# CHAPTER VIII

# CONTROL OF THE COOLING SYSTEM

## 1. Importance of cooling control

If the engine is to run properly the temperature of the engine must not fluctuate excessively under differing loads or at varying outside temperatures. The maintenance of an adequate temperature of the cylinder wall influences not only the losses caused by friction, but also the rate of wear of the cylinders.

If the walls of the cylinder are cold, oil on their walls is thick and offers strong resistance to the movement of the piston. This is particularly characteristic of high viscosity oils. The hotter the cylinder wall, the smaller the losses through friction. Fig. 104 [48] illustrates the relationship between friction losses and the temperature of the cooling water, such relationship being expressed by mean pressure $p_z$ in kg/cm$^2$ of the piston area. With regard to this friction a high temperature of the cylinder-wall is an advantage. The measurements were taken at a constant temperature of intake air.

Of particular significance is the rate of wear of the cylinders at low temperatures of the cylinder walls. If the engine is undercooled, products of the combustion condense on the cylinder walls, etching of the cylinder walls sets in and this, together with poor lubrication and high pressure of the upper rings is responsible for the excessive rate of wear of the cylinders. The highest rate of wear occurs in the upper third of the cylinder, which is an unmistakable proof that this is not an instance of mechanical wear alone, but that also chem-

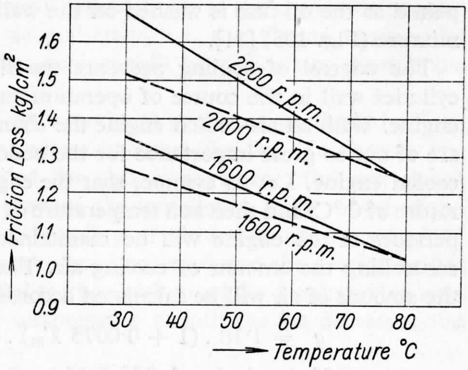


FIG. 104. Influence of cylinder (cooling water) temperature upon the average loss of pressure in a twelve-cylinder engine with 114.3 mm bore, 152.4 mm stroke and a compression ratio of 5.3 : 1 (full line). The dash line represents friction loss in an eight-cylinder engine, bore 140 mm, stroke 150 mm and compression ratio 5.4 : 1.

ical factors are at work. The rate of wear of the cylinders can be substantially lowered if the temperature of the cylinder is kept within an adequate level. Fig. 259 shows, in accordance with tests, the rate of wear as a function of the temperature of the cylinder. At low temperatures of the cylinder walls the increase in the rate of wear is noteworthy.

From daily experience we know that engines of vehicles used for long-distance travel suffer much less from wear than engines of vehicles employed

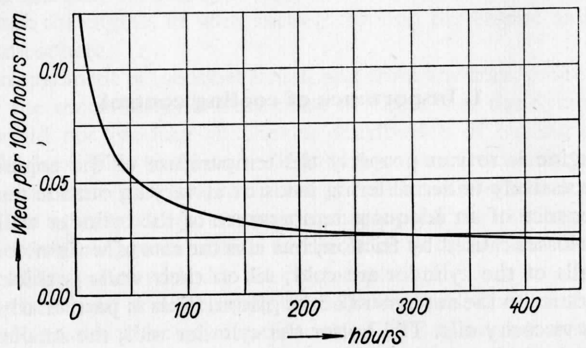


FIG. 105. Wear of cylinders plotted against running time in hours after one start.

for local traffic. In local traffic the engine is started up frequently. If the engine is started up at a low temperature, conditions for a low rate of wear are impaired as the oil film is washed off the walls of the cylinder by a rich starting mixture (Fig. 105) [21].

The control of cooling prevents the fluctuation of temperatures of the cylinder wall in the course of operation and enables a speedy heating of the engine. With an air-cooled engine the changes in the outside air temperature are of not so great importance for the conditions of cooling as with a water-cooled engine. Let us assume, that the engine runs first at an outside temperature of 0 °C, and then at a temperature of 40 °C. In both instances the temperature of the engine will be maintained at the same level only through controlling the amount of cooling air. The coefficient of heat transfer $q$ and the amount of air will be calculated according to the following equations:

$$q = 1{\cdot}18 \, . \, (1 + 0{\cdot}0075 \, T_m) \, . \, v_m^{0{\cdot}73} \text{ (kcal/m}^2\text{ h °C)},$$

$$V_a = A \, . \, k \, . \, \Delta p^{0{\cdot}55} \text{ (kg/h)}$$

where $T_m$ denotes the arithmetic mean of the absolute temperatures of fin surface and air (°K)

$v_m$ „ the mean velocity of air in the fin interspace (m/s)

$A$ „ the flow area between the fins of the cylinder (m²)

$k$ „ a constant,

$\Delta p$ „ velocity head between the fins (kg/m²)



The assumed values will produce conditions given in Table 17. Assuming the temperature of the outside air stands at 40 °C, the temperature difference in a water-cooled engine will be decreased to half its value, hence the amount of cooling-air will have to be increased by 147 % and the input of the fan will be increased 13·25 times. On the other hand, for an air-cooled engine all other conditions being equal, it will do to increase the amount of cooling-air by 32·8%, and the input of the fan, 2·33 times.

Despite these facts it is, however, essential to provide a cooling control also for air-cooled engines. Especially if running constantly undercooled during the wintermonths the engine will suffer from excessive wear. Furthermore the above example demonstrates that the control of cooling will make it possible to achieve substantial economies in the power consumed by the cooling system. Low sensitivity of an air-cooled engine to outside temperature makes these engines suitable for use in tropical regions.

## 2. Methods of cooling control

The cooling of air-cooled engines can be controlled by one of several methods. The simplest and most frequently applied method consists in throttling the cooling air. The feeding of cooling air can be governed by:

1. Throttling the inlet air to the fan,
2. Throttling the air between fan and engine,
3. Throttling the air leaving the engine.

Ad 1. To throttle the air introduced to the fan is of particular advantage where air leaves the engine at several points. Such is the case with engines whose cylinders are arranged in several rows, i.e. the V-type engine, flat engines and the like. In such instances it would be difficult to throttle the outgoing air.

This type of solution presents constructional problems particularly if the air has to be throttled at the point where it enters the fan. To throttle the air by louvres is not recommended for this arrangement, for part-closed louvres affect the direction of air towards the impeller or guide wheel of the fan. Fig. 106 shows a convenient throttling of air fed to the fan of a VW engine. A ring controlled by a thermostat is inserted into the suction orifice of the fan. If the pressurized air fed to the fan is used for heating, this type of control is not desirable for the air-pressure behind the fan decreases due to the throttling.

Ad 2. Throttling of air between fan and engine is practicable only with certain types of designs.

An example of such a control is shown in Fig. 107. It is the control of the air-cooled Phänomen engine provided with a radial fan, mounted directly on the crankshaft. The air is conveyed from the fan to the engine through a short, bent duct; into this duct, directly behind the fan two throttle valves are fitted, one of them being governed by a thermostat, and the other being mechanically connected with the throttle valve of the carburettor. A bellows-thermostat is located in the stream of air leaving the cylinders. The purpose of the second throttle valve, connected with the throttle valve of the carburettor, is to prevent overcooling of the engine on downhill runs.

