MERCEDES-BENZ D.B.601N

EXAMINATION OF THE ENGINE FITTED TO THE Me 109F, Me 110, He 113, AND MACCHI C200

By G. GEOFFREY SMITH, M.B.E.
(Exclusive Illustrations by M. A. Millar)

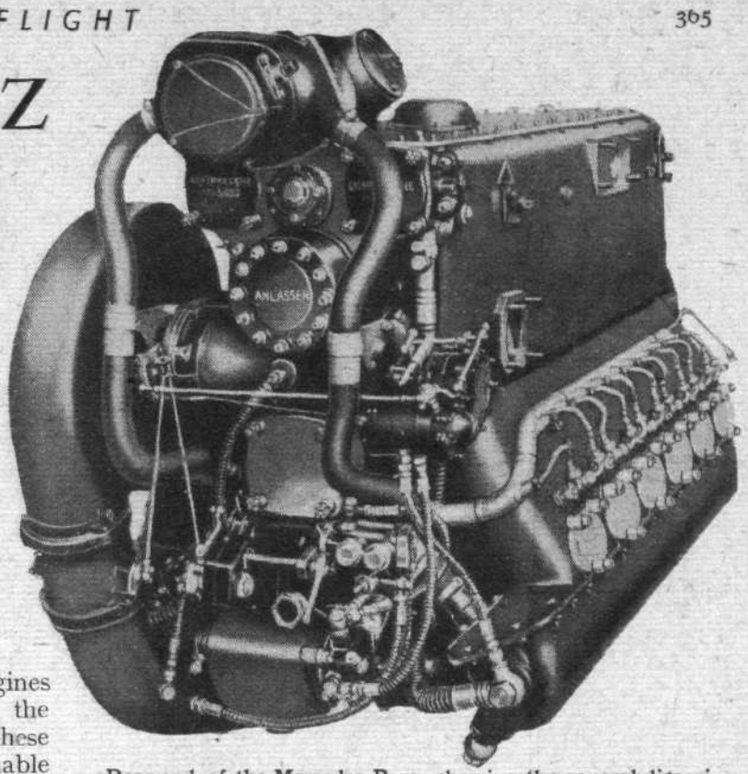
SPECIMENS of the newest German liquid-cooled engine brought down over this country have been stripped for inspection by aircraft engineers. By courtesy of the Ministry of Aircraft Production, *Flight* has examined several of these engines captured intact, and is pleased to add details to the series of aircraft engines already reviewed in these columns. Features of the engine include a variable speed supercharger, direct petrol injection into each cylinder by mechanical pump and injectors, and the inverted V cylinder layout common to German "in-line" engines, with provision for a cannon firing through the airscrew hub.

Famous aircraft engines which have been described and illustrated in *Flight* in recent months include the Bristol Hercules (November 27th, 1941), the Rolls-Royce Merlin XX (February 26th, 1942), and the Allison C.15 (March 26th, 1942). Each engine represents the highest development in design in their particular class, the liquid-cooled "in-line" types, including engines produced in Britain and America respectively.

These detailed particulars of Germany's most noted engine of the liquid-cooled type—the Mercedes-Benz D.B.601N—provide students of design with information and illustrations from which many interesting comparisons of the power units of various countries can be made.

