AERONAUTICAL ENGINEERING

Junkers Diesel Motors and Supercharging

By Dr. Ing. J. Gasterstädt

Very many people interested in Aviation, as opposed to those who make a living by it, are looking forward to the time when aero-motors run on non-inflammable fuels. Therefore we reproduce below a translation, reprinted from the Junkers house organ, "Junkers Nachrichten," of the lecture which Dr. Gasterstadt gave before the Lilienthal Gesellschaft in Berlin on October 13 last.

WHEN in 1929 Professor Junkers made public the trend of his research work with Diesel motors for aircraft in a lecture before the *Wissenschaftliche Gesellschaft für Luftfahrt*, the first promising flights had just been successfully made at Dessau. A new stage in aero-motor development in which interest had already been shown by aeronautical circles had begun.

Those in control of civil aviation were particularly interested in an economic aero-motor which had a low fuel consumption and the minimum of risk of outbreak of fire. They saw a great future for the Diesel aero-motor. The active support and co-operation of the Deutsche Lufthansa made possible in 1932 the putting of the first Junkers Diesel motor, a Jumo 204, into operation on a regular air service.

In spite of temporary setbacks, this new departure has been developed from year to year until to-day over 2,000 flying hours monthly have been completed by Diesel motors. Notwithstanding this extensive pioneer work the problem of the Diesel aero-motor is by no means solved. A number of promising attempts, for example, the Packard motor in America and others, have remained undeveloped.

There has been an increase in recent years in the number of experts who believe that the Diesel motor has no future for aircraft. Such opinions have been based on the rapid development of the gasoline motor in respect of the reduced specific weight and specific fuel consumption, made possible by the introduction of high octane fuels. The fuel consumptions obtained with petrol motors designed for very high-octane fuels have approached those obtainable with a Diesel motor.

While in other countries there has been a lack of enthusiasm and disappointment in the performance of Diesel motors, a definite and unswerving line of development has been followed in Germany. Efforts have primarily been devoted to adapting the motor for the purposes for which the Diesel system had obvious advantages, that is, for civil aviation, particularly for long distance services.

We are confident that the Diesel motor will assert itself in the air as it has done in all branches of modern road transport. Future development is naturally not confined to the Junkers motor in its present form as a six-cylinder in-line unit. On the contrary, constructional development in a new direction is envisaged which will lead to lighter and more efficient motors.

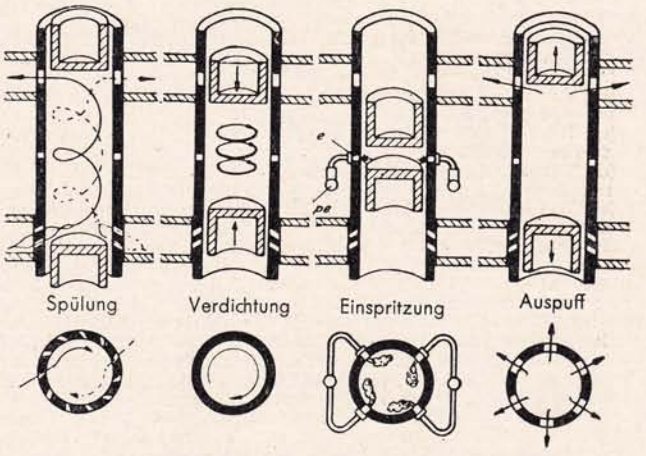


Fig. 1. How the Junkers two-piston two-stroke motor works. Spülung=scavenging; Verdichtung=compression; Einspritzung=injection; Auspuff=exhaust.

The ensuing remarks are intended to show the considerable progress towards the production of the light Diesel aero-motor which has been made by Junkers during the past five years, since the motor was first adopted for use in aircraft.

In the meantime, two further units of similar constructional characteristics have been added to the original Jumo 204 of about 28 litres cylinder capacity.

These are:—

(1) The now well-known Jumo 205 of 17 litres capacity.

(2) The Jumo 206 is now in course of development. This has a cylinder capacity of 25 litres. It will be much smaller than the

