

CHAPTER XIX

SOME EXAMPLES OF ENGINES PRODUCED

The study of fully developed engine types is a valuable aid to the designer. The development of a newly designed piston engine takes from three to four years' time and this period cannot be reduced unless the engine be derived from a fully developed and proven type. The development of a new type is very costly and before work on such a project is undertaken, suitable conditions must be created to warrant successful attainment of the object in mind.

To illustrate this, the development of the 28-cylinder radial Pratt and Whitney engine may be mentioned. Work on this engine took some 6 years, during which 22 000 test inghours were completed on 23 experimental engines. The progress of the work undertaken over such a long period is shown in Fig. 362. Beside the tests mentioned, experimental work was also carried out on a unit-cylinder test engine. These tests accounted for a further 40 000 hours. Further tests were undertaken over 2 000 hours with a single-row radial experimental engine. The development of the engine in question cost

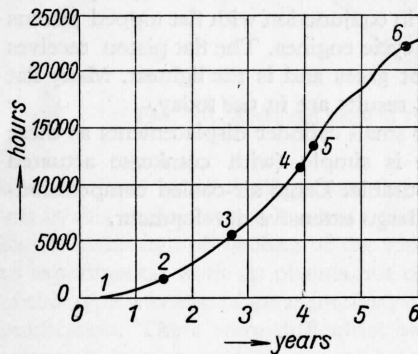


FIG. 362. Time schedule for the development of the Pratt and Whitney aircraft engine in hours of prototype tests.

1 — first run of the engine, 2 — first flight, 3 — production of the first prototype engine, 4 — performance test 150 hours, 5 — first series engine, 6 — performance test 150 hours with 17 % overload.

a sum total of 25 million U.S. dollars and this sum does not include the expenditure for developing the 18-cylinder engine, the well proven and highly perfected cylinders of which were used in the larger engine. The aim of the development work mentioned was "only" to group existing cylinders into a larger unit.

Such sums invested in development work cannot be recovered in small scale production of engines, as the cost per unit would be excessive. Large aircraft engines were therefore developed almost entirely during the war period, when considerations of cost were of secondary importance. The development costs

of engines for everyday use must however be calculated in the price of every unit. Designers are to be warned most seriously not to introduce new features of design just for the sake of novelty. A large number of able designers have in the past devoted their attention to the development of the reciprocating engine and in the majority of designs, features which have been highly perfected in production are used. Before deciding to adopt a new design, the manufacturer must investigate in detail and consider objectively the pros and cons of the new design. In doing so, the type of production machinery with which the factory is equipped must be borne in mind together with the experience of the design and engineering staff and the standard of specialization of skilled labour.

Much valuable experience for development may be gained from the study of perfected designs. Several interesting and well proven designs are therefore described. They may serve as useful reference for designers.

A. PETROL ENGINES

1. The A.B.C. Engine

This highly interesting design is a flat four-cylinder type with two-throw crankshaft. Such an arrangement results in unbalanced primary couples. To balance them, use is made of a special arrangement entailing the use of two

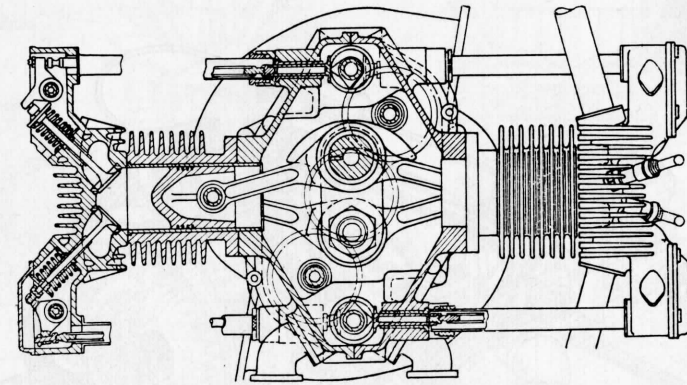


FIG. 363. Transverse section of the four-cylinder A.B.C. engine.

rotating masses (see section on engine balancing). These masses are on two additional shafts which are also used to transmit the drive to the camshafts. They are driven from the front end of the crankshaft through a gear drive and at their other extremities a 2 : 1 gear drives the camshafts. By balancing

primary couples of reciprocating masses, perfect engine balance is obtained.

The bore of this engine is 63.5 mm, stroke 76.2 mm, the displacement of the four-cylinder engine is therefore 960 cm³. Maximum performance is 30.5 b.h.p. at 4 000 rev/min. Both crankcase halves, the cylinder barrels and heads are of electron metal castings. Cast iron cylinder liners are used and the connecting rods are of Duralumin. In order to make it possible to locate the cylinders in directly opposing pairs, connecting rods are forked and their unsplit big-end eyes bear directly on floating bushes on the crankpins of the built-up crankshaft. The gudgeon pin is located directly in the little end eye, without bushing, of the Duralumin connecting rod. The valve gear incorporating two camshafts is also of interest. (Fig. 363.)

The weight of the engine without dynamo is 182 lb (70 kg,) which means a power weight: ratio of 2.3 b.h.p. per kg. A radial fan at the front end of the crankshaft supplies the cooling air. The engine is used as an auxiliary unit for use in aircraft. With a performance of 25 b.h.p. at 4 000 rev/min, the temperature of the cylinder head in the vicinity of the sparking plug is 180 C° and that of the tips of the cooling fins is 85 C°.

2. The BMW Engine

The BMW concern has entered the market with a rear-engined light car with an engine of 585 cm³ displacement. This is a flat twin derived from the well known motor cycle engine, the performance of which has been reduced in the interest of longer engine life and a more favourable torque curve from

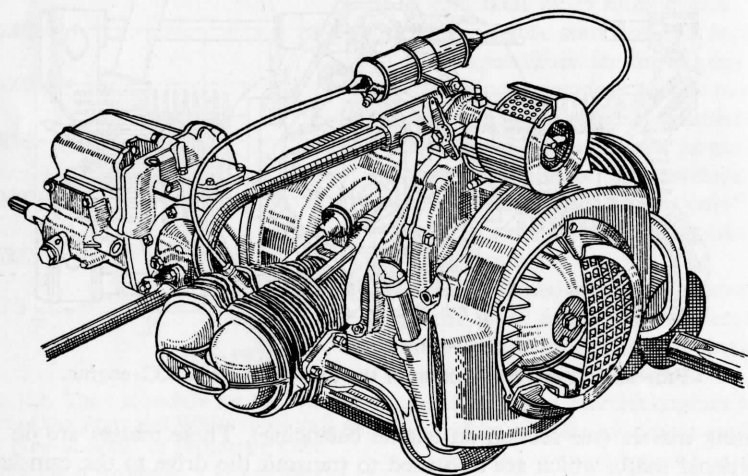


FIG. 364. Two-cylinder air-cooled BMW engine.

28 b.h.p. to 19.5 b.h.p. A radial fan fitted directly to the crankshaft is used for cooling air delivery. The cooling air is directed to the cylinders in the direction of the crankshaft axis, cool air being supplied to the exhaust valves. Cooling is regulated by two air-flaps controlled by a single thermostat. The single horizontal-draught Solex 28 FZP carburettor incorporates an acceleration pump and a starter jet.

With a bore of 74 mm and stroke of 68 mm and a standard compression ratio of 6.5 : 1, the maximum torque is 29 ft-lb (4 mkg) at 2 500 rev/min. The camshaft is located above the crankshaft and the overhead valve layout of the hemispherical head incorporates pushrods and rockers. An electric starter is used and this also serves as a dynamo of 130 W output. The engine is housed in the rear extremity of the vehicle and its general arrangement is apparent in Fig. 364.

3. The BSA Engine

An example of a parallel twin engine for motor cycle application is shown in Fig. 365. The bore of this engine is 70 mm, stroke 84 mm, displacement 646 cm³. The valves are actuated from a camshaft housed in the crankcase. The details of the valve drive are obvious from the sectional drawings. The direction of flow of air between the cylinders should be noted. The flywheel

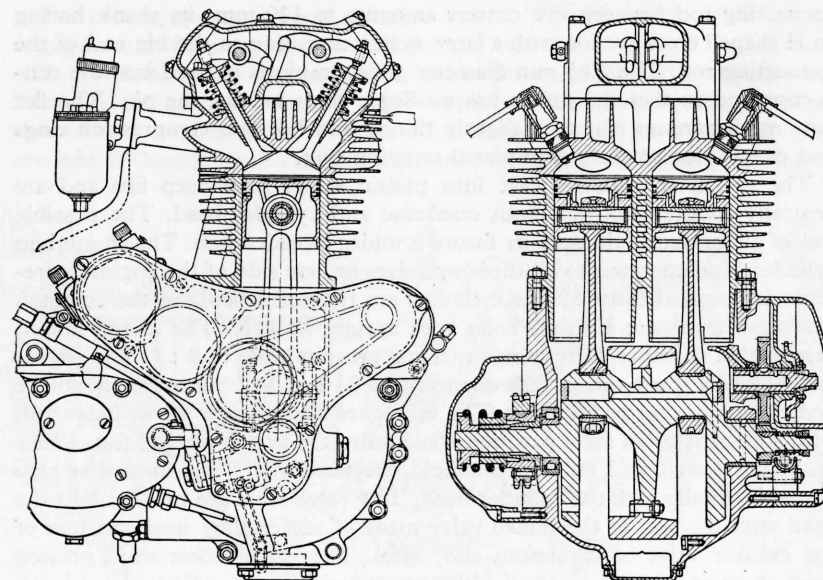


FIG. 365. Transverse and longitudinal sections of the BSA 646 cu. cm motor-cycle engine.

is flange fitted to the centre of the one-piece crankshaft, which revolves in two main bearings, one of which is a plain bearing. Pressure oil is brought to the crankshaft via this bearing.

Both the cylinders form an integral iron casting. As the cylinder axes are far apart for better cooling, it was found possible to place the flywheel between them.

4. The Chevrolet Corvair Engine

This is a six-cylinder air-cooled engine with 85.7 mm bore and 66 mm stroke. In order to reduce the overall height of this flat engine two separate Rochester carburettors are used, one for each side of the engine. The air cleaner mounted on the top of the engine and using shavings of plastic material as a filtering medium supplies air to both carburettors. Easier starting of the engine is made possible by a throttle placed before the filter. Aluminium was used abundantly as a material of construction. The silumin crankcase is split vertically and tightened by 8 bolts located near the main bearings. The main and crank pin bearings are made of nickel bronze with a thin coat of babbitt. The extremely stiff six-throw crankshaft is forged of steel, has no balance weight and its main journals are of a diameter of 53.4 mm. The length of the central and end bearings is 21 mm and of the other ones 19.5 mm. The crank pin bearing has a diameter of 45.7 and a width of 16.5 mm. The length of the connecting rod between eye centers amounts to 120 mm, its shank having an H shaped cross section with a large radius transition to the big end of the connecting rod. The 20.3 mm diameter gudgeon pin is pressed into the connecting rod so that the piston has no Seger rings locking the pin. The flat bottom aluminium piston is slightly tinned and has two compression rings and one U shaped chromium plated scraping ring.

The cast iron cylinders cast into plastic shells have deep fins and are centrally countersunk into both crankcase and cylinder head. The possible use of aluminium cylinders in future is under consideration. The aluminium cylinder head common to all three cylinders on one side of the engine represents an unusual feature. The cylinders are tightened between the common head and crankcase by thin bolts with sprung washers. The wedge-shaped combustion chamber corresponds to a compression ratio of 8 : 1. The engine has relatively small valves with diameters of 34.1 and 31.5 mm for the intake and exhaust valves respectively. The valves are located near the cylinder wall with sufficient room for a partition cooled directly by the vertical fins. Other fins on the wall and exhaust manifold are horizontal. The induction pipe is cast integrally with the cylinder head. The valve seats are pressed into the head with the seat of the intake valve made of nickel alloy steel and that of the exhaust valve of chromium alloy steel. The valve rocker arms, pressed from sheet metal with a spherical bearer directly on the cylinder head bolts, are of a design used also in other types of General Motors engines.

The valves are actuated by hollow push rods from the camshaft supported

by plain bearings without sleeves and housed directly in the crankcase. The valve tappets with plain followers have a hydraulic adjustment of valve clearance in harmony with the thermal expansion of the engine. The tube protecting the push rods is sealed by rubber rings and serves for the return of oil from the cylinder head supplied thereto through the hollow rods. The cast iron camshaft has 6 induction and 3 exhaust cams. Each exhaust cam actuates two tappets of opposing cylinders and is wider than the induction cam. Exhaust ducts in the cylinder are very short in order to prevent the transfer of heat from exhaust gases to the cylinder heads. Steel tubes are pressed into these ducts connecting them with the cast iron exhaust manifold. The geared oil pump is mounted on the extended shaft of the distributor driven by a helical gear from the crankshaft. If the oil temperature exceeds 70 °C, the oil is diverted to the cooler by means of a valve controlled by a thermostat. The total oil content of the engine is 3.8 litres.

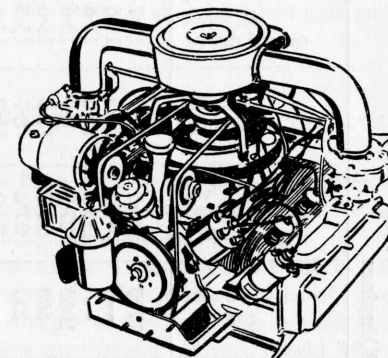


FIG. 366. The six-cylinder air-cooled Chevrolet Corvair engine.

The cooling system is another interesting feature of the engine. A radial fan with a vertical axis is placed directly above the crankcase. The impeller has 24 blades and an outer diameter of 279 mm. It is driven at a speed 1.58 times that of the crankshaft and delivers 51,000 litres of air per minute at 4,000 rev/min. A thermostat located in the stream of outgoing cooling air is connected

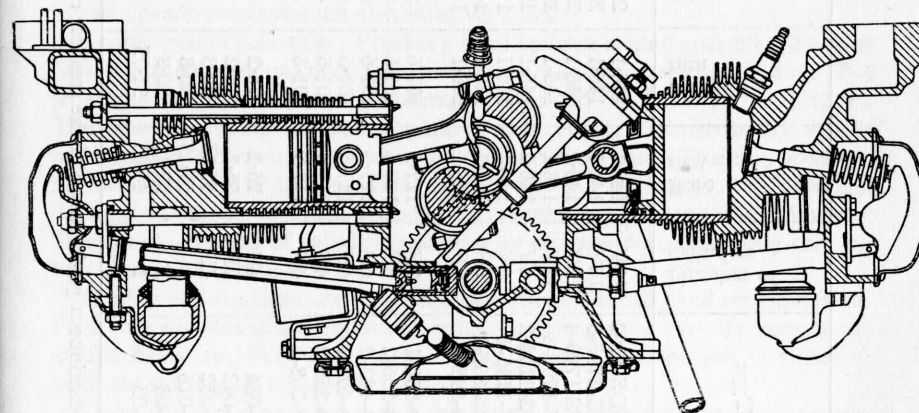


FIG. 367. Transverse section of the Chevrolet Corvair engine.

Table 47

Air-Cooled Continental Engines

Type	Number of cylinders	Bore mm	Stroke mm	Displacement cm ³	Performance b.h.p.	Speed rev/min	Weight kg	Unit performance b.h.p./litre	M.e.p. kg/cm ²	Mean piston velocity m/s	Unit weight kg/b.h.p.	Octane number of fuel
AVDS-1790	12V	146.1	146.1	29 400	750	2400	1700	25.5	9.55	11.7	2.27	100
AVS-1790-5	12V	146.1	146.1	29 400	1400	2800	—	47.7	15.3	13.6	—	80
AVS-1790-4	12V	146.1	146.1	29 400	1040	2800	—	35.4	11.4	13.6	—	80
AV-1790-3	12V	146.1	146.1	29 400	810	2800	1080	27.5	8.9	13.6	1.34	80
AVS-1195-2	8V	146.1	146.1	19 600	685	2800	660	35.0	11.3	13.6	0.96	80
AV-1195-1	8V	146.1	146.1	19 600	530	2800	635	27.0	8.7	13.6	1.2	80
AOS-895-1	6F	146.1	146.1	14 700	500	2800	—	34.0	11.0	13.6	—	80
AO-895-2	6F	146.1	146.1	14 700	375	2800	500	25.5	8.2	13.6	1.33	80
AO-536-1	8F	117.5	101.6	8 110	250	3000	403	28.4	8.5	10.2	1.61	80
AO-536-2	8F	117.5	101.6	8 810	200	3000	403	22.7	6.8	10.2	2.00	80
AO-402-2	6F	117.5	101.6	6 600	187	3000	345	28.4	8.5	10.2	1.85	80
AO-402-1	6F	117.5	101.6	6 600	150	3000	345	22.7	6.8	10.2	2.3	80
AO-268-2	4F	117.5	101.6	4 400	125	3000	283	28.4	8.5	10.2	2.28	80
AO-268-1	4F	117.5	101.6	4 400	100	3000	283	22.7	6.8	10.2	2.83	80
4A-084	4F	76.2	76.2	1 400	35	3600	79	25.0	6.3	9.2	2.25	72
2A-042	2F	76.2	76.2	700	17.5	3600	41	25.0	6.3	9.2	2.35	72
4A-032	4F	57.15	50.8	520	10.8	3600	32	20.8	5.2	6.1	2.95	72
2A-016	2	57.15	50.8	260	5.4	3600	18	20.8	5.2	6.1	3.3	72
1A-08	1	57.15	50.8	130	2.7	3600	11.5	20.8	5.2	6.1	4.25	72
1A-03	1	44.45	31.75	50	0.87	3600	6.8	17.4	4.35	3.8	7.85	72

The continuous performance of the smallest engine range is reduced to 57 % of the maximum figure given in the table.

with an orifice which is used for throttling the air inlet. The fan is driven by a V belt running at a 90° bend on two rollers located between the pulley of the crankshaft and that of the fan axle. The left hand roller is used for driving the dynamo at a speed 2.3 times of that of the crankshaft, whilst the right hand one is a guide roller.

The engine delivers 81 h.p. SAE at 4,400 rev/min corresponding to a specific performance of 35.4 b.h.p. per litre of displacement. The total swept volume of the engine amounts to 2,286 c.c. Fig. 366 shows a view of the engine and Fig. 367 the transverse section.

5. Continental Engines

The Continental aircraft engine works have developed three basic ranges of air-cooled engines, mainly for military use. These comprise engines with performances ranging from 0.5 to 1 400 b.h.p. as listed in Table 47.

The range which comprises the smallest engines, does not make use of all parts of standard dimensions, as for instance cylinders of three sizes of bore are used. Nevertheless it is claimed that 6 types of the range can replace the 78 types of engine used by the US Army during the Second World War. Some 800 component parts are needed for the engines whereas previously 23 000 different spare parts were needed for the same range of performance. The new engines are guaranteed to run for 1 500 hours between inspection; maintenance is said to be extremely simple with no tools used. The four-stroke cycle has been preferred to the light two-stroke engine on account of its reliable starting, silent running and low fuel consumption. The two-stroke engine was found to be at a disadvantage despite its weight, owing to excess carbon formation when running on standard army fuels and oils. The engines are used for various electric generating units and the mean effective pressures and piston speeds employed are therefore very low.

A compression ratio of 6 : 1 makes a fixed ignition setting possible. 72 octane fuel is burned without knock and the engines may be started and run on JP-4 jet aircraft engine fuel at temperatures of 0° to 125 °F, i.e. —18° to +52 °C. The crankcase sump on these engines is also cooled. Carburettor freezing is prevented by effective heating through an aluminium duct. There is, however, no formation of fuel line gas locks even at 52 °C. Fig. 368 shows a sectional drawing of the 1A 08 single-cylinder engine with a performance of 1.5 b. h.p. The simple method of splash lubrication by an extended connecting rod cap bolt should be noted.

The big end bearings are of aluminium (Alcoa XC-165) and are tin coated. Push rods are also of aluminium in order to take up the valve clearance as the engine heats up. Very little valve timing overlap is employed in order to facilitate starting and reliable idling.

There is no cooling control and the engine operates without it at temperatures ranging from —54 °C to +52 °C.

