combined with steam generation, may cause the internal pressure to rise up to 88 kPa (0.9 kgf/cm^2, 12.8 psi). The pressure valve opens, allowing coolant to escape and preventing rise in pressure. This protects the radiator.

(2) When radiator internal pressure is lower than atmospheric pressure



(1) Vacuum valve

Fig. 8-10 When radiator internal pressure is lower than atmospheric pressure

When coolant temperature drops, coolant volume decreases, reducing internal radiator pressure to below atmospheric pressure.
The vacuum valve opens, equalizing radiator internal pressure and atmospheric pressure, protecting the deformation of radiator.

3. COOLING FAN

A cooling fan moves the air required to disperse radiator heat. The exact type is generally selected after considering the following factors.

(1) Air direction (Suction/Pusher fan)

★ A suction type cooling fan is generally used on moving vehicles since air is taken in from the direction in which the vehicle is running.
★ When enclosing an engine in a noise-proof case, a suction type fan is used to prevent noise from being discharged.
★ A pusher type cooling fan is used for machines working in dusty places to prevent radiator clogging as cooling air passes through machine before entering the radiator.

(2) Cooling fan diameter

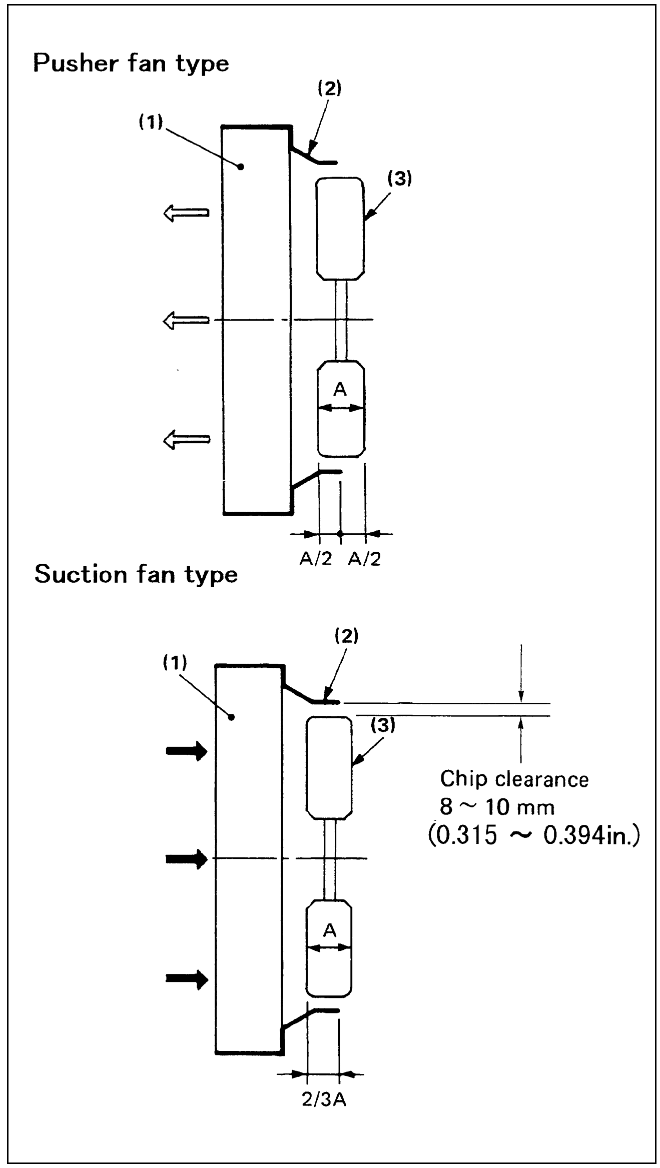
Generally, large diameter cooling fans provide sufficient cooling air at low rpm. However, the same cooling effect can be obtained with a smaller diameter fan by providing higher fan speed or fan blades with a steep-blade angle. This allows a more compact installation.
Standard cooling fans on KUBOTA engines have a 240 to 430 mm (9.4 to 16.9 in.) out side diameter.

(3) Cooling fan speed

Standard KUBOTA cooling fans are driven by the crankshaft via a V-belt and pulley to rotate approx. 0.9 to 1.4 times faster than engine speed.

(4) Shroud

A shroud is provided around the cooling fan on the radiator side to increase air flow efficiency.
The relative position of the shroud and fan are closely related to suction efficiency of air flow, but available positions are limited by the surrounding space.
Standard positioning is shown at Fig. 8-11.



(1) Radiator (2) Shroud (3) Fan

Fig. 8-11

(5) Air discharge

Generally, a 15 to 20% additional air discharge capacity is provided based on heat dispersion as a margin to ensure efficient cooling under most conditions.

(6) Power requirements

Power consumed for fan drive is in proportion to air discharge and radiator core air flow resistance. The calculation expressions are as follows.

$Ls = Lad / \eta ad$

Ls : Horsepower requirements (PS)

Lad : Adiabatic compression horsepower (PS)

$Lad = Pdf \cdot Q / 4500$

η ad : Adiabatic efficiency of fan (%)

(Generally 50 - 70%)

Q : Suction capacity (m^3/min.)

Pdf : Compression difference between the push side and the suction side (mmAq)

(The performance curves of cooling fans used for KUBOTA diesel enginse are shown in attached TECHNICAL INFORMATION.)

(7) Fan spacer

Various thickness spacers, which are installed between a fan and a water pump, are available. These are used to properly position the fan in the shroud. If thicker spacers than 21 mm (0.83 in.) on the S.M., 05 or 03-M, 07 series and 27 mm (1.06 in.) on the V3 series are installed, details of the installation should be sent and reviewed with the KUBOTA Engineering Department, in order to avoid excessive loading on the water pump bearings. If larger diameter and heavier fans than the KUBOTA standards are installed, the spacers are not recommended.

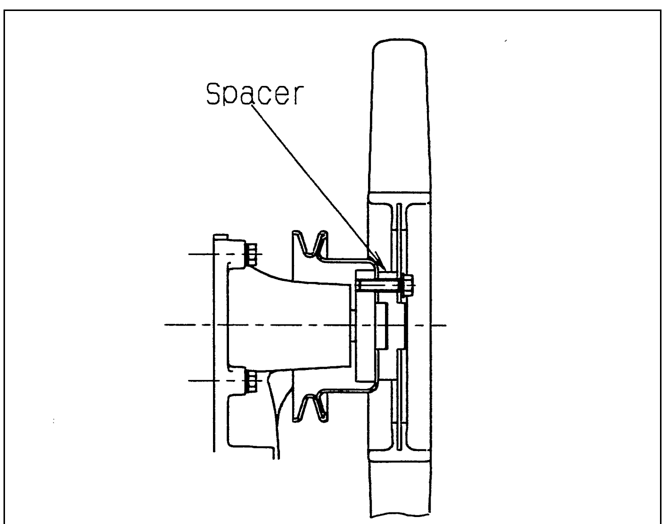


Fig. 8-12

(8) Electric fan

Use of electric fans on vehicles for radiator cooling has been increasing recently.
These fans turn at a constant speed regardless of engine speed.
However, in cases where cooling air is not enough due to insufficient vehicle velocity, the cooling effect on engine body, oil pan, etc is sometimes less than that of a direct-driving fan.
For this reason, cooling capacity and air flow around the engine must be examined and thorough tests conducted after the engine is installed.
Also, care must be taken to the capacity of alternator since the DC motor drives the fan.

