No. 627,219. Patented June 20, 1899.

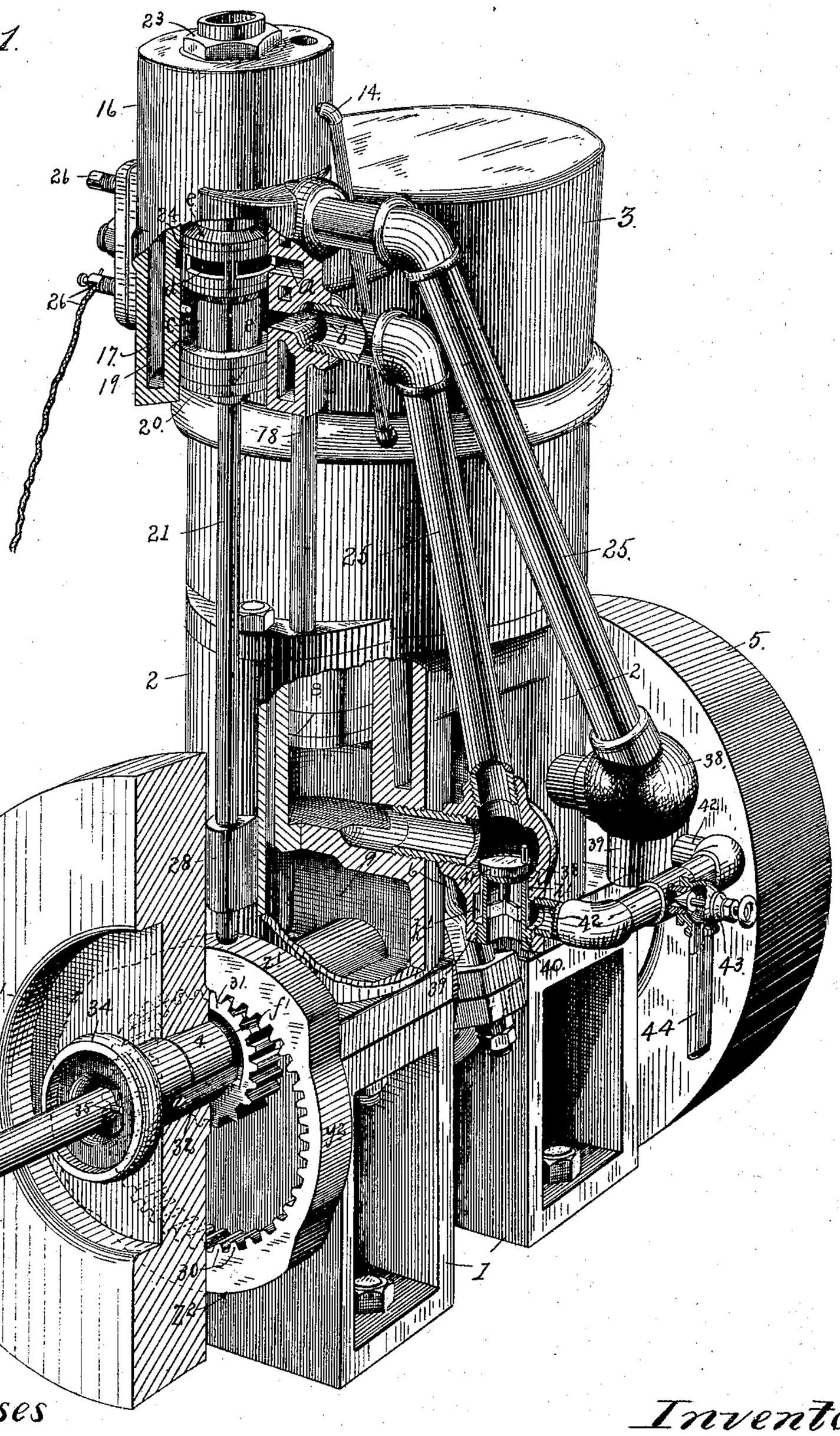
E. J. WOOLF.

AIR AND GAS ENGINE.

(Application filed Apr. 27, 1897.)

(No Model.) 4 Sheets—Sheet 1.

Fig. 1.



