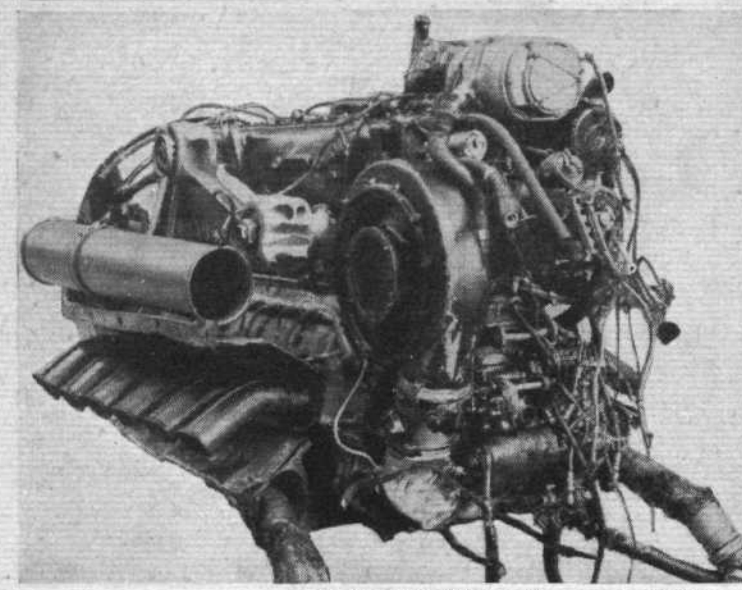
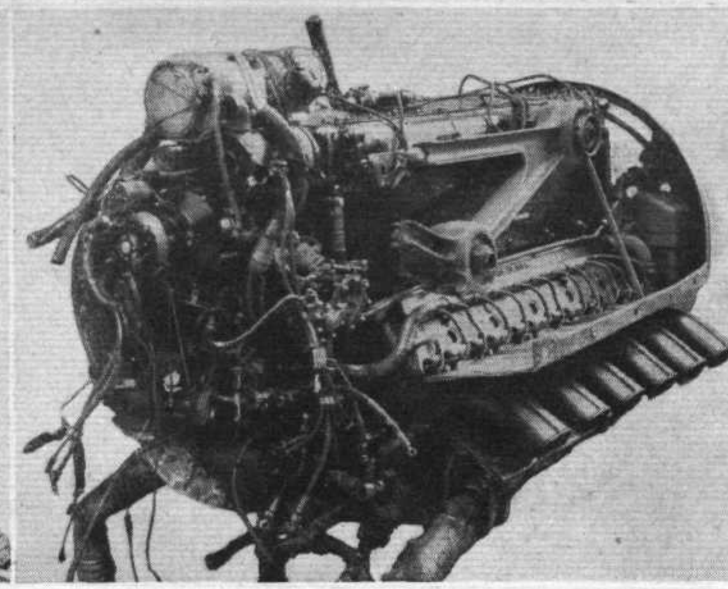
Enemy Aircraft—V.





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Rear view on the port side of the DB 601A. The air intake arrangements and the absence of ejector exhausts indicate the engine is out of a Heinkel He 111K.

In this view of the starboard side more details of the engine mounting can be seen. This is a magnesium alloy forging. The header tank for the cooling fluid will also be noticed at the front of the engine.

AN INVERTED VEE ENGINE

The Mercedes-Benz DB601A : Hydraulic Drive to Supercharger : Clockwork Boost Control : Roller Bearing Big Ends

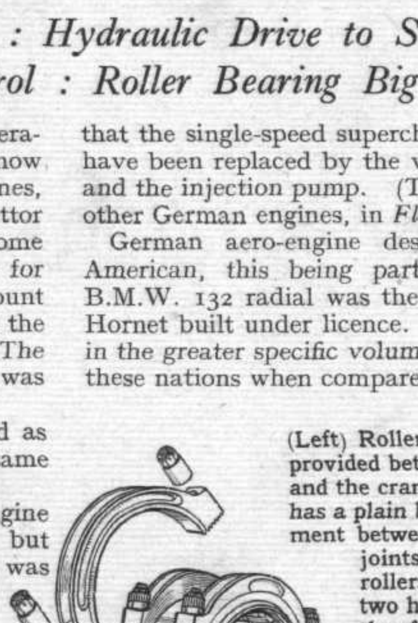
GERMAN military aircraft engaged upon the operational work of fighting or bombing are now exclusively equipped with petrol-injection engines, and the carburettor has been discarded. The carburettor is retained on the smaller engines used in trainers and some of the other non-operational types, but the preference for the injection system is most marked, probably on account of fuel economy and freedom from icing trouble. In the early months of the war carburettors were still in use. The direct-injection system on the Junkers Jumo 211A was described exclusively in *Flight* of January 18, 1940.