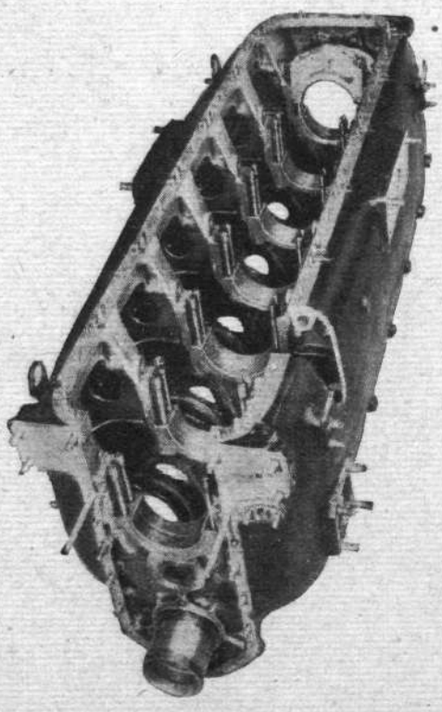
D.B.601N, of which some details of earlier examples brought down in this country were given in *Flight* of November 7th, 1940, differs most notably from the Merlin or Allison in that it is an inverted power unit, as indeed are all other service "in-line" engines of German origin. Its capacity of 33.9 litres (bore and stroke 150 × 160 mm.) is much larger than either the Merlin (27 litres) or the Allison (28.1 litres), but smaller than the fourteen-cylinder Hercules (38.7 litres). The net dry weight is 1,400lb. and with all accessories 1,540lb. Notable for its rugged design, the engine has a compression ratio of 7·9 to 1.

German engine designers have always favoured large cylinder capacity and lower boost pressures than are employed on British engines. In other words, the power developed is little greater than our own engines of smaller capacity, but being larger they naturally present a greater frontal area than British engines. The engine under review is approximately 68in. long. Routine maintenance is not easy with German engines, which may account for the special study of easy means of detachment and replacement. Auxiliaries for that reason are always mounted on the engine unit. It is estimated that overhaul of the engine is needed every 100 hours so that ready interchangeability is of paramount importance.



Rear end of the Mercedes-Benz, showing the general disposition of the supercharger, magneto and other auxiliaries. The main air duct from the supercharger is connected to a gallery induction pipe between the two inverted banks of cylinders.

The twelve cylinders, in banks of six, are set at 60 deg. to the crankshaft which drives the airscrew shaft through a pair of gears housed in a casing at the front end of the crankcase. A second important feature which characterises the Daimler-Benz is the hollow airscrew shaft through which a cannon fires from a mounting at the rear end of the engine. It seems safe to assume that the necessity of providing room for the cannon for armament purposes has influenced the basic design of the engine, especially in regard to the auxiliaries at the rear, in contrast to the layout of the Merlin or the Allison. A third point which constitutes a major difference is the system of direct injection of fuel into the cylinders, a practice employed on all German service engines.