Ad 3. Throttling of outgoing air is convenient wherever there is a single point of joint discharge of the air from the engine. This method produces

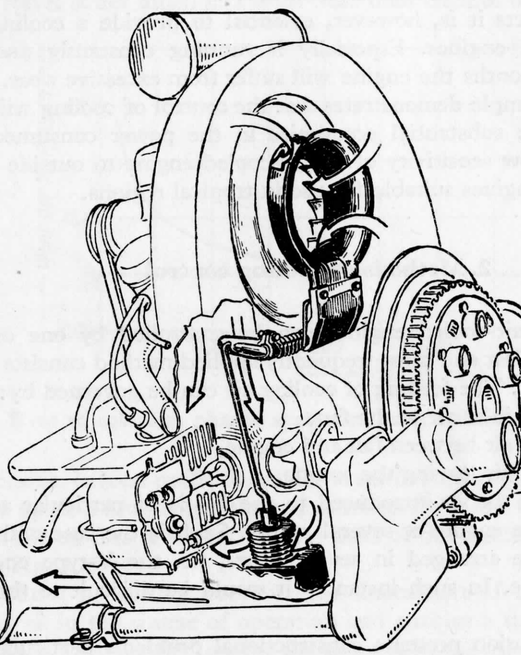

FIG. 106. Cooling control in the VW engine by throttling the air inlet. Automatic control is provided by a thermostat.

air-pressure under the hood of the engine to be used for heating the vehicle and the like. An instance of a control of this type is illustrated in Fig. 108: air leaving a V-type engine is throttled by two flaps connected in parallel, controlled by a thermostat.

Control effected through throttling leaves a very limited scope for saving on the power consumed by the fan; the throttling of air lowers the efficiency of the fan, so that a reduction in the amount of air will give only a slightly reduced input to the fan.

Cooling control through a change in the speed of the fan will result in a substantial economy in input. Taking into consideration that the amount of air flowing through the fan is directly proportionate to the speed while the



air-pressure is proportionate to the second power, and the input of the fan to the third power of the speed, the importance of economies of this type are apparent. If half of the original amount of air is required for the cooling, 1/8 of the initial input will be sufficient for the purpose. This is of particular importance in the case of partial load and a high speed fan, where the cooling input represents a major share in the effective performance of the engine.

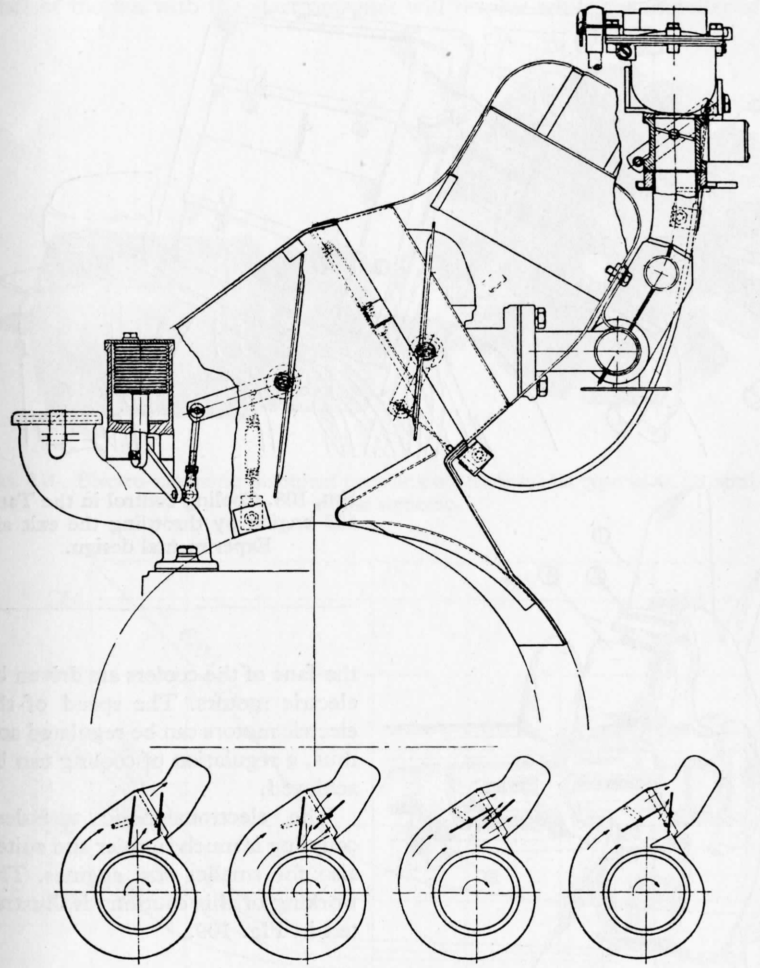

FIG. 107. Cooling control in the Phänomen engine by air throttling between fan and engine.

One flap is actuated by the thermostat, the second by the throttle of the carburettor. Bottom drawing illustrates function of control flaps during start and down-hill travel.

The speed of the fan can be changed by electrical, mechanical or hydraulic means.

Electrical transmission gear between engine and fan is desirable; it is, however, suited only for larger units. It is used for railway engines, where

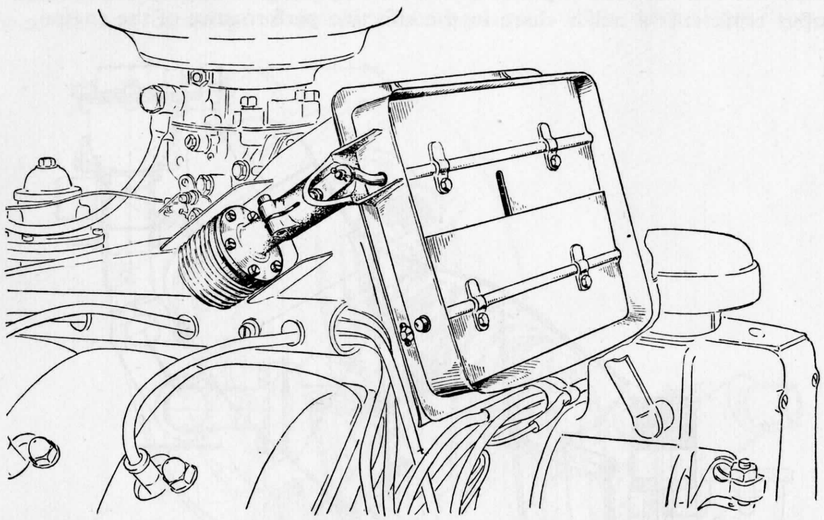

FIG. 108. Cooling control in the Tatra 603 engine by throttling the exit air. Experimental design.

the fans of the coolers are driven by electric motors. The speed of the electric motors can be regulated and thus, a regulation of cooling can be achieved.

The electromagnetic turbulent coupling is much simpler and suited also for smaller size engines. The working of this coupling is illustrated in Fig. 109.

