

July 17, 1928.

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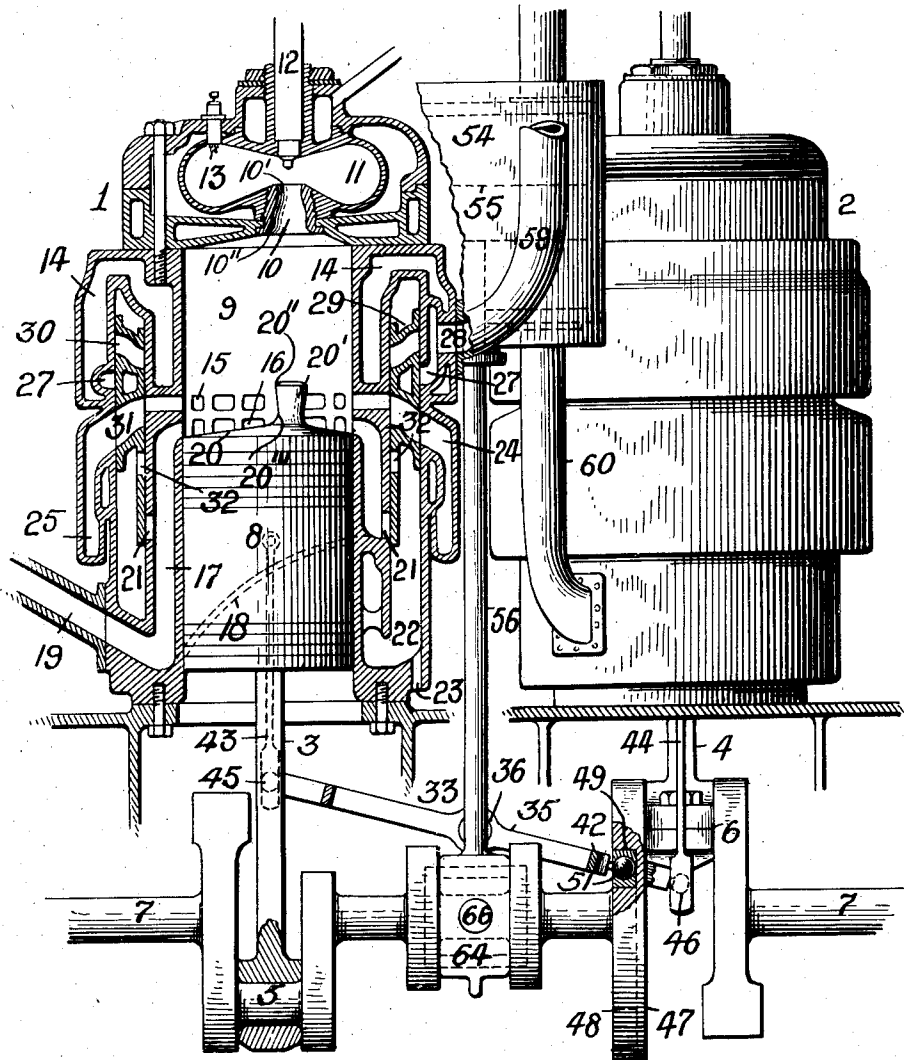
E. A. SPERRY

TWO-CYCLE SUPERCHARGING COMBUSTION ENGINE

Original Filed Aug. 5, 1922

3 Sheets-Sheet 1

Fig. 1.



Inventor
ELMER A. SPERRY.
By *his* Attorney
Robert H. Thompson

July 17, 1928.