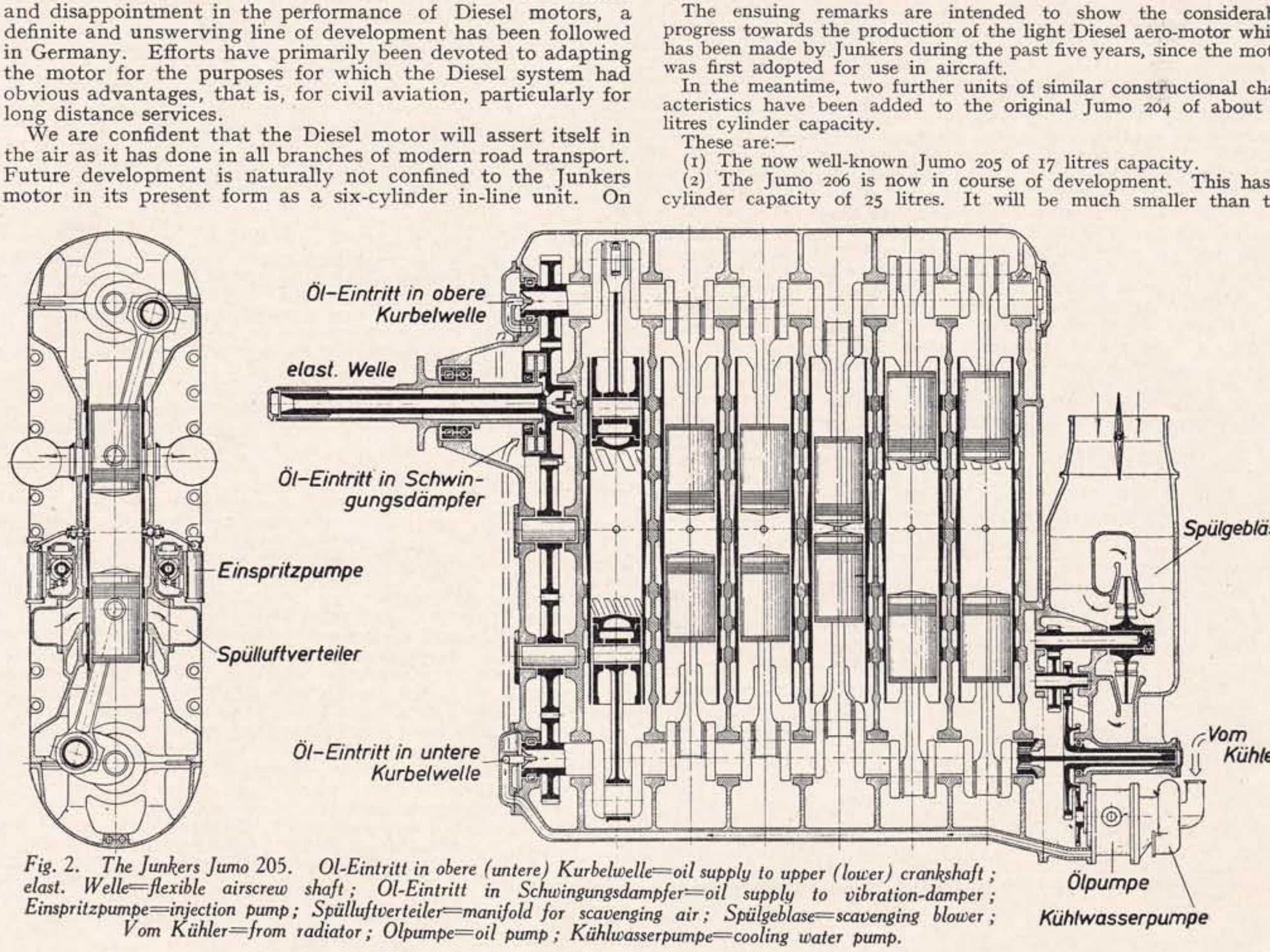


Fig. 2. The Junkers Jumo 205. Ol-Eintritt in obere (untere) Kurbelwelle=oil supply to upper (lower) crankshaft; elast. Welle=flexible airscrew shaft; Ol-Eintritt in Schwingungsdampfer=oil supply to vibration-damper; Einspritzpumpe=injection pump; Spülluftverteiler=manifold for scavenging air; Spülgeblase=scavenging blower; Vom Kühler=from radiator; Olpumpe=oil pump; Kühlwasserpumpe=cooling water pump.

Jumo 204, particularly in depth, and lighter in weight, and much more efficient. It is intended to replace the 204.

Before I deal with the differences in running and efficiency of the three types I should like to illustrate by means of two pictures that all three motors are designed on the same working and structural principles.

Fig. 1 shows the working principle. The motors utilise the two-stroke cycle. The two opposed pistons control the intake of scavenging air, and the expulsion of the exhaust gases through appropriate ports in the cylinder wall.

A high degree of swirl is imparted to the incoming air by means of the tangential adjustment of the scavenging slots and scavenging holes. This swirl is preserved as the pistons come together, and results in excellent mixing of the fuel and air when the former is injected at the end of the compression stroke through four symmetrically arranged nozzles.

This system which has no sleeves or valves, has great possibilities from the point of view of high-speed running. The present motor speeds of between 1,500 and 2,500 r.p.m. can certainly be increased to between 3,000 and 4,000 r.p.m.

Fig. 2 shows the following outstanding features of the construction of the Jumo 205:—

(a) The high, very rigid, but also heavy crankcase.

(b) The very light, elastic steel cylinder chambers with the two long, opposed pistons.

(c) The forward position of the gearing, necessitated by the use of two crankshafts.

(d) The vibration damper incorporated in the elastic drive of the airscrew.

(e) The scavenge-air blower which also provides a degree of supercharge.

(f) The injection pumps on both sides of each cylinder in front of the combustion chamber.

Once the six-cylinder, double-piston in-line motor had been selected, a very useful unit had been created in which the weight per litre of cylinder capacity was fixed within comparatively close limits. A comparison of the three types shows that in spite of considerable differences in the main dimensions and a progressive development in all the structural parts, the weight per litre of cylinder capacity has remained almost unchanged.

On the other hand, the weight per unit of power has been very considerably reduced, from 0.95 kgs. per h.p. (2.09 lb./h.p.) for the Jumo 204 to 0.63 kgs. per h.p. (1.39 lb./h.p.) for the Jumo 206. This reduction of about 35% in specific weight has been effected chiefly by raising the output per litre of cylinder capacity.

The 28 h.p. per litre for the Jumo 204 has been increased to 42 h.p. per litre for the Jumo 205 and Jumo 206. Recent results on a single-cylinder experimental unit indicate that an output of between 45 and 50 h.p. per litre can be expected.

The most important modification which made this increase in output possible was the reduction of the stroke-to-bore ratio which allowed an increase in motor speed without raising the piston speed. The comparative figures are:—

	Stroke to Bore Ratio
Jumo 204	3.5 : 1
Jumo 205	3.0 : 1
Jumo 206	2.5 : 1

Though reducing the stroke was an important factor in increasing engine speed, at the same time attempts to increase the output by increasing the brake mean effective pressure were necessary. Progress along both lines called for a thorough development in the construction of the motor and an extensive control of the combustion process. How this was tackled and the manner in which difficulties were overcome, I should like to illustrate with a few examples.