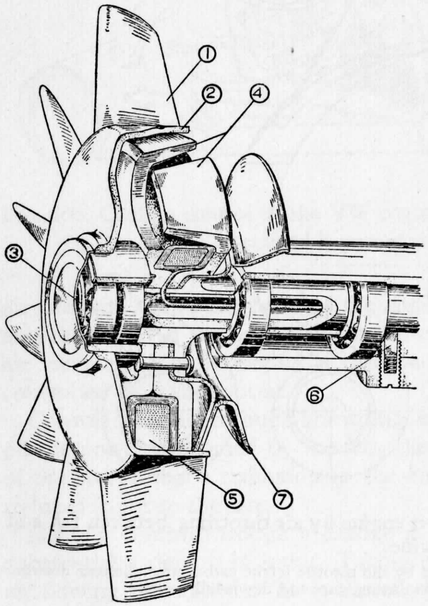


FIG. 109. Principle of the electro- ← magnetic turbulent coupling.



The impeller of fan *1* is fitted to steel drum *2* and by means of ball bearings it is mounted on shaft *3*. An electromagnet with alternate pole shoes *4* is rigidly fastened to this shaft. The electromagnet is excited by coil *5* which is fed through carbon leads *6*. The shaft of the fan is driven by the engine by means of a V-belt and belt-pulley *7*.

If the current is not switched on to the coil of the electromagnet, only the shaft of the fan with the electromagnet will revolve while the impeller of the

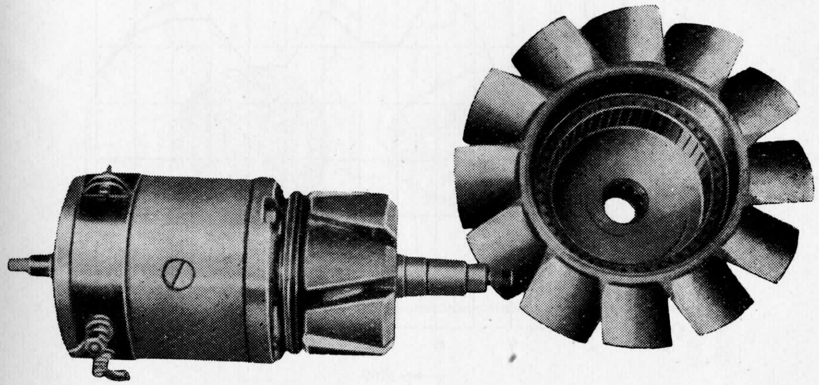

FIG. 110. Electro-magnetic turbulent coupling of the Scintilla type as an integral part of the dynamo.

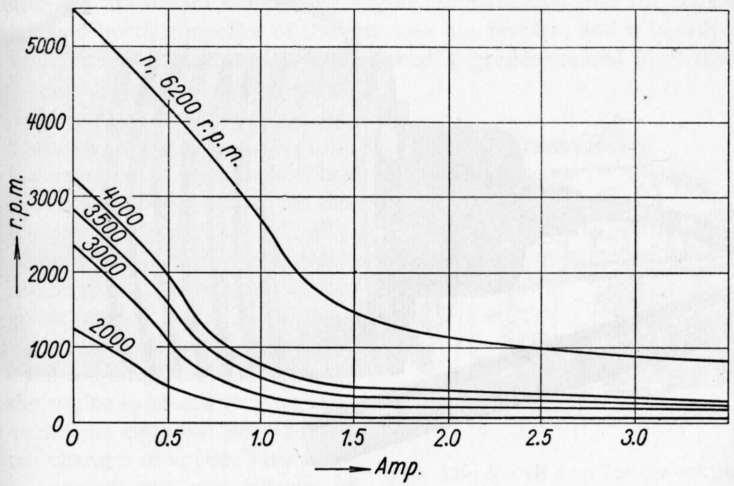


FIG. 111. Characteristics of the Scintilla electro-magnetic coupling. Effect of the exciting current on the magnet in Amp upon the coupling slip $n_1 - n_2$.

fan stands still. When current has been introduced into the coil, a magnetic field is set up between the pole shoes and crosses the steel drum of the impeller. With the intensity of the excitation of the electromagnet, the increasing speed of the steel drum of the impeller approaches more closely the speed of the electromagnet, ultimately giving slip of only about 4%.

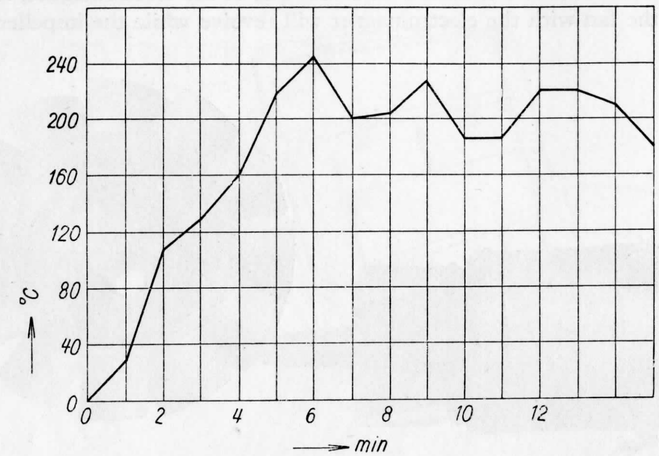


FIG. 112. Cylinder head temperatures after starting the Tatraplan engine with the Scintilla electro-magnetic coupling.

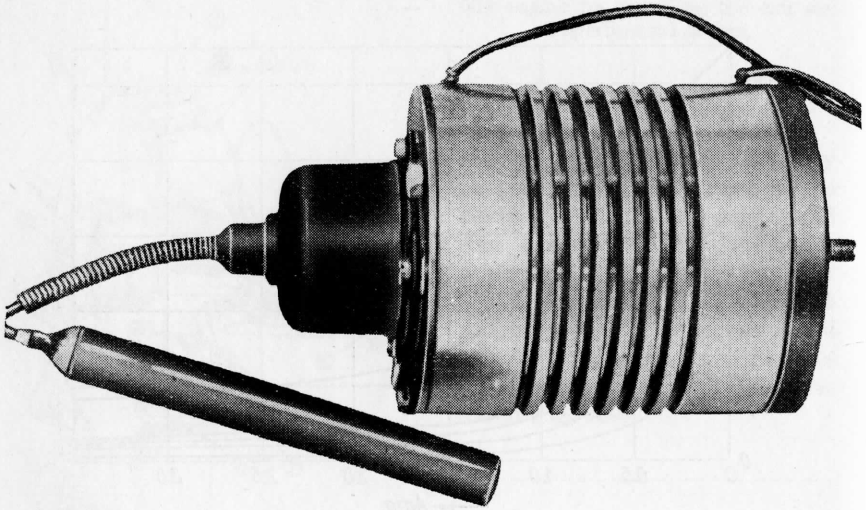

FIG. 113. Thermostatic device for continuous change of speed in the Scintilla electro-magnetic coupling.



