W. P. VALENTINE.

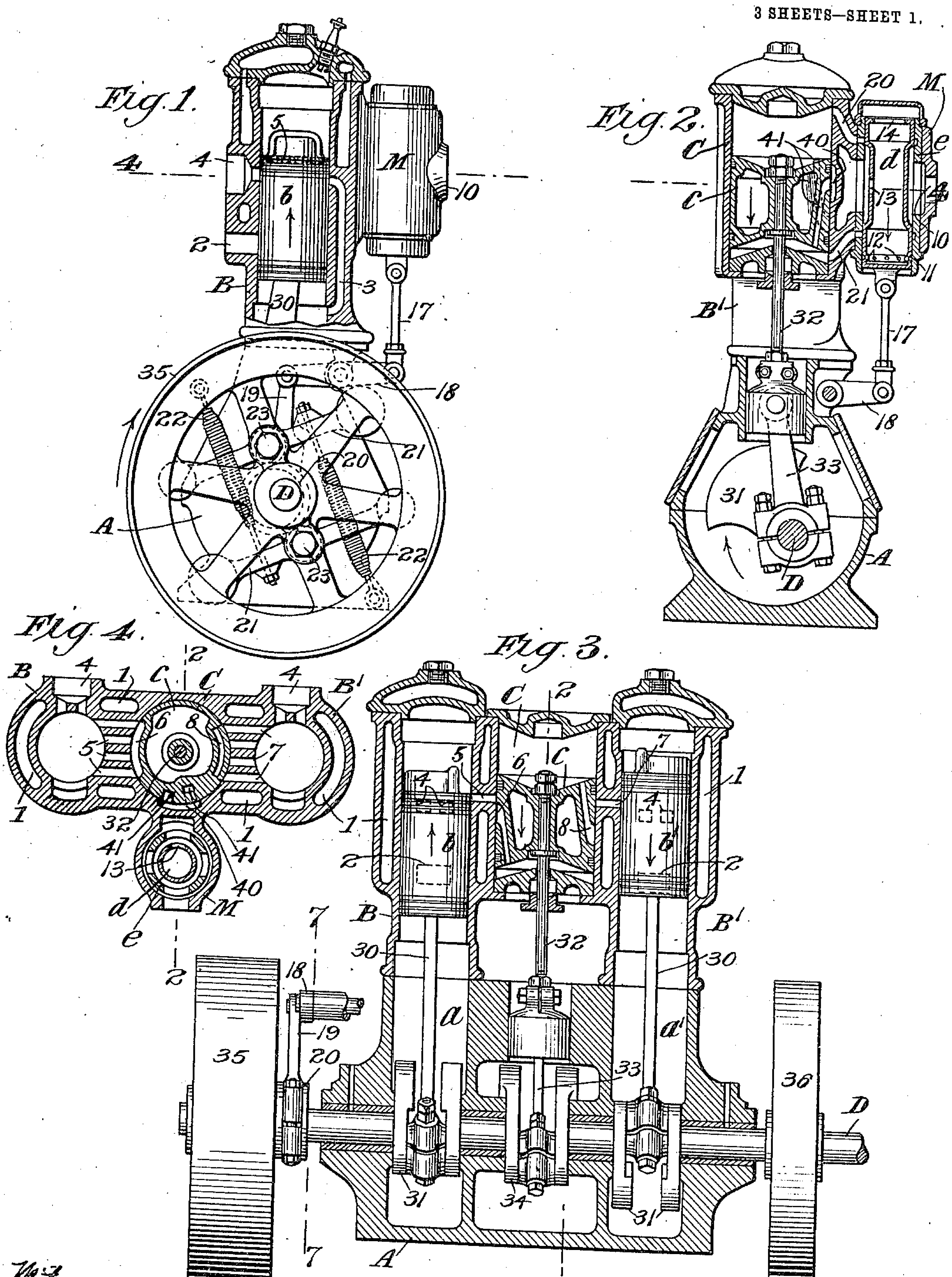
GAS ENGINE.

APPLICATION FILED MAY 4, 1909.

945,297.

Patented Jan. 4, 1910.

3 SHEETS—SHEET 1.



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3 SHEETS—SHEET 2.

Fig. 5.

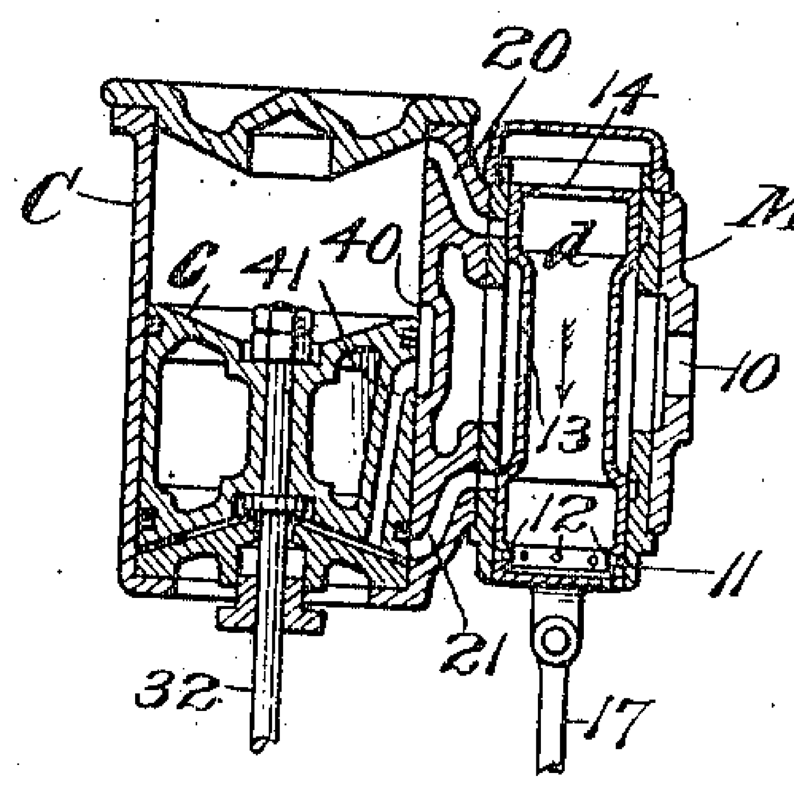


Fig. 6.