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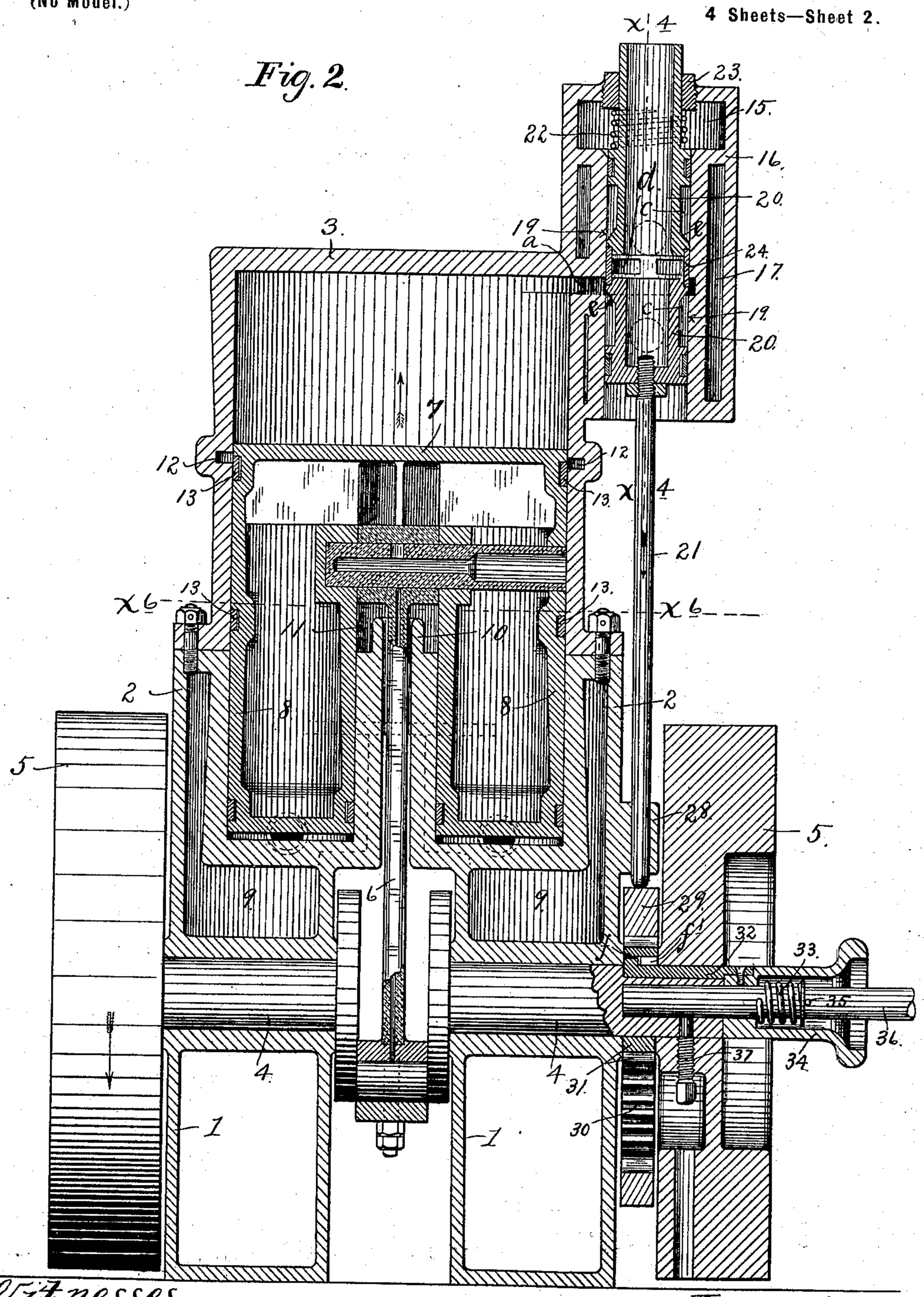
(No Model.) 4 Sheets—Sheet 2.

Fig. 2.



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(No Model.) 4 Sheets—Sheet 3.

Fig. 3.

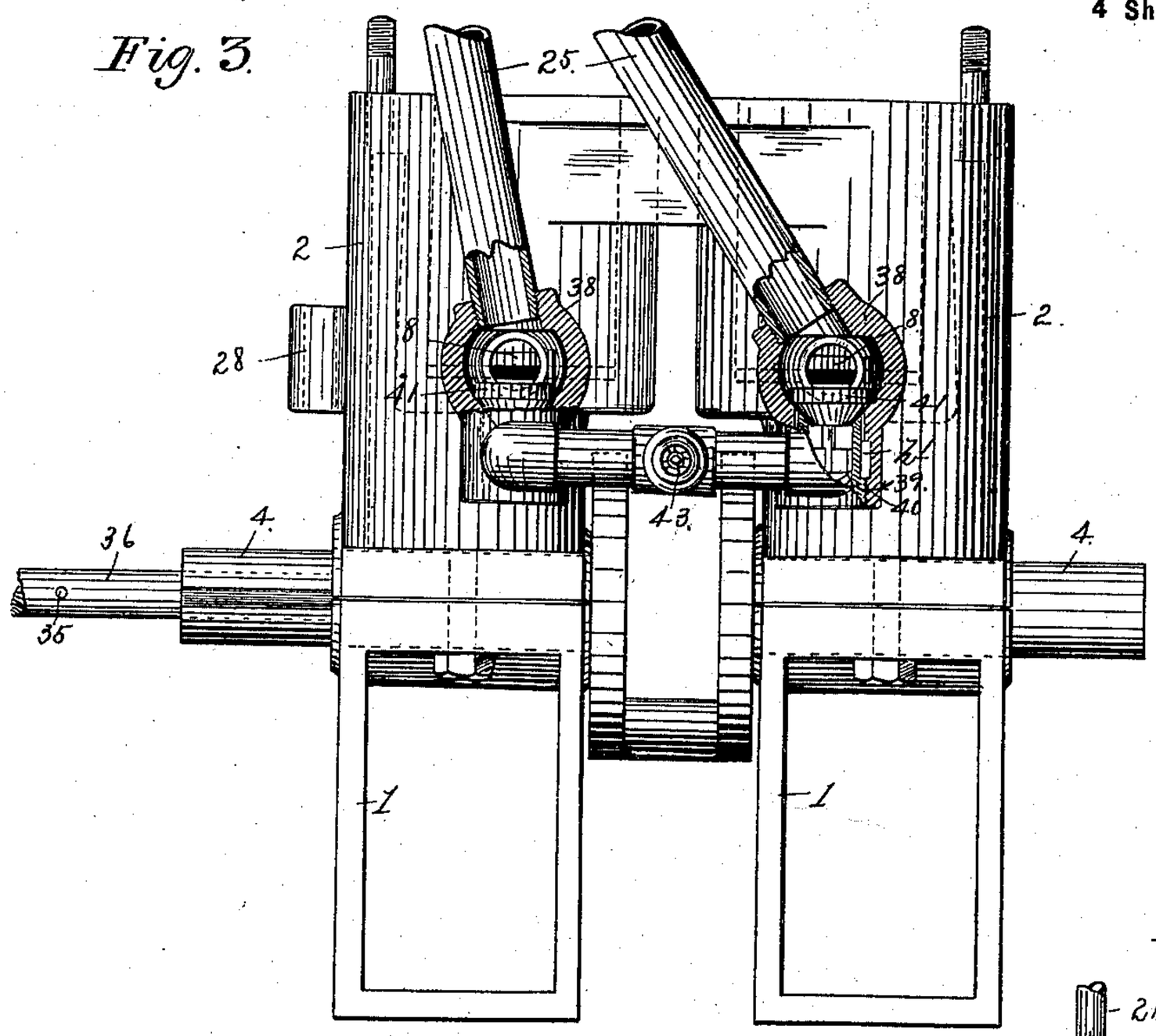


Fig 5.

