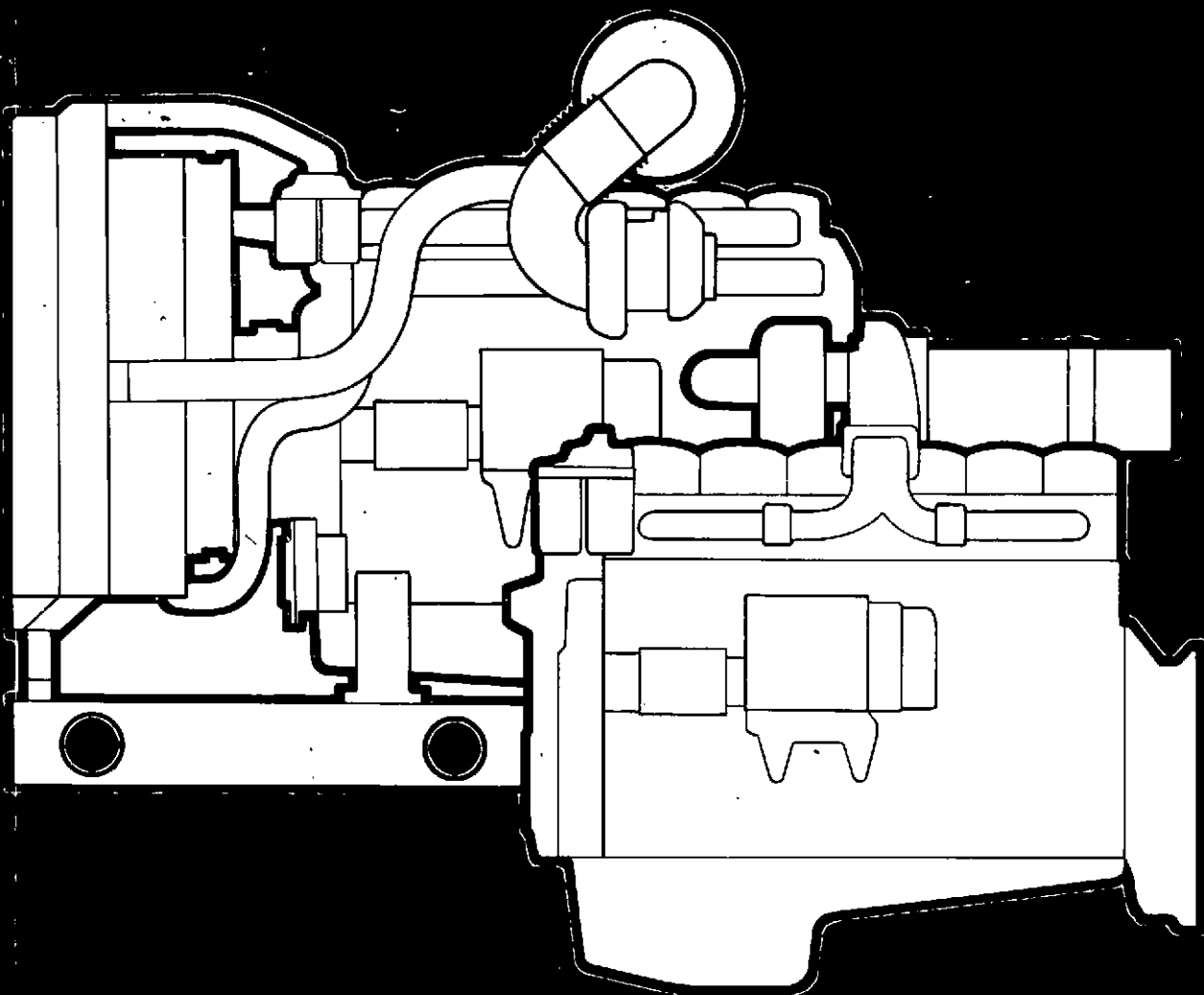


INSTALLATION

General instructions

● Industrial diesel engines



Cooling systems

Foreword

The installation instructions in the booklet apply to our industrial diesel engines and consist of general directions intended primarily for the guidance of draughtsmen in calculating and designing cooling systems.

For the system to be reliable, it is of the utmost importance that the recommendations given are followed and that the work is carried out with great care.

Should problems arise which are not dealt with here, please contact Volvo Penta for further information.

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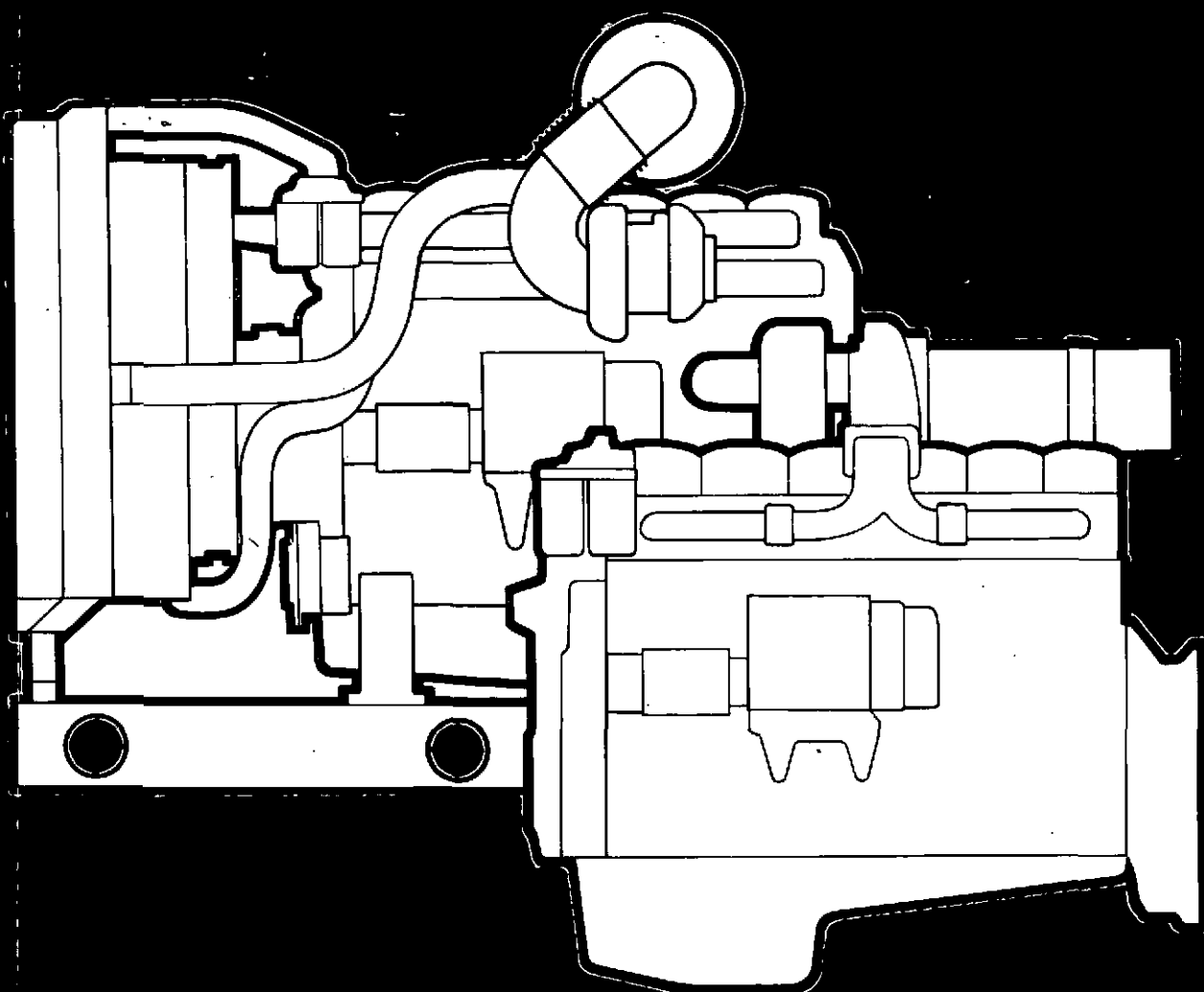
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General instructions