Either Mercedes-Benz or Daimler-Benz may be used as the name for the DB 601A engine; they refer to the same design made in different factories.

The inverted-vee type, of which this 12-cylinder engine is an example, is very popular in German design, but radials are also in use, and the Bramo Fafnir, which was previously a carburettor engine, now has petrol injection and is fitted to Dornier Do 215s. This engine has not the hydraulic supercharger drive of the DB 601, but has a two-speed supercharger.

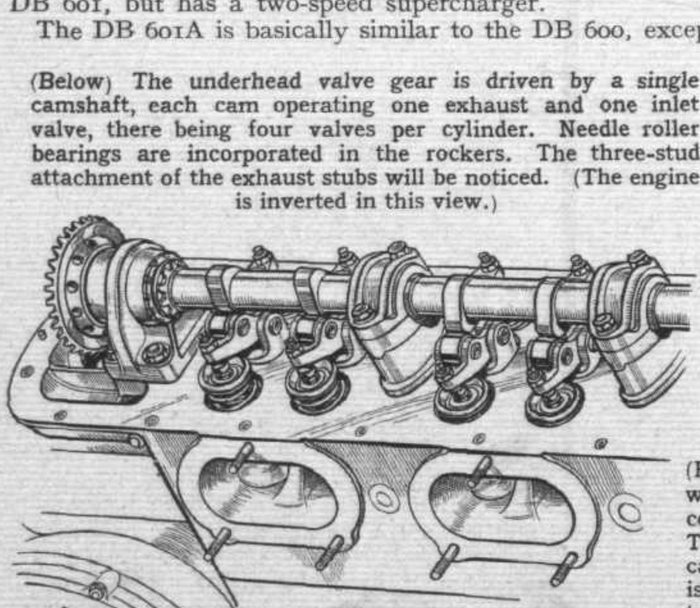
The DB 601A is basically similar to the DB 600, except that the single-speed supercharger and pressure carburettor have been replaced by the very interesting hydraulic drive and the injection pump. (The DB 600 was described, with other German engines, in *Flight* of November 16, 1939.)

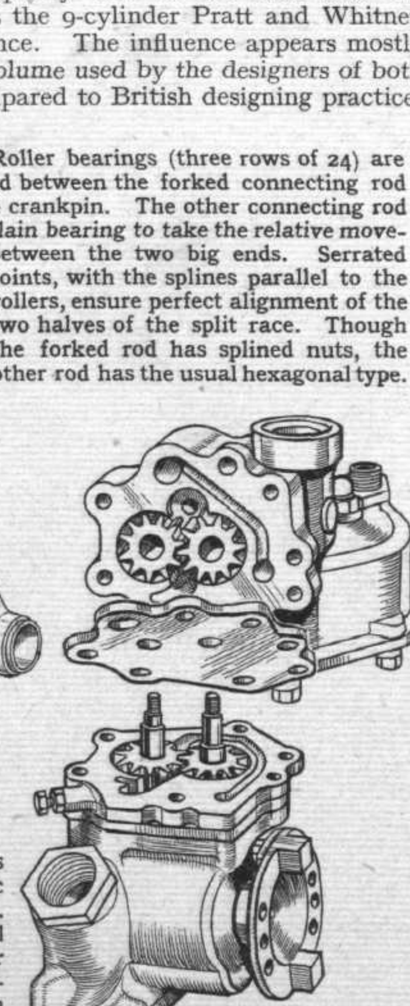
German aero-engine design has been influenced by American, this being partly due to the fact that the B.M.W. 132 radial was the 9-cylinder Pratt and Whitney Hornet built under licence. The influence appears mostly in the greater specific volume used by the designers of both these nations when compared to British designing practice.



