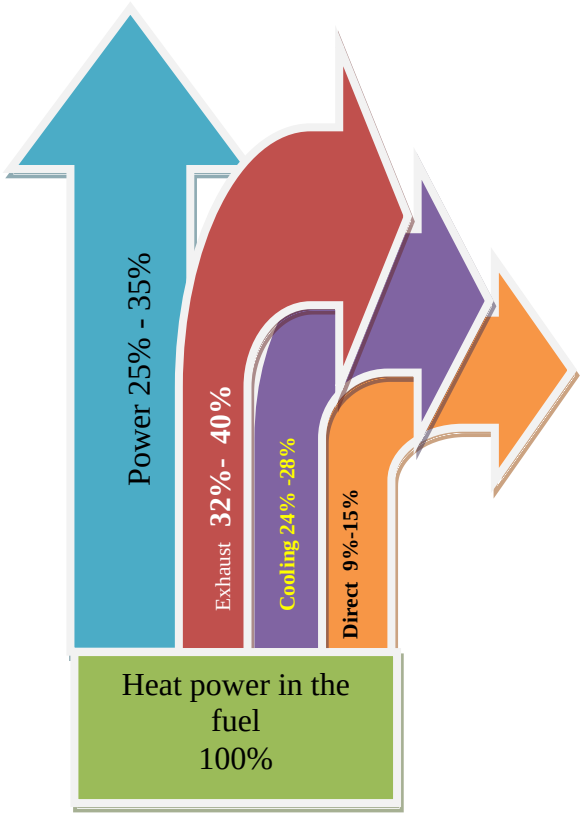
Internal combustion engines cooling

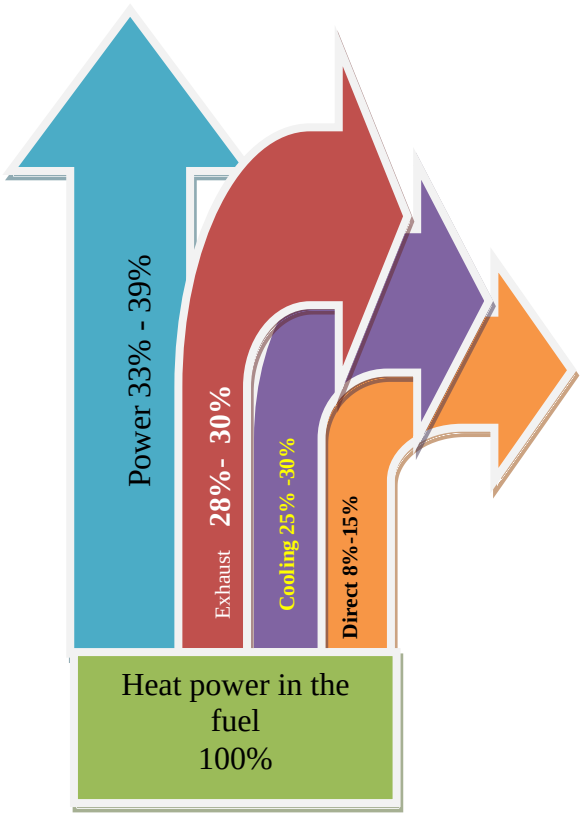
Cooling tasks:
- maintain a constant permissible temperature level and temperature drop in the most thermally stressed parts of the engine (head, cylinder block, valves, etc.),
-dissipate heat from the charge air, oil, and other places,
- ensure that the engine warms up quickly to operating temperature,
- other tasks e.g. heating

Cooling circuits:
1.) Main cooling circuit - cools the head, cylinders and exhaust
2.) Auxiliary cooling circuit - heat dissipation from oil, cooling of injectors, charge air, etc.
3.) Direct forced heat transfer - engine walls and radiation.