Cooling system

Different types of cooling system

The most usual arrangements for cooling are radiators and heat exchangers. In a few cases dilution tanks are also used, see page 11.

Which of these arrangements is to be used depends on the type of installation and the availability of cooling water.

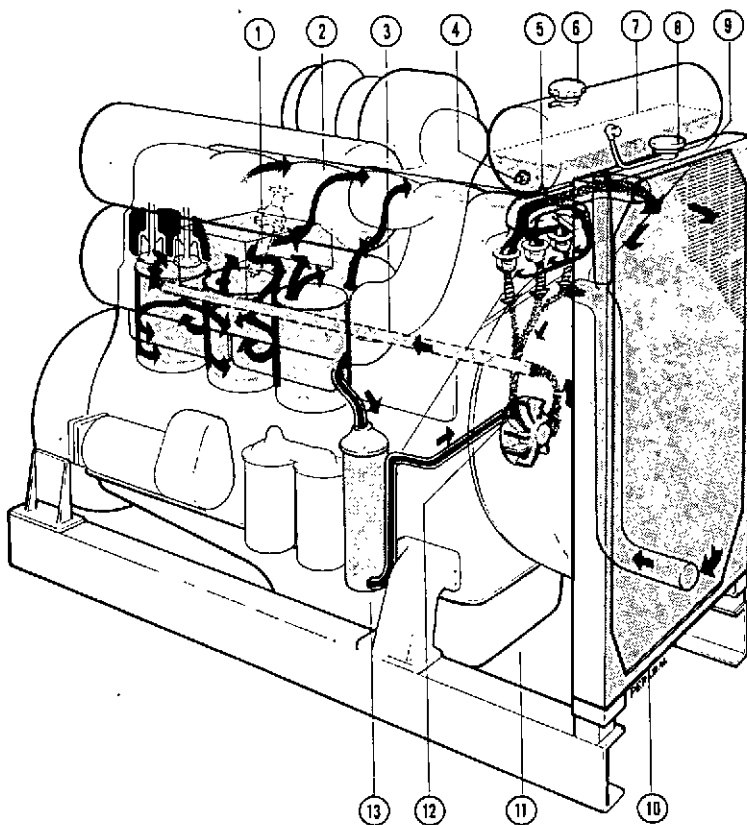
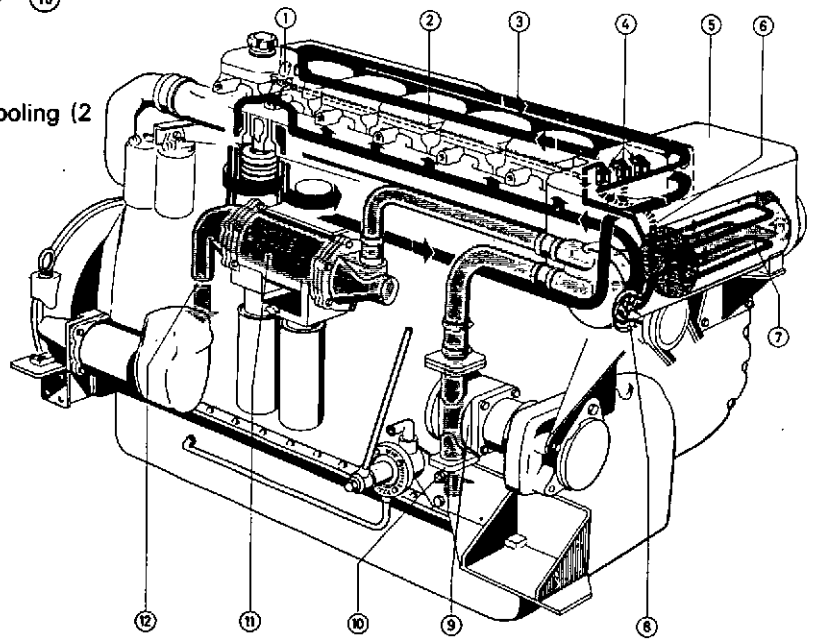


Fig. 1. Example of engine with cooling system of radiator type

1. Copper sleeve for injectors
2. Coolant return line
3. Distribution channel
4. Sender for level warning device (extra equipment)
5. Thermostats
6. Filler cap with pressure valve
7. Expansion tank (can also be fitted separately)
8. Cap (without pressure valve)
9. Equalizer pipe to expansion tank
10. Radiator
11. Oil cooler
12. Coolant pump
13. By-pass channels

Fig. 2. Example of engine with heat exchanger cooling (2 circuits, sea water and fresh water)

1. Injectors with copper sleeve
2. Air-venting channel
3. Water-cooled exhaust manifold
4. Thermostats
5. Expansion tank
6. By-pass line
7. Heat exchanger
8. Fresh-water pump (circulation pump)
9. Sea-water pump
10. Inlet, sea water
11. Oil cooler
12. Sea water from engine to outlet



General

When a cooling system is being dimensioned, particular attention must be paid to the following considerations.