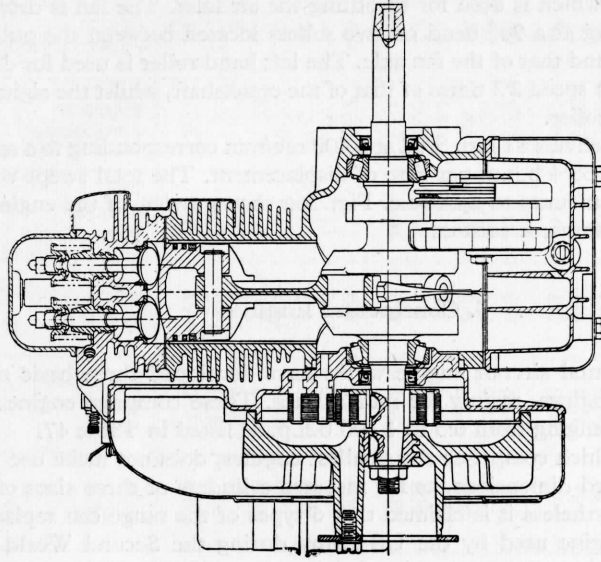
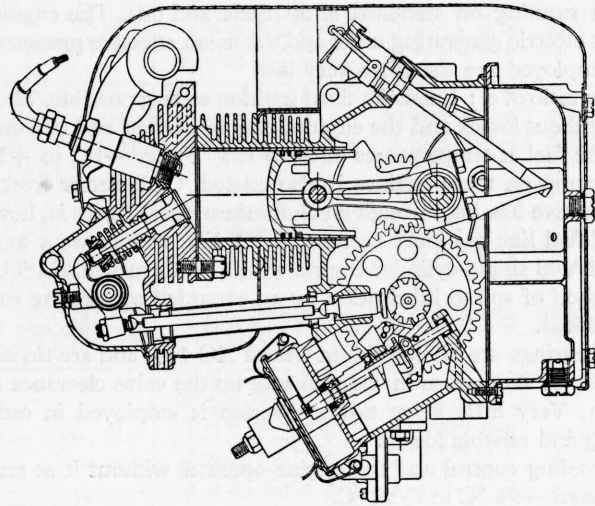


Fig. 368. Transverse and longitudinal sections of the single-cylinder Continental engine having a performance of 1.5 b.h.p.

Fig. 369. Characteristics of a cylinder of the medium series of Continental engines, bore 117.5 mm.

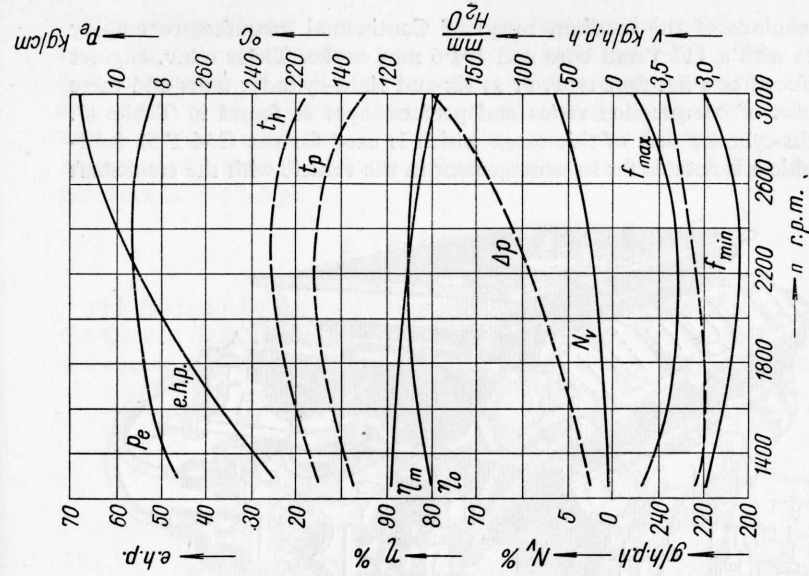
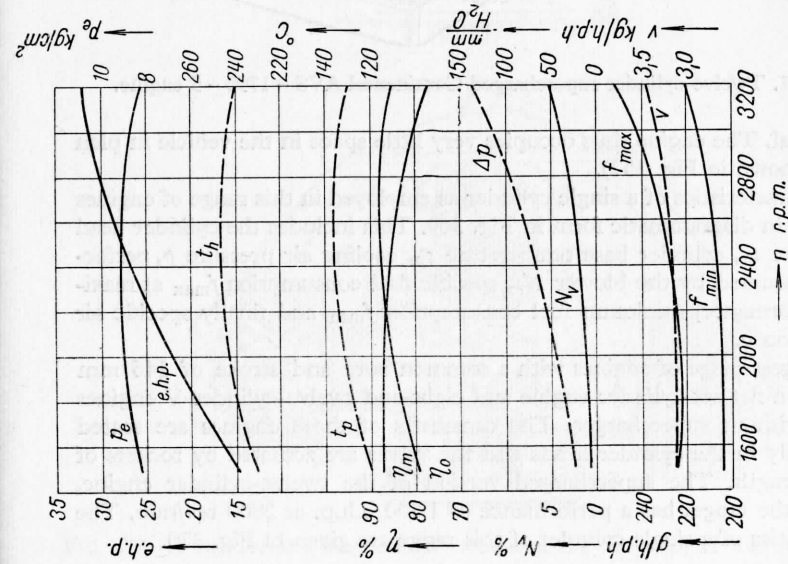


Fig. 370. Characteristics of a cylinder of the large series of Continental engines, bore 146.1 mm.

The engines of the medium range of Continental manufacture employ cylinders with a 117.5 mm bore and 101.6 mm stroke. These o.h.v. engines are produced as a flat four type, or as six- and eight-cylinder units and there is a choice of compression ratios and performances as found in Table 47. The eight-cylinder unit of this range which is used for the GM T 51 land-going vehicle is notable for its arrangement in the vehicle with the crankshaft

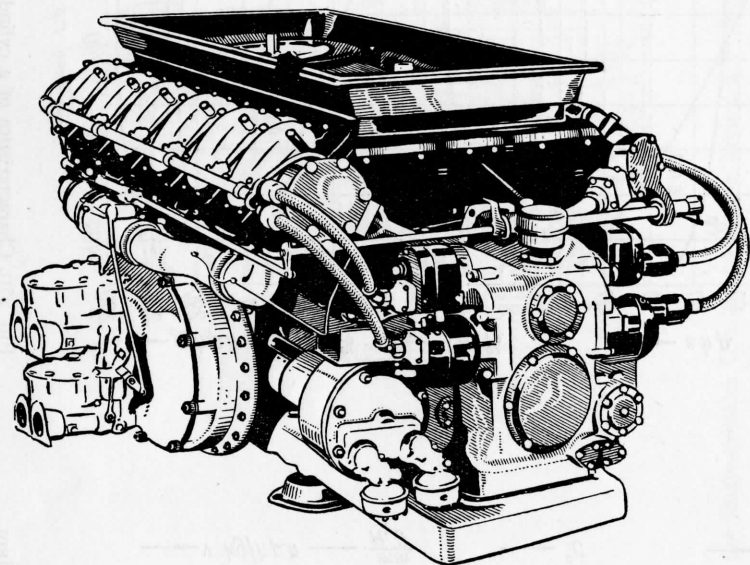


FIG. 371. Twelve-cylinder supercharged Continental AVS - 1790 - 5 engine.

axis vertical. The engine thus occupies very little space in the vehicle in plan view (as shown in Fig. 157).

The characteristics of a single cylinder as employed in this range of engines are shown in diagrammatic form in Fig. 369. This includes the cylinder head temperature t_h , cylinder base temperature t_p , cooling air pressure p , performance consumed by the blower N_v , specific fuel consumption $f_{\max}$ at maximum performance, minimum fuel consumption $f_{\min}$ and finally specific air consumption v .

The largest range of engines with a common bore and stroke of 146 mm comprises a flat six-cylinder engine and eight- and twelve-cylinder V engines with or without supercharger. The camshafts of these engines are seated eccentrically in the cylinder heads and the valves are actuated by rockers of unequal length. The supercharged version of the twelve-cylinder engine, largest of the range, has a performance of 1 400 b.h.p. at 2800 rev/min. The characteristics of a single cylinder of this range are given in Fig. 370.

The twelve-cylinder engine is interposed between the cooling air inlet and two vertically arranged axial fans driven by bevel gears (Fig. 371). An even flow distribution of cooling air over all cylinders is thus obtained. The fans are light in weight, take up little space and changes in air flow direction are kept down to a minimum. These engines are noted for their light weight. A compression-ignition engine recently developed has twelve cylinders and a performance of 750 b.h.p.

6. The Citroen Engine

This horizontally opposed twin-cylinder engine is used as prime mover for the Citroen light car. With a bore and stroke of 62 mm, the displacement of the engine is 375 cm³. The performance at 4 000 rev/min is 9 b.h.p., i.e.

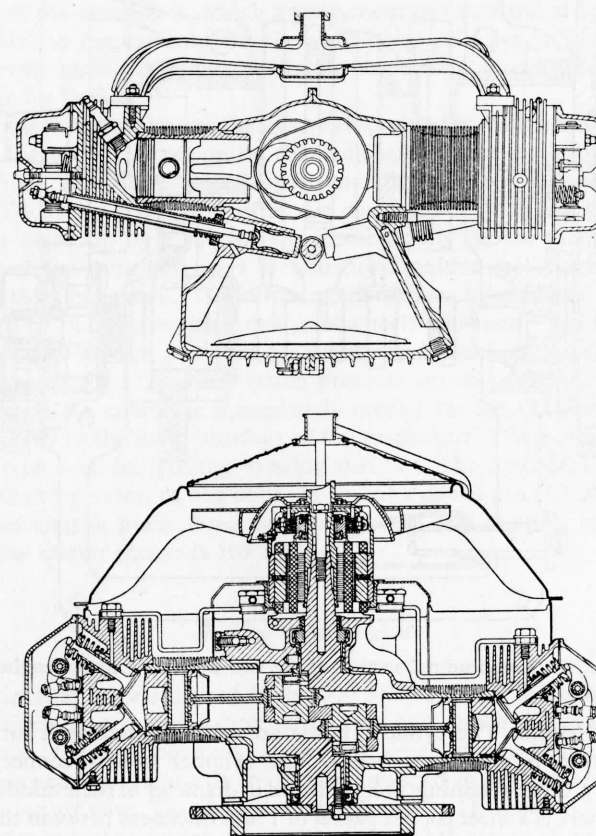


FIG. 372. Transverse and longitudinal sections of the two-cylinder Citroen engine.

24 b.h.p. per litre and an m.e.p. of 86.6 lb/in² (6.15 kg/cm²). The maximum torque of 16.56 ft-lb (2.38 mkg) is developed at 1 800 rev/min. The compression ratio of this engine is 6.2 : 1 (Fig. 372).

The overhead valves in the hemispherical head are inclined at an angle of 70° and actuated by push rods from the camshaft mounted below the crankshaft. The valve lifters are of 24 mm diameter and the push rods are

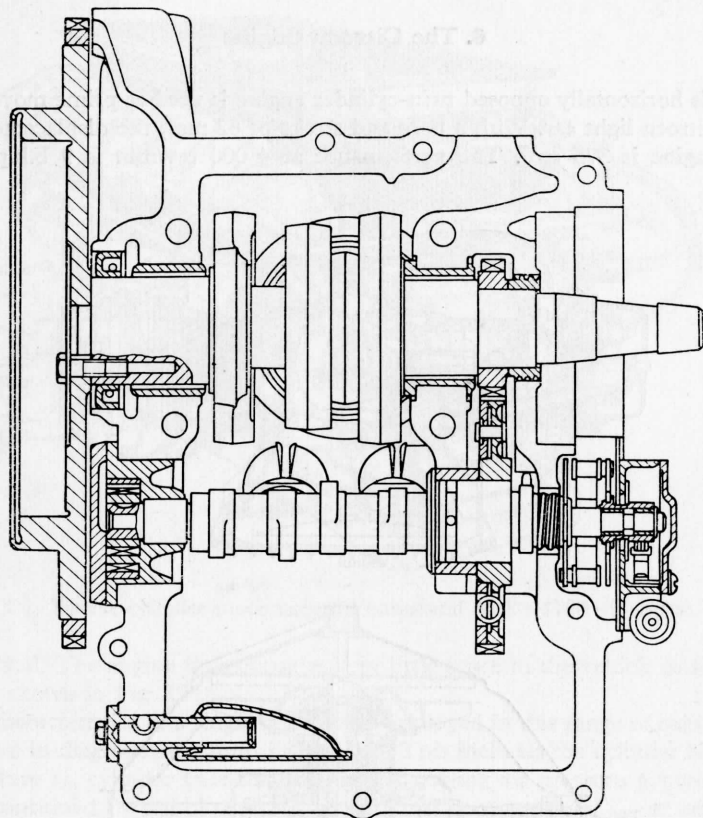


FIG. 373. Longitudinal section of the two-cylinder Citroen engine.

220 mm in length. The cylinder heads are of aluminium and both exhaust and induction pipes are upswept. The cylinder head is connected to the crankcase by three retaining bolts reduced in diameter in their middle portions to 8 mm. There is a sheet copper gasket of 1 mm thickness between the cylinder head and the cast iron cylinder barrel. The valve rockers are fitted with return springs and thus clearance is always maintained between the valve caps and

rockers only. The most recent version of the engine is fitted with pistons having offset domed crowns with resultant compression squish and a lower octane requirement of the engine.

Lubricating oil is brought to the cylinder head into an annular cavity surrounding the exhaust valve guide and hence by a drilled passage to the rocker box. The oil returns to the crankcase through the push rod cover tubes which are pressed into the cylinder heads and sealed by a spring loaded washer at their crankcase ends. The inlet valve seat angle is 60°, the exhaust valve seat angle 45°.

The crankcase is divided in the vertical plane of the crankshaft which is built up of five parts which are press fitted. One-piece connecting rods bear on lead bronze plain bearings; the crankpins are hardened. Such a layout makes for a small distance between cylinder centres resulting in reduced primary unbalanced couples. The dynamo is fitted directly on the tapered front end of the crankshaft, which arrangement obviates the use of a further bearing. Also on the crankshaft is the eight-blade axial fan, in front of which there is a wire mesh intake guard. Simple sheet metal ducting directs the air to the cylinder finning.

The arrangement of the camshaft drive is apparent in the longitudinal section shown in Fig. 373. The pinion on the camshaft has the teeth formed in two separate rows which are forced apart radially by three interposed helical springs. Thus any possible play in the camshaft drive is eliminated. Axial forces are taken up by a ring on the camshaft and by the pinion hub. The front end of the camshaft bears a centrifugal ignition mechanism controller acting on the distributor. The oil pump is driven by the rear end of the camshaft. The pump comprises two gear wheels with outer and inner teeth.

A non-return valve is provided for crankcase breathing ensuring constant under-pressure in the crankcase which prevents any oil leakage. The oil cooler is mounted on the crankcase immediately behind the fan. Oil passing through this is then fed to the main bearings of the crankshaft. These bearings are of the plain type with composition bearing surfaces. The flywheel is attached to the crankshaft by means of five bolts (M 8) and a dowel pin of 8 mm diameter. The starter ring is press fitted on the flywheel and the gear ratio between flywheel and starter pinion is 107 : 9.

7. The Fiat Engine

A parallel twin engine is used in the 500 Nuova FIAT light car. This is of 479 cm³ displacement with a bore of 66 mm and stroke 70 mm. Maximum performance of the engines fitted to the first series of cars was 13 b.h.p. The parallel overhead valves of this engine are arranged in a plane at right angles to the cooling air flow. The downdraught Weber 24 IBM carburettor is fitted with an easy starting device. Plugs 14 mm of 225 rating (Bosch) are used. A single roller chain transmits the drive to the camshaft. A centrifugal oil

cleaner is incorporated in the hub of the belt pulley. 12 V coil ignition is used. A radial fan is mounted on the shaft of the dynamo which provides an output of 180 W. A thermostat controlled shutter regulates engine cooling by recirculating heated air through the fan until operating temperature is reached. The general arrangement of the engine and cooling system is shown in Fig. 125. See also Figs. 374 and 375.

8. The Jawa Engine

The best known Jawa motor cycle engine is the 250 cm³ single cylinder type with two-stroke engine. Single cylinder two-stroke engines can be cooled with safety up to this capacity. The engine in question has a bore of 65 mm and stroke of 75 mm and its performance in 8 b.h.p. at 4 000 rev/min (Fig. 376). The location of the carburettor of this three port engine under a special cover is interesting. The piston is of the flat top kind and reverse flow scavenging is employed.

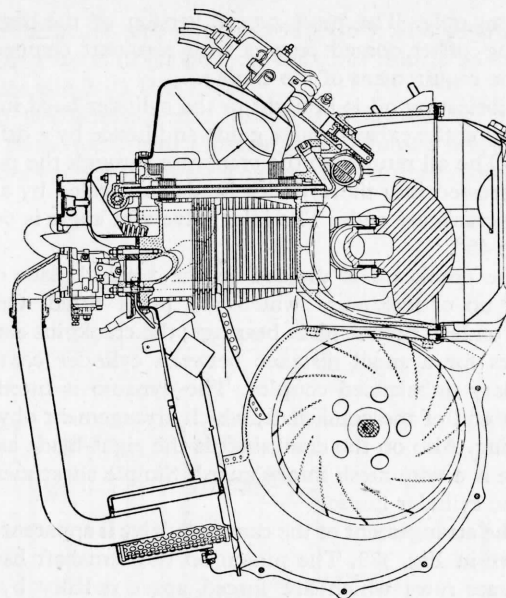


Fig. 374. Two transverse sections of the Fiat 500 engine.

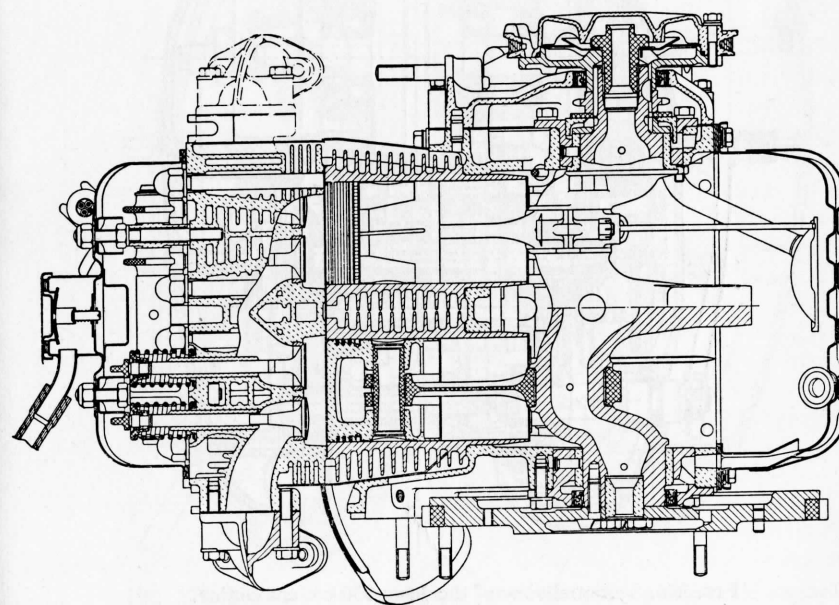
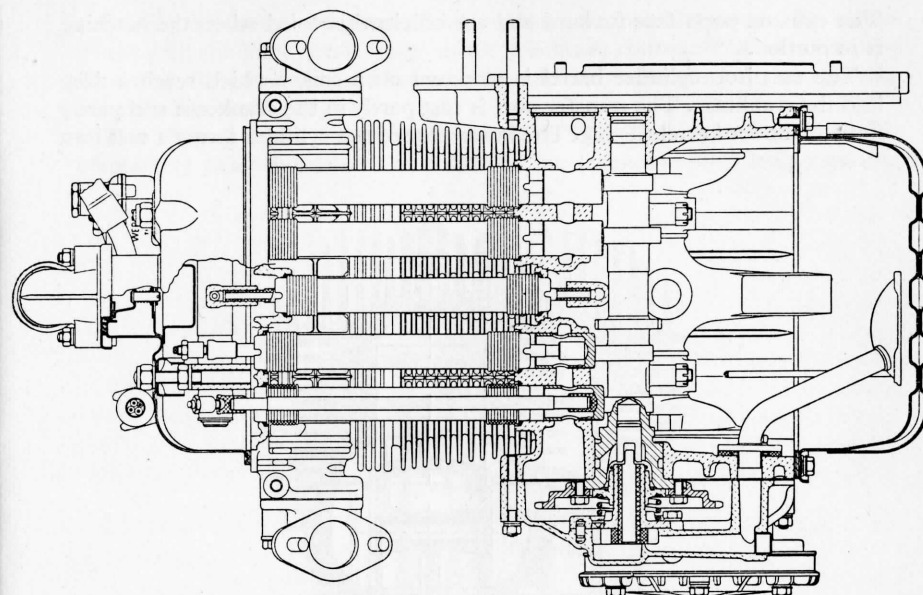
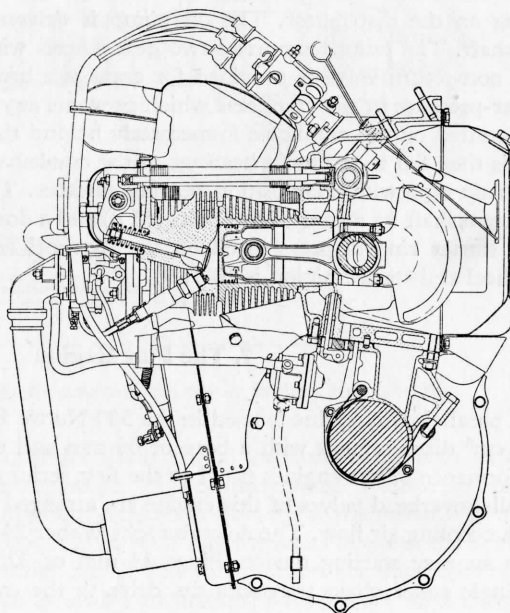


Fig. 375. Two longitudinal sections of the Fiat 500 engine.