Internal combustion engine heat balance:
Sankey graphs



Thermal balance of a petrol engine

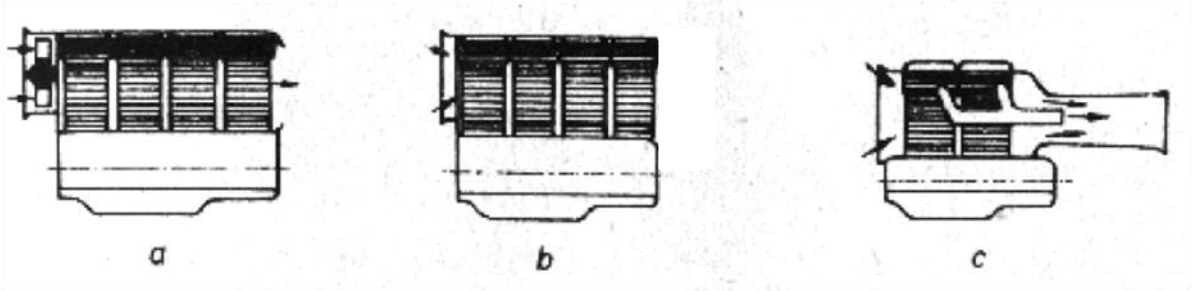


Thermal balance of a diesel engine

About 65-75% of the heat is removed from the cylinder head 35-25% of the heat

Types of cooling:
1. Liquid
2. Air
3. Combined

Air cooling
A.) Fan cooling
B.) Impulse cooling
C.) Ejector cooling

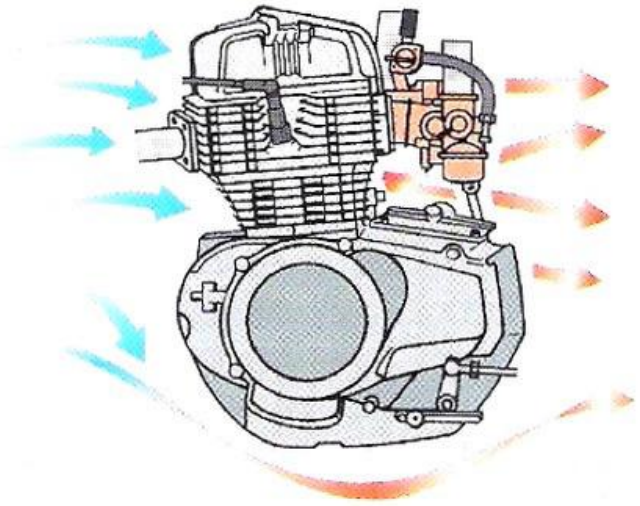


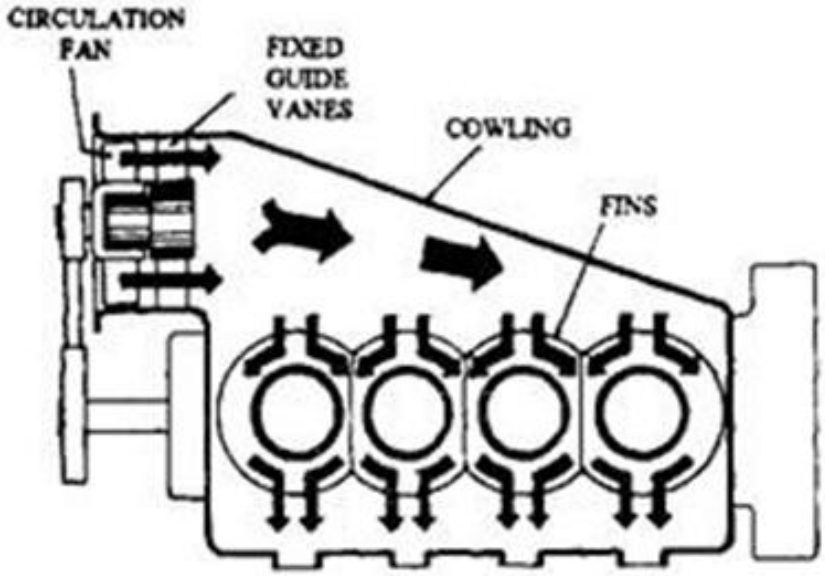
40% of heat is removed from the exhaust pipe, 30-40% from the lower part of the head and 20% of heat through the intake valve.

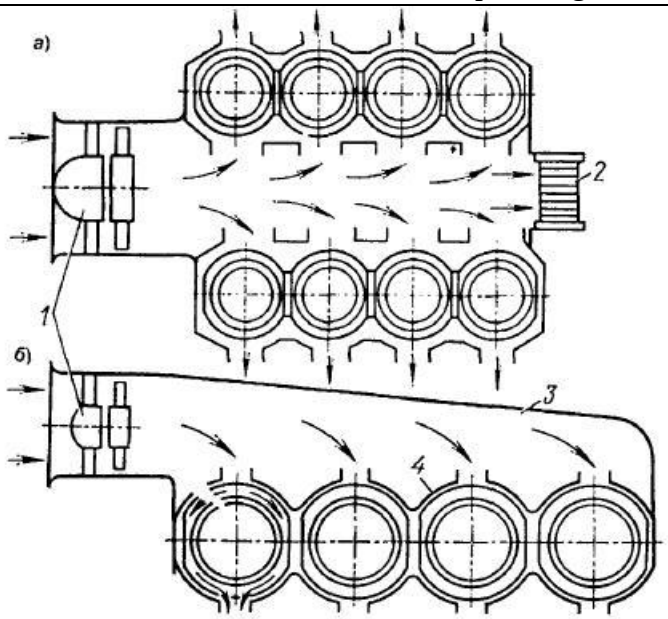
Advantages of air cooling:
does not need coolant,
easy maintenance,
high reliability in extreme conditions,
faster engine start-up to operating temperature,
structurally simple and lighter engine.

