

SECTION 5, CHAPTER 3

COOLING SYSTEMS

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Introduction

1. Since power is developed in spark and compression ignition engines by burning a fuel/air mixture, the combustion chambers and such parts as pistons, valves, etc., are subjected to great heat. Although the best power output is obtained from an engine that is hot, there are certain factors which make it essential to dissipate much of this heat. It may not seem very economical to use heat as the form of energy and then to waste quite a proportion of what is available, but if this was not done the engine would not continue to run. If the temperature of the engine was allowed to get too high, any of the following troubles could occur:—

- (a) Burning away of the lubricating oil film with consequent seizure of working parts.
- (b) Spontaneous ignition of the incoming mixture on the induction strokes.
- (c) Loss of power caused by a smaller weight of mixture entering the cylinders at each induction stroke.
- (d) Weakening or even melting of metal components.

2. It is therefore necessary to incorporate a system for cooling the engine, and at the same time allow the engine to attain a temperature sufficiently high to allow for the greatest efficiency in operation, without detriment to the components and the weight of combustible mixture entering the cylinders. Excessive cooling will keep the engine at a low temperature; this prevents proper vaporization of the gasoline, leading to further waste, loss of power, objectionable dilution of the lubricating oil, as well as causing corrosion and the formation of sludge. For certain engines there are particular operating temperatures which produce the most satisfactory results; these will be determined by the manufacturer and it will be found that, in general, the operating temperature is in the region of 75°C. to 90°C.

3. There are two main systems used to dispose of the excess heat, i.e. direct air cooling and water cooling; it may be said that all cooling is by air for, as will be seen later, a radiator is used with a water cooling system to get rid of the heat. The factors involved in the choice of the particular system are, of course, design problems, and are therefore outside the scope of these notes.

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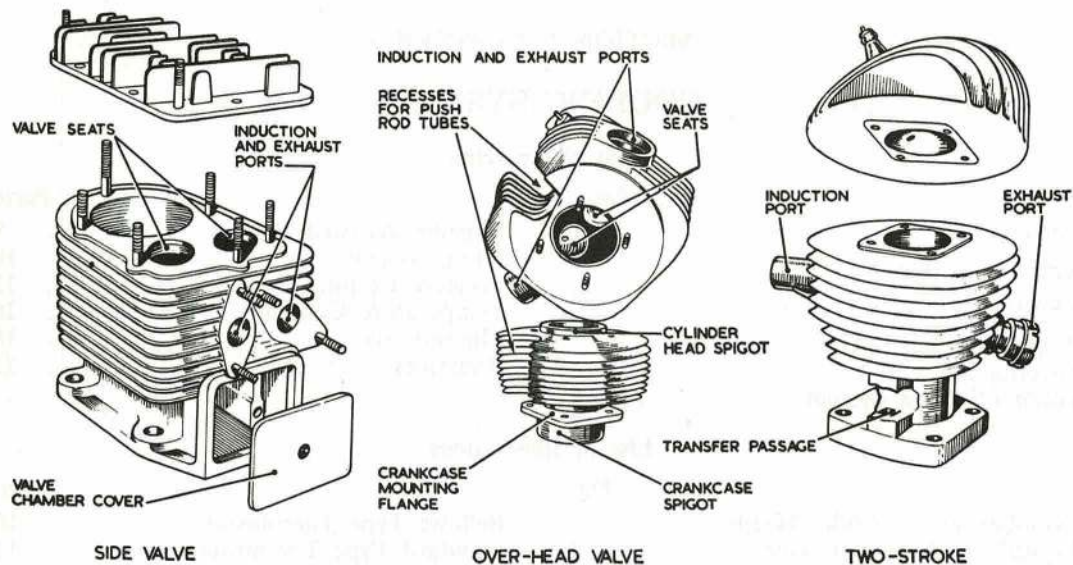


