

No. 651,742.

Patented June 12, 1900.

J. C. ANDERSON.

METHOD OF MOVING PISTONS OF EXPLOSIVE ENGINES.

(Application filed Apr. 5, 1900.)

(No Model.)

8 Sheets—Sheet 1.

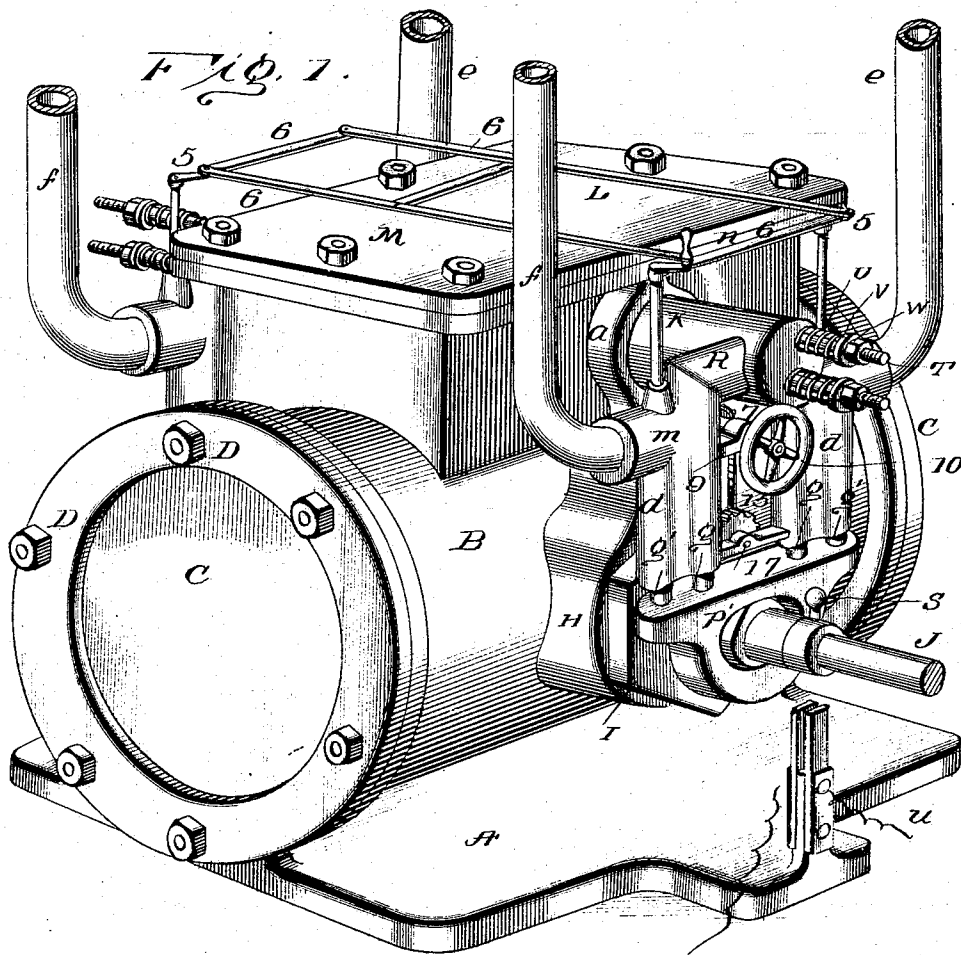
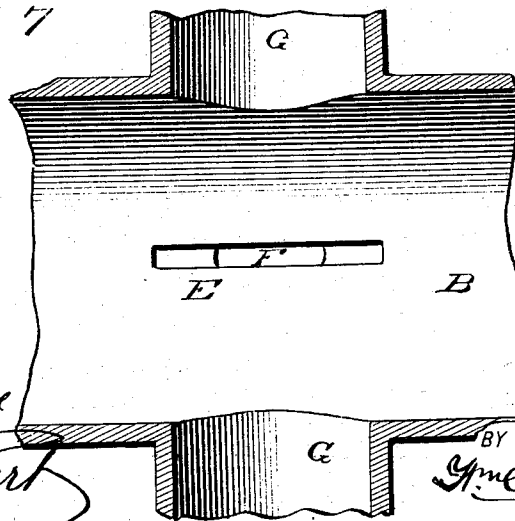


Fig. 7.