The exhaust ports face forward and are efficiently cooled when the machine is in motion.

The cast iron cylinder barrel is mounted on a spigot which reaches deep into the crankcase. The transfer port is cast partly in the crankcase and partly in the cylinder barrel casting. The lower part of the cylinder forms a cast iron

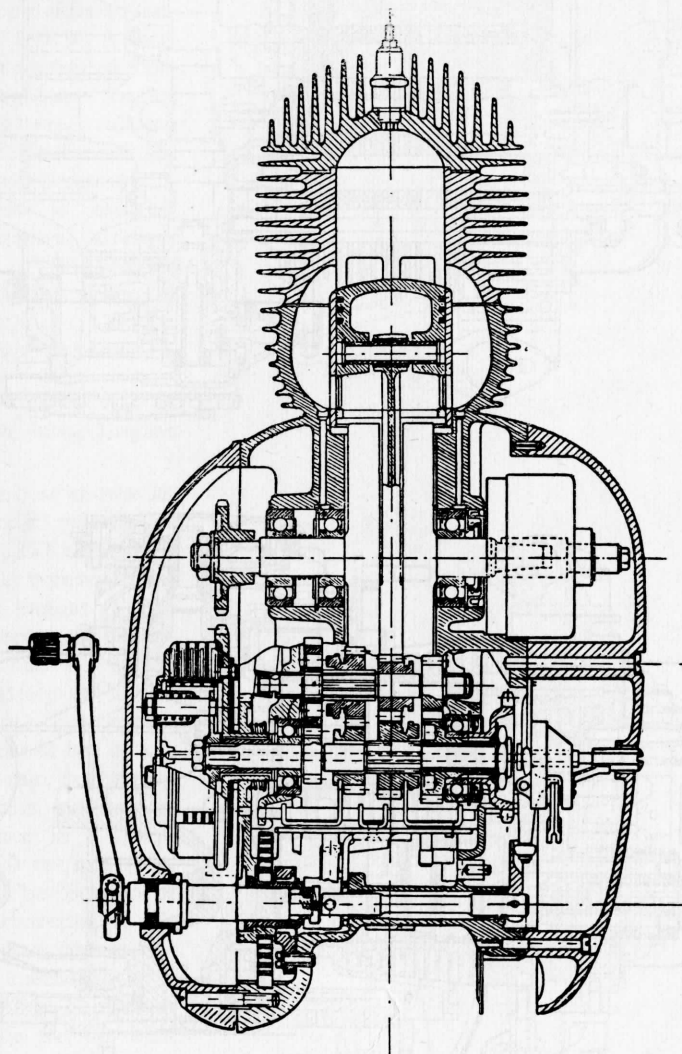


FIG. 376. Sectional view of the Jawa 250 cu. cm engine.

sleeve in the finned crankcase and the inlet port opening cut in the sleeve mates with the inlet port passage in the crankcase casting. The carburettor is fitted to a flange on the crankcase and need not be detached when removing the cylinder barrel.

The 350 c.c. engine has two cylinders (Fig. 377). Each cylinder and head is completely independent and is bolted to the crankcase by 3 long retaining

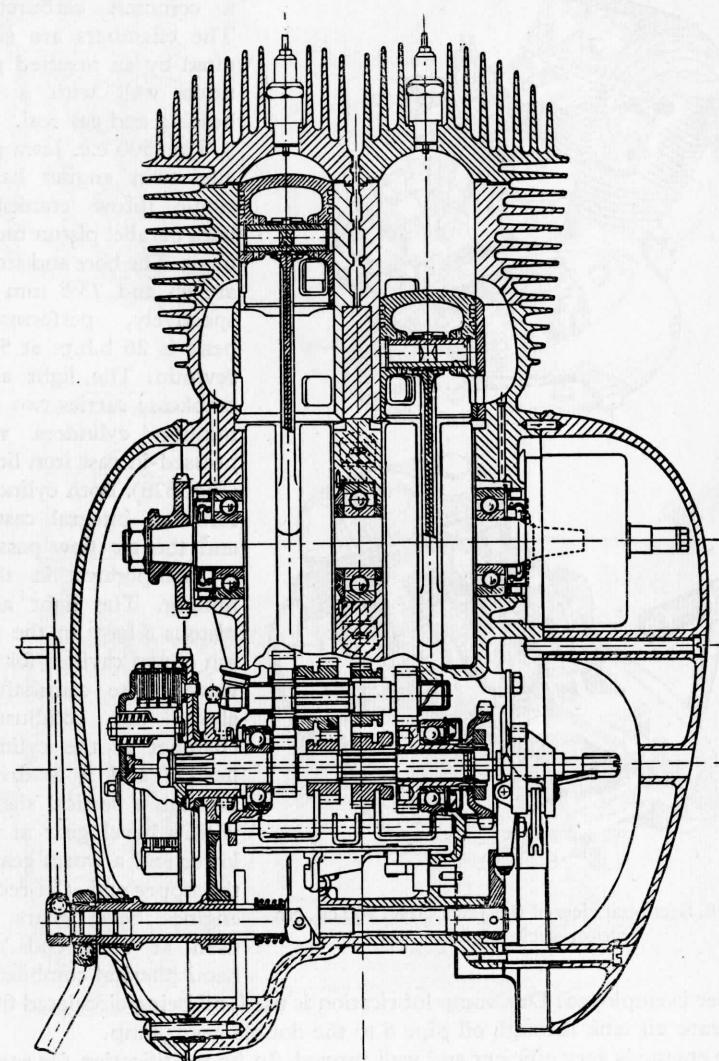


FIG. 377. Two-cylinder two-stroke Jawa 350 cu. cm motor-cycle engine.

bolts. The general design follows the 250 c.c. engine practice. In order to keep the firing intervals regular, the crankpins are 180° crankshaft rotation apart.

Efficient cooling is ensured by an adequate flow area of the cooling air stream between the two cylinders. Both cylinders and the separate crankcase breathing chambers share a common carburettor. The chambers are separated by an inserted partition wall with a ball bearing and gas seal.

The 500 c.c. Jawa parallel twin engine has a single throw crankshaft with parallel piston movement. The bore and stroke are 65 and 73.5 mm respectively, performance peak is 26 b.h.p. at 5500 rev/min. The light alloy crankcase carries two aluminium cylinders with pressed-in cast iron liners (Fig. 378). Both cylinders form an integral casting and the air flow passage is incorporated in their finning. The light alloy pistons 3 have in the piston crown cavities for the valves. The camshaft is above the combustion chamber in the cylinder head 4 and it is driven through a vertical shaft 5 with a bevel gear at the lower and a worm gear at the upper end. (In recent engines bevel gears are used at both ends.) A hemispherical combustion

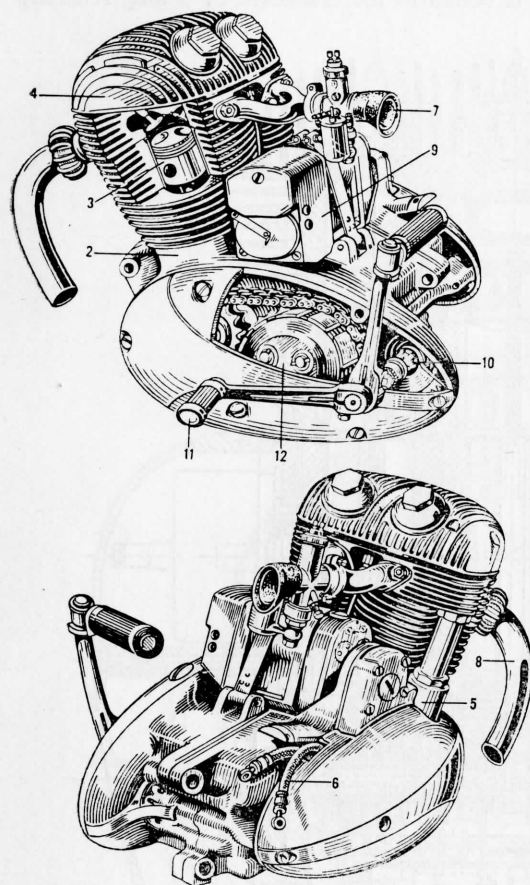


Fig. 378. Sectional view of the Jawa OHC 500 cu. cm motor-cycle engine.

chamber is employed. Dry sump lubrication is used, oil being circulated from a separate oil tank through oil pipe 6 to the double gear pump.

The engine is very efficient and well proved. In its modification for racing purposes the Jawa 500 motor cycle achieved outstanding results.

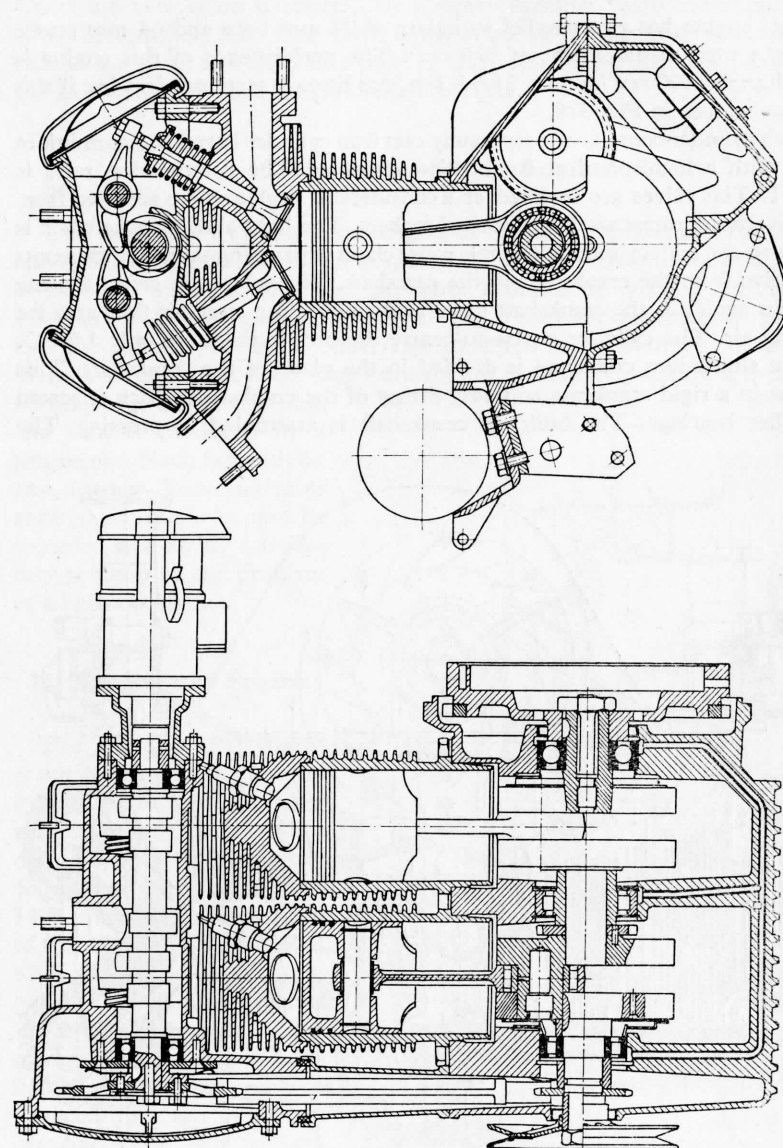


Fig. 379. Longitudinal and transverse sections of the Lloyd engine.

9. The Lloyd Engine

This engine has two parallel cylinders of 77 mm bore and 64 mm stroke giving a total displacement of 596 cm³. The performance of this engine is 19 b.h.p. at 4500 rev/min i.e. 31.6 b.h.p. per litre. A sectional drawing of this engine is given in Fig. 379.

Each cylinder consists of a separately cast iron cylinder barrel and aluminium head with a hemispherical combustion chamber. The compression ratio is 6.6 : 1. The valves are inclined at a considerable angle and are actuated from the overhead camshaft by means of rockers. The light alloy camshaft box is common for both cylinders. A single roller chain with spring tightener transmits the drive from the crankshaft to the camshaft. The valves are set in a plane at right angles to the crankshaft axis. This results in a large air flow area for cooling air. The cylinder centre-to-centre distance is therefore only 1.38 D.

The aluminium crankcase is divided in the plane of the crankshaft. This results in a rigid crankcase and easy fitting of the crankshaft which is seated in roller bearings. The built up crankshaft is assembled by pressing. The

oil pump is driven from the middle of the crankshaft by spur gears. Crankcase ventilation is effected by a rotary breather valve communicating with the camshaft box. The valve is mounted on the camshaft immediately behind the chain sprocket. Two ports in this rotary valve open the passage to the camshaft box when the pistons are at b.d.c.

10. The Panhard Dyna Engine

This horizontally opposed twin engine of 850 cm³ displacement has a bore and stroke of 85 mm and 75 mm respectively. Engine performance is 40 b.h.p. at 5000 rev/min, i.e. 47 b.h.p. per litre. Aluminium cylinder barrels cast integrally with their heads are employed (Fig. 310). Cast iron liners are pressed into the barrels. As both cylinders are mounted individually on the engine, there is nothing to obstruct high finning; low cooling air pressure is therefore sufficient for effective cooling and this is produced by a simple two-blade fan without any ducting. Torsional valve springs are used. It may be regarded as a highly satisfactory solution of the problem of a light car engine.

11. The Porsche Engine

The Porsche 1500 engine is outstanding in its class by its high performance and low weight. It is a flat four-cylinder type, bore 85 mm, stroke 66 mm and a displacement of 1498 cm³. The performance of this engine is 100 b.h.p. at 6200 rev/min, i.e. 67 b.h.p. per litre. Maximum torque is 87 ft-lb (12.1 m/kg). The combustion chamber is hemispherical and each valve is actuated by an individual camshaft. The light rockers interposed between the cams and valve caps are not pivoted on a bush, but are simply an-

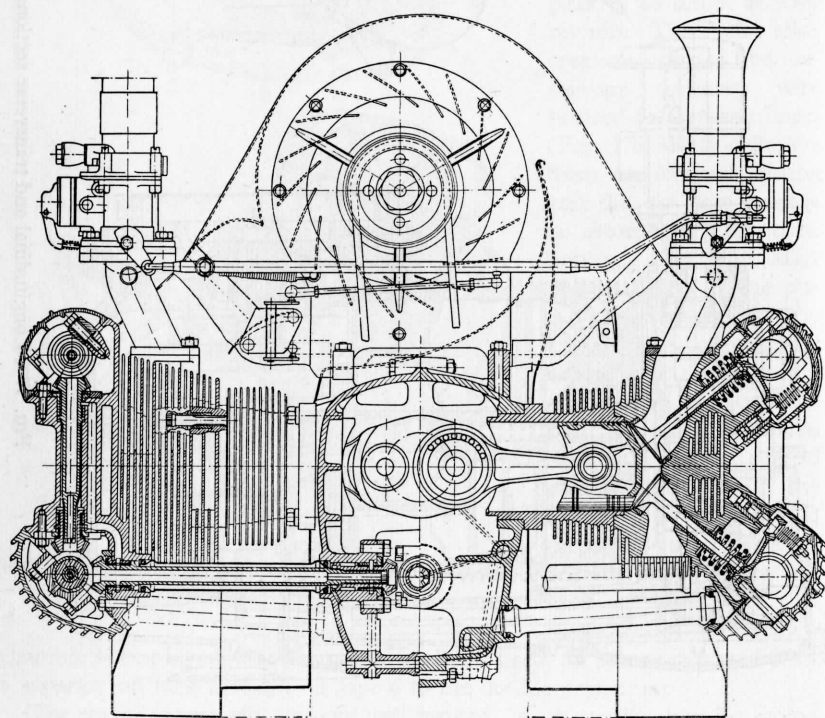


FIG. 380. Transverse section of the Porsche engine.

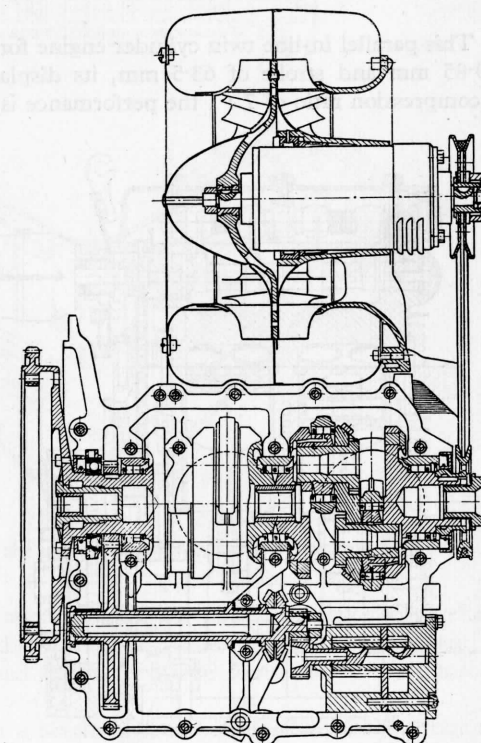


FIG. 381. Longitudinal section of the Porsche engine.

chored by a stud to the cylinder head to which they are pressed by a spring. The valves are at an angle of 78° .

As already stated, the engine incorporates four camshafts, each driven from the crankshaft through bevel gears and inclined shafts. The compression ratio of the standard engine is 9 : 1, demanding fuel of 86 octane rating. Cylinders are cast in aluminium and their bores are hard chromium plated – an arrangement whereby high cooling efficiency is attained. The crankshaft and connecting rods operate in rolling contact bearings. The twin radial fan is driven by the crankshaft through a belt at a ratio of 1 : 1. At 6200 rev/min the fan supplies 4290 ft³ (66 m³) of air per minute. Dual ignition is employed with Bosch W 240 T 21 sparking plugs. Two twin-choke Solex 40 PJJ carburettors provide the mixture. The fuel is delivered by two electric pumps. Sectional views of the engine are shown in Figs. 380 and 381.

12. The Sunbeam Engine

This parallel in-line twin cylinder engine for motor cycle use has a bore of 69.85 mm and stroke of 63.5 mm, its displacement being 487 cm³. With a compression ratio of 7 : 1 the performance is 23 b.h.p. at 5750 rev/min.

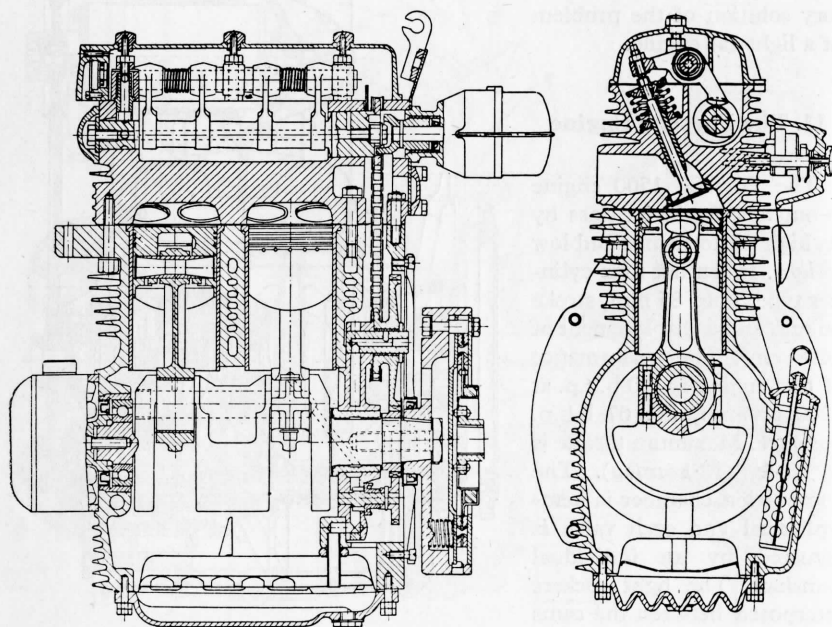


FIG. 382. Longitudinal and transverse section of the Sunbeam motor-cycle engine.

The engine design follows current automobile practice. The cylinders form an integral light alloy casting with the crankcase; austenitic iron liners are pressed into them. Air passages are provided between the cylinders. The crankshaft is cast and is fitted with three counterweights balancing primary reciprocating masses to 50%. The large rear crankcase cover facilitates the fitting of the crankcase assembly into the tunnel-type crankcase. The oil pump

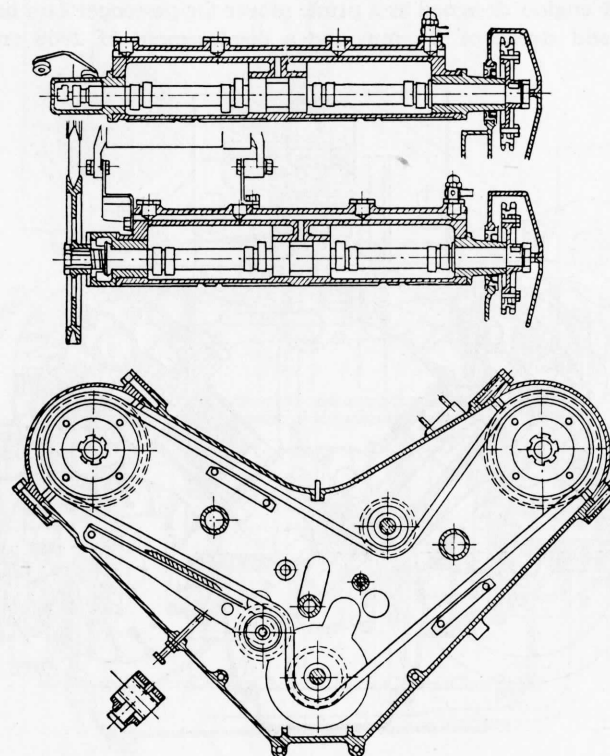


FIG. 383. Drive of the valve gear of the Tatra 87 engine.

is incorporated in this cover together with the pinion driving the overhead camshaft by a single roller chain. The distributor is driven by one end of the camshaft. Valves are actuated by rockers. The front end of the camshaft drives the dynamo.

