April 18, 1933. L. W. LINDBERG 1,904,871

MULTIPLE EXPANSION ENGINE

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Fig. 1.

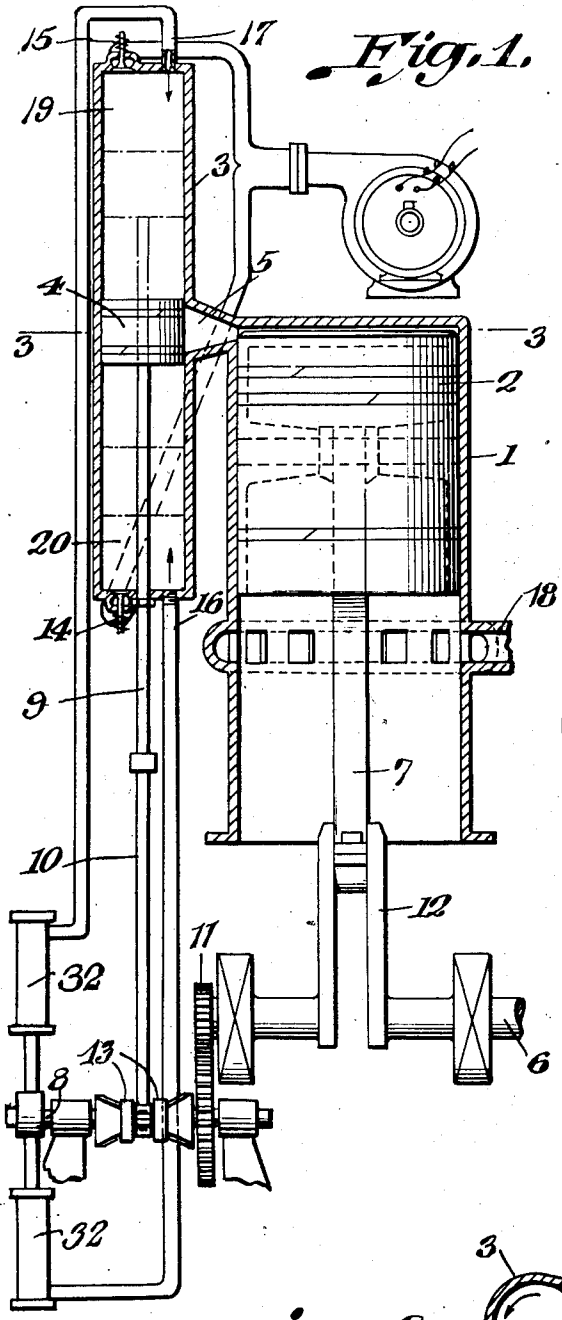

Fig. 2.

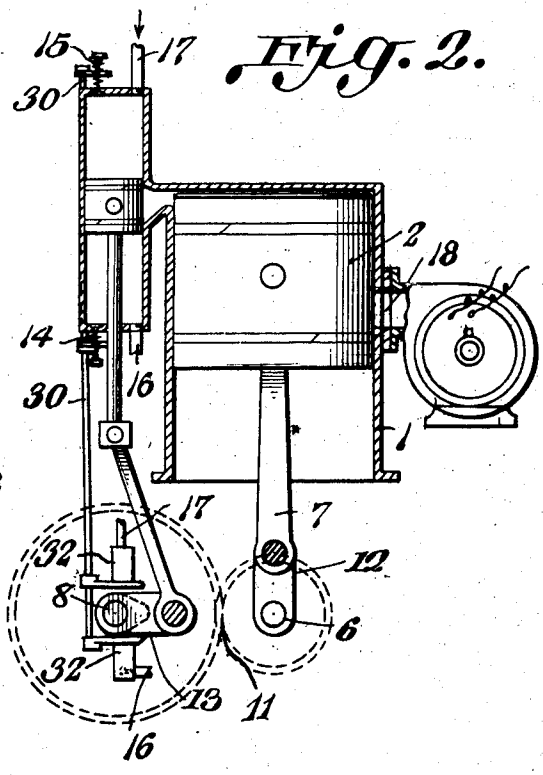

Fig. 3.