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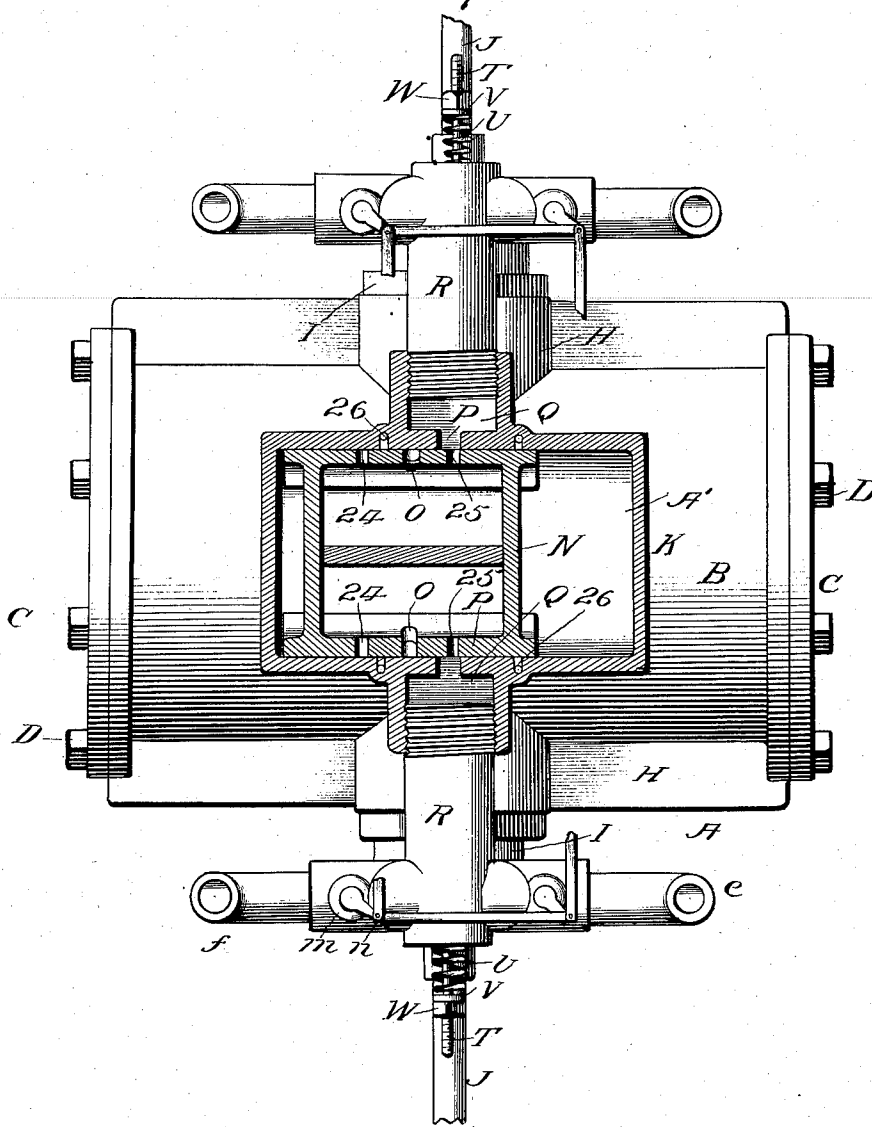
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8 Sheets—Sheet 2.

FIG. 2.