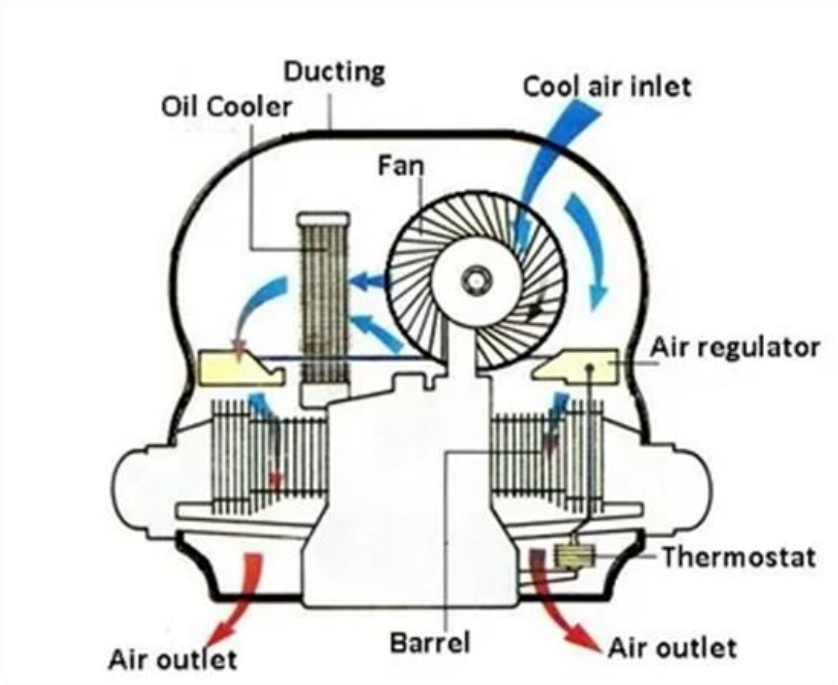
Disadvantages of air cooling:
uneven flow - formation of different temperature zones,
less uniformity of the temperature drop between the cooled surfaces,
higher engine operating temperature - affecting lubrication and faster oil degradation,
higher noise,
high consumption of motor power for fan drive - (in direct comparison, when adding water pump + radiator fan - discutable),
more demanding system for cabin heating,
large temperature drop between incoming and outgoing air.

