# CHAPTER 4

## The Junkers Jumo 205 Diesel Engine

Junkers Jumo Diesel aircraft engines are the only large engines functioning on the two-cycle principle which are used in modern aviation. They are built in Germany and are used extensively in both civil and military airplanes in that country. The best known model is the Jumo 205 which has been built by the thousands in a specially-equipped factory. This engine is not supercharged although it is equipped with a centrifugal-type blower. Like other Jumo Diesels it is water-cooled and of low frontal area (Fig. 35).

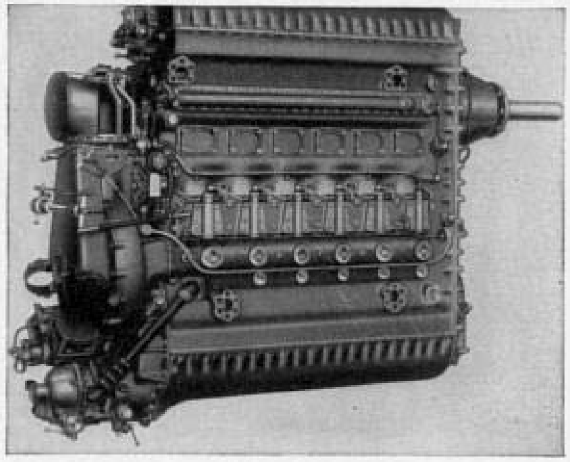

**Fig. 35.**—*Junkers Jumo 205 Diesel aircraft engine.*

The Jumo 205 has six in-line cylinders and two crankshafts-one at the top and the other at the bottom of the cylinder block connected by a train of gear wheels. It also has two opposed pistons and two connecting rods in each cylinder so that virtually it is a twelve-cylinder engine. It has no cylinder heads and the combustion chamber in each cylinder is formed between the crowns of the two pistons when they are at the tops of their strokes. This type of Diesel forms an interesting contrast to the opposed-piston gasoline engine which has one crankshaft and one or more pairs of opposed pistons and cylinders with separate heads and combustion chambers.

Another feature of the Jumo 205 is its unique valving. In this engine as in other Junkers Jumo Diesel aircraft engines, the inlet valves and exhaust valves and their operating mechanism have been eliminated and in their place are inlet ports and exhaust ports controlled by the movement of the pistons. The inlet ports are around the lower end of the cylinder liner and the exhaust ports are around the upper end. The movements of the pistons up and down in the liner cause the ports to be covered and uncovered at the right time in a simple yet effective manner.

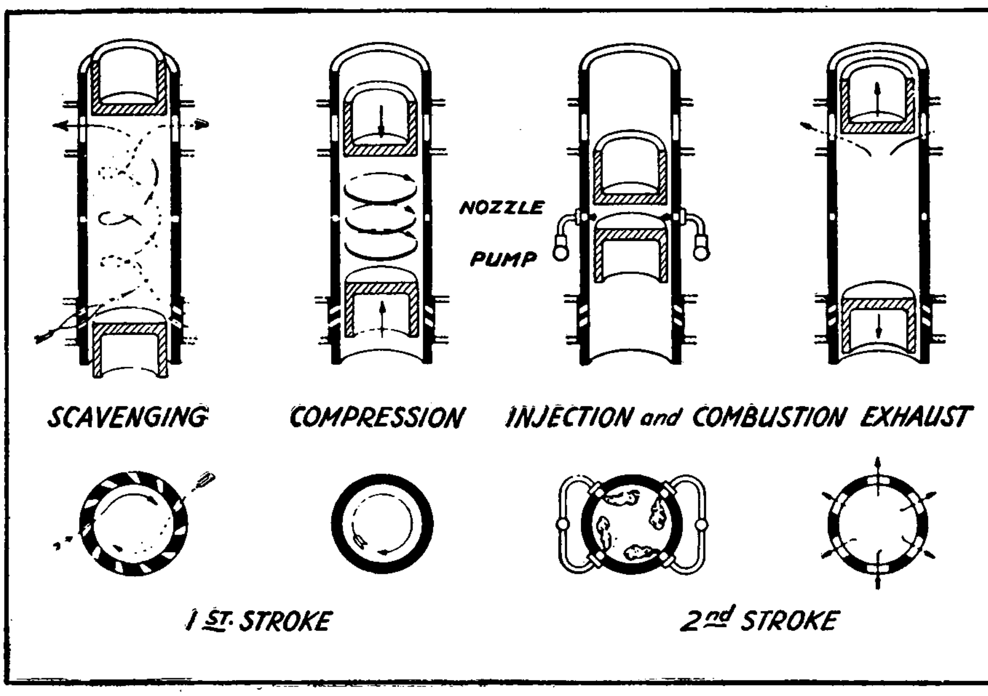


**Fig. 36.**—*Functioning of piston-controlled ports.*

When the engine is running the air charge in the cylinder is compressed between the two pistons as they approach each other. The fuel charge is injected in finely atomized form into the combustion chamber just before top dead center. The fuel ignites quickly in the highly-heated air and the resultant gases of combustion force the two pistons apart on their expansion strokes. The upper or exhaust piston is timed so that it has a slight lead over the lower or intake piston and the exhaust ports are uncovered first. This timing permits most of the burnt gases to escape before the inlet ports are uncovered and clean air rushes into the cylinder under slight pressure from the blower (Fig. 36).