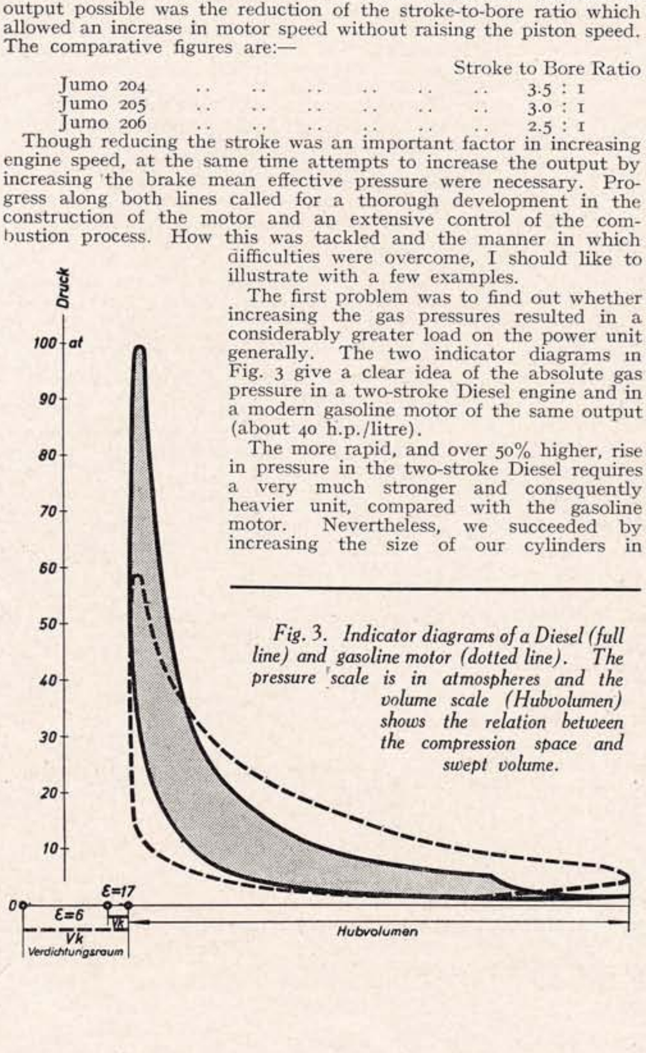


Fig. 3. Indicator diagrams of a Diesel (full line) and gasoline motor (dotted line). The pressure scale is in atmospheres and the volume scale (Hubvolumen) shows the relation between the compression space and swept volume.

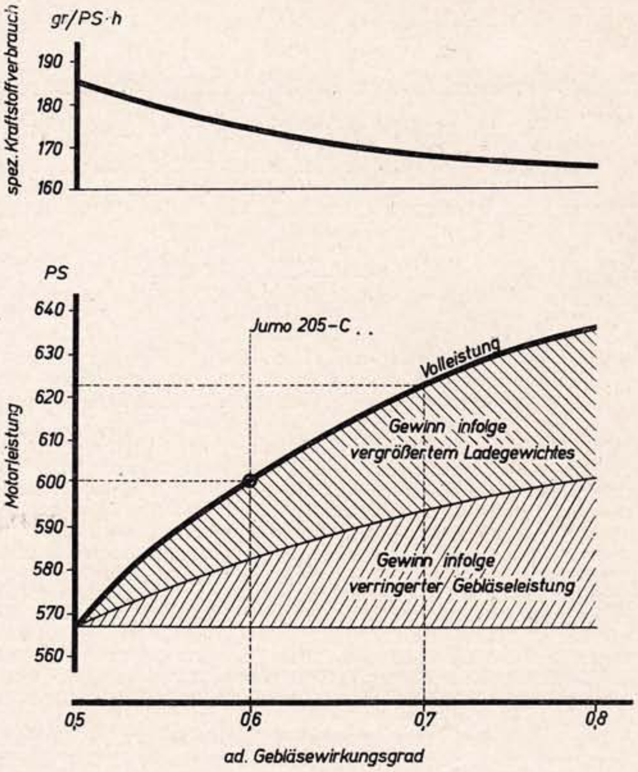


Fig. 4. The top curve shows specific fuel consumption in grms. per h.p./hr. plotted against supercharger efficiency. The bottom curves show the output of the Jumo 205 plotted against blower efficiency. The upper shaded area shows the gain which results from the greater weight of the air charge. The lower shaded area shows the gain from the reduced power needed to drive the blower.

The first problem was to find out whether increasing the gas pressures resulted in a considerably greater load on the power unit generally. The two indicator diagrams in Fig. 3 give a clear idea of the absolute gas pressure in a two-stroke Diesel engine and in a modern gasoline motor of the same output (about 40 h.p./litre).

The more rapid, and over 50% higher, rise in pressure in the two-stroke Diesel requires a very much stronger and consequently heavier unit, compared with the gasoline motor. Nevertheless, we succeeded by increasing the size of our cylinders in maintaining a constant maximum pressure, and at the same time obtaining a high mean effective pressure,—thereby avoiding the need further to strengthen the power unit.

Obviously, the high gas pressure, and the rapid pressure rise in the cylinder, also result in a correspondingly greater tendency to vibration of the power unit. We are to-day in a position to control these vibrations throughout the entire range of motor speed. The most dangerous vibration is adequately dealt with by the use of a very elastic airscrew shaft. The remaining vibrations are reduced to impotence by the use of dampers.

With regard to the scavenging and charging processes, the first essential for complete combustion is the introduction of a charge of pure air of the greatest possible density, that is of low temperature and high pressure. When we changed over to short-stroke high-speed motors the scavenging effect was at first adversely affected, which added considerably to the amount of work to be done by the scavenging air.

A lot of experimental work was necessary to correct this defect. We were assisted by the knowledge that the high rate of swirl of the scavenging air, necessary for the formation of the combustion mixture, was at the same time an obstacle to the complete expulsion of the exhaust gases. As a result of this swirl the colder and heavier fresh air tended to be thrown outward, leaving a core of warm exhaust gases in the centre of the cylinder. With a short stroke, that is, with a greater cylinder diameter this effect was particularly noticeable.