Fig. 1. CYLINDERS AND CYLINDER HEADS

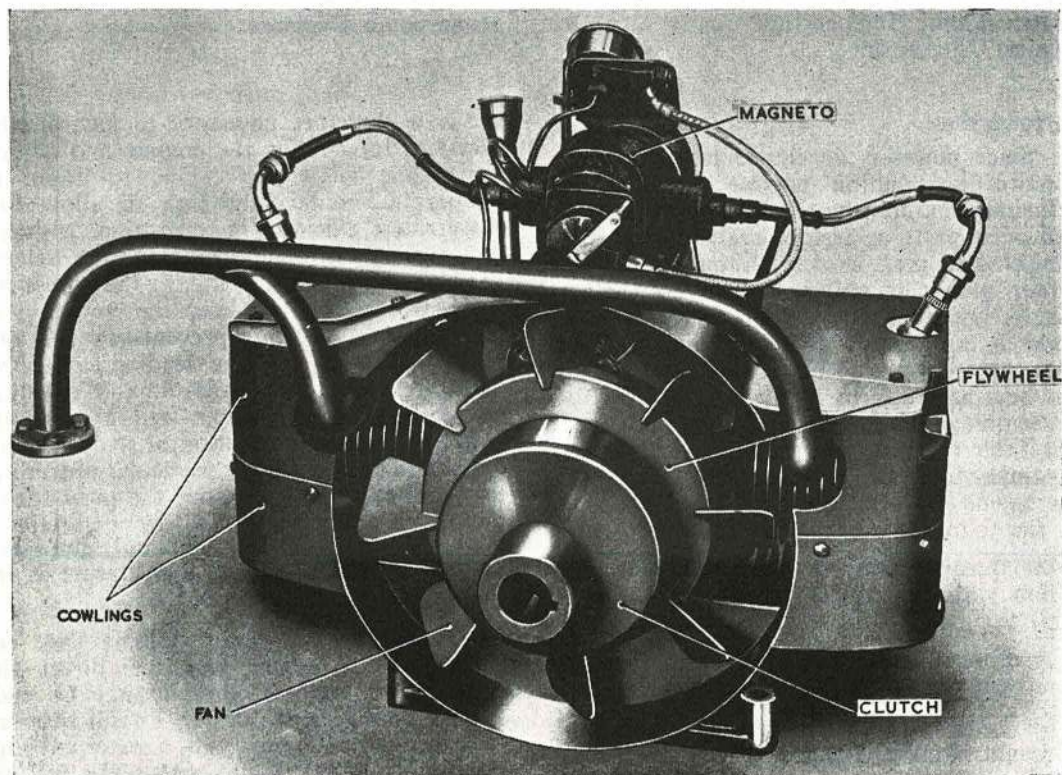


Fig. 2. TYPICAL AIR COOLED ENGINE

AIR COOLING

General

4. Direct cooling by air relies upon a continuous flow of cool air passing over the engine all the time it is in operation. This method has several advantages over water cooling in that it is free from the trouble of freezing, simpler construction can be employed, and weight can be saved. The cylinders, cylinder heads, and sometimes the crankcases of air cooled engines, are suitably finned to provide a large volume of metal for absorbing the heat and a large surface area exposed to the stream of air for its dissipation (Fig. 1).

5. Natural flow air cooling is rather difficult to control, and the difficulties increase as the size of the cylinder increases. With multi-cylinder engines the flow of air is controlled by suitable baffles and cowlings, so as to be distributed in the required amounts to the various cylinders and their hottest

parts; therefore, adequate flow of air is often obtained by the use of a fan, frequently incorporated with the flywheel (Fig. 2). Air cooled engines of small power output, and in both two and four stroke applications, are widely used for operating ground equipment; a typical example is shown at Fig. 2.

WATER COOLING

Introduction

6. Heat is far more readily transferred from metal to water than from metal to air, and the final transfer of heat from water to air, is readily accomplished by a radiator having a large cooling surface. The system can be designed, i.e. with regard to capacity and cooling surface so that for any particular application the temperature can be kept within the required limits. A few small engines which are not required to run for very long periods are not fitted with a radiator but are "hopper" cooled, i.e.