(Left) Roller bearings (three rows of 24) are provided between the forked connecting rod and the crankpin. The other connecting rod has a plain bearing to take the relative movement between the two big ends. Serrated joints, with the splines parallel to the rollers, ensure perfect alignment of the two halves of the split race. Though the forked rod has splined nuts, the other rod has the usual hexagonal type.

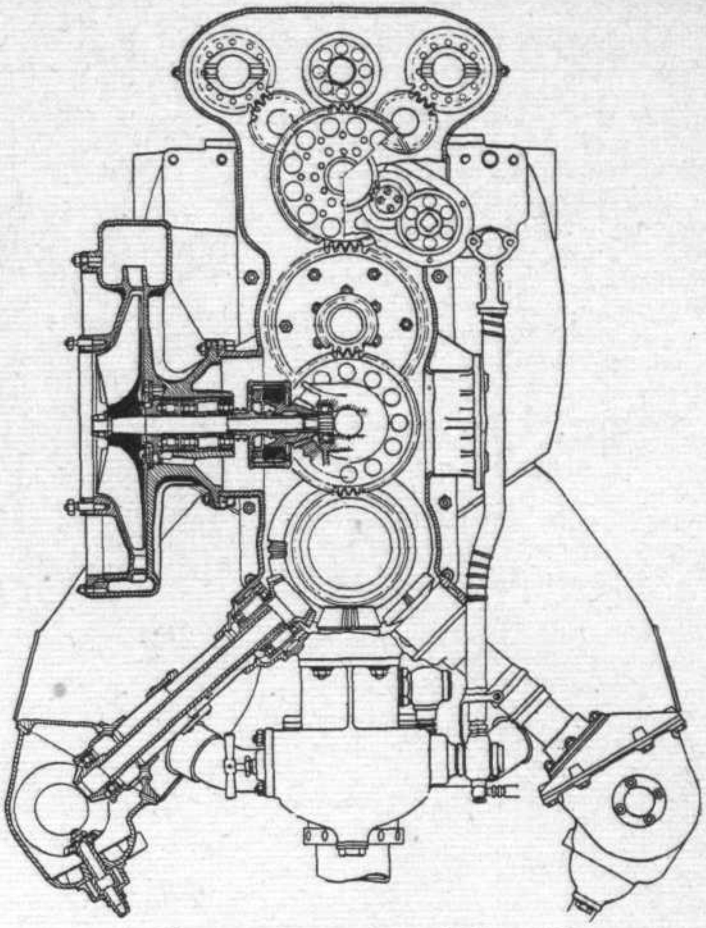
(Below) The underhead valve gear is driven by a single camshaft, each cam operating one exhaust and one inlet valve, there being four valves per cylinder. Needle roller bearings are incorporated in the rockers. The three-stud attachment of the exhaust stubs will be noticed. (The engine is inverted in this view.)





(Right) The two gear-type pumps which deliver oil to the hydraulic coupling of the supercharger drive. The lower one delivers its full capacity constantly but the upper is governed by an altitude-controlled capsule which is housed in the right of the body of the pump.

A comparison of the take-off power of our Rolls-Royce Merlin X with its capacity of 27 litres against that of the DB 601A with the considerably larger capacity of 33.9 litres is revealing. The Merlin rating gives 1,065 h.p. for three minutes at $5\frac{3}{4}$ lb./sq. in. boost and 3,000 r.p.m. The DB 601A rating is very similar, being 1,050 h.p. for one minute with a boost of 5.2 lb./sq. in. at 2,400 r.p.m. The difference in capacity is, of course, most marked.



The supercharger of the DB 600 will be seen in this drawing. The DB 600 was the forerunner of the DB 601A and has the same dimensions, but lacked the hydraulic coupling.

