THE JUNKERS ENGINE

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Editor's Note. This is the last of a series of articles on the Diesel Engine and is published with permission of the *Pacific Marine Review*.

THIS, the last article, will be devoted to a description of this interesting type of Diesel engine. There is no restriction placed upon the discussion of German machines and the writer is in a better position to talk about this engine than about other foreign types because of personal experience in its construction and operation in Germany during 1915–1918.

Prof. Junkers, the originator of this type of Diesel engine, is perhaps best known as the maker of the calorimeter accepted for a long time as standard. He has devoted himself almost entirely to the study of heat.

In 1893 he began work on an engine having two pistons in one cylinder, to be run on gas. This was a year after Dr. Diesel began his experiments. The Oeschelhauser-Junkers gas engine was unsuccessful, because of the great difficulty of injecting the gas. As a result of the first experiments Prof. Junkers conceived the idea of operating the engine on the Diesel cycle and using oil as a fuel. He devoted himself to a study of the thermodynamic troubles of the Diesel engine and a mechanical study of the double piston principle. Though both the double piston engine and the Diesel cycle were known, yet the combination of the two was unique and the result of sound scientific deduction. For the most efficient operation of the Diesel engine, high compression, with the attendant high temperatures and extreme heat flow, is necessary. Such compressions, temperatures and heat flow could not be controlled in the single piston engine, but were possible of restraint by the elimination of the cylinder head and valves, substituting a piston for the elements removed. The double piston possessed the advantages of elimination of cylinder head and valves, perfect balance (even in a single cylinder), perfect operation on the two stroke cycle (because of good scavenging conditions) a long stroke-to-bore ratio, removal of stress from the frame (since the gas pressure is constrained between the two pistons instead of between piston and cylinder head), lower height for a given bore and stroke and more flexible cylinder construction reducing the danger of cracking at high compressions. Against this must be charged an extra piston per cylinder, greater length per cylinder with single crank shaft construction, greater number of bearings on the crank shaft and moving parts of large size above the housing. The latter two points can be omitted when two propellers, and therefore two crank shafts are possible.

The engine operates as follows: referring to fig. 1, the cylinder is assumed to be filled with fresh air from the previous scavenging period. The pistons approach each other, compressing the air between them—line F–A in the ideal card. At the end of compression (pistons as in A) the fuel is injected and the combustion takes place without either a rise or fall in pressure-line A–B in the ideal card. During this period the pistons have moved about twelve per cent of their stroke. The expansion takes place—line B–C in the card—and the pistons reach the position shown in C. At this point one of the pistons opens a row of ports extending around the circumference of the cylinder, permitting the gases to exhaust almost to atmospheric pressure-line C–D in the card. At the point D (position of pistons D) the second piston opens another row of ports at the opposite end of the cylinder permitting the scavenging air to enter under low pressure, drive the burnt gases out before it and fill the cylinder with a charge of fresh and cool air—line D–E–F in the card. By this time the pistons have passed their outer dead

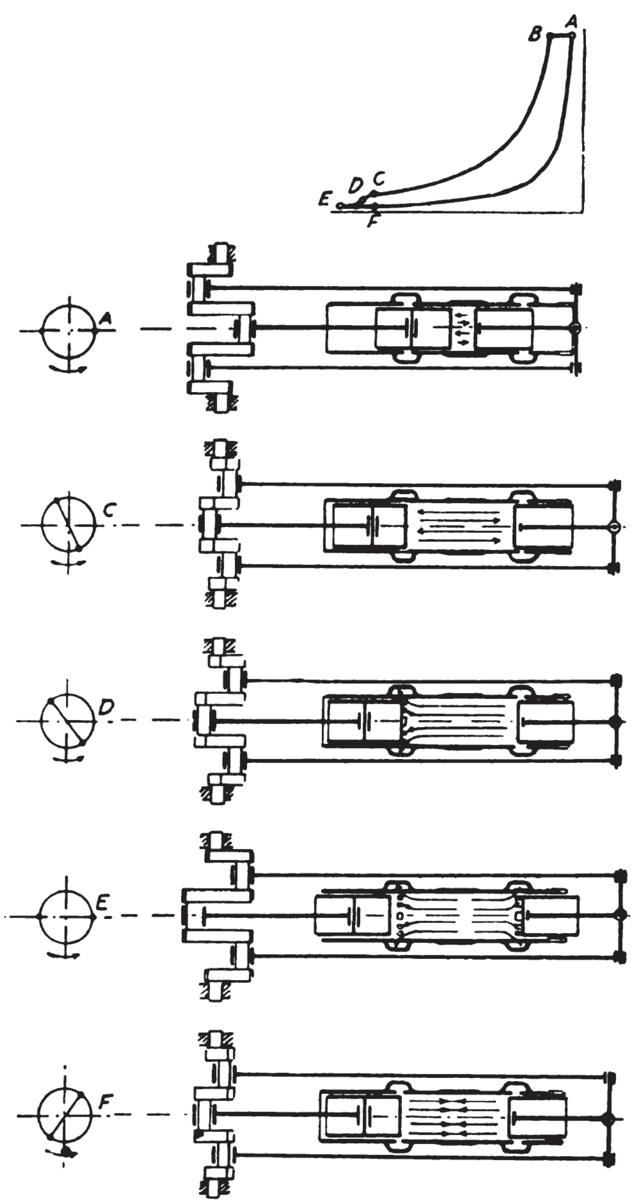

Fig. 1

centre and have returned to the original position (F), ready for a repetition of the cycle.