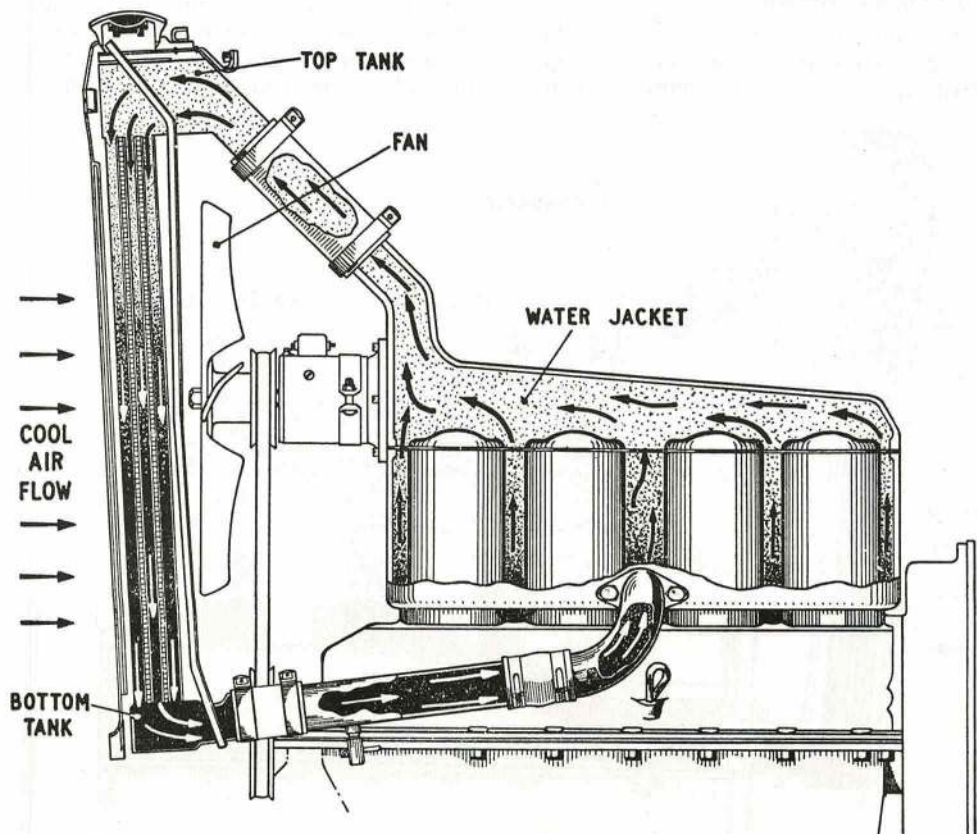


Fig. 3. THERMO-SYPHON COOLING SYSTEM

sufficient water is contained in a tank or hopper, often combined with the cylinder head, for normal cooling needs.

7. As has already been seen in Chapter 1, water cooled cylinders and cylinder heads are provided with passages to allow water to flow around the hot parts of the engine. Thus the engine is provided with a "water jacket", and a connection at the top of the engine enables the water to be piped to the top of the radiator, whence it is cooled whilst passing to the bottom, where an outlet is connected to an inlet connection situated at the bottom of the cylinder jacket. The usual way of ensuring a sufficient flow of air through the radiator is by means of a fan which is driven by a belt from the crank-shaft pulley. There are several methods in general use to circulate the water through the system, some of which make use of additional components; these systems are described in the following paragraphs.

Thermo-Syphon Method

8. A necessity of the system is that the water must circulate, and this system, illustrated at Fig. 3, is its simplest form.

The water circulates by virtue of "*convection*", i.e. the natural movement of water when it is heated; hot water is lighter than cold water so, therefore, it rises, and cold water sinks to take its place. The water surrounding the engine, on becoming heated, rises through the connecting hose and enters the top or header tank of the radiator; in so doing it displaces the cool water in the bottom tank of the radiator, so that it flows into the water jacket and in turn is heated. The water which left the bottom tank is replaced by water which has passed through the radiator and, in so doing, been cooled by the air flow. Thus, it will be seen, there is a continuous circulation of the water, provided that the water level is not allowed to fall below the level of the delivery pipe to the top tank of the radiator.

Impeller Assisted System

9. The speed of circulation of the cooling water in the thermo-syphon system may be too slow for certain applications, but this trouble can be overcome by the use of an impeller assisted system (Fig. 4). This is a modification of the thermo-syphon system, in that to assist circulation, an impeller is

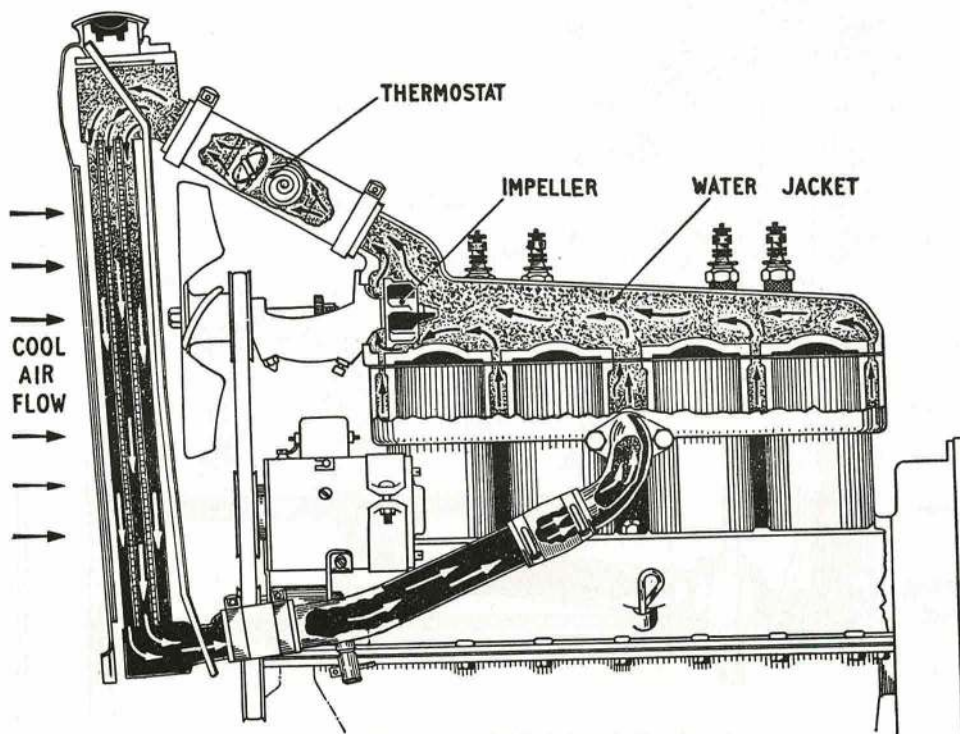


Fig. 4. IMPELLER TYPE COOLING SYSTEM

fitted at the water outlet from the cylinder head. The impeller is usually mounted on an extension of the fan spindle and both are driven by a belt from the crankshaft pulley. The clearance around the impeller blades is such that, should the impeller cease to function, circulation still continues, though at a reduced rate, by thermo-syphon action.