1. The highest ambient air temperature at which the system must be able to work without the temperature of the coolant leaving the engine exceeding 93°C^* at max. power output. By *ambient air temperature* is here meant the temperature of the air flowing into the radiator. The rise in temperature due to radiation heat must also be taken into account.
2. The amount of dirt on the radiator which will after a given time cause reduced cooling efficiency. (When the radiator is installed, care must be taken to ensure that it is accessible for cleaning.) A certain blocking on the water side must be taken into account.
3. The height above sea level at which the system is to work.
4. For mobile installations, the fan chosen must be of such a design (suction or pressure) that the fan performance will not be affected by the airflow.

* Those of our engines which have automatic stop cut out when the temperature reaches $97^{\circ}\text{C} \pm 3^{\circ}$. For classified engines, this temperature is $92^{\circ}\text{C} \pm 2^{\circ}$.

5. A 40 % glycol admixture in the cooling water reduces the heat transfer capacity sufficiently to cause a rise of $2-3^{\circ}\text{C}$ in the coolant temperature compared with coolant consisting of water only.

In order to avoid blocking on the water side, softened water or rain water should be used in areas where the water is normally hard (high lime content). A cooling water filter of the "Perry" type may be used in order to keep the cooling system free from deposits, particularly when water with a high lime content is used. The filter also has anti-corrosive properties and keeps the acidity (pH value) to a normal level. There is also a mechanical filtration. Note that the coolant must be changed once a year even if a filter is used.

We recommend that anti-corrosive additive be mixed into the coolant in areas where there is no risk of frost. This additive must not be used, however, if the engine has a cooling water filter of the "Perry" type.

Where there is a risk of frost, at least 40 % glycol (max. 60 %) must be mixed into the cooling water. CAUTION. Glycol must not be used together with certain anti-corrosive additives; check first with the manufacturer.

Radiators

A radiator in combination with a cooling air fan driven by the engine is the most common cooling system in industrial engines. For this system to function it is necessary for sufficient quantities of cooling water and cool air to be able to pass through the radiator.

It is therefore important for radiator and pipes to be properly dimensioned and for there to be the smallest possible constriction of the air flow.

Remember also that every component which is mounted in the cooling system in such a way as to cause counterpressure on the water side not only reduces the volume of water through the radiator but also causes a rise in pressure in the thermostat housing and upper radiator tank and in the hoses between them.

Cooling performance should preferably be raised by increasing the size of the radiator and improving air passages. The fan (blade pitch) may be modified or the fan speed increased only as a last resort, as such modifications often increase the noise level and the power requirement of the fan.

Dirt on the air side quickly reduces the cooling effect. The problem can be countered by regular washing with grease-dissolving agents. High-pressure washing or the use of compressed air is not recommended, as there is a considerable risk of the ribs deforming.

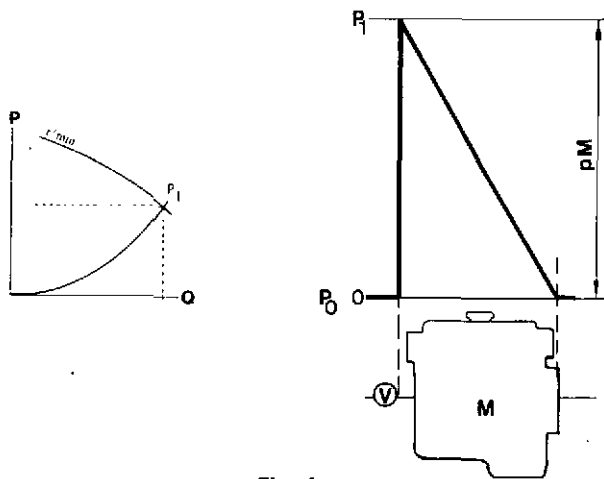


Fig. 4

- V = Water pump
- P₀ = Pressure on suction side of pump (may be zero or less than zero, see under heading "Expansion tank")
- P₁ = Pressure on delivery side of pump
- p_M = Pressure drop across engine block with thermostats fully open

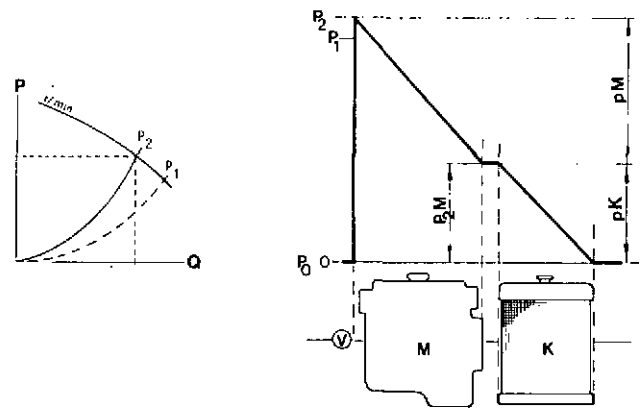


Fig. 5

- P₂ = Pressure on delivery side of pump
- p_K = Pressure drop across radiator
- P_{2M} = Pressure which affects thermostat housing, upper tank of radiator and hoses between them

Coolant flow and pressure

When various components are coupled into a cooling system, the coolant flow and pressure are affected as shown in figs. 4, 5 and 6.

When the pump speed is altered, the change in the pressure drop always follows the pressure drop curve (performance line) for the installation.

Fig. 4 shows in diagram form the pressure (P₁) of the coolant when it leaves the water pump and goes into the cooling channels of the engine. It also shows the pressure drop (p_M) which occurs when the coolant passes through the engine.

The pressure P₁ = the pressure at the point of intersection of the speed curve and the pressure drop curve.

The total pressure drop in the system (in this case p_M) will always be the same as the pump pressure concerned (in this case P₁).

If the pressure drop is increased by the inclusion in the system of a radiator with a pressure drop p_K, see fig. 5, this has to be compensated for by an increased pump pressure.

It is clear from the pump diagram that the only way to obtain a higher pump pressure at the same speed is to follow the speed curve from the point P₁ to the left to, for example, point P₂, i.e. towards a lower flow of coolant. The reduced volume of coolant through the engine block involves a lower flow velocity and thus also a smaller pressure drop across the engine (p_M).

The total pressure drop p_M + p_K will be equal to the pump pressure P₂, however. As may be seen from fig. 5, the thermostat housing of the engine, the upper tank of the radiator and the hoses between them will be subjected to a pressure of p_{2M} (which is equal in magnitude to p_K).

In fig. 6 an oil cooler with a pressure drop p_{Ok} has been included in the system. In order to compensate for this drop in pressure, the pump pressure has been raised from P₂ to P₃, again at the expense of a reduced flow of coolant. In the pump diagram this corresponds to a move from point P₂ to P₃.