It will be noted that, with this arrangement, better scavenging is possible than in a four stroke cycle engine, since the clearance space of the latter engine is always filled with bad gases, whereas, with two pistons, the entire volume of burnt gases is driven out without any tendency toward eddying or mixing.

It is impossible with the two stroke cycle single piston to secure good scavenging, which accounts for the fact that such engines deliver only 50 per cent more power than a four stroke cycle engine of same bore and stroke. Theoretically, of course, the ratio is two to one in favor of the two stroke cycle since there are twice as many power impulses in a given number of revolutions. The double piston engine attains this ratio because of perfect scavenging.

In the sixteen years of experimental work preceding the building of the first of these engines much time was devoted to the study of the transfer of heat from a gas to and through a metal wall. There are four factors affecting this transfer—temperature, pressure, eddying and the character of the metal surfaces.

Eddying or motion in the gas itself is one of the most important. By the use of two pistons the eddying factor is greatly reduced. Entrance and exit of gases through valves in the cylinder head, or deflection against baffle plates sets up heavy initial whirling.

The character of the metal surfaces, so far as Diesel engines are concerned, may be neglected since machined cast iron is universally used.

High pressures and temperatures are essential and may be placed at a par for all types.

The previous considerations assumed equal areas of metal wall exposed to the gases. The greatest possibility of saving consists in reducing the surface of the combustion space and here the double piston construction has a great advantage. It is during the period when the temperature, pressure and eddying are at the maximum that heat energy must be saved and not toward the end of the stroke shortly before exhaust takes place.

The piston may generally be considered as a poor absorber of heat, since it is either uncooled or only slightly cooled, but the cylinder wall and particularly the cylinder head are responsible for the transfer of almost 35 per cent of the total available heat energy of the fuel to the cooling water. But the double piston construction permits the elimination of the cylinder head, substituting a poor heat absorber, and, with a large stroke-to-bore ratio, a considerable reduction of the wall surface as compared with the enclosed volume. Heat is work, and 35 per cent of the heat lost is 35 per cent of the brake horse power gone. This point is therefore highly important.

Two of the greatest difficulties with the Diesel engines were the cracking of the cylinder heads and liners. Prof. Junkers, having dispensed with the head, had only the liner to consider. High pressures and temperatures are necessary, not only for efficient operation, but particularly for the use of low grade fuels. The liner performs two functions with respect to the gases. It restrains the pressures and retains as much heat in the gases as possible. It is not the pressure that causes breakage, but the heat flow. The thicker the cylinder wall the greater the stress induced by the heat flow, but the higher the pressure or the greater the cylinder diameter the thicker must be the wall to stand the total pressure. Therefore, with ordinary construction, the pressure or the cylinder diameter which can be used is limited, and even with low pressures the cylinder diameter is restricted to that point at which the liner is thick enough to carry the load and still not too thick to crack under the temperature stresses induced by the intense heat flow. It must be remembered that the energy transformation in a Diesel engine takes place in a space equal to about one two-hundredth part of that occupied by a steam boiler of equal capacity. Prof. Junkers divided these two functions between two different members. In his construction the liner proper is always made thin enough to avoid cracking from the heat flow. Around the liner is shrunk a steel jacket, ribbed on the inside to permit the circulation of water. This member carries the gas pressure. This makes unlimited pressures and diameters possible. Further, the cylinder for a double piston engine is nothing more than a tube free at both ends to expand or contract. This removes longitudinal strains from this member. Unfortunately this liner and jacket construction is inapplicable to the single piston engine, because it cannot be applied to the cylinder head, a much more complicated and difficult member to construct for high pressures and heat flow. As a practical example of the success of this construction, maximum pressures of 1278 pounds, per sq. in. were carried in such a cylinder during continuous runs, with attendant mean effective pressures of 213 lbs. per sq. in. The engine on which this was accomplished develops 1000 horse power in two cylinders each about 17″ by 34″ (450 by 900 mm) at 180 r. p. m. The excellent thermal conditions made possible a fuel consumption of 0.36#/ brake horse power hour. The heating value of the oil was 10,080 cal/kg. (18,144 B. T. U./#.)

The lower height of such an engine, assuming same bore, stroke and r. p. m. is due to the fact that the stroke is divided between two pistons. The crank throw, is therefore cut in half and the connecting rod will be half as long. This reduction in the connecting rod length more than compensates for the extra piston on top. The average reduction in height is about 20 per cent.

This engine is probably the most interesting Diesel development. A few of them have been built in this country, but unfortunately for us, the greatest development of the engine has taken place in Germany since the war began and there has not been sufficient technical information available here to make the construction commerciably successful.