The valves are disposed in a single row and inclined by 22.5° from the vertical axis of the engine. A suitably shaped combustion chamber with a large squish area results. The valve seats are pressed into the aluminium head, the inlet valve port diameter being 33.3 mm, that of the exhaust port 30.1 mm.

The camshaft is housed direct in the aluminium head. Light alloy connecting rods forged of RR56 of 114.3 mm centre-to-centre length are used. Fig. 382 shows the transverse and longitudinal sections of the engine.

13. The Tatra 87 Engine

This V-8 engine designed as a prime mover for passenger cars has a bore of 75 mm and stroke of 84 mm and a displacement of 2968 cm³. With

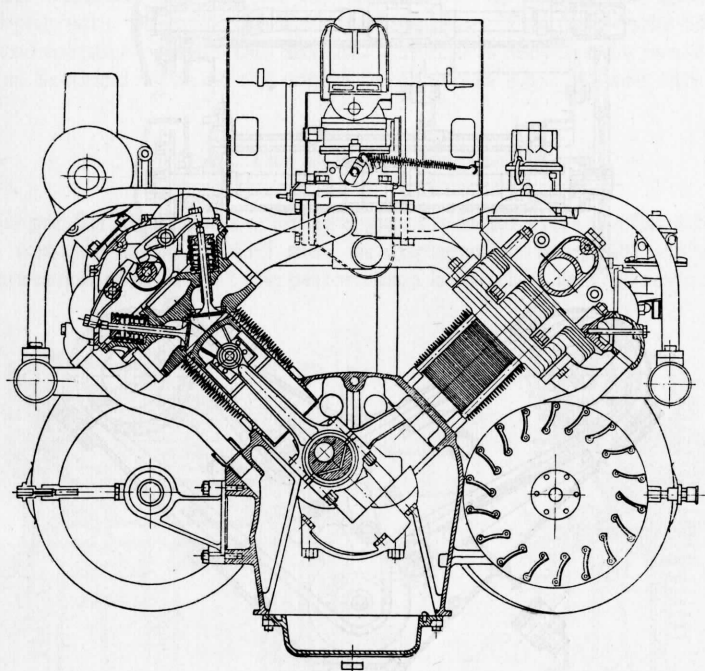


FIG. 384. Transverse section of the eight-cylinder Tatra 87 engine.

a 5.6 : 1 compression ratio, the performance is 70 b.h.p. at 3600 rev/min. The engine weighs 505 lb (194 kg).

This engine has a hemispherical combustion chamber with valves actuated by rockers bearing on an overhead camshaft. Each cylinder with its head forms an individual unit and the camshaft for four cylinders of each bank is mounted in its separate housing (Fig. 383). The attachment of this camshaft housing must provide for small differences in heat expansion which may arise e.g. when one cylinder is out of action.

The camshafts are roller chain driven from the front end of the crankshaft. This form of drive can take up the small variations of distance between the shaft centres with varying engine temperature. Chain guides and a special tightener prevent chain whip. The front cover mounting on the camshaft housing must be resilient. The rear ends of the camshaft are utilized for

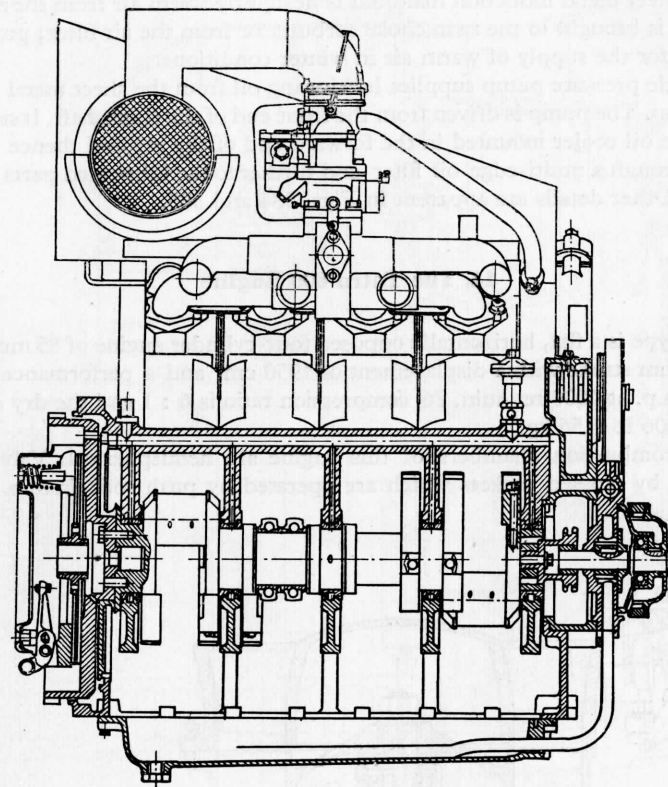


FIG. 385. Longitudinal section of the eight-cylinder Tatra 87 engine.

dynamo and distributor drive. The use of an overhead camshaft prevents valve clearance variation owing to expansion of the engine by heat.

The two banks of cylinders are mounted at an angle of 90°. The crankcase, made of electron metal, has a detachable sump to facilitate crankshaft fitting. The crankshaft is of four-throw type with throws 90° apart and balancing of primary reciprocating masses is achieved by means of bobweights attached to the crankshaft webs. The crankshaft is seated in plain main bearings with white metal surfaces.

Two radial fans arranged on both sides of the engine supply the cooling air. They are driven by V belts which are tightened by pivoting the fan pulleys away from the crankshaft pulley. This is arranged by turning the fan shaft about a swivel bearing located between the impellers. Air leaving the fan impeller is directed by a spiral cowling mainly to the cylinder heads and directional changes of flow are kept to a minimum.

The sheet metal induction manifold is heated by warm air from the engine. Cold air is brought to the twin choke carburettor from the air filter; provision is made for the supply of warm air in winter conditions.

A single pressure pump supplies lubricating oil from the sheet metal crankcase sump. The pump is driven from the front end of the crankshaft. It supplies oil to the oil cooler mounted in the forward end of the car and thence the oil flows through a multi-edge oil filter and further to the lubricated parts of the engine. Other details are apparent in Figs. 384 and 385.

14. The Tatra 600 Engine

This type is a flat, horizontally opposed four-cylinder engine of 85 mm bore and 86 mm stroke with a displacement of 1950 cm³ and a performance of 52 to 55 b.h.p. at 4000 rev/min. Its compression ratio is 6 : 1 and the dry engine weighs 406 lb (156 kg.)

The combustion chambers of this engine are hemispherical. Valves are actuated by crossed rockers which are operated by push rods from a single

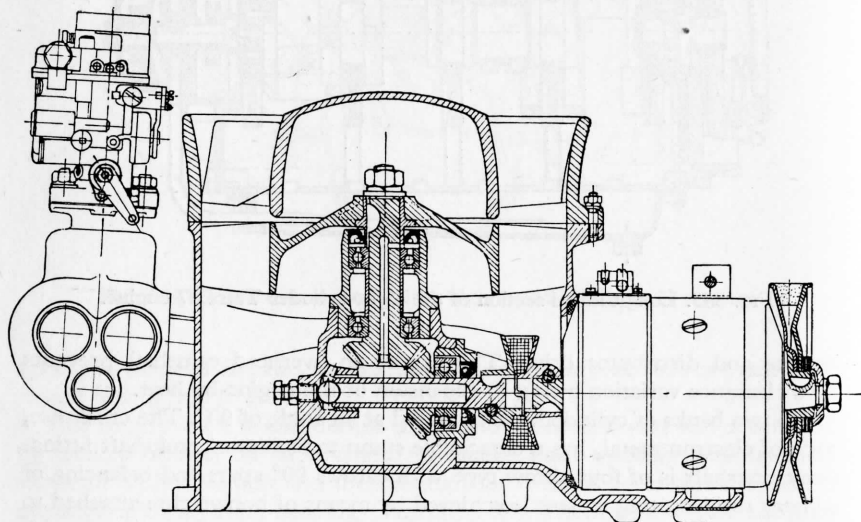


FIG. 386. Longitudinal section of the fan drive of the Tatra 600 engine with vertical fan.

camshaft housed in the crankcase below the crankshaft (Fig. 103). Oil is supplied to the valve mechanism through valve lifters, aluminium push rods and drilled valve rockers; it returns through the push rod cover tubes. Rocker box covers are sheet metal pressings shaped with regard to easy access to the sparking plugs.

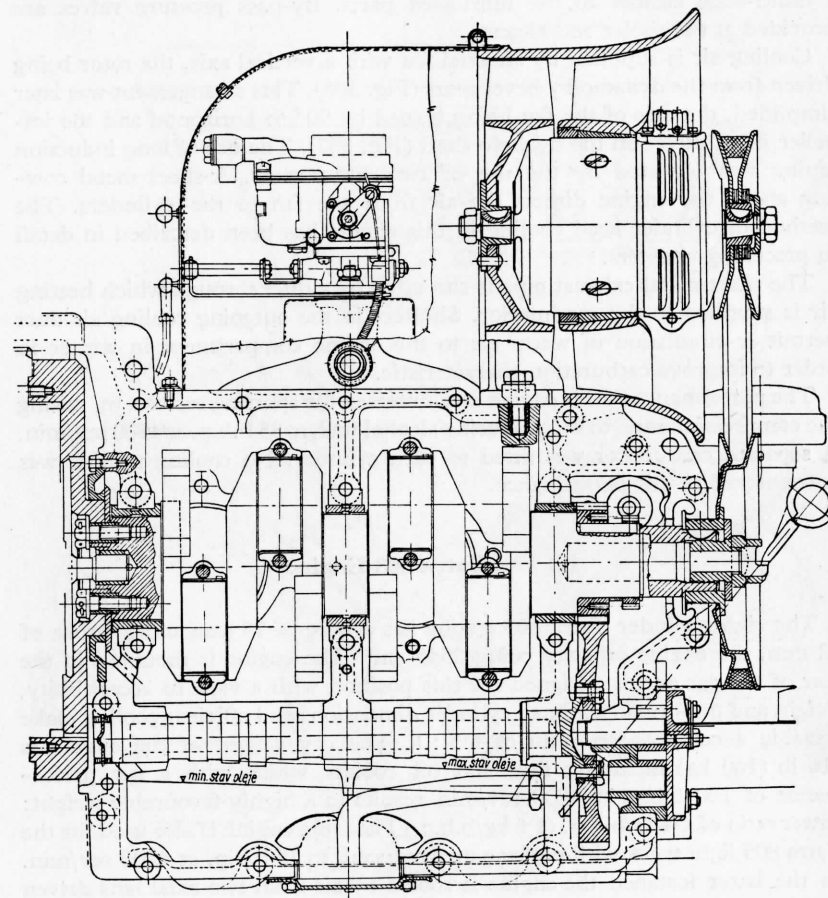


FIG. 387. Longitudinal section of the Tatra 600 engine with horizontal fan.

The aluminium alloy crankcase is split in the plane of the crankshaft. Both halves in which the main bearings are mounted, are bolted together. The camshaft is housed directly in the aluminium crankcase. The crankshaft with four throws 180° apart is extremely rigid, as the engine is of the short-stroke type. The camshaft is driven from the front end of the crankshaft through gear

pinions and the ignition distributor through worm gears. The distributor shaft incorporates a fuel pump drive cam.

The lubricating oil pump is driven by the front end of the camshaft, the supply of oil being stored in the finned crankcase. Oil is forced from the pump through the oil cooler mounted in the front part of the car and, through a multi-edge cleaner to the lubricated parts. By-pass pressure valves are provided at the cooler and cleaner.

Cooling air is supplied by an axial fan with a vertical axis, the rotor being driven from the dynamo by bevel gears (Fig. 386). This arrangement was later simplified, the axis of the fan being turned by 90° to horizontal and the impeller fitted direct on the dynamo shaft (Fig. 387). The use of long induction piping was obviated by the use of two carburettors. A sheet metal cowling above the engine directs the air from the fan to the cylinders. The method of cylinder head cooling in this engine has been described in detail in preceding chapters.

The sheet metal exhaust pipe is shrouded by a duct through which heating air is supplied to the car interior. Shutters in the outgoing cooling air duct permit re-circulation of warm air to the engine compartment in winter in order to improve carburation characteristic.

The performance of this engine was increased for sporting car use, by raising the compression ratio to 9:1 and using alcohol fuel, to 85 b.h.p. at 4500 rev/min. A separate carburettor was fitted to each cylinder. No cooling trouble was encountered at this performance.

15. The Tatra 603 Engine

The eight-cylinder Tatra 603 engine has a bore of 75 mm and a stroke of 72 mm, the engine capacity being 2545 cm³. The engine is mounted in the rear of the car and is designed for this position with a view to accessibility, weight and performance. Small cylinder dimensions and efficient cooling make possible a compression ratio of 6.5:1. The dry weight of the engine is 416 lb (160 kg) including fans and oil coolers, which with a net performance of 100 b.h.p. at 4800 rev/min results in a highly favourable weight: power ratio of 4.1 lb/b.h.p. (1.6 kg/b.h.p.) The same engine is also used for the Tatra 805 light truck with performance reduced to 75 b.h.p. at 4200 rev/min. In the latter instance the engine is cooled by air from two axial fans driven by V belts forcing air to the cylinders, cool air reaching exhaust valves first. Warm air leaves the engine past the induction manifold.

In the Tatra 603 F engine for passenger car use the cooling arrangement is modified in that it comprises two axial fans placed at the sides of the engine, which draw the air over the engine. Thus fresh cooling air is brought to the engine past the carburettors and induction manifolds. With such an arrangement the induction side of the cylinder head runs at a lower temperature, which makes for higher volumetric efficiency of the engine. Two twin-choke

Motorpal 30 SSOP carburettors also aid high volumetric efficiency at high engine speeds.

The induction-type cooling layout employed has the advantage of an even distribution of cooling air over all cylinders. An additional air stream entering

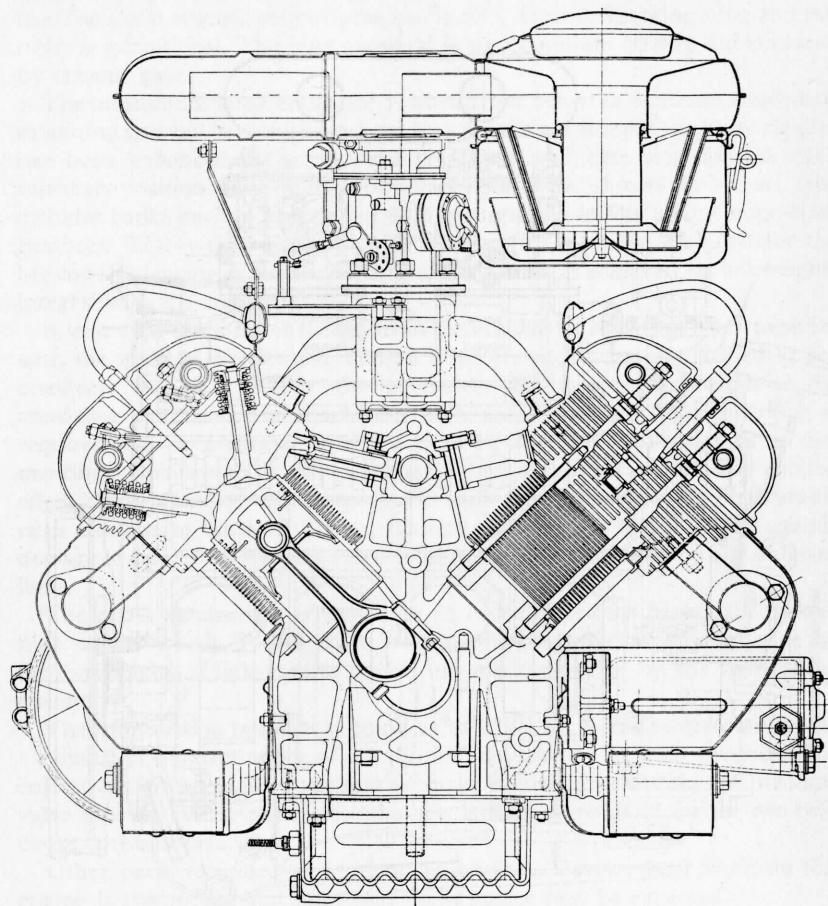


FIG. 388. Transverse section of the Tatra 603 F engine.

from atmosphere direct to the exhaust valve ensures an uniform temperature of the whole cylinder circumference. The cast iron cylinders have machined fins with a small spacing of 3.4 mm, the mean fin thickness being 1 mm. A bellows-type thermostat controls engine cooling by operating the air-flap in the outlet ducting behind the fan. Fresh air is also drawn through two oil

coolers mounted on the engine sides. The general layout of this engine is depicted in Figs. 388 and 389.

The combustion chambers of this engine are hemispherical and widely inclined valves are operated by short push rods from a camshaft mounted high in the crankcase. The weight of all valve gear component parts is very low, thus

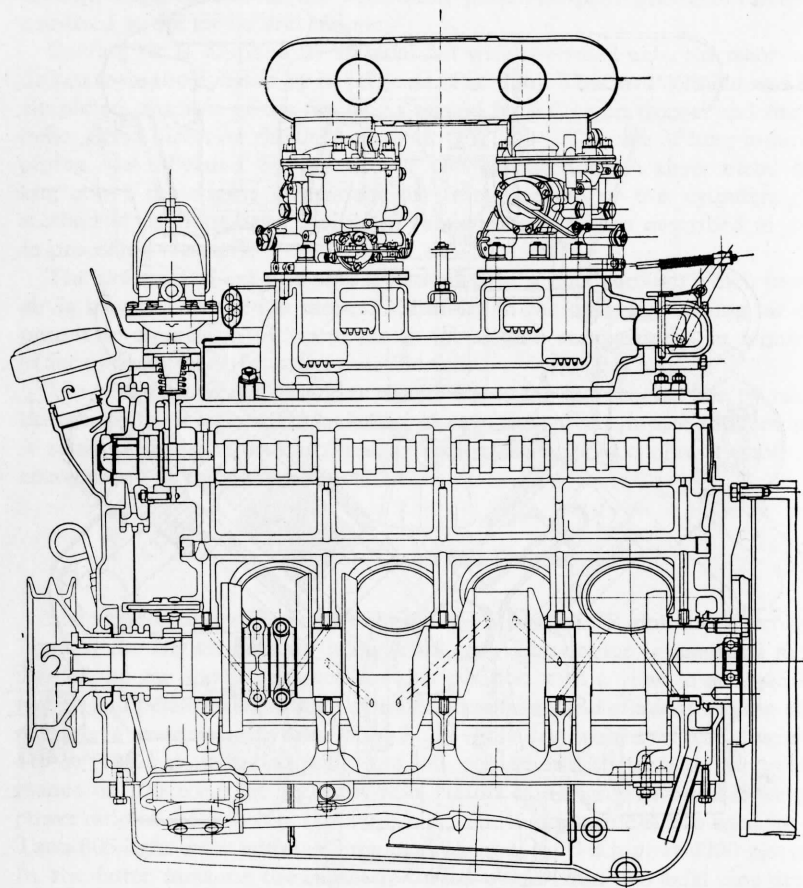


FIG. 339. Longitudinal section of the Tatra 603 F engine.

reducing the stress on the valve gear at high engine speeds. Volumetric efficiency is also high owing to small cylinder dimensions and to the large valves employed. As the valves are in a plane perpendicular to that of the crankshaft, the cooling air flow area is sufficiently large. The cooling surface area of the cylinder head is 2130 cm^2 , compared with the 1190 cm^2 area of the

Tatra 87 engine with identical bore diameter. The cylinder surface cooling area is 1575 cm^2 .

The close grouping of cylinders in each bank (with centre-to-centre distances of only 100 mm) results in an engine of very small overall length. Neither in weight nor in dimensions does this engine exceed the corresponding values for the Tatra 600 engine, yet performance is 60% higher. Sparking plug accessibility is exceptional. The inlet manifold is an aluminium casting and is heated by exhaust gases.

The aluminium alloy crankcase is open from below to facilitate crankshaft mounting and the opening is covered by a sheet steel sump. Crankcase rigidity has been enhanced by an upward crankcase wall extension for the high camshaft position. The four-throw crankshaft with throws 90° apart (the cylinder banks enclose an angle of 90°) is supported in five plain composition bearings. Thin-walled bearings with lead-bronze bushings are used for the big ends. Balancing of primary reciprocating masses is achieved by bobweights integral with the crankshaft.