The reduced volume of coolant gives a lower flow velocity, which leads to a reduction in the pressure drop across the engine (p_M) and the radiator (p_K).

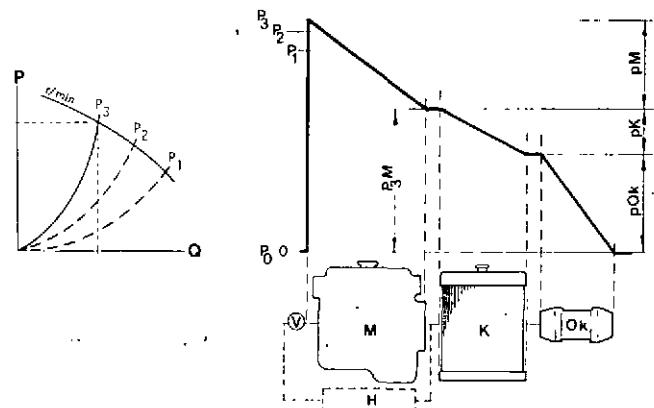


Fig. 6

- P₃ = Pressure on delivery side of pump
- p_{Ok} = Pressure drop across oil cooler
- H = Cab heater

The total pressure drop $p_M + p_K + p_{0k}$ is equal in magnitude to the pump pressure P_3 . The thermostat housing of the engine, the upper tank of the radiator and the hoses between them will be subjected to the pressure P_{3M} , which is equal to $p_K + p_{0k}$.

This pressure rises for every component which is included and may become so great that the excess pressure valve on the radiator opens and lets out coolant. The excess pressure valve usually opens at approx. 30 Pa (0.3 kp/cm²).

Note that in a system with a separate expansion tank as shown in fig. 7 the excess pressure valve does not open at the pressure mentioned. The result may instead be that coolant hoses burst, the upper tank of the radiator deforms or the functioning of the thermostats is affected. If, for example, a cab heater is included as shown in fig. 6, this too may be affected by the high pressure, possibly leading to failure of soldered joints and to leakage.

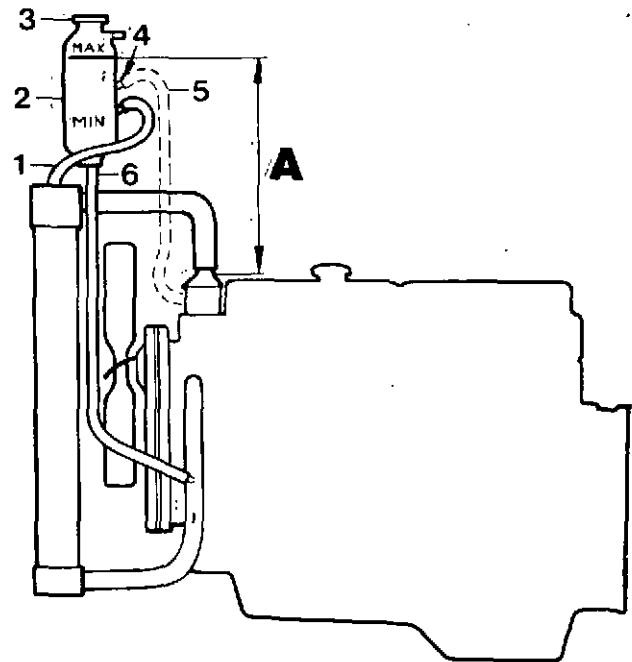


Fig. 7. Cooling system with separately mounted expansion tank

1. Venting line (max. inside diam. 5 mm)
2. Expansion tank
3. Filler cap with excess pressure and underpressure valve
4. Place for sensor for fluid level switch
5. Venting line, mounted only if thermostats lack venting holes (max. inside diam. 5 mm)
6. Delivery line (min. inside diam. 15 mm)
- A. Max. 5 m

Expansion tank

As mentioned earlier, the pressure on the suction side of the pump may be zero or less than zero. Since the boiling point of water falls as pressure drops, there is a risk of vaporization on the suction side of the pump when the temperature of the coolant rises. Should vaporization occur, the capacity of the pump will be reduced (there is cavitation and water is delivered intermittently), which usually leads to the cooling system boiling and/or to damage to the water pump. In order to prevent this, a separate expansion tank may be included as shown in fig. 7. A static pressure (water column) is thus obtained on the suction side of the pump. In such a system a simpler version of the radiator may be used with no built-in expansion tank and with no filler cap and excess pressure valve.

The expansion tank should be placed at a higher level than the highest part of the rest of the cooling system. The difference in height between the level of the coolant in the expansion tank and the thermostat housing of the engine must not exceed 5 m, however. Another advantage of a separate expansion tank is that the circulating coolant is not mixed with air to the same extent as in the cooling system where there is air in the upper part of the radiator. This reduces the risk of corrosion and obstructed circulation and improves the transfer of heat to the coolant.

The thermostats of the engines are provided as standard with venting holes for automatic venting at the thermostat housing. If these thermostats are replaced by other models without venting holes a venting line must be connected between the thermostat housing and the expansion tank (see dotted line, fig. 7).

NOTE. This line must not be connected to the venting line between the radiator and the expansion tank.

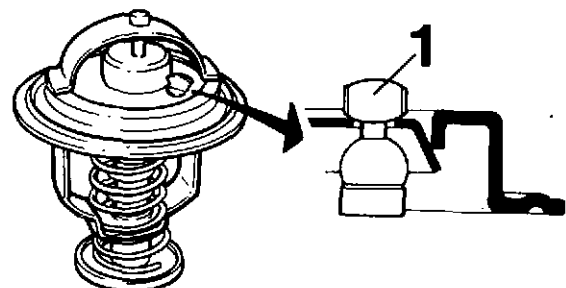


Fig. 8. Thermostat with venting hole

1. "Giggle pin" valve

Dimensioning

When dimensioning cooling systems one starts from the values for coolant heat and radiation heat. These values are stated in the brochure for the engine concerned, see file "Sales Manual". The amount of heat removed per hour should be calculated with regard to the intermittent output at the engine speed concerned.

The particular volumes of water for different engines and speeds are obtained from the pump diagram, see engine brochure concerned.

The temperature drop across the radiator should be about 5–7°C for a new system with thermostats fully open. Note the following:

- A. As the temperature of the ambient air rises, the efficiency of the cooling system is reduced, partly because of the smaller difference in temperature between the coolant and the ambient air, partly because of the reduced volume of air passing through the radiator (due to the lower air density).
- B. The efficiency of a cooling system is reduced as height above sea level increases (lower air density). This decrease is greater than the reduction in the output of the engine, so a cooling system which functions efficiently at sea level may be inadequate for service at a higher altitude.