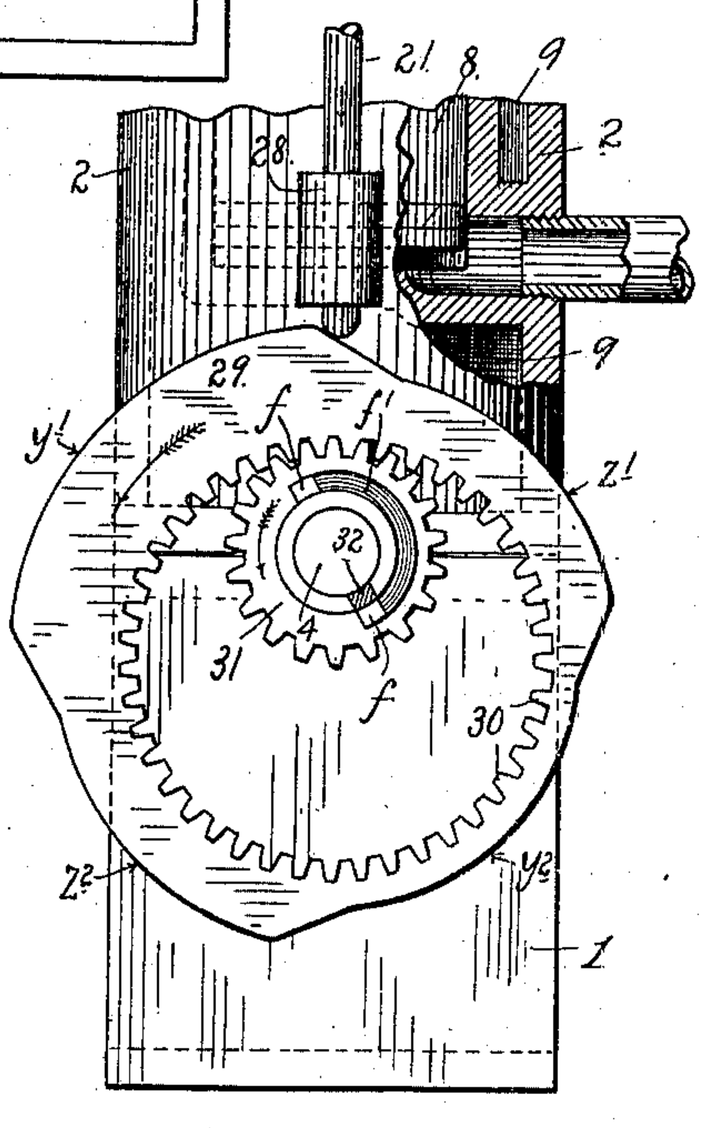
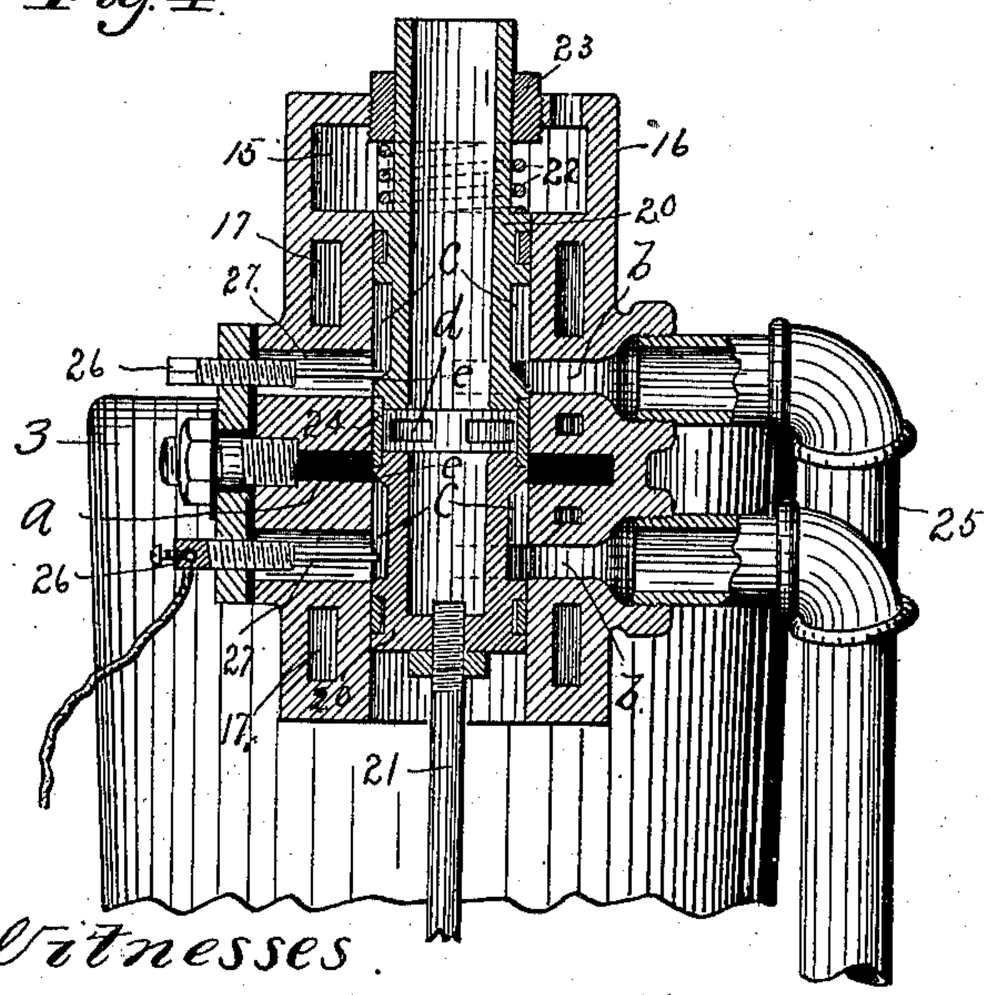


Fig 4.



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(No Model.) 4 Sheets—Sheet 4.

Fig 6.