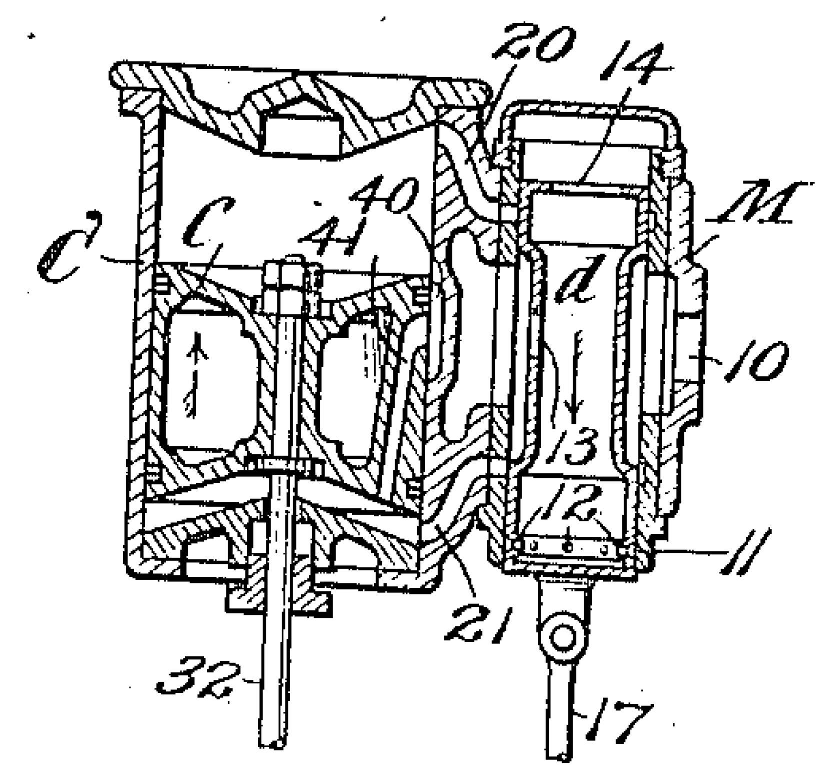


Fig. 7.

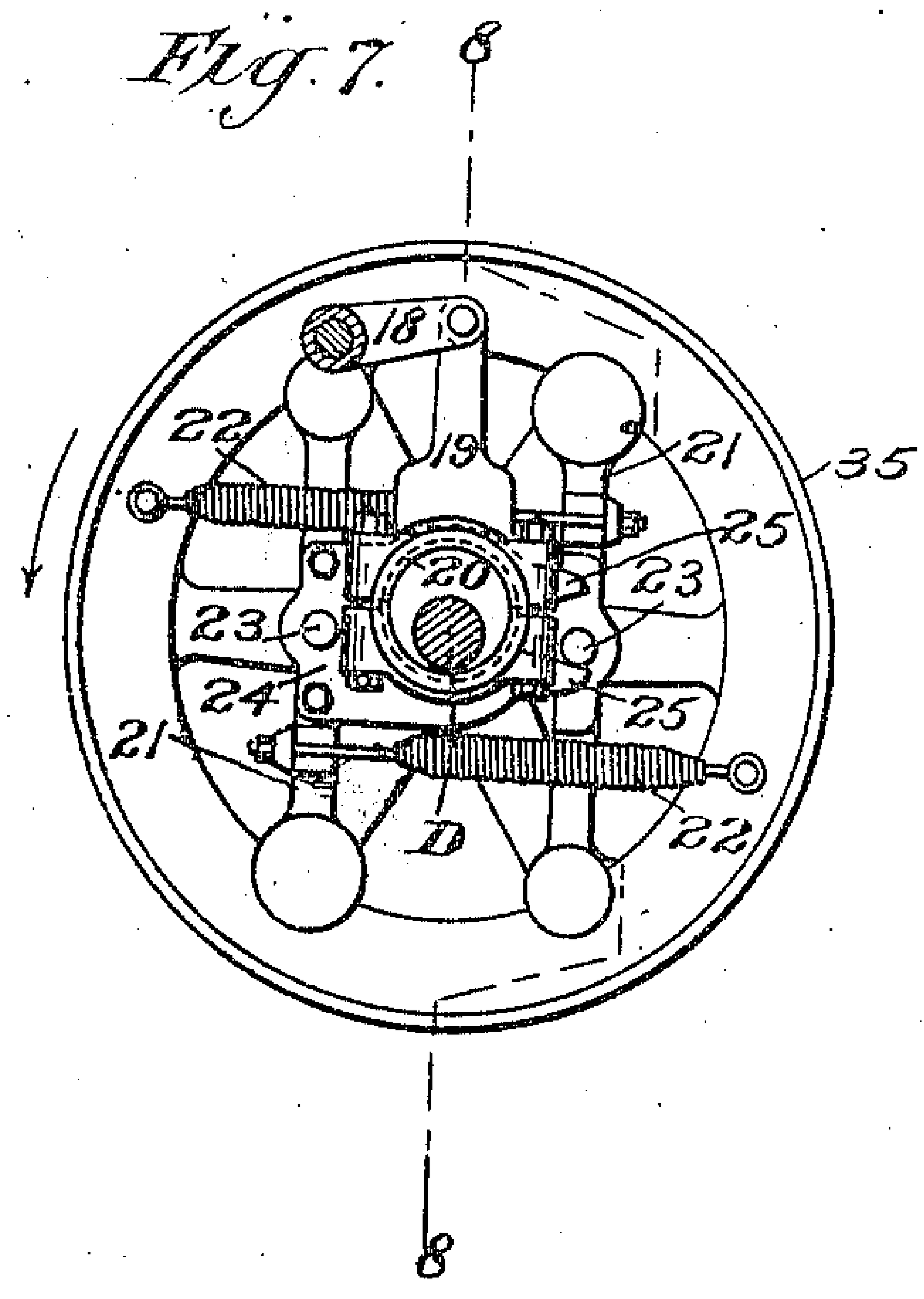
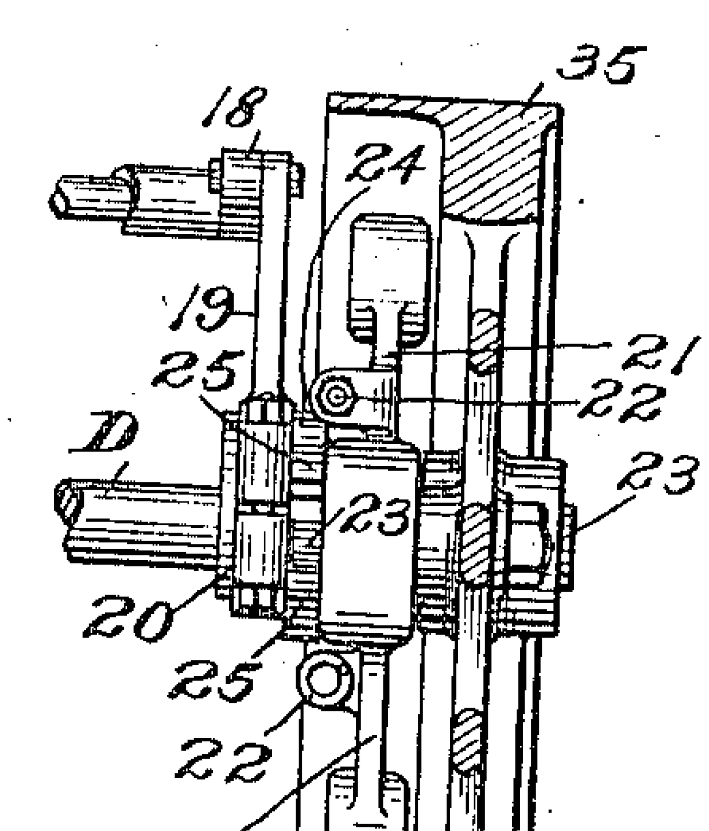


Fig. 8.