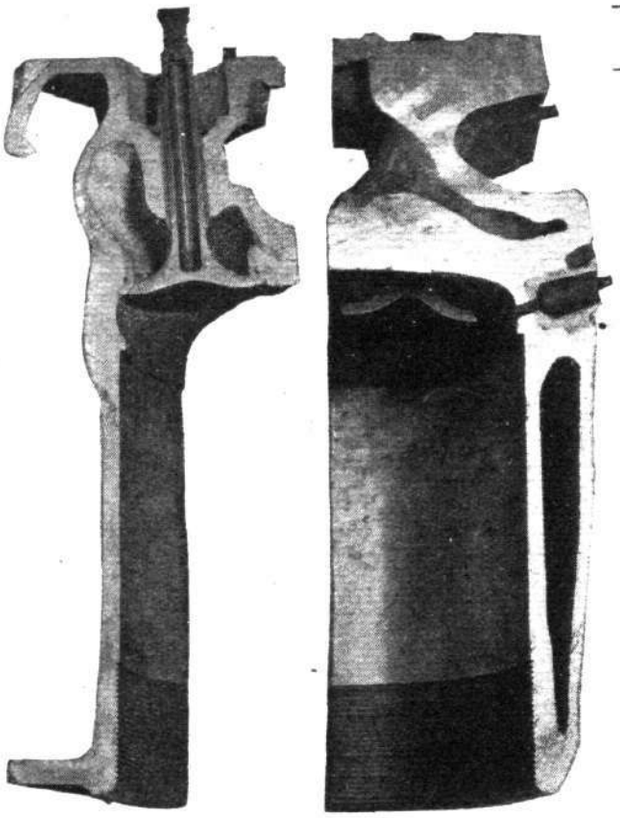


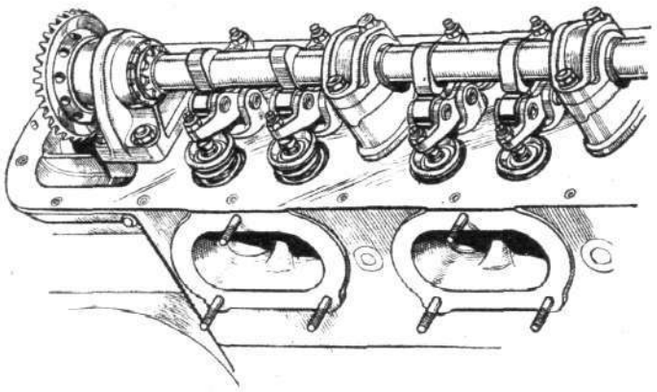
The crankshaft is carried in seven lead-bronze bearings in the crankcase, which is well braced with ribs and is of considerable strength. In the lower side can be seen the tubular mounting through which the cannon fires.

Internal Details

The cylinder blocks are one-piece alloy castings, which include the cylinder barrels, water jackets, cylinder heads and valve pockets, and passages for the four valves to each cylinder. Into each barrel is screwed a cylinder liner in dry contact with the cylinder block, and when the block is fitted into position, the six liners project into the crankcase. A ring, internally threaded on to screwed portions of the projecting sleeve, and with gear teeth cut in its outer face, is utilised to pull each cylinder sleeve inwards against machined faces on the inside of the crankcase.

MERCEDES-BENZ D.B.601N





(Left) A section of the D.B.601N cylinder block sawn through to show design of cylinder walls, coolant passages, valve ports and valves. (Above) The single camshaft on each cylinder block operates two inlet and two exhaust valves per cylinder, shown reversed. Rollers are interposed between cams and rockers.

Thus the cylinder block, as a whole, is fixed to the crankcase by six rings per block, and there are no rubber gaskets, either in the block or in its assembly in the crankcase. In order to rotate the rings for assembly or dismantling, a special tool, fitted with a small gear wheel, is engaged with the gear teeth cut in the rings and then rotated by hand. The coolant circulated in the cylinder jackets is water, with the addition of 50 per cent. glycol as an anti-freeze.

The crankcase is of considerable depth, and the cover on top is a flat duralumin lid held in place by a number of small studs and nuts. A six-throw balanced crankshaft, weighing 150 lb., runs in seven plain lead-bronze bearings, and each bearing structure is stiffened by a transverse rod across the crankcase webs above the bearings, and is retained by external nuts. The main bearing of each pair of connecting rods on the crankpin has three tracks of rollers (72 rollers per bearing), retained in split duralumin cages, but the single-blade connecting rod has a plain lead-bronze bearing only, over the outside of the roller bearing.

Elaborate precautions have been taken by special serrated joints in the halves of both forked and plain rods to register the bearings for accurate assembly and smooth working, and the retaining nuts are splined (not machined hexagonally) for special tools during assembly. Three compression and two scraper rings are fitted to each of the pistons, which have concave heads, and the gudgeon pins float in the piston bosses, domed ends being fitted to prevent scruffing of the cylinder walls. The gudgeon-pin phosphor-bronze bearings are a fixture in the connecting-rod small-ends.

The airscrew reduction gears are of normal design, but are contained in a very short and compact housing—

Components of the supercharger, including the impellor and unit carrying diffuser vanes.

the pinion on the crankshaft having 36 teeth engaging with 56 teeth on the airscrew shaft gear wheel (1.55 to 1 ratio). Another type has a ratio of 1.88 to 1. A feature of the D.B.601 and other German aircraft engines is that the airscrew and its hub are attached direct to the reduction-gear shaft by a serrated face-to-face joint, and not in the normal manner by an horizontally splined coupling between the hub and airscrew shaft.