Pump System

10. This system (Fig. 5) is also similar to the thermo-syphon system, with additionally a centrifugal impeller type pump fitted between the bottom tank of the radiator

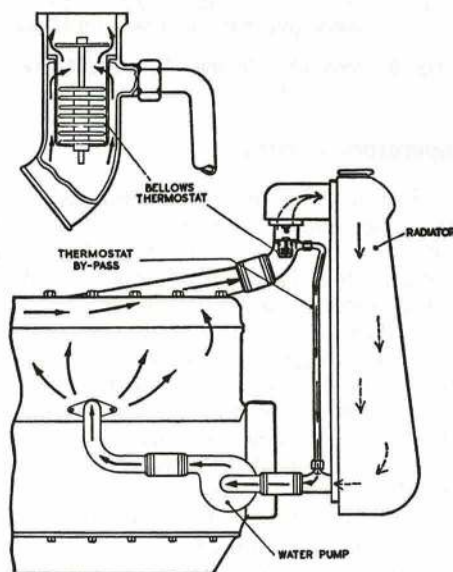


Fig. 5. PUMP COOLING SYSTEM

and the inlet connection to the cylinder water jacket. In general, the thermo-syphon system requires a larger radiator and carries a greater amount of water than the pump circulation system; furthermore, a rather larger temperature difference is necessary to produce the requisite circulation in the former system. These defects have resulted in the adoption of the pump system, particularly for the larger types of engines. Unlike the impeller which only helps circulation, the pump in this system governs the water circulation, therefore, a defective pump may be the cause of an engine overheating.

11. **Water Pump.** The usual type of water pump that is used consists of two main

parts, a round casing and an impeller (Fig. 6). The impeller consists of a disc having a number of curved vanes, and it is mounted on a spindle which is driven by the engine. A seal is provided where the impeller spindle

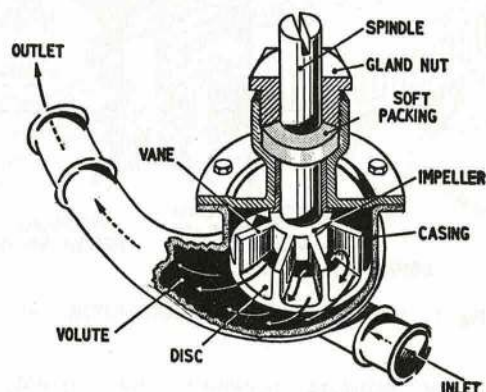


Fig. 6. WATER PUMP

passes through the casing, in order to maintain a water-tight joint. This seal may be a spring-loaded or adjustable gland, packed with some form of material such as greased asbestos string, but the most widely used form of seal is a graphitic carbon ring, which may revolve with the impeller or be stationary in the housing. The water enters the casing at the centre of the rapidly turning impeller, where it is flung out into the casing by centrifugal force; the water then flows along the volute or snail-shaped casing to the outlet pipe connected to the bottom of the cylinder water jacket.

Pressure Cooling System

12. A pressure cooling system is one that is sealed to allow pressure to build up inside, and thus increase the boiling point of the water. A pressure radiator cap (Fig. 7) is used, and a valve in the cap prevents the system from venting to atmosphere until a predetermined pressure has built up. The degree to which a system needs to be pressurized depends upon the climatic and atmospheric conditions in which the engine is operating. At high altitudes, the boiling temperature of water in a normal atmospheric system is appreciably reduced, but by pressurizing the system it is increased, the increase being dependent upon the pressure in the system (Fig. 8).

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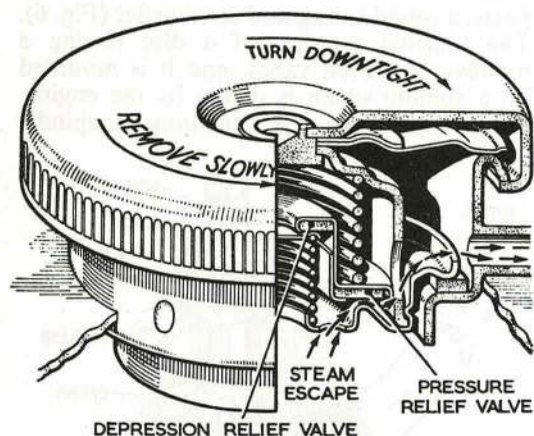


Fig. 7. PRESSURE COOLING RADIATOR CAP

13. By utilizing pressure, the capacity necessary for cooling the water is reduced, consequently, the size of the radiator and fan can be correspondingly reduced. By raising the pressure in a system the loss of water caused by vaporization is reduced, therefore, replenishment of the system is required less frequently. The formation of scale inside the radiator is also retarded, thereby increasing its life.