The principle of air flow

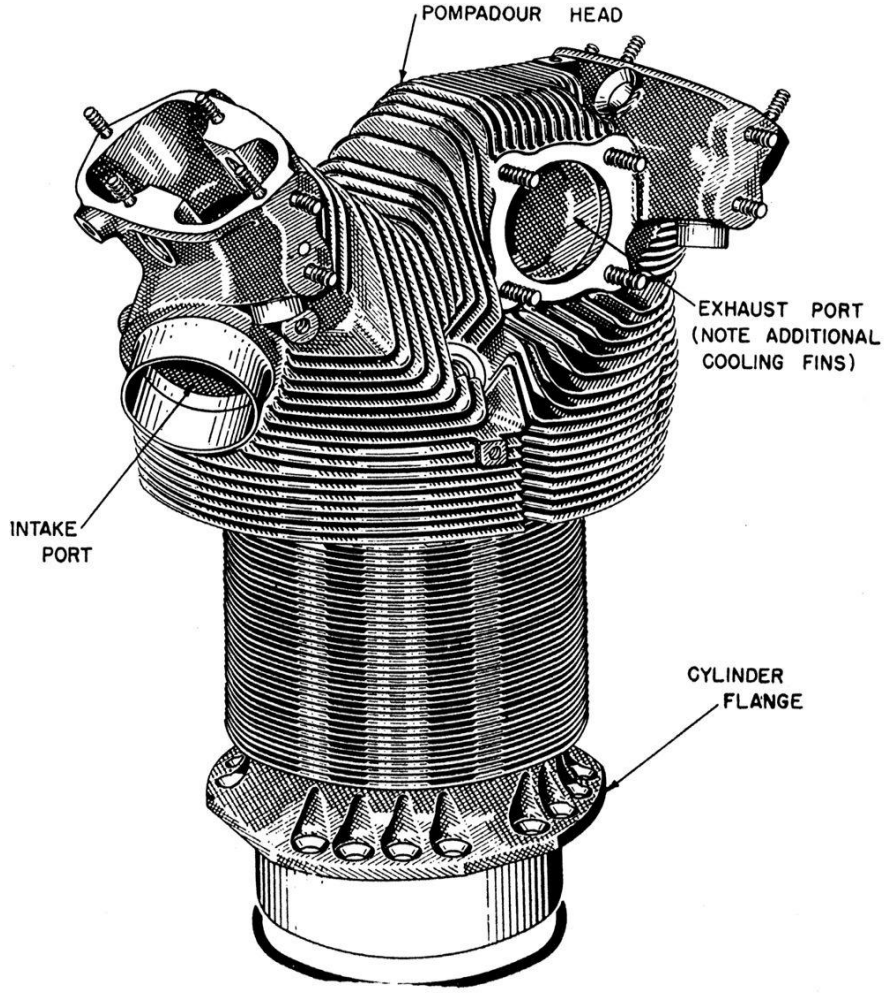


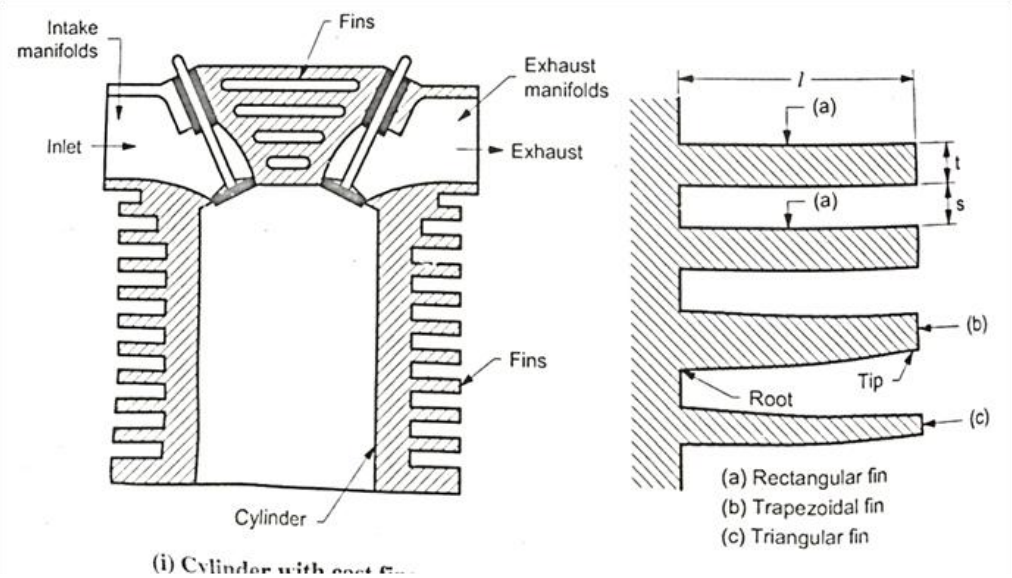






Ribs are important in air cooling - shape, size, density and location.





(i) Cylinder with cast fi...

The ribs must be designed to ensure the best possible heat dissipation. The ribs are usually made by casting directly on the cylinder or head, they are usually made of a light alloy, they are dimensioned to take advantage of the high thermal conductivity of the material. Coarse

base ribs also contribute to an even distribution of peripheral temperature. Figure 2 shows the approximate heat path in two cases and proves that paradoxically long ribs cannot efficiently dissipate heat and that your coldest cylinder is indeed the warmest.

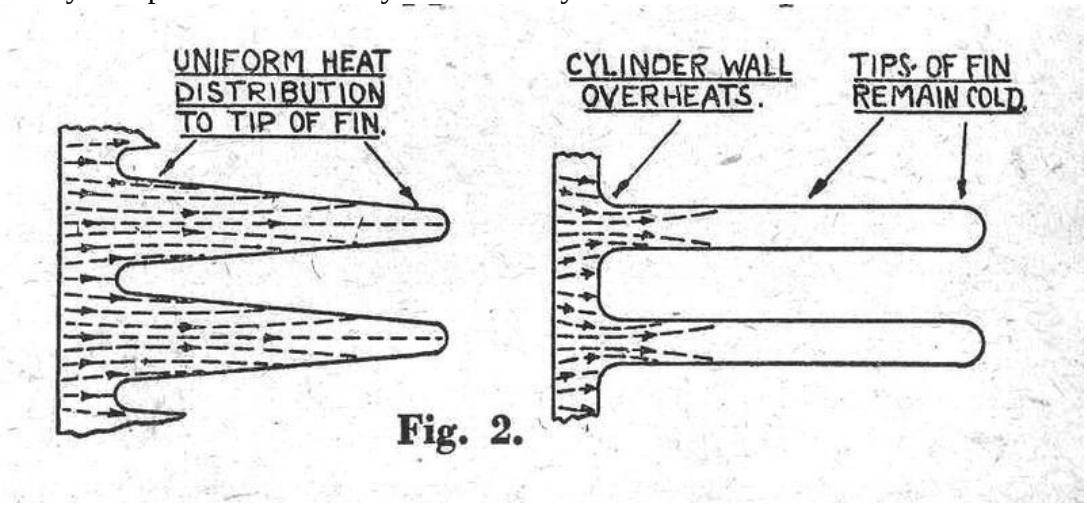


Fig. 2.

