G. J. SPOHRER.

INTERNAL COMBUSTION ENGINE.

APPLICATION FILED MAR. 16, 1918.

1,361,109.

Patented Dec. 7, 1920.

2 SHEETS—SHEET 1.

Fig. 1,

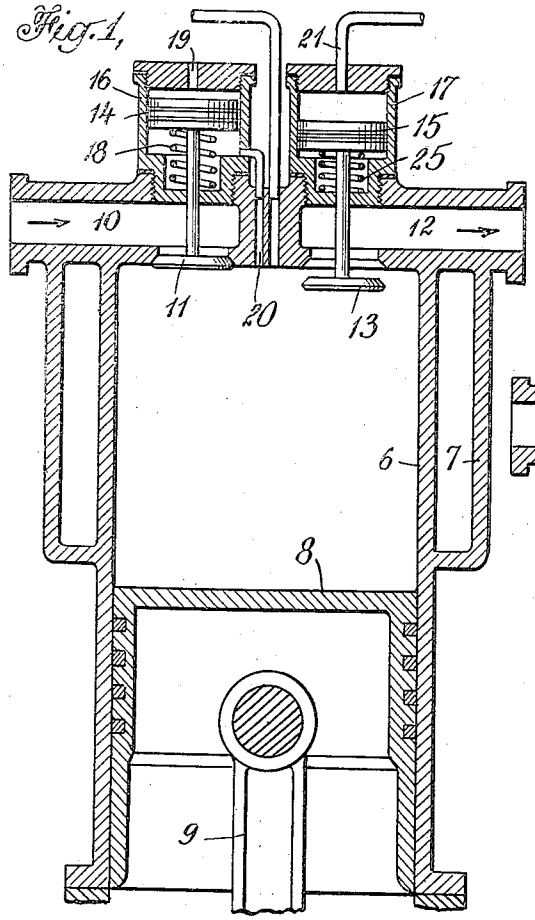


Fig. 2,

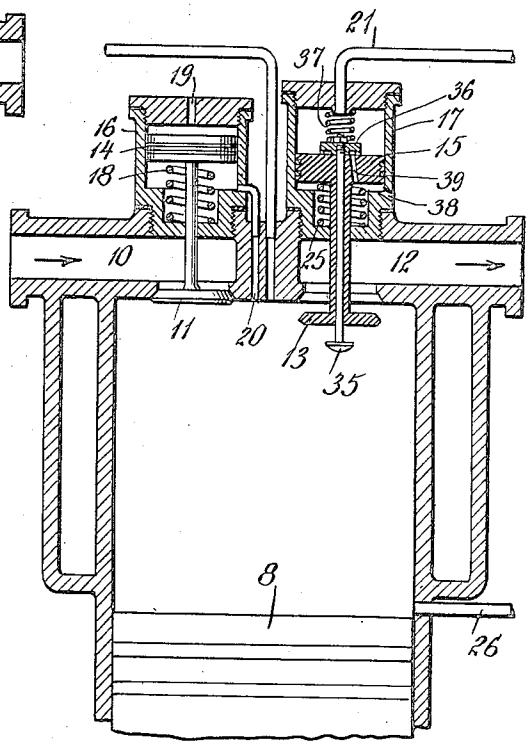
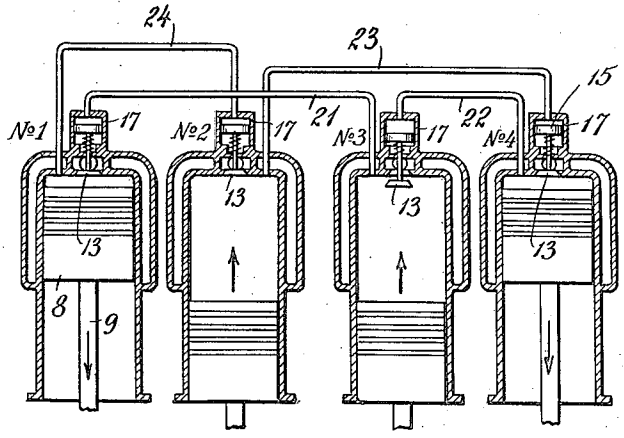


Fig. 3,



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2 SHEETS—SHEET 2.