We, therefore, altered the direction of the individual scavenging ports, so that those ports which were open last on the down-stroke of the scavenging piston could project an air blast into the centre of the cylinder, and thus expel the remaining exhaust gases. The results were surprisingly good.

We succeeded after a certain amount of experiment, in reducing considerably the amount of scavenging air necessary for efficient combustion. Whereas the Jumo 204 and Jumo 205 required a volume of scavenging air equal to approximately 1.6 times the cylinder capacity, the amount of scavenging air required for the Jumo 206 with the above mentioned arrangement of ports was reduced to 1.3 times the cylinder capacity.

In this wise the brake mean effective pressure could be raised from 7 to 8 atmospheres (100 to 115 lb. per sq. in.) without increasing the specific fuel consumption. With the experimental single-cylinder unit an increase of output of 20% was recently obtained. These values correspond to a brake mean effective pressure of between 16 and 19 atmospheres (230 to 240 lb./sq. in.) for a four-stroke cycle.

Work on the improvement of the efficiency of the supercharger itself was equally successful.

Fig. 4 shows the marked effect of the efficiency of the supercharger on the useful motor power. With an increase in the efficiency of the supercharger, the power output is doubled; first by a reduction in the power required to drive the supercharger, secondly by an increase in the motor efficiency with the lowering of the temperature of the in-going air. An increase in the supercharger efficiency means less heating of the air, which results in a denser charge to the cylinders and a greater power output for the same amount of fuel.

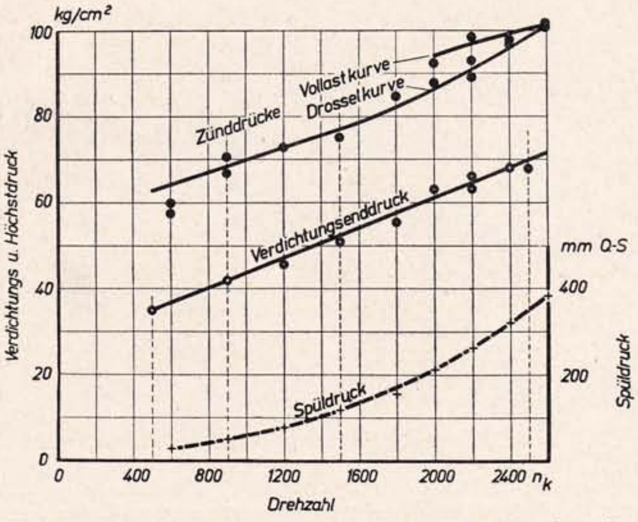


Fig. 5. Pressure variation against engine speed. The "Vollastkurve" shows max. pressures at full throttle. The "Drosselkurve" shows maximum pressures recorded on the propeller curve. The spots marked "Zünddrücke" show the ignition pressure. The "Verdichtungsenddruck" curve shows the max. compression pressure. The "Spüldruck" shows scavenging pressure.

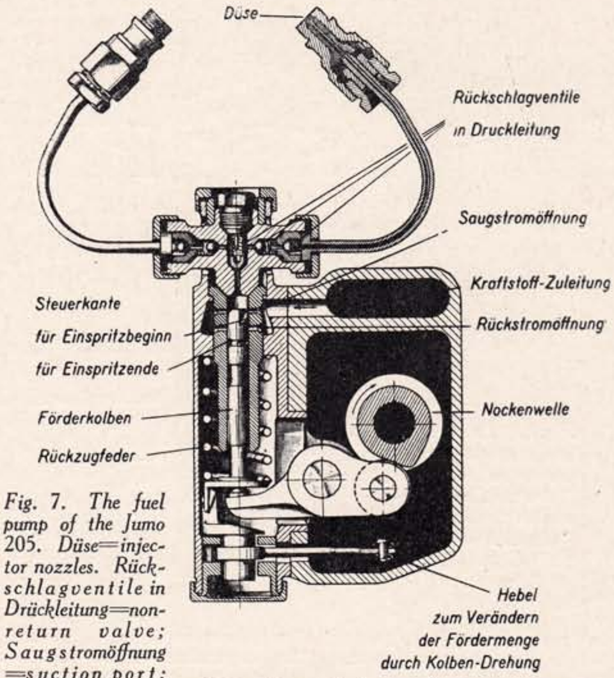


Fig. 7. The fuel pump of the Jumo 205. Düse=injector nozzles. Rückschlagventile in Drückleitung=non-return valve; Saugstromöffnung =suction port; Kraftstoff-Zuleitung = fuel inlet ; Rückstromöffnung = return port ; Steuerkante für Einspritzbeginn (Einspritzende)=control-edge for start (finish) of injection ; Förderkolben=delivery piston ; Nockenwelle= camshaft ; Rückzugfeder=return spring ; Hebel zum Verandern, etc.= lever to control injection by rotation of piston.

The pressure of the air charge in the cylinder as well as its temperature plays a very important part in controlling the weight of charge, and therefore the output. Experiments show that by careful timing, even in fast-running motors, the cylinder can be charged almost up to a pressure equal to that of the scavenge air.

Fig. 5 shows the relation between compression pressure and scavenge pressure for various motor speeds. The compression pressure may be accurately measured if, for example, fuel injection to any one cylinder is temporarily cut off. The maximum ignition pressure curve with full fuel charge shows that in spite of an increased load there is very little increase in compression pressure, when running at high speed, a fact which is very useful in selecting the ignition pressure for high-speed running.

With a quartz indicator the pressure variation during injection and the actual combustion process can be followed. The original pressure diagram (Fig. 6) gives an idea of the relation between injection and combustion. The pressure in the lead to the injector and the pressure in the cylinder are recorded on the same chart.