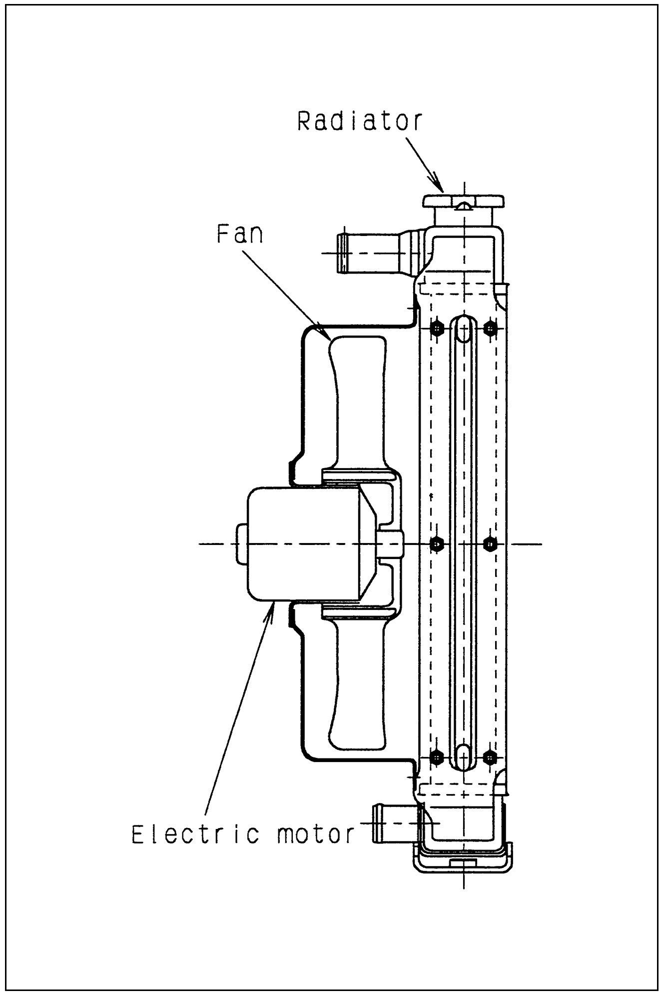


Fig. 8-13

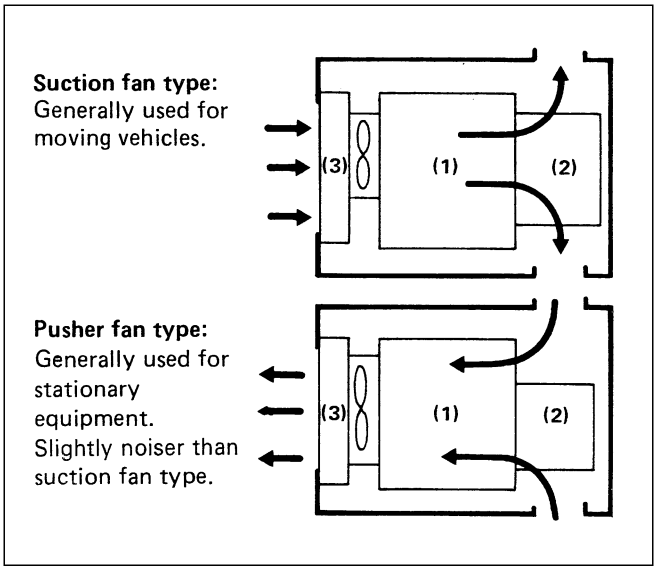
Great care should be taken in the selection of temperature switches and the use of fan relay switches to ensure positive switch relay function.

4. COVERING

Most engines are covered to some extent. Additional design importance is given to system compactness and noise reduction.
Covering encases the engine. The most important factor to be considered in covering the engine is heat radiation.

(1) Air cleaner must be positioned where fresh, clean air is available. Care must also be used to avoid adverse effect on engine output.

(2) Radiator fan



(1) Engine (2) Generator (3) Radiator

Fig. 8-14 Encloser type

(3) Heat balance

When the engine is covered for noise reduction, check carefully cooling system on running to avoid over heat.
It is very important.

(4) Maintenance

Machines must also be designed for easy check, supply or replacement of fuel, lubricating oil, coolant and filter elements.

5. WATER PUMP

A centrifugal water pump with an impeller is mounted on top of the gear case at the front of the engine (radiator side). It pumps heated coolant from the cylinder head to the radiator. A seal is used to prevent leakage from around the pump shaft. The fan driving pulley is connected to the end of the pump shaft and both water pump and fan are driven by the crankshaft via the V-belt.

★ The performance curves of water pump are in accordance with attached technical information.

6. THERMOSTAT

Coolant is adjusted to the proper temperature by the thermostat located at the upper part of the cylinder head before being fed to the radiator. With thermostat control the coolant does not enter the radiator when engine temperature is low and only circulates inside the engine until it reaches a certain temperature.

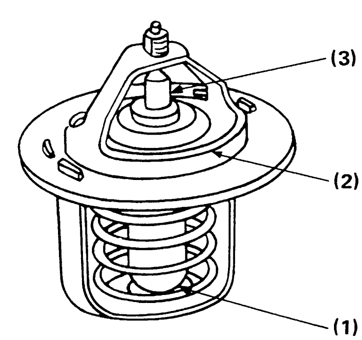
★ Typical specification

For Super Mini series	
Valve opening temperature	: 71 °C (159.8 °F)
Valve full open temperature	: 85 °C (185 °F)
Valve lift	: 6 mm (0.236 in.)

For 05 series and 03-M series	
Valve opening temperature	: 71 °C (159.8 °F)
Valve full open temperature	: 85 °C (185 °F)
Valve lift	: 8 mm (0.315 in.)

For 07 series	
V2607 Engine	
Valve opening temperature	: 82 °C (180 °F)
Valve full open temperature	: 95 °C (203 °F)
Valve lift	: 8 mm (0.315 in.)
V3307 Engine	
Valve opening temperature	: 76.5 °C (169.7 °F)
Valve full open temperature	: 90 °C (194 °F)
Valve lift	: 8 mm (0.315 in.)

For V3 series	
Valve opening temperature	: 76.5 °C (169.7 °F)
Valve full open temperature	: 90 °C (194 °F)
Valve lift	: 8 mm (0.315 in.)