Hydraulic Coupling

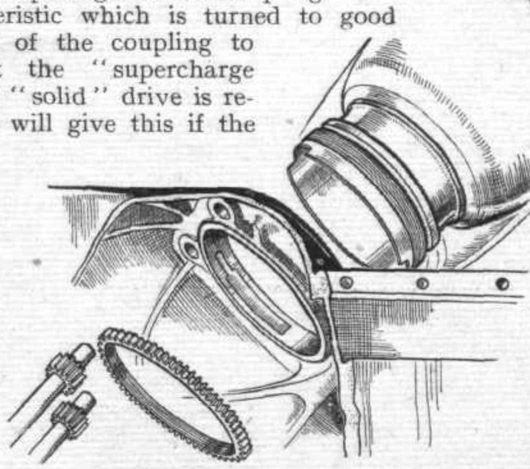
What is undoubtedly the most interesting feature—it is believed to be unique—is the fluid drive to the supercharger. This hydraulic coupling operates on the principle of the "fluid flywheel" well known in automobile engineering. Under this system power is transmitted from driving to driven member by the continuous circulation of oil in the curved channels of both members.

In the drive of the DB 601A, oil is pumped along a passage A in the shaft of the driving member (the other end of which runs in a spigot bearing) and then emerges through the radial holes of the shaft B into the radial passages C of this member. The rotation causes it to flow outwards, and the shape of the passages is such that the oil is directed into the similar passages D of the driven member. As it has a component of tangential velocity it impinges on the vanes and so drives the member round.

The fluid, in going from driving to driven member, must cross the small gap between them, and a certain loss of fluid occurs continuously. Hence the need for pumping the oil into the coupling. Slip between driving and driven members is always a characteristic of hydraulic couplings, but this decreases with increase of speed and is also affected by the amount of oil in the passages of the coupling.

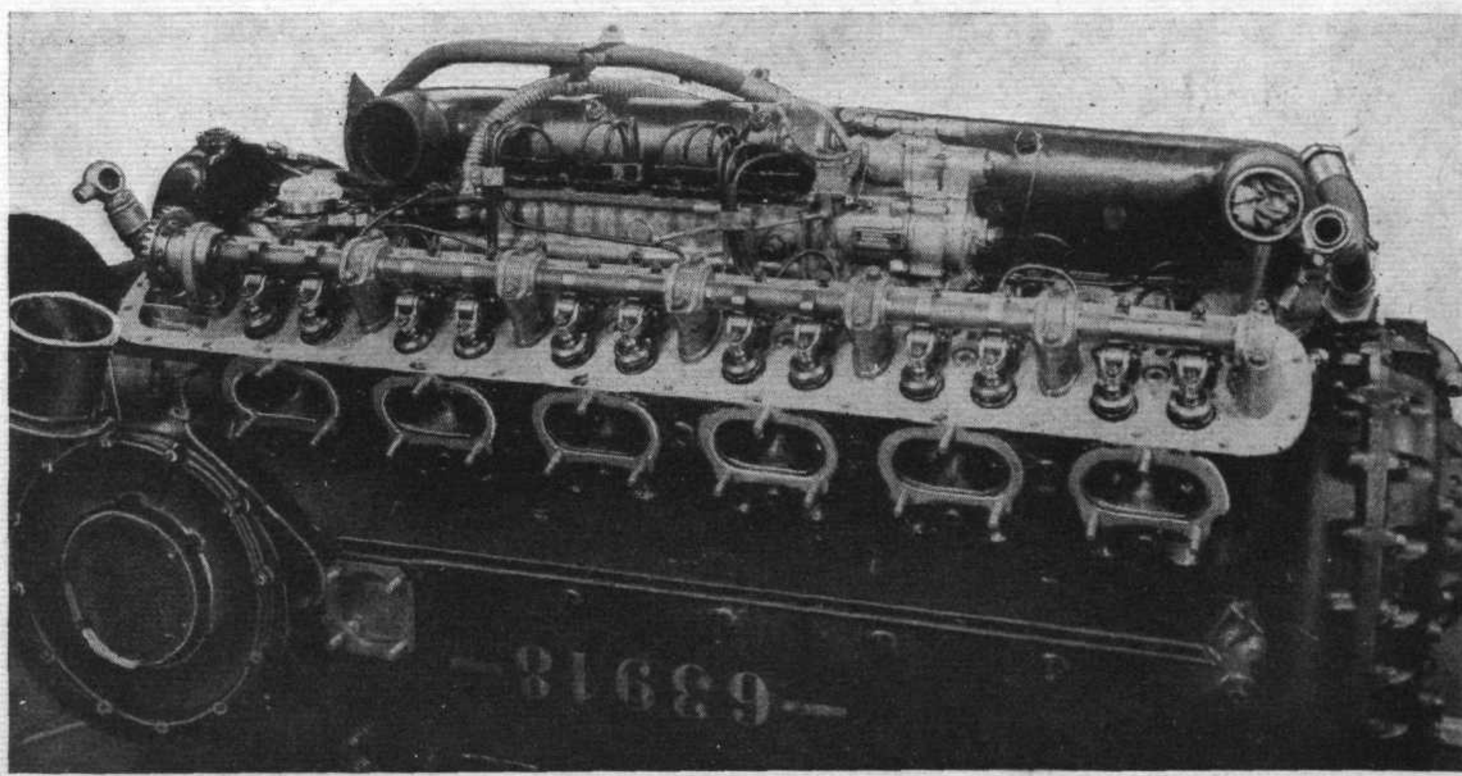
It is this last characteristic which is turned to good account in the adoption of the coupling to supercharger drive. At the "supercharge altitude" of the engine a "solid" drive is required, and the coupling will give this if the oil passages are kept filled. (This must be qualified by saying that hydraulic drive is never quite "solid," the minimum of slip never being lower than 2 or 3 per cent.)