The expression ATB (air to boil) is often used as a measure of cooling capacity.

$$ATB = 100^{\circ}\text{C}^* - (t_w - t_a)$$

where t_w = water temp. at outlet from engine
 t_a = ambient air temp.

The value of ATB at performance testing should be as high as possible. The temperature of the outgoing coolant should be as low as possible.

The target value for ATB: approx. 5°C above the highest anticipated ambient air temperature. For tropical conditions ATB should be around 50°C.

* The boiling point of the cooling water at sea level. For boiling points at different altitudes, see table on page 11. NOTE. For engines with automatic alarm and stop one should instead work on the basis of a temperature of 97°C (92° for classified engines).

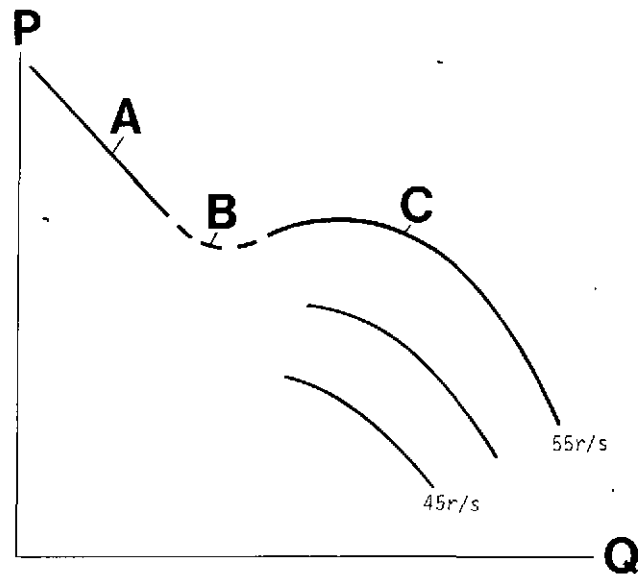


Fig. 9. Schematic fan diagram

- A,B,C. Curve for fan speed
B P. Pressure (mm w.g.)
Q. Volume of air (m^3/hr)

Fan capacity

The speed curves drawn on a pressure/flow diagram for an axial flow fan have three sections, A, B and C (see fig. 9).

The curve section A applies when the fan is working against a high pressure and functioning like a centrifugal fan. The curve section C applies when the fan is working against a lower pressure and functioning more on the aerofoil principle. To be efficient, the fan should be working on curve section C. In the dip, the curve section B (dotted line), the fan works unsteadily, resulting in noise and low output.

The volume of air delivered by a fan which is run at a constant speed varies according to the counterpressure against which it is working. One says that the fan works with different degrees of throttling, from fully throttled, where the volume of air is zero, to "free delivery", where the fan works without external resistance (only dynamic pressure).

Usually only the static pressure is included in the fan diagram. The total pressure (P_t) is obtained only when the fan and engine are installed, together with fan housing, fan ring or fan guard and other components which affect the air flow. The total pressure is made up of two pressures, the static pressure (P_s) and the dynamic pressure (P_d).

$$P_t = P_s + P_d$$

The dynamic pressure depends on the area which the fan sweeps, the air flow and the air velocity.

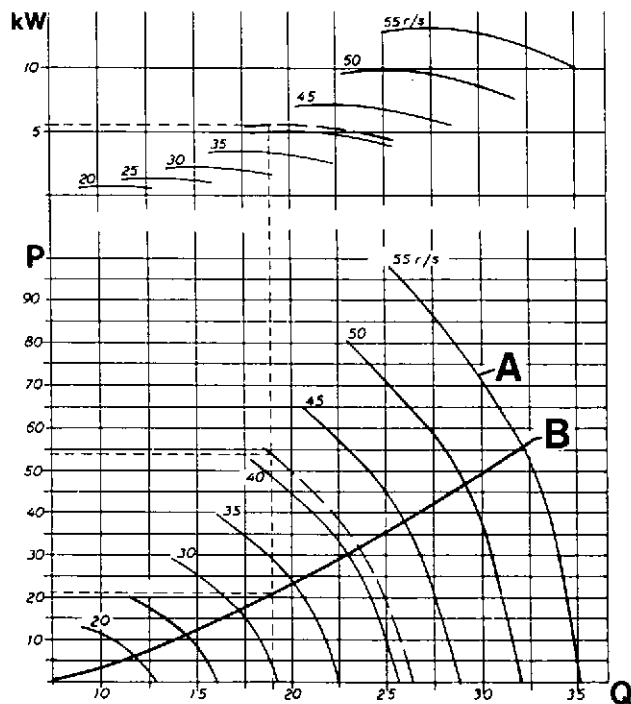


Fig. 10. Fan diagram for fan, part no. 843517 (620 mm suction fan)

- A. Curve for fan speed, r/s
- B. Pressure drop curve for radiator, part no. 844090
- P. Static pressure in mm water gauge
- Q. Air flow in $1000 \text{ m}^3/\text{hr}$

Fig. 10 shows the capacity of a 620 mm suction fan (part no. 843517) at $+20^\circ\text{C}$ and a barometric pressure of 750 mm Hg. The upper part of the diagram shows the power requirement of the fan as a function of the air flow.

Curve B shows the pressure drop for the radiator, part no. 844090.

By subtracting the pressure drop across the radiator from the pressure delivered by the fan, one can see how great a pressure drop can be permitted in the remainder of the system.

Example: A TD70G engine is to be run at a speed of 2000 r/min.

$$\frac{\text{Fan speed}}{\text{Engine speed}} = 1.23^*$$

The speed of the fan will then be $2000 \times 1.23 = 2460 \text{ r/min} = 41 \text{ r/s}$. The necessary volume of air has been calculated to be $19000 \text{ m}^3/\text{hr}$. According to the diagram the static pressure is about 54 mm w.g. The pressure drop across the radiator is then 21 mm w.g. The max. pressure drop which can be permitted for built-in components is thus $54 - 21 \text{ mm} = 33 \text{ mm w.g.}$, of which the majority is lost in pressure drop across the fan housing, engine etc. The diagram also shows that the power requirement for the fan is approx. 6 kW.

If a fan is run at different speeds (n) in a constant system.

- Q will be proportional to n
- P_t , P_s and P_d will be proportional to n^2
- The power requirement will be proportional to n^3

* This value applies only to engines in the 70 series.