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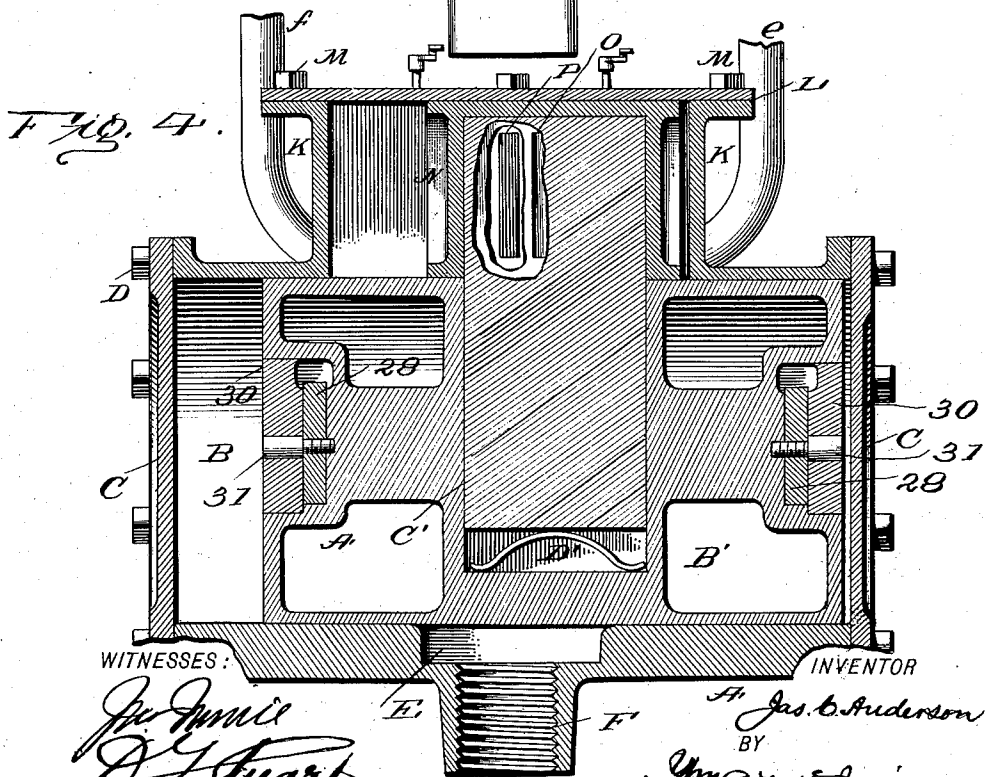
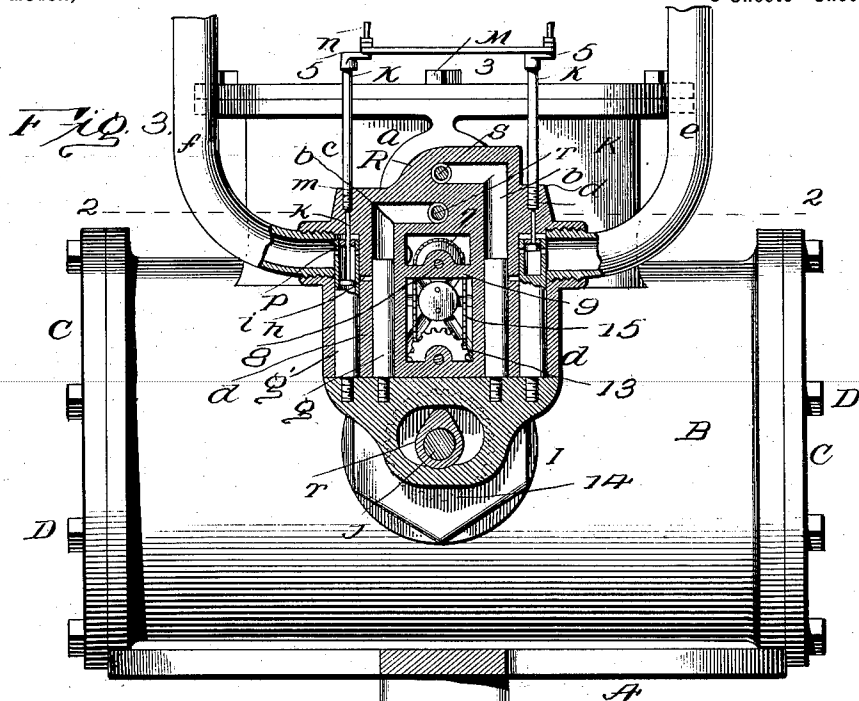
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8 Sheets—Sheet 3.