Two Cams for Four Valves

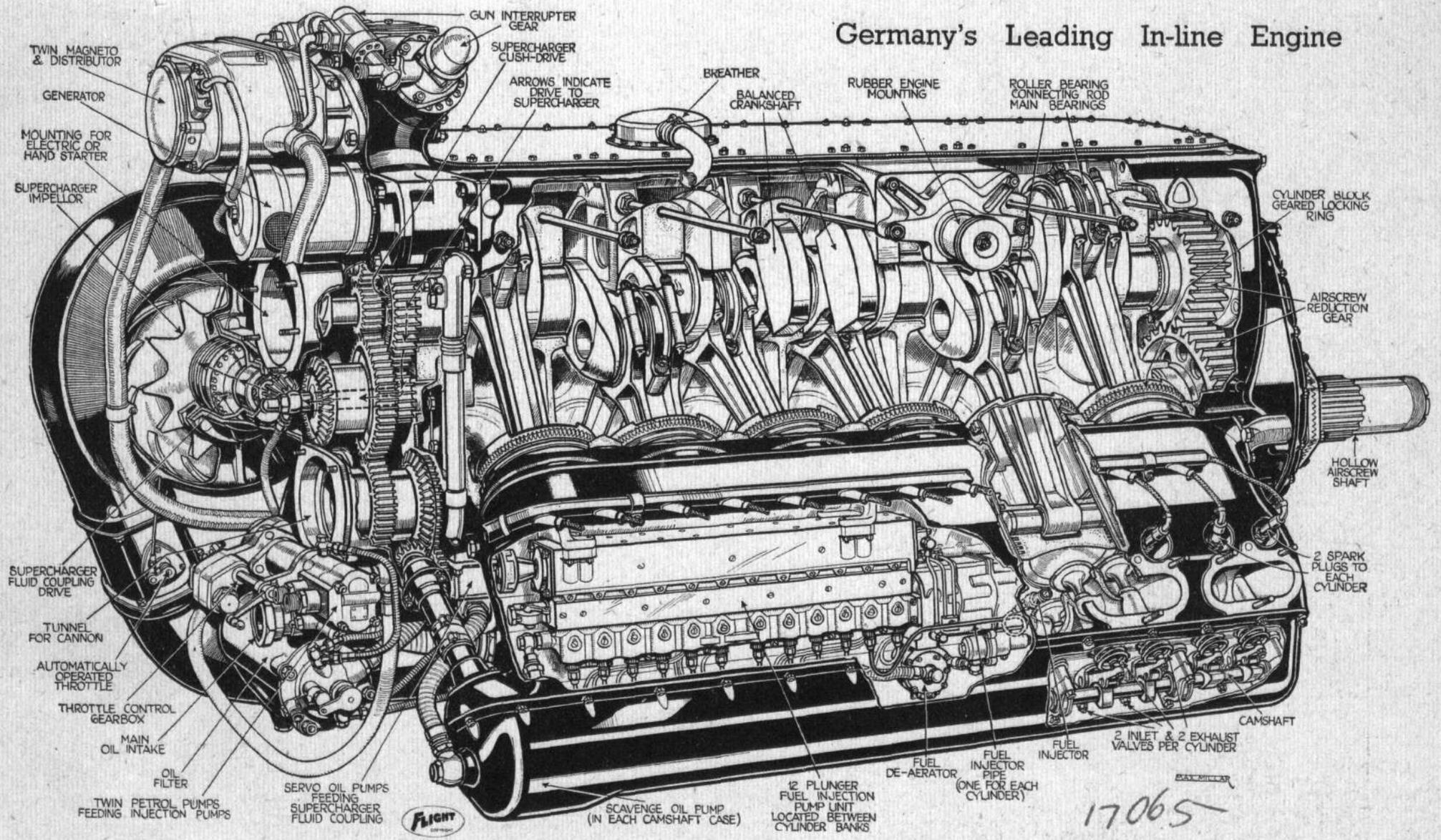
Two inlet and two exhaust valves are fitted to each cylinder in inserted valve seats—both inlet and exhaust valves being stellited—while the exhaust valves are sodium cooled. The valves are operated through short rockers, and ball joints are interposed between rocker and valve stem. One cam successively operates an inlet and exhaust valve per revolution through the arrangement of rockers, thus two cams only are required for the four valves. Two sparking plugs per cylinder are located on the outer side of the engine, and their firing points are directly opposite to the fuel-injection nozzle in the combustion chamber.