Fans

The total pressure drop in an installation is made up of a number of partial pressure drops caused by radiator, engine block, fan housing, fan guard, grillework, flap valves, air escapes etc. Of these pressure drops, those across the radiator and the engine block are the largest (altogether 80–85 % of the total) and the most difficult to alter. This means that a pressure drop of only 15–20 % is permitted in the rest of the system.

NOTE. In order to give the most advantageous air distribution and air velocity, the distance between the fan and the radiator should be as great as possible, and at least 100 mm.

It is also important to have the fan placed in the centre of the radiator. Otherwise the air distribution across the radiator will be impaired.

Suction and pressure fan

The fan may work either by suction (drawing air through the radiator) or pressure (blowing air through the radiator). For two similar fans where only the direction of the airstream differs, the same diagram applies. However, both the pressure drop and the cooling effect will be altered by changing the direction of the air flow in a particular installation.

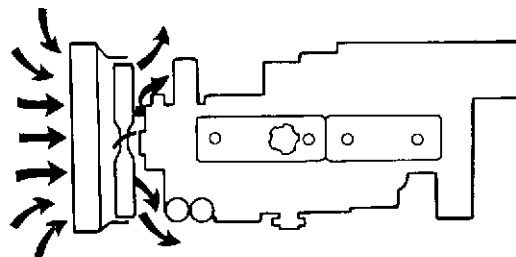


Fig. 11. Suction fan

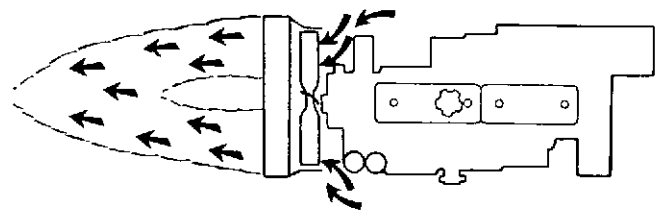


Fig. 12. Pressure fan

Figs. 11 and 12 show a system with a suction or a pressure fan mounted on the engine.

As is shown by fig. 11, the airstream through the radiator is relatively evenly distributed across the whole radiator area, whereas that in fig. 12 is concentrated in a more or less annular area (little flow in the centre and corners of the radiator). But a more even air distribution may be obtained in the latter system by increasing the distance between the fan and the radiator.

If the same volume of air is to pass both the radiators, the air velocity must be increased in the system with a pressure fan, on account of the reduced area of the actual flow. The pressure drop across the radiator in this system thus becomes greater. The system with the suction fan as shown in fig. 11 has a relatively large pressure drop at the engine block because the airstream has suddenly to change direction. A pressure fan gives a better flow here, and also a lower pressure drop.

A component in the cooling system causes the greatest pressure drop if it is placed in the airstream on the pressure side of the fan.

In addition to its influence on pressure drop, a system with a pressure fan has a lower cooling effect, because the cooling air is warmed by about 10–12°C when passing the engine and the exhaust pipe. In theory this means that in systems which are otherwise similar, one can permit an ambient temperature which is approx. 10°C higher in a system such as that in fig. 11.

In certain cases, however, the latter system may give too high a temperature in the engine compartment. Where this is so, an installation such as that shown in fig. 13 may be a satisfactory solution.

Fan mounted in front of the radiator

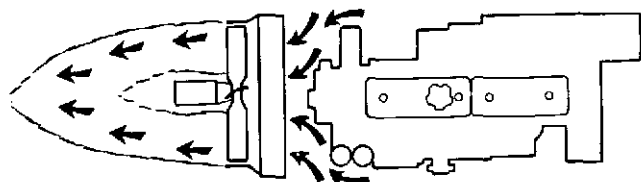


Fig. 13. Suction fan mounted in front of the radiator

This installation has the same fan and direction of flow as that in fig. 12, enabling the engine temperature to be kept down. By mounting the fan in front of the radiator, the flow through the radiator is made to resemble that in fig. 11 (even distribution, lower pressure drop). The clearance between engine and radiator becomes greater than in fig. 12, which also results in a lower pressure drop. In addition, the pressure drop on the delivery side of the fan can be kept low by suitable design and dimensioning of guards and grilles.

The lower pressure drop obtained in installations of this type results in larger volumes of air passing through the radiator, which in turn means that the air passing the engine and exhaust pipe does not have time to warm up as much as in an installation such as that shown in fig. 12. The cooling effect will in most cases be as good as or even better than in an installation as shown in fig. 11. An installation of the type shown in fig. 13 is particularly good in those cases where it is necessary to mount the radiator either vertically or horizontally offset from the line of the engine. The fan can then be mounted directly in front of the radiator and driven by, for example, an electric or a hydraulic motor. Mounting the fan on the engine may appear less costly but the large pressure drop caused by the engine block often means that a considerably larger radiator and fan have to be used than if the installation was designed to give a better air flow.

Soundproofing

In order to give "silent" (noise-suppressed) installations it is often necessary to reduce the noise level by leading the air through baffles both in front of and behind the radiator. In order to overcome the pressure drop caused by these baffles, the pressure drop at the engine block may be eliminated by moving the radiator and fan away from the engine.

NOTE. For a cooling system to function efficiently the air which has passed through and been warmed up by the radiator must be prevented from recirculating.

Large engine rooms

Engine installations with radiators in large engine rooms must contain arrangements (air intakes, air outlets, air escapes and possibly ventilating fans) which permit the cooling air to flow to and from the radiator with the minimum possible resistance. The air escape must be fitted tightly to the radiator in order to prevent recirculation of the cooling air. If the distance between radiator and ventilation opening is large, the cost of air escapes of adequate size may be high. It may then be profitable to fit a special radiator with an electrically driven fan at an opening in an outer wall as shown in fig. 14.