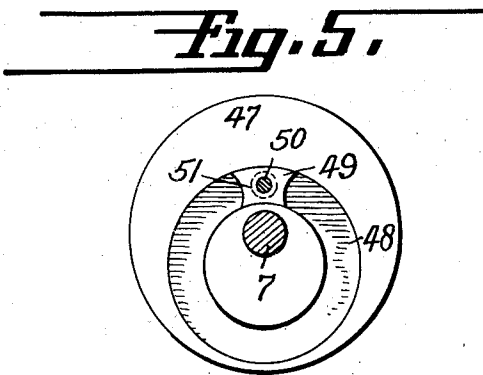
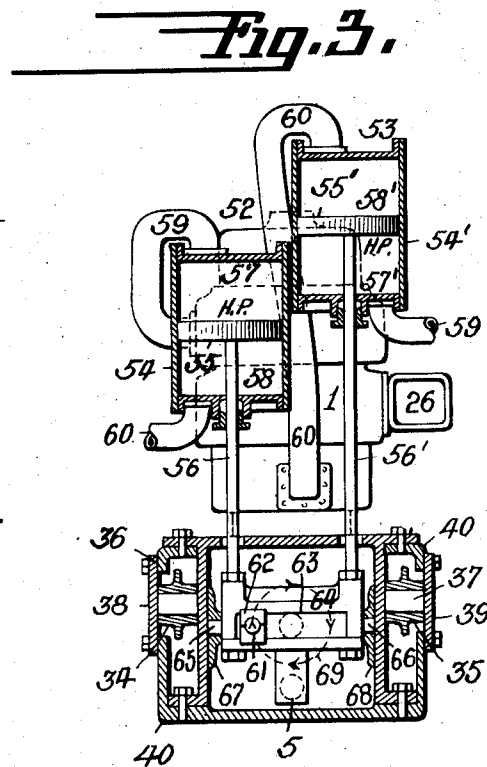
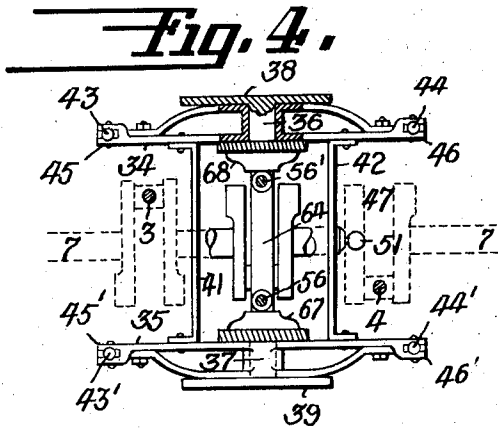
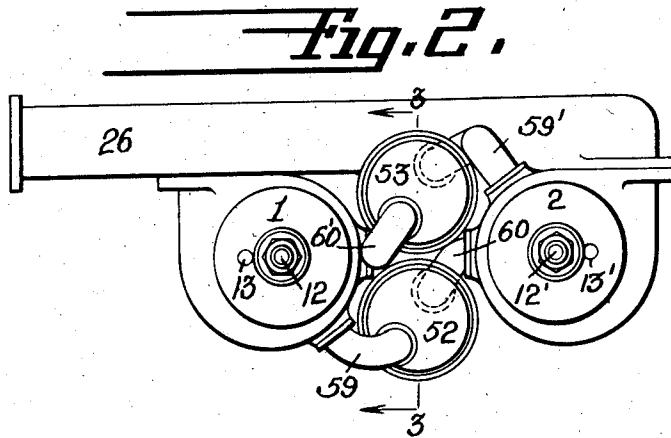
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3 Sheets-Sheet 2



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ELMER A. SPERRY.
By *his* Attorney
Herbert H. Thompson

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3 Sheets-Sheet 3

Fig. 6. Fig. 7. Fig. 8.

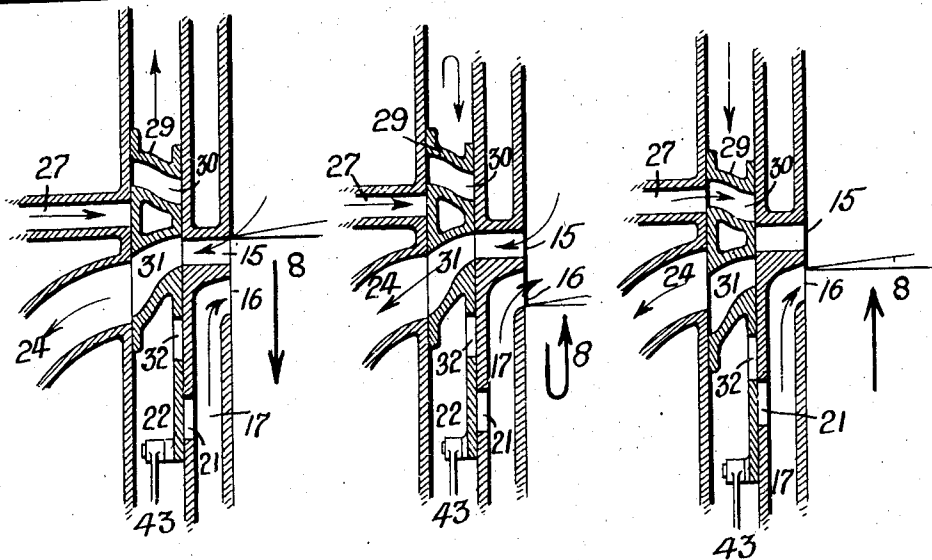


Fig. 10.

Fig. 9.