Because both the inlet ports and the exhaust ports are open at the same time momentarily, the cylinder is said to have straight-through scavenging. The volume of air supplied by the blower during each cycle of operations is approximately fifty per cent greater than the cylinder displacement so that plenty of it is available for scavenging the burnt gases through the exhaust ports. Strong rotational swirl is imparted to the outgoing gases and the incoming air by constructing the exhaust ports and the inlet ports tangentially in the cylinder liner.

When the pistons have passed bottom dead center and commence to approach each other once more, they cover first the exhaust ports and then the inlet ports. Compression of the air charge then commences while the strong rotational swirl imparted to the air is maintained to create good turbulence. This turbulence causes the air and fuel to mix rapidly when the latter is injected and results in good combustion and high power output. The low fuel consumption obtainable with the engine is due to the good combustion and the straight-through scavenging which prevents pollution of the air charge.

**CONSTRUCTION DETAILS**

The main part of the Junkers Jumo 205 Diesel which is also the power section, is the aluminum alloy cylinder block. This casting contains integral supports for the bearings for the two crankshafts and passages for the cooling water which surrounds the cylinder liners when they are in place. Six bores are machined in the casting for these liners with several guides to hold them in correct alignment. The liners are machined from nitralloy steel forgings and are secured with locking rings at the bottom of the bores so that they can expand upward. Several rows of small inlet ports, eight large exhaust ports, and numerous grooves to increase the cooling area around the combustion chamber are machined in the liner which is then chromium plated on the outside to prevent rust and corrosion (Fig. 37).

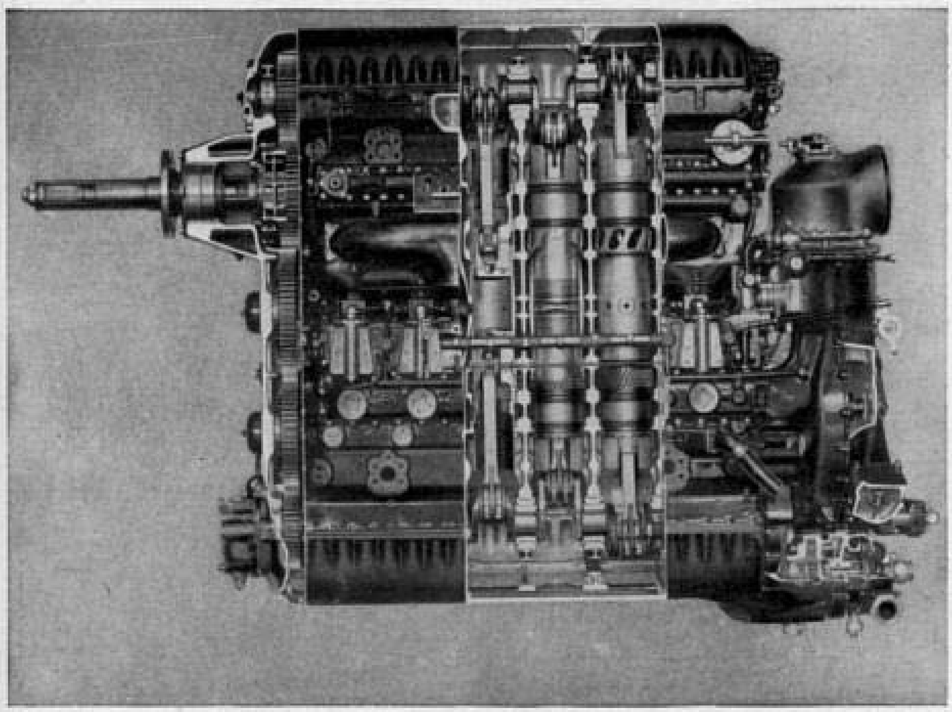

Fig. 37.—Cut-away view of engine showing construction.