Being inverted, the Mercedes-Benz engine has no sump, and oil draining from the crankshaft and connecting rods gravitates through fore-and-aft drain pipes to the lowest point in the crankshaft casings (rear end), where scavenge pumps driven from the camshaft pass the oil back to the oil tanks.

Since clear fore-and-aft space is required for the mounting of a cannon at the rear of the crankcase, the supercharger has necessarily had to be mounted with its impellor axes transverse to the centre line of the engine to place the bulk of the supercharger volute casing on one side, and not in the positions found in the Merlin XX, Allison, or other "in-line" engines. As no carburettor

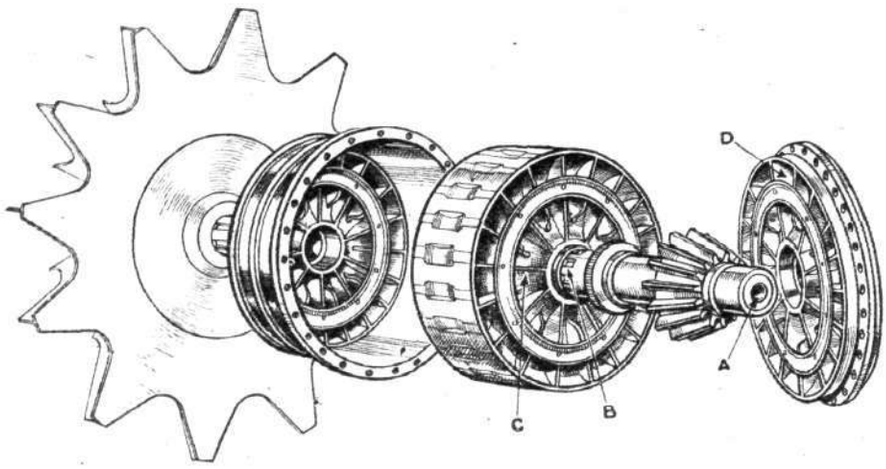
THE INVERTED V TWELVE CYLINDER D.B.601N

Germany's Leading In-line Engine

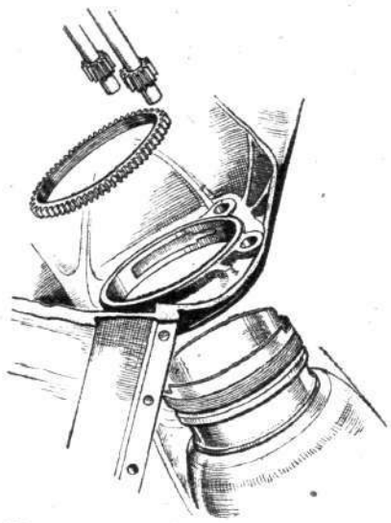


Part-sectional drawing of the liquid-cooled D.B.601N of 33.9 litres, bore and stroke 150 × 160 mm. Features of the engine are the twelve plunger in-line direct injection pump, and the fluid coupling which provides an infinitely variable gear for the supercharger drive. B.H.P. at 2,600 r.p.m. is 1,270, which for a weight of 1,540 lb. = 1.20 lb./h.p.

MERCEDES-BENZ D B.601N



Components of the fluid coupling which provides the infinitely variable drive for the supercharger impellor.



When the cylinder blocks are in position on the crankcase two hand-operated spindles and pinions are employed to rotate the geared locking rings when the latter are screwed in position on the cylinder liners.

exists on the Mercedes-Benz, the supercharger can be mounted on the engine, but a bevel gear operating at high speeds has to be introduced to transmit the drive through a right angle to the impellor, which rotates at approximately 10.39 to 1 crankshaft speed.