A gear type oil pump is driven from the crankshaft by worm gears together with the ignition distributor. The oil flows through a passage drilled in the crankcase wall to and from the oil coolers mounted on both sides of the crankcase. As the cooler attachment bolts are drilled, no separate tubing is required and no separate oil unions need be attended to during engine dismantling. Cooling air is drawn through the oil coolers, making the cooling effect independent of vehicle speed. Oil from the coolers flows through multi-edge cleaners to lubricated parts. Coolers and cleaners are protected against damage in winter by by-pass valves. Oil pressure is indicated by a dashboard light.

The crank mechanism is very light in order to reduce frictional losses at high engine speeds. Piston skirts are cut-away in order to provide space for the bobweights. High engine speeds are made possible by the light crank assembly.

The compression ratio has been raised to 12 : 1 for racing purposes and with alcohol fuel a performance of 200 b.h.p. was reached at 7500 rev/min. The engine can go up to 8000 rev/min with the following modifications: stronger valve springs, racing camshaft and a new induction manifold for the two twin choke carburettors.

Other parts remained as in standard engines. Development work on this engine is continuing and improved performance may be expected.

16. The Vespa Engine

This is a typical two-stroke twin cylinder engine with both bore and stroke of 63 mm. The engine displacement is 394 cm^3 and performance is 14 b.h.p. at 4350 rev/min. A maximum torque of 19.5 ft lb (2.7 mkg) is produced. The timing of mixture entering the crankcase of this engine is not controlled

by the bottom edge of the piston skirt but by ports in the flywheel and an unsymmetric timing diagram is thus obtained. A Solex 26 AHCD carburettor is fitted. The radial fan is V belt driven and its positioning is apparent in Fig. 390. The engine is mounted in the rear of the vehicle.

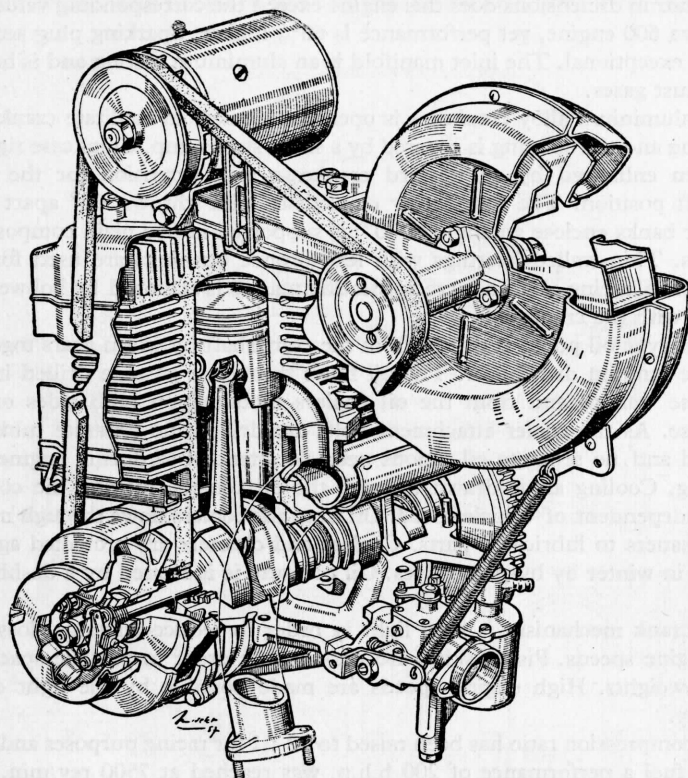


FIG. 390. Sectional view of the two-stroke Vespa engine.

B. COMPRESSION-IGNITION ENGINES

1. The ČKD Engine

The 6V 145-ADR engine was the result of the first effort of the ČKD works to produce an air-cooled heavy duty engine of large cylinder dimensions. Previously air-cooled engines with bores exceeding 140 mm had been designed for aircraft and tank propulsion. The ČKD engine is, however, intended for

railway and tractor use. The engine in question is composed of standard parts which are common for a six- and twelve-cylinder layout. By the additional use of superchargers, engines of four different and regularly stepped performances

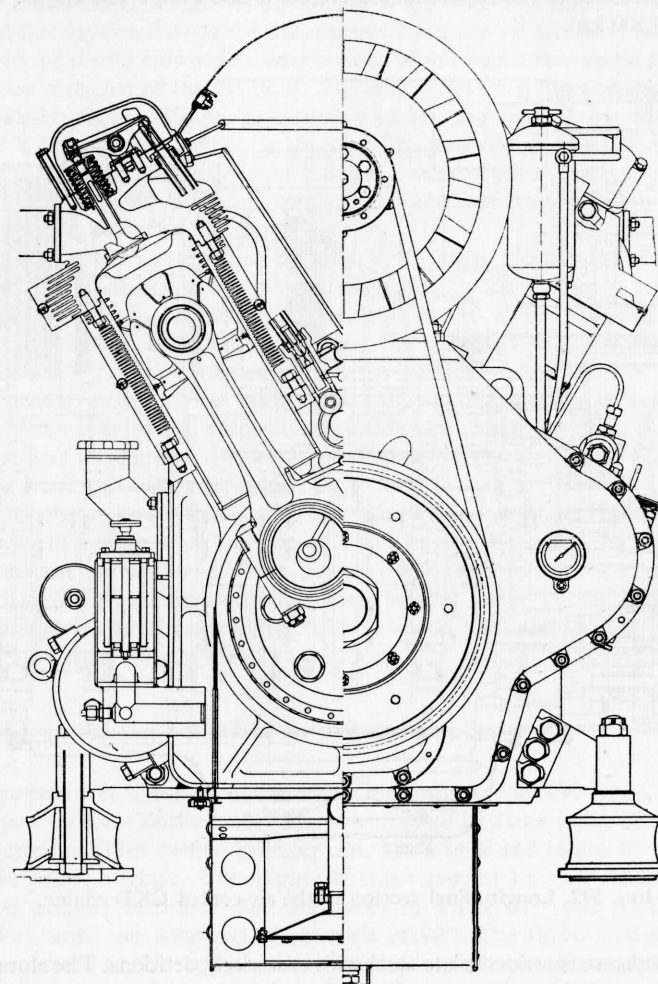


FIG. 391. Transverse section of the air-cooled ČKD engine.

are available. The engine is designed with a view to heavy duty conditions and easy maintenance and approaches automobile design practice rather than that common for aircraft. Its specific characteristics compare very favourably with those of similar, but water-cooled engines.

The bore of this engine being 145 mm and stroke 180 mm, the displacement is 17.8 litres for the six-cylinder unit. A continuous performance of 150 b.h.p. is given at 1400 rev/min with a possible peak of 180 b.h.p. at the same speed. The performance of the supercharged engine is 220 b.h.p. The engine weighs 2866 lb (1300 kg).

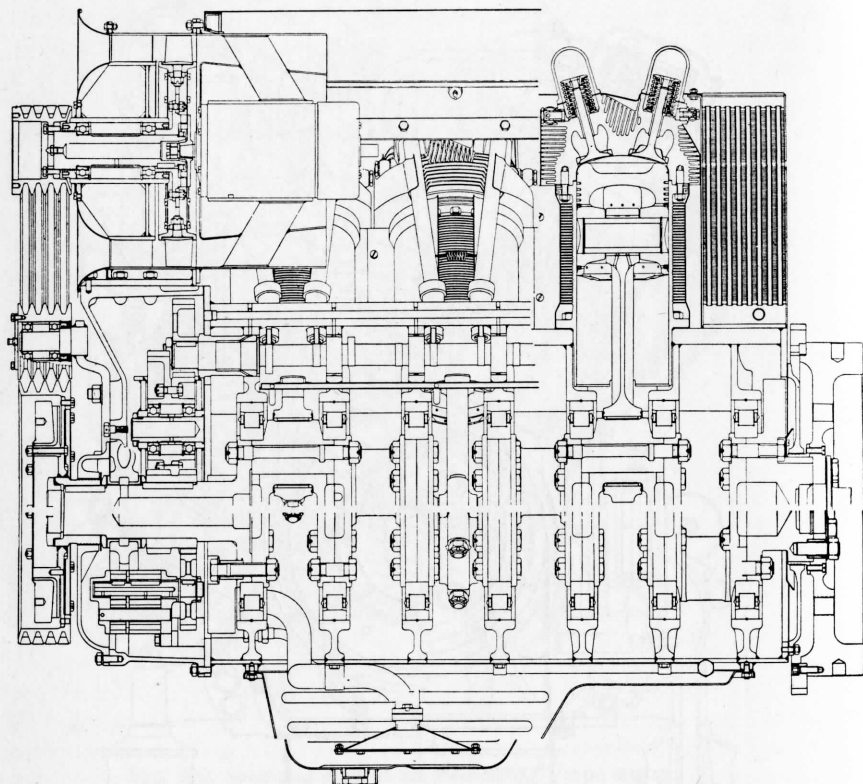


FIG. 392. Longitudinal section of the air-cooled ČKD engine.

The crankcase is welded plate steel with cast steel partitions. The aluminium pistons are cooled by oil sprays directed against the underside of the crowns by fixed nozzles (Fig. 391). The connecting rod is fully machined with bearings cast in lead-bronze. The crankpins of 100 mm diameter are surface hardened. The built-up crankshaft is housed in seven roller main bearings, the front journal being fitted with a pulley for the fan belt drive incorporating a rubber damper of torsional vibrations.

A single camshaft, driven by spur gears from the front end of the crankshaft,

is employed. The injector pump attached to the side of the engine is readily accessible. The cylinder head is of aluminium alloy and it carries two slightly inclined valves. Note the finning of the exhaust valve area which is apparent in the longitudinal section of the engine (Fig. 392). The injector nozzles are located sideways on the edge of the combustion chamber which is formed by a cavity in the piston crown. In a later version of the engine the nozzle axis almost coincides with that of the cylinder. The steel cylinder is nitrided and the head is attached by bolts and a flange without a gasket, thus simplifying dismantling.

The V arrangement which is unusual for six-cylinder engines gives small overall dimensions and enables the standardization of parts for the twelve-cylinder unit. The direct-injection combustion chamber makes for low fuel consumption and a clean exhaust.

The engine is started either by a 24 V 15 b.h.p. electric starter or by an auxiliary air cooled petrol engine. Cooling air for the engine is supplied by an axial fan at the rate of 88 ft³ (2.5 m³) and at 110 to 120 mm water column pressure to the spaces between cylinders. The relatively wide spacing of cylinders has made possible the use of extensive finning of the cylinders (8700 cm²) and cylinder heads (7800 cm²). The uniform distribution of temperature through the cylinders is aided by a quickly detachable cowling. A complete cylinder unit weighs 55 lb (25 kg), the cylinder barrel weighing 30.8 lb (14 kg) and the head without accessories 17.6 lb (8 kg).

The twelve-cylinder unit using the same basic component parts has also two banks of cylinders inclined by 60°. The engine displacement is 35.6 litres and constant performance 300 b.h.p. at 1400 rev/min with a maximum of 330 b.h.p. This performance is increased to 450 b.h.p. by the addition of a supercharger. Overall engine dimensions: width 1190 mm, height 1320 mm, length 1910 mm, weight 4365 lb (1980 kg).

2. The Continental Engine

A compression-ignition engine with a performance of 750 b.h.p. has been developed by the Continental works to complete its large range of air-cooled petrol engines. This twelve-cylinder unit has a bore and stroke of 146.1 mm like the petrol engines. The engine is supercharged by two exhaust turbochargers and its technical data are given in Table 47 (type AVDS-1790). Cylinder banks are arranged at an angle of 90°. The turbo-charged engine can be uprated to 850 b.h.p. and it is automatically compensated for loss of performance at high altitude or through high inlet air temperature. The chief advantage of the compression-ignition engine is indicated in this instance by a fuel consumption 40% lower than that of a similar petrol engine.

The cooling air is provided by two axial fans. This arrangement makes for a uniform distribution of air flow over the cylinders and the shortest possible exit route of the warm air from the armoured engine compartment. The bullet-proof grilles offer a considerable resistance to air flow and the total fan

input is therefore almost double normal requirements. The cooling fans consume 110 b.h.p. at maximum engine speed. The axial fans have a diameter of 25.9 in (660 mm) and they rotate at twice crankshaft speed. The cylinder head temperature with an output of 750 b.h.p. is only 175 °C, the pressure head at the cylinders being 150 mm water column. Such a low cylinder head temperature is conducive to freedom from injection nozzle troubles.

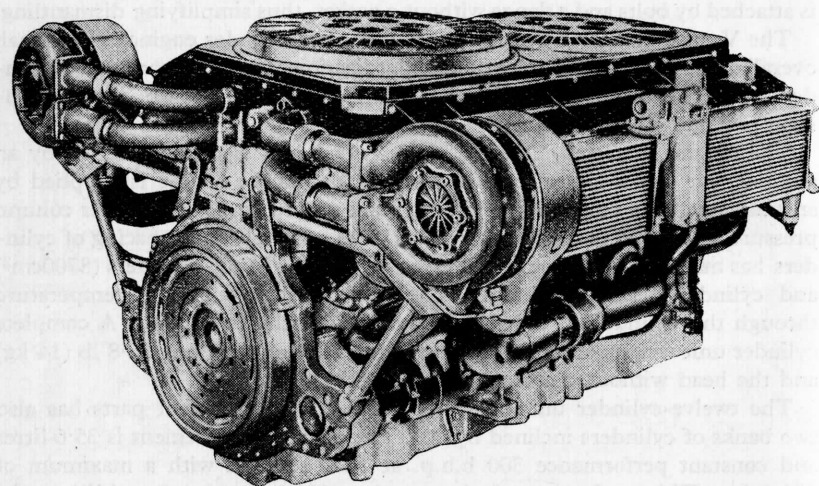


FIG. 393. View of the Continental 750 b.h.p. compression-ignition engine using turbo-chargers.

The pistons are cooled by oil sprays directed at the crown interior face from fixed nozzles from a separate oil pump supplying 75 litres of oil per minute, with thermostatic control set for 60 °C. The lubrication pump has an output of 190 litres per minute with an 80 μ full-flow filter in the circuit.

Injection pump and turbo-charger oil is cleaned separately by a finer, 25 μ filter. The fuel is supplied by the fuel delivery pump at a pressure of 25 lb/in² (1.75 kg/cm²) at a rate of 750 litres per hour, and running on JP-4 fuel or kerosene is therefore possible.

The maximum m.e.p. occurs between 1600 and 1800 rev/min and amounts to 1564 to 1791 lb/in² (110 to 126 kg/cm²). The crankcase is therefore extremely robust and forms a strong foundation for plain bearings which are 4.25 in (108 mm) in diameter and 1.9 in (50 mm) in length. The lead-bronze big end bearings have a diameter of 3.74 in (95.25 mm) and a length of 1.34 in (34.5 mm). An extremely rigid crankshaft is used with webs 1.5 in (40 mm) wide and reciprocating masses are balanced to 85 %. Cylinder centres are 8.97 in (228.6 mm) apart, i.e. 1.56 D. The general layout of the engine is shown in Fig. 393.

3. The Deutz Engine

Deutz engines are being produced in a standardized range comprising single to four-cylinder units as well as six- and eight-cylinder units. The technical data of the range are given in Table 48. The basic cylinder of the range has a bore of 110 mm and a stroke of 140 mm. The swirl chamber of this engine has been mentioned previously and is apparent in the transverse section of

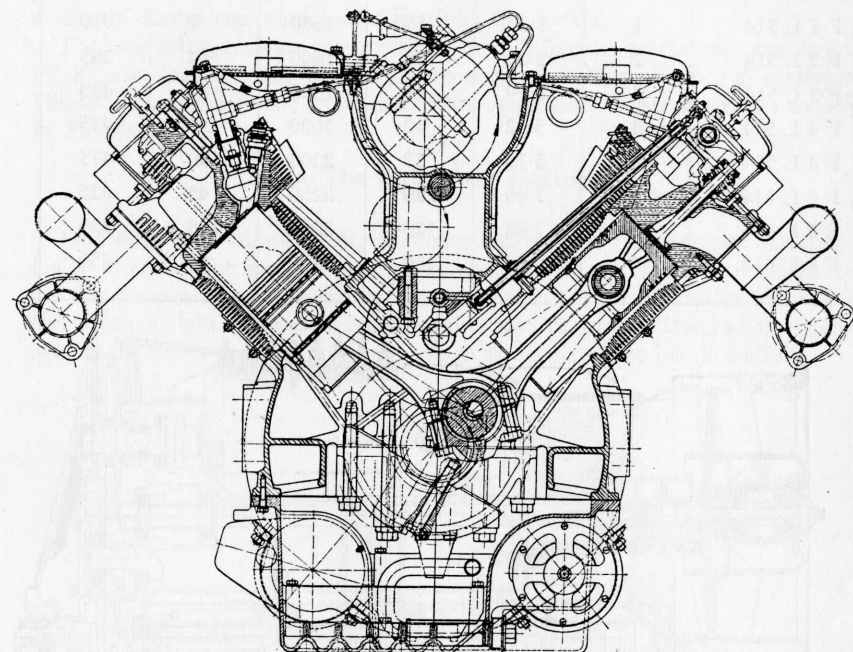


FIG. 394. Transverse section of the eight-cylinder Deutz engine.

the eight-cylinder engine in Fig. 394. An electric glow plug is fitted in the chamber to facilitate starting. The cylinder head was designed with a view to the possibility of conversion for running on substitute fuels. Figs. 216 and 217 show a section through the four-cylinder unit.

The eight-cylinder unit has two banks of cylinders at an angle of 90°, resulting in regular firing intervals which make it possible to attain satisfactory engine balancing. The crankcase is extended at its upper extremity to form a cradle in which the injection pump is mounted, the accessibility of the latter from above thus being very good and the rigidity of the former being enhanced. The crankshaft is seated in plain bearings which somewhat increases the overall length of the engine. The timing gear drive is

Specifications of Deutz Engines

Table 48

	Number of cylinders	Displacement litres	Performance b.h.p.	Speed rev/min	Maximum torque kgm	Weight kg
F 1 L 514	1	1.33	15	1650	7	330
F 2 L 514	2	2.66	30	1600	14	385
F 3 L 514	3	3.99	45	1600	21	430
F 4 L 514	4	5.32	60	1600	30	475
F 4 L 514	4	5.32	82	2300	30	475
F 6 L 514	6	7.98	120	2250	45	625
F 6 L 614	6	7.98	120	2250	45	725
F 8 L 614	8	10.64	160	2250	60	850

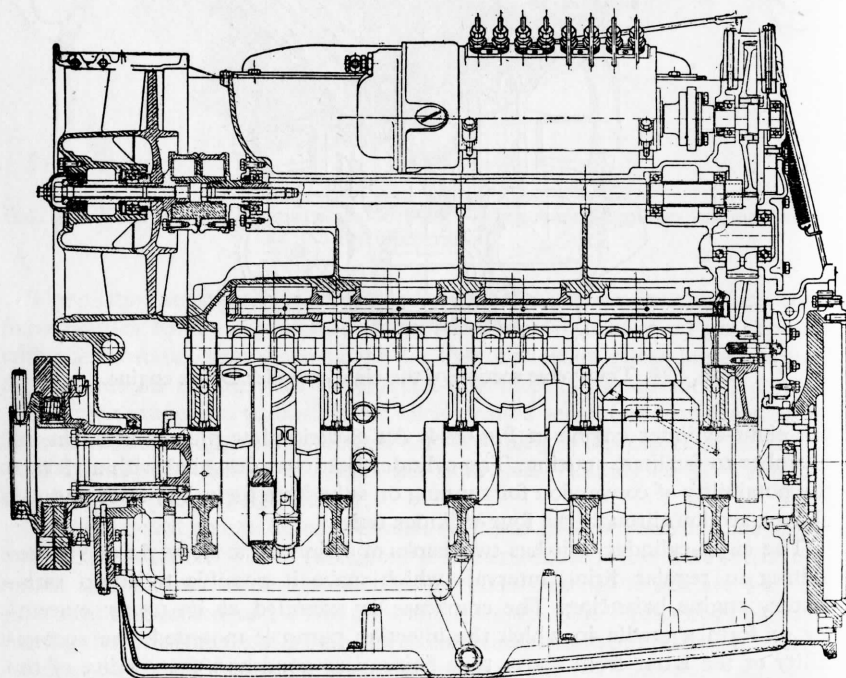


FIG. 395. Longitudinal section of the eight-cylinder Deutz engine.

from the flywheel end i. e. from the vicinity of the nodal point of torsional vibration, which is particularly beneficial for the injection pump drive.

The axial fan is also driven from the flywheel end through gears and a long inclined shaft with flexible coupling. The fan supplies air at a pressure of 210 mm water column and works at an efficiency of 70 %. The consumption of air is 35.3 ft³/b.h.p.h (1 m³ per b.h.p./h). The six-cylinder engine is produced both as an in-line unit and as a V engine (range 64). It is interesting to note that the V engine is heavier by 220 lb (100 kg), the difference being evidently due to the much wider spacing of cylinders.