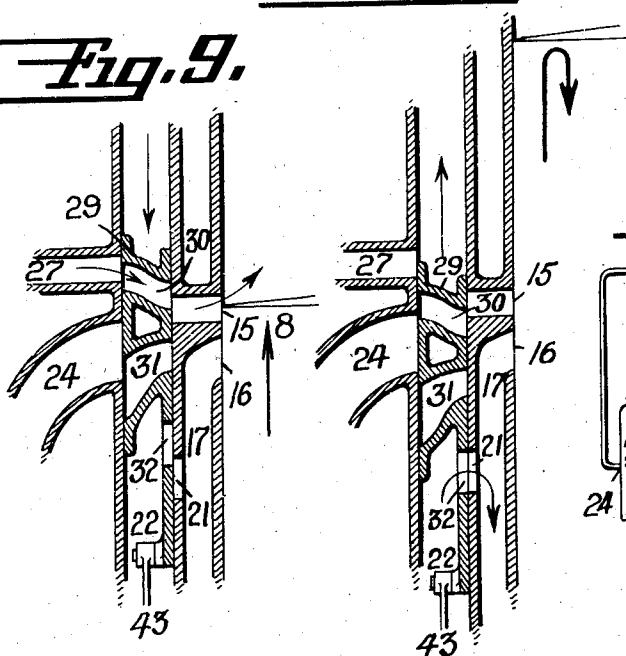
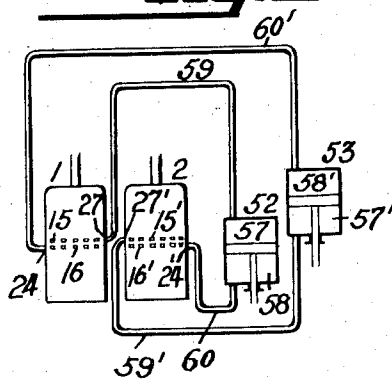


Fig. 11.



Inventor

ELMER A. SPERRY.

By *Herbert F. Thompson* Attorney

Herbert F. Thompson

Patented July 17, 1928.

1,677,305

UNITED STATES PATENT OFFICE.

ELMER A. SPERRY, OF BROOKLYN, NEW YORK, ASSIGNOR TO THE SPERRY DEVELOPMENT COMPANY, OF BROOKLYN, NEW YORK, A CORPORATION OF DELAWARE.

TWO-CYCLE SUPERCHARGING COMBUSTION ENGINE.

Original application filed August 5, 1922, Serial No. 579,863. Divided and this application filed October 7, 1924. Serial No. 742,093.

My invention relates to combustion engines and has for its objects the provision of an improved device of this character. This case is a division of my application Serial No. 579,863, filed August 5, 1922.

More specifically, my invention relates to a novel method of increasing the efficiency of two-cycle combustion engines by supercharging. I accomplish the supercharging of such an engine by providing suitable ports in the cylinders, and sources of high and low pressure fluids, the communication between said sources and said ports being controlled by a sliding valve, which is arranged to permit the low pressure fluid to scavenge the combustion chamber after an explosion, and to supercharge the combustion chamber with high pressure fluid on the ascending stroke of the piston.

Another novel feature of my invention is the provision of a plurality of air pumps, each having high and low pressure chambers, arranged oppositely with respect to each other, and interconnected with the cylinders, so that a novel form of sliding valve may cause the desired pressure to be supplied and connect the idle chamber of the pumps to air.

Other novel features of my invention reside in the arrangement and construction of parts to accomplish its object.

My invention will be better understood from the following description taken in connection with the accompanying drawings, and its scope will be pointed out in the appended claims.

In the drawings, illustrating what I now consider to be a preferred form of my invention,

Fig. 1 is a front elevation of a two cylinder combustion engine, with parts shown in section.

Fig. 2 is a top view of the engine shown in Fig. 1.

Fig. 3 is a section taken on the line 3—3 of Fig. 2.

Fig. 4 is an enlarged detail, partly in section, of mechanism for controlling the sliding valve of the engine.

Fig. 5 is an enlarged detail of mechanism employed to actuate the member shown in Fig. 4.

Figs. 6 to 10 inclusive are sectional views of the several ports and valves in various operative positions, and

Fig. 11 is a diagram illustrating the connections between the air pumps and the cylinders.

Referring to the drawings, in Fig. 1, there are shown two cylinders, 1, 2, having piston rods 3, 4, respectively, operatively connected to the respective crank pins 5, 6, on a crank shaft 7.

The construction of the two cylinders being preferably identical, it will not be necessary to describe but one, for which purpose cylinder 1 has been shown in section.

A piston 8 is suitably secured to the rod 3, and arranged to reciprocate within the cylinder 1 in the usual manner. The piston chamber of the cylinder indicated at 9, is connected by a cylindrical passage or throat 10, having a peculiar contour, to be fully described hereinafter, to a combustion chamber 11, in which are located a fuel injection valve or atomizer 12 and an ignition plug 13, (if desired). A passage 14, formed in the cylinder frame surrounds the space 9 as shown, for water circulation. In operation, the combustion chamber 11 becomes hot enough to ignite the charge. As shown in Fig. 1, the combustion chamber 11 is of the hot bulb type and is eccentrically positioned with respect to the vertical axis of the piston chamber 9. The purpose of this arrangement will later appear.