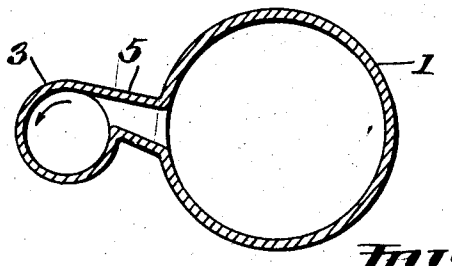

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Fig. 4.

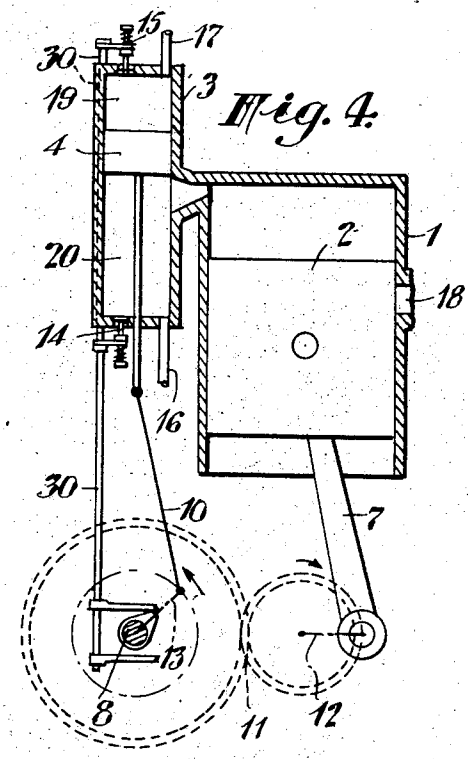

Fig. 5.

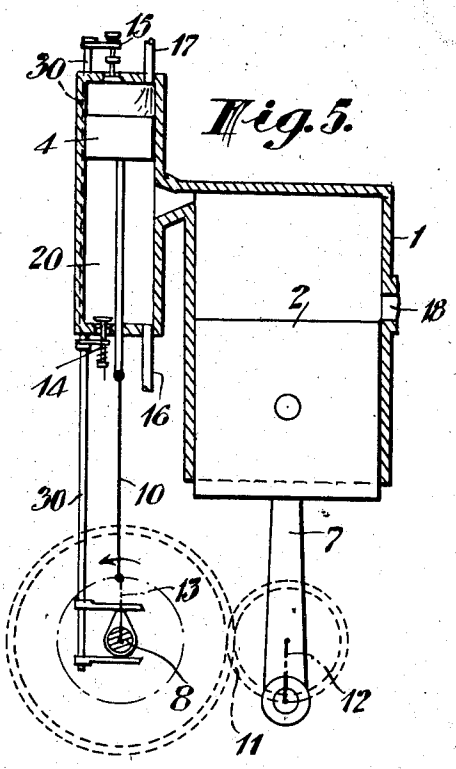

Fig. 6.

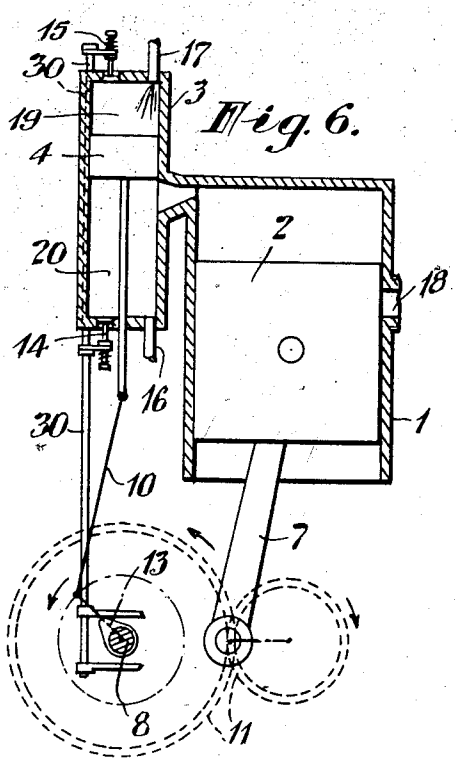

Fig. 7.