14. **Precautions.** When removing the radiator filler cap of a hot engine, care must be taken to avoid being scalded; it is possible for the water in the radiator to boil when the cap is removed and the pressure released, therefore, it is advisable to remove the cap partially and let the pressure escape before completely removing the cap. Special bayonet fitting caps are sometimes used, and these are removed in two movements—one part-turn releases the pressure and the next turn removes the cap.

15. **Filling the System.** Care should be taken to fill the system to its correct capacity; in some systems a mark on the filler neck indicates the full level, whilst on other systems the filler neck is designed so that over-filling is automatically prevented. A pressurized system should always be filled when the engine is warm, so that the thermostat will be open to allow the water to flow into the cooling jacket. If water is added to the radiator when the engine is cold, the closed thermostat will prevent the water from entering the cylinder jacket, and a false "full" condition will result.

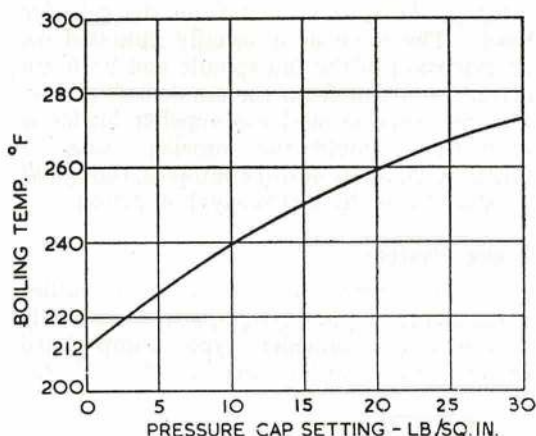


Fig. 8. WATER BOILING TEMPERATURE

Temperature Control

16. In cold weather the engine takes an appreciable time to reach its normal working temperature, so that a cooling system of minimum capacity would then be adequate; a pump system, because circulation commences immediately the engine is started, would take longer to "warm up" than a thermo-syphon system. In warm or hot weather, however, when a greater circulation of water is needed to ensure adequate cooling, a system of maximum capacity is required. Obviously, the system is designed to ensure that the water does not reach boiling point even in the hottest expected operating conditions. It is, therefore, a desirable requirement, that the temperature of the cooling system is raised to the normal working temperature as quickly as possible, and is then maintained at that temperature for continuous operation of the engine.

17. The temperature of the water can be controlled in several ways, one way being to control the flow of cooling air through the radiator by means of a "blind" or "shutters"; these are usually hand controlled, although there are examples where the shutters are thermostatically controlled, and can be set to maintain the required temperature as shown by the reading on a radiator thermometer. Another widely used method is the fitting of a thermostatically controlled valve (Fig. 9) to control the circulation of the water in the system.

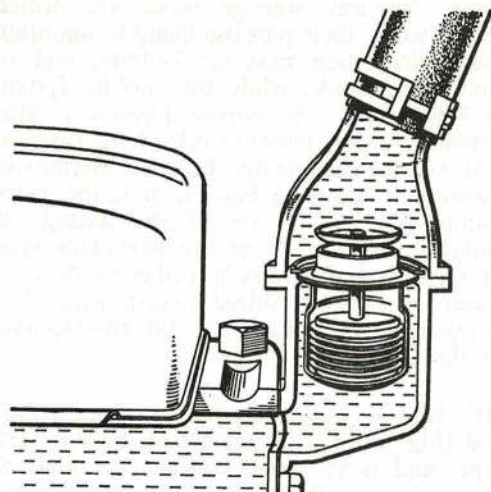


Fig. 9. TYPICAL THERMOSTAT

Thermostats

18. **General.** The thermostat fitted in the water-cooling system of an engine consists of a mushroom type valve controlled by a concertina or bellows-like vessel. The

bellows contain a volatile liquid, e.g. ether, which causes the bellows to expand or contract as the temperature rises or falls. When it is cold, and until it reaches a pre-determined temperature, the water in the engine is prevented by the closed valve of the thermostat from entering the radiator (Fig. 10). This allows the water in the jacket surrounding the cylinders and combustion chambers to warm-up rapidly, until a temperature is reached when the thermostat opens and allows a gradually increasing flow of water to pass through to the radiator for cooling. In the event of the bellows becoming punctured, the capsule assembly will expand and open the valve to the radiator. Thus, the system will then function as if the thermostat was not there and will not cause overheating; the probable symptoms will be, a longer time to reach, or perhaps failure to reach normal operating temperature, depending upon the particular operating conditions.