Fig. 4,

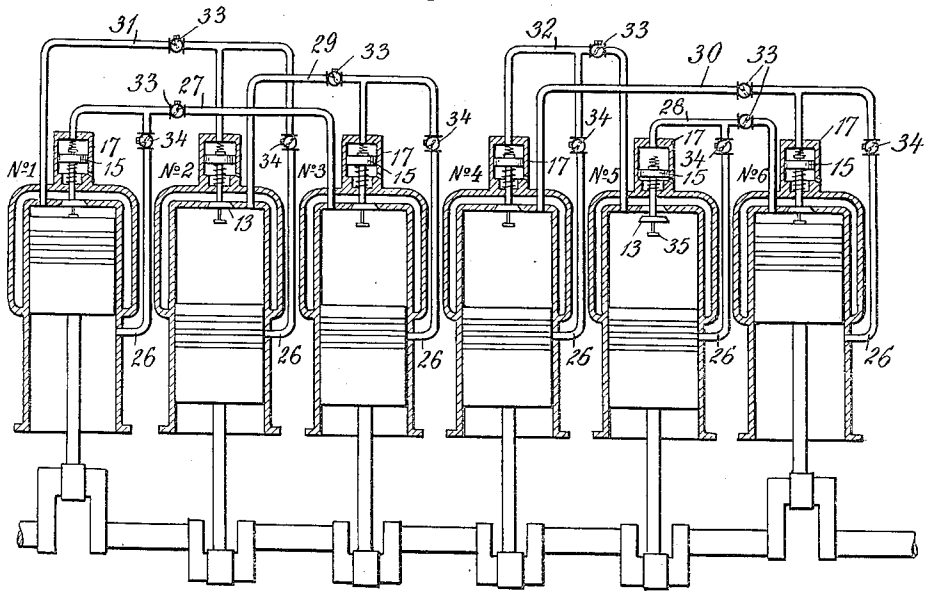


Fig. 5,

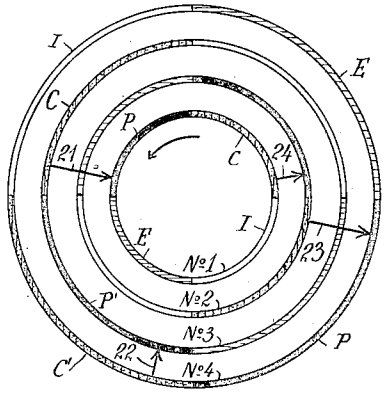
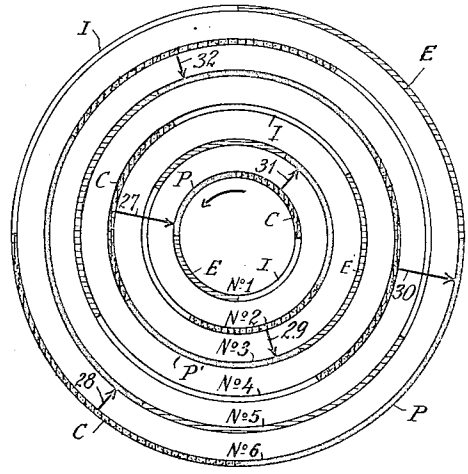


Fig. 6,



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INTERNAL-COMBUSTION ENGINE.

1,361,109. Specification of Letters Patent. Patented Dec. 7, 1920.

Application filed March 16, 1918. Serial No. 222,639.

To all whom it may concern:

Be it known that I, GREGORY J. SPOHRER, a citizen of the United States, residing at East Orange, in the county of Essex, State of New Jersey, have invented certain new and useful Improvements in Internal-Combustion Engines; and I do hereby declare the following to be a full, clear, and exact description of the invention, such as will enable others skilled in the art to which it appertains to make and use the same.