The cylinder is formed preferably with two parallel series of ports 15, 16, which I prefer to extend around the cylinder. The lower series of ports 16, is located so as to fully communicate with the chamber 9, just as the piston 8 reaches the end of its expansion or descending stroke. These ports 16, are closed by the piston on its compression or ascending stroke, shortly after said stroke begins. The ports 16 communicate with a closed chamber 17 formed in the cylinder casing, positioned concentric with the piston chamber, the bottom of which is indicated by the dash line 18 in Fig. 1. The chamber 17 communicates with a passage 19, which latter passage leads to a source of low pressure or scavenging air, preferably in the vicinity of 3 pounds per square inch,

which source will be fully described hereinafter. The face of the piston 8 is in the form of a truncated cone, as indicated at 20, whose vortex is eccentrically located with respect to the center line of the piston chamber, so as to present a longer and more gradual slope adjacent ports 16 nearest the passage 19. A cylindrical member or plug 20' is seated on the truncated face of the cone portion 20. Preferably, this plug is made of nichrome steel, better to withstand the pressure and high temperature from the combustion chamber. This plug is suitably secured to the member 20, and is arranged to cooperate with the throat 10 to create the desired turbulent condition in the combustion chamber, as will be later described.

From the foregoing, it will be seen that when the piston 8 is at the end of its descending stroke, low pressure air may enter the ports 16, sweeping over the cone portion 20, by which the air is directed upwardly. Since the air pressure varies inversely with the distance, the air entering the ports 16 nearest the supply passage 19 is directed upwardly by the gradually sloping face of member 20, while the air entering the more remote ports 16 is directed upwardly by the steeper slope of member 20, so as to obtain a more efficient scavenging of the piston chamber 9, to which further reference will be made. The passage 10 to the combustion chamber 11, which is also shown as being eccentric with respect to the vertical axis of the piston chamber 9, is arranged to receive the cone member 20. Obviously, by this arrangement, the incoming air currents are directed by the piston face upwardly in columns eccentric to the vertical axis of the piston chamber to the passage 10.

To attain the highest efficiency in turbulence in the combustion chamber 11, especially with gas of the high density employed in engines of this character, the prime consideration is a gradual but rapid acceleration of the gases confined to proportions that can be practically carried out, with a minimum consumption of power in creating such turbulence. To accomplish this, I have devised a contour or configuration of the throat 10, which is such as to utilize the gradually decreasing piston velocities together with the decreasing piston displacement as the top dead center is approached, which will give a gradual acceleration to the air jet itself up to high velocities, terminating not necessarily at the top, but somewhere near this point, with the highest velocity in the cycle. The purpose of this is to gradually though positively energize the vortex and raise it to very high values through prolonged tangential impingement of the jet.

A vortex is the ideal condition of turbulence. It exemplifies the persistence of motion of high velocity as almost nothing else

in nature does. To understand the conditions present in the solid injection engine, let us contrast it with the Otto cycle, where the fuel and the air are associated, constantly comingling over a very extended period starting with a very vigorous intermingling at the carburetor, up through the manifold, during all of the inhalation stroke and also especially during the energetic compression stroke, becoming in this way very intimately associated before the spark ignites them. This cycle of operation requires only about 2 cu. ft. of air per B. H. P., whereas with the Diesel cycle between 3 and 4 cu. ft. of air are required because the fuel is never brought in contact with the air until the instant that combustion is required and has no time for anything like intimate comingling. There is no other method of operating. In the Diesel the fuel must not enter until the compression is complete, or nearly so, and thus in an engine of say 1200 R. P. M., we have 40 strokes per second and it is during about 1/10th of this stroke that we would like to have the fuel come in, become thoroughly comingled with the air, start and actually complete the combustion,—all within about 1/400th of a second. On its face this is impossible, but if we can make up for the extreme shortness of the time by extreme condition of turbulence, whereby enormous swirling velocities of the air are set up and directed so as to repeatedly pass a given point, and selecting this point for the location of the jet so that vigorous and oft repeated impingement between each of several jets and the air can be accomplished, then, and then only, can we hope to approach or perhaps even better the performance of the Otto cycle, with the advantages of greatly enhanced compression and therefore much higher efficiency, complete elimination of detonation and the use of extremely cheap forms of fuel.