Below the supercharge height it is desired to run the supercharger at lower



(Left) The "dry" cylinder liner is attached to the cylinder block by a screwed joint. At its other end the liner is retained in the crankcase by a ring nut which is tightened by means of one or two of the tools shown. When rotated in the holes in the crankcase, the pinion of the tool engages with the gearing on the ring nut.

(Below) The Mercedes-Benz DB 601 A inverted vee-twelve engine is seen here in the upside down position during maintenance work at an Air Ministry station prior to testing. The bank of injection pumps, the valve gear and the supercharger will be noticed

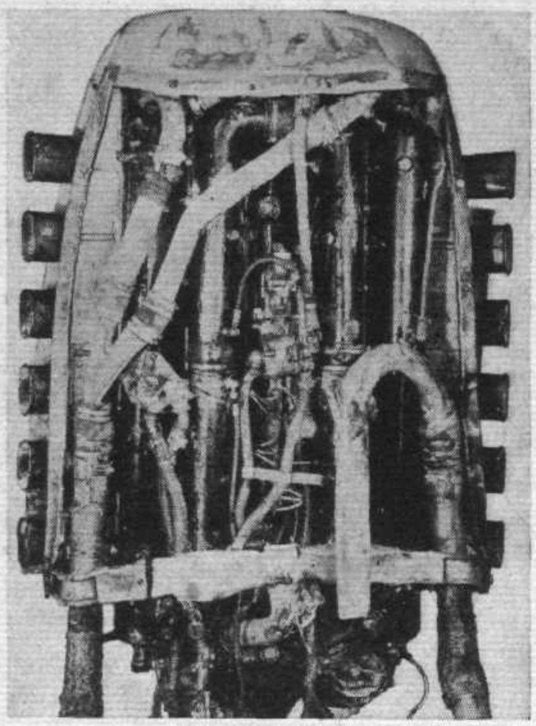


AN INVERTED VEE ENGINE (CONTINUED)

speeds in relation to the engine, and this is accomplished by reducing the oil supply to the coupling. A two-stage pump supplies the coupling from the main pressure oil filter, each pump stage being of the normal gear design. The first stage has no control on it and supplies the whole of its output to the coupling, so that there is always some oil present in the spaces. The output of the second stage is governed by a capsule which responds to intake pressure, so controlling a piston valve which divides the oil between the coupling and the by-pass back to the engine sump. The second stage commences delivery to the coupling at a barometric height of 4,900ft., and full delivery occurs at 11,500ft. approximately. In this way is the desired result of a variable-speed drive between engine and supercharger obtained.

On the Mercedes-Benz the hydraulic coupling is a double-sided one, the driving member being on the inside with one driven member on each end. End thrust is thereby balanced. The inner parts of the hydraulic coupling are light-alloy die-castings. The annular rings of curved section, which are attached to the radial vanes and so help to form the correct shape for the fluid channels, are not part of the die-casting. They are separately made and pinned to the vanes, this form of construction simplifying the die-casting considerably.