This invention relates to internal combustion engines and more particularly to certain improvements in the contruction and operation of the valves of such an engine.

The distinguishing characteristic of the invention consists in the use of gases derived from the cylinders of a multi-cylinder engine in actuating or controlling the actuation of the valves, particularly the exhaust valves. The stem of each exhaust valve may be secured to a piston movable in a cylinder to which a gas under pressure is admitted to force the exhaust valve to the open position. In this way the construction of the engine may be greatly simplified and its operation made much more smooth, particularly in that the provision of a cam shaft, cams, and push rods for opening the exhaust valves is made unnecessary.

In any four-cycle internal combustion engine having four or more cylinders, there is always at least one cylinder in which compression is taking place at the time when it is desirable to open the exhaust valve of another cylinder. The increased pressure produced by the compression stroke in one cylinder may be employed for opening the exhaust valve of another cylinder and the connections from the several cylinders to the exhaust valves of other cylinders may readily be made such that each exhaust valve will be connected at the time when it should be opened to a cylinder in which compression is taking place.

In a four-cylinder engine, for instance, the exhaust valve of each cylinder should be opened when the piston of that cylinder nears the end of its power stroke. At that time the piston of the cylinder in which an explosion is to occur next in order is nearing the completion of its compression stroke and the contents of the cylinder are under a high degree of compression. Therefore, that cylinder in which compression is taking place may be connected to the devices for opening the exhaust valve of the first cylinder, the areas of the parts subjected to the pressure within the cylinder whose exhaust valve is to be opened and the pressure of the gas used for opening that valve being so proportioned that the opening movement of the valve will occur at the appropriate time in the downward movement of the piston. After the exhaust valve has been opened near the end of the power stroke of a piston, it should remain open throughout the remainder of the power stroke and the next succeeding stroke which would be the exhaust stroke, and it might even remain open during a small fractional portion of the next stroke, that is, a small fractional portion of the inlet stroke at the beginning thereof. When the valve has been opened by the compression pressure in another cylinder, it will be held open by that pressure until the end of the compression stroke, when combustion takes place in that cylinder, resulting in the creation of an even higher pressure and this pressure would serve to maintain the exhaust valve in its open position. The valve would therefore remain open until the exhaust valve in the actuating cylinder was opened, whereupon the decrease of the pressure in the actuating cylinder to substantially atmospheric pressure would permit the actuated exhaust valve to be closed by its spring. In this way, not only is the provision of a cam mechanism for opening the exhaust valve rendered unnecessary, but also the time of the opening and closing movements of each exhaust valve may be made more or less self-regulating in response to changes in the relation of the two pressures acting upon the exhaust valve, namely, the pressure within the cylinder of the valve, and the pressure within the cylinder from which the actuating pressure is derived.

In an eight-cylinder engine, particularly an eight-cylinder engine of the V type, the same or practically the same arrangement as that above referred to in connection with a four-cylinder engine may be employed, the engine being preferably treated as two four-cylinder engines.

In a six-cylinder engine, the conditions are not so favorable to utilization of the invention in the simple form applicable to four-cylinder engines for the reason that the compression stroke in one cylinder is not coincident with the power stroke in another cylinder. It has been proposed heretofore to

actuate the exhaust valve of an internal combustion engine by the pressure existing in the cylinder near the end of the power stroke, as by providing a port in the cylinder wall opened by the piston near the end of its downward movement on the power stroke to admit the pressure then existing in the cylinder to an auxiliary piston for opening the exhaust valve, means being provided for holding the exhaust valve open for an appropriate time thereafter. This provision alone is unreliable in practice for the reason that in event of a misfire there would be no substantial pressure existing in the cylinder at the time when the port above referred to was open, and therefore the exhaust valve would not be opened; this would result in churning up the air or gas which was in the cylinder and alternate expansion and compression thereof. In adapting my invention for use in connection with six-cylinder engines, I prefer to make use of this old expedient and to combine therewith connections whereby the compression pressure in each cylinder is made effective to open the inlet valve of another cylinder in event of a failure of the exhaust valve of that other cylinder to be opened by the pressure existing within the cylinder, when the port above referred to is open near the end of the power stroke.