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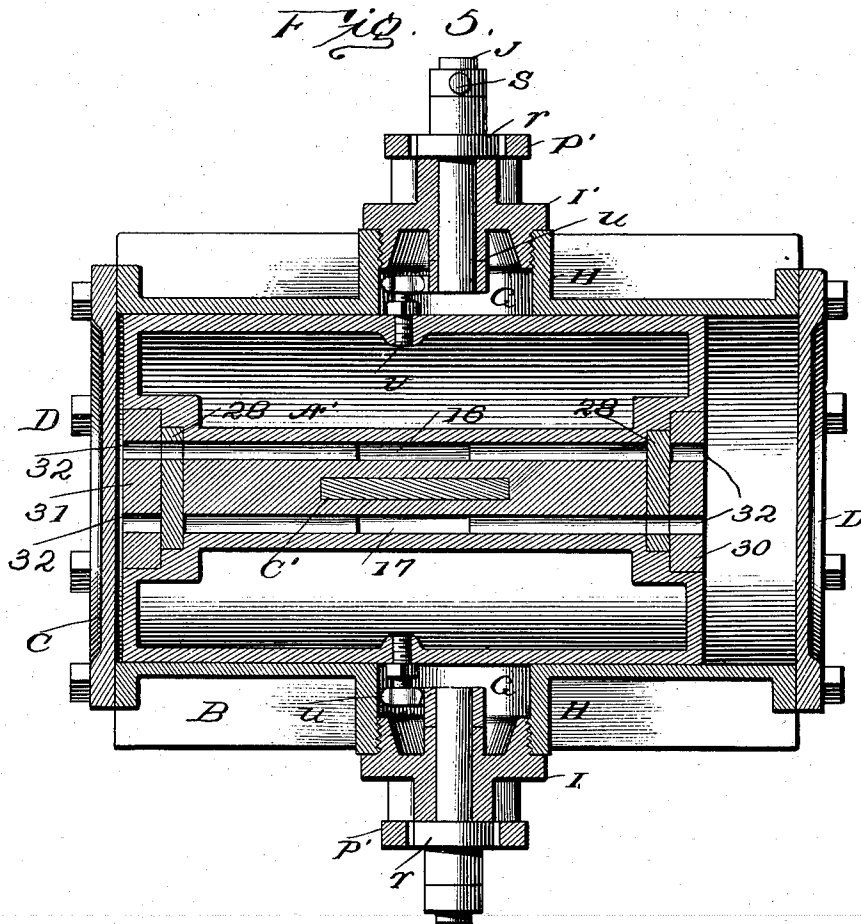
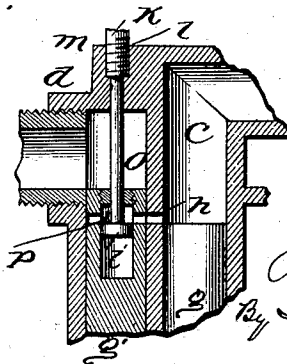


Fig. 8.