The same heat flux principle is observed in the cylinder head in Figure 3 and the eccentric arrangement of the cylinder ribs mixes harmoniously with the "streamline" or "tear" elevation.

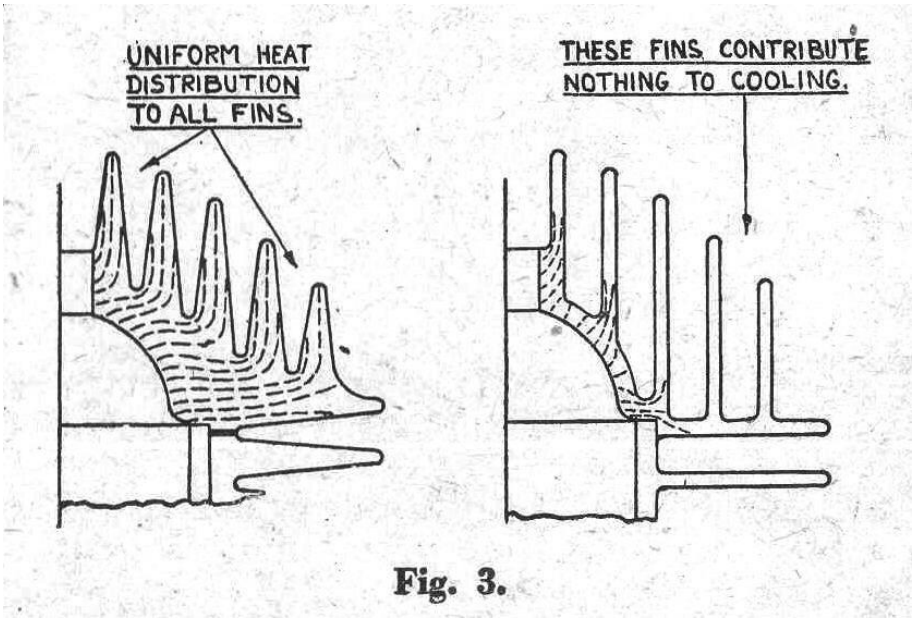


Fig. 3.

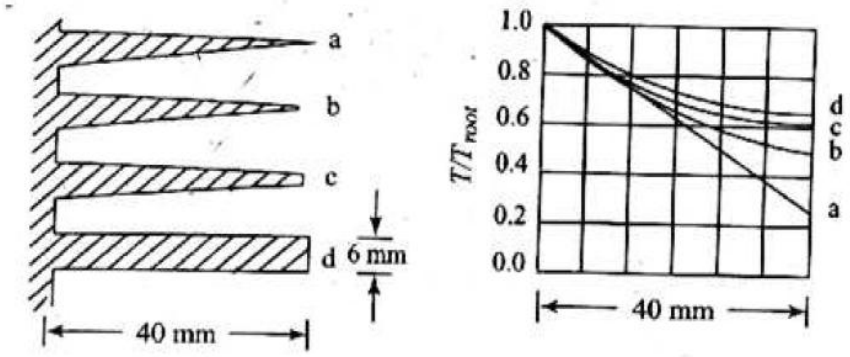
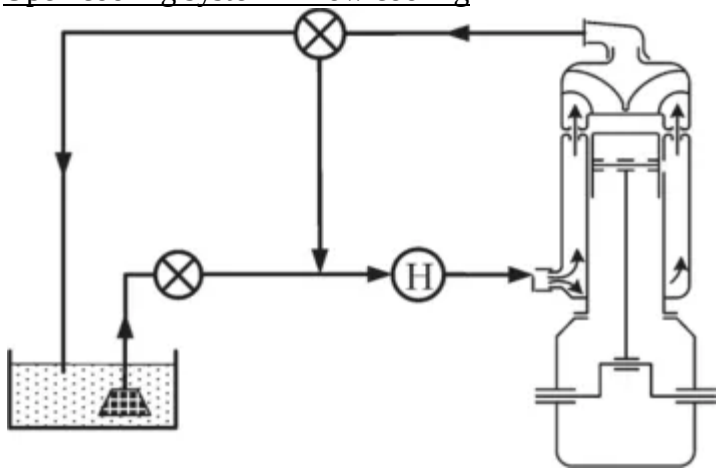