The extraordinarily clean cut-off and almost vibration-free operation of the injection pump can be seen. About ten degrees of crank-angle after injection the pressure in the cylinder increases, due to combustion. This delay, known as ignition lag, occupies about two-thirds of the total injection time on the diagram with a full charge.

Recent experience has shown that retarded injection is desirable as during the injection period the process of mixing the fuel with the circulating air takes place. For this reason we did not obtain particularly good results from the use of special Diesel fuels of particularly good ignition quality (high cetene value) whereas commercial gasoils such as that used by the Deutsche Lufthansa, with an ignition value of between 50 and 70 cetene numbers, gave good results.

Fig. 7 shows the Junkers injection pump. This injects the whole of the fuel charge into the cylinder at a pressure of 550 atmospheres (8,100 lb. per sq. in.) in less than one-thousandth of a second just before top dead centre. In building this unit, we aim at making all movable parts as strong as possible in view of the high injection pressures of the two-stroke high-speed motor. At the same time the size of the pump drive and accessories are kept as small as possible in view of their position immediately in front of the combustion chamber.

The fact that in flying service the pumps require no attention, and not uncommonly run for 600 to 800 hours between overhauls, is not only caused by their design but by the ever-increasing precision of their manufacture. The Junkers pump has given satisfactory results at speeds over 50% higher than the present rated motor speeds.

I now come to the problem of temperature variations in the combustion chamber, particularly in the pistons. The difficulty of controlling the heat flow was only solved after we had developed a means for completely preventing the gases from blowing past the pistons despite the high combustion processes in the high-speed two-stroke engine.

Ordinary piston rings were quite useless. After many failures and experiments the solution was eventually found by attaching a completely closed, loosely-fitting thin ring at the extreme end of the piston-head between the special auxiliary piston-crown known as the heat-protecting plate and the actual body of the piston. Under pressure from the gases, the ring is forced tightly against both the piston and the sides of the cylinder wall and forms a very effective seal.

It is so closely fitted that there is just room at normal working temperatures for a thin film of oil between the piston crown and the cylinder walls. We have found that the ring cannot be shifted from its position, even with the highest gas pressures encountered. (Fig. 8.)

You may well ask how such a ring, fitted with such a small clearance, continues to function without seizure in conjunction with a piston which is running at high temperatures. I must confine my reply to saying that the very small radial thickness of the ring is of decisive importance in retaining its predetermined diameter, and that the physical and metallurgical requirements for the ring material are now known.

The effectiveness of the pressure rings is nevertheless impaired if there are any large or irregular variations in the cylinder diameter, when the motor is running. The actual temperatures in the cylinder wall have been measured by means of thermo-couples. Fig. 9 shows the temperatures recorded under full load.

One must admit that despite an evidently careful circulation of the cooling water, the temperature of the cylinder-wall in the proximity of the dead air space, that is of the actual combustion space, is well

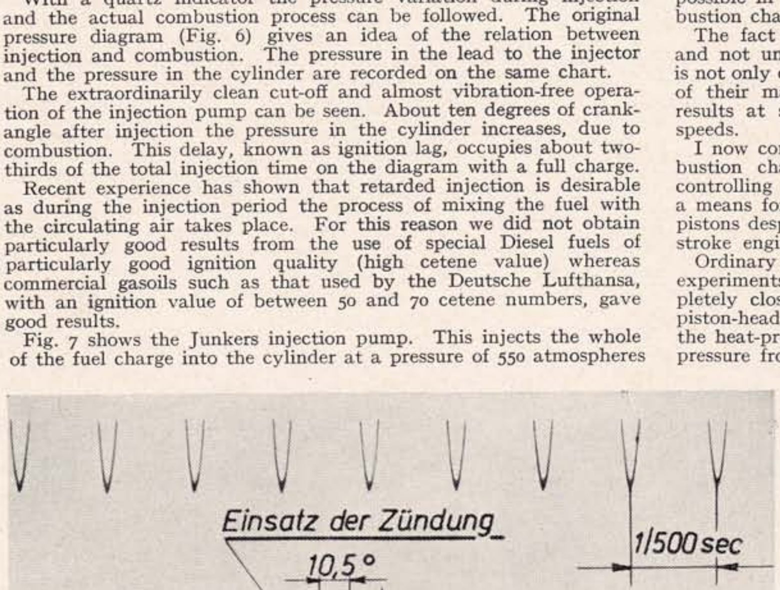


Fig. 6. Pressure variations in cylinder (zylinder) and injection pump (Einspritzpumpe). Einspritz-Beginn=start of injection ; Einsatz der Zündung=start of combustion.

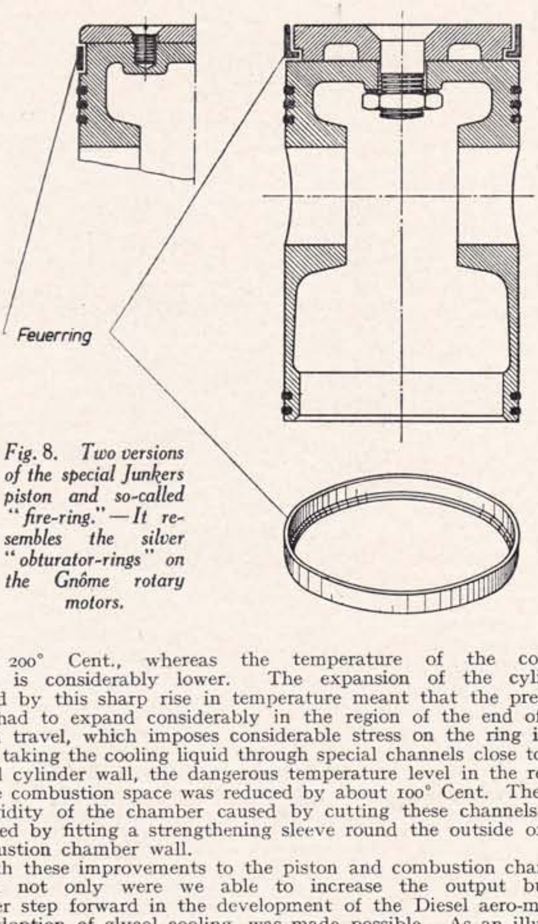


Fig. 8. Two versions of the special Junkers piston and so-called "fire-ring."—It resembles the silver "obturator-rings" on the Gnôme rotary motors.