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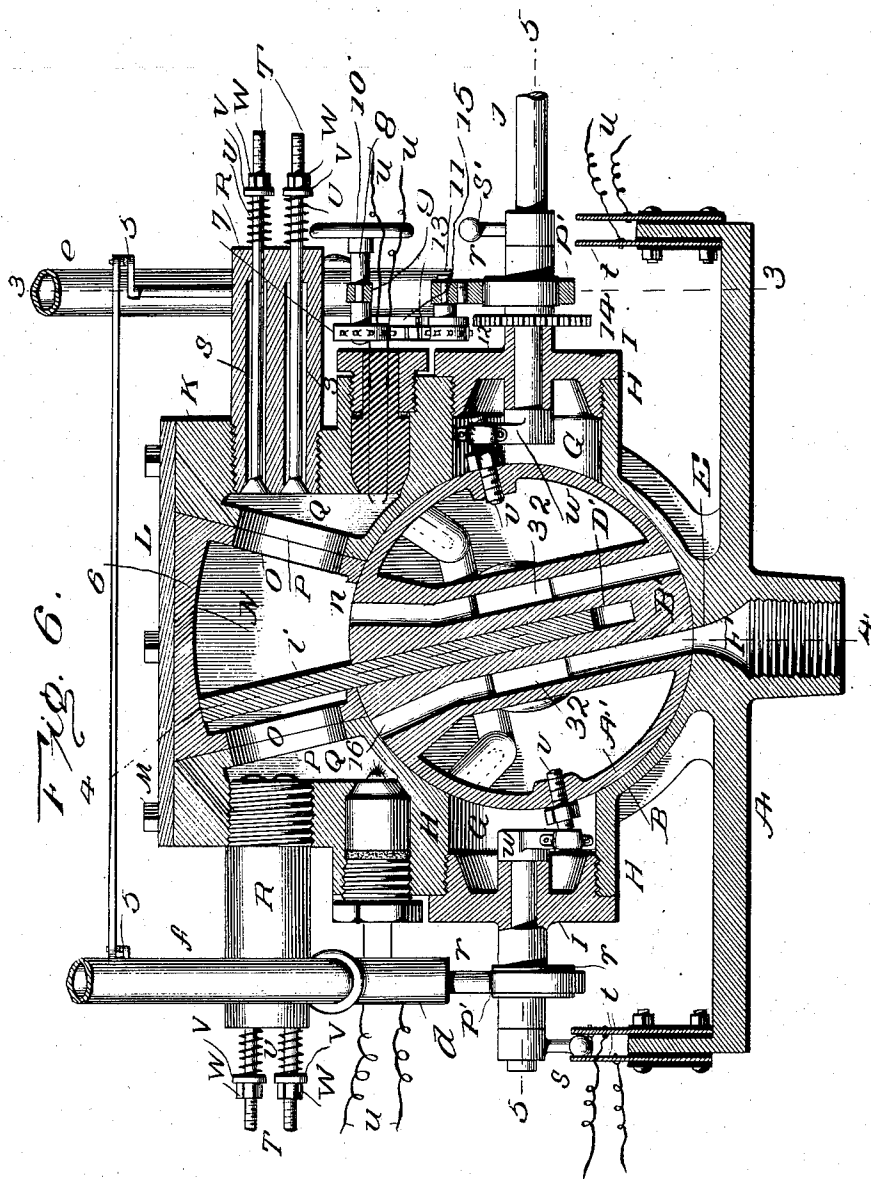
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8 Sheets—Sheet 5.



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FIG. 9.

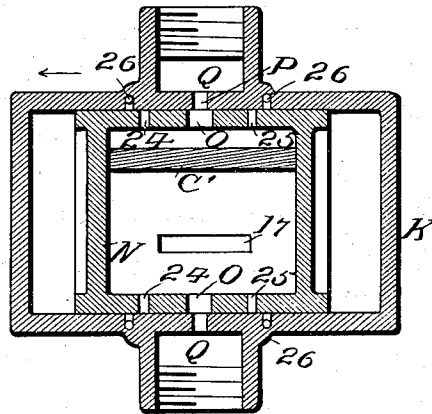


FIG. 10.