My invention also involves certain improvements in the construction of the inlet valves of an internal combustion engine, particularly those of the type in which the inlet valve is opened by suction. This involves the provision of a piston connected to the inlet valve and moving within an auxiliary cylinder which is connected to the main cylinder. In this way the suction which opens the inlet valve at the beginning of the inlet stroke, and the compression which closes it at the beginning of the compression stroke, are made effective upon a greatly increased area so that the movements of the inlet valve are effected much more quickly and may be of greater magnitude.

These and other features of the invention will be better understood by reference to the following description in connection with the accompanying drawings, which illustrate embodiments of the invention. In these drawings, Figure 1 is a central section through the cylinder of an engine constructed in accordance with the invention; Fig. 2 is a view corresponding to Fig. 1 and illustrating a modification of the exhaust valve construction; Fig. 3 is a diagrammatic view of a four-cylinder engine showing the cylinders in section; Fig. 4 is a view similar to Fig. 3 and illustrating a six-cylinder engine; Fig. 5 is a diagram of the operation of the four-cylinder engine shown in Fig. 3; and Fig. 6 is a similar view with respect to the six-cylinder engine of Fig. 4.

Referring to these drawings, 6 indicates a cylinder of the usual or any suitable construction provided with a water jacket 7 and having a piston 8 reciprocating therein. The piston is connected to a crank shaft by a connecting rod 9 in the usual manner. The inlet passage is shown at 10 controlled by a valve 11 and the exhaust passage is shown at 12 controlled by a valve 13. The stems of these two valves have small auxiliary pistons 14 and 15 secured to their upper ends and adapted to reciprocate in small auxiliary cylinders 16 and 17 respectively. The inlet valve is provided with a spring 18 coiled about its stem and acting on the valve to force it to its closed position in which it is shown in Fig. 1. The cap which closes the end of the cylinder 16 is provided with a connection to atmosphere, as shown at 19. From below the piston 14 of the inlet valve a connection is made from the interior of the auxiliary cylinder 16 to the interior of the main cylinder 6. Such a connection is shown at 20.

When the piston 8 starts downwardly on its inlet stroke, it rarefies the air or gas within the cylinder 6 somewhat and the suction is exerted not only upon the face of the valve 11 but also upon the lower face of the piston 14, and by reason of the greatly increased area upon which this suction is effective, the valve is moved quickly to its open position against the tension of its spring 18. Also, when the piston 8 begins its next upward stroke, that is, the compression stroke, the intial compression of the gases within the cylinder is effective on the face of valve 11 and also upon the under side of the piston 14. This pressure, added to the force exerted by the spring 18, moves the inlet valve quickly to the closed position.

The cap which closes the upper end of the auxiliary cylinder 17 for the exhaust valve is provided with an opening in which the end of a pipe 21 is secured, the pipe being in communication with the space within the cylinder 17 above the piston 15. Fig. 3 shows, diagrammatically, a four-cylinder four-cycle engine provided with exhaust valves of the construction above described in connection with Fig. 1. The two pistons in the two outside cylinders are shown at the upper limits of their reciprocatory movement and two pistons of the inside cylinders are shown at the lower limits of their movement, this being the relation which exists when the usual type of crank shaft for a four-cylinder engine is employed. The firing order of the cylinders will be assumed to be 1, 3, 4, 2, that being a usual firing order for a four-cylinder four-cycle internal combustion engine. Assuming that the piston of cylinder No. 1 is at the beginning of its power stroke, the piston of cylinder No. 3 is at the beginning of its compression

stroke. When the piston of cylinder No. 1 nears the end of its power stroke, its exhaust valve should be opened. At that time the piston of cylinder No. 3 would be near the end of its compression stroke and the gas within that cylinder would be under substantial compression. The upper end of cylinder No. 3 is therefore connected by the pipe 21 to the auxiliary cylinder 17 of the exhaust valve of cylinder No. 1. Similarly, the piston of cylinder No. 4 makes its compression stroke when the piston of cylinder No. 3 makes its power stroke, and therefore the upper end of cylinder No. 4 is similarly connected by a pipe 22 to the auxiliary cylinder for the exhaust valve of the cylinder No. 3. Also, cylinder No. 2 is connected by a pipe 23 to the exhaust valve of cylinder No. 4 and cylinder No. 1 is connected by a pipe 24 to the exhaust valve of cylinder No. 2.