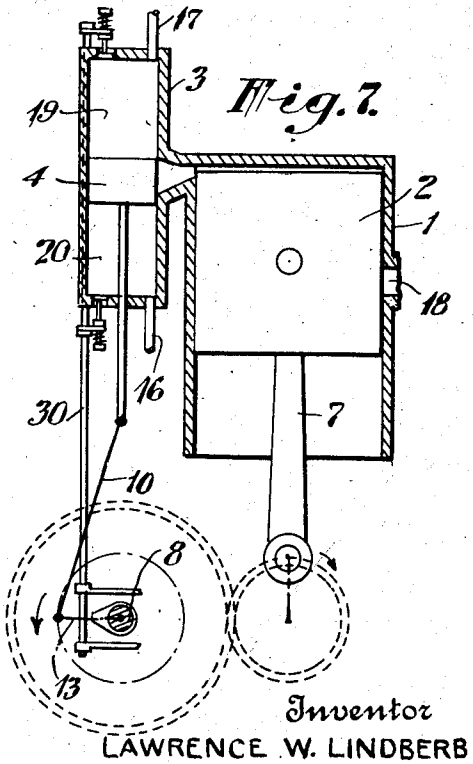

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Fig. 8.

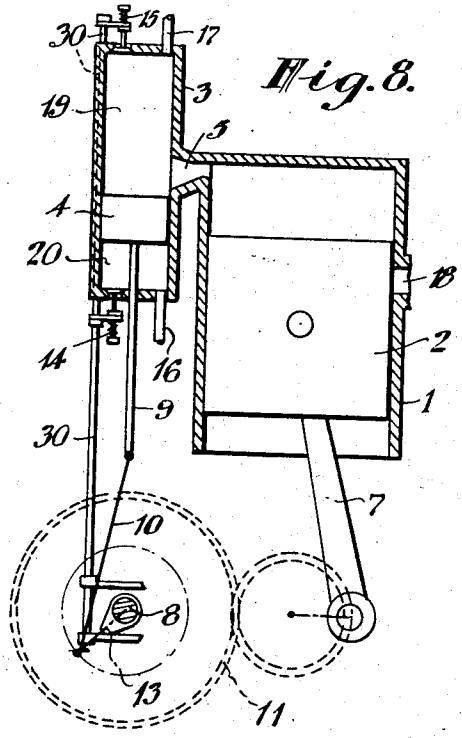


Fig. 9.

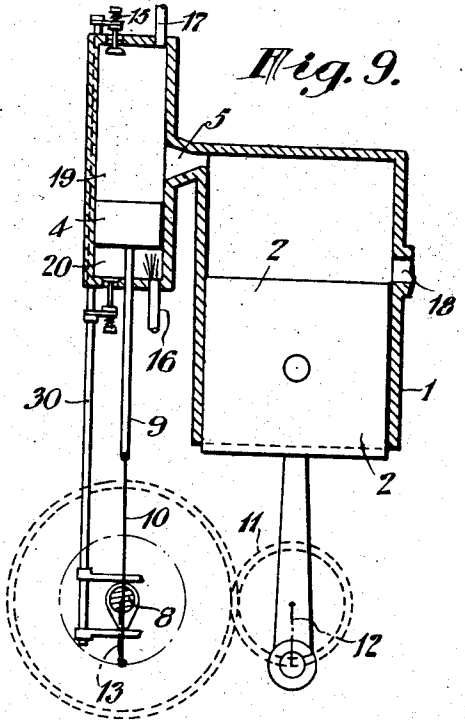


Fig. 10.