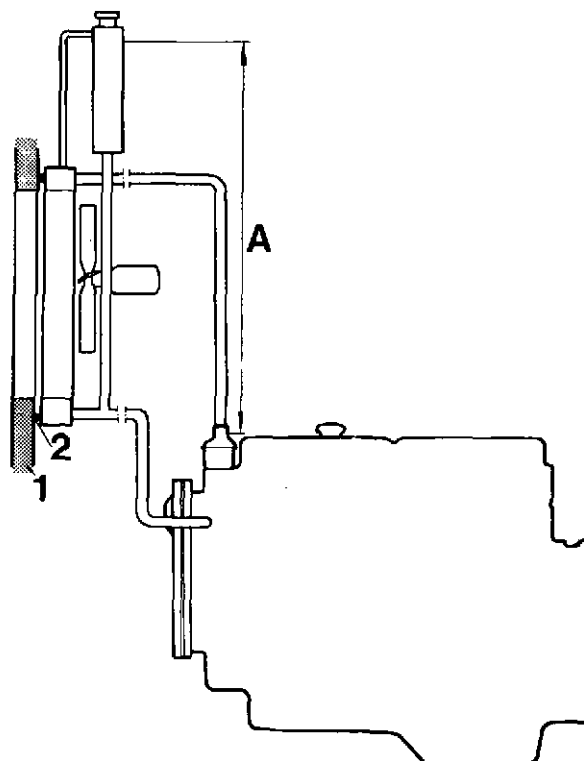


Fig. 14. Cooling system with radiator placed at an opening in an outer wall

- 1. Wall
- 2. Seal
- A. Max. 5 m

Fan housing

For the values in the fan diagram to hold good, the radiator must be fitted with a fan housing and a fan ring mounted as shown in figs. 15, 16 or 17. In certain installations, e.g. for engines with rubber suspension or where there are substantial impact stresses, the lateral motion of the fan and/or the radiator may be so great that a special fan ring has to be mounted as per fig. 17. This ring is screwed firmly onto the engine and thus follows the lateral motion of the fan, keeping the clearance "B" within the prescribed limits. A bellows of suitable material is mounted between fan ring and fan casing.

A = 10-15 mm
B = Max. 7.5 mm

The arrows show the direction of the air flow

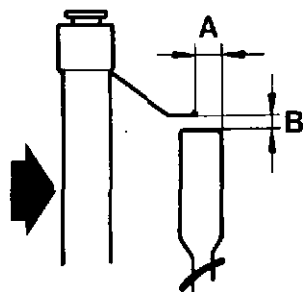


Fig. 15

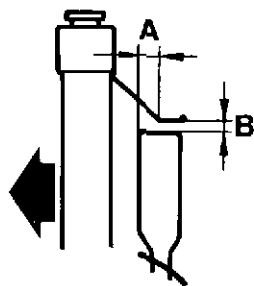


Fig. 16

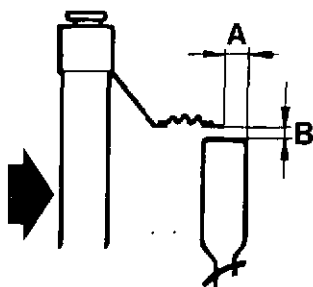


Fig. 17

Radiation heat

Radiation heat from engine and exhaust pipe and in certain cases from driven units may cause high temperatures in the engine compartment. This can be prevented by using pressure fans and/or ventilating fans. If the temperature exceeds 60°C, functioning of, in particular, alternator, charging regulator and stop solenoid may be impaired.

Remember that a high air temperature leads to reduced engine power. Where it is difficult to maintain a low temperature in the engine compartment, combustion air should be taken from outside the engine compartment via hoses or pipes direct to the air filter.

Testing

Every new cooling system installation must be tested early in the prototype stage in order to enable necessary modifications to be made before the start of production. During testing, the normal thermostats of the engine should be removed and replaced with thermostats which are locked in the fully open position, see fig. 18. This will give a full volume of water through the radiator, corresponding to the speed. The temperature difference between the air coming into the radiator and the coolant at the outlet from the engine which is measured at the test will be that applying in normal service.

If, for example, the difference in temperature at testing is 50°C, this means that when the engine is running with a max. coolant temperature of 97°C* (at intermittent output), an ambient air temperature of $97 - 50 = 47^\circ$ can be permitted. This temperature should however be reduced somewhat to allow for dirt and blocking of the radiator.

* Applies to engines with a temperature switch and automatic stop ($92 \pm 2^\circ$ for classified engines). For other engines the temperature concerned is 100°C.

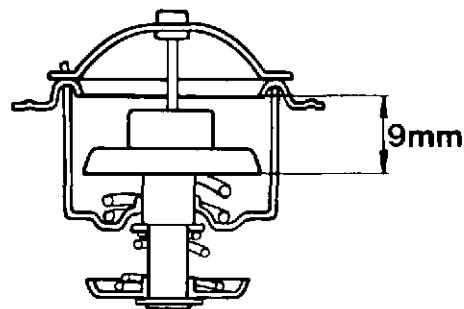


Fig. 18. Thermostat locked in open position. Caution. Do not lock with an object which can come adrift and damage the pump or block the cooling channels.

Thermal efficiency

If the requirements and instructions contained in this chapter for the designing of cooling systems seem difficult to meet, consider the following.

Only about 1/3 of the heat generated in an engine installation is normally utilized to useful effect. This is a rough calculation – the figure for our engines is about 40 %. Of the remainder, about a half is lost with exhaust gases and the rest has to be removed by the coolant.

This means that if one takes a useful output of 100 h.p. from an engine, about 75 h.p. in cooling water heat, together with that part of the exhaust heat which heats the cooling air by radiation, has to be removed via the radiator.

Connection of extra equipment

See also dimension sketch for engine concerned.

Converter oil cooler

If a converter oil cooler is to be connected to a cooling system, the pressure drop must be limited to a minimum. Connect the oil cooler to the line between the radiator and the intake to the engine, see fig. 19, so that the connecting lines required for the coolant are as short as possible. If necessary it is preferable to use longer pipelines for the oil. Ensure also that the coolant lines are of large enough diameter and that they contain as few bends as possible.

In order to allow the coolant to circulate through the oil cooler even when the thermostats are shut, a line of small bore (max. 10 mm inside diam.) is fitted between the oil cooler and the engine block as shown in fig 19.

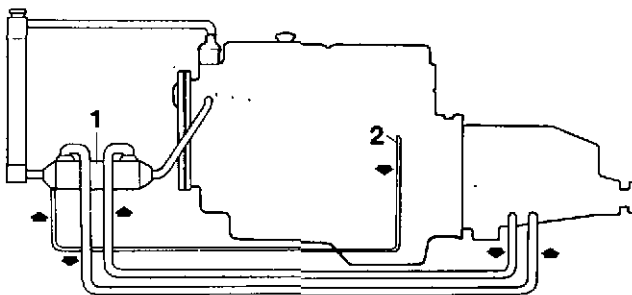


Fig. 19. Cooling system with converter oil cooler

1. Oil cooler
2. Coolant pipe (max. inside diam. 10 mm)

Electric engine heater, mounted on engine block

The heater may be mounted in one of the threaded cleaning holes on the right side of the cylinder block. The 60 series has only one hole; other engines have six. Mount the heater so that it is not damaged by heat from the exhaust pipe.