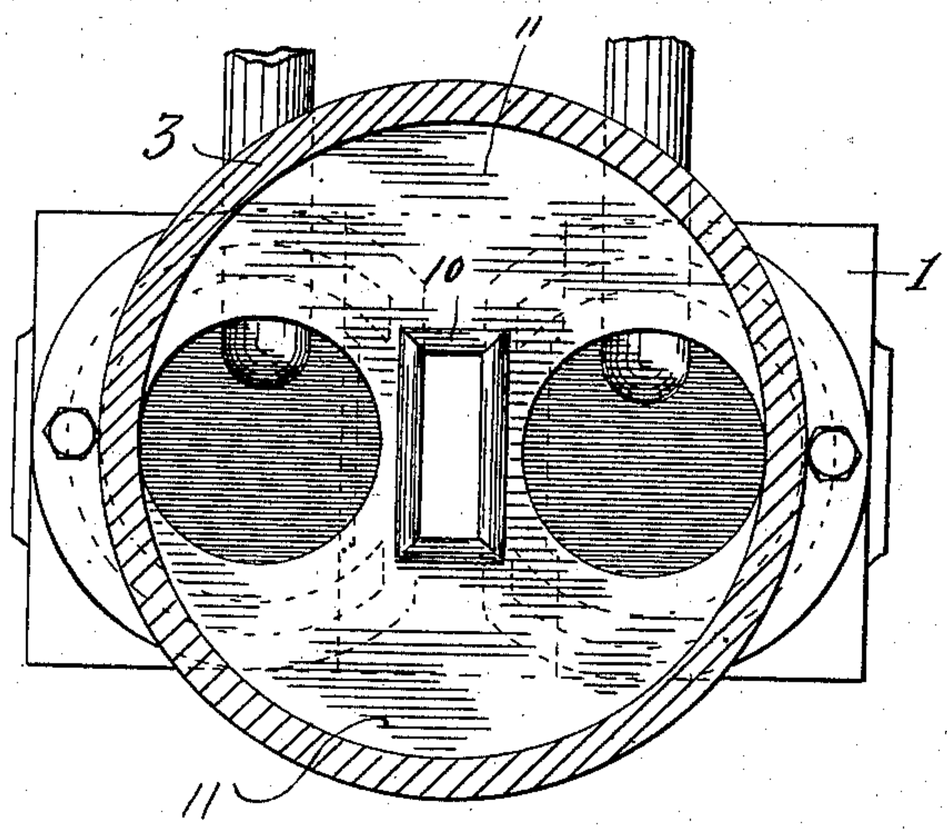
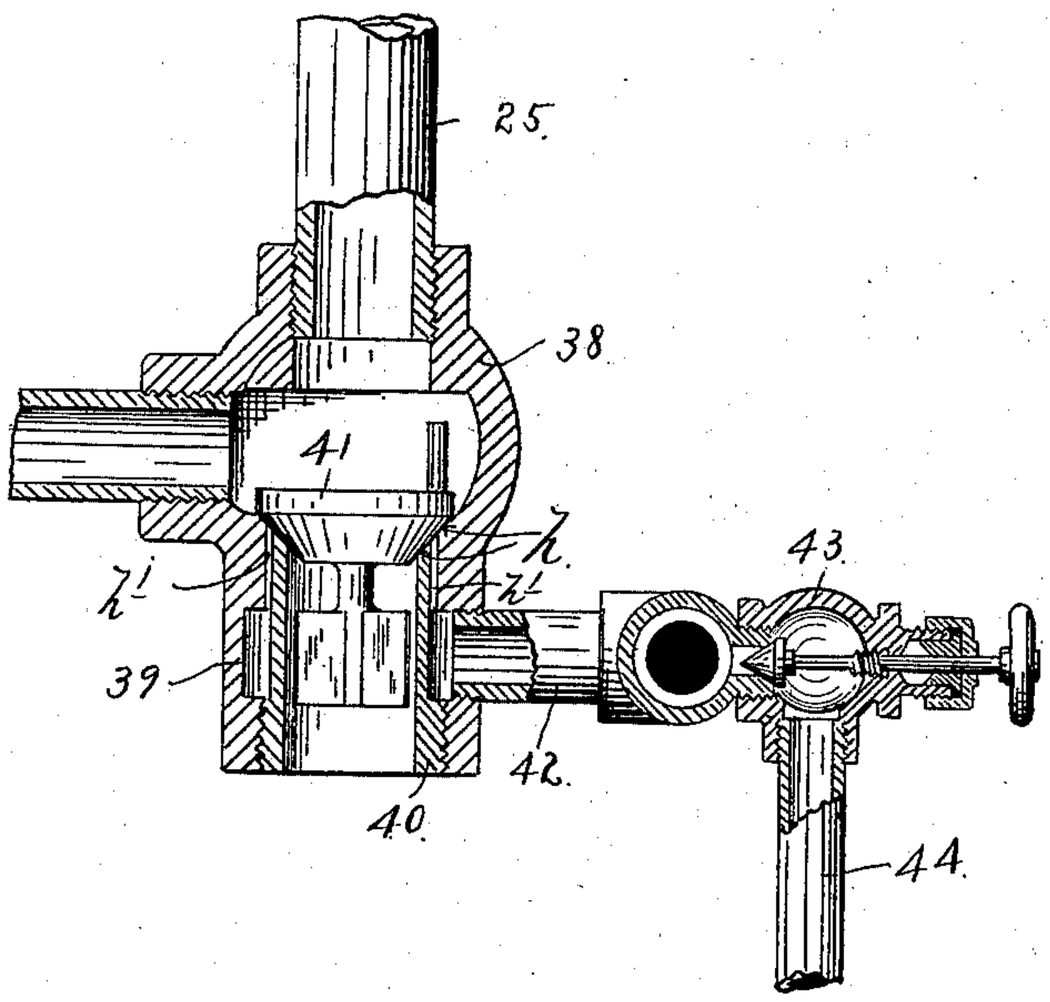


Fig. 7.



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UNITED STATES PATENT OFFICE.

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AIR AND GAS ENGINE.

SPECIFICATION forming part of Letters Patent No. 627,219, dated June 20, 1899.

Application filed April 27, 1897. Serial No. 634,182. (No model.)