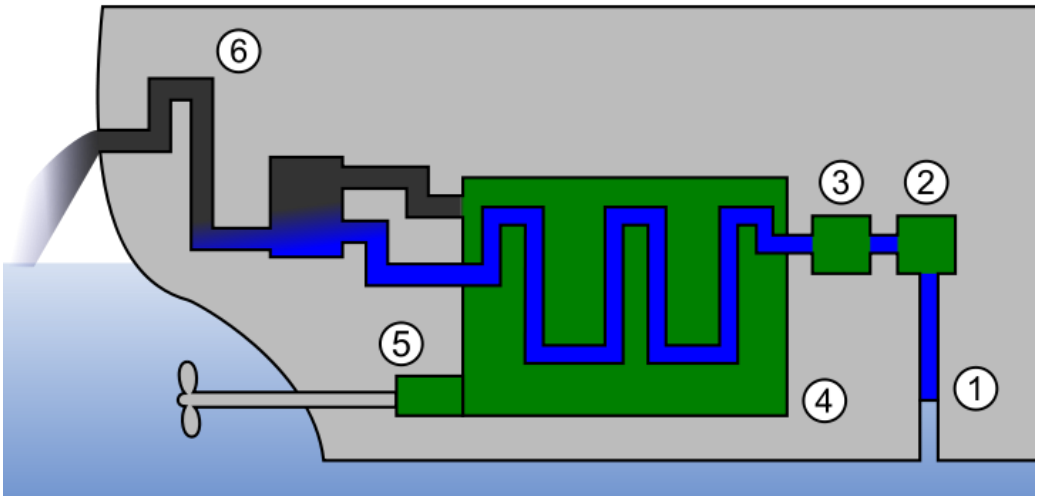
Figure 4: A Comparison of the Fins Different Cross Section as Shown in Figure

Liquid cooling

The fluid dissipates heat from the head and engine block. The fluid moves in the cavities that are created for this purpose. The coolant is primarily water, but it has limited use, especially at temperatures below 0 ° C it freezes to solid and at temperatures above 100 ° C it changes state to gaseous - it changes to steam. The great advantage of water is the high cooling efficiency, thanks to its large heat capacity of 4,187 kJ • kg^{-1} • K^{-1}. heat capacity expresses the ability to absorb heat and means that 4,187 kJ of thermal energy is consumed to increase the temperature of 1 kg of water by 1 K (1 K ≅ 1 ° C). For comparison, e.g. heat capacity 1 kg of air 1,005 kJ • kg^{-1} • K^{-1}; engine oil 1.67 kJ • kg^{-1} • K^{-1}; ethylene glycol 2.41 kJ • kg^{-1} • K^{-1}; propylene glycol 2.48 kJ • kg^{-1} • K^{-1}. The last two substances, ethylene glycol or propylene glycol, are used to form an antifreeze mixture in combination with water, usually 60% water content, reaching a freezing point of -27 ° C.

Open cooling system - Flow cooling

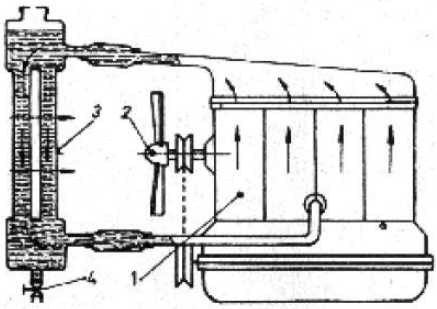




1. Safety Valve 2. Filter 3. Pump 4. Engine IC 5. Clutch and Gearbox 6. Outlet pipe

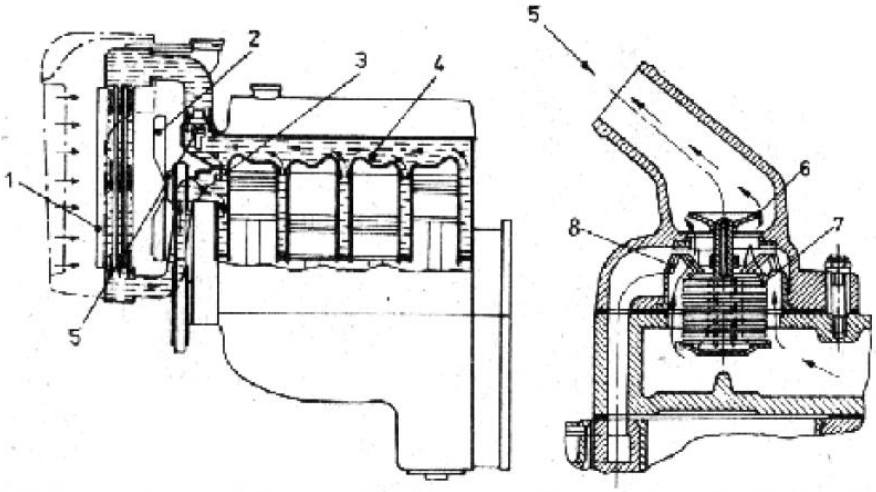
Closed cooling system - Circulating cooling