The clearance between the inner driving unit and the outer driven casing is very close. The slots on the inner unit probably serve to aid lubrication. The driven casing is of steel, ribbed on the outside to give strength with lightness.



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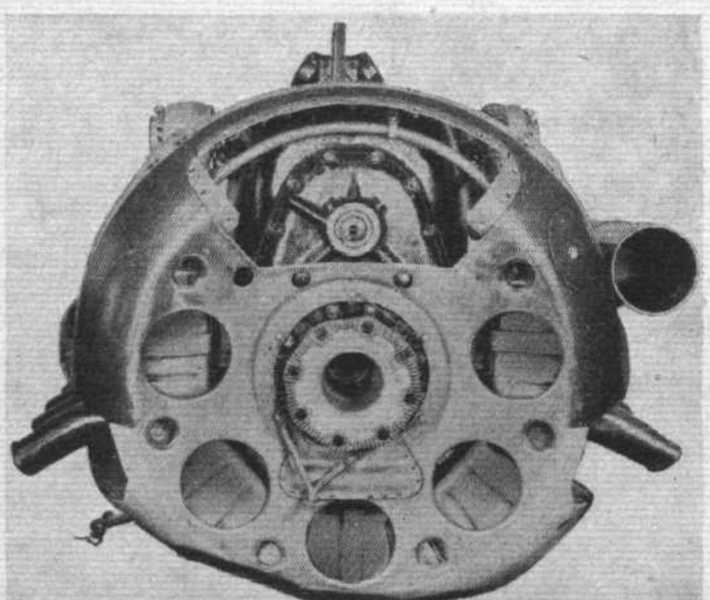
View of the underside of a damaged Mercedes-Benz DB 601A. The injection pumps lie in between the two banks of cylinders.

A capsule-controlled butterfly throttle controls the supercharger delivery, and a second throttle, operated by the pilot, controls the air supply to the engine, and therefore the induction manifold pressure. The capsule controlling the first throttle is subjected to the pressure between the two throttles.

Worthy of note is the clockwork mechanism which permits the boost to be increased for one minute only at take-off. The German boost gauge is marked, not in kilogrammes per square mm. or millimetres of mercury, but in tenths of an atmosphere. The dial shows from 0.6 to 1.8, which limits are much wider than those which can be reached. It has been reported that the Mercedes-Benz has run up to 1.45 atmospheres (+6.3 lb./sq. in.) and 2,500 r.p.m. for take-off, but this seems very high and the claim has not been substantiated. The highest figure seen on a machine by Air Ministry technicians was 1.4 atmospheres (+5.6 lb./sq. in.) on a Heinkel He 111K.

The supercharger is mounted neatly on the port side of the engine, with its axis at right angles to the crankshaft. This necessitates bevel gearing for the drive (which has a ratio of 10.39 to 1) but allows the air intake to be of neat design with merely one right-angle turn, well louvred to minimise eddy loss.



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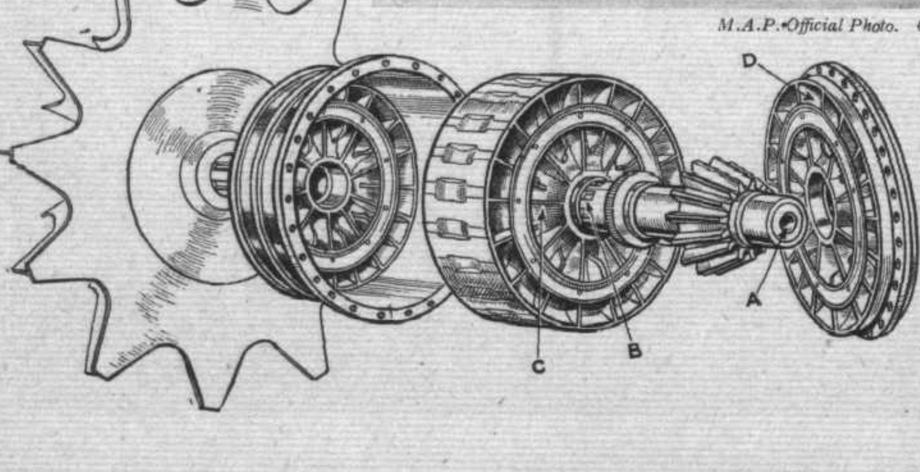

(Right) The front view of the DB 601A shows the splined flange for the attachment of the airscrew hub, and the horseshoe-shaped header tank under the cowling. The air intake is on the right.