To all whom it may concern:

Be it known that I, ELLIS J. WOOLF, a citizen of the United States, residing at Minneapolis, in the county of Hennepin and State of Minnesota, have invented certain new and useful Improvements in Air and Gas 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.

My invention relates to air and gas engines, and has for its object to improve the same with a view of simplicity and compactness of construction, convenience of manipulation, increased efficiency in action, and greater economy in fuel.

To these ends my invention consists of the novel devices and combinations of devices which will be hereinafter described, and defined in the claims.

The preferred form of my invention is illustrated in the accompanying drawings, wherein like notations refer to like parts throughout the several views.

Figure 1 is a perspective view, with some parts broken away and others shown in section, illustrating my improved compound engine. Fig. 2 is a view, chiefly in vertical central section, in the plane of the crank-shaft, but with some parts broken away and others shown in elevation. Fig. 3 is a view in front elevation showing the lower part of the engine illustrated in Figs. 1 and 2. Fig. 4 is a view, chiefly in vertical central section, through the valve and valve-seat and some of the other parts, substantially on the line x^4 x^4 of Fig. 2. Fig. 5 is a detail, chiefly in end elevation, but partly in section, showing the valve-gear and some other parts. Fig. 6 is a horizontal section on the line x^6 x^6 of Fig. 2 for showing the relation of the oil-well to the high-pressure pistons. Fig. 7 is a detail in sectional perspective for showing the relation of the feed devices.

The numerals 1 represent a pair of bed-castings, to which is securely bolted the casting 2 for the high-pressure cylinders. To the high-pressure cylinder 2 is securely bolted the low-pressure-cylinder casting 3. The castings 1 and 2 are so constructed and disposed as to form the bearings for the crank-shaft 4. The crank-shaft 4 is provided with a pair of fly-wheels 5 at its opposite ends. The castings 1 and 2 are also so constructed and disposed as to afford clearance for the crank of the crank-shaft and for the main rod 6, by which the crank is connected to the low-pressure piston 7. To the low-pressure piston 7 are secured the high-pressure pistons 8. These pistons 7 and 8 are so related to the high and low pressure cylinder castings as to separate the operative ends of the high and low pressure cylinders in a manner which may be readily understood from an inspection of Figs. 1, 2, and 6. The high-pressure-cylinder casting 2 is recessed to afford a water-jacketing chamber 9, through which the water is circulated in any suitable way for keeping the high-pressure cylinders cool. It has already been noted that the high-pressure-cylinder castings are separated to afford clearance for the main rod 6, and the upper ends of these castings are provided with an upwardly-extending flange 10, entirely surrounding the said main rod 6, which flange 10 coöperates with the lower end of the low-pressure-cylinder casting 3 to afford a recess or chamber adapted to serve as an oil-well 11, through which the high-pressure pistons must move. The low-pressure-cylinder casting 3 is provided with an internal oil duct or well or groove 12, disposed substantially central to the low-pressure piston's travel, and the low-pressure piston 7 is provided with a pair of packing-rings 13, spaced apart from each other a distance substantially equal to the piston's stroke, as best shown in Fig. 2. In virtue of this disposition of the said parts 12 and 13 the low-pressure piston 7 is constantly subject to a body of oil from said duct or well 12, which is held between said packing-rings 13. Oil is supplied to the duct 12 in any suitable way, but as shown the supply thereto is afforded through a small pipe 14, leading to a comparatively large oil cup or cavity 15 in the upper end of the valve-chest casting 16. The said valve-chest casting 16 is shown as formed integral with the low-pressure-cylinder casting 3 and as provided with a water-jacketing chamber

17, through which cooling-water is circulated in any suitable way. The water-jacketing chamber 9 of the high-pressure-cylinder casting 2 and the said chamber 17 of the valve-chest casting 16 are connected by circulating-pipe 18, as shown in Fig. 1 as part of the circulating connections. The said valve-chest casting 16 is constructed to afford a seat 19 for a piston-valve, which is constructed in two separable sections 20. The lower member of the valve-sections 20 is connected to the valve-rod 21, and the upper member of said valve-sections 20 is subject to the action of a spring 22, which reacts between a shoulder on said valve-section and a guide-nut 23, screwed into the top of the valve-chest casting. The two valve-sections 20 are rabbeted at their opposing ends to afford a seat for a spring packing-ring 24, which connects the two. The valve-seat 19 is provided with a single port *a*, leading to the low-pressure cylinder, and with a pair of high-pressure ports *b*, leading to the respective high-pressure cylinders through suitable pipes 25. The said high-pressure ports *b* are located one on each side of the centrally-disposed low-pressure port *a*. The valve is provided with a central exhaust-port *d*, shown as formed by openings in the packing-ring 24, which connects the two valve-sections 20, and is also provided with a pair of high-pressure ports *c*, one on each side of said central exhaust-port *d*. The high-pressure ports *c* of the valve are so constructed as to be constantly in communication with the high-pressure ports *b* of the valve-seat. The coöperative action of these ports in the valve and the seat will be noted after describing the valve-gear. A pair of electrodes 26, suitably insulated, project through suitable thimbles or passages 27 of the valve-chest casting into the high-pressure ports *c* of the valve and are adapted to contact with the valve under the travel of the same at the proper times for igniting the charges in the high-pressure-cylinder clearances. The valve itself receives current from the main castings or in any other suitable way through the proper connections (not shown,) so as to serve as one of the members of the coöperative electrodes necessary to produce the electric spark. The surfaces of the valve which contact with the electrodes 26 are shown at *e* in Fig. 4 and some of the other views. These contact-surfaces *e* on the valve must of course be properly located with respect to the electrodes 26, so as to contact at the proper times.