The true vortex will accomplish this, but to obtain high velocities of these highly dense pressure fluids within this vortex, the large inertia factor of the entire mass must be carefully reckoned with and especially that of the outer layers must be gradually overcome to create the true circular motion and bring it up to a very high velocity without creating wasteful eddies, which are found to use up the energization in general turbulence as counter-distinguished from the pure vortex action and defeating completely the pure swirl of the vortex, especially at high velocity. The vortex, properly safeguarded and thus gradually built up to extremely high velocities, offers a complete solution to the vexed question of complete association between the fuel and the oxygen of the air, especially when using the simple methods of solid injection. The jet, streams or other form of fuel projection into this

vortex is preferably from the center of the ring, straight across to its outer margin approximately in the plane of the annulus. In this way, during the above extremely brief projection of the fuel, the streams are not only impinged and air-washed, but repeatedly cut, say, ten to twenty times by the rapid revolution of the vortex. The fluid in the vortex, by my process of gradual though positive acceleration, finally attains, in one instance, the startling velocity of something on the order of 75,000 revolutions per minute, affording a very complete illustration of how velocities may be substituted for time in producing an extremely intimate mixture of fuel and air. It must be remembered that the piston while accomplishing this is very rapidly retarded and finally brought to rest.

The plug 20' is preferably of a substantially conical formation, with its greatest diameter at its base; as plug 20 tapers from its base upwardly to a certain point 20''' which may or may not be intermediate between the top and the base. Beyond point 20''' the block may or may not flare slightly for a distance to point 20'' from where the plug again tapers upwardly to its top. At its base the plug is enlarged so as to coincide with and form a continuation of the sloped surface of the cone portion 20 of the piston. As will later appear, the throat 10 is most constricted at one point. Since the plug is of greatest diameter at a single point, obviously, it will require less energy for the plug to force air through the most constricted portion by this arrangement, than it would, if the plug were of a uniform diameter, since if the plug were of a uniform diameter, there would be less clearance between it and the other parts of the throat 10, and of course, greater opposition to the passage of air.

In order to give a gradual yet rapid acceleration to the air entering the combustion chamber 11, the throat 10 is formed with a peculiar contour or with varying diameters, the smallest of which is preferably located near its upper end, in the vicinity of the point indicated at 10', but at a point adjacent or below the effective diameter 20'' of the plug 20' when it is at the end of its compression stroke. From its most constricted portion 10' downwardly to a point near its lower opening, say at 10'', the diameters within the throat vary, and gradually increase in size, but not necessarily in equal steps. For instance, the upper part of the contour of the throat between the points 10' and 10'' is steeper than the lower part. The diameters of the throat 10 are determined by the piston velocity, the ratio of the smallest diameter of the throat to the entire area of the cylinder, the compression ratio, and the ratio of the largest part of the plug to the most constricted portion of the throat.

The contour of the throat 10, will of course vary with any of its determining factors. It may be varied to obtain any desired air velocity through its most constricted portion and must be designed in view of the variable factors mentioned present in a given case, the general law, well known to those skilled in the art, of the velocity of gases under compression through orifices, controlling. The lower portion of the throat 10 from the point 10'' downwardly, flares outwardly substantially to coincide with the cone surface of the plug 20' and member 20, and of course is also determined by the variable factors mentioned to create the desired air acceleration.

The collector chamber 17 (Fig. 1) is provided with a series of ports 21, in communication with a chamber 22 formed within the cylinder casing concentric with the piston chamber, which latter chamber has a series of ports 23 leading to the open air. The chamber 22 is provided with a series of ports 24, leading to a collector chamber 25, which communicates with an exhaust passage 26. Said chamber 22 is also provided with a series of ports 27, leading to a collector chamber 28, which communicates with a source of high pressure air, say 20 pounds per square inch.

The upper series of ports 15 also communicate with the chamber 22, and are opened and closed by the descending and ascending stroke of the piston, respectively, on the side within the cylinder. The outer or opposite end of the ports 15 is controlled by a sliding valve 29, which may connect them with either ports 24 or 27. The valve 29 is of cylindrical formation, concentrically positioned with respect to piston chamber 9, and located within the chamber 22. Said valve is formed with three parallel series of circumferential ports 30, 31, 32 and is arranged to reciprocate oppositely to the piston of its cylinder with the proper lead and lag factors.

As shown in Fig. 1, the piston rods 3, 4, are separated 180°, which of course causes the pistons of cylinders 1, 2, to reciprocate oppositely. In order to accomplish the opposite reciprocation of the valves 29 in their proper phase, that is, approximately in quadrature with their respective pistons 8, I have provided a rocker 33, shown in Figs. 1, 4, formed with two parallel arms 34, 35, journaled at their middle points on bearings 36, 37 respectively. These bearings are formed on small plates 38, 39, which plates are rigidly secured to a supporting frame 40, the arrangement being clearly shown in Fig. 3. The arms 34, 35 are suitably united by parallel cross-pieces 41, 42 to form a rocking unit about the bearings 36, 37. Each of the valves 29 of the respective cylinders 1, 2, are connected to the rocker 33 by rods 43,