over 200° Cent., whereas the temperature of the cooling liquid is considerably lower. The expansion of the cylinder caused by this sharp rise in temperature meant that the pressure ring had to expand considerably in the region of the end of the piston travel, which imposes considerable stress on the ring itself.

By taking the cooling liquid through special channels close to the actual cylinder wall, the dangerous temperature level in the region of the combustion space was reduced by about 100° Cent. The loss in rigidity of the chamber caused by cutting these channels was restored by fitting a strengthening sleeve round the outside of the combustion chamber wall.

With these improvements to the piston and combustion chamber design not only were we able to increase the output but a further step forward in the development of the Diesel aero-motor, the adoption of glycol cooling, was made possible. As an illustration of the improved performance made possible by the above-mentioned modifications, an increase in power output from 600 to 700 h.p. has been recorded with the Jumo 205.

After the initial experiments, with their unavoidable teething troubles, we have now made tests with a glycol-cooled Jumo 205. This motor has been approved for flight service at an output of 600 h.p. The first glycol-cooled engines are now being prepared for trial flights.

The highest admissible cooling temperature is 130° Cent. The specific fuel consumption is identical with that obtained on the water-cooled motor. The adoption of glycol cooling permits the use of smaller radiators and consequently a reduction in weight and air resistance. This aerodynamic advantage considerably improves the possibilities of using Diesel aero-motors in high-speed aircraft.

Finally, mention should be made of the problem on which Junkers have expended a considerable amount of thought and have recently arrived at a practical solution. That is to say, the design of Diesel aero-motors for commercial flying at high levels. Many attempts have already been made to utilise exhaust gases by means of an exhaust-gas turbine to drive a supercharger to restore the power output at high levels.

On account of the high temperature of the exhaust gases (800-1,000° Cent.) of the petrol motor, the adoption of an exhaust-driven turbine would tend to prejudice the safety of the installation. Probably insuperable difficulties would also arise in regard to the material for the manifolding and turbine equipment itself.

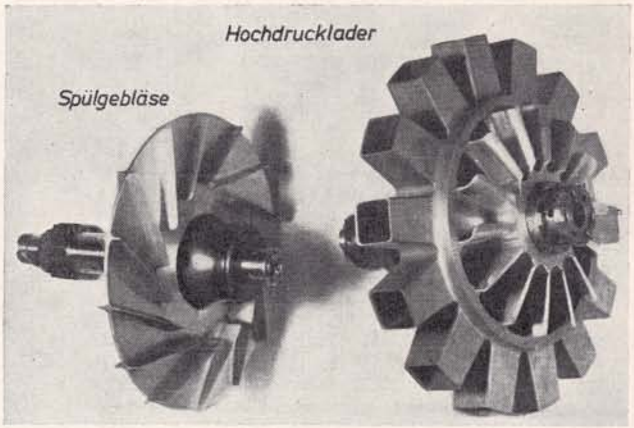


Fig. 11. (Left) Scavenging blower. (Right) High-pressure supercharger.

On the other hand, the exhaust gas temperatures of the two-stroke Diesel motor do not rise above about 500-550° Cent. and thus do not constitute any serious objection to the adoption of the exhaust-driven turbine. Two consecutive experiments were made with two basically different systems to connect up the exhaust-driven turbine, supercharger, and the motor itself.

We experimented with a single-stage blower to maintain sea-level power up to 4,000 to 5,000 metres (12,300 to 15,500 feet). At sea level this blower was only used to produce scavenge pressure and was driven only by the motor. Between the motor and the blower is a differential drive so arranged that the turbine can be operated by the exhaust gases when the requisite height has been reached.

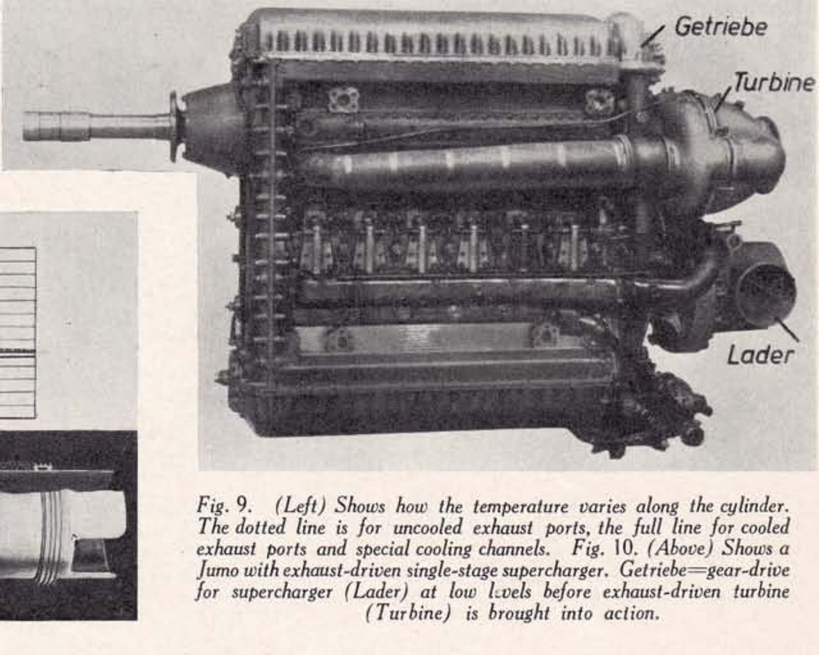
Thus the turbine is used to provide the necessary auxiliary power for flying high by speeding up the blower. Further developments then lead to the design of a two-stage turbo-blower. The exhaust-gas turbine and the first stage of the supercharger constitute a unit independent of the motor.