The valve-rod 21 is shown as passing through a suitable guide-lug 28, formed on the high-pressure-cylinder casting and under the action of the spring 22 is held with its lower end pressing on the face or periphery of a cam 29. This cam 29 is provided with an internal gear 30, which engages with a gear 31. (Shown as mounted directly on the crank-shaft 4.) The said cam 29 is carried by or rides on the said gear 31 and turns therewith. The said cam 29 is provided with the proper cam-surfaces for imparting to the valve a four-step motion. These cam-surfaces are marked y', y^2, z', and z^2. y' and y^2 represent the cam-surfaces which control the admission from the two high-pressure cylinders to the single low-pressure cylinder, and the cam-surfaces z' and z^2 control the two corresponding final exhausts from the low-pressure cylinder. The cam 29 and the gear-wheel 31 are of such relative sizes that the gear-wheel or crank-shaft turns twice while the cam-wheel 29 turns once. The four steps of motion on the valve are of equal length and occur in equal times, each step being in the same time as one stroke of the pistons. The cam-surfaces y', y^2, z', and z^2 on the cam-wheel 29 are therefore constructed to produce these equal steps of movement on the valve. As these cam-surfaces act for equal times, it follows that each corresponds to one stroke of the piston in the cycle of the engine's action. Hence if the cam should be shifted a distance equal to one of said cam-surfaces or if the cam should be held stationary while the pistons make one stroke it is obvious that the timing of the cam actions on the valve would come right to effect the distribution in the proper way for driving the engine in the opposite direction. With the construction shown the latter plan is pursued—to-wit, the cam is held stationary for one stroke of the pistons in order to reverse the engine under motion. To accomplish this result, as shown, the gear-wheel 31 is provided with a pair of keyways *f*, one hundred and eighty degrees apart, at the opposite limits of the segmental groove *f'* in the hub of said gear-wheel, and the driving-shaft is provided with a suitable key 32, mounted in a keyway of said shaft for sliding movement therein and held under tension from a spring 33 to engage with said keyways *f* or the segmental groove *f'*, connecting the two keyways. As shown, the spring 33 reacts between a handle-sleeve 34, to which the key 32 is attached, and a pin 35 on a transmitting-shaft 36, shown as extending into a seat for the same in the main or driving shaft and coupled thereto by a suitable set-screw 37 or other suitable means. With this construction the handpiece 34 slides on the transmitting-shaft 36 and carries the key 32 therewith. Hence by pulling on the handpiece 34 the key 32 may be pulled out from either of the keyways *f* of the gear 31 against the tension of the spring 33, so as to permit the inner end of the key to ride against the hub of the gear 31 within the limits of the segmental groove *f*. It has already been noted that the annular gear 30 on the cam and the gear-wheel 31 are related as one to two, and hence when the key 32 is pulled out from one of the keyways *f*, as before stated, the gear and cam will stand stationary, while the shaft moves through one hundred and eighty degrees, thereby effecting the shift, as hitherto noted. The further

effects in reversing the engine will be stated in connection with the general description of the operation of the engine as an entirety.

It will be understood, of course, that while the valve-driving gear 31 is shown as mounted directly on the crank-shaft and the cam 29 as having an internal gear 30 and mounted to ride on the driving-gear 31 this is simply a convenient arrangement with a view of compactness of structure. It is obvious, of course, that these parts 29 and 31 might be otherwise mounted, so long as they sustain the same relation to the movements of the valve and the pistons.

From the foregoing description it will be seen that the cam 29 has the internal gear 30, which engages the driving gear-wheel 31 and turns therewith, but on a center eccentric to the center of said driving gear-wheel.

Having regard now to the feed devices for the supply of air and gas or oil, it has already been noted that the high-pressure ports *b* of the distribution-valve seat are tapped by a pair of pipes 25, leading to the respective high-pressure cylinders. At their lowest points, as shown, the said pipes 25 are provided with valve-casings 38, which serve to connect the two sections of the respective pipes 25 and are provided with downwardly-projecting nipple-like extensions 39, which open to the atmosphere. Into the nipples 39 are screwed open-ended bushings 40, which serve as the air-supply pipes. The bushings 40 are smaller at their upper ends than the internal diameters of the nipples 39 and are of the proper shape to coöperate with parts of the internal surfaces of the casings 38 to form a valve-seat *h* for a gravity-valve 41, which is seated thereon. The parts 39 and 40 are so related in virtue of their difference of size at their inner ends or by counterboring or otherwise to afford an annular passage *h'*, which taps the valve-seat *h* and is controlled by the gravity-valve 41. The annular passages *h'* between the parts 39 and 40 are tapped by the opposite ends of a gas or oil supply pipe section 42. The pipe-section 42 is provided with an ordinary throttling feed-valve 43, to which gas or oil is supplied through a pipe 44, leading to a reservoir of oil or gas under pressure.

Operation: All the different parts of my improved compound engine have now been specified as the same are shown in the accompanying drawings. The operation of the engine as an entirety will now be briefly summarized. This engine, like other gas-engines, must in the first instance be started by hand. Let it be assumed that the engine has thus been started and that a charge of air and gas has been compressed in the clearance-space for the right-hand member of the two high-pressure cylinders. Then all the parts would be in the positions shown in Figs. 2, 4, and 5. From this point the cycle of the actions will be traced, starting with the explosion. It will be seen by reference to Figs. 2, 4, and 5 that the valve is moving down and that the upper contact-surface *e* on the valve is about to separate from the upper electrode 26 for producing the electric spark and igniting the charge in the right-hand member of the high-pressure cylinders. As quick as the explosion occurs the pistons of course make an upward or a working high-pressure stroke, and the position of the valve during this stroke is shown in Fig. 1, by reference to which it will be seen that the said valve is in position to cause the exhaust-port *d* therein to coöperate with the single port *a* in the seat, leading to the low-pressure cylinder, for permitting the final exhaust from the low-pressure cylinder through the center of the distribution-valve. During this same outward or working stroke of the right-hand member of the two high-pressure cylinders a charge was sucked into the left-hand high-pressure cylinder. As the pistons approach the limit of their outward movement on said stroke the valve again begins to move downward for bringing the upper member of the high-pressure port *c* in the valve into registration with the single low-pressure port *a* of the seat, and thereby establishing the connection between the right-hand high-pressure cylinder and the low-pressure cylinder. This of course admits the partially-used gases from the high-pressure cylinder into the low-pressure cylinder. The downstroke of the pistons is then made under the effect of the gases in the low-pressure cylinder acting on the relatively large low-pressure piston. To make the action of the valve still more distinct, it may be further noted that during the outward or working stroke of the right-hand high-pressure piston the valve-rod 21 was riding on the cam-surface z', while during the downward stroke or working stroke of the low-pressure piston the said valve-rod 21 was riding on the cam-surface y^2. During said low-pressure or downward stroke the charge previously drawn into the left-hand high-pressure cylinder was compressed into the clearance-space for that cylinder and the contact was made between the lower contact-surface *e* on the valve and the lower member of the electrodes 26. These two strokes completed one revolution of the crank-shaft. The low and high pressure cylinders and clearance-spaces are so proportioned that a partial vacuum will be produced in the low-pressure cylinder before the completion of the low-pressure stroke, and the timing of the valve is such that the connection or communication between the high and low pressure cylinders is maintained substantially to the end of the low-pressure stroke. Hence under the effect of the vacuum thus produced in the low-pressure cylinder all the spent materials remaining in the high-pressure clearance will be drawn out therefrom and into the low-pressure cylinder, thus scavenging the high-pressure clearance. The feed-valve 41 is located on the opposite side of the high-pressure clearance with respect to the low-pressure cylinder, and hence un-