This type of coupling is the basis of the electromagnetic coupling, forming one unit together with the dynamo and tested on the Tatraplan engine. This is shown in Fig. 110. The alternate pole shoes of the electromagnet can be distinctly seen on the dynamo. The impeller of the fan with the steel drum has been dismounted. The details of this coupling are apparent from

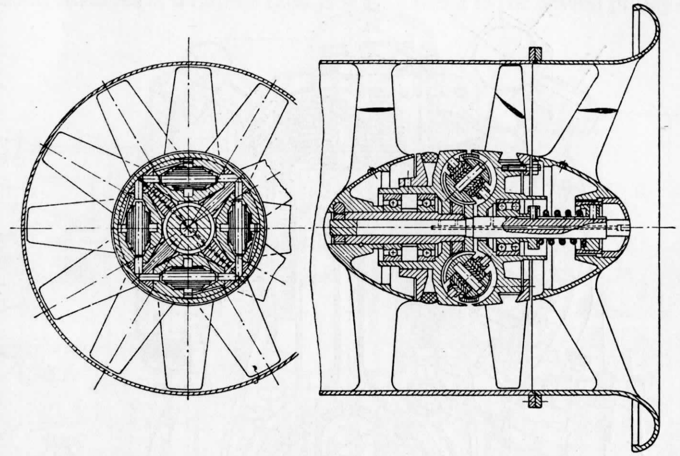

FIG. 114. Friction gear for the continuous change of fan speed.

Fig. 111. The coupling is switched on by a bimetallic thermostat, fitted in the outgoing air stream behind the engine. Immediately after the engine has been started up the impeller of the fan does not revolve, and it is only after the temperature of the engine has reached a predetermined level that the thermostat will switch on current to the turbulent coupling and the fan will begin to supply air. As soon as the temperature of the engine has dropped below the set limit, the fan is automatically switched off. Fig. 112 records the relationship between the temperature of the head of the Tatraplan engine provided with a control of the cooling by means of a turbulent coupling, and time. It shows that the engine is heated very rapidly.

A turbulent coupling provides for gradual changes in speed. This alternative requires the replacement of the switch by a thermostat-controlled

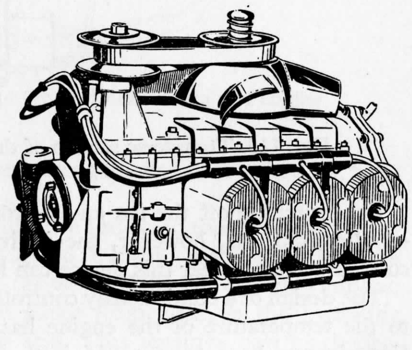

FIG. 115. V-belt gear for the continuous change of fan speed in the Jack and Heinz engine.

resistance for the excitation of the electromagnet. However, such a device is both expensive and delicate. When the speed is changed, the efficiency of the turbulent coupling drops. Hence the costliness of the device is not warranted by adequate saving in input. A thermostatic device for gradual changes in speed is illustrated in Fig. 113.

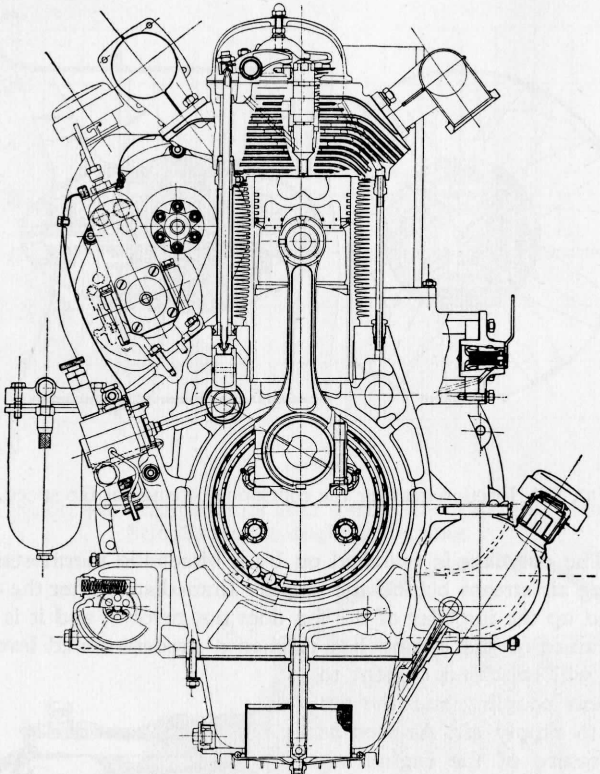

FIG. 116. Transverse section of the four-cylinder Tatra 924 engine.

For switching off the fan an electromagnetically opened friction coupling can be used. As, however, the individual elements of a friction coupling suffer from high wear this device can hardly be recommended.

The design of a continuously controlled mechanical gear operating according to the temperature of the engine has not been satisfactorily solved as yet. Experiments have been made, with a friction gear of the Hyes type, operating by means of friction discs. The drive is controlled by tilting the discs (Fig. 114).



The air-cooled Jack and Heinz slide-valve engine applies a very simple method of changing the speed of the V-belt driven fan. (Fig. 115). The two sections of the driving pulley are moved closer together or apart by the action of a thermostat and the two sections of the driven pulley, by means of a spring. If the two sections are moved closer, the rate of transmission increases and the fan revolves at a higher rate. A spring fitted to the driven pulley ensures

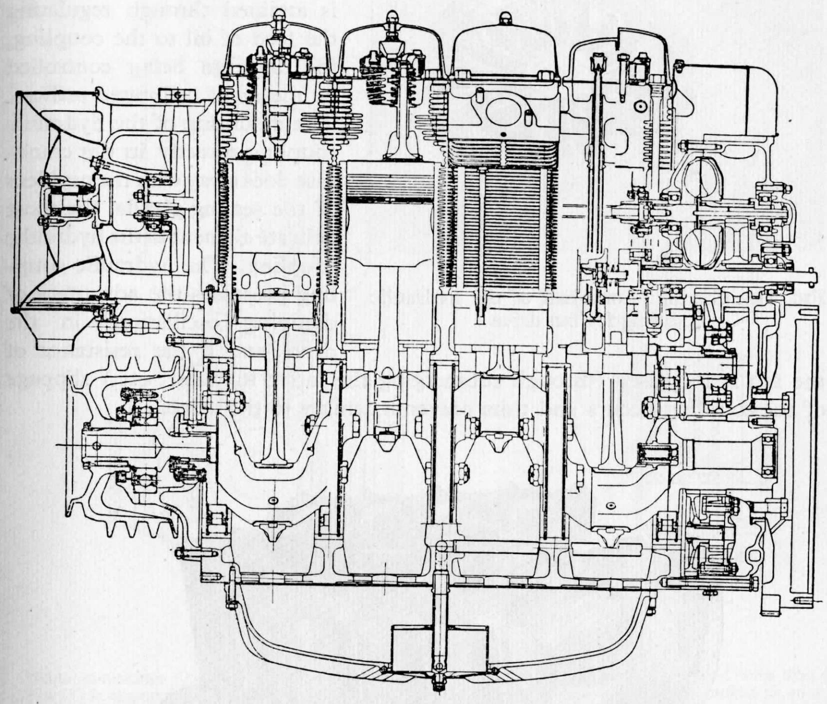

FIG. 117. Longitudinal section of the four-cylinder Tatra 924 engine.

the required tightening of the belt. This arrangement is not suited for large fans driven by several belts.