Automatic - pressure drop



Samoobežné chladenie: 1 – chladiaci plášť motora, 2 – ventilátor, 3 – chladič, 4 – vypúšťací kohút

Forced circulation - by means of a pump

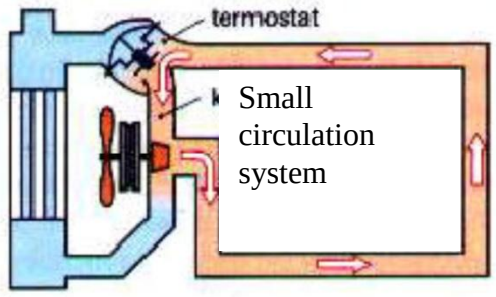


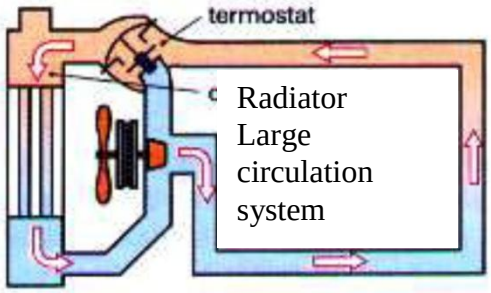
Chladenie s núteným obehom: 1 – chladič, 2 – ventilátor, 3 – čerpadlo chladiacej kvapaliny, 4 – vodný plášť motora, 5– termostat, 6– tanierový ventil termostatu 7 - vlnovec termostatu, 8 – obtokový ventil termostetu

Note:

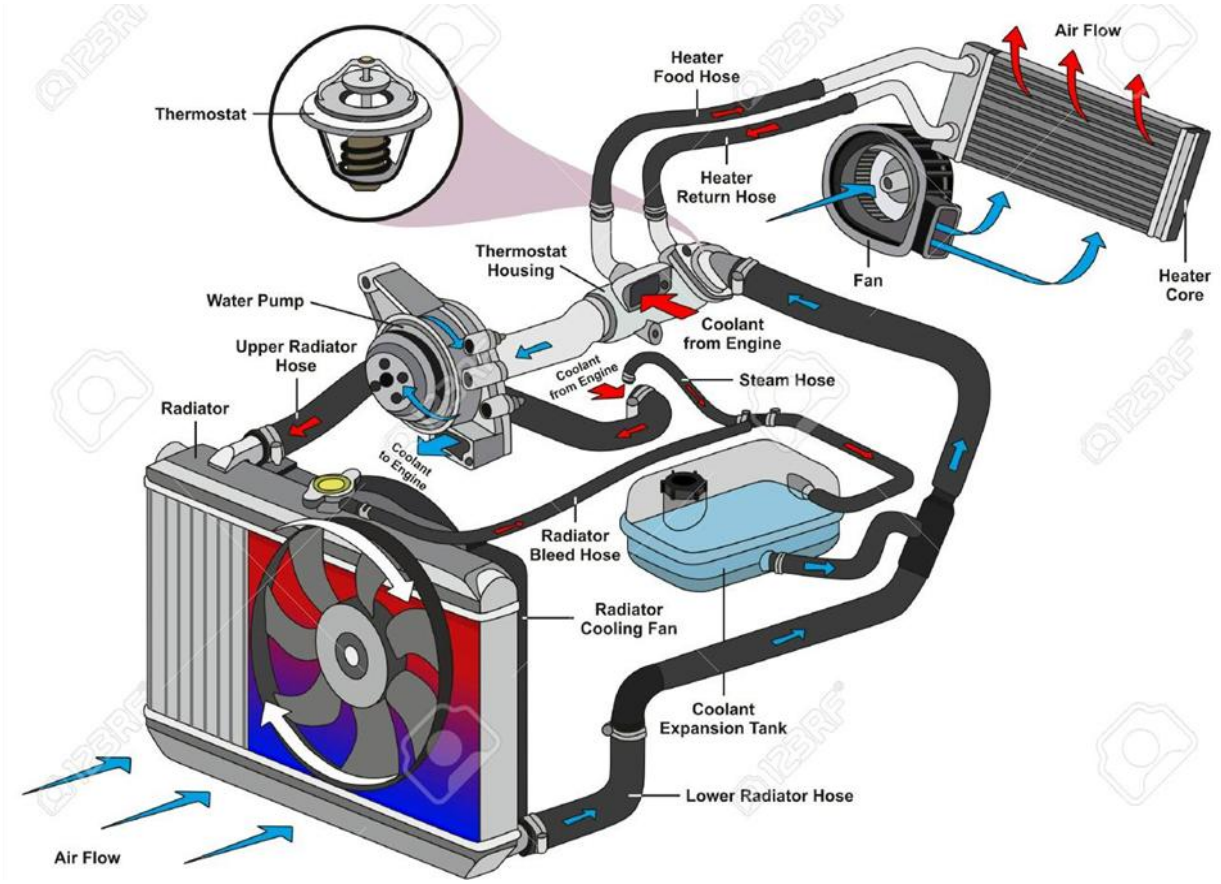
1. During self-cooling, the temperature in the cooler drops from 90 - 95˚ C to 35 - 40˚ C.
2. In pump cooling, the pump is between the lower radiator chamber and the engine cooling jacket.