The relative size of each exhaust valve and the upper surface of its actuating piston 15 and also the pressure exerted by the spring 25 which forces the exhaust valve toward its seat, must be proportioned accurately in order to effect the opening and closing of the exhaust valve at the proper times. It will be appreciated that while the piston of cylinder No. 1 is moving downward on its power stroke, the pressure within the cylinder is decreasing steadily and also while the piston in cylinder No. 3 is moving upward on its compression stroke, the pressure upon that cylinder is steadily increasing. The first of these pressures is effected upwardly on the face of the exhaust valve upon cylinder No. 1, and the second of these pressures is effected downwardly on the piston 15 of the exhaust valve cylinder No. 1. With the areas of the parts 13 and 15 and the force exerted by the spring 25 properly proportioned with relation to these pressures, the exhaust valve 13 will be moved to its open position at the proper instant in the downward movement of the piston in cylinder No. 1 on its power stroke, that is, when the piston in cylinder No. 1 has reached the desired point in its downward movement. The exhaust valve will be held open thereafter by the increasing pressure in cylinder No. 3. Then, when explosion takes place in cylinder No. 3, the pressure in that cylinder will be further increased and this increased pressure will continue to maintain the exhaust valve of cylinder No. 1 in its open position. Then the piston of cylinder No. 3 moves downward on its power stroke while the piston of cylinder No. 1 moves upward on its exhaust stroke, the exhaust valve of cylinder No. 1 remaining open, until finally the exhaust valve of cylinder No. 3 is opened, resulting in such a decrease of pressure upon the upper face of the auxiliary piston 15 of the exhaust valve of cylinder No. 1 that that valve is closed by its spring 25. Similar action takes place in each of the other cylinders on opening and closing the exhaust valve of that cylinder.

The action above described may be followed more accurately in connection with Fig. 5, wherein the action taking place in the four cylinders is represented by concentric circles, each circle corresponding to the four-cycle operation in a cylinder and representing two complete revolutions of the engine shaft. The heavy quadrant of each circle, indicated by the letter "P" on the circle of cylinder No. 1, represents the power stroke of the corresponding cylinder, and the shaded quadrant of each circle, represented by the letter "C" on the circle of cylinder No. 3, represents the compression stroke in that cylinder. As indicated by the arrow in this figure each power stroke of a cylinder follows the compression stroke of that cylinder. The compression stroke of each cylinder is concurrent with the power stroke in another cylinder. Thus, the compression stroke in the cylinder No. 3 is concurrent with the power stroke in cylinder No. 1. The pipe connections for making the compression pressure in one cylinder effective to open the exhanst valve of another cylinder at the proper time must therefore be from cylinder No. 3 to cylinder No. 1, as indicated by the line 21 on Fig. 6, from cylinder No. 4 to cylinder No. 3, as indicated by the line 22, from cylinder No. 2 to cylinder No. 4, as indicated by the line 23, and from cylinder No. 1 to cylinder No. 2, as indicated by the line 24. By reference to Fig. 5, it will be seen that as above described, the compression in cylinder No. 3 is increasing during the power stroke in cylinder No. 1, and will operate through the connection 21 to open the exhaust valve of cylinder No. 1 toward the end of the power stroke in cylinder No. 1. Following this compression stroke in cylinder No. 3, the power stroke takes place in that cylinder, as indicated at P′ on Fig. 5, and the pressure of the gases in cylinder No. 3 during this power stroke will be effective through the connection 21 to hold the exhaust valve of cylinder No. 1 open during the exhaust stroke of cylinder No. 1, indicated at E. Toward the end of the power stroke P′ in cylinder No. 3, the exhaust valve of that cylinder will be opened by the compression pressure in cylinder No. 4, indicated at C′, through the connection 22, resulting in such a decrease of the pressure exerted through the connection 21 that the exhaust valve of cylinder No. 1 is closed.