The properties of the hydraulic coupling are similar to those of the electromagnetic turbulent coupling. No mechanical friction arises and thus the coupling does not suffer from mechanical wear. With the electric coupling only the carbons for feeding the current suffer from wear, in the hydraulic coupling friction occurs only in the oil seal. This sensitive part of the hydraulic coupling can be dispensed with if the whole unit is mounted in the crankcase of the engine and filled with oil.

The manufacture of hydraulic couplings is simple and the couplings are not subject to wear. As the character of the transmitted torque is the same as that of the input to the fan, with a filled hydraulic coupling the slip is constant within the entire speed range. Hence the control of speed and of the slip of the coupling can be altered by a change in the oil. In practice, this objective is attained through regulating the feed of oil to the coupling, the drainage being controlled by means of calibrated orifices. The mounting of the hydraulic coupling directly in the crankcase does away with the problem of the sealing glands, the most delicate element in the hydraulic coupling. The hydraulic coupling possesses the advantage of damping oscillations in the drive, and if the resistance of the fan is increased (through submerging the latter in water, etc.) slippage of the coupling occurs and thus prevents damage to the drive.

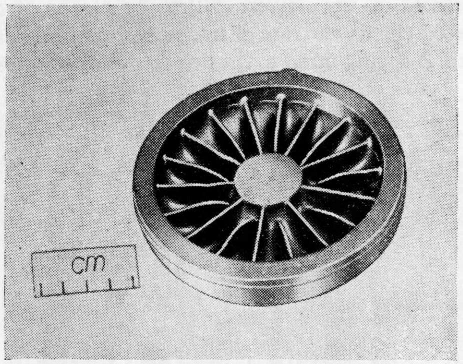


FIG. 118. Casting of one half of the hydraulic coupling for fan drive

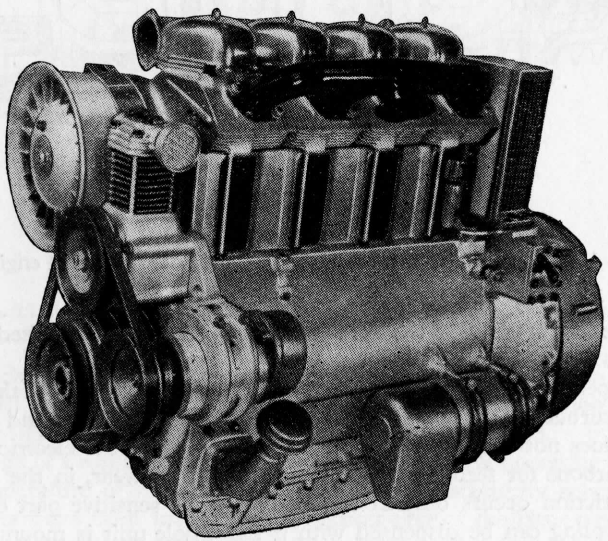

FIG. 119. View of the four-cylinder Tatra 924 engine.



Because of this advantage, control based on the above principle has been applied to the new series of Tatra diesel engines with 120 mm bore and 130 mm stroke. Figs. 116 and 117 show cross- and longitudinal sections of a four-cylinder T 924 Tatra engine. The longitudinal section illustrates the arrangement of the hydraulic coupling in the driving system of the fan. The power is transmitted to the fan from the rear end of the crankshaft (from the

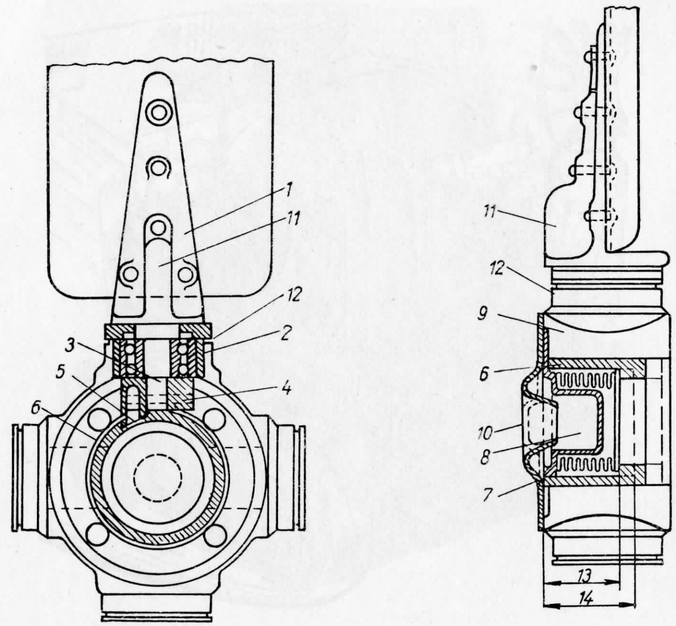


FIG. 120. Fan with feathering blades.

Blade mountings (*1*) are located in ball bearings (*2*). Lower journal (*3*) is connected with disc (*4*). Pin (*5*) is engaged in the opening of disc (*4*) and actuated by its hub (*6*) which is shifted in an axial direction by bellows thermostat (*7*). The liquid heating the thermostat is led into compartment (*8*). Length of the thermostat in a cold engine equals *13*, in a hot engine it increases to *14*.

flywheel) through gears and a long flexible shaft. One section of the hydraulic coupling is connected with a pinion gear, while the other section with the guard is connected directly to the shaft of the fan. The manufacture of the hydraulic coupling is not involved. Both sections are machined from the same type of casting (see Fig. 118), with cast vanes, so that only the surface and the hub of the wheel have to be machined.

As long as the hydraulic coupling is not filled with oil, slippage will occur and the fan remains stationary. The feed of oil to the coupling is controlled by a bellows-thermostat, mounted in the air-stream leaving the cylinders. As soon as the engine (outgoing air) begins to heat, the oil-feed to the hydraulic coupling opens and the fan operates. The perimeter of the outer section of this type of coupling is provided with calibrated openings through which oil returns constantly from the coupling into the crank case. As at constant speed the oil-pressure at the perimeter of the coupling is proportionate to the quantity of oil, equilibrium between oil change and drain is reached at a certain rate of filling. For this reason, through controlling the amount of incoming oil, the rate of filling and thus also the slippage of the coupling can be controlled.

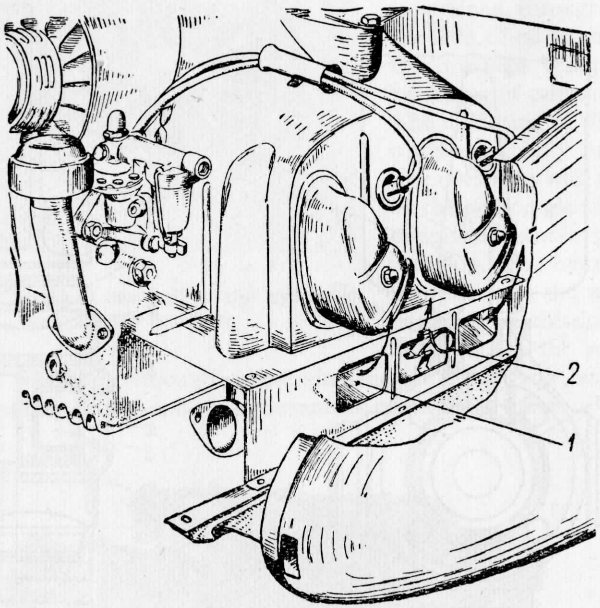


FIG. 121. Control by air by-pass in the Tatraplan engine.