19. **Standard Type.** The standard type of thermostat (Fig. 11) is intended for fitment in the water outlet passage from the

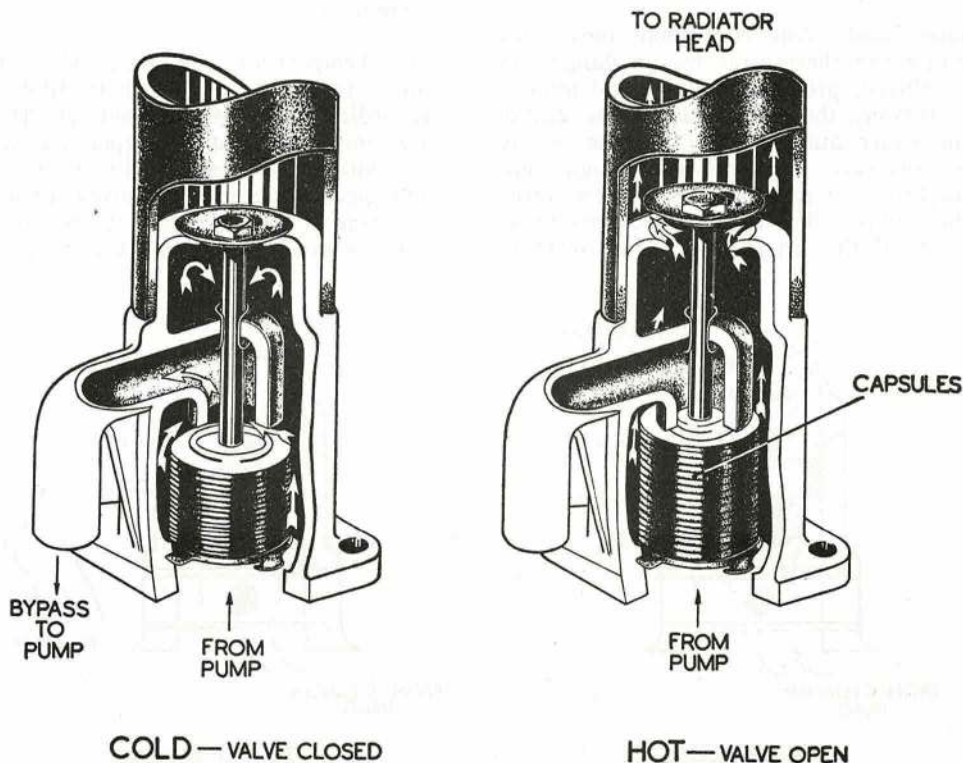


Fig. 10. BELLOWS TYPE THERMOSTAT

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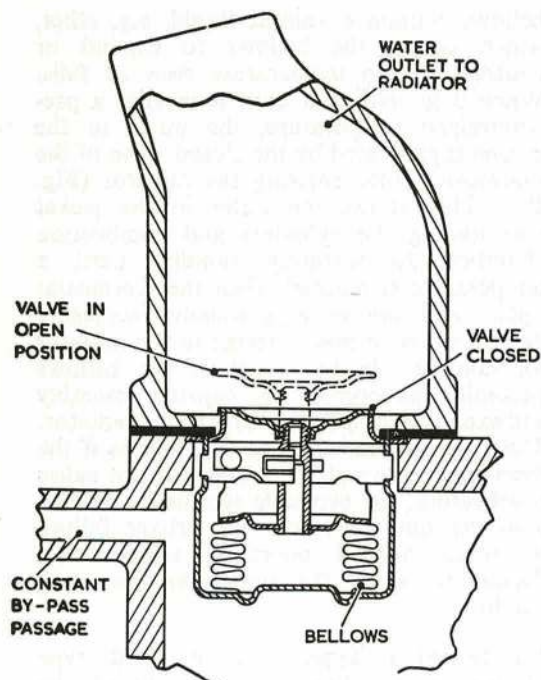


Fig. 11. STANDARD TYPE THERMOSTAT

cylinder head. Any convenient means for retaining the thermostat by its flange can be employed, provided that a good joint is made between the thermostat and its seating in the water outlet pipe, otherwise, where water pressure is appreciably high, unallowed-for circulation may to a large extent nullify the temperature governing function of the thermostat. One or more

small diameter seepage holes are drilled in the valve, their purpose being to maintain some circulation past the bellows, and to prevent air locks while the cooling system is being filled. A by-pass passage is also provided on the pressure side of the thermostat, and the passage may be in the thermostat housing as shown in Fig. 11, or in the water pump body. The size of the passage is suitably determined for the particular type of engine, and allows a sufficient flow of water to avoid localized over-heating, but is not so large as to reduce the effectiveness of the thermostat.

20. By-Pass Type. The by-pass type thermostat (Fig. 12) is a refinement of the standard type, and is so called because the flow of water through the by-pass is controlled by this type of thermostat, the by-pass passage being sufficiently large to allow free circulation of the water when the radiator is short circuited. When, however, the main valve is open, the by-pass is correspondingly closed, thus automatically transferring the full flow of water through the radiator and employing the full cooling capacity of the system.