Fluid Supercharger Drive

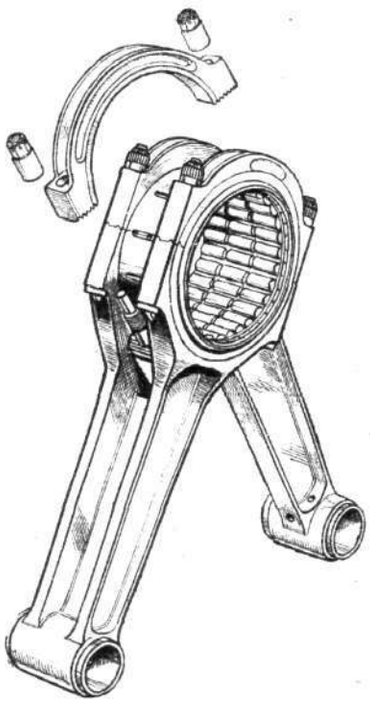
Four gear wheels and a fluid coupling comprise the driving mechanism of the supercharger. At the rear end of the crankshaft, a large gear wheel transmits the drive through a spring-loaded cush hub to a smaller gear wheel mounted on a fore-and-aft layshaft. At the rear end of this layshaft is a crown bevel wheel engaging with a small bevel pinion which rotates the driving end of the fluid coupling. The driven side of this coupling is splined to the impellor, and the complete coupling and impellor runs in ball bearings.

From previous descriptions published in *Flight*, it will be recalled that oil is fed into the fluid coupling by two engine-driven pumps, one maintaining a constant oil supply suitable for operating the supercharger at ground level and low altitude, while the second pump supplies extra oil for higher altitudes. Oil is supplied to the coupling through the hole A and then passes out of the shaft B through small holes to the curved passages C of the driving member. By centrifugal action the oil is flung into the passages of the driven member D and so provides a fluid drive. This form of hydraulic drive is duplicated on the opposite end of the unit to balance end thrust. The coupling is thus an infinitely variable gear, with a minimum slip of 2½ per cent. under the most favourable conditions of drive. It provides lower boost pressures at sea level and automatically increases the boost as altitude increases at or above the supercharged height.

The supercharger forces air through a pipe of large diameter to a gallery induction pipe between the cylinder blocks, which feeds the cylinders via elongated passages to the inlet valves.

Direct Fuel Injection

A fuel-injection pump unit, having 12 plungers in a row, is located under the engine between the cylinder blocks, and a 3 mm. bore steel pipe is fitted between each pump and a fuel injector in one of the cylinders. Fuel is injected at 15-20 lb. per sq. in. into the combustion chambers. The pump plungers are operated by 12 cams on a camshaft within the pump body, the camshaft being rotated by gears at the rear end of the crankcase at half crankshaft speed. A twin gear-type pump at the rear of the engine supplies fuel under pressure to the injection pump from the main petrol tanks in the aircraft, and between these two pump units is fitted a de-aerator for abstracting air from the fuel before the latter reaches the injector pumps.



One pair of Mercedes-Benz connecting rods. The main big-end bearing has three tracks of rollers, while the bearing of the single blade rod has a lead-bronze liner.

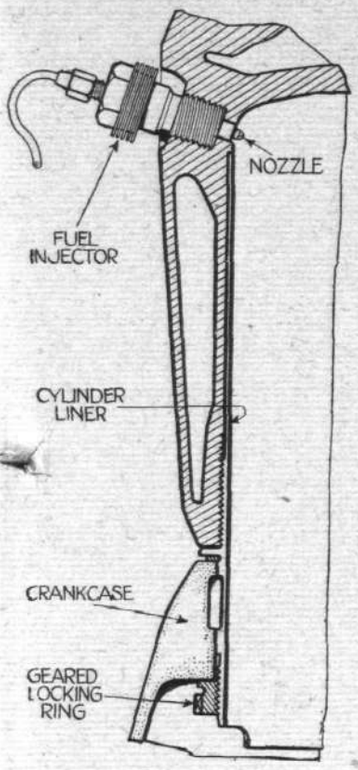
For the purpose of injecting fuel into the cylinder, the injector nozzle unit is of complicated construction and is built up of a number of parts shown in the sectional drawing. In addition to an internal labyrinth filter for the fuel, there is a spring-loaded non-return valve to eliminate combustion pressure reaction on the fuel flow, and also internal lagging of the fuel nozzle to prevent gassing of the fuel during injection. The complete unit screws into the cylinder block in the same manner as a sparking plug.