This type of control has proved satisfactory in operation and has been applied to a series of engines. In the four-cylinder T-924 Tatra engine the bellows thermostat is fitted in the stream of the air leaving the last cylinder. In Fig. 119 the thermostat can be seen in front of the oil-cooler.

Control by way of altering the pitch of the blades of the fan is another method enabling considerable economies to be made. As the blades are exposed to a powerful centrifugal force and at the same time must revolve readily, they have to be mounted on roller bearings. Hence, the design of a fan of this type is rather complicated [56].

Fig. 120 illustrates a fan with adjustable blades, mounted in a recent water-cooled engine.

Water from the engine enters through branch *10* into a box in which an alcohol thermostat *7* is fitted. When the water is heated the thermostat begins to expand, it moves hub *6* towards the right and increases the angle of inclination of the blades of the fan. It is thus possible to obtain a change in the amount of cooling air and energy consumed without a change in the transmission from engine to fan.



Control through changing the temperature of cooling air is also very advantageous, since it provides an improved air-fuel mixture for the engine. If the temperature of the air under the guard is maintained at a constant level,

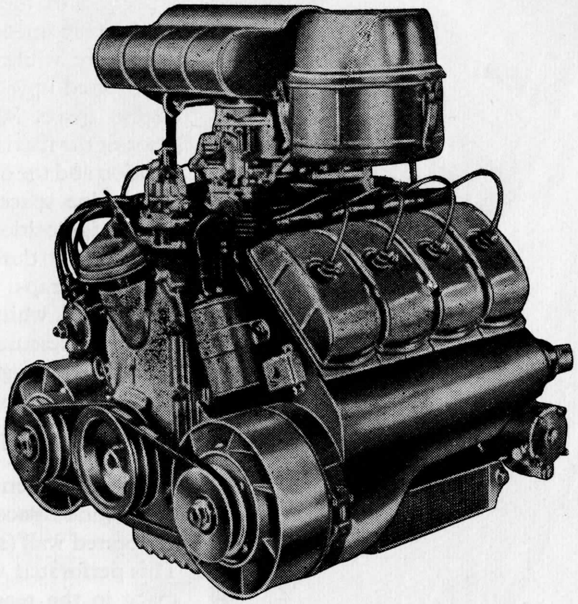

FIG. 122. View of the Tatra 603 engine.

the air drawn into the engine has an even temperature, and the irregularities in combustion caused by the intake of excessively cold air and by the condensation are eliminated.

Such a method is shown in Fig. 121. With this engine the cooling air travels from top to bottom, and is discharged below the car. If flap *1* is opened, steel spring *2* keeps this flap opened in such a position as to reach the stream of outgoing air and deflect the latter to a horizontal direction below the guard of the engine. This hot air "heats" the entire space below the guard, from which also the air for the engine is drawn.

The design of the Tatra 603 car also uses cooling control through changing the temperature of the cooling air. Fig. 122 gives the overall view of the Tatra 603 engine. Distinctly noticeable are the fans drawing air from the proximity of the carburettor and the induction tubing across the cylinders and extruding it by way of the shortest path through the openings in the rear to atmosphere. The control valve is governed by a bellows thermostat. By means of the closed valve the outgoing air from the fans is deflected upwards and through orifices opened by the valve it enters the engine space to be drawn round the carburettor into the engine (see Fig. 123).

Fig. 123. View of the thermostat operating the cooling control flap.

If the valve is part-opened, a portion of the air escapes by the rear opening into the atmospere while the balance is deflected upwards into the engine space. With the engine hot the flap is in its upper position and the openings into the engine space are closed.

In this position air is introduced into the engine space from air traps in the rear mudguards, which utilize the dynamic pressure head. The air passes through the extensive space in the rear mudguard, loses speed and is partially filtered of coarse impurities. It then passes into the engine space through a perforated wall (see Fig. 124). This perforated wall and the space in the rear mudguard act as sound insulation between engine and body.

The control of the cooling of the Fiat 500 engine is solved in a similar manner. In Fig. 125 the radial fan can be seen, from which the air is directed primarily towards the cylinder heads. Air is inducted by a flexible hose from the space below the rear window. A portion of hot air leaving the engine is led by piping likewise into this suction space. However, the hot-air outlet is shut off by a thermostat-controlled flap. As long as the engine is cool the flap is opened and the fan partly returns the hot air for the cooling of the engine. If the temperature of inlet air is 0 °C, the flap is completely opened, while at a temperature of 20 °C it is completely closed. In this latter instance the engine draws cold air only.

The suction box is fitted to the body and it is connected to the engine by flexible hoses. This is why the thermostat mounted in this box is not affected



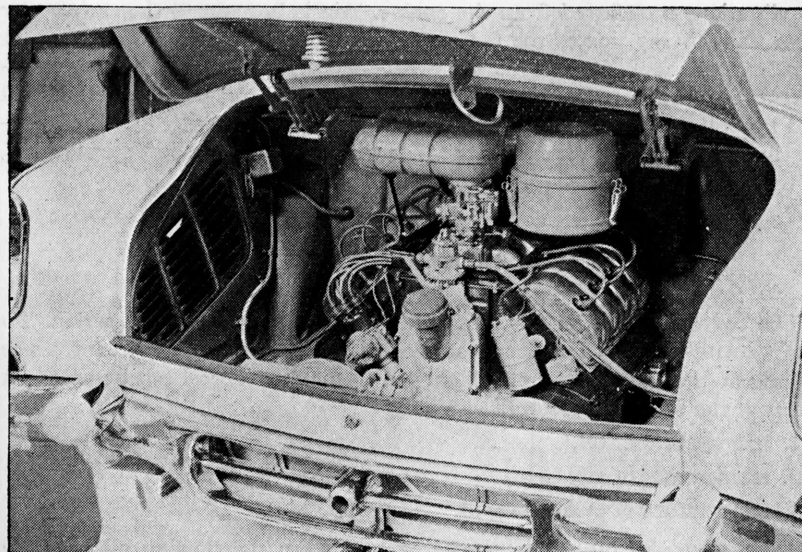

Fig. 124. Cooling air enters the engine compartment of the Tatra 603 through the perforated wall of the rear mud guards and leaves it through an opening in the rear bumper.