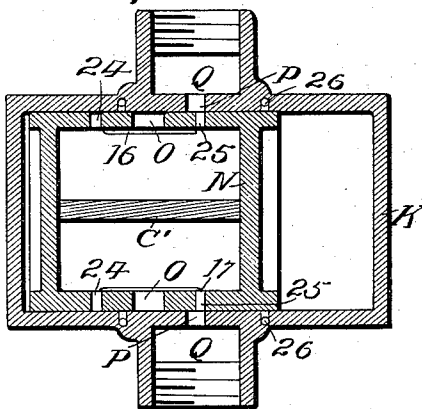


FIG. 11.

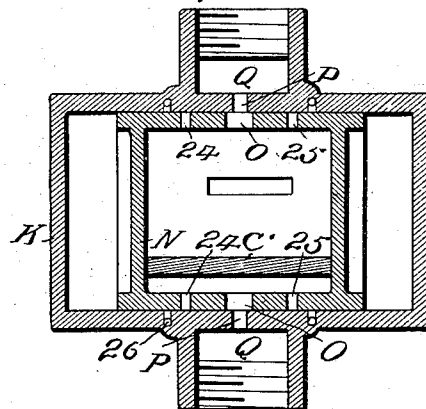
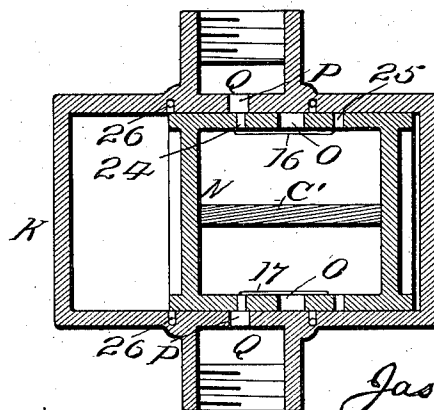


FIG. 12.



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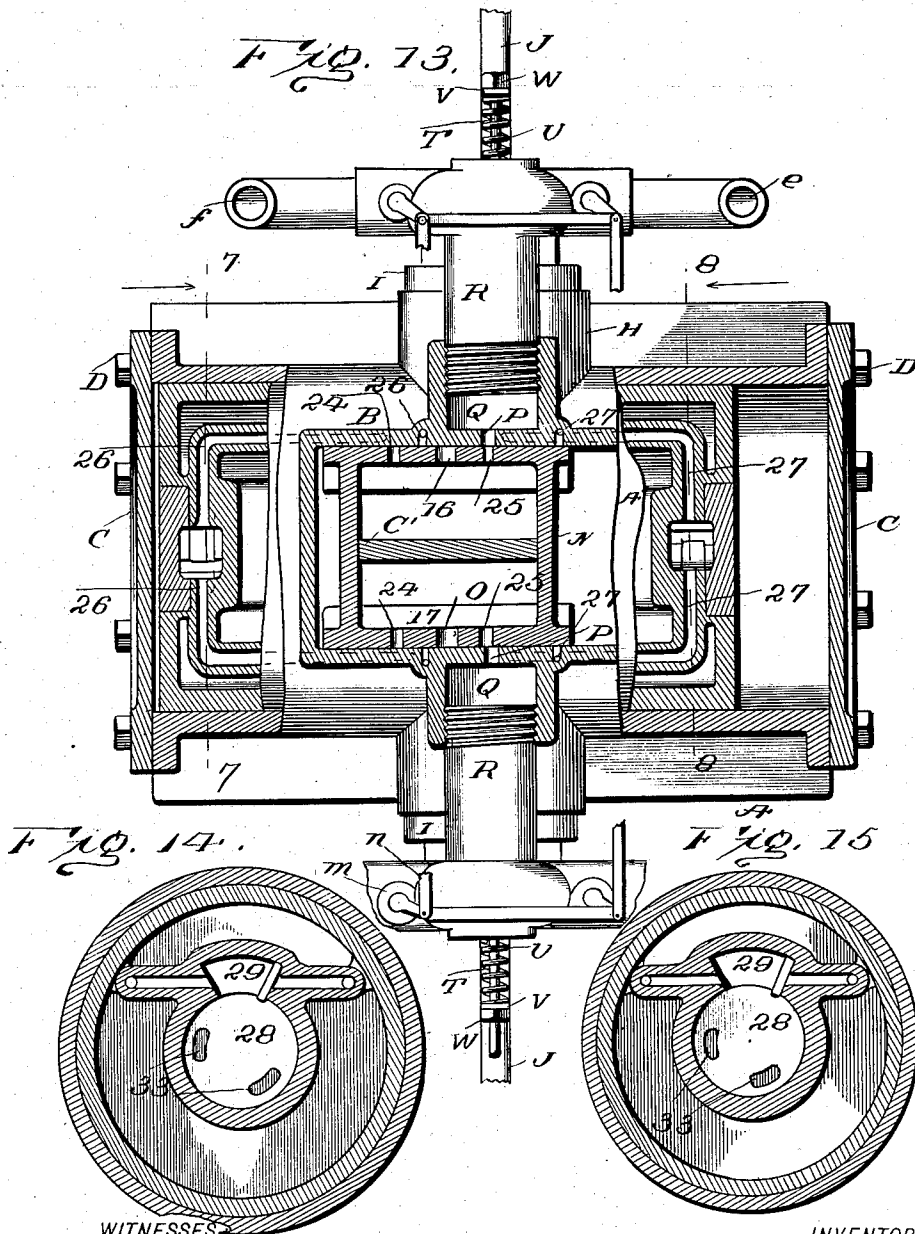
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8 Sheets—Sheet 7.