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3 SHEETS—SHEET 3.

Fig. 9.

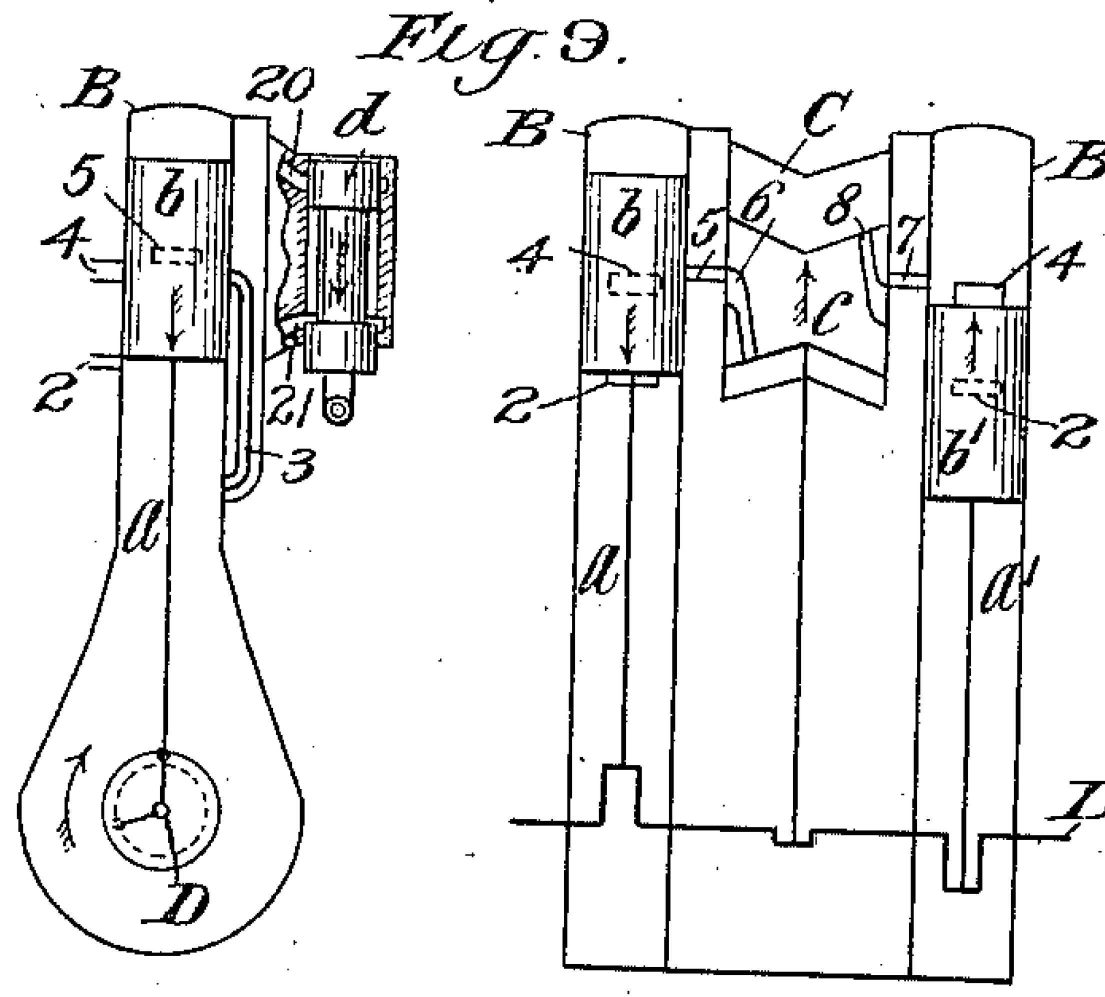


Fig. 10.