43' and 44, 44' respectively. The rods 43, 43' are suitably secured, preferably diametrically opposite to the valve 8 at one end. At their opposite ends, said rods are formed with sockets to receive balls, 45, 45', the former being indicated by dash line in Fig. 1. The rods 44, 44' are secured to the corresponding valve 8 in cylinder 2, and engage balls 46, 46' in a similar manner to that described in connection with rods 43, 43'. The rocker 33 is rocked by means of an eccentric connection on the crank shaft 7. The crank pin 6 is supported by a disk 47, on the inner surface of which is formed an eccentric circular slot 48, shown in Fig. 5, and indicated by dash lines in Fig. 1. In said slot is fitted a shoe 49, having a socket 50, to be engaged by a ball 51, rigidly supported in any suitable manner on the cross-piece 42. The shoe 49 may slide in the slot 48. It is therefore obvious that when said disk 47 rotates, the travel of said shoe, carrying the ball 51, will rock the rocker 33, and thereby oppositely reciprocate the valves 29 of the two cylinders in a manner readily understood. However, in order that the respective valves 29 will reciprocate in proper phase with the respective pistons of their cylinders, the eccentric slot 48 has been so positioned as to bring this about.

As previously indicated herein, two different air pressures are employed in my invention, namely a high pressure of say about 20 pounds per square inch and a low pressure of say about 3 pounds per square inch. The high pressure air is employed to supercharge the engines, and the low pressure is employed to scavenge the combustion chambers. This air may be provided in any suitable manner, but I preferably provide two air pumps 52, 53 (Fig. 3) for the cylinders 1, 2 respectively. The air pump 52 comprises a cylinder 54, in which a piston 55 is arranged to reciprocate, said piston being actuated by a rod 56. The cylinder 54 has high pressure and low pressure chambers 57, 58, respectively, which arrangement is well known in the art. The high pressure chamber 57 communicates with cylinder 1 through a passage 59 to the collector chamber 28 and ports 27. The low pressure chamber 58 is connected by a passage 60 to the passage of cylinder 2 corresponding to passage 19. The air pump 53 is in every respect similar to the pump 52, except that its high and low pressure chambers are reversed.

The reason therefore is obvious, when it is recalled that the cylinder 2 which it supplies, operates in a direction opposite to the cylinder 1. The corresponding parts of pump 2 have been given identical numbers with those of pump 1, but primed. The low pressure chamber 58' is connected to cylinder 1 by a passage 60' to passage 19.

The high pressure 57 communicates with cylinder 2 through a passage 59' to ports 27'. The interconnections between the cylinders 1, 2 and pumps 52, 53 are diagrammatically shown in Fig. 11, which arrangement is employed in supplying air to the pumps, as will hereinafter be pointed out. The pumps are so arranged that high pressure air will be supplied to the respective cylinders on the ascending stroke of the cylinder pistons and low pressure will be supplied just previously. The air pumps are driven by a crank pin 61, on the shaft 7, displaced properly from the cranks. The pin 61 carries a pair of guide plates 62, but one of which is visible in Fig. 3, and is arranged to travel in a slot 63 of a frame 64, placed at right angles to the crank shaft 7. The piston rods 56, 56' are respectively rigidly secured to the frame 64 in any suitable manner. The frame 64 is provided with two bearings 65, 66 journaled in guides 67, 68 respectively, slidably arranged within the frame 40. Therefore, when the crank 7 rotates clockwise, the crank pin 61 describes a circle as indicated by the dashes and arrowheads 69 in Fig. 3. The pistons 55, 55' are thereby driven in a manner readily understood. However, it should be observed that by this arrangement the pin 61 is always on the side to actuate the piston which is compressing the high pressure air on either pump.

Having described one embodiment of the structural details of my invention, its operation will be readily understood by referring to Figs. 6 to 10 inclusive, in which, for the sake of simplicity, a single port of the several series is illustrated.

Assuming that the piston 8 has just reached the end of its ascending stroke, and that the combustion chamber 11 is filled with air under heavy pressure, the turbulence in the combustion chamber having taken place through the vortical operation hereinbefore described in detail. At this moment the member 20' is within the cylindrical passage 10, the atomizer 12 has injected the fuel and the charge is ignited either automatically or by the plug 13. Now, since the member 20' is not exactly fitted into the cylindrical passage 10, the explosive gases pass into the chamber 9. The piston 8 is impelled downwardly, and as it reaches the position indicated in Fig. 6, it is about to open the port 15. As it continues its downward movement, the port 15 is opened. In the meantime, the valve 29 has ascended bringing the port 15 through its port 31 into communication with port 24, leading to the exhaust passage 26. The combustion gases can now escape through the passage 24. Continuing its downward movement, the piston 8 uncovers port 16, which admits low pressure air as shown in