The connecting rods are mounted side-by-side in pairs on common crankpins (V 8) and inclined big end caps are used. A friction damper of torsional vibrations is fitted to the front end of the crankshaft. Other details are shown in Fig. 395.

4. The Guiberson Engine

This air-cooled nine-cylinder compression-ignition radial engine was originally intended for aircraft use but its characteristics did not prove suitable for that purpose. It did, however, prove suitable as a prime mover for tanks, for which a light air-cooled radial engine was required. The radial engine proved its worth despite its height, which is excessive for use in tanks.

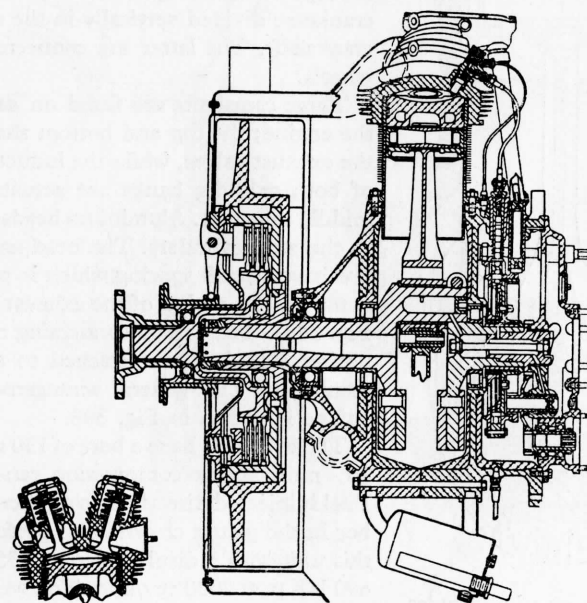


FIG. 396. Section of the Guiberson engine.

The engine has a bore of 130 mm and a stroke of 140 mm, the displacement being 16.74 cm³ and performance 265 b.h.p. at 2260 rev/min, which results in a weight: performance ratio of 2.3 lb/b.h.p. (1.1 kg/b.h.p.), the weight of the engine being 693 lb (290 kg).

Each cylinder is fitted with its own injection pump. The combustion chamber is lentil-shaped and the nozzle is located at its periphery. An axial fan mounted direct on the crankshaft is employed (this being an advantage of the radial engine). The air-cooled Continental radial petrol engine was also employed for the same purpose. The design of the Guiberson engine is shown in Fig. 396.

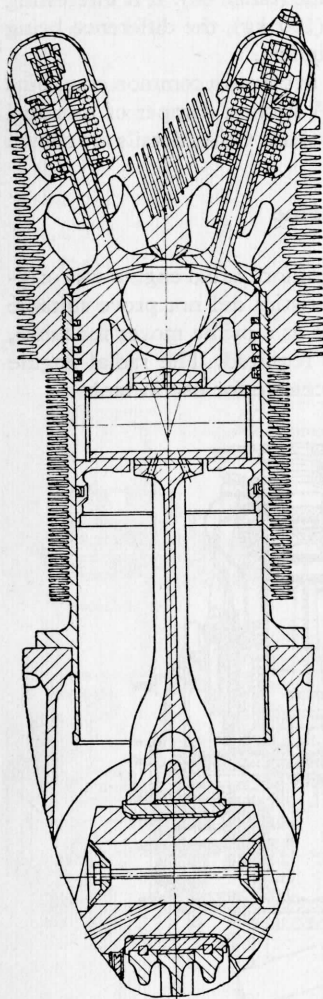


FIG. 397. Section of a cylinder of the MAN compression-ignition engine.

5. The MAN Engine

The 16-cylinder MAN engine is an interesting design of a compact tank engine. Owing to limited space and accessibility the cylinders of the engine are arranged in the unusual H shape. In fact, the unit consists of two superposed flat 8-cylinders with a common crankcase divided vertically in the axis of the crankshaft. The latter are connected by gear wheels.

Three camshafts are fitted on each side of the engine; the top and bottom shaft operate the exhaust valves, while the induction valves of both cylinder banks are actuated by the middle camshaft. Aluminium heads are bolted to the steel cylinders. The head and cylinder fins have a small spacing which is particularly dense in the region of the exhaust valve (see Fig. 397). The forked connecting rods of opposing cylinders are attached to a common crank pin. The general arrangement of the engine is shown in Fig. 398.

The cylinders have a bore of 130 mm, stroke 165 mm, and a compression ratio 15.5 : 1. Fuel is injected directly into a spherical chamber in the piston crown. The performance of this unit with a displacement of 35.1 litres is 690 b.h.p. at 2000 rev/min. The weight of the engine is 3400 lb (1545 kg) which corresponds to a weight: performance ratio of 4.9 lb/b.h.p.

(2.24 kg/b.h.p.). Supercharging by a mechanically driven centrifugal supercharger, which would result in a performance of 900 b.h.p., was also considered.

The development of this engine was not completed.

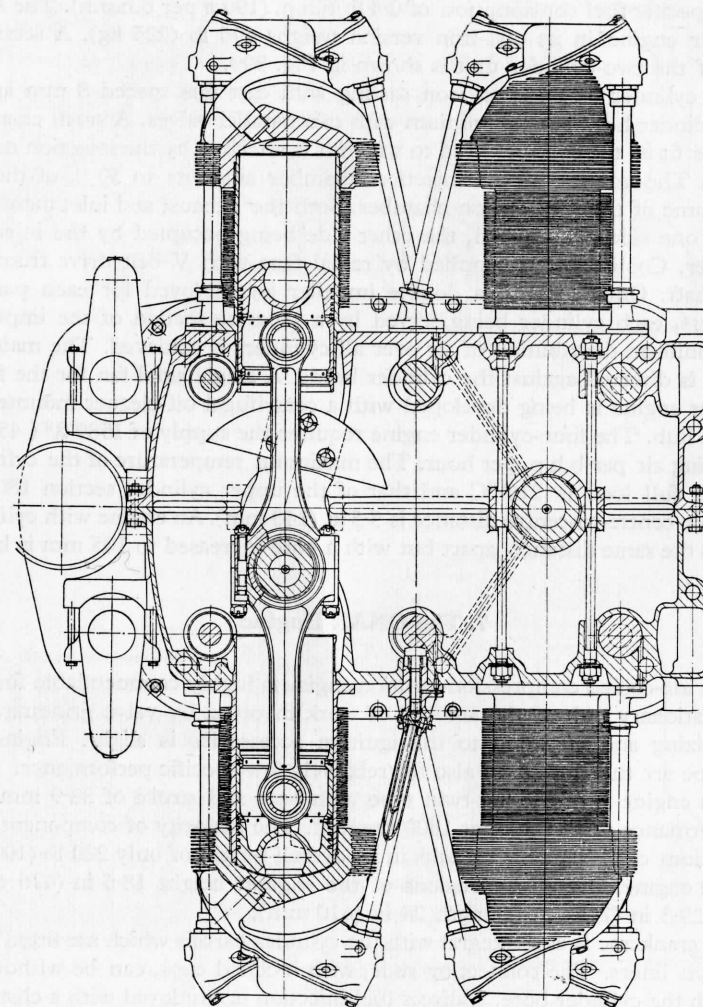


FIG. 398. Transverse section of the sixteen-cylinder MAN engine.

6. The N.A.T.I. Engine

A development of the Soviet Tractor Research Institute (N.A.T.I.) is a two- or four-cylinder unit with compression-ignition. The bore of the two-cylinder DV 13 type engine is 90 mm, stroke 115 mm. The performance of this unit is 14 b.h.p. at 1600 rev/min. The four-cylinder DV 30 unit has a bore of 92 mm and stroke of 120 mm and its performance is 32 b.h.p. at 1600 rev/min and a specific fuel consumption of 0.4 lb/b.h.p. (190 g per b.h.p.h). The four-cylinder engine in its cast-iron version weighs 496 lb (225 kg). A sectional view of the two-cylinder unit is shown in Fig. 399.

The cylinder barrel is an iron casting with cast fins spaced 8 mm apart. The cylinder head is of aluminium with two parallel valves. A small chamber is a free fit in the cylinder head to which it is attached by the injection nozzle carrier. The volume of the injection chamber amounts to 30 % of the total volume of the combustion chamber. Both the exhaust and inlet manifolds are on one side of the head, the other side being occupied by the injection chamber. Cooling air is supplied by radial fans with V belt drive from the crankshaft. One fan with a double impeller is employed for each pair of cylinders, each cylinder being served by a separate section of the impeller. Thus uniform distribution of air over all cylinders is achieved. The main air stream is directed against the cylinder heads. A single axial fan for the four-cylinder engine is being developed with a centrifugal oil-cleaner mounted in the fan hub. The four-cylinder engine requires the supply of 1589 ft³ (45 m³) of cooling air per b.h.p. per hour. The maximum temperature of the cylinder head at full load is 210 °C and that of the upper cylinder section 180 °C. Cylinder centre-to-centre distance is 5.5 in (140 mm). An engine with cylinder centres the same distance apart but with a bore increased to 105 mm is being tested.

7. The ONAN Engine

This air-cooled compression-ignition engine is highly commendable for use as a stationary unit as the amount of work involved by valve grinding, decarbonizing and attention to the ignition accessories is slight. Engines of this type are therefore used also for relatively low specific performance.

This engine is of the flat-twin type with bore and stroke of 88.9 mm and a performance at 12 b.h.p. at 1800 rev/min. The majority of components are aluminium castings, which results in an overall weight of only 220 lb (100 kg) for the engine. Overall dimensions of the engine: height 18.6 in (476 mm), width 29.3 in (745 mm), length 24 in (610 mm).

The crankcase is cast integral with the cylinder barrels which are fitted with cast iron liners. The connecting rods, with inclined caps, can be withdrawn through the cylinder bore. Indirect fuel injection is employed with a chamber formed directly in the aluminium head. The camshaft is housed above the crankshaft and incorporates cams for the two injection pumps. The large oil

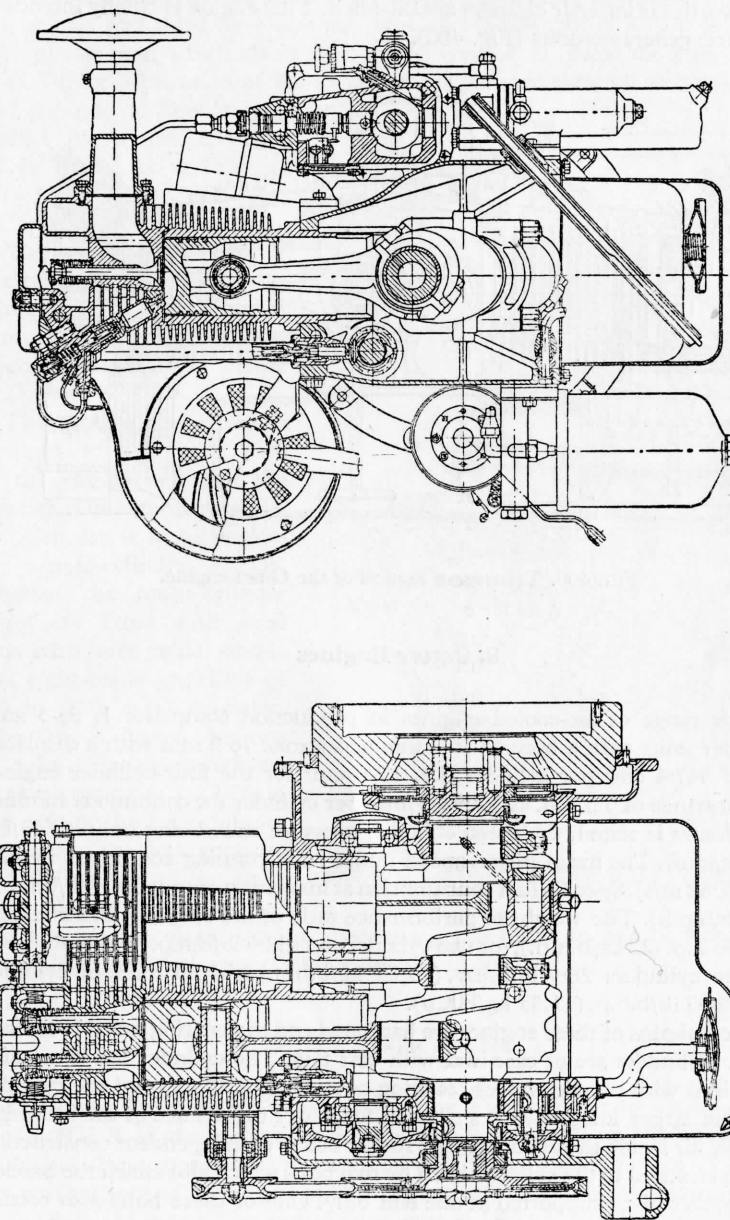


Fig. 399. Longitudinal and transverse sections of the NATI engine.

tank under the engine forms the base of the unit. The large oil cleaner in the tank is worth noting. Air cleaners are oil-filled. This engine is chiefly intended for electric generator units (Fig. 400).

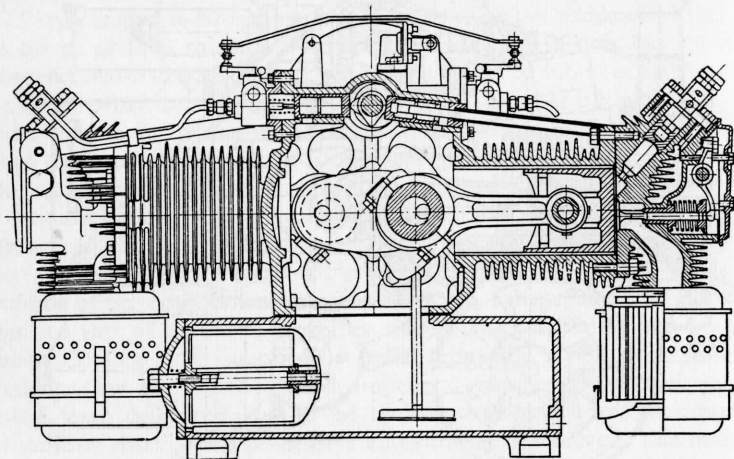


FIG. 400. Transverse section of the Onan engine.

8. Petter Engines

A new range of air-cooled engines in production comprises 1, 2, 3 and 4 cylinder units with a bore of 76.2 mm and stroke 76.2 mm with a displacement of 347.4 cm³ per cylinder, i.e. 1390 cm³ for the four-cylinder engine. A performance of 5 b.h.p. at 3000 rev/min per cylinder for continuous running for 12 hours is stated, the mean effective pressure thus being only 61 lb/in² (4.32 kg/cm²). The mean piston speed under such running conditions is only 25 ft/s (7.62 m/s). Specific fuel consumption at maximum output is 0.5 lb/b.h.p.h (233 g/b.h.p.h). The weight to performance ratio of the single cylinder engine is 48 lb/b.h.p. (22 kg/b.h.p.), for two cylinders it is 32.9 lb/b.h.p. (14.9 kg/b.h.p.), for three cylinders 28.9 lb/b.h.p. (13.25 kg/b.h.p.) and for the four-cylinder engine 24.7 lb/b.h.p. (11.35 kg/b.h.p.).

The crankpins of these engines are hardened and the bearing metal is of lead-bronze. Cylinders are of cast iron with cast fins. The cylinder heads are also of cast iron with parallel valves reaching outward slightly beyond the cylinder wall. The larger inlet valve is shrouded for better turbulence of the incoming charge of air inside the cylinder. The rocker box is of independent construction and it is attached to the cylinder head by two bolts which also attach the bracket of the rocker pivot supported at one end only. One of these bolts also retains the aluminium rocker box cover.

The hemispherical combustion chamber is formed in the piston crown which has cavities for the valves. The upper piston ring is chromium plated, the second and third have oblique faces and the fourth is an oil ring. The fifth piston ring, which also serves for oil control, is below the gudgeon pin boss. Oil for lubrication of the rocker gear is pumped through an outside pipe and the rate of flow is controlled by a needle valve. Valve timing is as follows: IO - 10°, IC - 50°, EO - 45°, EC - 15°.

The injector nozzles are of the twin jet type and are inclined by 30°. The compression ratio is 18.5 : 1 and injection begins 29° before T.D.C.

The cooling air stream is brought to the inlet side of the engine first and the cowling is quickly detachable. A radial fan is employed on the single-cylinder engine, whereas the multi-cylinder types are fitted with axial fans with inlet guide wheels and eight-blade impellers of 7.9 in (203 mm) diameter. The fan is driven by two V belts. The crankshaft-to-blower gearing is 1 : 1.79 in the case of the four-cylinder engine and the static pressure at 5375 rev/min of the fan is only 30 mm water column and the volume of air 1590 m³ per hour. The input to one blower is 1.15 b.h.p. The sectional view of this engine is in Fig. 401.

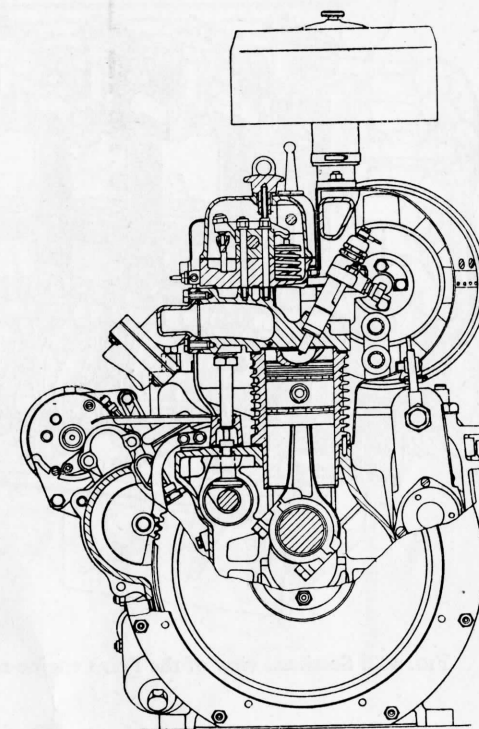


FIG. 401. Transverse section of the Petter engine.

9. The Praga Engine

The Praga Automobile Works manufacture a six-cylinder air-cooled engine for its V 3 S off-the-road truck. This engine is derived from the Tatra range with its 110 mm bore and 130 mm stroke. With a displacement of 7412 cm³, the performance of the engine is 98 b.h.p. at 2100 rev/min. Maximum torque is 260 ft-lb (36 mkg.). The compression ratio is 16.5 : 1. Valve timing: IO - 4°, IC - 50°, EO - 45°, EC - 15°.

IC - 48° , EO - 42° , EC - 10° . The end of fuel injection occurs at 13° to 15° before T.D.C. A diagrammatic sectional view of this engine is shown in Fig. 402.

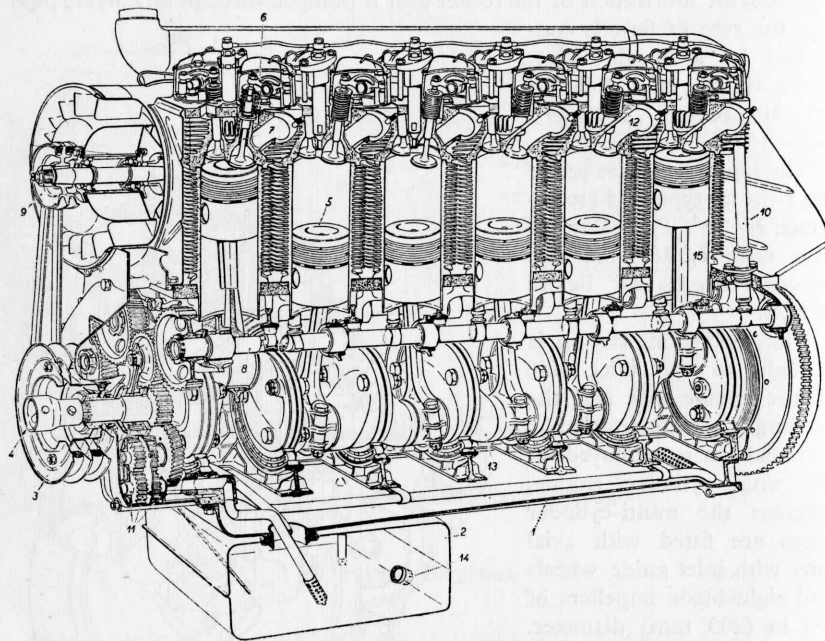


FIG. 402. Sectional view of the Praga engine mounted in the V3S lorries.

10. The Simmering Engine

The general layout of this air-cooled compression-ignition engine is influenced by the fact that it was intended as a prime mover for tanks. In order to keep the engine light and small, the "flattened X" layout was adopted for the sixteen-cylinder engine. With a bore of 135 mm and a stroke of 160 mm, the engine displacement is 36.8 litres. The performance is 750 b.h.p. at 2000 rev/min. The net weight of the engine without the exhaust gas turbine driven supercharger is 4077 lb (1850 kg) and the gross weight 4959 lb (2250 kg).