Rise of pump circulation to working temperature - small circulation, large circulation





Liquid cooling system - parts



Advantages of liquid cooling:
even engine cooling, small temperature difference,
lower engine noise,
use for heating, more sensitive regulation,
possibility of engine preheating.

Disadvantages of liquid cooling:
more complex construction of the head,
engine block, higher maintenance requirements,
higher space requirements,
more complicated system,
less suitable for extreme applications.

Cooling system design
The amount of heat produced required for cooling

$$Q_{chl} = q_{ch}.m_{pe}.P_e.H_d$$

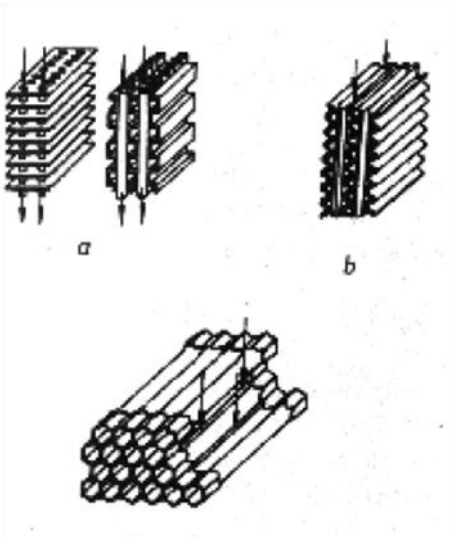
qch- coefficient depending on the motor concept
liquid-cooled spark ignition engines - 0.25-0.3
air-cooled petrol engines - 0.1-0.15
liquid cooled diesel engines - 0.25-0.35
air-cooled diesel engines - 0.1-0.2
m_{pe}- efficient consumption
P_e-Effective power,
H_d-Fuel calorific value

Amount of coolant

$$Q_{chl} = M_{ch}.c_{ch}.\Delta T_{ch}$$

M_{ch}- [kg / s] refrigerant flow rate
c_{ch}- [$J.kg^{-1}.K^{-1}$] - specific heat of coolant
ΔT_{ch}- [K] - temperature drop between inlet and outlet coolant

The temperature drop must not be too large max. 10 ° C to avoid excessive thermal stresses. With air cooling, the temperature drop is up to 60-80 ° C. The cylinder temperature is 140 ° C to 190 ° C. The air temperature between the ribs is 50-80 ° C.



– Usporiadanie chladiča:
a – rúrkové, b – lamelové,
c – voštinové

Radiator area

$$Q_{chl} = k.S.\Delta t$$

k- total heat transfer coefficient dependent from the design of the radiator
k = 10-60 [$Wm^2.K^{-1}$] - smooth radiator tubes a)

k = 60-250 [$Wm^2.K^{-1}$] - finned radiator
k = 15-350 [$Wm^2.K^{-1}$] - lameral radiator b)
k = 20-120 [$Wm^2.K^{-1}$] - honeycomb radiator c)
S- area of the cooler
Δt- medium temperature gradient

Cooling circuit control
Air cooling system:
by restricting the air flow
by changing the fan parameters

Liquid cooling system:
by changing the coolant flow
by change of cooling air flow through the radiator
by change the size of the effective area of the cooler

Secondary cooling circuit - Intake air cooling system.
The aim is to keep the intake air temperature constant!
If necessary - cold start - start-up, engine idling, engine under low load it is necessary to heat the intake air.