**THE CRANKSHAFTS**

The two crankshafts are of the six-throw type with counterbalances. They are supported in seven lead-bronze bushings of large diameter. Spur gear wheels attached to flanges at the front ends of the crankshafts transmit the drive through three intermediate gear wheels to the propeller shaft. The intermediate gear wheels are mounted on roller bearings and the entire gear train is enclosed by a cover plate which also contains the bearings for the propeller shaft. A vibration damper of the hydraulic type in which lubricating oil under pressure circulates between the paddles of a damper wheel and recesses in its housing is mounted inside the top intermediate gear wheel. The damper wheel is connected to the propeller shaft by means of a flexible splined shaft.

**THE PISTONS**

The pistons are machined from aluminum alloy forgings. They have unusually long skirts with a length-to-diameter ratio of approximately 2:1. A fire-plate of special heat-resisting steel is attached to each piston crown by four long anchor bolts fitted with strong compression rings to compensate for the unequal expansion of the two metals. Four compression rings are fitted above the piston pin and an oil scraper ring is located at the bottom of the skirt. In addition there is what is known as a fire-ring around the lower edge of the fire-plate with its

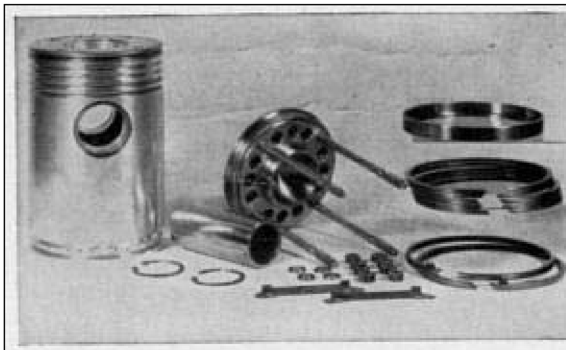

Fig. 38.—Piston assembly including fire-plate and fire-ring.

lower edge resting on a Niresist insert cast in the piston wall. The fire-ring is of L-section so that the gases of combustion tend to force it outward and seal it against the cylinder wall. Its object is to protect the compression rings from the flaming gases of combustion and at the same time prevent gas leakage past them (Fig. 38).

**THE CONNECTING RODS**
The connecting rods are made of chrome nickel steel and are of I-section. Aluminum alloy bushings are used in the big-ends and needle or quill bearings in the small-ends. The piston pin is hollow and of the fixed type. The propeller shaft is made of chrome nickel .steel and is supported at its mid-point by a roller bearing and a ball thrust bearing and at its inner end by a needle bearing. The gear train provides the propeller shaft with a reduction drive of 1.58:1.

**THE BLOWER**
The blower which supplies the air for scavenging the cylinders and filling them with their air charge is attached to the rear of the cylinder block where it is driven through gearing from the lower crankshaft. The blower is of the centrifugal type and contains a disc-shaped impeller with blades on both sides tangential to the hub. The air is drawn in through a large screened intake, compressed to a pressure of 5 lb. per sq. in. and forced through manifolds along both sides of the cylinder block to the inlet ports. The output of the blower can be regulated by means of a shutter in its intake.

A slipping clutch is provided between the drive shaft and the impeller of the blower to protect the latter from sudden overloads. If the engine crankshaft speed increases very rapidly when the throttle is opened, the clutch slips until a safe ratio between the two rotating masses has been reached. The same protective action occurs when the engine throttle is closed and this is important in a Diesel which stops very quickly due to its high compression.

**FUEL INJECTION PUMPS**
The fuel injection system comprises two high-pressure injection pumps and four injectors for each cylinder of the engine. The pumps are arranged in sets of six along each side of the cylinder block where they are actuated by two camshafts driven from the center intermediate gear wheel of the gear trim. The pumps operate at crankshaft speed to suit the two-cycle functioning of the engine. Each set is an independent unit capable of supplying the engine at full load. The pumps and the camshaft covers on which they are mounted can be removed quickly for servicing (Fig. 39).

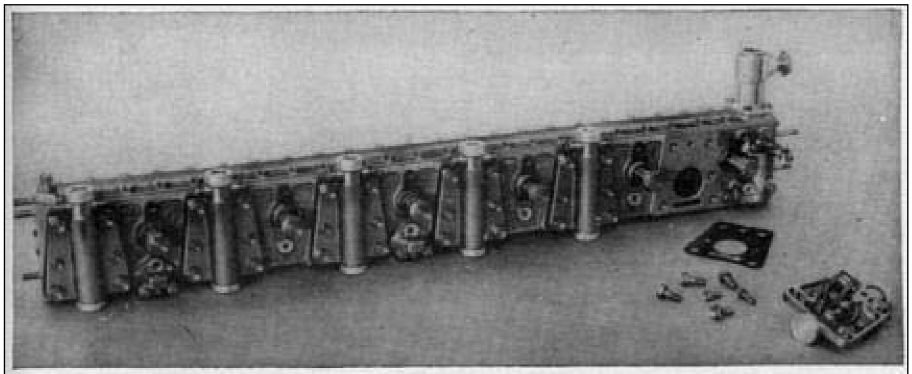

**Fig. 39.**—*Set of six fuel injection pumps on camshaft cover.*

The two injectors are screwed through the cylinder block into the cylinder liner with an angle of 90 degrees between them. The two injectors on the other side of the cylinder block are arranged in a similar manner so that even distribution of fuel is obtained. The injectors have two-hole nozzles which spray the fuel fan-wise into the combustion chamber.