It is apparent from the sectional drawing of the engine shown in Fig. 403, that each crankpin bears a master rod with three connecting rods. Cast lead-bronze is used for the 3.5 in (90 mm) diameter big end bearing. The crankpins are hardened. Steel cylinders are screwed into aluminium cylinder heads and

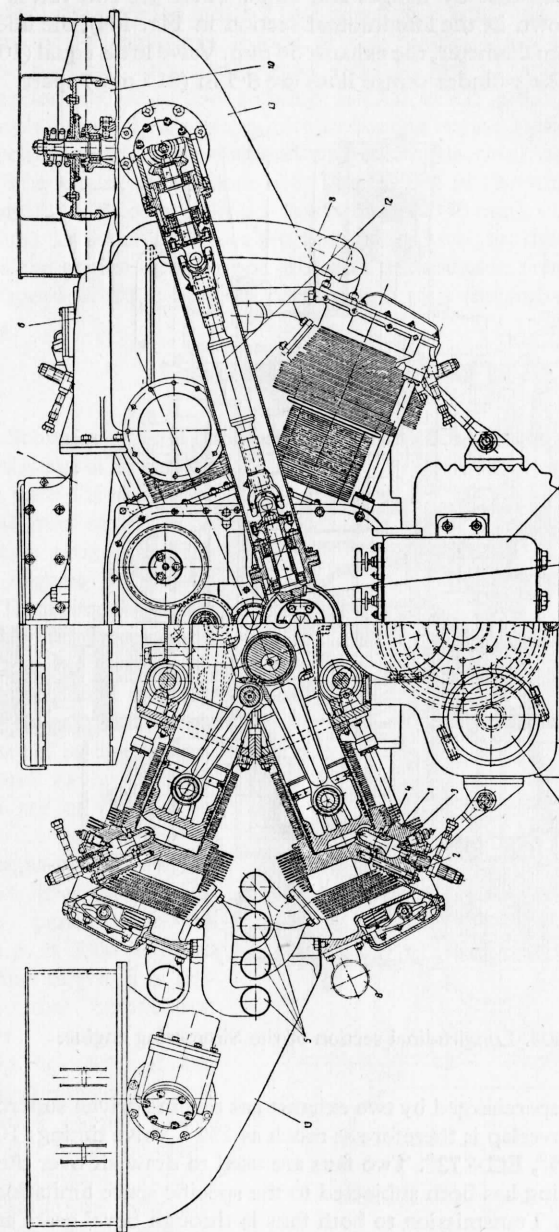


FIG. 403. Transverse section of the Simmering engine.

attached to the crankcase by flanges and bolts. There are two valves in each cylinder head (shown in the longitudinal section in Fig. 404), the inlet valve port being of 60 mm diameter, the exhaust 56 mm. Valve lift is equal (10.5 mm) for both valves. The cylinder centre lines are 8.5 in (215 mm) apart.

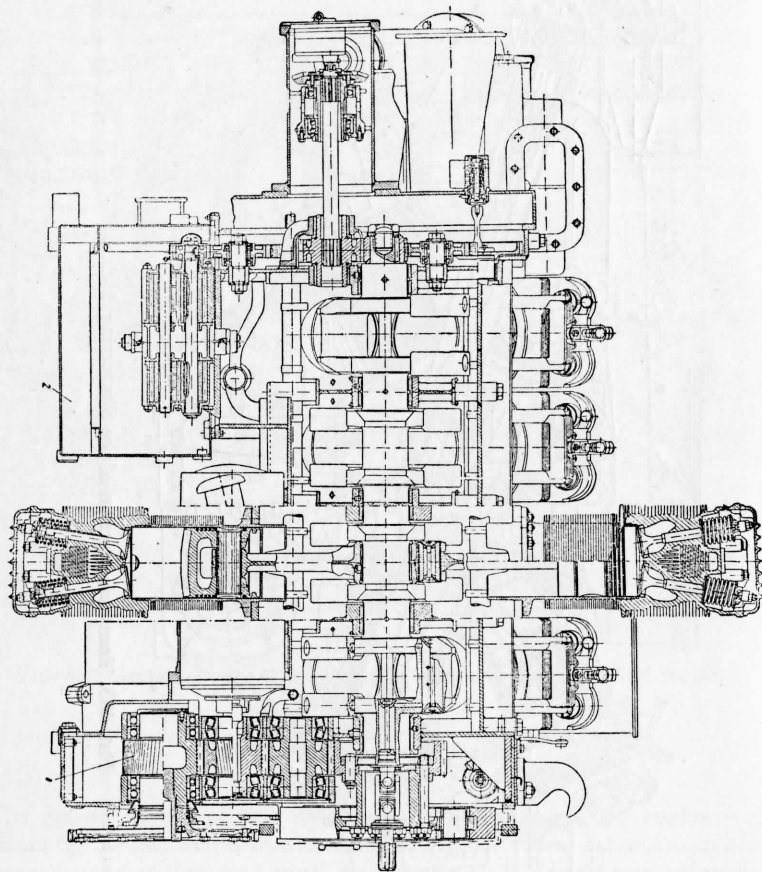


FIG. 404. Longitudinal section of the Simmering engine.

The engine is supercharged by two exhaust gas turbine driven superchargers and valve timing overlap is therefore as much as 135° . Valve timing: IO - 62° , IC - 35° , EO - 45° , EC - 72° . Two fans are used to draw air over the engine and their positioning has been subjected to the specific space limitations of an armoured vehicle. Transmission to both fans is through bevel gears and each has a performance of $212 \text{ ft}^3 (6 \text{ m}^3)$.

A special chamber for indirect fuel injection is employed in the design as is apparent in the transverse section of the engine. Glow plugs are used to facilitate starting. The compression ratio is $14.5 : 1$ and the specific fuel consumption is 0.40 to 0.49 lb/b.h.p. h (200 to 225 g/b.h.p. h). The rate of fuel supply per stroke decreases with increasing engine speed and thus suitable torque characteristics are obtained and cooling is aided at maximum engine speed. The engine dimensions are: height 35.4 in (900mm), length 45.2 in (1150 mm), width over cylinder heads 53 in (1350 mm), overall width 106 in (2700 mm). In order to reduce gearbox size and weight, the intermediate gear between the engine and gearbox increases transmission revolutions so that an engine speed of 2000 rev/min corresponds to a transmission speed of 3000 rev/min.

11. The S.L.M. Engines

The Schweizerische Lokomotiv- und Maschinenfabrik produces a standardized range of air-cooled engines with 110 mm bore and 140 mm stroke. The production programme includes engines in various layouts from single-cylinder to four-cylinder types and four, eight and twelve-cylinder units. Units with up to and including six cylinders are of in-line design, eight- and twelve-cylinder engines are of the flat or V type.

The eight-cylinder engine of 10.64 litres has a continuous performance of 120 b.h.p. at 2000 rev/min. Direct fuel injection is employed, the combustion chamber shape being shown in Figs. 405 and 406. The cylinder head is of cast iron and a copper gasket separates it from the cylinder. The crankshaft runs in plain aluminium bearings.

Air is drawn into the cylinders from the ducting

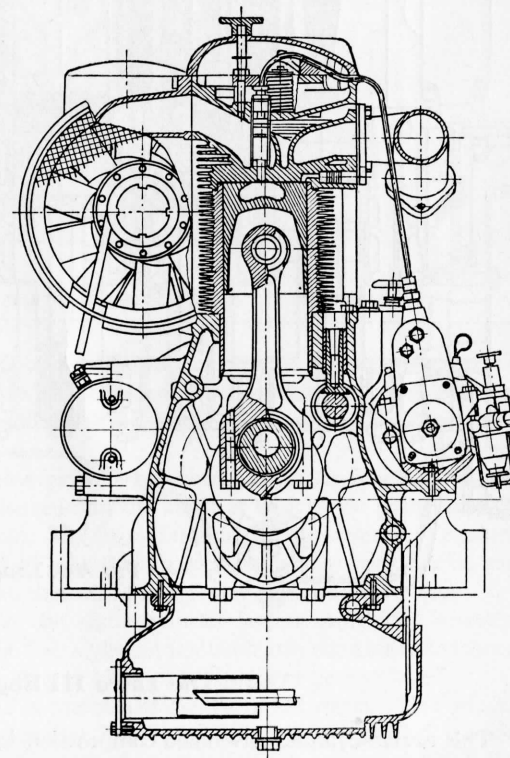


FIG. 405. Transverse section of the S.L.M. engine.

between the fan and engine, thus the slight supercharging effect of the fan is utilized. The oil cooler is mounted in this pressurized zone.

A notable feature of S.L.M. flat engines is the close spacing of cylinders which are only 5.9 in (150 mm) apart, despite the use of plain bearings; this amounts to 1.36 D with a 110 mm bore. Axial fans with two impellers are also used for the flat engines.

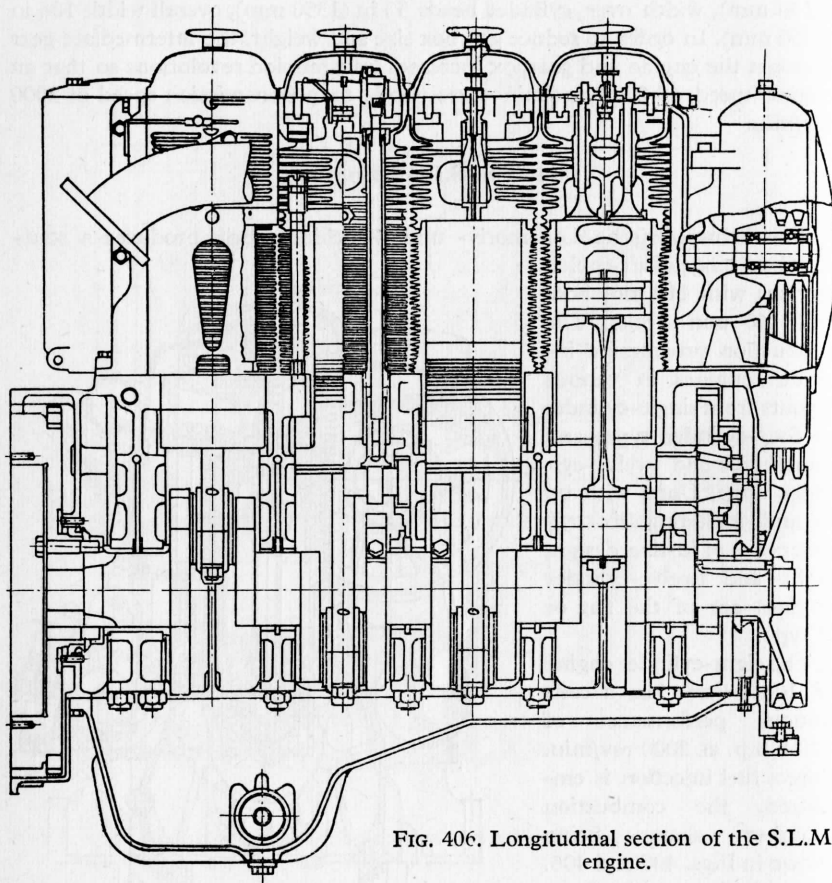


FIG. 406. Longitudinal section of the S.L.M. engine.

12. The Tatra 111 Engine

This twelve-cylinder air-cooled compression-ignition engine has a bore and stroke of 110 mm and 130 mm respectively and a displacement of 14 825 cm³. The cylinders are arranged in two banks at an angle of 75°. This com-

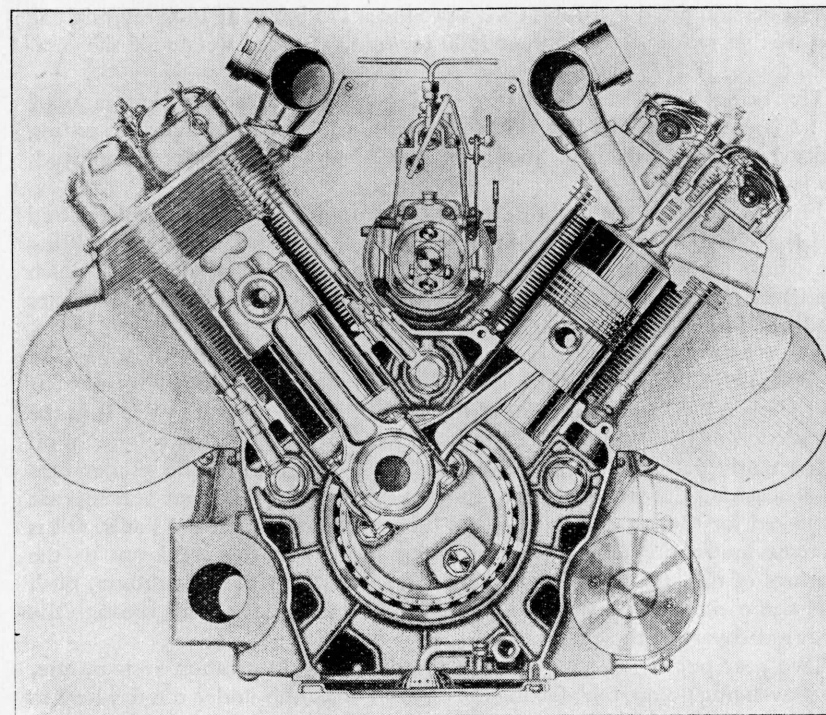


FIG. 407. Transverse section of the Tatra 111 oil engine.

paratively wide angle was chosen in order to provide sufficient space for the injection pump between both banks and also to make it possible to use the same angle for eight- and twelve-cylinder engines of the same basic range.

This twelve-cylinder engine is well balanced, as an in-line six-cylinder engine is inherently well balanced and the angle at which two such units are mounted is of no consequence. The firing intervals are however not regularly timed 60° apart, but 75° and 45°. As their succession is very rapid in the case of the twelve-cylinder engine, this slight irregularity is no disadvantage.

Similar conditions exist in the eight-cylinder layout in which, however, a secondary couple of both the four-cylinder in-line banks remains unbalanced. A crankshaft with crankpins spaced 180° must therefore be employed.

Direct fuel injection is used in the case of the Tatra 111 engine. The original hemispherical combustion chamber has been replaced by one of toroidal shape with high turbulence (Fig. 407). A maximum performance of 220 b.h.p. is supplied at 2250 rev/min.

The version fitted in 10-ton trucks produces 175 b.h.p. at 1800 rev/min and that used in railcars 160 b.h.p. at 1500 rev/min. The dry weight of the complete engine is 2173 lb (986 kg).

The firing order is 1-8-5-10-3-7-6-11-2-9-4-12. A compression ratio of 17 : 1 is employed. The injection pump with a fixed end-of-injection setting is fitted with 8 mm diameter plungers. A five-jet injection nozzle is employed, the jet diameter being 0.25 mm.

In order to facilitate starting, an injection timing override control is fitted and the injection pump drive incorporates a special dog clutch, permitting the pump to be cranked with the engine at rest – an arrangement which facilitates starting at very low temperature. The injection (opening) pressure is adjusted to 2844 lb/in² (200 kg/cm²).

The six-throw crankshaft is mounted in seven oversize roller bearings. As is apparent in the longitudinal section of Fig. 408, oil enters the crankshaft via the plain bearing at the front of the engine. As the pressure valve is in the last section of the crankshaft (adjacent to the flywheel), a large volume of oil is constantly flowing through the crankshaft, not permitting the temperature of oil reaching the last big-end bearing to rise excessively. Plain bearings are employed for the big-end with a lead-bronze lining of the steel shells. Oil is brought under pressure through passages drilled in the crankcase to the bearings of the camshafts from where it flows through the valve lifters, push rods and rockers to the valve. It returns from the cylinder heads through the push rod covers to the crankcase.

Two gear pumps are employed in the dry sump lubrication system, one, the scavenging pump, transferring the oil from the sump under the flywheel to the oil tank, the other, lubricating pump, drawing the oil from the oil tank and forcing it to the lubricated parts.

The timing gear comprises three camshafts. They and the fuel injection pump are driven from the crankshaft by spur gears. The engine is cooled by two axial fans for which the drive was originally arranged from the camshafts by roller chain and torsion bar, but which are belt driven from the front end of the crankshaft in the last modified type. The V belt also drives the reciprocating compressor mounted on the front engine cover. In the new version of the engine, dynamos are mounted in the hubs of the axial fans; their dashboard charging lights also signal the correct operation of the fans.

The induction manifold on the original engine was on the outward side of the cylinder banks, but on new engines the exhaust manifold faces outward. This modification resulted in a uniform distribution of temperature over the cylinder heads which are of aluminium alloy.

The tunnel-type crankcase is of cast iron. The engine is overhung on a flange at the flywheel end which connects it with the gearbox.

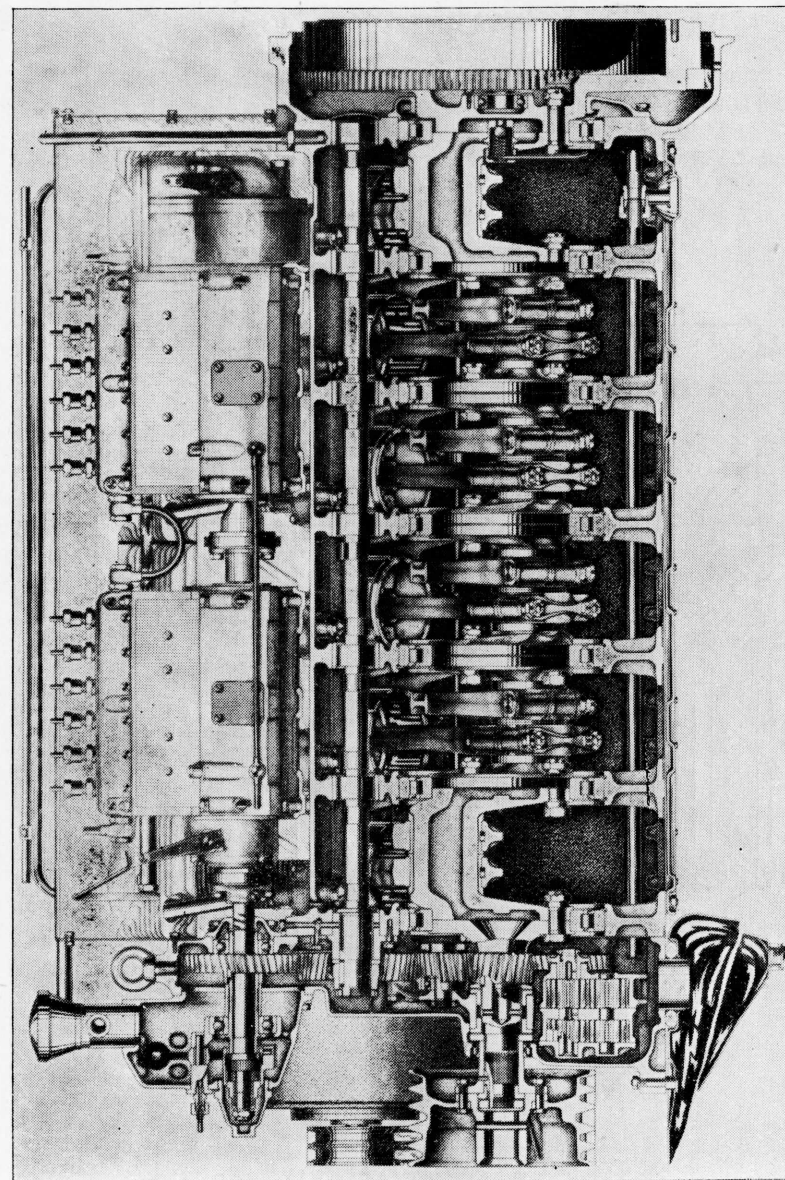


Fig. 408. Longitudinal section of the Tatra 111 oil engine.

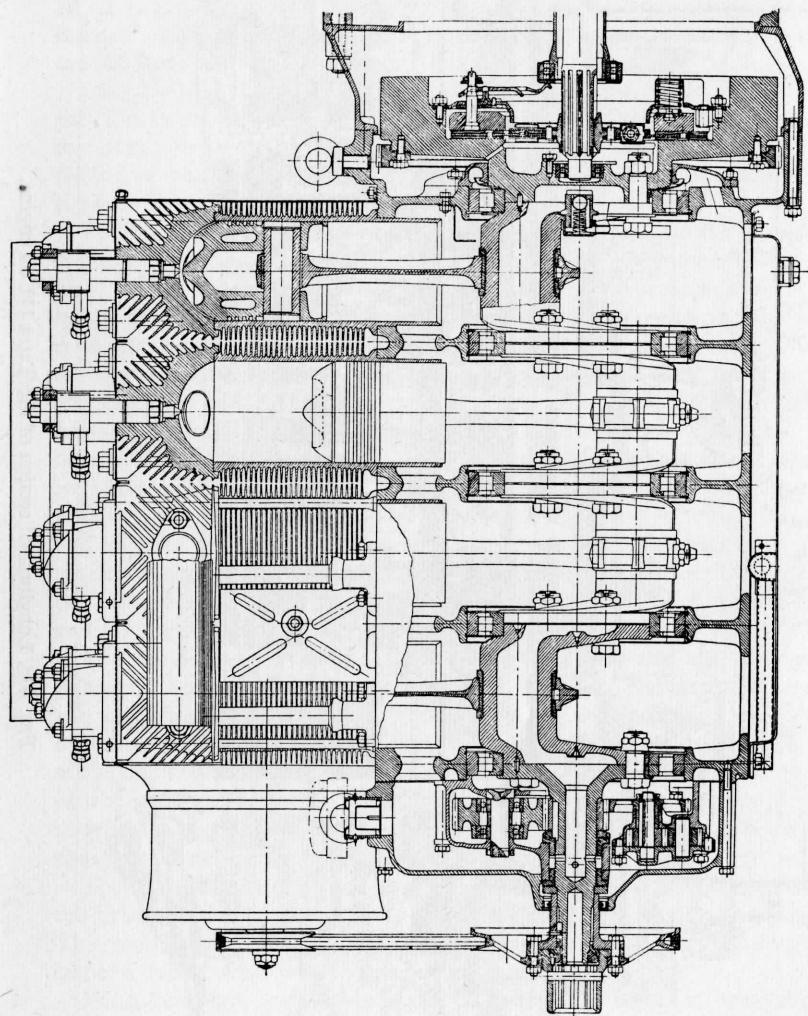


FIG. 409. Longitudinal section of the Tatra 114 engine.