der the action of said vacuum in the low-pressure cylinder the spent gases will first be pulled over into the low-pressure cylinder and then the feed-valve 41 will lift and permit a supply of air or of commingled air and gas, which will immediately replace the said spent gases in the high-pressure clearance. So far in the cycle we have considered one revolution of the shaft produced from one high-pressure stroke—to-wit, that from the right-hand high-pressure piston—and one low-pressure stroke under the compounding of the gases, and at the end of these two strokes the charge was compressed, as before stated, in the left-hand high-pressure clearance, with the electrodes in position for ignition. Hence upon explosion an outward or working stroke will be made by the left-hand member of the high-pressure pistons and the valve-rod 21 will ride on the cam-surface z^2. During this working stroke of the left-hand high-pressure piston the charge in the right-hand cylinder is completed by the vacuum produced therein. The supply for thus completing the charge in the right-hand pressure-cylinder is afforded through the same feed-valve 41 which had already admitted sufficient charge to fill the clearance-space of that high-pressure cylinder under the action of the vacuum in the low-pressure cylinder during the preceding low-pressure stroke. As the pistons near the completion of their outward stroke under the explosion in the left-hand high-pressure cylinder the valve moves upward to its limit under the action of the cam-surface y', thereby bringing the lower member of the high-pressure ports c in the valve into registration with the low-pressure port a and establishing communication between the low-pressure cylinder and the left-hand member of the high-pressure cylinders. This of course gives the compound action required for the next low-pressure or downward stroke, thereby compressing the charge in the right-hand high-pressure cylinder and producing the partial vacuum necessary to scavenge the left-hand high-pressure clearance and admit a charge through the valve 41 of air and gas to replace the same. This second low-pressure stroke of course completes the cycle at the end of the second revolution of the crank-shaft.

Having regard to the reversing of the engine when under motion, it is only necessary to pull out the key 32 and permit the shaft to turn through one hundred and eighty degrees while the gear 31 and the cam 29 remain stationary, as hitherto described. During this time the inner end of the key rides on the hub of the wheel 31 within the limits of the groove f', as hitherto noted, and at the end of said one-hundred-and-eighty-degrees movement of the shaft the spring-pressed key will engage with the opposite member of the keyways f, thereby again causing the gear and cam to turn with the shaft. This continued movement of the shaft in the original direction for one hundred and eighty degrees without the gear 31 and cam 29 and then the continued movement of all three of said parts in the original direction takes place under the effect of the momentum of the moving parts until the stop and reverse. As quick as the gear 31 was relocked to the driving-shaft after the shaft had turned one hundred and eighty degrees while the gear and cam stood still, the said cam was in position to make the valve motions come right for effecting the distribution in such a way as to drive the engine in the opposite direction. Otherwise stated, the cam 29 stood still while the pistons made one stroke, and when the gear 31 again becomes locked to the shaft, so as to carry the cam forward therewith under the momentum of the moving parts, the valve motions will come right to convert the low-pressure cylinder into a pump and establish communication alternately therefrom to the high-pressure cylinders. Hence under the continued motion of the engine in the original direction under the momentum of the fly-wheels and other moving parts air will be stored under pressure in the high-pressure cylinders alternately by the pump action of the low-pressure cylinder, and this storage and compression will continue until the pressure is sufficient to stop the engine, and thereupon the air thus stored in the high-pressure cylinders under pressure will become instantly available to reverse and start the engine in the opposite direction. It has already been noted that the valve motions were reversed by the shift on the gear. Hence whatever energy was stored in the high-pressure cylinders while the low-pressure cylinder was acting as a pump under the momentum of the moving parts will become available for starting the engine in the other direction. The engine having thus been started by said storage and the valve motions being right for this reverse direction, the supply of air and gas will be drawn from the regular sources as soon as the storage has been exhausted. In this improved engine, therefore, the reverse under motion is entirely automatic. It is also obvious that with the engine herein disclosed pressure is operative on the crank at every stroke. An explosion takes place at every other stroke; but between the two explosions or high-pressure strokes occurs a low-pressure stroke, thus rendering pressure available at every stroke in the cycle of actions. By thus providing an organization wherein the two high-pressure cylinders cooperate alternately with the single low-pressure cylinder it will be seen that high efficiency, with compactness of structure, is secured. It will be understood, however, that the coaction of each high-pressure cylinder with said low-pressure cylinder is independent of the other high-pressure cylinder. Otherwise stated, some of the features of the invention would apply equally well to a compound engine wherein only one high-pres-

sure cylinder is used. The disposition of the high-pressure-cylinder castings in respect to the low-pressure cylinder and the separation of their operative ends by the three pistons is incident to the construction shown and is advantageous for compactness of structure, oiling, &c.; but it will be understood that the said three cylinders and the other coöperative parts might be otherwise disposed so far as the essentials of the action are concerned as long as all three coöperate on a common crank-shaft. It will be further understood that many of the minor features of the construction might be changed without departing from the spirit of my invention.