A Jumo 205 fitted with a single-stage exhaust-driven supercharger did its first trial flights last Summer, including a number of test flights up to 6,000 metres (18,500 feet). Fig. 10 shows the engine with the exhaust-driven turbine, the high-pressure blower and the differential spur-wheel drive. In flight the performance of this experimental exhaust-driven supercharger was satisfactory, although this first experimental type did not maintain sea-level power output high enough to justify its extra weight.

Some valuable and significant data were obtained during these high level flights with a new torque-measuring instrument developed by the Deutsche Versuchanstalt für Luftfahrt.

Besides these high level flights, developments of the exhaust-gas turbine, and the two-stage high-pressure supercharger were continued with satisfactory results on the test bench. An exhaust-gas turbine weighing 30 kg. is in operation, which develops 160 h.p. at 6,000 metres (18,500 feet).

Fig. 11 shows the most important stages in the development of the supercharger. In place of the open rotor there is a closed-channel rotor with a rotating system of inlet deflectors and guides. The strength of this rotor is such that a pressure ratio of 2.2 to 1 can be obtained. With such a fully-developed exhaust-driven



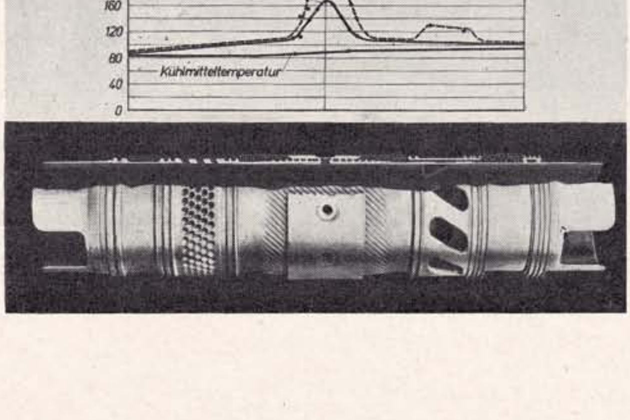


Fig. 9. (Left) Shows how the temperature varies along the cylinder. The dotted line is for uncooled exhaust ports, the full line for cooled exhaust ports and special cooling channels. Fig. 10. (Above) Shows a Jumo with exhaust-driven single-stage supercharger. Getriebe=gear-drive for supercharger (Lader) at low levels before exhaust-driven turbine (Turbine) is brought into action.

supercharger ground-level power can be kept up with the same fuel consumption up to a given pressure height. At heights of between 4,000 and 6,000 metres (12,300 to 18,500 ft.) specific fuel consumptions of 160 grams per h.p./hour (.352 lb. per h.p./hr.) were obtained.

I have now reached the end of my lecture. I set out to show the line taken by Junkers in the development of Diesel aero-motors and the prospect of further developments in the near future.

We believe that the Diesel motor by reason of its advantage in service and the safety of its fuel, will be used in air traffic to an ever-increasing extent. When I look back upon statements I made seven years ago, I realise that an important step in the development of the Diesel aero-motor has already been reached. I refer to the practical introduction of the Diesel aero-motor in commercial air-line service.

During the past few months, thanks to the enterprise of the Deutsche Lufthansa, we have had a practical demonstration of the possibilities of Diesel motors for long-distance service. I speak in particular of the recent flight of the high-speed Ju 86 to Bathurst and back, and the North Atlantic crossings in both directions by two Dornier Do 18 flying-boats with Jumo 205 motors.

Such performances are more convincing than any prophecy. Even if he does not indulge in prophecy the constructor must always think of the future and of new possibilities. The development of the Junkers Diesel continues in the direction of higher output and lower specific weight. We contemplate an output of between 1,500 and 2,000 h.p. at a specific weight of less than 0.5 kg. per h.p. (1.1 lb. per h.p.).

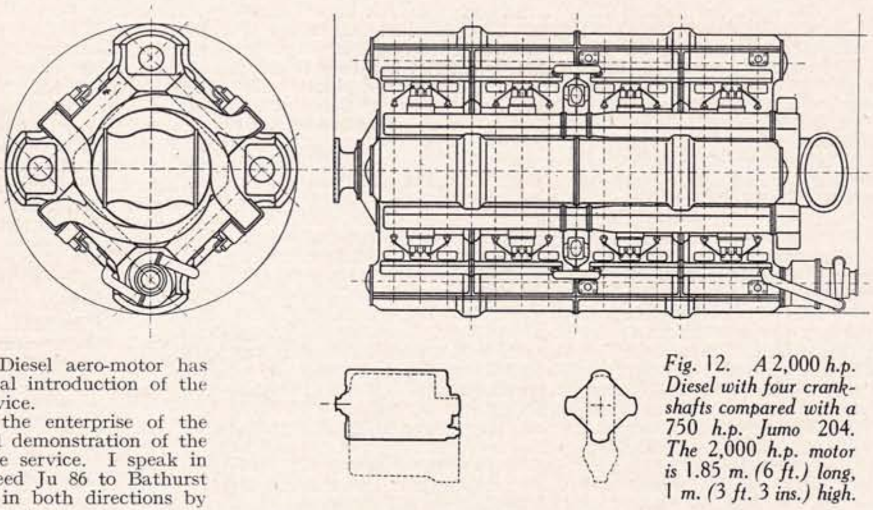


Fig. 12. A 2,000 h.p. Diesel with four crankshafts compared with a 750 h.p. Jumo 204. The 2,000 h.p. motor is 1.85 m. (6 ft.) long, 1 m. (3 ft. 3 ins.) high.