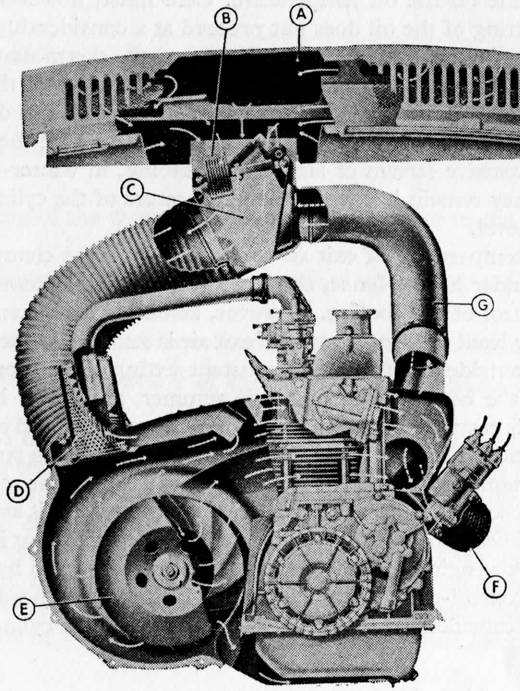


Fig. 125. Cooling control in the Fiat 500 engine. →

by vibrations transferred from the engine. Air is brought to the carburettor from the delivery side of the fan and is therefore also heated in winter. A small overpressure of cooling air improves the charging of the engine. As is apparent from the illustration, the whole of the cooling circuit is entirely closed and no polluted air from the vicinity of the engine can enter it. The opening for the incoming air below the rear window is located sufficiently high, so that clean air is inducted.

### 3. Automatic control

The control should be automatic, i.e. independent of driver's action. To comply with this requirement a thermostat must be employed to control the cooling by the temperature of the engine. Automatic control can be based on either of the following factors:

1. temperature of oil,
2. temperature of air,
3. temperature of cylinder-head.

Temperature of oil. The transfer of heat from the flowing oil into the thermostat takes place under favourable conditions and is not liable to fluctuation. For this reason it is advantageous to base the control of the cooling of the engine on the oil temperature. Care must, however, be taken to ensure that heating of the oil does not proceed at a considerably lower rate than the heating of the cylinders. In the latter case the thermostat would not react sufficiently readily to the changes in the temperature of the engine. Besides, it will be necessary to maintain the temperature of oil in a definite relationship to the temperature of the cylinder head. Assuming, that the oil sump is exposed to an intensive stream of air during running, in winter-time the temperature of oil may remain low while the temperature of the cylinder head has reached a high level.

The temperature of exit air reacts readily to the changes of temperature of the cylinder head. Hence, the temperature of air is most frequently used for the control of the cooling. However, assuming a constant temperature of the cylinder head the temperature of exit air is strongly influenced by the temperature of outside (inlet) air. At a constant setting of the thermostat, the temperature of the head will be higher in summer, and lower in winter. This irregularity is restricted in scope if the thermostat is exposed to radiation heat from the cylinder head, or if the temperature of inlet air is controlled.

The temperature of the cylinder head is the most relevant value for control of cooling. However, no convenient thermostat is available of sufficiently small dimensions to fit it into the cylinder head without impairing the cooling. In aircraft engines thermocouples are frequently fitted by drilling, to signalize on the control-panel the temperatures of individual heads.

To a considerable extent the temperature of the cylinder head depends on



the load of the engine. If, therefore, the load of the engine is used as a criterion for the cooling control, the scope of the thermostat will be narrowed, the latter being called upon only to balance the difference in the outside temperature through changing the speed. Rapid changes in the load of the engine will not strain the thermostat, for such rapid changes in temperature will be automatically prevented. One of the following methods can be used to advantage:

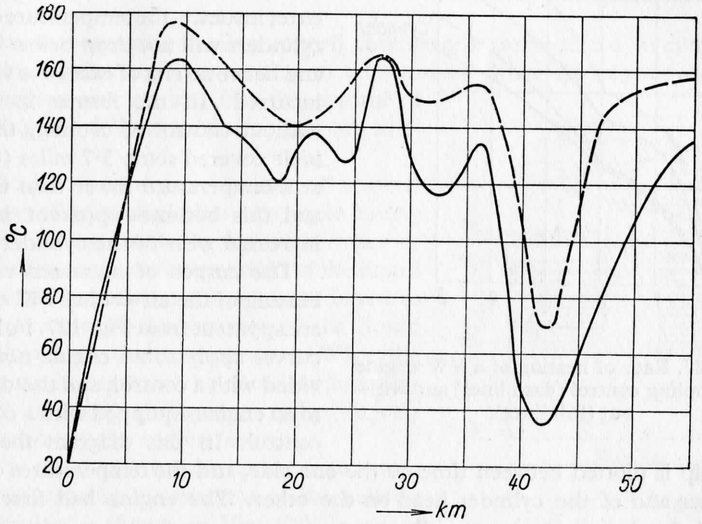


FIG. 126. Dependence of cylinder temperature in the VW engine upon distance. Full line — without thermostat, dash line — with thermostat.

1. mechanical linking of the throttle valve of the carburettor to the control device,
2. utilizing the vacuum in the induction manifold to correct the control of cooling,
3. correcting the cooling by the torque transmitted from the engine.

Experience alone will show which of these alternative methods is preferable.

The purpose of the automatic control is, in the first place, to reduce the fluctuation of the temperature of the engine during the running of the vehicle. If the cooling has been rated and dimensioned for hot summer weather, then, without a control, the engine will be undercooled in the winter-months. If excessive wear of the cylinders is to be avoided, their temperature must not drop below 70 °C. Fig. 126 illustrates the relationship of the temperature of the cylinder of a VW engine and the number of kilometers in a hilly region, at the outside temperature of —5 °C. When the vehicle runs down long slopes, the temperature of the cylinder drops as low as 35 °C. This temperature implies considerable wear of the cylinder, as the combustion products may condense on the walls (sulphur trioxide condenses at 45 °C) [8].

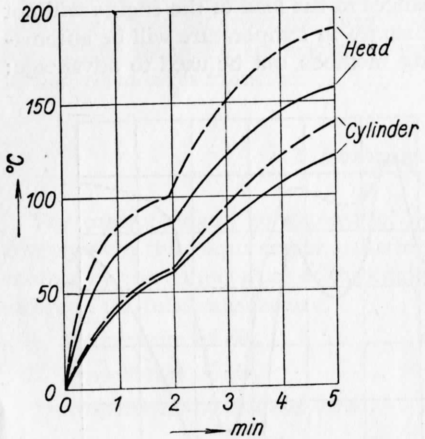


FIG. 127. Rate of heating of a VW engine with cooling control (dash lines) and without (full lines).

The dashed line indicates the temperatures of the cylinder on the same track, with a controlled cooling. In the latter instance, the temperature of the cylinders will not drop below 70 °C and hence no risk of excessive wear is incurred. In the former instance, without control of cooling, the vehicle covered some 3·7 miles (6 km) at a temperature lower than 60 °C, and this becomes apparent in the increased wear of the cylinder.

The curves of increased rate of heating of the air-cooled VW engine are apparent from Fig. 127. Full-line curves apply to an engine not provided with a control, and the dashed to an engine equipped with a cooling control. In this diagram the relationship is plotted between time on the one side, and the temperatures of the cylinder and of the cylinder head on the other. The engine had first been heated for two minutes on idle run, and at the lapse of two minutes it was run on even ground. The temperature of the outside air was 0 °C. After three minutes, the temperature of the cylinder equipped with a control of cooling was 15% and the temperature of the cylinder head was 22% higher than the temperatures registered in engines not provided with a cooling control.