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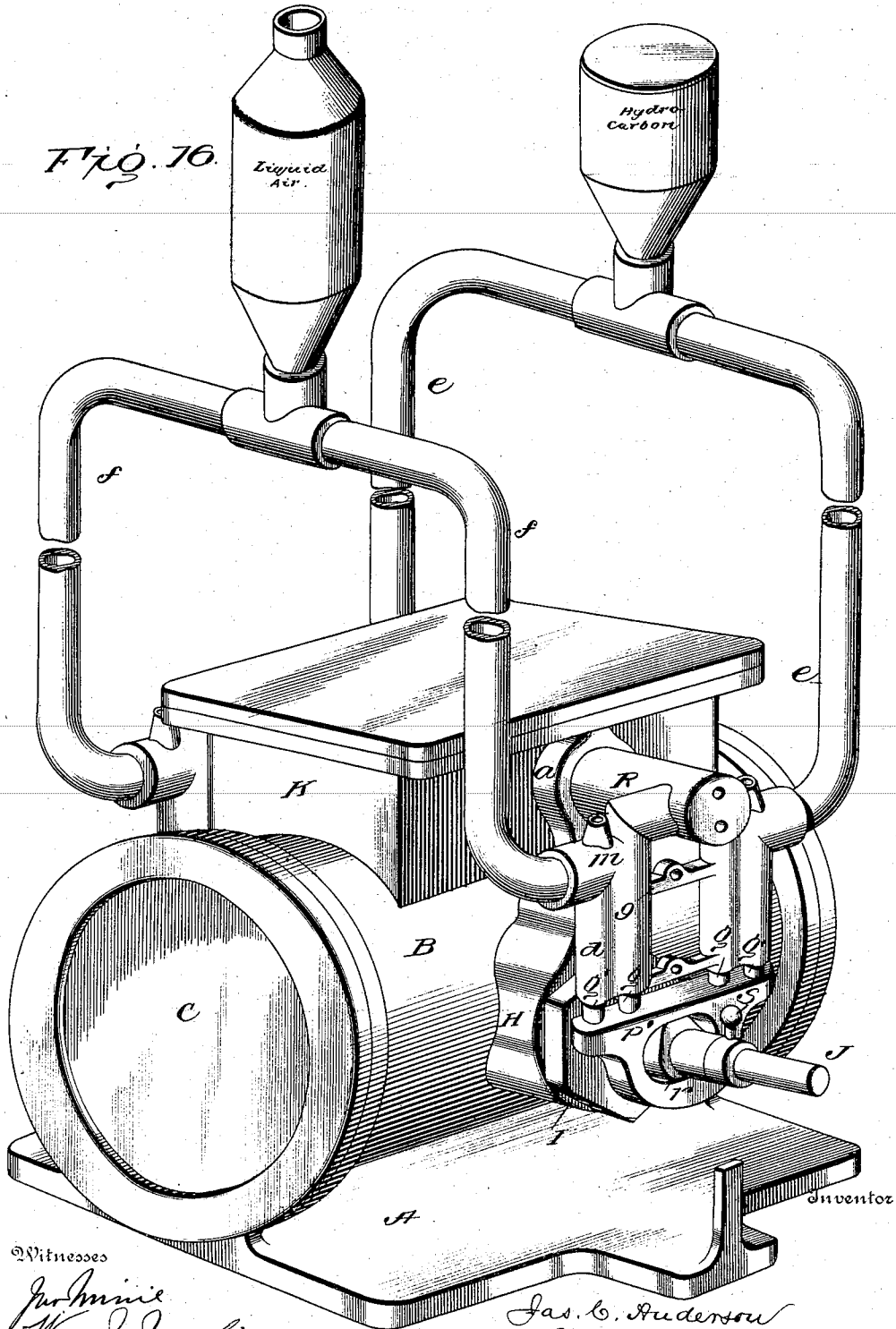
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8 Sheets—Sheet 8.