21. Temperature Settings. The start-to-open temperature for thermostats varies according to the requirements of the engine. The most usual start-to-open temperatures are within the range of 156°F. to 165°F., and thermostats are set during manufacture to open at one specified temperature; this temperature is usually marked on the instru-

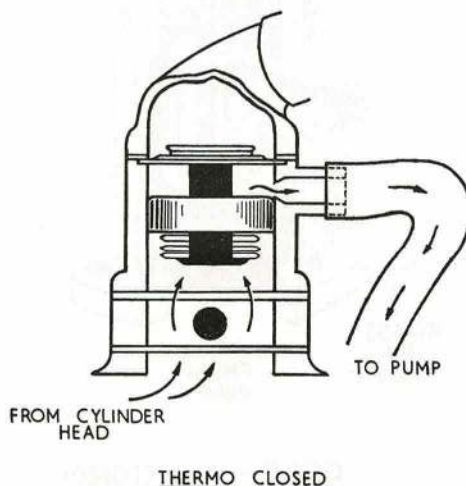
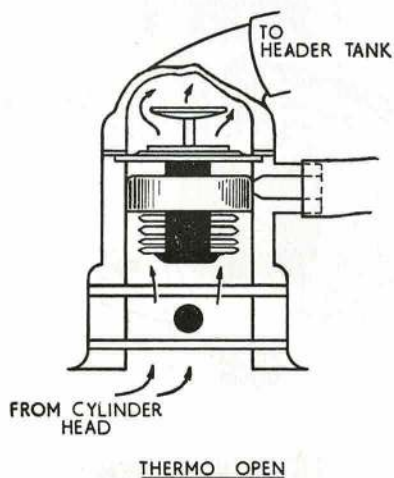


Fig. 12. BY-PASS THERMOSTAT

ment. A setting higher than the aforementioned range may be desirable for certain applications, e.g. diesel engines, or for particular operating conditions.

Radiators

22. The radiator is the component to which the hot water flows from the engine in order to be cooled; it is a heat-dissipating arrangement of tubes, known as the core, fitted between two tanks. The header tank is connected by hose to the outlet pipe of the cylinder head, and the bottom tank is connected by hose to the water pump or the cylinder water inlet pipe, depending upon the type of system in use. There are various methods of construction, some of which are described in the following paragraphs, but they can broadly be classed into two main categories:—

(a) The vertical water tube types in which the water falls through a number of tubes from an upper header tank to the lower tank, while the air flows horizontally between the tubes.

(b) The cellular types in which the air flows horizontally through short tubes assembled like a honeycomb, with small clearances between them for vertical circulation of the water.



Fig. 13. FILM RADIATOR

23. **Film Radiator.** The core of a film type radiator (Fig. 13) consists of a number of wide, flat tubes made of brass, bent in zig-zag fashion, and on one type each tube is separated by a thin strip of metal. The tubes are soldered to the separating strips, and supports are soldered at each side to give rigidity to the core structure. On another type, the zig-zag tubes have no separating strips between but are soldered to each other at the high points of the zig-zags. The top and bottom tanks are soldered directly to the top and bottom of the core, so that water flows through the tubes and is cooled by the comparatively large surface area of the tubes exposed to the air.

24. **Tube and Fin-Gill Radiator.** The tube and fin-gill radiator (Fig. 14) consists of a number of tubes passing through flat plate cooling gills. The ends of the tubes are located in holes in two plates which form

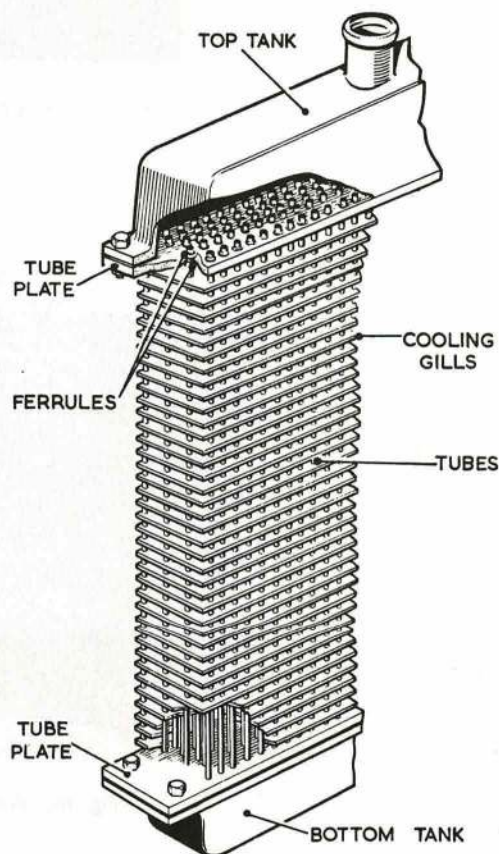


Fig. 14. TUBE AND FIN-GILL RADIATOR

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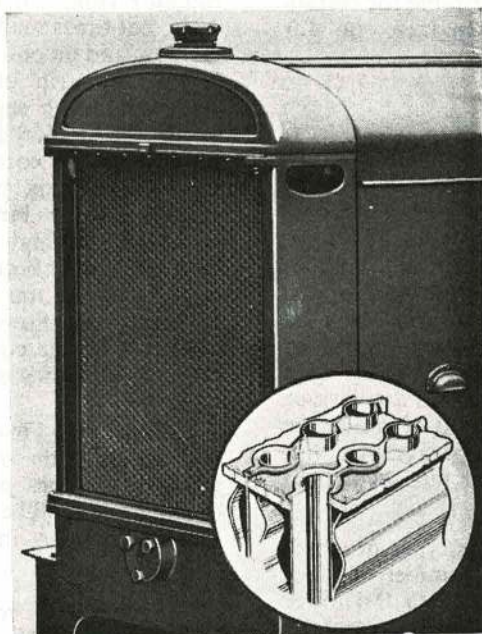