Strenuous duties are imposed upon the injection pumps. The two pumps and their four injectors for each cylinder operate simultaneously and when the engine is running at 2,200 r.p.m., they deliver approximately 37 injections each second. During each injection period the pressure of the fuel in the pumps is raised from approximately zero to 8,000 lb. per sq. in. and then returned to zero (A pressure of 5 lb. per sq. in. is maintained in the supply lines to the injection pumps by the fuel transfer pumps on the engine). At the same time the small fuel charge is metered accurately and its timing is controlled. Both precision and ruggedness are built into the injection pumps and they run for 800 hours between overhauls.

**THE LUBRICATION SYSTEM**
Lubrication of the engine is effected by means of a pressure pump and a duplex scavenge pump functioning on the dry sump principle. The two scavenge pump units suck the oil out of the lower crankcase sump and force it through a cooler into the oil tank. From the latter it feeds through a wire-mesh filter into the pressure pump which forces it through a metal-element filter on the front of the engine into the high-pressure lines. Oil is supplied to the vibration damper at a pressure of 50 lb. per sq. in. but its pressure is reduced by a regulator valve to 25 lb. per sq. in. for the other working parts of the

engine. Constant oil pressure is maintained in the crankshaft and connecting rod big-end bearings by automatic overflow valves. The gear wheels in the gear train are lubricated through small nozzles which spray the oil onto the teeth where they mesh. Splash lubrication is used for the pistons and the connecting rod small-ends.

## THE COOLING SYSTEM AND ACCESSORIES

The water used for cooling the engine is circulated by a centrifugal-type pump. It is pumped into passages at the bottom of the cylinder liners and circulates upward to passages connected with outlets on both sides of the cylinder block. Any steam which forms passes through a pipe to an auxiliary tank where it condenses and is fed back into the system. The weight of the cooling system for a 700 h.p. Jumo 205-E Diesel (including radiator, auxiliary tank and 732 gallons of water) adds approximately 290 lb. to the installation weight of the engine. The dry weight of the engine is 1,260 lb.

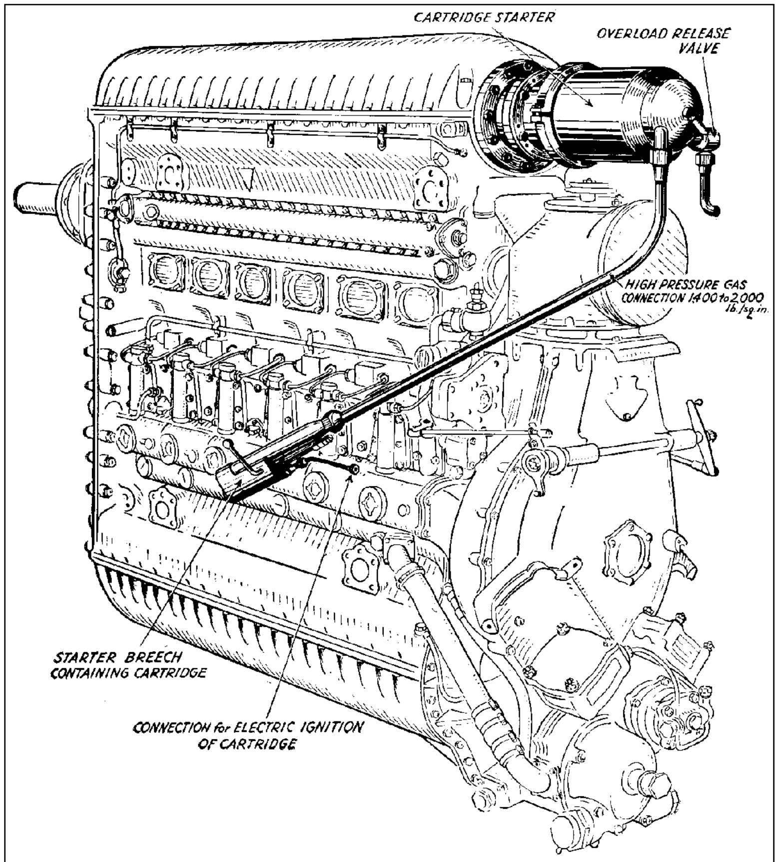


Fig. 40.—Cartridge starter mounted on engine.