(Below) The hydraulic coupling driving the supercharger. Oil is supplied to it 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 it is flung into the passages of the driven member D and so causes it to rotate. The arrangement is duplicated on the other end, so balancing end thrust.

Big-end Roller Bearings

The big-end bearing of the connecting rod shows considerable enterprise in design, roller bearings having been used. This has three tracks of 24 rollers each, running on the crankpin and in steel split outer races, with a split light alloy cage. Serrated joints are used as shown in the drawing. At each of the crankpins there is one forked rod running on the roller race, while the other is a plain rod running on a lead-bronze bearing outside the race. In the small end bronze bushes are fitted. An unusual type of nut is used on the forked rod. Instead of having hexagonal flats, the nut is of circular form with numerous splines. The first explanation that this was for ease in tightening up the nut by small amounts does not seem to be the correct one, as hexagonal nuts are used on the bolts of the other rod. Lubrication

AN INVERTED VEE ENGINE (CONTINUED)

of the big end is by forced feed to the roller bearings and then out to the plain bearing.

Cylinder Liners

The cylinder liners are of the "dry" type made of steel. By their tension they hold the surrounding light alloy cylinder blocks into the crankcase. The attachment to the crankcase is made by a screwed joint with a large ring nut. On the outside of this are cut gear teeth which engage with the tool used to screw up the nut. This might be described as a screwdriver with a small gear pinion instead of a blade. A spigot on the end of this tool is inserted into a hole in the casting and the tool rotated. This turns the ring nut and so tightens it. Considerable mechanical advantage is available for tightening, and two such tools can be used simultaneously if required. The crankcase is a light-alloy casting with well designed reinforcing webs. The thin light-alloy top is dowelled and secured by numerous small studs.

The above arrangement of cylinder liner is different from that adopted in the Rolls-Royce Merlin, which employs "wet" liners and does not utilise the liner as a means of attachment for holding cylinder block and crankcase together. Instead, a number of long steel bolts perform this function. The Merlin design seems superior, and the provision of an easier path along which heat may flow from the cylinder through the "wet" liner no doubt is part of the reason why specific power output is higher.

Unlike British designs, these Daimler-Benz engines are water-cooled. Glycol is used in the cooling fluid in the proportion of 30 per cent. Glycol, 70 per cent. water for bombers, and 50-50 for fighters, but the operating temperature has not been raised because of this. The addition of Glycol appears to be for anti-freeze purposes only

To each block of cylinders there is only one camshaft. Each cam operates two valves, an inlet and an exhaust. There are two inlet and two exhaust valves to each cylinder. Between the stud on the rocker arm and the end of the tappet is a floating spherical joint. Rocker arms have needle roller bearings, and tappet adjustments are most accessible. The whole valve gear is very well arranged.

A Bosch magneto is fitted to the DB 601A, this being a twin ignition unit with two electrical circuits but only one drive from the engine, so not true "dual ignition." This is not universal German practice.

Injection Pumps

Before going to the injection pumps the pètrol goes through the de-aerator, which is interposed between the fuel pump and the injection pump. The injection pumps are of Bosch type, the twelve being arranged neatly in line in four groups of three. They operate in exactly the same way as the Junkers pump on the Jumo 211A, but they are mounted in a more accessible manner.

The injectors on the DB 601A differ from the Junkers type, which is simply a nozzle designed to admit the charge to the cylinder in a finely divided state. But the type which Mercedes-Benz fit is not only a nozzle but is spring-loaded to act also as a valve.

All German engines for military operation have been found to contain 92 octane leaded fuel in the tanks. This grade of fuel is used for take-off and all other conditions of flight. But the DB 601A was designed for 87 octane, so higher-grade fuel is apparently not yet short.

The German method of attaching the airscrew to the engine differs from the parallel splining of the shaft used as standard in this country. Their method adopts flange-mounting in preference to shaft-mounting, and carries the drive to the airscrew hub by two plates bolted together, the load being carried through radial serrations on the faces of the plates.