What I claim, and desire to secure by Letters Patent of the United States, is as follows:

1. A compound engine comprising a single low-pressure cylinder, a pair of high-pressure cylinders, with all of said cylinders coupled to a common shaft, a distribution valve or valves, and a single valve-gear, with said valve mechanism so arranged as to cause the two high-pressure cylinders to coöperate alternately with the single low-pressure cylinder, substantially as described.

2. In a compound engine wherein a pair of high-pressure cylinders coöperate with a single low-pressure cylinder, the combination with a valve-seat having a single low-pressure port serving to admit from both of said high-pressure cylinders and to effect the final exhaust therefrom, of a valve on said seat having ports coöperating with said low-pressure port and a pair of high-pressure ports in the seat, to effect the complete distribution, substantially as described.

3. In a compound engine, the combination with a single low-pressure cylinder, of a pair of high-pressure cylinders opening into said low-pressure cylinder, pistons separating the operative ends of said three cylinders from each other, and coöperating on a common main rod, and valve mechanism for causing the two high-pressure cylinders to coöperate alternately with the single low-pressure cylinder, substantially as described.

4. In an air and gas engine, the combination with a cylinder having an internal oil well or duct opening to the piston, substantially central of the piston's travel, of a piston having a pair of packing-rings spaced apart a distance substantially equal to the piston's stroke, whereby the piston is constantly subject to a body of oil held between said rings and supplied from said duct, substantially as described.

5. In an upright compound engine, the combination with a single low-pressure cylinder, of a pair of high-pressure cylinders opening into said low-pressure cylinder, pistons separating the operative ends of said three cylinders from each other and coöperating on a common main rod, valve mechanism for causing the two high-pressure cylinders to coöperate alternately with the single low-pressure cylinder, with the two high-pressure-cylinder castings spaced apart, to afford clearance for the main rod, and provided with upwardly-extended flanges surrounding said rod and coöperating with the low-pressure-cylinder casting to form an oil-well surrounding the high-pressure pistons, substantially as described.

6. The combination with the single low-pressure cylinder and the pair of high-pressure cylinders, of the valve-seat having the single low-pressure port and the pair of high-pressure ports, the valve on said seat having a final exhaust-port, and provided with a pair of high-pressure ports always in communication with the high-pressure-cylinder clearances, and a pair of igniter-electrodes projecting one into each of said high-pressure ports of the valve, and contacting with the valve as a coöperative electrode, for insuring the explosions, in the respective high-pressure cylinders, at the proper times, under the travel of the valve, substantially as described.

7. In an explosive compound engine, the combination with a valve-seat having a single low-pressure port and a high-pressure port of a valve having an exhaust-port and provided with a high-pressure port always in communication with the high-pressure-cylinder clearance, an igniter-electrode projecting into said high-pressure port of the valve and adapted to contact with a surface thereon for igniting the charge, and a valve-gear constructed and arranged to impart to the said valve a four-step motion, to wit, one for compression and contact, a second for explosion in the high-pressure cylinder, a third for compression in the high and admission to the low pressure cylinder, and a fourth for final exhaust from the low and the recharging of the high pressure cylinder, substantially as described.

8. In a compound engine, the combination with a single low-pressure cylinder and a pair of high-pressure cylinders, of a valve-seat having a single low-pressure port and a pair of high-pressure ports, a valve having a central exhaust-port and a pair of high-pressure ports communicating always with said high-pressure ports in the seat, and a valve-gear constructed and arranged to impart a four-step motion to said valve, whereby the two high-pressure cylinders are made to coöperate alternately with said single low-pressure cylinder, substantially as described.

9. In an explosive compound engine, the combination with a single low-pressure cylinder and a pair of high-pressure cylinders, of a valve-seat having a single low-pressure port and a pair of high-pressure ports, a valve having a central exhaust-port and a pair of high-pressure ports always in communication with the coöperating high-pressure ports of the seat, a pair of igniter-electrodes projecting into said high-pressure ports of the valve and adapted to contact therewith under the valve travel, and a valve-gear constructed and arranged to impart a four-step motion to

said valve, for effecting the explosions and the complete distributions, in their proper order, substantially as described.

10. In an explosive compound engine, the combination with a high and a low pressure cylinder coupled to a common crank-shaft, of a reversing-valve mechanism constructed and arranged to cause the low-pressure cylinder to act as a pump, when the gear is reversed, while in motion, whereby, under the momentum of the moving parts, air, under pressure, will be stored in the high-pressure cylinder, for reversing and starting the engine in the opposite direction, substantially as described.

11. In an explosive compound engine, the combination with a single low-pressure cylinder and a pair of high-pressure cylinders, all coöperating on a common crank-shaft, of a distribution-valve and valve-seat constructed and arranged to cause the two high-pressure cylinders to coöperate alternately with said single low-pressure cylinder, and a reversing valve-gear operative on said valve, with said valve and gear so constructed and arranged that when reversed, under motion, the low-pressure cylinder will act as a pump, under the momentum of the moving parts, whereby air, under pressure, will be stored alternately in the two high-pressure cylinders and become operative to reverse and start the engine in the opposite direction, substantially as described.

12. The combination with the single low-pressure cylinder and the pair of high-pressure cylinders, of the valve-seat having a single low-pressure port centrally located, and the pair of high-pressure ports, one on each side thereof, the distribution-valve on said seat, having a central exhaust-port and the pair of high-pressure ports, on opposite sides thereof, always in communication with the coöperating high-pressure ports of said seat, and the reversing valve-gear comprising a gear-wheel receiving motion from the crank-shaft, a cam driven thereby and shaped to impart a four-step motion to said valve, and means for rotatively shifting the gear-wheel in respect to the crank-shaft, or vice versa, for changing the timing of the cam action and reversing the engine, substantially as described.

In testimony whereof I affix my signature in presence of two witnesses.

ELLIS J. WOOLF.

Witnesses:
JAS. F. WILLIAMSON,
F. D. MERCHANT.