Various drives for accessories are provided at the rear of the engine. The upper crankshaft has outlets for attaching two tachometers and provision is made for mounting an electric-inertia starter or a cartridge-type starter (Fig. 40). Drives for an electric generator and air compressors or vacuum pumps are provided from a tail-shaft attached to the lower crankshaft. The engine starts quickly with a Bosch electric inertia starter similar to the Eclipse starter used in the United States. A small atomizer attachment can be used to spray a special mixture of gasoline, ether and lubricating oil into one of the air intake manifolds when starting the engine in cold weather.

## FUEL INJECTION SYSTEM

As has been mentioned previously, the fuel injection pumps on the Junkers Jumo 205 Diesel are of the individual single-unit type. The most important parts of the pump are the housing, the detachable barrel, the plunger, the roller cam arm for actuating the plunger, and the two fuel discharge valves at the top of the pressure chamber in the barrel. There is also a simple control mechanism whereby the plunger can be rotated slightly in the barrel to regulate the output of the pump (Fig. 41).

The stroke of the plunger is constant and the pump is designed so that the quantity of fuel admitted into the pressure chamber prior to compression can be varied. The plunger is constructed with an angular or sloping groove cut in its upper end and an annular groove around it slightly lower down. The annular groove is connected with the top surface of the plunger by a vertical hole and a number of small horizontal holes. The pressure chamber in the upper part of the barrel has a row of inlet ports around its lower end which communicate with the suction chamber of the housing. There are a number of outlet ports lower down in the barrel which also communicate with the suction chamber.

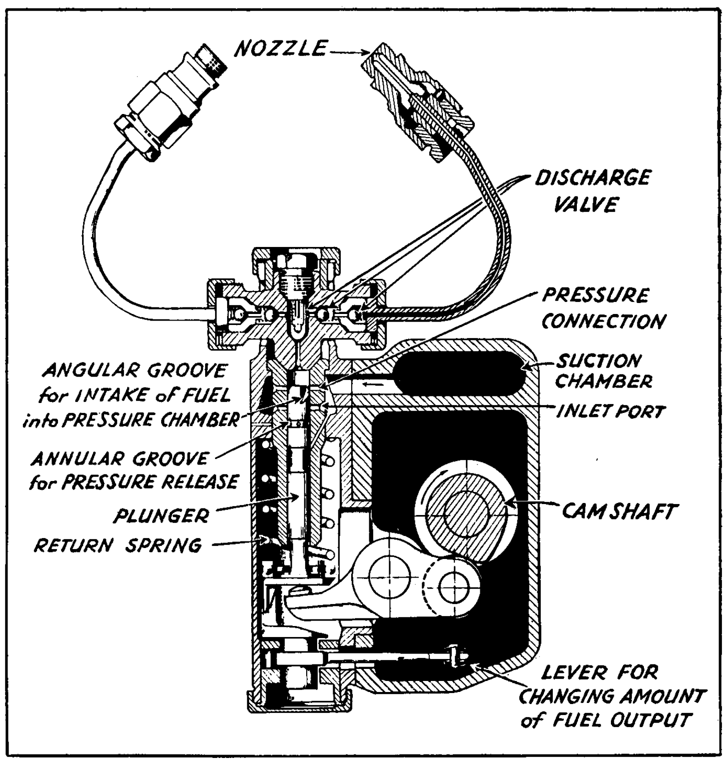


Fig. 41.—Junkers fuel injection pump and its two injectors.

The full-load operation of the pump is as follows: When the plunger approaches the bottom of its stroke it uncovers the inlet ports and fuel flows from the suction chamber along the angular groove up into the pressure chamber. The annular groove in the plunger is below the level of the outlet ports and so the fuel cannot run out. When the plunger rises, intake of fuel ceases as soon as the angular groove is above the inlet ports. The fuel in the pressure chamber then is compressed and forced out through the spring-loaded discharge valves into the high-pressure lines to the two injectors. When the plunger is near the top of its stroke the annular groove comes into communication with the outlet ports and the remainder of the fuel in the pressure chamber by-passes down through the holes in the plunger into the suction chamber. Discharge of fuel then ceases and the discharge valves snap to their seats.

The output of the pump is reduced by rotating the plunger slightly so that the angular groove does not cut off communication with the inlet ports so soon when it commences to rise in the barrel. Thus, a portion of the fuel in the compression chamber is forced back through the inlet ports and a smaller fuel charge is compressed and discharged to the injectors in order to reduce the output of the pump to zero and thereby stop the engine, the plunger is rotated until the angular groove permits communication between the pressure chamber and the inlet ports at all positions of plunger stroke. As rotation of the plunger changes the moment of commencement of fuel intake the functions of throttle control and timing control are combined in the one control lever.