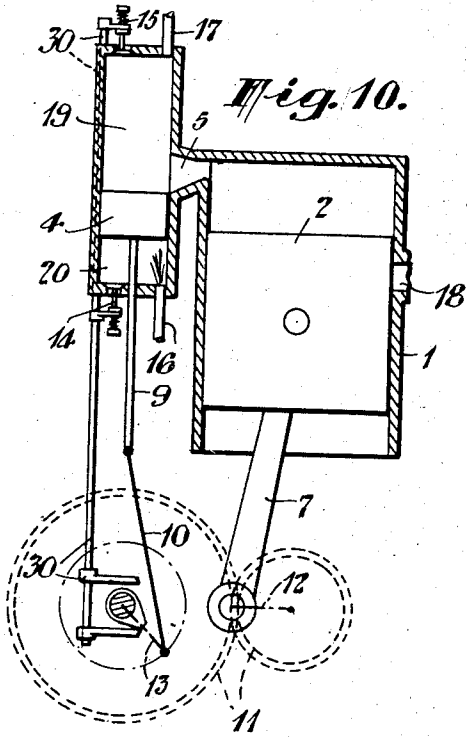
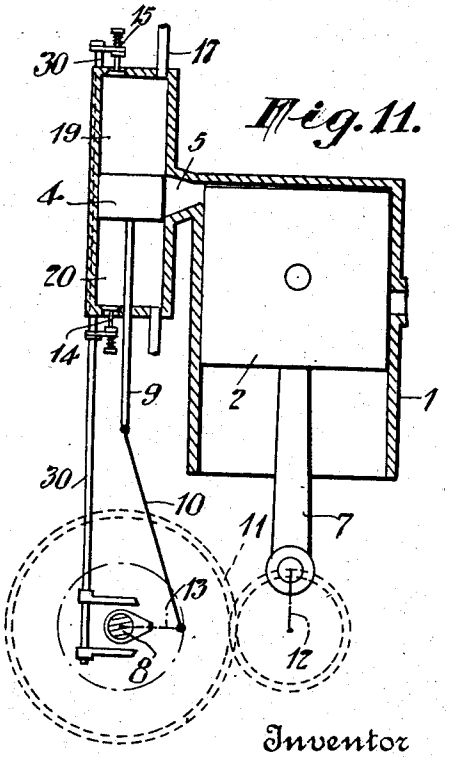


Fig. 11.



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UNITED STATES PATENT OFFICE

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MULTIPLE EXPANSION ENGINE

Application filed August 27, 1928. Serial No. 302,269.

This invention relates to a multiple expansion, internal combustion engine, particularly adapted for operation upon the Diesel or similar cycles.

It is among the objects of this invention to overcome numerous difficulties in the way of the practical attainment of Diesel engine efficiency in small, high speed engines suitable for automotive purposes, and to improve the efficiency of Diesel engines generally.

In multiple expansion engines difficulty has heretofore been encountered in the operation and maintenance of the transfer valve due to the high temperatures to which this valve is subjected. The valve seat and transfer passage being exposed to highly corrosive gases at high temperature and flowing at high velocity quickly becomes pitted while the transfer valve itself is liable to warp. Thus while it has been known since Diesel's original disclosure of his invention that his cycle should be theoretically desirable in multiple expansion engines because of the higher horsepower per pound of engine weight, such a construction has never been commercially feasible because of the lack of dependability and durability.

It is an object of this invention to provide a construction which will avoid the difficulties met with in the transfer valves of multiple expansion engines by eliminating such valves.

It is a further object of this invention to provide an effective interior cooling of the transfer passage by passing the cool scavenging air therethrough, and again passing the air charge, therethrough while being compressed.

While the low pressure cylinder of a multiple expansion engine is not exposed to such high temperatures as are present in the high pressure cylinder during the combustion period, this cylinder is, in engines such as have heretofore been attempted, continuously exposed to hot products of combustion. There is no opportunity for internal cooling of such low pressure cylinders as occurs in the cylinder of a simple engine upon drawing in and compressing a cold air charge. Thus instead of being exposed to hot products of combustion, only half of the time this cylinder no sooner completes the exhaust of one charge than another under high temperature and pressure enters. The result is that this cylinder, despite the fact that it is not exposed to such high maximum temperatures as the high pressure cylinder, is liable to become overheated in the course of continuous operation.