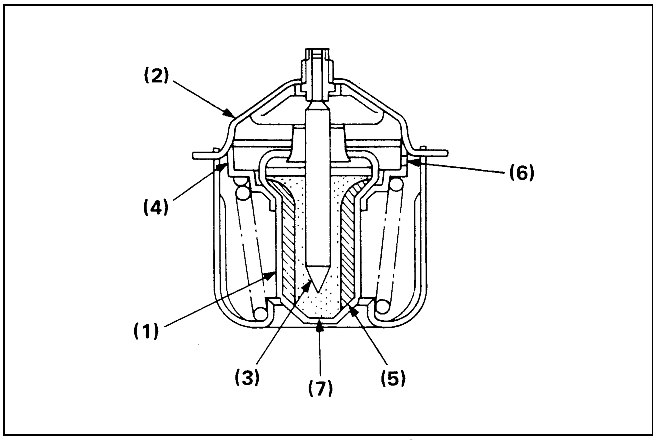


(1) Pellet (2) Seat (3) Spindle

Fig. 8-15 Thermostat

A wax pellet-type thermostat is controlled by waxed sealed in a pellet. The wax is solid at low temperature but liquefies and expands when heated to open the thermostat valve.

(1) At low temperature [below 71 °C (159.8 °F) or below 76.5 °C (169.7 °F)]

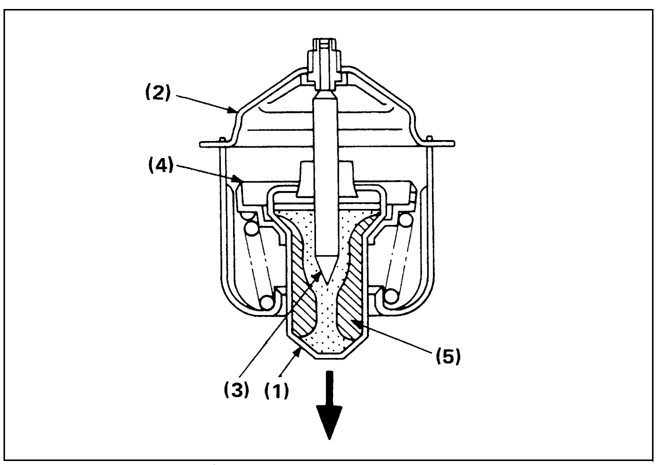


(1) Pellet (2) Seat (3) Spindle (4) Valve (5) Wax(solid) (6) Leak hole (7) Synthetic rubber

Fig. 8-16 At low temperature

When the thermostat is closed, cooling water does not enter the radiator but only circulates inside the engine through the water return pipe. Any air remaining in the engine's water jacket escapes to radiator side through the leak hole (6) in the thermostat.

(2) At high temperature [above 71 °C (159.8 °F) or above 76.5 °C (169.7 °F)]



(1) Pellet (2) Seat (3) Spindle (4) Valve (5) Wax (liquid)

Fig. 8-17 At high temperature

When the coolant temperature exceeds 71 °C (159.8 °F) or 76.5 °C (169.7 °F), wax turns from a solid into a liquid (5) and expands.

Since the spindle (3) is fixed, the pellet (1) pushes the valve (4) from its seat (2), and coolant flows form the cylinder head to the radiator.

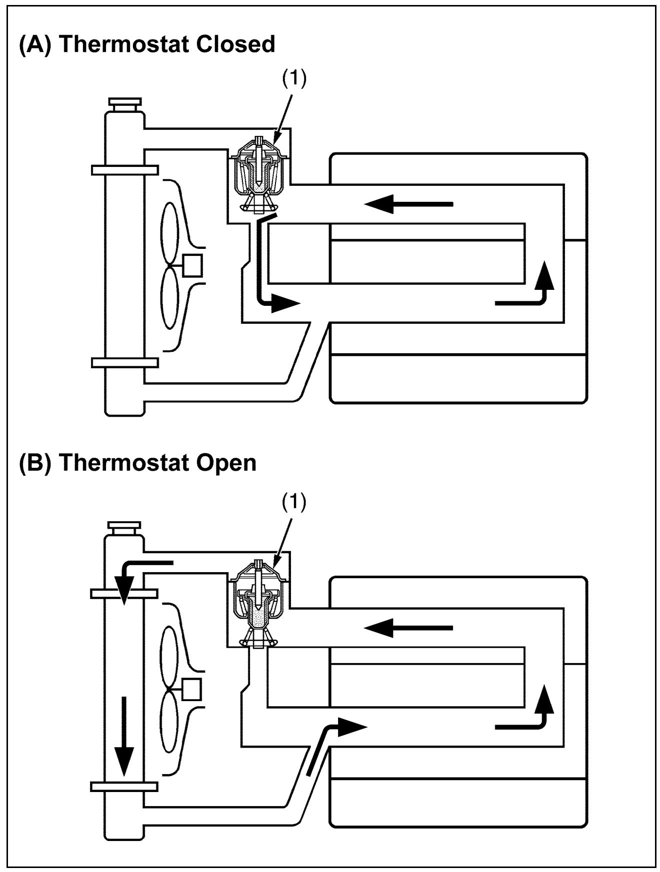
• Thermostat for 03-M, 07, V3 series engines

Bottom bypass system is introduced in 03-M, 07, V3 series for improving the cooling performance of the radiator.

While the temperature of coolant in the engine is low, the thermostat is held closed and the coolant is allowed to flow through the bypass pipe and to circulate in the engine.

When the temperature exceeds the thermostat valve opening level, the thermostat fully opens itself to prevent the hot coolant from flowing through the bypass into the engine.

In this way, the radiator can boost its cooling performance.



(1) Thermostat

Fig. 8-18 Thermostat for 03-M, 07, V3 series

● Thermostat for 07 and V3 series engines

07 and V3 series engine employ the three step valve opening type thermostat to reduces thermal shock radically.

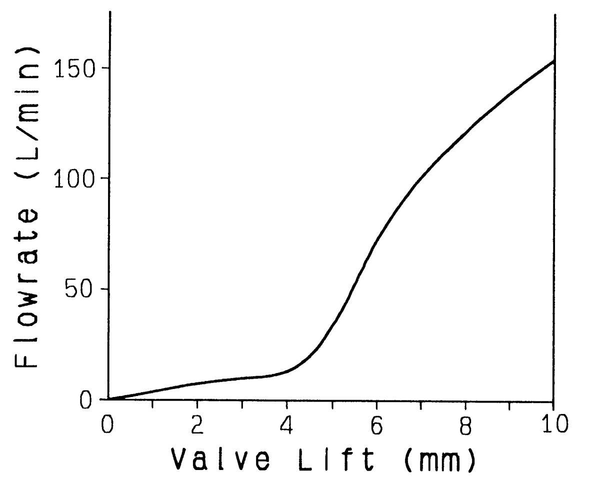


Fig. 8-19 Valve lift versus flow rate

The 07 and V3 series engine are equipped with the flow control thermostat. The valve has a notch to control the coolant flow rate smoothly in small steps.