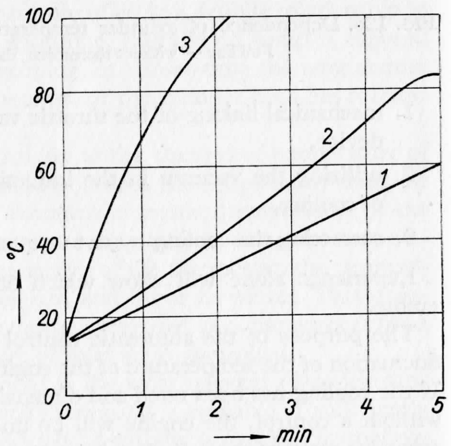


FIG. 128. Rate of heating of Deutz engines cooled by water and air.

*1* — water-cooled engine without control, *2* — water-cooled engine with control, *3* — air-cooled engine.

The diagram demonstrates one of the noteworthy advantages of the air-cooled engine, namely speedy warming up. As only a limited quantity of material is concentrated around the cylinder, the cylinder can reach a temperature of 80 °C after only three minutes, while in a water-cooled engine the heating of the water-contents in the block up to that temperature takes much longer. The difference between the cooling times of an air- and a water-cooled Deutz diesel engine [32] of equal dimensions can be observed in Fig. 128.



## 4. Thermostats

For an automatic cooling control thermostats are required to control the cooling of the engine according to temperature either directly, or indirectly through a servomotor. For the control of cooling the following thermostats are suitable.

Alcohol thermostats, consist of a metal bellows filled with alcohol, or a liquid having a low boiling point. As the temperature of the casing increases evaporation of the liquid sets in and a pressure arises proportionate to the pressure of the vapours of the liquid employed at that temperature. With the increase in pressure the metal bellows expands in length and governs either directly or indirectly the cooling control.

The metal bellows also serves at the same time as a spring. An example of the bellows thermostat is shown in Fig. 129. In order to increase the stroke a lever-type gear is employed. The operating force of the thermostat is illustrated in Fig. 130.

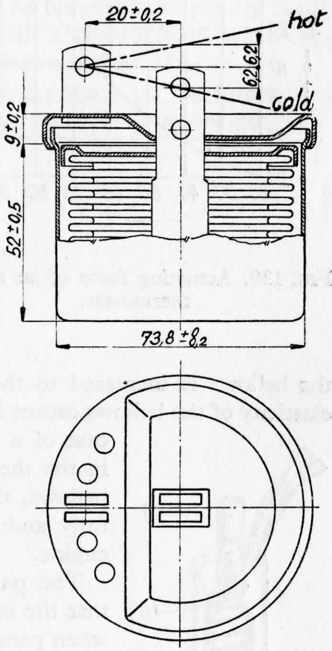


FIG. 129. Alcohol thermostat.

The beginning and the end of the action of the thermostat is determined by the boiling point of the liquid, the operating force, by the diameter of the bellows, and the control path, by the length of the bellows. According to the required temperature a suitable liquid or a mixture of different liquids must be selected.

The bellows thermostat is the most universal, and it is easy to manufacture. However, if fitted directly to the engine, the risk is incurred of bursting the bellows through vibrations. The greater the stress imposed on the material of the bellows, the greater the risk of bursting. It is therefore preferable to fit the thermostat separate from the engine as is the case with the Tatra 603 (Fig. 123), or Fiat 500 (Fig. 125). It is also beneficial for the life of the thermostat not to use the full permissible stroke, as the latter would impose a severe stress on the material of the bellows.

Vacuum thermostats can also be used. When cold, the thermostat is contracted by the effect of the vacuum acting contrary to the force of the bellows (spring). When the liquid has evaporated the pressure of the vapours inside

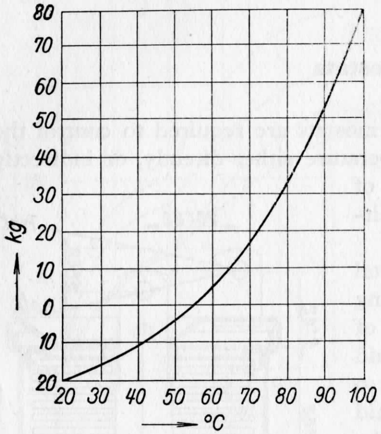


FIG. 130. Actuating force of an alcohol thermostat.

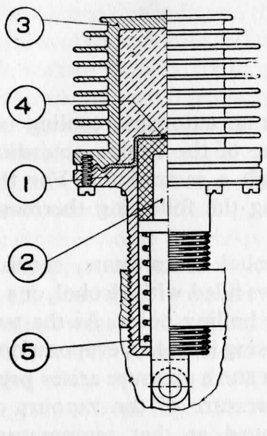


FIG. 131. Paraffin thermostat.
*1* — body, *2* — piston, *3* — finned container, *4* — sealing diaphragm, *5* — reverse motion spring.

the bellows is increased to the atmospheric pressure or above it, and the elasticity of the bellows causes it to lengthen. This feature is useful in that in case of a breakdown in operation caused by a leakage in the thermostat atmospheric pressure will enter the bellows, the thermostat will open the cooling system fully and thus prevent overheating and seizing of the engine.

The paraffin thermostat operates on the principle that the contents of paraffin are increased considerably when paraffin passes from the solid into the liquid state. Such change in volume is utilized to operate a small plunger governing the control. A cross-section of a paraffin thermostat is illustrated in Fig. 131. The thermostat consists of body *1*, in which a guide for plunger *2* has been moulded. Vessel *3* containing the paraffin has been fitted to the thermostat body. The paraffin is separated

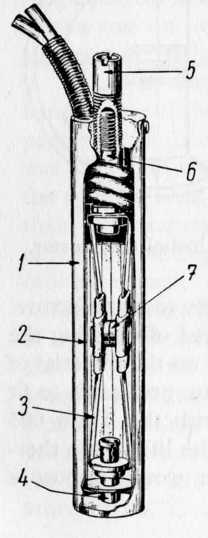


FIG. 132. Bimetal connector.
*1* — cover tube, *2* — internal insulation, *3* — bimetal spring, *4* — pin, *5* — adjusting screw, *6* — fixing screw, *7* — silver terminals.



from the plunger by a neoprene diaphragm *4*, preventing the emptying of the paraffin from the pan. The plunger is held in its extreme position by spring *5*, fitted in the body of the thermostat.

If the thermostat is heated, at a definite temperature the state of the paraffin will change, the increased volume of the liquid paraffin will act through the diaphragm on the plunger of the thermostat. The operating force of the paraffin thermostat is considerable. According to the temperature at which the thermostat is to operate, different substances can be used.

The bimetal thermostat consists of two metals with differing thermal expansions. As a rule strips of two different metals are welded together forming a rod or a spiral. The bimetallic thermostat is simple and dependable. But its operating force and control path are small. The bimetal is frequently used for thermostatic electric switches, operating with a considerable accuracy, up to $\pm$ 1/20 °C. A thermostat of this type is shown in Fig. 132.

For electric switches it is an advantage to have contacts on the bimetallic spring which at a critical temperature will change suddenly from one position to the other and thus prevent burning.