It is one of the objects of this invention to provide for the internal cooling of the low pressure cylinder, and the piston reciprocating therein by scavenging the products of combustion therefrom when the piston is in its outermost position, and by performing a partial compression of the air in this cylinder on the next inward stroke whereby a substantial amount of internal cooling will be effected while at the same time providing a compact and simple construction. As a result the low pressure cylinder and the piston thereof may be cheaply constructed and of light weight. The piston may be of larger diameter than usual before water cooling of the same becomes necessary.

A further difficulty is encountered in the construction of Diesel engines of high speed such as would be suitable for automotive purposes and particularly for aviation in that at high speeds the combustion is poor due to the fact that insufficient time is available for the injected fuel to be diffused throughout the air charge and burned therein.

It is one of the objects of this invention to provide a construction in which the crank connected to the high pressure piston rotates at one half the speed of the crank connected to the low pressure piston whereby ample time will be provided for combustion in the high pressure cylinder while rapid expansion will be provided for in the low pressure cylinder. The advantage of high horsepower per pound of weight which is the primary advantage of high speed engines is obtained in this construction since the low pressure piston, which is of relatively large bore and largely determines the horse-power of the engine, reciprocates at high speed.

A further difficulty which arises in connection with multiple expansion internal engines resides in the fact that upon first open-

ing the transfer valve between the high and low pressure cylinders there is a tendency, because of the great difference in pressure between the two cylinders, for the gases in the high pressure cylinder to flow into the low pressure cylinder through the fine orifice formed before the transfer valve is fully opened. This wiredrawing of part of the charge results in the conversion of part of the useful energy into heat which cannot be recovered.

It is one of the objects of this invention to provide a construction in which the transfer passage shall be opened quickly and in which a certain amount of pressure in the low pressure cylinder together with the quick opening of the transfer passage prevent any material flow of gases therethrough until the passage is so far opened that a free flow of gases from the high pressure cylinder to the low pressure cylinder may occur without wiredrawing.

These and other objects of the invention will be explained in connection with the accompanying drawings, in which:

Fig. 1 is a longitudinal section through an engine embodying a preferred form of the invention, certain parts being omitted for the sake of clearness;

Fig. 2 is a similar section through one unit of a multiple cylinder engine;

Fig. 3 is a transverse section of the cylinders of the engine taken on line 3—3 of Fig. 1;

Figs. 4 to 11 illustrate the relative positions of the pistons at different points in the cycle of operation.

With reference to Fig. 2, 1 indicates a relatively large cylinder having a piston 2 reciprocative therein; and 3, a small cylinder having a double acting piston 4 reciprocative therein. The upper part of cylinder 1 is connected by a passage 5 with cylinder 3, said passage being controlled by the piston 4 in such manner that the passage is just closed when the piston 4 is in the middle of its stroke.

Piston 2 is connected with a crank shaft 6 by the usual connecting rod 7. Piston 4 is connected to a crank shaft 8 by a piston rod 9 and connecting rod 10. The two shafts, 6 and 8 are connected through two to one gearing 11 so that shaft 6 revolves twice to every revolution of shaft 8, and the two cranks 12 and 13 are so positioned that when the piston 2 is at upper dead center the piston 4 is in the middle of its stroke as shown in the drawings. In the form shown in Fig. 2 exhaust valves 14 and 15 which are positively actuated by usual gearing, indicated at 30, are provided in each end of the cylinder 3. Fuel supply lines 16 and 17 are connected to conventional fuel supply pumps such as indicated at 32 which supply fuel into each end of cylinder 3 through spray nozzles. Scavenging air ports 18 are provided in the lower end of cylinder 1 and are adapted to be uncovered by piston 2 when the same is in its lowermost position.