Fig. 15. MULTIPLE-TUBE RADIATOR

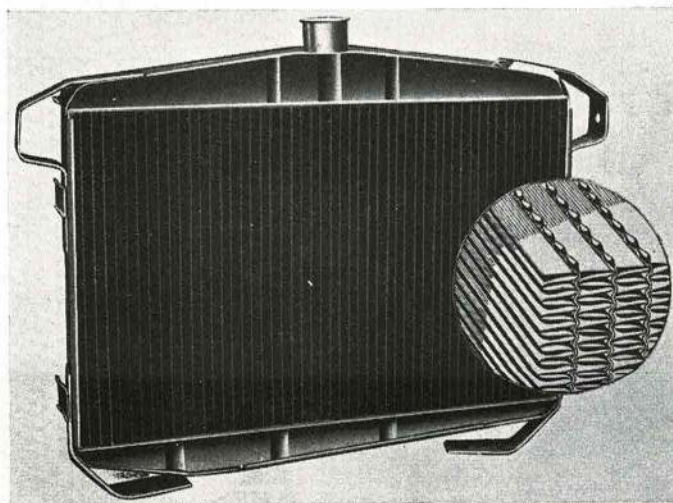


Fig. 16. FLAT TUBE RADIATOR

the top and bottom of the core, and are secured by ferrules soldered to the tubes and the endplates. The tubes on some radiators are swaged over to form flanges on the plates, the flanges then being soldered to the plates to form watertight joints. The top and bottom tanks are bolted to the tube plates, and the side supports are bolted to the tanks. The water flows through the tubes which are positioned so that the airflow can play on each and every tube, the cooling gills assisting in the dissipation of the heat.

25. Multiple-Tube Radiator. The multiple-tube radiator (Fig. 15) consists of a number of tube strips separated by corrugated cooling gills. Each tube strip consists of a number of tubes manufactured as one piece, the ends of the tube strips passing through holes and slots in two plates which form the top and bottom of the core. The ends of the tubes are swaged over to form flanges on the plates, and the flanges are soldered to the plates to make a watertight joint. The cooling gills between the tube strips have the high points of the corrugations soldered to the strips to form a rigid structure. The top and bottom tanks are bolted to the tube-plates, and the side supports are bolted to the tanks. Water passes through the

tube strips, and the cooling gills assist the dissipation of heat.

26. Flat Tube Radiator. This type of radiator (Fig. 16) consists of a number of flat tubes separated by closely corrugated cooling gills; the tubes and cooling gills are soldered together to form a rigid structure. The top and bottom tanks are soldered directly to the top and bottom of the core, and the side supports are soldered to the sides of the core and the top of the top tank. Water flows through the flat tubes, and the cooling gills assist the dissipation of heat.

27. Honeycomb Radiator. This type of radiator (Fig. 17) is of the cellular type, and the core is made of a number of tubes which may be shaped like double-ended box spanners or they may be circular. The centre portions of the tubes are round and are smaller in diameter than the ends, the ends being soldered together; this formation leaves a small space between the tubes through which the water flows. The top and bottom tanks are soldered directly to the top and bottom of the core. Air flows through the hollow tubes and cools the water as it flows down and around the outside of the centre portions of the tubes on its way from the top to the bottom tank.

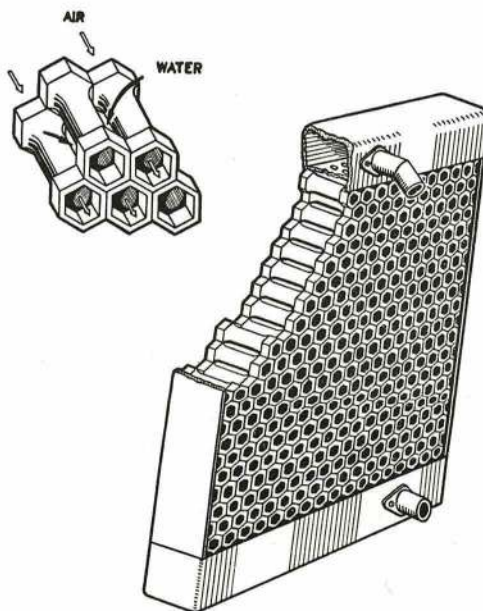


Fig. 17. HONEYCOMB RADIATOR

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