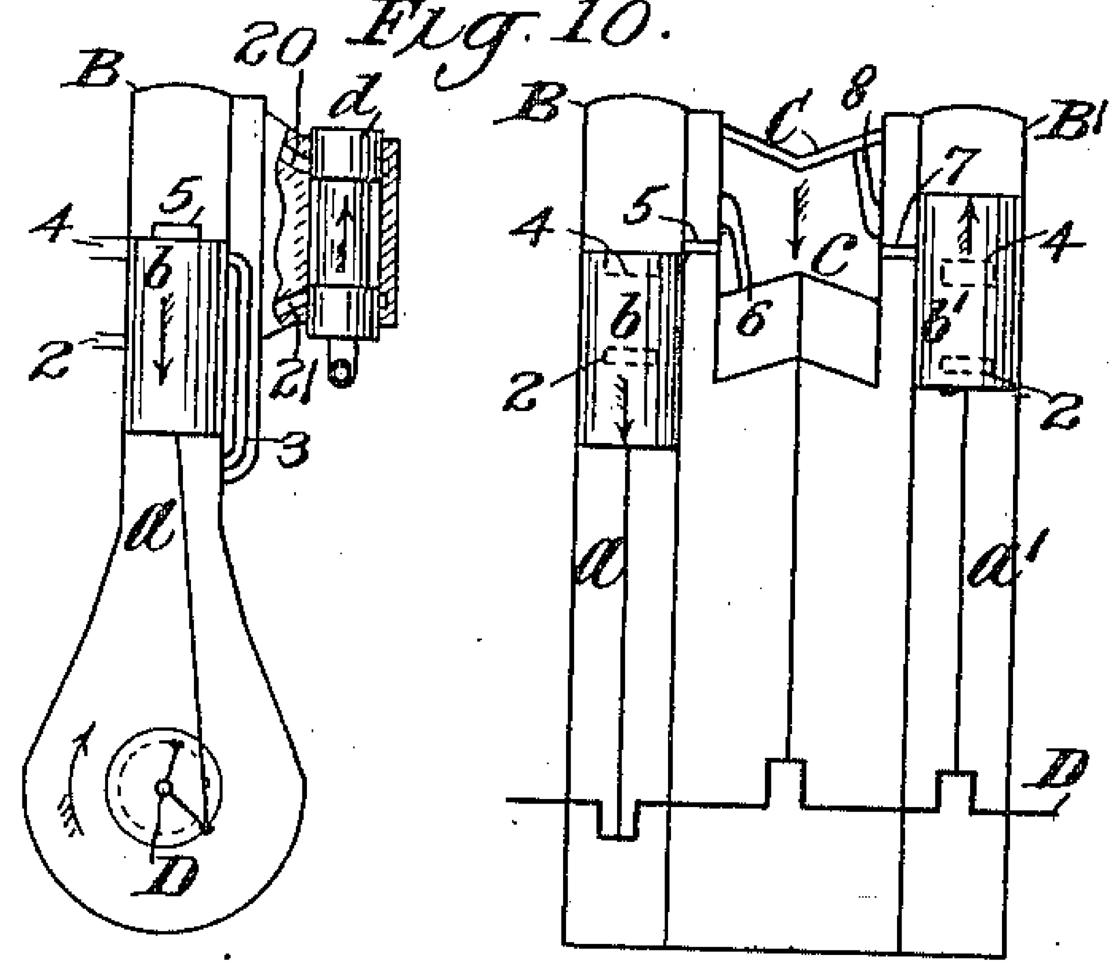


Fig. 11.

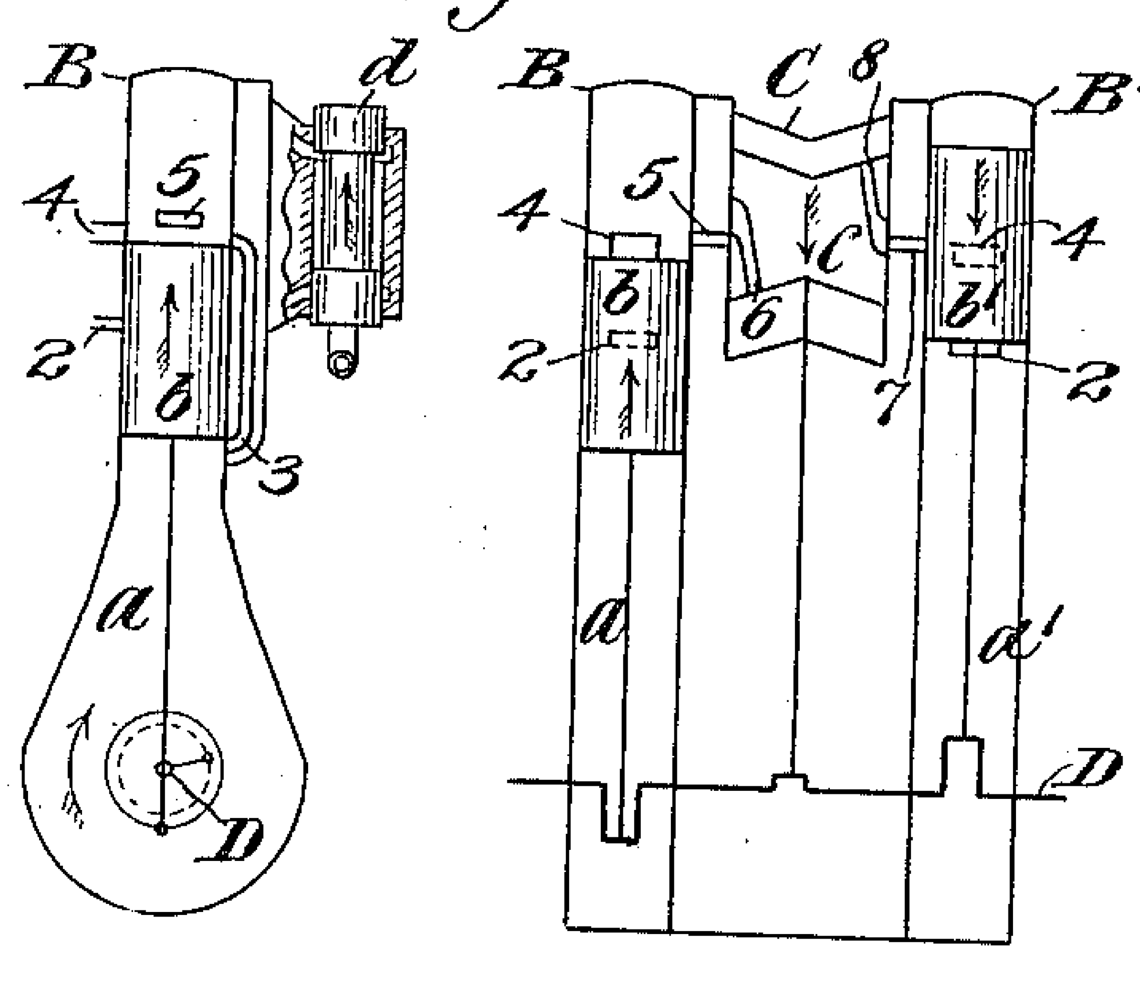


Fig. 12.