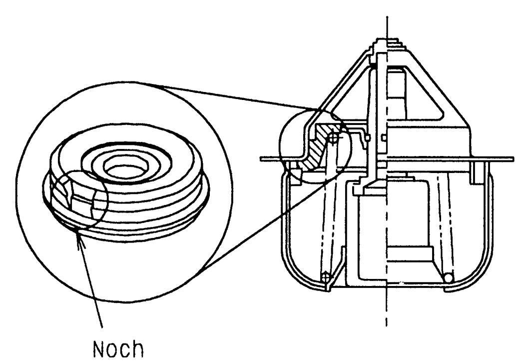


Fig. 8-20 Thermostat for V3 series

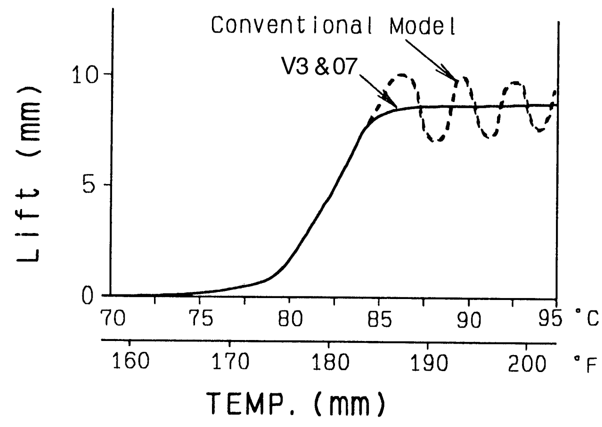


Fig. 8-21 Comparison of temperature rise form

(3) Coolant temperature for KUBOTA diesel engines

The coolant temperature is under the control of load, engine speed. cooling fan, radiator, water pump, thermostat, type of enclosure, pressure of radiator cap, ambient temperature and so on.

In case that the coolant is the mixture of 50% water and 50% ethylene glycol, the allowable water temperature is as follows :

Allowable coolant temperature	110 °C (230 °F)
Pressure of radiator cap	82 to 96 kPa
	0.84 to 0.98 kgf/cm^2
	12 to 14 psi

Note :

When a local radiator is procured by customers and pressure of the radiator cap is 48 kPa (0.49 kgf/cm^2 , 7 psi), the allowable coolant temperature is 104.4 °C (220 °F).

The coolant temperature must be under the above temperature at maximum ambient temperature condition [51.7 °C to 54.4 °C (125 °F to 130 °F)].

If an emergency shut down system is used, the temperature switch must be set at the allowable temperature listed in the above table.

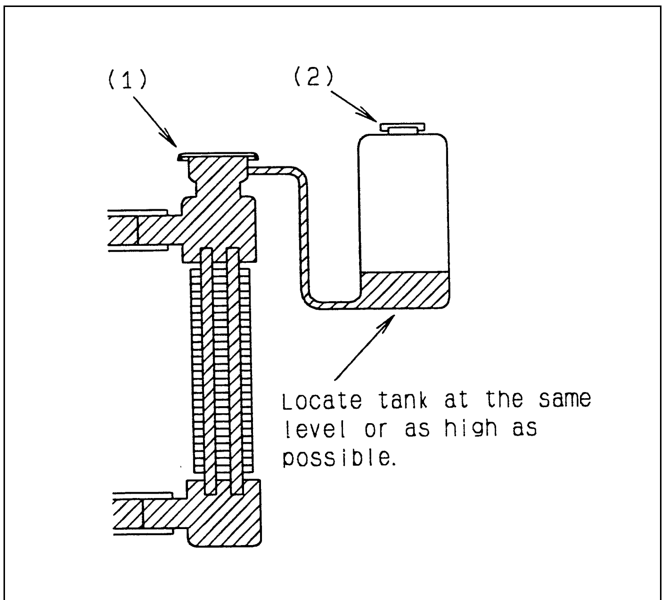
7. COOLANT RECOVERY TANK

The following benefits are provided by installing a coolant recovery tank independently to the radiator.

1) The radiator is always completely full which prevents entrance of air into the cooling system.
2) Any coolant overflow due to heat expansion is transferred to the coolant recovery tank and returns to the radiator when the temperature lowers. This eliminates coolant waste and the need to add coolant periodically.
3) Coolant is replenished to the coolant recovery tank only. Maintenance can be done easily if coolant level is visible.

【Types of coolant recovery tanks】

1) Semi-sealed type : An open-air type with slight natural evaporation of coolant, but low cost.
2) Actual capacity of a coolant recovery tank should be sized more than about 10% of total cooling system capacity.



(1) Cap with pressure valve (2) Cap with air bleed

Fig. 8-22 Semi-sealed type

8. OIL COOLER

Oil in a separate hydraulic implement (e.g. HST) linked to the engine is cooled either by the same radiator for the engine, or by an oil cooler installed in front or rear of the radiator. Capacity and wind resistance factors must be carefully examined.
The fig below shows an example of oil cooler located in front of the radiator. In this case, the oil cooler should be considered to position as uniform restriction as possible.

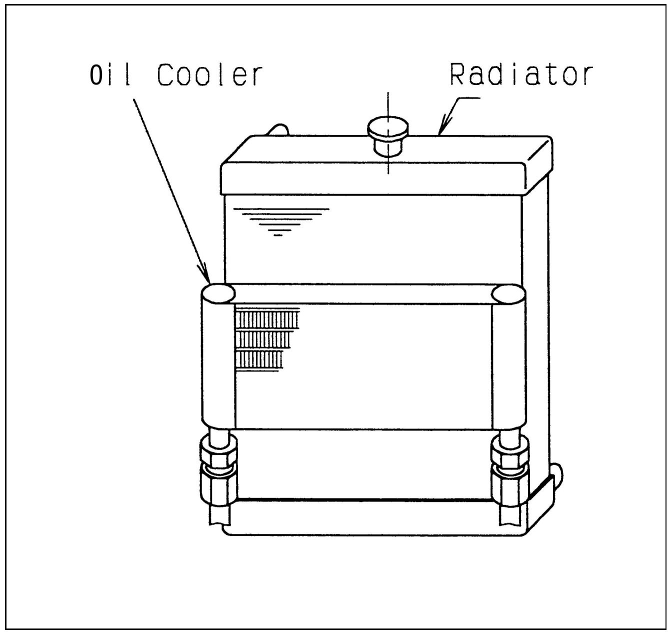


Fig. 8-23

An oil cooling system is available using the coolant circuit of the engine. This also requires careful study of air resistance and heat exchange factors.
Please contact the KUBOTA for details.