Junkers fuel injectors are different from those in other Diesel aircraft engines in that they are of the open type without hydraulically-operated or mechanically-operated nozzle valves. Open-type injectors function quite satisfactorily in high-speed Diesels provided there is a slight reduction of pressure and volume in the high-pressure line when fuel discharge ceases. The nozzle in the Junkers injector has two small holes or slots in its end so that when the two jets of fuel emerge under high pressure they impinge upon each other and form a fan-shaped spray as in a carbide lamp (Fig. 42).

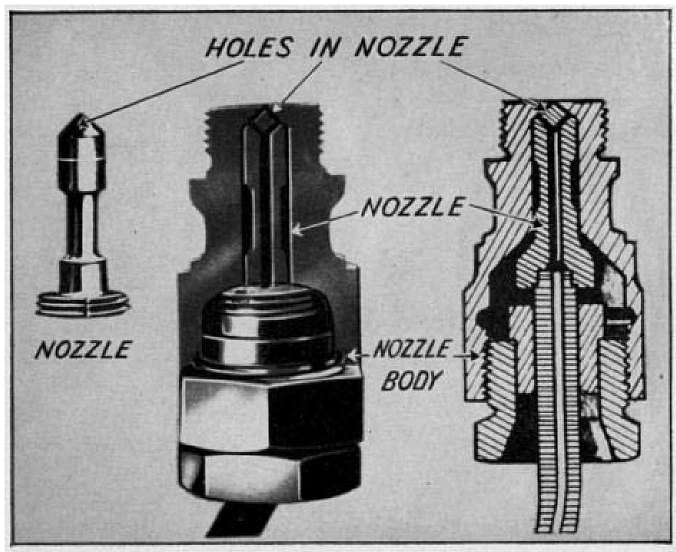

**Fig. 42.**—*Fuel injector showing construction of nozzle.*

**PRODUCING THE ENGINES**

The production of aircraft engines usually proceeds in three stages. First, one or two experimental engines are built for test purposes and every effort is made to "get the bugs out of them" on the ground and in the air. Next comes small-series production which may involve the building of a few engines or a hundred or more depending upon the need. The final stage of mass production necessitates equipping the existing factory or a new one with special machinery and tools so that thousands of the engines can be built by the latest flow-line production methods.

In 1938, mass production of Jumo 205 Diesels with power outputs ranging from 700 h.p. to 880 h.p. was in full swing in the Junkers factories in Germany. Most of the engines were for the Luftwaffe or German Air Force although a few of them were for Deutsche Lufthansa, Germany's national airline. Mass production of Jumo Diesel aircraft engines is particularly interesting to watch although the procedure is similar to that followed for water-cooled and liquid-cooled gasoline aircraft engines. The same methods are used in Germany as in the United States.

Beginning with the largest part of the engine, the cylinder block is one of the most complicated parts to machine. It has to be faced at the back and the front and also at the top and the bottom, and then have bores for the six cylinder liners machined in it with great accuracy. The last-mentioned operation is performed on a specially-designed horizontal boring machine equipped with three boring bars by moving the cylinder block horizontally in the saddle after the first three bores have been completed. The cylinder liners are machined from hollow steel forgings and have slots milled in them for the exhaust ports and a multitude of small holes drilled in them for the inlet ports. Spiral grooves are milled around the center part of the liner to increase the area exposed to the cooling water (Fig. 43).

The assembly of the engine is carried out with the cylinder block mounted in a rotatable stand so that it can be turned to the most convenient position for the work to be performed. The assembly operations include securing the cylinder liners in their bores, inserting the piston and connecting rod assemblies, mounting the crankshafts in their bearings, and mounting the blower at the rear of the cylinder block.