Boost Pressure

The ratio of fuel-air supply to the cylinders is governed by the boost air pressure, which, in turn, regulates (by servo action) the precise quantity of fuel metered into the cylinders. Injection is also automatically controlled by altitude conditions, air temperature, etc., also by servo action. Boost pressure is, in the first instance, controlled direct by a throttle located in the pressure air stream between supercharger and cylinders, and operated by the pilot, but a second throttle in the same air flow is automatically actuated by servo mechanism so that, should the boost pressure rise above a certain point, the second throttle overrides the effect of the pilot's throttle, and the engine continues to run under safe conditions of supercharging.

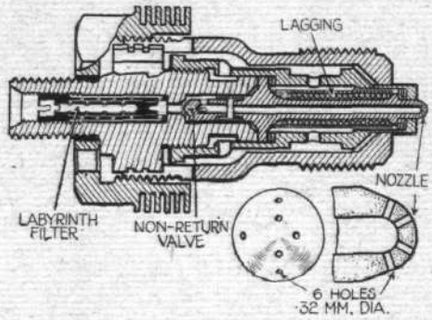
At maximum emergency power of 1,270 b.h.p. at 2,600 r.p.m. at 16,270ft., the boost pressure is 7.81 lb./sq. in. For take-off, at 2,600 r.p.m., 1,200 h.p. is developed with 7.81 lb./sq. in. boost pressure. An in-

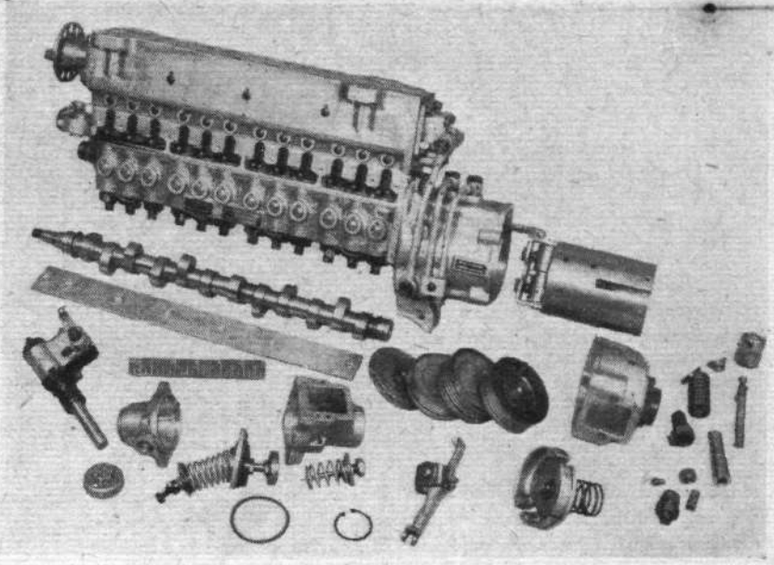
MERCEDES-BENZ D.B.601 N



(Left) The cylinder block is secured to the crankcase by a geared locking ring on each cylinder liner.

(Below) Section of the fuel injector fitted to each cylinder. A 3 mm. bore pipe feeds fuel into the labyrinth filter, from whence the fuel passes a non-return valve to the nozzle provided with six small jets. The lagging is employed to prevent vaporization of the fuel by local heat.