9. COOLING SYSTEM PRECAUTIONS

(1) Prevention of air entrapment

If air should enter the cooling system at point of connection, it can result in abnormal boiling, reduced pump performance, and overheating locally. This can cause loss of coolant due to air expansion and other problems.
Connections must be carefully checked. The same applies to exhaust gas entering due to faulty cylinder head gaskets.

(2) Radiator surface cleaning

The surface of the radiator is important to overall cooling performance. If the surface becomes dirty, overheating will result. A dust net is sometimes provided at the front and a wiper is installed to automatically clean the surface according to circumstances.

(3) Radiator support

A radiator must be properly supported to prevent vibration and impact if the engine is installed in a moving vehicle.
The Fig. 8-24 shows typical radiator installation.

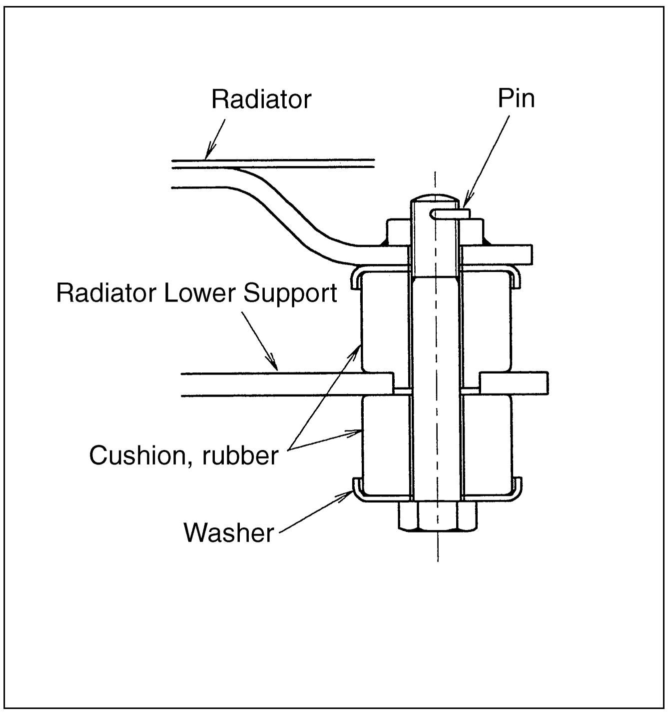
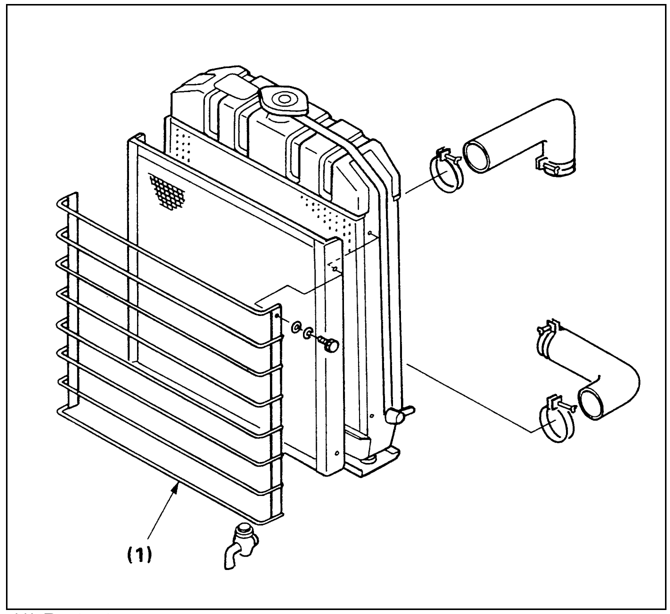


Fig. 8-24 An example of installation of KUBOTA radiator

Note :
Use upper support depending on the vibration level.

(4) Protection of radiator

If the radiator surface is directly exposed to outside, a protective frame should be installed around it. A typical example is shown Fig. 8-25.



(1) Protector

Fig. 8-25

(5) Prevention of air recirculation

It is important to take cool air into the radiator in order to get the best cooling effect.

Therefore when engine compartment is designed, suitable barriers and ducting arrangements around the radiator must be considered to prevent hot air recirculation.

Below show examples of compartment designs.

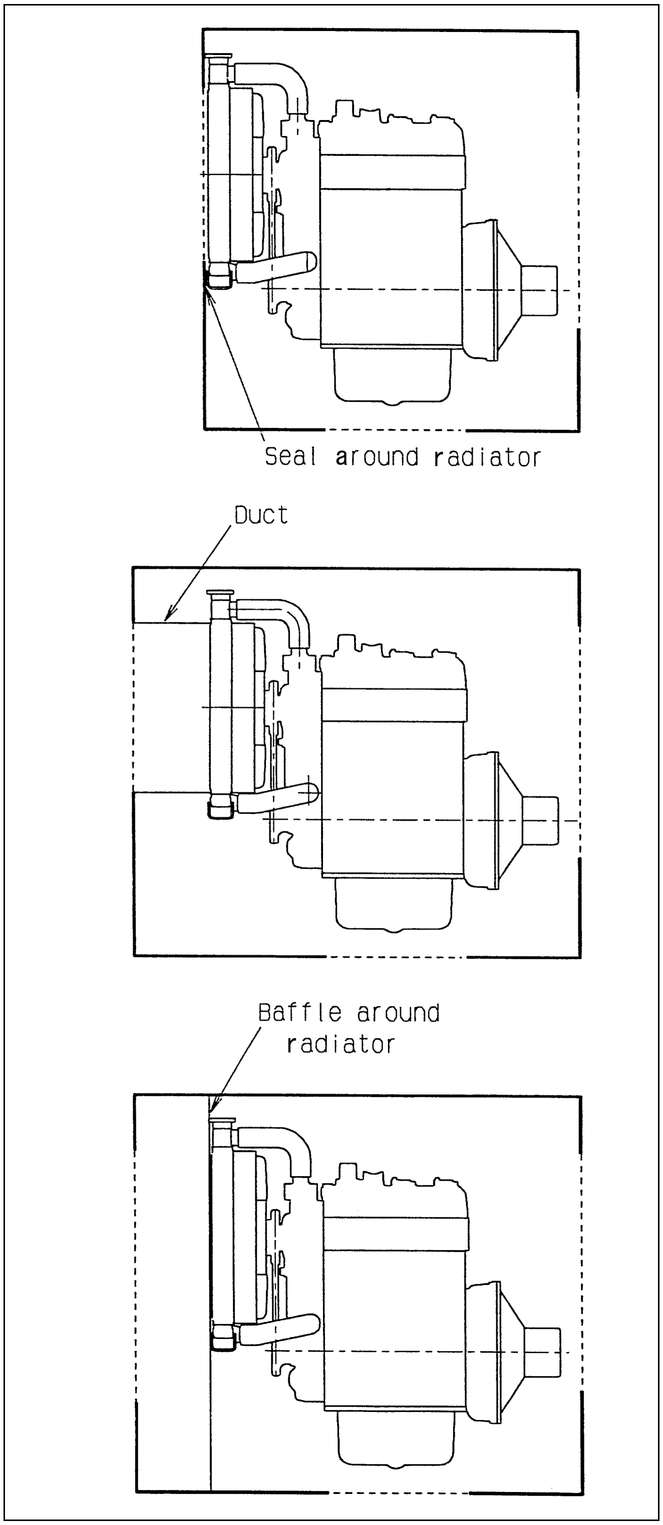


Fig. 8-26

(6) Entrance and exit of air blow

Open area of entrance and exit of air flow should be enough to prevent air flow reduction.