In applying the construction indicated in Figs. 3 and 5 to an eight-cylinder engine, the arrangement may be substantially the same, treating the engine as two four-cylinder engines.

Referring now to Fig. 4, the application of the invention to a six-cylinder engine will be described. Each cylinder is provided with an exhaust valve and an auxiliary cylinder and piston in the manner above described. In addition, each cylinder is provided with a port in its side wall which is uncovered by the downward movement of the piston and this port is connected by a pipe 26 to the space in the auxiliary cylinder 17 above the piston 15 therein. Considering this provision alone, the downward movement of the piston on its power stroke would finally open communication from the interior of the cylinder to the pipe 26 and the pressure then existing within the cylinder would be exerted through the connection 26 upon the upper face of the auxiliary piston 15 to open the exhaust valve. This, with suitable provision for holding the exhaust valve open for the appropriate time might be effective to cause proper operation of the exhaust valve except in case of a misfire within the cylinder. If the gases in the cylinder were not exploded, the piston would move downward without the development of the usual high pressure within the cylinder so that when the connection to pipe 26 was opened, there would be no pressure effective through the pipe 26 to open the exhaust valve. As a result, the piston would move back, compressing the gas within the cylinder and would move down on its next stroke without drawing gas into the cylinder through the inlet valve. I prefer to employ the provision above described including the passage 26 for making the explosion pressure effective to open the exhaust valve and to combine therewith means for making the compression pressure in another cylinder effective to open the exhaust valve at any time when that valve is not opened by pressure exerted through the passage 26, as for instance, in event of a failure to ignite the gas within the cylinder. This is accomplished by the provision of connections from one cylinder to the exhaust valve actuating device of another cylinder, similar to that above described in connection with Figs. 3 and 5. In Fig. 4, the firing order is assumed to be cylinders Nos. 1, 5, 3, 6, 2, 4, this being the usual firing order employed with six-cylinder engines. Therefore, the top of cylinder No. 3 is connected to the exhaust valve actuating device of cylinder No. 1 by a passage 27. Cylinder No. 6 is connected to cylinder No. 5 by a passage 28. Cylinder No. 2 is connected to cylinder No. 3 by a passage 29. Cylinder No. 4 is connected to cylinder No. 6 by a passsage 30. Clyinder No. 1 is connected to cylinder No. 2 by a passage 31, and cylinder No. 5 is connected to cylinder No. 4 by a passage 32. Each of these several passages is provided with a check valve, as indicated at 33, to prevent backward flow of the gases therethrough, and also each of the passages 26 is provided with a check valve 34 for a similar purpose.

Fig. 6 is a diagram similar to Fig. 5 of the action taking place in the several cylinders. The power stroke in cylinder No. 1 is indicated by the letter P. During the last two-thirds of this power stroke the piston in cylinder No. 3 is moving on its compression stroke, as indicated at C. Therefore a connection is made from the top of cylinder No. 3 to the exhaust valve actuating cylinder of cylinder No. 1, as indicated at 27, and the parts of the exhaust valve of cylinder No. 1 affected by the pressures existing in cylinders Nos. 1 and 3, are so proportioned as to open the exhaust valve of cylinder No. 1 near the end of its power stroke, that is, shortly before the piston of cylinder No. 3 has completed two-thirds of its compression stroke. The valve having been opened thus, it is held open by the increasing pressure of the compression in cylinder No. 3 and by the higher pressure existing thereafter during the power stroke P′ in cylinder No. 3 corresponding to the exhaust stroke valve in cylinder No. 1. Near the end of the power stroke P′ in cylinder No. 3, the exhaust valve of that cylinder is opened by the compression pressure in cylinder No. 2 exerted through the connection 29. The decrease in the pressure in cylinder No. 3, occasioned by the opening of its exhaust valve, causes a corresponding decrease in the pressure exerted through connection 27 in the top of the auxiliary cylinder of cylinder No. 1, and permits the exhaust valve of cylinder No. 1 to be moved to its closed position by its actuating spring 25.