The final illustration (Fig. 12) is designed to show you the possibilities of such ideas. The most important feature is the abandonment of the six-cylinder in-line construction in favour of four crank motors. Besides the gain in efficiency and reduction in weight, this type of construction results in considerable saving in space as compared with the first Jumo 204 motor. Even if this picture only represents the first design sketches, it does serve as a basis for future high efficiency Diesel aero-motors.

More About Plastics

RED HERRINGS are not a bit like foxes, but hounds seem to find their scent more chaseworthy. Likewise people seem to enjoy chasing equally highly coloured fish, but of more figurative kind, in debate rather than discussing the argument before the meeting. At least one such fish manifested itself in the discussion which followed Dr. de Bruyne's lecture on "Plastic Materials for Aircraft Construction" before the Royal Aeronautical Society on Jan. 29, of which a *précis* appeared in THE AEROPLANE.

With the excellent intention of making his subject easy on the understanding, Dr. de Bruyne referred to all phenol-formaldehyde resins as "Bakelites" and all such materials when reinforced with fabric or cord as "Aerolite." Speakers promptly made the mistake of taking "Aerolite" to be a trade name coined to describe a proprietary product and therefore one to be invidiously compared with existing types.

Actually the "Aerolite" of the paper is merely the type name, as it were, of all fabric-reinforced phenol-formaldehyde resins. Instead of spending the limited time, available for discussion, on the derivation and meteorological aspects of "Aerolite,"—nobody remembered the famous pistons of that name,—we might have heard more about the practical applications of synthesised materials.

And this brings us to another point. The Royal Aeronautical Society represents the massed brains and experience of the British Aircraft Industry which in its own time does manage to produce the finest aircraft in the World. One would imagine that such ability could be better employed than overlooking, as it does at present, the routine running of a library, lecture programme, examinations and the office work of the scholarship scheme financed by the Society of British Aircraft Constructors,—particularly when all are in the capable hands of Capt. Laurence Pritchard and his efficient staff.

Aircraft engineers, prominent in their profession, should be more profitably engaged. We ought not to allow the existence of the Aeronautical Research Committee and the despotic beneficence of the Air Ministry to let our aircraft engineers get into the habit of having their advance thinking done for them.

Concerted action by their own professional body could do much for the aircraft engineers' own industry. The development of synthesised materials, such as plastics, for aircraft construction is one of them.

The Aircraft Industry and the Plastics Industry are both growing fast. Both are vital to the continued prosperous existence of this country. Both would benefit by the mutual interchange of ideas. But there is no link between them.

The liaison work done by Dr. de Bruyne and his associates of Aero Research Ltd., as between one aircraft company and one producer of synthetic resins, affords an excellent example of what might be done by members of the Royal Aeronautical Society working in conjunction with similarly representative members of the Plastics Industry.

Such linkage between the two great industries may not yet be of obvious enough necessity to warrant Air Ministry or Aeronautical Research Committee patronage. But the opportunity of producing by synthesis structural materials, ideal for each separate application, should appeal to the aircraft engineer as much as the opportunity to make his industry independent of outside supplies should appeal to the realist constructor.

The next move lies with the Royal Aeronautical Society. We hope they take it.

Hereafter follows a report of the discussion:—

The Discussion

MR. H. E. WIMPERIS, C.B., C.B.E., M.A., F.R.Ae.S., M.I.E.E. (Director of Scientific Research, Air Ministry), Chairman, said that Dr. de Bruyne had delivered an excellent lecture on a subject which was new to a great many. He had told them all about "Aerolite" and there must be some present who had also experimented with this substance. Their views would be very interesting to hear.

He called on Mr. Langley to open the discussion.

MR. MARCUS LANGLEY, M.I.Ae.E. (British Aircraft Manufacturing Co. Ltd.), said that he had not been prepared to open the discussion and would therefore be slow in collecting his thoughts. The first point that had struck him during this excellent lecture was the language difficulty. There must be many terms with which chemists may be familiar but engineers are not, and also *vice versa*. He asked the meaning of the word "syneresis."

Could consistent plastic materials be got in the same way as metals are consistent, so that one would be able to forecast their properties exactly?

In the curve shown of glued joints he noticed that the strength of phenol resin tested at 100° Cent. had a marked drop in strength of about a third after 10 hrs. He wondered whether this was repeated at other temperatures and if so what the effect would be on an aeroplane in tropical conditions. The temperature might be 50° Cent., but would this lower temperature over a much longer time cause the same drop in strength?

He asked for an explanation of the curves produced to illustrate the bearing strength of "Aerolite."

The properties of "Aerolite" of strength in compression and weakness in tension were much the same as those of concrete. Consequently research work already done on reinforced concrete might help very much in the understanding of "Aerolite."

Had metal-mesh reinforcements been tried yet and, if so, with what results?

Before Dr. de Bruyne's lecture he had thought that large mouldings might play a part in the future development of aeroplanes, but Dr. de Bruyne had shown that an increase in moulding pressure on "Aerolite" greatly raises the strength. This had rather dashed his hopes on the moulding question, but when further research had been done he still hoped to see large components moulded. In this direction might lie the cheap and popular aeroplane of the future.

MR. W. O. MANNING, F.R.Ae.S., wanted to know the compressive strength parallel to the cords of the cord material (cresol resin) with 33 cords per in.

Fifteen years ago they had used three-ply to keep the shape of the leading edges. This had never been very satisfactory because the three-ply of that day warped easily.