The open area should be at least, the same as radiator core area or more.

Opening the bottom of engine compartment is an effective way to make engine oil temperature lower.

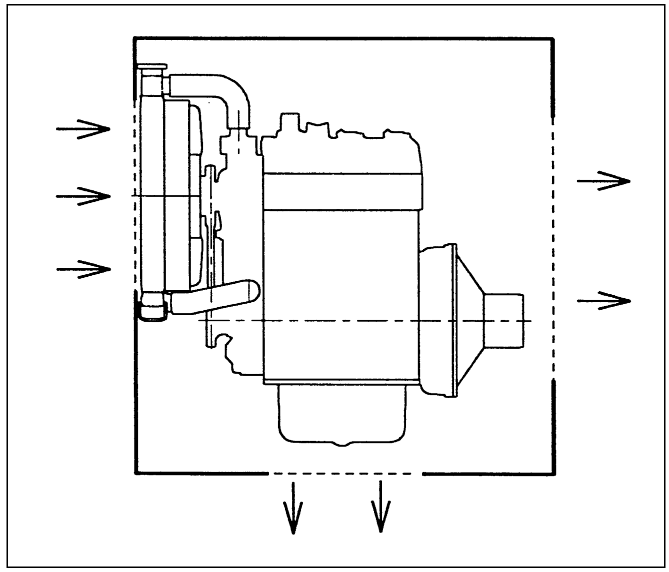


Fig. 8-27

10. HEAT REJECTION TO COOLANT

The amount of cooling loss, which can be dispersed by coolant in an engine is expressed as follows :

Ho = Hu × Ne × be × i/1000
The amount of heat dispersion by coolant of each engine is in accordance with attached TECHNICAL INFORMATON.
where as ; Ho : Amount of heat dispersion by cooling water (cooling loss) kJ/hr (kcal/hr) be : Specific fuel consumption (gr/kW•hr) i : Dispersion ratio to cooling water (%) Hu : Diesel fuel low caloric value 43074 kJ/kg (10290 kcal/kg) Ne : Engine output (kW)

11. RADIATOR CAPACITY

(1) General

Generally, water at atmospheric pressure boils at 100 °C (212 °F).

As the pressure inside the radiator is raised higher than the atmospheric pressure, the boiling point is also raised, and thereby the coolant temperature in the radiator can be kept lower than the boiling point, thus preventing eventual cavitation inside the pump.

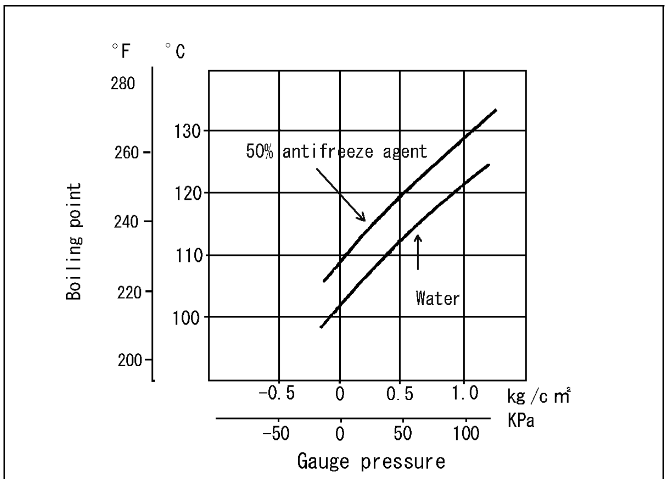


Fig. 8-28 A boiling point of water at different pressures

Boiling point of coolant

Rad. cap pressure	% of water /antifreeze	Boiling point	
		°C	°F
0 kPa {0 kgf/cm^2 (0 psi) }	100% water	100	212
	50/50	108	226
88.2 kPa {0.9 kgf/cm^2 (13 psi) }	100% water	118	244
	50/50	126	259

(2) Determination of a radiator size

The final determination of a radiator size is dependent on the load, ambient temperature and whether the engine is in a compartment or not, always select a larger radiator if a severe condition exists.

1) Factors of radiator size determination

[Operating condition]

Ambient temperature ⇒ Will the engine be open to the air or enclosed ?
Ambient pressure ⇒ Will the engine be used at high altitudes ?
Ambient humidity ⇒ Will the engine be used in extremely dry areas ?
Dust conditions ⇒ Will dust adhere to radiator surface ?
Movement of vehicle ⇒ Will the engine be installed in a moving vehicle ?
Load pattern ⇒ Will overloads be applied frequently ?
Cooling ⇒ Will the oil and/or hydraulic system also be cooled ?

[Construction]

Cooling water ⇒ How is it sufficient ?
Air flow ⇒ Is surrounding air nomally still ?
Type of radiator ⇒ Is it readily available ?
Space ⇒ How much space is available for radiator installation ?

2) Step of radiator specification determination

1) Determine heat load.
2) Determine overheating limit
3) Determine specifications of cooling system.

(3) Cooling capacity checking methods

1) Air-to-boil (ATB) test

ATB is a quick and easy method to determine a machines present cooling efficiency and help predict the cooling performance at elevated ambient temperatures.

[Test equipment]

- Temperature meter or data collector and at least 6-thermocouple probes and 4-optional probes
- A 50/50 mixture of Ethylene Glycol anti-freeze must be used in the engine
- 88.2 kPa {0.9 kgf/cm^2 (12.8 psi)} rated radiator cap installed
- Blocked open thermostat
- Engine tachometer

[Test conditions]

(a) Ambient temperature of at least 24 °C (75 °F) is required for accurate testing.
If outside temperature is below 24 °C (75 °F) testing must be completed in a heated room.
- Testing in temperatures below 24 °C (75 °F) or in high winds might produce inaccurate results.
- Ambient temperature readings should be taken approximately 3 m (10 ft) from the machine.

(b) Machine must be tested at a duty cycle that represents the worst case scenario that the machine will be used in the field.

(c) All machine enclosure panels, screens and fan shrouding must be in place.