The operation of the engine may best be understood with reference to Figs. 2 and 4 to 11: As the piston 4 moves upwardly from the position shown in Fig. 2 to that of Fig. 4, it completely cuts off communication between the clearance space of cylinder 1 and the upper space 19 of cylinder 3 so that a body of air which has already been compressed to a pressure of around 200 pounds in cylinder 1, is trapped and further compressed in space 19. Simultaneously this movement of piston 4 opens communication between the lower space 20 of cylinder 3 and the clearance space of cylinder 1, so that products of combustion under high pressure expand from the lower space 20 into cylinder 1 as the piston 2 therein moves downwardly from the position shown.

Since the shaft 6 revolves at twice the speed of shaft 8, the piston 2 will complete one full stroke, reaching its lower dead center as shown in Fig. 5 in the same time it takes piston 4 to complete one half of its stroke; that is, to move from the position shown at midstroke to its upper dead center. The piston 2 having uncovered scavenging air ports 18, a charge of air passes through cylinder 1, passage 5, and cylinder 3, forcing products of combustion out through valve 14 which has been positively opened just prior to the uncovering of ports 18.

Simultaneously with this scavenging operation in space 20, fuel is supplied to the highly compressed air in space 19. The piston 4 now moves downwardly on its working stroke, the fuel supply continuing during a portion of this stroke as in usual Diesel engine operation.

Simultaneously with the downward movement of piston 4 the piston 2 moves upwardly, the ports 18 and the valve 14 are closed as shown in Fig. 6 and the fresh charge of air above piston 2 and below piston 4 is compressed by the simultaneous movement of the two pistons. By the time piston 2 approaches its upper dead center nearly all of the air in the cylinder 1 will have been forced into space 20 of cylinder 3. Since the passage 5 between these two cylinders opens tangentially into cylinder 3 as shown in Fig. 3, the air in cylinder 3 is given a whirling motion in the direction of the arrow. Just at the upper dead center of the piston 2 as shown in Fig. 7 the passage 5 is cut off by piston 4 and a body of whirling air is trapped below this piston in space 20. Immediately thereafter, the passage 5 is opened by piston 4 and the products of combustion under high pressure from space 19 expand in cylinder 1 as piston 2 moves downwardly. Expansion in cylinder

1 thus occurs simultaneously with continued expansion in cylinder 3 upon the further downward movement of piston 4 after opening passage 5 as may be seen in Fig. 8. At lower dead center of piston 4 the upper space 19 of cylinder 3 is scavenged as seen in Fig. 9 while combustion takes place in the lower end forcing piston 4 upwardly through the position shown in Fig. 10. The cycle thus repeats itself with combustion occurring alternately in the compression spaces 19 and 20 of cylinder 3.

It will be seen that in this construction a multiple expansion Diesel engine is provided in which the transfer passage is closed and opened by the high pressure piston while the same is moving at about its highest velocity. The fact that piston 4 is moving at its highest velocity at the time of opening the passage 5 has a tendency to prevent any wiredrawing of the hot products of combustion in passing from the high pressure cylinder to the low pressure cylinder, such as would be liable to occur in opening such a port by a piston approaching its dead center position or by the gradual opening of a poppet valve. The passage is opened so suddenly that there is an orifice of large cross section provided before any material quantity of the gases can pass through the narrow slit which is first formed. Any tendency of the gases to pass through the orifice formed by the edge of the piston 4 and the passage 5 before such orifice is large enough to permit the free flow of the gases, without wiredrawing is further prevented by the fact that the pressure of the compressed air in the small clearance space of cylinder 1 and passage 5 is already at about 200 lbs. per square inch. This pressure in passage 5 combined with the high speed at which the passage is opened effectively prevents any wiredrawing of the charge in the course of its transfer from the high pressure to the low pressure cylinder, even though the pressure in the high pressure cylinder is at this time considerably above the pressure in the low pressure cylinder. Thus one of the sources of power loss in multiple expansion combustion engines such as have heretofore been attempted is completely avoided.

Since the small, high-pressure cylinder alone is subjected to the high pressures and temperatures prevailing during combustion, the small cylinder alone need be constructed to withstand these pressures and temperatures.