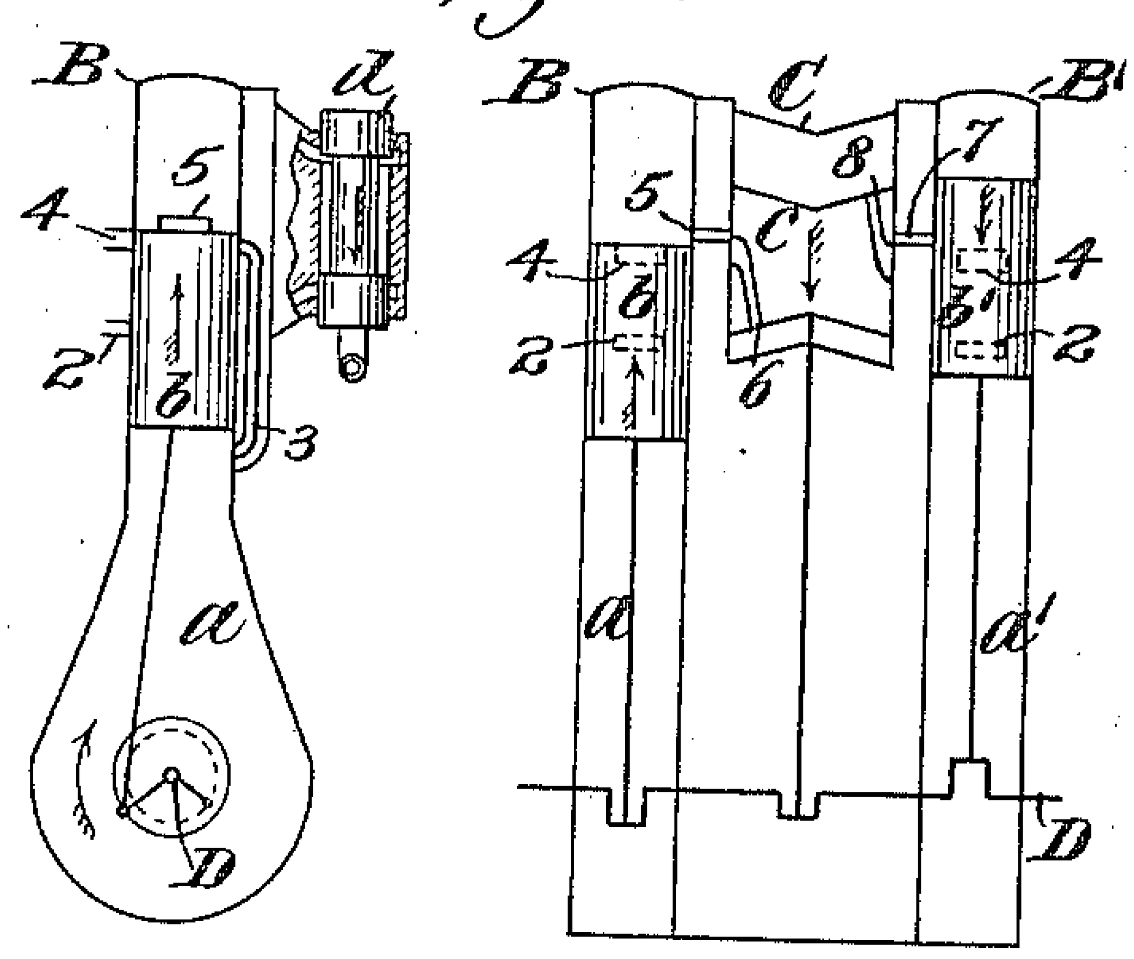


Fig. 13.

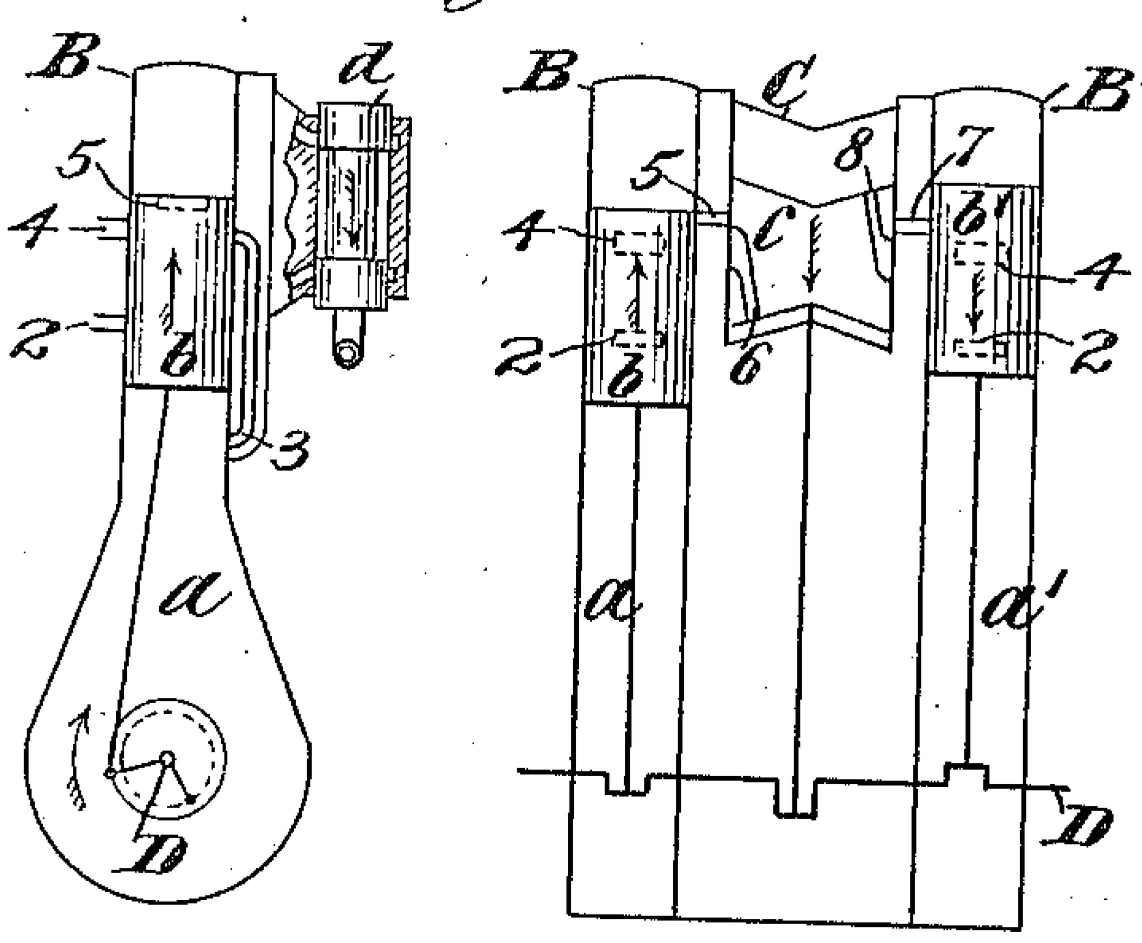
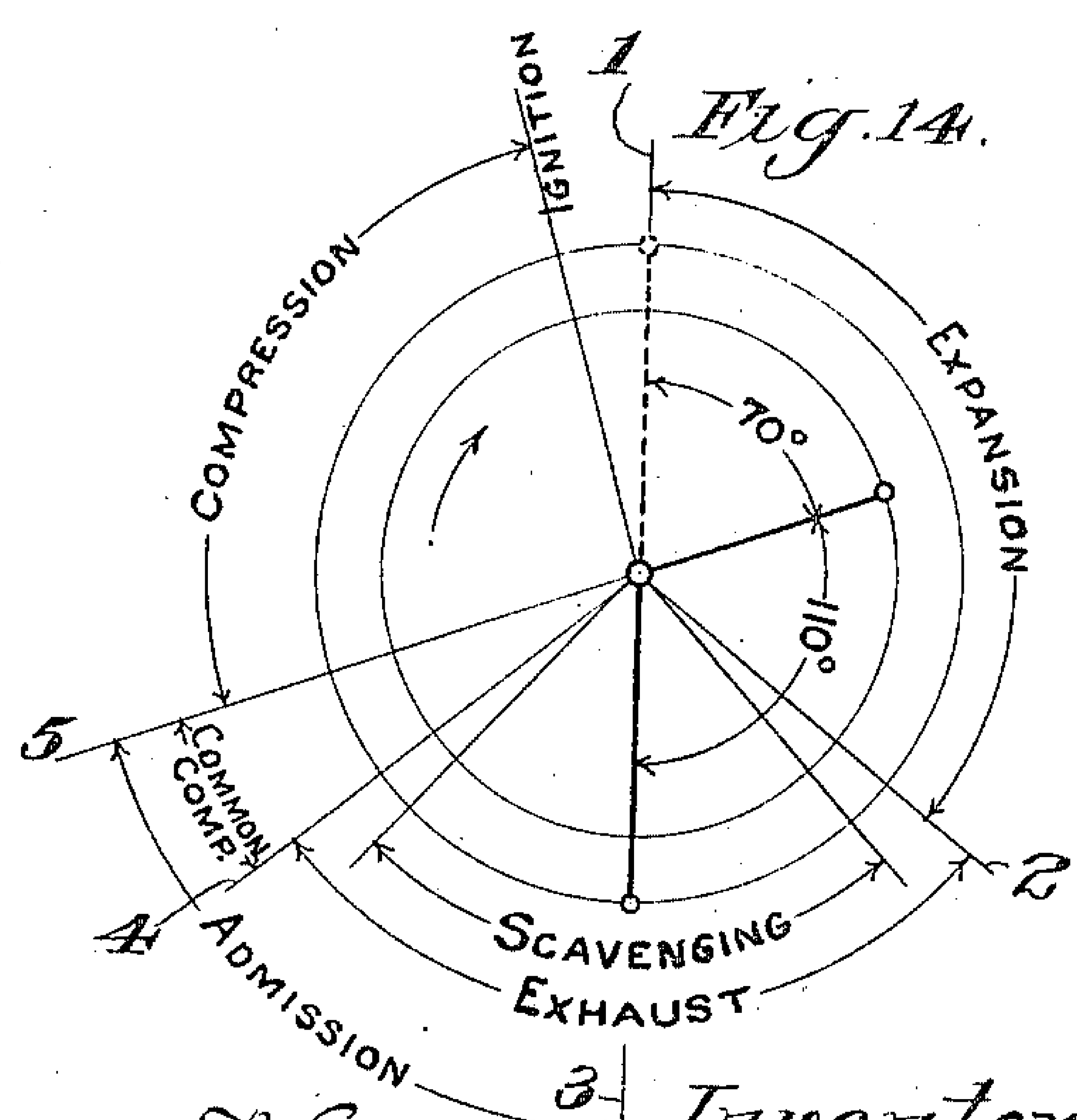