Fig. 7. This air is caused to sweep into the chamber 9 by the peculiar formation of the piston face in the manner described, and thoroughly scavenge the chamber 9. The piston 8 having reached the end of its descending stroke commences to ascend, the valve 29 simultaneously descending. The piston being near its dead center is moving comparatively slowly, while valve 29 is moving relatively faster. As the piston 8 ascends, the port 16 is being closed by it, the port 15 being first closed by the valve 29, as shown in Fig. 8, at which time the chamber 9 is now full of low pressure air. Then as the piston 8 continues to slowly ascend, the valve quickly descends bringing port 15 into communication with port 27, connected to the high pressure air source, through the valve port 30, thereby supercharging the chamber 9. Continuing its upward movement, as shown in Fig. 9, the piston closes port 15, thereby shutting off the high pressure air, and the valve 29 continues to descend, thereby placing port 27 in communication with chamber 22, and bringing ports 21, 32 into communication, thereby opening a passage between chambers 17, 22. In the meantime, the piston 8 completes its ascending stroke, whereupon the charge is ignited in the manner described, and the cycle of operation repeated.

Assuming that the ports, indicated in Figs. 6 to 10 inclusive relate to cylinder 1, then port 27 is in communication with high pressure chamber 57 of pump 52, and port 24 is in communication with low pressure chamber 58' of pump 53. As previously described, the respective pistons of pumps 52, 53, reciprocate simultaneously in the same direction. Referring particularly to Fig. 10 in which the cylinder piston 8 is about to descend, the explosion just having taken place; at this instant, the pistons 55, 55' of pumps 52, 53, respectively are at the end of their ascending strokes, and commence to descend. Since the port 27 is now in communication with chamber 22, which is connected to the open air by port 23, the high pressure chamber 57 of pump 52, may take in air through passage 59, chamber 28 and port 27. At the same time, the chamber 17 being in communication with the chamber 22, through ports 21, 32, the low pressure chamber 58' of pump 53 may take in air through passages 60', 19 and chamber 17. The low pressure chamber 58 of pump 52 and the high pressure chamber 57' of pump 53, take in air on the ascending stroke of the pump pistons through cylinder 2 in a similar manner.

While I have described my invention as embodied in concrete form in accordance with the provisions of the patent statutes, it should be understood that I do not limit

my invention thereto, since various modifications thereof will suggest themselves to those skilled in the art without departing from the spirit of my invention, the scope of which is set forth in the annexed claims.

Having herein described my invention, what I claim and desire to secure by Letters Patent is:

1. A combustion engine comprising in combination a cylinder and piston, an inlet port for said cylinder, controlled by said piston, a source of fluid pressure connected to said port, a second port for said cylinder controlled at one end by said piston, a second source of fluid pressure, an exhaust passage and means for alternately connecting the opposite end of the latter port to the exhaust passage and to said second source of fluid pressure.

2. A combustion engine comprising in combination a cylinder and piston, a port for said cylinder controlled by the piston positioned to be open when the piston is at the end of its descending stroke, a source of fluid pressure connected to said port, an exhaust port for said cylinder, a second source of fluid pressure, and means connecting the exhaust port to said second source of fluid pressure as or after the first port is closed by the ascending piston.

3. A combustion engine comprising in combination a cylinder, a piston, a port for the cylinder positioned to be closed on the ascending stroke of the piston, a source of low pressure fluid connected to said port, an exhaust open while said port is open, and positioned to be closed by the piston after said port is closed, a source of high pressure fluid and means for connecting the exhaust to said latter source upon the closing of said port.

4. A combustion engine comprising in combination a cylinder, a piston, an exhaust passage, a source of fluid pressure, an open air chamber, a port for the cylinder controlled at one end by the piston, means for successively connecting said port to said exhaust passage and said source of fluid pressure, and connecting said source of fluid pressure to said open air chamber.

5. A combustion engine comprising in combination a cylinder, a piston, an open air chamber, an exhaust port positioned to be opened by the piston as it descends, a source of fluid pressure, a second port in communication with said fluid source positioned to be opened by the piston after the exhaust port is opened, and means for connecting said second port to the open air chamber when that port is closed.

6. A combustion engine comprising in combination a cylinder, a piston, a port for the cylinder controlled at one end by the piston, an exhaust passage, a source of fluid pressure, means for varying the connection

of said port at its opposite end to connect the same successively to said passage and said source and means for reciprocating said latter means oppositely to the piston.

5 7. A combustion engine comprising in combination a cylinder, a piston, an open air chamber, an exhaust passage, a source of fluid under low pressure, a source of fluid under high pressure, a port for said cylinder controlled at one end by said piston and positioned to be opened as the piston descends, a second port in communication with said source of low pressure fluid controlled by said piston positioned to be opened after the first mentioned port is opened, a third port connecting said source of low pressure fluid to the open chamber, and a sliding valve arranged to reciprocate oppositely to said piston having a port to connect the first mentioned port to the exhaust passage when the second mentioned port is open, a port to connect the first mentioned port to the high pressure fluid source when the second mentioned port is closed, a port connecting said low pressure fluid source to the open chamber when the second mentioned port is closed in which position the high pressure fluid source is also connected to said open chamber.