The cylinders 1 and 3 may be cooled in any desired manner. The two cylinders are arranged parallel to each other and as closely together as possible so that the transfer passage will be short, the space between the two cylinders being merely sufficient for cooling purposes.

The piston 2 will ordinarily be made as large as possible consistent with its high speed and absence of liquid cooling. It will be observed that the diameter of piston 2 may be larger than in conventional engines before resort must be made to liquid cooling. This is because this piston is not continuously exposed to hot products of combustion as is the low pressure piston of the conventional multiple expansion internal combustion engine, but is half of the time exposed to relatively cool air. Furthermore, the cool scavenging air from ports 18 passes directly over the surface of the piston 2 cooling the same as it enters the cylinder.

In designing engines in accordance with this invention it will in some cases be desirable to supply the scavenging air through valves 14 and 15 and exhaust through ports 18 as shown in Fig. 1. This construction would be particularly desirable where the products of combustion are still under some pressure when the piston 2 reaches its lower dead center. Under these conditions in order to save the valves 14 and 15 from exposure to the hot products of combustion passing through them at high velocity the ports 18 will be used for exhaust and valves 14 and 15 for scavenging air. In any case the quantity of scavenging air supplied is preferably sufficient to more than fill both cylinders so a small part will blow out through the exhaust carrying the hot products of combustion away from the engine, and cooling the parts adjacent the exhaust valve or ports.

It will also be seen that if the air is supplied through valves 14 and 15 the passage 5 will be heated less by products of combustion passing therethrough and cooled more by the air. This is because the products of combustion in cylinder 1 do not in this case have to pass back through the transfer passage in order to be exhausted through the valve 14 or 15 and the air entering through either of these valves must largely pass through the transfer passage in order to scavenge cylinder 1 and fill the same with a charge of fresh air. Under these circumstances the greater portion of the air therefor passing through the transfer passage twice, once during scavenging, and once during compression. Thus the determination of the question whether the air shall be introduced through valves 14 and 15 or through ports 18 will depend upon which features are most to be desired considering the use to which the engine is to be put.

Combustion may proceed in the high pressure cylinder until just a few degrees prior to the opening of transfer passage 5. There is therefore ample time provided for complete diffusion and combustion of the fuel in the body of whirling air which may take place through almost one half of the stroke of the relatively slow moving piston 4. Combustion proceeds in a chamber which is of relatively large volume in proportion to

area of the chamber wall, affording proportionately smaller heat losses. When combustion is completed the construction provides for extremely rapid expansion in the cylinder 1, the rapidity of the expansion being augmented by continued downward movement of piston 4. While in the usual construction either rapid expansion must be sacrificed for the sake of complete combustion or vice versa. In the present case both of these desirable features are obtained in the same construction.

Power may be taken off from either shaft or from both. Thus shaft 6 may lead to one propeller and shaft 8 to another propeller. The gearing 11 in this case is not subjected to the strain of transmitting the full load but merely to that required to maintain the pistons 2 and 4 in proper relation.

The combination of the cylinder 1 and the cylinder 3 constitute a single unit of the engine. It will be obvious to any one skilled in the design of internal combustion engines that a plurality of these units may be used in any engine and so arranged as to obtain the proper balance.

Other arrangements of the parts may obviously be used.

While the invention is, as has been pointed out, particularly adapted for operation upon the Diesel or similar cycles, the invention is in certain aspects applicable to internal combustion engines generally and is not limited to any particular combustion cycle except where such cycle is particularly specified in certain of the following claims.

Having thus described the invention what is claimed as new is:

In a two cycle multiple expansion internal combustion engine a high pressure cylinder, a low pressure cylinder, a transfer passage between said cylinders, means to supply a scavenging air charge to one of said cylinders, means whereby said scavenging air passes through said transfer passage to scavenge the other of said cylinders whereby a fresh charge fills both cylinders, means for partially and simultaneously compressing the charge in both cylinders to a predetermined pressure and means to further compress said charge in said high pressure cylinder alone.

In testimony whereof I affix my signature.

LAWRENCE W. LINDBERG.