(Above) The Bosch twelve-plunger injection pump and a few of its parts. The camshaft with twelve cams for operating the plungers is of special interest.

genious mechanism allows for increased boost and power for take-off for the duration of one minute. When opening up, the pilot gives an increased movement to his throttle lever, which also operates a clockwork gear in the control mechanism. This clockwork device keeps the throttle at its extra opening until a small slipstream-operated windmill retards the opening at the end of a minute, and the engine then returns to its normal full-throttle power. There is also another mechanism on the engine, interconnected with the throttle and the oil-pressure system, by which the spark plugs are cleaned by temporary advancement of the ignition when the engine has been started up from cold (when the plugs tend to oil up), retardation of ignition to normal being restored shortly afterwards.

Engine Auxiliaries

At the rear of the engine, and driven by gears from the crankshaft, are the gun-interrupter mechanisms (for Me 109), Bosch dual magneto, and electric generator. Electric or hand starters can be bolted to the casing at the rear end of the crankcase below the magneto and driven direct through a dog coupling to the crankshaft. Below the cannon mounting are located the throttle mechanism and main oil filter and fuel pumps, and all external fuel and oil pipes are wire wound and flexible, with banjo connection fittings. The twin delivery centrifugal coolant pump and main oil-pressure pumps are located between the cylinder blocks and in front of the main oil filter.

Net dry weight is 1,400 lb., but with all accessories, coolant header tank, piping and airscrew control gear, etc., the weight is 1,540 lb. Thus, at 1,270 maximum b.h.p. at 2,600 r.p.m., a figure of 1.20 lb./h.p. is obtained.

A feature of German design is quick interchangeability. The D.B. engine designed for rapid detachment and replacement in the aircraft is complete with auxiliaries. It has electron cantilever bearers of sturdy section supported by four rubber-metal reinforced mountings—two high up at the forward end of the crankcase and two at a lower position at the rear.

Carburation Features

In comparing the major features of the Merlin, Allison and Daimler-Benz, it is interesting to note that the three engines have entirely different systems of introducing air and fuel into the cylinders. Whereas carburettors of normal design are fitted to the Merlin, and air-fuel mixture passes as a homogeneous stream through the supercharger, the Allison has a triple venturi carburettor which passes air only to a point in the supercharger intake elbow where it meets a metered flow of fuel issuing from a single jet and supplied under pressure from the fuel pump in the engine, the jet supplying fuel for the 12 cylinders. In the case of the D.B., air only is conveyed direct to the combustion chambers, where it meets the fuel sprayed from the injector nozzles just before the ignition point. A short curved intake on the port side of the engine cowling conducts air through a wire mesh grid to the supercharger impellor.

V.D.M. propellers are used, the motor with its pitch-limit control and filter unit being carried on a bracket supported by the engine crankcase. As the controlling energy is separate from the engine, the airscrew can be feathered with the engine stopped. The blades are interchangeable, and a blade can be removed for inspection and replaced in about 20 minutes. The total weight of the airscrew is 304 lb., including the motor bracket and wiring.

LIQUID-COOLED IN-LINE ENGINES

	Bore	Stroke	Capacity	Comp. Ratio	Horse-power	Weight	Lb. per h.p.
	Inches	Inches	Litres			Lb.	
Merlin XX	5.4	6.0	27.0	6 : 1	1,175 at 2,850 r.p.m. at 17,500ft. 1,240 at 2,850 r.p.m. at 10,000ft.	1,450	1.13
Allison C.15... ...	5.5	6.0	28.1	6.65 : 1	1,090 at 3,000 r.p.m. at 13,200ft.	1,340	1.23
Mercedes-Benz D.B.601 N	5.9	6.29	33.9	7.9 : 1	1,270 at 2,600 r.p.m. at 16,250ft.	1,540	1.20

Companion articles in this series of descriptions of prominent aircraft engines of the war appeared in the following issues :—

BRISTOL HERCULES—November 27th, 1941.

ROLLS-ROYCE MERLIN XX—February 26th, 1942.

ALLISON—March 26th, 1942.