[Test setup]

1. Install blocked open thermostat.
2. Install thermocouples to record the following data.
   a. Radiator coolant in (Top tank)
   b. Radiator coolant out (Optional but recommended)
   c. Air cleaner inlet air
   d. Engine oil
   e. Exhaust gas
   f. Engine speed
   g. Ambient
   h. Radiator air in (Optional)
   i. Compartment air (Optional)
   j. Radiator air out (Optional)
   k. Hydraulic oil (Optional)

Note :

- **Engine speed and exhaust temperature is required to estimate the engine loading.**
- **Radiator coolant temperature readings must be taken in the coolant stream.**
- **Ambient temperature readings should be taken 3 m (10 ft) from the unit.**
- **Oil temperature should be taken in the oil sump as close to the center as possible.**

3. Operate the unit at its most severe operating condition until the coolant temperature is stabilized (does not change more than 2 °C (36 °F) in 15 minutes). Stabilization usually takes place after operating the engine for 45 minutes to 1.5 hours under loaded condition.
4. Record data in **Temperature Measuring Sheet** in small time increments until stabilization temperature is reached.
5. To calculate ATB
   88.2 kPa {0.9 kgf/cm^2 (12.8 psi)} radiator cap

   ATB (Air-To-Boil) = (A-B) + C

   A=Theoretical coolant boiling temperature or maximum allowable coolant temperature
   - 110 °C (230 °F) is Kubota's maximum allowable coolant temperature with a 88.2 kPa {0.9 kgf/cm^2 (12.8 psi)} radiator cap.
     If a 48.3 kPa {0.5 kgf/cm^2 (7 psi)} cap is used, substiute 104 °C (220 °F) in place of 110 °C (230 °F).

   B=Top tank or engine coolant out line temperature (Thermostat fully open)
   C=Actual ambient temperature recorded during test

Example: A D722 using a 88.2 kPa {0.9 kgf/cm^2 (12.8 psi)} radiator cap running in a turf tractor under severe operating conditions.
The top tank coolant temperature was measured at 90 °C (195 °F). The ambient was recorded at 29 °C (85 °F). Therefore;
ATB = {110 °C (230 °F) - 90 °C (195 °F)} + 29 °C (85 °F)
ATB = 20 °C (35 °F) + 29 °C (85 °F)
ATB = 49 °C (120 °F)

[To evaluate ATB]

Kubota's minimum allowable ATB is 49 °C (120 °F).
An ATB below 49 °C (120 °F) indicates limited cooling reserve.
Using the above example, the ATB of 49 °C (120 °F) means that if the ambient temperature would rise from 29 °C (85 °F) to 49 °C (120 °F) then the top tank coolant temperature would rise to the maximum allowable of 110 °C (230 °F).

- The ATB is the maximum ambient temperature which the machine can operate in and not exceed Kubota's maximum coolant temperature.

The equipment manufacturer should determine the unit's anticipated operating ambient and design the cooling system to provide for proper cooling under all potential operating conditions.
Since it is not always possible to test the application at the highest anticipated ambient, a higher than 49 °C (120 °F) ambient should be the target.

[Summation]

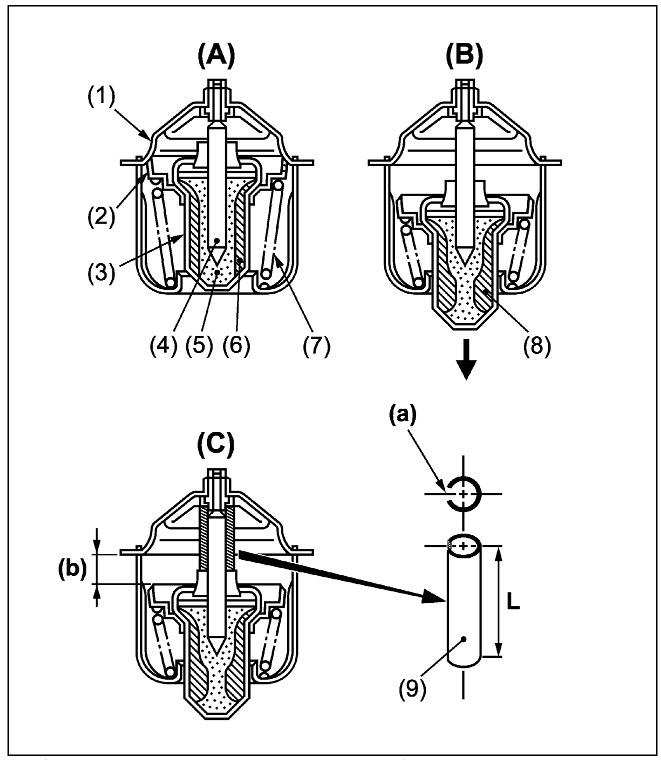
1. ATB test can be used for engineering evaluations and is a part of a standard Application Review.
2. ATB should be **49 °C (120 °F) or higher.**
3. ATB figures higher than 49 °C (120 °F) will provide the greatest cooling reserve and maximum engine life.
4. The radiator inlet air temperature must not be more than -12 °C (10 °F) above ambient temperature, recorded 3 m (10 ft) from the machine.
   Higher than -12 °C (10 °F) indicates poor air re-circulation.
5. The difference between the top tank temperature and bottom tank coolant temperature should be approximately -5 °C (10 °F).
   A greater differential might indicate too much restriction in the cooling circuit.
6. If the machine is operated at altitude, the air density and the cooling fan airflow across the radiator will decrease.
   Therefore, the higher the ATB the more reserve is available.
7. The use of 50/50 mixture of anti-freeze and water only adds about -15 °C (5 °F) to the top tank temperature over pure water.
   However, the boiling point under cap pressure of 88.2 kPa {0.9 kgf/cm^2 (12.8 psi)} increases from 118 °C (244 °F) to 126 °C (259 °F) using a 50/50 mixture.
8. Air filter inlet should be positioned to take in air at or near ambient temperature.
   High inlet temperatures can have a negative effect on ATB and oil temperature.
9. **Oil temperature must be below 120 °C (248 °F) Intermittent Duty** {110 °C (230 °F) Continuous Duty}.
   Elevated temperatures can increase oil oxidation and must be corrected.
   - Elevated oil temperatures can be a result of high air intake temperatures, high engine compartment temperatures, poor air recirculation or inadequate cooling system capacity.

[Sleeve used to hold thermostat open]

Sleeve length

Series	Length (L)
S.M. series	12.0 to 12.5 mm (0.47 to 0.49 in.)
05 series	14.0 to 14.5 mm (0.55 to 0.57 in.)
03-M series	14.0 to 14.5 mm (0.55 to 0.57 in.)
07 series	14.0 to 14.5 mm (0.55 to 0.57 in.)
V3 series	14.0 to 14.5 mm (0.55 to 0.57 in.)

Above sleeve lengths will provide valve openings of :
6 mm (0.24 in.) for S.M. series
8 mm (0.31 in.) for 05, 03-M, 07, V3 series



(1) Seat
(2) Valve
(3) Pellet
(4) Spindle
(5) Synthetic rubber
(6) Wax (Solid)
(7) Spring
(8) Wax (Liquid)
(9) Copper tubing 6.35 mm dia. (0.25 in. dia.)