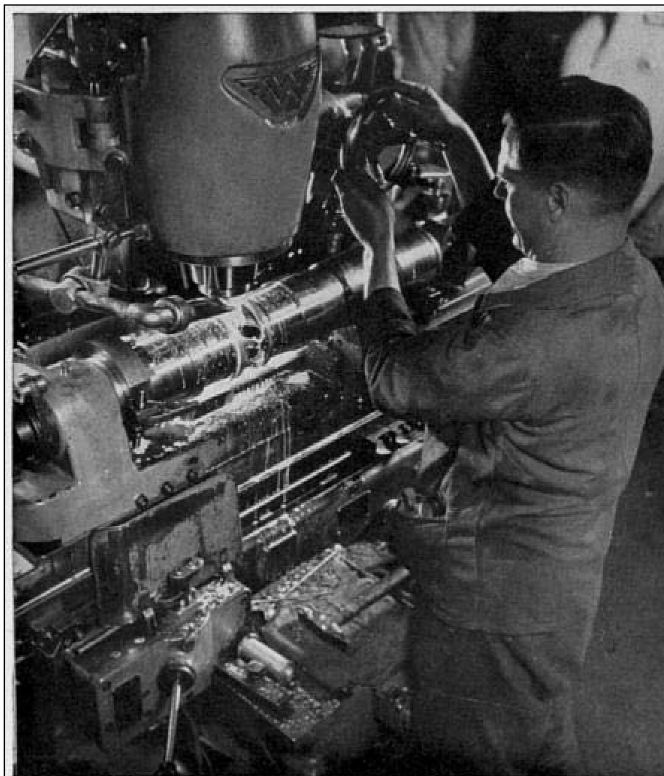

Fig. 43.—Milling exhaust ports in a cylinder liner.

At definite intervals the engine stand is advanced along the flow line and sub-assemblies and pieces of equipment are added until the engine reaches the end of the line and is complete (Fig. 44). Then it is removed from the assembly line, its controls are adjusted, and it is taken to one of the engine test houses. After its tests it is disassembled to check for wear and then reassembled and given a short test run before being shipped to its destination.

**ENGINE TESTING**

The methods used for testing Diesel aircraft engines are similar to those used for gasoline aircraft engines. Sometimes the engine is mounted on an electric dynamometer stand where its power is absorbed in driving an electric generator, or it is coupled to a water brake which absorbs the load. A more common procedure is to run the engine in a test cell or in the open with a short test club of coarse pitch on the propeller shaft (Fig. 45). The engineers running the test and recording the readings of the various instruments are located in a room with shatter-proof windows which is made as sound-proof as possible. The exhaust gases are led away through flexible metallic pipes of large diameter so that they are silenced to an appreciable extent.

**BENCH TESTS**

The bench tests which a Junkers 205 Diesel must pass consist of runs of several hours' duration at gradually increasing throttle opening and load until the rated output of the engine is attained. There are also short runs of a few minutes' duration at full throttle to check the take-off output of the engine. In the case of military engines an overload run sometimes is specified. Fuel and lubricating oil consumption are measured carefully during the test runs, together with the temperature of the cooling water and the lubricating oil and various pressures in the engine.

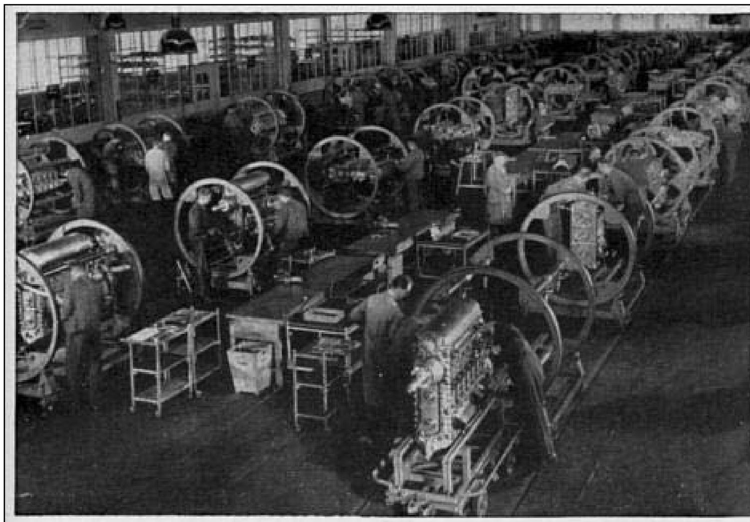

Fig. 44.—Mass production of Junkers Jumo 205 Diesels.

**PERFORMANCE STATISTICS**

The Jumo 205-C Diesel which was used extensively in 1936 and 1937, was rated at 600 h.p. at 2,200 r.p.m. and cruised at 510 h.p. at 2,100 r.p.m. Since then its power output has been raised by increasing its r.p.m., until now the Jumo 205-E model is rated at 700 h.p. at 2,600 r.p.m. The Jumo 205-D, which is a military engine, develops a maximum output of 880 h.p. at 3,000 r.p.m. The specific fuel consumption of these three engines is approximately the same, namely, 0.35 lb. per h.p. per hour at cruising speed and 0.37 lb. per h.p. per hour at full load (Fig. 46). These performances are obtained without a supercharger. When the engine is supercharged with an exhaust-driven supercharger the gear-driven blower is retained for starting purposes. The Jumo 207, as the engine then is known, develops 1,000 h.p. for take-off and maintains this output at an altitude of 20,000 feet.