Fig. 14.



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UNITED STATES PATENT OFFICE.

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GAS-ENGINE.

945,297. Specification of Letters Patent. Patented Jan. 4, 1910.

Application filed May 4, 1909. Serial No. 493,848.

To all whom it may concern:

Be it known that I, WARREN P. VALENTINE, a citizen of the United States, residing at Holyoke, county of Hampden, and State of Massachusetts, have invented certain new and useful Improvements in Gas-Engines, fully described and represented in the following specification and the accompanying drawings, forming a part of the same.

This invention relates to gas engines, and the special object of the invention is to provide a simple, cheap, light and durable gas engine which may be run at high rates of speed with certainty and economy and which will have a high efficiency under very light as well as under heavy and moderate loads.

The invention consists in certain novel features of construction and combinations of parts all as fully hereinafter described and specifically pointed out in the claims.

In the accompanying drawings forming part of this specification and which show a gas engine embodying the various features of the invention in a preferred form:—Figure 1 is an end elevation partly in section through the left-hand power cylinder of Fig. 3. Fig. 2 is a section on line 2 of Figs. 3 and 4. Fig. 3 is a sectional elevation of the engine on a plane passing through the center of the power cylinders, fuel pump cylinder and crank shaft bearings. Fig. 4 is a section on line 4 of Figs. 1 and 2. Figs. 5 and 6 are sectional views of the fuel pump cylinder and valve corresponding to Fig. 2 but showing the pump piston and valve in different positions. Fig. 7 is a view taken on line 7 of Fig. 3 showing the governor. Fig. 8 is a section on line 8 of Fig. 7. Figs. 9 to 13 are diagrams showing the power and pump pistons and the valve in different positions corresponding to the divisions of the cycle shown in Fig. 14. Fig. 14 is a cycle diagram of the engine shown.

Referring to the drawings, which show a two-cylinder engine, A is a base casing which forms air chambers a, a' in which air is compressed for scavenging. On the base casing are mounted the power cylinders B and B′ and the fuel pump cylinder C. The power cylinders and fuel pump cylinders are preferably cast in one piece, as shown, to avoid leakage and for economy in construction, and the power cylinders are shown as having the usual water jackets 1. The crank shaft D is mounted in bearings in the base casing A, and is connected to the upper pistons b, b' by pitmen 30 connected to cranks 31 set 180° apart, and the fuel piston c is connected with the crank shaft by means of the piston rod 32, pitman 33 and crank 34. The pump crank is offset from its leading power crank something more than 90°, preferably approximately 110°, as shown in the drawings and as indicated in the diagram Fig. 14, instead of being set at approximately 90° from the power cranks. The advantage of setting the pump crank at such a greater angular distance behind the power cranks will be apparent as other features of the invention are described hereinafter. The crank shaft is shown as carrying two balance wheels 35 and 36, in one of which the governing mechanism hereinafter described is mounted.

Each of the air chambers a, a' is provided with a port 2 for the admission of air, and these chambers are connected to the explosion end of the power cylinders B, B′ by ports 3 opening into the power cylinders at or near the line of the exhaust ports 4. The charge is admitted to the power cylinder B from below the pump piston c through port 5 in the cylinder wall and port 6 in the piston c, and the charge is admitted to the power cylinder B′ from above the pump piston c through similarly arranged ports 7 and 8, the admission ports thus being controlled by both the power and pump pistons and admission to the power cylinders occurring only when both pistons are in the proper position.