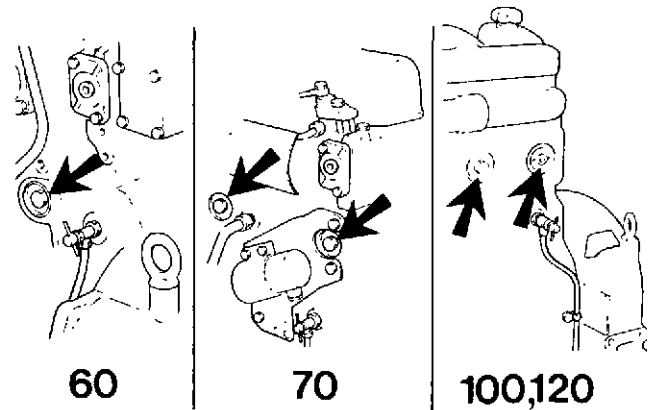


Fig. 20. Holes for placement of electric engine heater on cylinder block

Engine heater, mounted at side of engine

The heater should be placed so that the connecting lines required are as short as possible. Connection is as per fig. 21. The arrows indicate the direction of flow of the water.

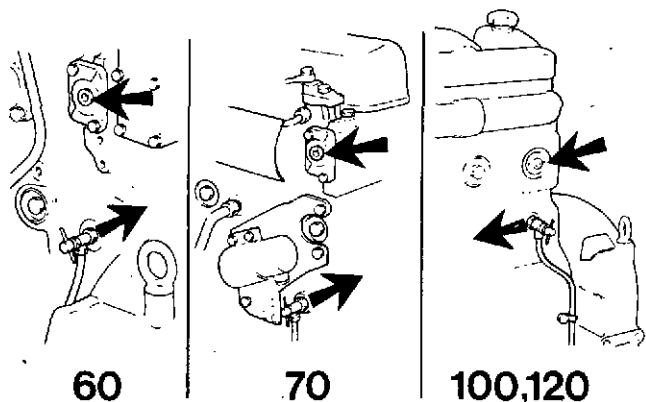


Fig. 21. Position of connection of separately mounted engine heater (the arrows indicate the direction of flow of the water)

Cab heater

The cab heater should be dimensioned not to take out excessive heat. Otherwise the engine may not attain the correct operating temperature and wear will increase. The lines should be of sufficient size to facilitate circulation. The heating system must be provided with a drain cock at its lowest point and an air valve at its highest. If the unit is placed higher than the engine, there must be an expansion tank placed higher than the cab heater.

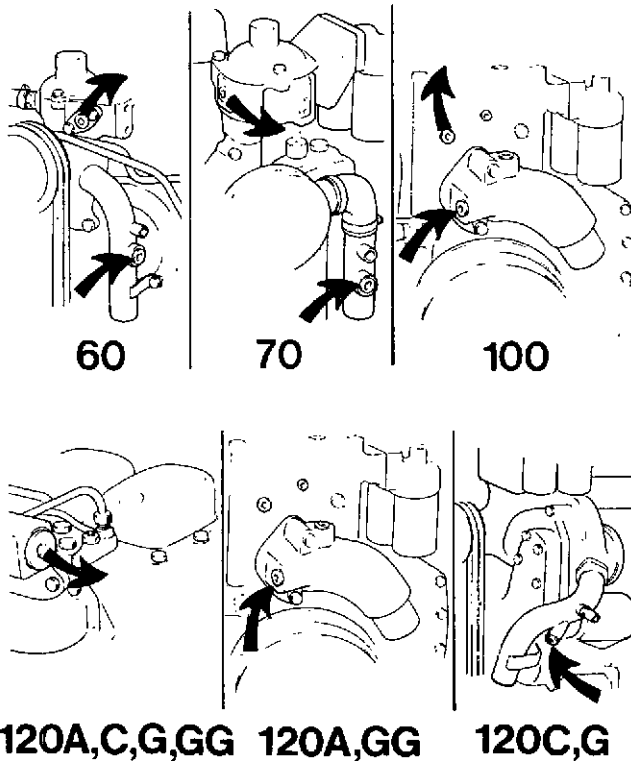


Fig. 22. Position for connection of cab heater (the arrows indicate the direction of flow of the water)

Cooling system with heat exchanger or dilution tank

The requirements concerning pressure drop in pipes and in other parts of these cooling systems are the same as those stated for systems with radiators. For these systems also, the static pressure is limited to 5 m w.g. When a dilution tank is used, fresh water is conveyed continuously to the engine, which means that the risk of sedimentation and corrosion is considerably greater than with a closed system. It should also be borne in mind that a ventilating fan may be needed in these installations in order to remove radiation heat.

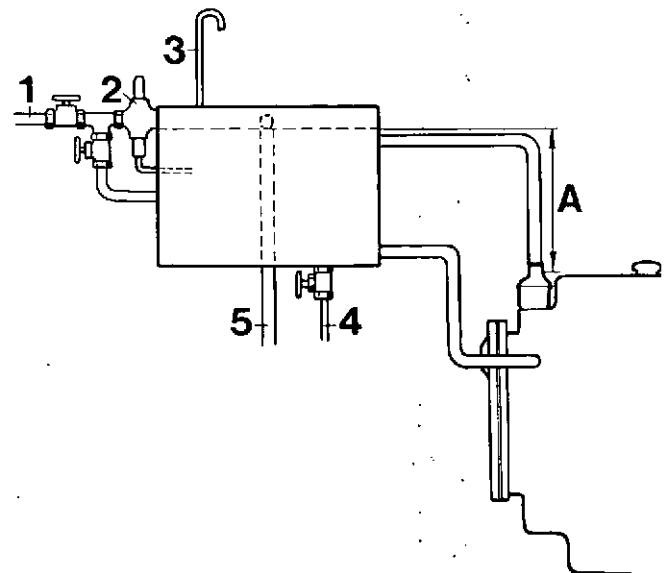


Fig. 23. Cooling system with dilution tank

- 1 = From water mains
- 2 = Thermostat valve
- 3 = Air pipe
- 4 = Drain cock
- 5 = Overflow pipe
- A = Max. 5 m, min. 0.2 m

Boiling point of water in relation to height above sea level

Height above sea level, metres	Atmospheric pressure kPa (kp/cm ²)	Boiling point of water, C°
0	101 (1.03)	100
500	95 (0.97)	98.2
1000	89 (0.91)	96.5
1500	84 (0.86)	94.8
2000	79 (0.81)	93.3
2500	74 (0.76)	91.6
3000	69 (0.71)	89.8
3500	65 (0.67)	88.3
4000	61 (0.63)	86.7

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