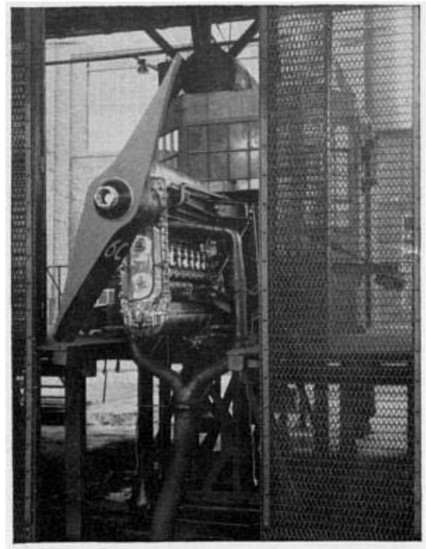

Fig. 45.—Junkers Jumo 205 Diesel on test stand.

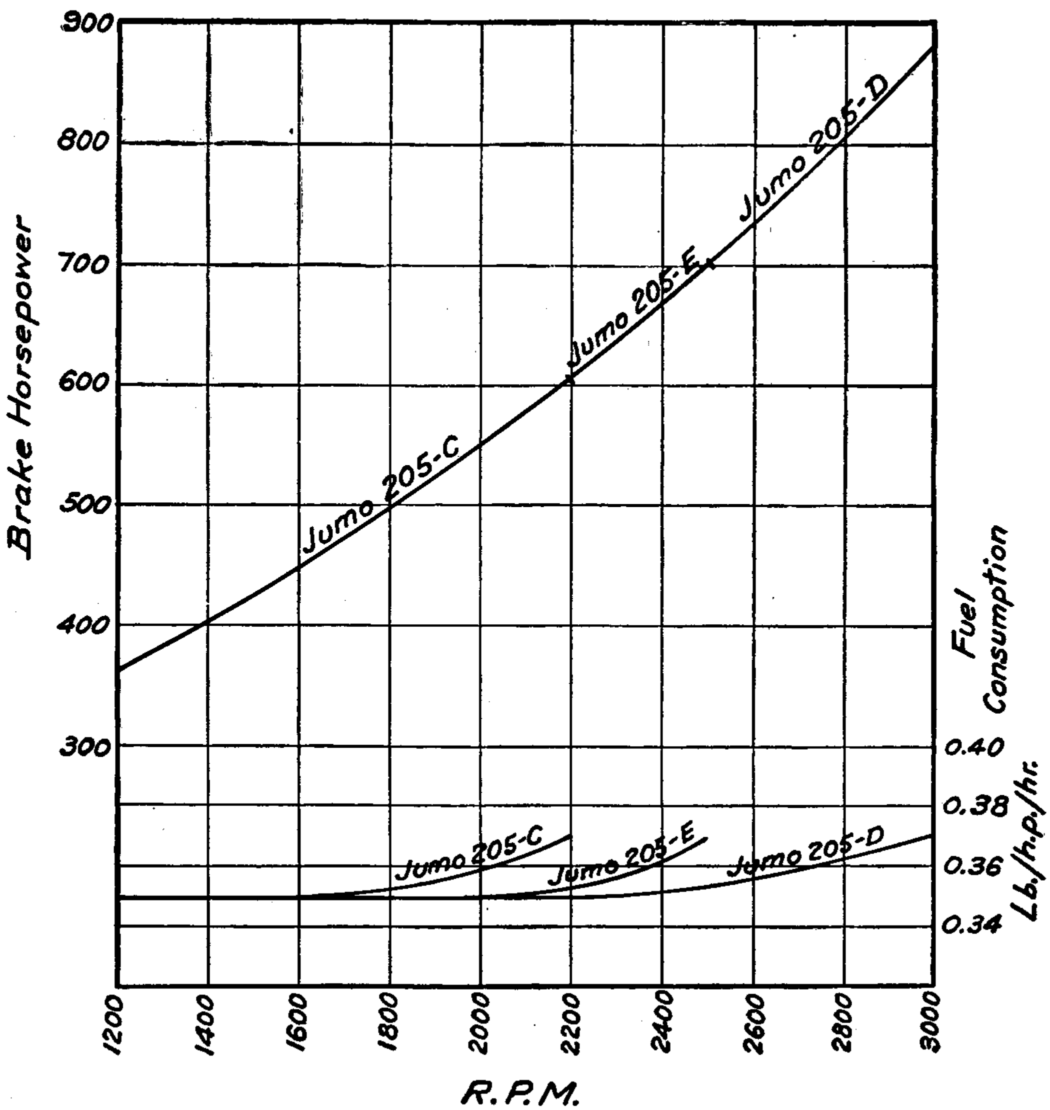


Fig. 46.—Power and fuel consumption curves.