In any internal combustion engine of the four-cycle type, it is desirable to open the exhaust valve a substantial time before the piston reaches the end of its downward movement. As the piston nears the end of its downward movement, the pressure of the expanding gases upon the piston becomes less effective in causing rotation of the engine shaft; in fact, the torque produced during this portion of the power stroke may be so small as to make it desirable to discontinue the production of power so far as concerns this cylinder a substantial period before the piston reaches the end of its downward movement so as to enlarge the period during which the exhaust valve is open, thereby making the exhaust of the products of combustion more complete and aiding the cooling of the cylinder. The point of opening the exhaust valve may be as much as 60° of rotation of the engine shaft prior to the end of the downward movement of the piston on its power stroke. If the development of power during the power stroke P′ in cylinder No. 3 were made to terminate at a point

represented by 60° of rotation of the engine shaft prior to the end of the downward movement of the piston in that cylinder, the termination of the development of power would be coincident with the end of the upward movement of the piston in cylinder No. 1 on its exhaust stroke and the closing of the exhaust valve of cylinder No. 1 might take place at this point and be occasioned by the opening of the exhaust valve in cylinder No. 3. As a matter of fact, the closing of the exhaust valve in cylinder No. 1 may be made to occur slightly beyond the completion of the upward movement of the piston of cylinder No. 1 on its exhaust stroke, that is, during the first portion of the inlet stroke in cylinder No. 1 indicated at I on Fig. 6. This provision is not uncommon in internal combustion engines and it will be appreciated that the closure of the exhaust valve in cylinder No. 1 may be made to occur at this point as a result of the opening of the exhaust valve of cylinder No. 3, and the reduction of pressure in cylinder No. 3 and connection 27 incident thereto.

In order to insure closure of the exhaust valve of each cylinder when the piston of that cylinder reaches the end of its upward movement on the exhaust stroke, I may employ the construction illustrated in Fig. 2. Here the stem of the exhaust valve 13 has an axial opening to receive the stem of an auxiliary valve having a head 35 lying below the exhaust valve 13. The stem of this auxiliary valve is secured at its upper end to a valve 36 which is normally pressed by a light spring 37 down upon the upper face of the piston 15 and covers a passage 39 leading through the piston 15. Below the piston 15 the cylinder 17 is provided with a passage 38 leading to the atmosphere. When the piston 8 moves upward on its exhaust stroke, its face engages the auxiliary valve head 35 and moves the valve stem, together with the valve 36, upward against the tension of spring 37 sufficient to allow the escape of the gas within the cylinder 17 through the passage 39 through the valve 15 and to atmosphere through the passage 38. By thus relieving the pressure above the piston 15, the exhaust valve 13 may be moved to its seat by its spring 25. The stem to which the head 35 and valve 36 are secured may be extended and tapered at its end so that when the valve is raised by the piston, the end of the stem closes the end of the pipe 21 extending through the cap of the cylinder 17.

I claim:

1. In a four-cycle internal combustion engine, the combination of a plurality of cylinders, an exhaust valve for each cylinder, an auxiliary cylinder on each cylinder, a piston in each auxiliary cylinder connected to the corresponding exhaust valve, a spring acting on the piston for normally holding the exhaust valve in closed position, and a conduit through which gas pressure from another cylinder may be transmitted to the piston of each auxiliary cylinder to overcome the effect of the spring and open the exhaust valve.

2. In an internal combustion engine, a plurality of cylinders, an exhaust valve for each cylinder, means for actuating the valve of each cylinder by the effect of pressure in that cylinder, and means for insuring the opening of each valve in the event of misfire in its cylinder.

3. In an internal combustion engine, a plurality of cylinders, an exhaust valve for each cylinder, means for actuating the valve of each cylinder by the effect of pressure in that cylinder, and auxiliary means for actuating each valve in response to the difference between the pressure in its cylinder and the pressure in another cylinder.