(A) Thermostat closed
(B) Thermostat fully open
(C) Thermostat fully open (Sleeve installed)
(a) Split with hacksaw blade
(b) 6 mm (0.24 in.) or 8 mm (0.31 in.)

Fig. 8-29 Thermostat

2) Normal heat test

This method can be used instead of the air-to-boil test. Apply the maximum horsepower and torque to the engine at the maximum required operating temperature, and measure the engine water temperature to check for overheating.

12. COOLANT

Quality of coolant is an important factor.
Cooling is adversely affected by corrosion of engine parts. This can reduce engine output and shorten engine life.

(1) Nature of water

Water is used for cooling since it absorbs heat well and is readily available. Coolant boils at 100 °C (212 °F) freezes at 0 °C (32 °F) and has other disadvantages such as a tendency to leave deposits and corrode metal parts.
These disadvantages can cause cooling system problems. Special measures, such as those listed below, are required :

a) Raising of the boiling point by pressurizing the cooling system (Radiator cap) and using antifreeze.
b) Lowering the freezing point by using antifreeze.
c) Selecting water carefully and using a rust preventive.
d) Don't use hard water.

(2) Deposits and rust

Deposits (scale) can be generated wherever water exists and can accumulate easily in the cylinder block and cylinder head where temperature is consistently high and where the radiator temperature varies greatly. Deposits will take the form of brown and sticky tar, and have very poor thermal conductivity. Accumulated deposits restrict water circulation and reduce the overall cooling effect.
Rust, on the other hand, is gathered on metal parts and restricts water circulation if left untreated.
Rust also lowers the overall cooling effect (like deposits), because it has poor thermal conductivity. Rusted metal surfaces become rough and pitted. Metal pieces can become scaled and thick and lose their strength, causing cracks or fatigue failure.

(3) Grade of water

Clean soft water should be used for the cooling system. Distilled water, tap water, and pure rain are especially recommended. Natural water generally contains minerals and sometimes salt, which can oxdize metal and accelerate corrosion. On the other hand, hard water is liable to create deposits more quickly. If impure water has to be used for cooling, completely flush the cooling system and add a rust preventive.

13. FREEZING AND ANTIFREEZE COOLANT

(1) Freezing of coolant

Water freezes at 0 °C (32 °F), and its volume expands approximately 9%. This expansion force is so great that water loses its fluidity. When the cooling water freezes in the cooling system, expansion can crack the engine and radiator or lead to other damage.

(2) Major components of antifreeze coolant

Freezing temperature is lowered to prevent the freezing of coolant by adding ethylene glycol, etc..

★ Ethylene glycol

Ethylene glycol has no odor, will not evaporate and will not affect paints and coatings. It has a high boiling point, and can be used along with an anti-corrosive agent in the summer.

(3) Types and characteristics of antifreeze coolant

KUBOTA recommends the use of ethylene glycol base antifreeze coolant of permanent type which is most commonly used.

★ Characteristics of permanent type antifreeze coolant

【Characteristics of antifreeze】

Main components	Ethylene glycol
Specific gravity 20 °C (68 °F)	Above 1.12
Boiling point	145 °C (293 °F)
Flash point	Flame retardant but burns
Hygroscopicity	Very easily absorbs humidity
Freezing of undiluted solution or mixture	Freezes sometimes below -20 °C (-4 °F)

【Characteristics during use】

Boiling point	100 to 113 °C (212 to 235.4 °F)
Evaporation of main components	Small evaporation
Boiling of during operation	No

(4) Caution in using antifreeze coolant

1) Never use poor quality antifreeze coolant

The main components of the antifreeze coolant can corrode metal, gathering rust in the cooling system over an extended period. Corrosion is caused by acids and various kinds of additives which are used to neutralize them. Some additives give the cooling water alkaline properties that can rapidly corrode light metal.

Poor quality antifreeze has poor content of corrosion preventive. The content further becomes less potent with the dilution of water.

For this reason, poor quality antifreeze accelerates metal corrosion.

2) Do not use antifreeze for extended periods

Except for quality permanent antifreeze coolant which does not require replacement for a long time. Drain the antifreeze coolant mixture when it is not in use and flush the cooling system.

Use of antifreeze coolant for an extended time can result in increased corrosion within the cooling system.

3) Use permanent type ethylene glycol antifreeze coolant when temperature of coolant exceeds 100 °C (212 °F).

4) Completely cover the container since the undiluted solution is hygroscopic.

5) Undiluted solutions of permanent type can freeze below -20 °C (-4 °F) in some cases, so watch the temperature carefully.

6) Never drink antifreeze coolant, because they are poisonous.

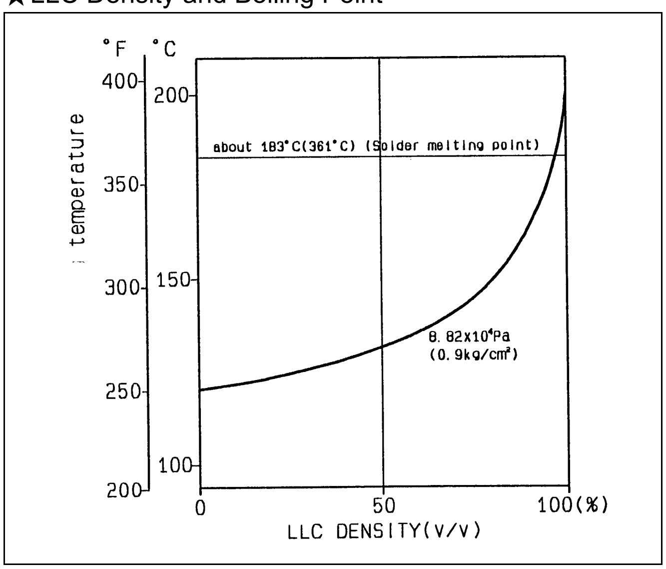
7) Do not spill antifreeze coolant over painted surfaces since they may dissolve paint.

(5) Dilution rations

Always use a 50/50 mix of ethylene glycol coolant in KUBOTA engines.
Contact KUBOTA concerning coolant for extreme conditions.

When the density becomes too high, the boiling point rises and the solder strength lowers, resulting in a dangerous situation. The following drawing shows the relation between the boiling point and density.

★LLC Density and Boiling Point



L.L.C : Long Life Coolant

(6) Adding antifreeze coolant

1) Completely drain the cooling water and flush the cooling system.

2) Check for leaks or loose connections at the radiator, cylinder head gasket, drain cock, etc..

3) Mix antifreeze coolant and water at the specified ratio before pouring into engine.

4) For replenishment, add 50/50 mix to cooling system for permanent types.

Note :
If antifreeze and water are not mixed thoroughly, before putting into the engine, hot spots may develop leading to engine overheating.