The fuel employed is any suitable gaseous fuel which is mixed with the fres hair in the cylinder after the scavenging, this fuel being admitted alternately above and below the pump piston c through ports 20 and 21. The fuel mixture of air and gas may be supplied from any suitable source, and its admission to the pump through the ports 20 and 21 is controlled by a slide valve d mounted in a casing M. The valve d is a cylindrical valve sliding in a cylindrical housing e. The valve casing M has an admission port 10 and is open at the bottom, and the lower end of the valve is formed with an annular groove 11 which is connected with the interior of the valve by small holes 12. This construction permits of ready removal of the valve and convenient access to the interior of the valve casing.

while the escape of fuel mixture by leakage is provided against by the annular groove and holes 12, since any escaping gas will pass from the groove through the holes to the interior of the valve, from which it can pass through an opening 13. An opening 14 is also provided from the interior of the valve to the closed upper end of the casing. The valve is connected by a link 17 to a lever 18 to which is also connected a rod 19 extending from an eccentric 20 which is mounted to rotate with the fly wheel 35. The eccentric thus operates to reciprocate the valve, and for the purpose of regulating the charge in accordance with the load the position and throw of the eccentric are controlled by a governor so that the length of the reciprocations of the valve and the extent of opening of the fuel ports 20, 21, will be lessened as the load is decreased and increased as the load is increased. Any form of governor may be used for this purpose. A common form of wheel governor is shown in the drawings and especially in Figs. 1, 7 and 8. As here shown the fly-wheel 35 carries two weight arms 21 mounted to swing on pivot studs 23 secured in the arms of the fly-wheel, and the heavier ends of which are drawn inward by springs 22. Secured on one of the weight arms 21 so as to swing therewith, is a frame 24 carrying the eccentric 20 so that the swinging of the weight arm 21 to which the frame 24 is secured shifts the eccentric to increase or decrease the eccentric throw and the movement of the valve *d* through stem 16, link 17, lever 18 and eccentric rod 19, which is actuated by the eccentric 20. The other weight arm 21 serves as a counterbalance to the weight arm carrying the frame 24, and the movement of the frame 24 and the weight arm in both directions is limited by stops 25 carried by the frame 24 on opposite sides of the extended end of pivot stud 23, which the stops 25 engage at the limit of movement of frame 24 in either direction. In Figs. 2, 9 and 10, the parts are shown in position with one of the stops 25 engaging the end of the stud 23 as when the engine is at rest. On increase of speed, with the fly-wheel rotating in the direction shown by the arrow in Fig. 7, the heavier ends of the weight arms 21 will swing outward, and thus swing the frame 24 to move the eccentric and eccentric rod 19 downward, in Fig. 7, thus varying the position and throw of the valve *d* in accordance with the speed of the engine.

The charging ports 5 and 7 are opened by the pump piston as it nears the end of its stroke and after the power pistons have passed below such ports, and are closed again by the pump and power pistons before the pump piston completes its stroke. There is thus entrapped in the compression end of the pump cylinder at the end of each stroke of the pump piston a quantity of fuel mixture equal to the remainder of the stroke plus the clearance volume. This mixture thus entrapped is then further compressed by the continued motion of the pump piston until the opposite end of the pump piston passes the end of a recessed port 40 in the wall of the cylinder, thereby opening a passage through a flash port 41 to allow the compressed mixture to pass from the compression end to the suction end of the cylinder. A flash port 41 is provided from each end of the piston so as to permit the entrapped mixture to pass at the end of each stroke of the pump piston through and past the piston to the suction end of the cylinder.

The valve *d* is formed to have an inside lap so as to keep the inlet ports to the pump cylinder closed while the flash ports are performing their functions. For this purpose the lap must be sufficient to close the inlet port to the suction end of the cylinder slightly before the opening of the flash port by the pump piston and to open the inlet port to the opposite end of the pump cylinder, which has then become the suction end, slightly after the pump piston at the beginning of its succeeding stroke has closed the flash port.

The closing of the charging port from the pump cylinder to the power cylinder before the end of the stroke of the pump piston prevents the blowing back of the more or less neutral gases from the power cylinder to the pump cylinder, which in engines governed by throttling the intake is liable to occur at light loads when the charging port is not closed until the pump piston reaches the end of its stroke, at which time compression in the pump cylinder has ceased. This early closing of the charging port results in a further compression of the fuel mixture remaining in the compression end of the pump cylinder, which compression is relieved by the use of the flash ports. The flash ports by allowing such compressed fuel gas to pass to the suction end of the pump cylinder thus serve a double purpose—that of raising the volumetric efficiency of the fuel pump, and that of relieving the pressure in the clearance spaces, so that, as the valve opens the supply ports, no back puff from the clearance spaces through the carbureter will take place. Such back puff through the carbureter would be uneconomical and also disturbing to the action of the carbureter.

The operation of the engine and the timing of the opening and closing of the various ports will be understood from a brief description in connection with the drawings.

Figs. 1 to 3 show the parts in position as in Fig. 13, while compression is taking place in the cylinder B and expansion is taking place in the cylinder B′. In the diagrams, Figs. 9 to 13, the parts are shown in position with the power piston B in the positions indicated by the cycle division lines 1 to 5 in the cycle diagram Fig. 14. In Fig. 9, which corresponds with line 1 of the cycle diagram, expansion is about to begin in cylinder B, while admission is about to take place in cylinder B′. In Fig. 10, which corresponds with line 2 of the cycle diagram, the power piston B is about to open the exhaust and scavenging ports, and compression is taking place in cylinder B′. In Fig. 11, which corresponds with line 3 of the cycle diagram, admission is about to take place in cylinder B and expansion is about to begin in cylinder B′. In Fig. 12, corresponding to line 4 of the cycle diagram, the exhaust port has been closed and compression is about to begin in cylinder B, and expansion is taking place in cylinder B′. In Fig. 13, which corresponds with line 5 of the cycle diagram, the charging port has been closed and compression is taking place in cylinder B, while expansion continues in cylinder B′.

The operation with regard to cylinder B is as follows: When the power piston *b* has reached the position shown in Fig. 9 at the end of its instroke, the air supply port 2 has been opened to admit air to the compression chamber A, and, ignition having taken place, the piston moves downward through the expansion operation, closing the port 2 and compressing the air in the chamber *a*. The exhaust, scavenging and charging ports remain closed until the piston reaches the position shown in Fig. 10, whereupon by the continued downward movement of the piston the exhaust port 4 is first opened, and immediately afterward the scavening port 3 is opened, so that the air compressed in the chamber *a* during the expansion movement of the piston *b* rushes into the cylinder B, hastens the exhaust and sweeps the cylinder clear of the explosion gases so that no waste gases are left in the cylinder to be mixed with the incoming charge. After the piston *b* passes the end of the charging port 5, and during the first part of the exhaust and scavenging, the charging port is kept closed by the pump piston *c*, which is meanwhile moving downward to compress the charge which has been drawn into the lower end of the pump cylinder on the upward stroke of the pump piston. The charging port remains closed until the parts reach the position shown in Fig. 11, after which by the continued downward movement of the pump piston, the charging port 5 is opened and the charge which has been compressed below the pump piston is admitted to the cylinder B above the piston *b*. During the first part of the admission period, the exhaust port remains open and the in-rushing charge assists in the scavenging operation and clears the cylinder of a large part of the air which enters from the scavenging port 3, thus insuring a full charge with less compression in the pump cylinder than would otherwise be necessary. After the scavenging and exhaust ports have been closed by the upward movement of the piston *b*, the admission port remains open and admission continues as indicated by Fig. 12, and common compression by both power and pump pistons together takes place until the position shown by Fig. 13 is reached, when, with the pump and power pistons timed as shown, the charging port 5 is closed by both pistons. From this point in the cycle, compression takes place in the cylinder B as the piston *b* moves upward until at or about the end of the up or outstroke of the piston, ignition takes place again and the cycle is repeated. At the moment the charging port 5 is closed, as shown in Fig. 13, compression is still taking place in the lower end of the pump cylinder by the continued downward movement of the pump piston. The fuel mixture thus entrapped in the compression end of the pump cylinder, after being further compressed, passes to the suction end of the cylinder through the flash port 41 as hereinbefore explained, and as shown in Fig. 5, both the ports 20, 21 being then closed by the valve *d* as shown in this figure. By the time the power piston *b* has reached the end of its compression movement shown in Fig. 9, the pump piston has started its upstroke, compressing in the upper end of the pump cylinder the charge which was drawn in on the down stroke, and drawing a fresh charge into the lower end of the cylinder through the inlet port 21 which has meanwhile been opened by the downward movement of the valve *d*, which port 21 is not opened by valve *d* until the piston *c* on its upward movement has closed the flash port 41 as shown in Fig. 6. This action of the valve *d* is the same in opening port 20 for the down stroke of piston *c*, keeping both ports 20, 21 closed during the time the flash port from the upper end of the cylinder C is open.