30 8. A combustion engine comprising in combination a plurality of cylinders, high and low pressure intake ports for each of said cylinders, and a plurality of air pumps each having high and low pressure chambers, the high pressure chamber of one and the low pressure chamber of the other of said pumps being connected to the high and low pressure intake ports of one of the cylinders respectively, and the remaining high and low pressure chambers being connected to the high and low pressure intake ports respectively of the other cylinder.

40 9. A combustion engine comprising in combination a cylinder having high and low pressure fluid intake ports, two air pumps each having high and low pressure chambers, the high pressure chamber of one and the low pressure chamber of the other of said pumps being connected to said high and low pressure ports respectively, means for closing said ports, and means connecting said high and low pressure chambers to open air when both of said ports are closed.

50 10. A combustion engine comprising in combination two cylinders having pistons arranged to reciprocate oppositely, each of said cylinders having two ports controlled at one end by its respective piston, means for varying the connection at the opposite end of one of said ports and means for reciprocating said latter means of both cylinders approximately in quadrature with their respective pistons.

60 11. A combustion engine comprising in combination two cylinders having pistons

secured to a crank shaft to reciprocate oppositely, two ports for each of said cylinders controlled at one end by their respective pistons, a sliding valve controlling the opposite end of one of said ports for each cylinder, a member pivoted between said cylinders, means securing one of said sliding valves to each end of said member, and means actuated by said shaft for rocking said member about its pivot to reciprocate said valves.

70 12. A combustion engine comprising in combination a pair of cylinders and means for supplying air of different pressures to said cylinders comprising a pair of air pumps, each having oppositely arranged high and low pressure chambers, means connecting the high pressure chamber of one of the pumps and the low pressure chamber of the other pump to one of the cylinders, means connecting the remaining high and low pressure chambers to the other cylinder, a crank shaft driven by said cylinders, and means intermediate said cylinders for operating said pumps.

80 13. In a combustion engine having a plurality of cylinders and a shaft driven thereby having a crank pin, means for supplying air to said cylinders of different pressures comprising a plurality of pumps each having high and low pressure chambers, a fixed frame, sliding guides therein formed with bearings, a carriage journaled in said bearings formed with a slot at right angles to said shaft, the pistons of said pumps being secured to said carriage, and a sliding member in said slot actuated by said crank pin.

90 14. In a combustion engine, the combination with a cylinder and piston, of an exhaust port in the wall of said cylinder adapted to be uncovered by the piston, means for scavenging said cylinder, and means for supercharging the cylinder through said port with air under pressure.

100 15. In a combustion engine, the combination with the cylinder and piston, ports in the walls of said cylinder adapted to be opened and closed by said piston, a sleeve valve cooperating therewith, air compressing means for supplying said cylinder with compressed air, and means whereby said valve controls the said compressing means.

110 16. In a multi-cylinder combustion engine, the combination with a plurality of cylinders, a sleeve valve for each cylinder, a plurality of super-charging pumps adapted to supply air to each cylinder at different pressures, said valves serving to control both the combustion cylinders and pumps.

120 17. In a multi-cylinder combustion engine, the combination with a plurality of cylinders, a sleeve valve for each cylinder, a plurality of super-charging pumps adapted to supply air to each cylinder at different pressures, each valve in cooperation with the

piston serving to control the intake and exhaust of the respective cylinder and the intake and discharge of the both pumps connected thereto.

5 18. In a combustion engine, the combination with the cylinder and piston, ports in the walls of said cylinder adapted to be opened and closed by said piston, a sleeve valve cooperating therewith, dual air com-
10 pressing means for supplying said cylinder with compressed air at different pressures, said valve also acting to control both of said compressing means.

15 19. In a combustion engine having a pair of cylinders and a shaft driven thereby having a crank pin, means for supplying air to said cylinders of different pressures comprising a pair of pumps, each having high and low pressure ends, said high and low pres-
20 sure ends of the two pumps being reversed, a fixed frame, sliding guides therein formed with bearings, a carriage journaled in said bearings formed with a slot at right angles to said shaft, the pistons of said pumps be-

ing secured to said carriage, and a sliding member in said slot actuated by said crank pin.

20. In a combustion engine having a pair of cylinders and a shaft driven thereby having a crank pin, means for supplying air to said cylinders of different pressures comprising a pair of pumps mounted at right angles to said shaft with one pump on each side thereof, each pump having high and low pressure ends, said high and low pressure ends of the two pumps being reversed, a fixed frame, sliding guides therein formed with bearings, a carriage journaled in said bearings formed with a slot at right angles to said shaft, the pistons of said pumps being secured to said carriage, and a sliding member reciprocated in said slot by said crank pin arranged to be in the slot and nearest the pump working under high pressure.

In testimony whereof I have affixed my signature.

ELMER A. SPERRY.