13. The Tatra 114 Engine

This in-line four-cylinder engine is derived from the twelve-cylinder Tatra 111 engine the basic parts of which are used. Complete cylinders, valve gear and crank mechanism are interchangeable with the larger unit. With a bore of 110 mm and a stroke of 130 mm, the displacement is 4940 cm³ and the

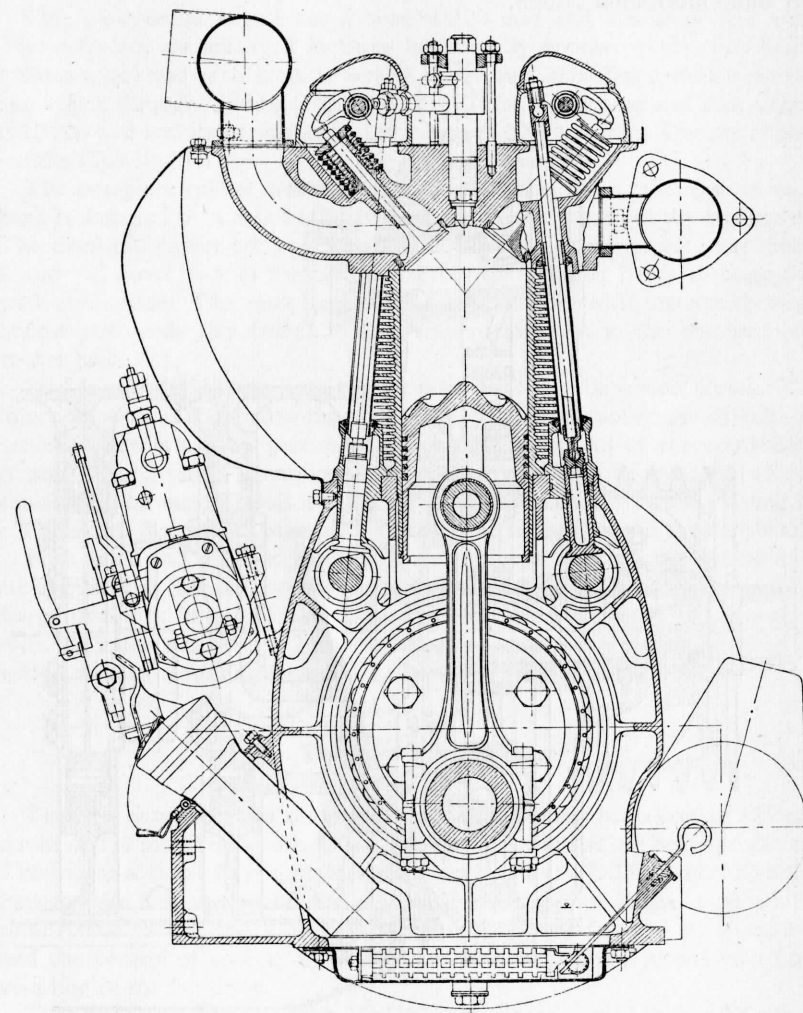


FIG. 410. Transverse section of the Tatra 114 engine.

performance at 2000 rev/min is 65 b.h.p. The weight of the engine including accessories is 1113 lb (505 kg).

The tunnel crankcase is of cast iron and the crankshaft is seated in five roller bearings.

The cylinders are spaced, as in the V engines, 6.1 in (155 mm) and thus sufficient room is available for the big-end bearings (Fig. 409). A single oil pump driven by gears from the front end of the crankshaft, is used in the wet sump lubrication system.

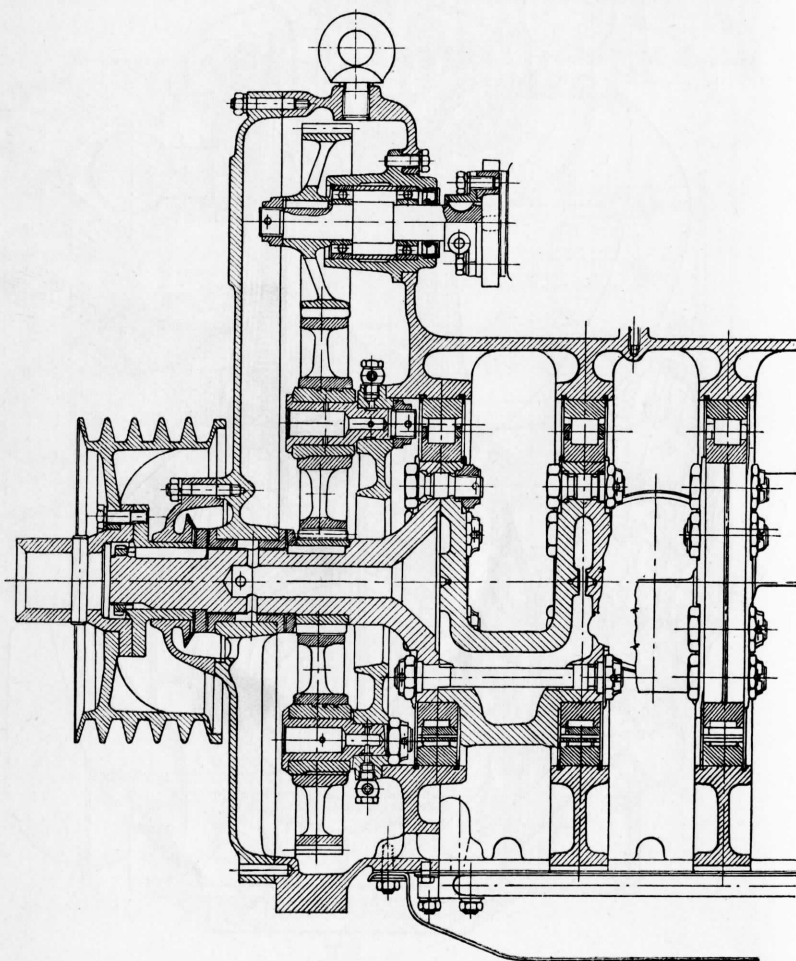


FIG. 411. Longitudinal section of the Tatra 116 engine.

Cooling is by an axial fan for which the drive is taken off the front end of the crankshaft and transmitted by a V belt. The injection pump is mounted on the same side of the engine as the fan. Fig. 410 shows a transverse section of this engine in its older form.

14. The Tatra 116 Engine

This six-cylinder engine has a bore of 120 mm and stroke of 150 mm. The cylinders are arranged in three horizontally opposed pairs (this being a flat engine) and each bank is served by its own axial fan driven from the crankshaft through V belts (Figs. 265, 411). The displacement of this engine is 10 200 cm³ and its performance 130 b.h.p. at 2000 rev/min. The dry engine weighs 1543 lb (700 kg).

The one-piece tunnel crankcase is an iron casting. The valve gear of each bank is actuated by a camshaft driven by a toothed gear from the crankshaft. The overhead valves are parallel and the injector is located between them. Return oil flows back to the crankcase from the cylinder heads through the push rod covers. The valve gear is lubricated in the usual manner through hollow push rods and drilled rockers which supply oil to the flattened ball rocker pads.

Fuel is injected directly into the toroidal cavity in the piston crown. The injection pump is attached to the upper side of the crankcase and is driven – as are the camshafts – by gear wheels from the front end of the crankshaft. A gear-type oil pump is employed and it is driven from the front end of one camshaft. The supply of oil is stored in the crankcase sump. Oil is cleaned by a multi-edge filter and a pressure warning light is provided on the dashboard.

Both inlet and exhaust manifolds are upswept against the direction of cooling air flow. The six-throw crankshaft is supported in seven roller bearings. Large openings in the crankcase base permit the withdrawal of connecting rods. Cylinder centres are 7.81 in (200 mm) apart. The engine is designed with a view to mounting it under the frame of a seven-ton truck.

15. The New Tatra Range

The new range of Tatra compression-ignition engines has a bore of 120 and stroke of 130 mm. Units with 1, 2, 4, 6, 8 and 12 cylinders are being produced. The technical data of these engines are given in Table 49. The main difference between the new range and the old lies in the use of a single camshaft for timing both in-line and V engines, the use of a single fan also for V engines and the control of cooling by a variation of fan speed by means of a fluid coupling in the fan drive.

The cylinder centre lines are 6.1 in (155 mm) apart, i.e. 1.29 D. Parallel valves are employed in the aluminium cylinder head and their plane is at a considera-

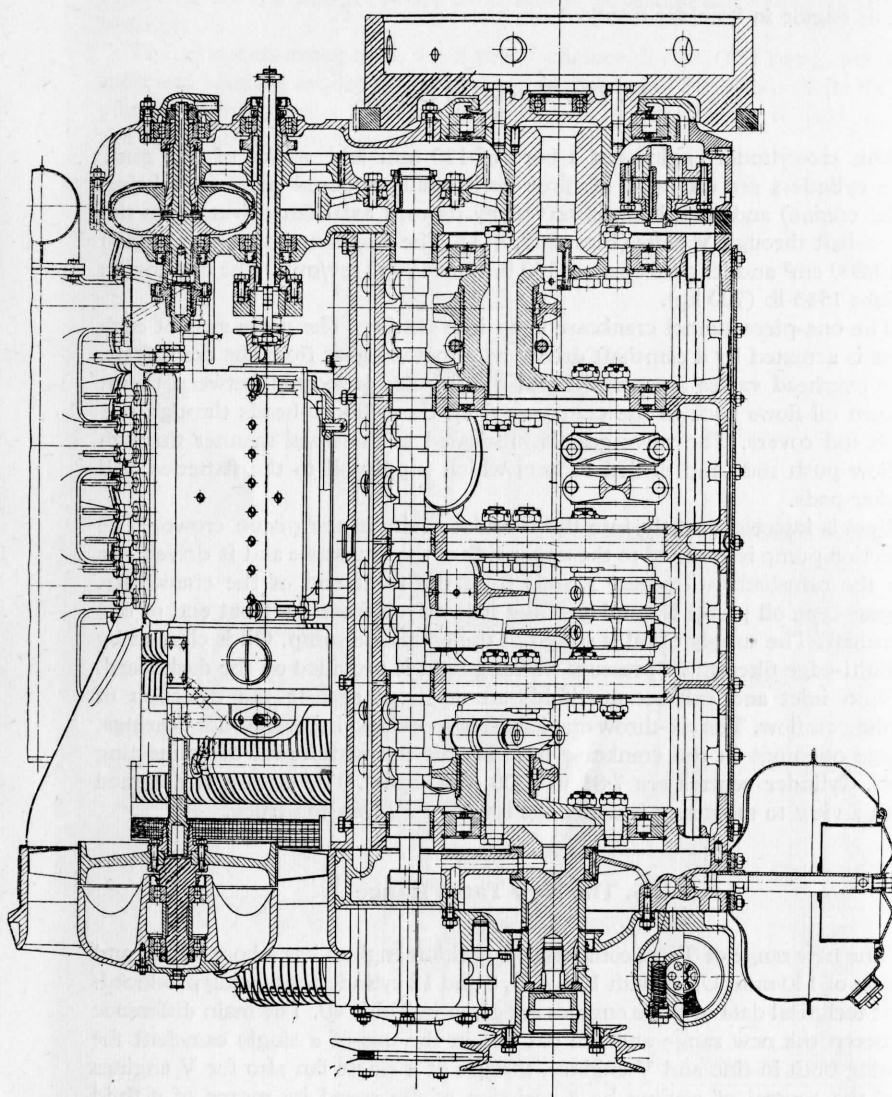


FIG. 412. Longitudinal section of the Tatra 928 engine.

Air-Cooled 120 mm Bore Tatra Engines

Table 49

Type	924	926	928	930
Number of cylinders	4	6V	8V	12V
Bore, mm	120	120	120	120
Stroke, mm	130	130	130	130
Engine displacement, cm ³	5,876	8,814	11,752	17,628
Compression ratio	16.5	16.5	16.5	16.5
Performance, b.h.p.	80	132	180	270
Speed, rev/min	2,000	2,000	2,000	2,000
Unit performance, b.h.p./litre	13.6	15.0	15.3	15.3
M.e.p., kg/cm ²	6.1	6.75	6.9	6.9
Mean piston velocity, m/s	8.7	8.7	8.7	8.7
Weight of dry engine, kg	450	560	595	900
Unit weight, kg/b.h.p.	5.6	4.25	3.3	3.3
Length of engine, mm	970	911	1,066	1,163
Width of engine, mm	654	958	958	958
Height of engine, mm	970	994	994	994

ble inclination from the crankshaft axis which arrangement has the advantage of a sufficient air flow area despite the close grouping of the cylinders. Both exhaust and inlet pipes in the cylinder head are kept short. The injection nozzle is almost concentric with the cylinder and a central combustion chamber in the piston crown is employed. The injection pump, camshaft and blower are driven from the flywheel end of the crankshaft, where torsional vibration of the crankshaft is at its lowest. The fan is driven through gears and a fluid coupling which regulates the speed of the fan. In a cold engine the coupling is not filled with oil and slip occurs. As the engine warms up, a thermostat placed in the stream of cooling air coming from the cylinders opens the oil inlet valve to the coupling, which becomes filled with oil and the slip is reduced to a low percentage. The fan then supplies the full amount of cooling air. This fluid-coupling control is reliable in operation and no wear occurs.

The rear end of the crankshaft also drives the dual oil pump, one section of which pumps the oil from the flywheel end of the crankcase to the oil tank in the front part of the engine and the other supplies oil under pressure from the tank, through a cooler and cleaner to the engine. A dog clutch is incorporated in the fuel injection pump drive permitting turning of the injection pump while the engine is stationary. When starting from cold it is thus

possible to inject, prior to turning the engine, a sufficient amount of fuel oil into the cylinders to dilute the oil on the cylinder walls and thus to provide more favourable conditions for a cold start. The arrangement is apparent in the longitudinal section of the Tatra 928 engine in Fig. 412. The transverse section through this engine (Fig. 413) shows the arrangement of the injection pump and blower drive.

The crankshaft is built-up from steel castings and is housed in roller bearings. The tunnel-type crankcase forms a rigid foundation for the two banks of cylinders which are arranged at an angle of 75° . The same basic parts are employed for the derived six-cylinder engine (Fig. 414) and the twelve-cylinder engine (Fig. 415). It is intended to fit exhaust gas turbine superchargers to the eight- and twelve-cylinder engines in order to raise their performance. Highly favourable weight to power ratios will thus be obtained. The four-cylinder unit, for operation under extremely unfavourable conditions such as in combined harvesters, is equipped with a rotary gauze cooling air inlet filter which is self-cleaned by compressed air supplied by a reciprocating compressor (Fig. 117).

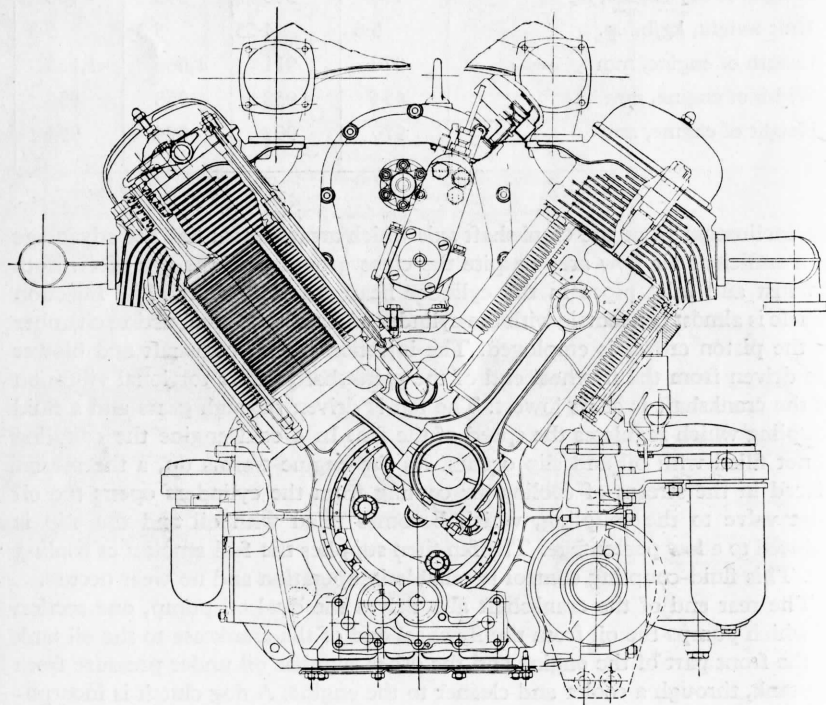


FIG. 413. Transverse section of the Tatra 928 engine.

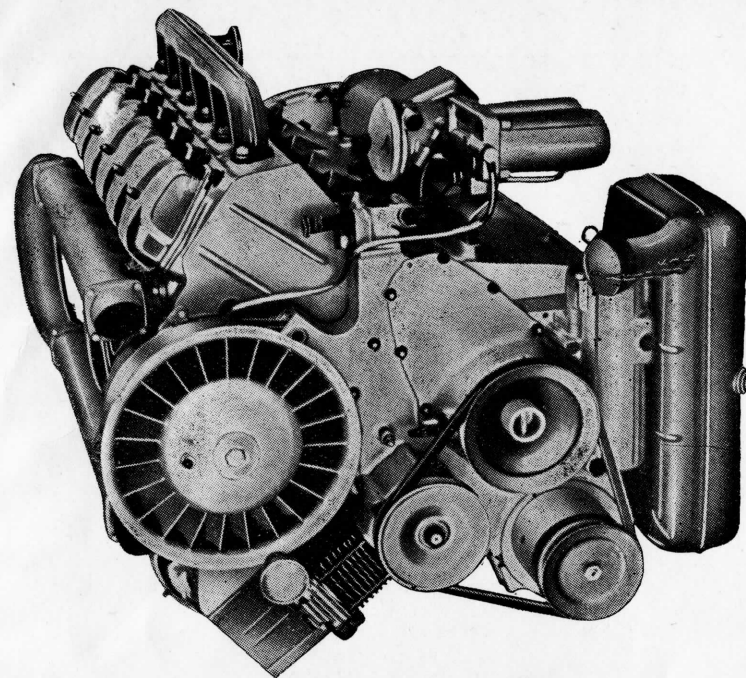


FIG. 415. Twelve-cylinder Tatra 930 engine.

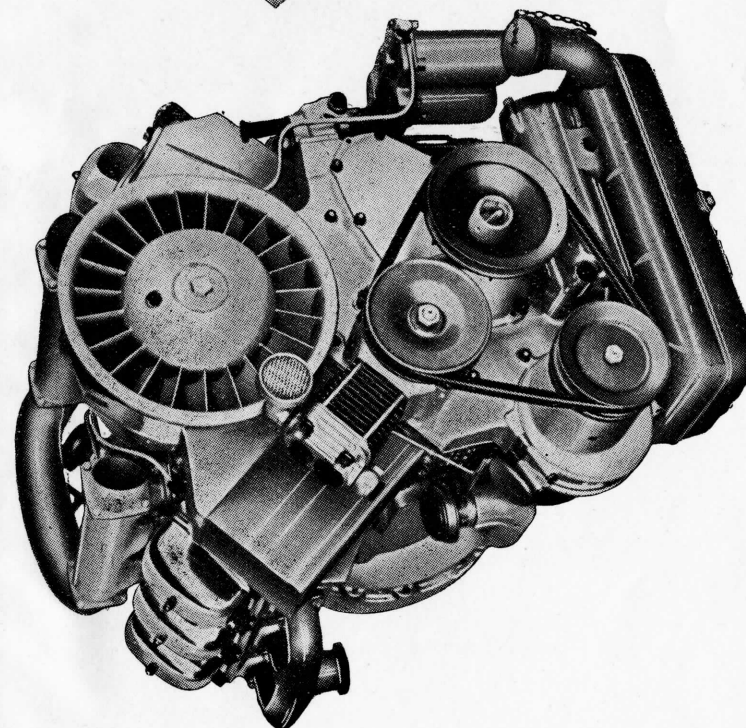


FIG. 414. Six-cylinder Tatra 926 engine.