4. In a four-cycle internal combustion engine, the combination of a plurality of cylinders, an exhaust valve for each cylinder, means for operating each exhaust valve by gas pressure, a connection from each cylinder to the said means of that cylinder for operating the exhaust valve, and a connection to the said means of each cylinder from another cylinder of the engine; substantially as described.

5. In a four-cycle internal combustion engine, the combination of a plurality of cylinders, an exhaust valve for each cylinder, means for operating each exhaust valve by gas pressure, a connection from each cylinder to the said means of that cylinder for operating the exhaust valve, and a connection to the said means of each cylinder of the engine from the cylinder of the engine in which compression takes place during the power stroke in the cylinder corresponding to the said means; substantially as described.

6. In a four-cycle internal combustion engine, a plurality of cylinders, an exhaust valve for each cylinder, means for opening the exhaust valve of each cylinder by gas pressure derived from that cylinder near the end of the power stroke within the cylinder, and means for insuring opening of the exhaust valve of each cylinder in event of the misfire; substantially as described.

7. In a four-cycle internal combustion engine, the combination of a plurality of cylinders, an exhaust valve for each cylinder, means for opening the exhaust valve of each cylinder by gas pressure derived from that cylinder by opening a port leading from the cylinder by the movement of the piston near the end of the power stroke of the piston, and auxiliary means for supplying gas pressure to open the exhaust valve of each cylinder when ignition of the gases within the cylinder does not take place; substantially as described.

8. In a four-cycle internal combustion engine, the combination of a plurality of cylinders, an exhaust valve for each cylinder, means for opening each exhaust valve by gas pressure, a passage through which gas pressure is supplied to the said means of each cylinder from another cylinder of the engine, a piston in each cylinder, means for closing the exhaust valve of each cylinder actuated by the movement of the piston of that cylinder; substantially as described.

9. In a four-cycle internal combustion engine, the combination of a plurality of cylinders, an exhaust valve for each cylinder, a piston in each cylinder, an auxiliary cylinder on each cylinder, a piston in each auxiliary cylinder connected to the corresponding exhaust valve, a passage through which gas pressure is supplied to the auxiliary cylinder of each cylinder of the engine from another cylinder of the engine, and means for relieving the pressure in each auxiliary cylinder by the movement of the piston of the corresponding cylinder; substantially as described.

10. In a four-cycle internal combustion engine, the combination of a plurality of cylinders, an exhaust valve for each cylinder, a piston in each cylinder, an auxiliary cylinder on each cylinder, a piston in each auxiliary cylinder connected to the corresponding exhaust valve, a passage through which gas pressure may be supplied to one side of the piston of the auxiliary cylinder of each cylinder of the engine from another cylinder of the engine, and a passage through which gas pressure may also be supplied to the same side of the piston of each auxiliary cylinder from the cylinder on which the auxiliary cylinder is mounted.

11. In a four-cycle internal combustion engine, the combination of a plurality of cylinders, an exhaust valve for each cylinder, means for opening each exhaust valve by gas pressure, a passage through which gas pressure is supplied to the said means of each cylinder from another cylinder of the engine, a piston in each cylinder, and means under the control of the piston in each cylinder for relieving gas pressure on the exhaust valve opening means of the same cylinder to permit the exhaust valve to close.

12. In a four-cycle internal combustion engine, the combination of a plurality of cylinders, an exhaust valve for each cylinder, an auxiliary cylinder on each cylinder, a piston in each auxiliary cylinder connected to the exhaust valve of the same cylinder, and having an effective area substantially greater than the effective area of the exhaust valve, a spring acting on each piston for normally holding the exhaust valve connected thereto in closed position, and a conduit through which gas pressure from another cylinder of the engine may be transmitted to the piston of each auxiliary cylinder to overcome the effect of the spring and open the corresponding exhaust valve.

In testimony whereof I affix my signature.

GREGORY J. SPOHRER