The cycle of the power piston *b′* is the same as that of the piston *b*, except that the successive stages of the cycle occur 180° behind those of the piston *b;* and obviously also the movement and operation of the pump piston on its upstroke bear the same relation to the operation of the piston *b′* as they bear on the downstroke to the operation of piston *b*.

While the invention has been illustrated and described as applied to a two-cylinder engine, in which a power stroke in each cylinder at each revolution of the crank shaft is secured, the pump piston supplying the charge alternately to the two cylinders, and while certain features of the invention are limited to such a construction, it will be understood that the claims not thus limited include an engine having but a single power cylinder, in which case the pump cylinder might be single acting instead of double acting as shown.

It will be seen that in the preferred construction shown the desired timing of the opening and closing of the various ports of the engine is secured without the use of valves in contact with the hot gases of combustion, the difficulties incident to the effect of such hot gas on valves being thus avoided.

What is claimed is:

1. In a gas engine, the combination of a power cylinder and its piston, a pump cylinder and its piston, a charging passage connecting the pump cylinder and power cylinder, means for causing the charging passage to be opened when the pump piston has made part of its compression stroke and to be closed before the pump piston has completed its stroke, and means for admitting the fuel gas to the pump cylinder.

2. In a gas engine, the combination of a power cylinder and its piston, a pump cylinder and its piston, a charging passage connecting the pump cylinder and power cylinder, means for causing the charging passage to be opened when the pump piston has made part of its compression stroke and to be closed before the pump piston has completed its stroke, a flash port for relieving the pressure developed in the pump cylinder after the closing of the charging passage, an inlet passage for supplying fuel to the pump cylinder, and a valve for controlling said inlet passage timed to open said passage after the flash port has been closed.

3. In a gas engine, the combination of a power cylinder and its piston, a pump cylinder and its piston, a charging passage connecting the pump cylinder and power cylinder controlled by both the pump and power pistons and closed before the pump piston reaches the end of its stroke, a flash port controlled by the pump piston and opened to relieve the pressure in the pump cylinder after the charging passage is closed, and means for admitting the fuel gas to the pump cylinder after the closing of the flash port.

4. In a gas engine, the combination with two power cylinders and their pistons, of a double acting pump cylinder and its piston, charging passages leading one from one end of the pump cylinder to one of the power cylinders and the other from the other end of the pump cylinder to the other power cylinder, means for causing the charging passages to be opened alternately on successive strokes of the pump piston when the pump piston has made part of its stroke and to be closed before the pump piston has completed its stroke, flash ports opened after the closing of the charging passages to allow the compressed fuel to pass from the compression end of the pump cylinder to the suction end thereof, and means for admitting the fuel gas to the pump cylinder.

5. In a gas engine, the combination with two power cylinders and their pistons, of a double acting pump cylinder and its piston, charging passages leading one from one end of the pump cylinder to one of the power cylinders and the other from the other end of the pump cylinder to the other power cylinder, means for causing the charging passages to be opened alternately on successive strokes of the pump piston when the pump piston has made part of its stroke and to be closed before the pump piston has completed its stroke, flash ports opened after the closing of the charging passages to allow the compressed fuel to pass from the compression end of the pump cylinder to the suction end thereof, an inlet passage to each end of the pump cylinder, and a valve for controlling said inlet passages having inside lap to close both inlet passages while the flash port is open.

6. In a gas engine, the combination with two power cylinders and their pistons, of a double acting pump cylinder and its piston, charging passages connecting the pump cylinder and the power cylinders, each charging passage being controlled by the pump piston and a power piston and being closed before the pump piston reaches the end of its stroke, flash ports controlled by the pump piston for the passage of the compressed fuel from the compression end to the suction end of the pump cylinder after the charging passages have been closed, and means for controlling the admission of the fuel gas to the pump cylinder.

7. In a gas engine, the combination with two power cylinders and their pistons, of a double acting pump cylinder and its piston, charging passages connecting the pump cylinder and the power cylinders, each charging passage being controlled by the pump piston and a power piston, said charging passages being opened alternately on successive strokes of the pump piston as it approaches the end of its stroke and being closed before the pump piston reaches the end of its stroke, flash ports controlled by the pump piston for the passage of the compressed fuel from the compression end to the suction end of the pump cylinder after the charging passages have been closed, an inlet passage to each end of the pump cylinder, a valve for controlling said inlet passages having inside lap sufficient to cause both of the inlet passages to remain closed while either flash port is open, and a governor for automatically controlling the speed of the engine by varying the throw of said valve.

8. In a gas engine, the combination of a power cylinder and its piston, a pump cylin-

der and its piston, a charging passage connecting the pump cylinder and power cylinder controlled by the pump piston, and means for driving the pump piston from the power piston to cause its movement to follow the movement of the power piston at an angular distance substantially greater than 90°.

9. In a gas engine, the combination of a power cylinder and its piston, a pump cylinder and its piston, an air chamber in which the engine compresses air, a charging passage connecting the pump cylinder and power cylinder controlled by both the pump piston and the power piston, a scavenging passage connecting the power cylinder with the air chamber and controlled by the power piston, cylinder exhaust and air chamber inlet ports controlled by the power piston, and a crank for driving the pump piston set at approximately 110° behind the power crank.

In testimony whereof, I have hereunto set my hand, in the presence of two subscribing witnesses.

WARREN P. VALENTINE.

Witnesses:

William C. McLeod,

Wills M. Fleming.