A large number of German engines have been captured and are available for test and experiment in the engine laboratories of the Air Ministry. Some of them have had very few operational flying hours, even as low as under ten. And many are of recent date of manufacture, the name plate of one out of a Messerschmitt Me 109 indicating that it was made in the first half of this year.

The standard of workmanship seen on the details of the Mercedes-Benz engines which have been captured can only be described as excellent. Also the arrangement of piping is very neat and some thought has been expended on the placing of accessories. But whether this has been entirely successful is doubtful, for as one observer described it, they appeared to be "regimented." Mercedes-Benz design is not so heavy in appearance as Junkers.

The designers appear to have gone in for simplicity of appearance, sometimes at the cost of the general excellence of the engine. They do not seem to have equalled Rolls-Royce and Bristol in the finesse and artistry of design.

Power-Weight Ratio

The particular engine inspected had not been power-tested on the brake, but it was expected to give within about 40 h.p. of the rated powers. Using the take-off rating of 1,050 h.p. and the weight of 1,610 lb., the power-weight ratio is 1.53 lb./h.p.

The take-off power of 1,050 h.p. is lower than the figure which has been accepted previously and which *Flight* has published as 1,150 h.p. But after careful examination, Air Ministry technicians state that they can find no evidence of the engine being used at take-off powers higher than this.

Other data on the engine are:

CONTROL: Single throttle control from pilot's cockpit.

BORE AND STROKE: 150 mm. × 160 mm.

STROKE VOLUME: 33.9 litres.

COMPRESSION RATIO: 6.9/1.

REDUCTION GEAR: Spur type, 14/9.

THRUST BEARING: Normal ball type.

WIDTH: 29.1in. LENGTH: 67.5in. HEIGHT: 40.5in.

WEIGHT: Oily, with fuel pump, generator, hydraulic pump, starter, airscrew control gear, piping and wiring to bulkhead: 1,610 lb.

CRANKSHAFT: One-piece type, with six cranks at 120 deg. and eight balance weights each consisting of two plates riveted on each side of a crankweb extension. Runs in seven lead-bronze bearings. Front end splined to take splined mounting sleeve of reduction gear pinion. Rear end fitted with starter dog and accessory drive.

BIG-END BEARING: Roller type with three tracks of 24 rollers each, running on crankpins and in steel split outer races, with split light-alloy cage, with serrated joints.

PISTONS: Light alloy of normal design, floating gudgeon pin. Three compression rings and two scraper rings.

VALVE GEAR: Bevel drive to camshafts. Single underhead shaft on each block, with one cam operating one inlet and exhaust valve, through rocker arms with needle roller bearings.

VALVES: Hollow stem, exhaust valve sodium cooled.

SPARKING PLUGS: Two per cylinder, fitted on outside of block.

INJECTION PUMP: Bosch twelve-cylinder in-line type, fitted between cylinder blocks, and controlled by induction manifold pressure sensitive diaphragm, altitude pressure sensitive capsule stack, and induction temperature sensitive capsule. De-aerator interposed between fuel pump and injection pump.

MAGNETO: Bosch twin unit, Z.M.12 B.R.4 type.

AUXILIARIES: Mounted on gear box at rear end; gear-type fuel pump, 24-volt, 1,500-watt generator, swashplate driven six-plunger hydraulic pump (alternatively, vacuum pump), centrifugal coolant pump, and hand/electric inertia starter.

OIL PUMPS: Gear-type pressure pump delivering through wire-wound filter. The main oil supply is led by drilled crankcase passages to the main bearings. Scavenge oil drains from front and rear to the camcase covers, in each of which is a gear-type pump.

POWER: Take-off, 1,050 b.h.p. at 5.2 lb./sq. in. boost and 2,400 r.p.m. (limited by clockwork to 1 min.).
For 5 min., at ground level, 950 b.h.p. at 3.75 lb./sq. in. and 2,400 r.p.m.
Power at altitude, 970 b.h.p. at 2.4 lb./sq. in. and 2,300 r.p.m. at 12,000ft.

OIL COOLER: The cooler area is increased by 50 per cent. in order to dissipate the energy not transmitted by the supercharger hydraulic coupling at maximum slip.

EXHAUSTS: Ejector-type exhaust stubs are fitted when the engine is installed in the Me 109