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METHOD OF MOVING PISTONS OF EXPLOSIVE-ENGINES.

SPECIFICATION forming part of Letters Patent No. 651,742, dated June 12, 1900.

Original application filed December 9, 1899, Serial No. 739,830. Divided and this application filed April 5, 1900. Serial No. 11,669. (No model.)

To all whom it may concern:

Be it known that I, JAMES C. ANDERSON, a citizen of the United States, residing at Highland Park, in the county of Lake and State of Illinois, have invented certain new and useful Improvements in Methods of Moving Pistons of Explosive-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 a new and useful method of moving the pistons of explosive-engines, and especially in giving to the pistons reciprocating and rotative action, as fully described in a pending application for Letters Patent filed by me on the 9th day of December, 1899, Serial No. 739,830, and of which this is a divisional application under requirement by the Patent Office in said application.

My present invention deals with the use of liquid air as one of the agents to produce explosive force for driving the piston, and in order that its advantages may be fully understood I will first call attention to some of the known properties of liquid air.

It is well known that liquid air is the result of excessive compression of atmospheric air and is composed principally of nitrogen and oxygen in about the proportion of four to one, respectively, and that when placed in an open vessel it will by absorption of heat from the surrounding atmosphere throw off a much larger proportion of nitrogen than oxygen, thus leaving the latter in a more concentrated condition, and hence more available as an explosive agent when mixed in suitable proportions with hydrocarbon. It is one of the purposes of my invention to take advantage of this fact, and I therefore contemplate purposely eliminating to a large extent the nitrogen constituent of liquid air, and to thus not only deprive it of a constituent which tends to retard or quench combustion, but at the same time to put the oxygen in such condition that it will sustain rapid combustion when mixed in suitable proportions with hydrocarbon, and hence when such combustion takes place in a closed chamber opening to the piston of an engine the force and efficiency of the engine will be proportionately

increased. In utilizing liquid air thus denitrogenized and mixed with hydrocarbon as an explosive agent for driving the piston I am enabled to use the heat generated by the explosion to successively expand the succeeding charges of denitrogenized liquid air and hydrocarbon, and thus utilize such expansion as an initial force to partially move the piston, while at the same time the heated chamber is cooled during the time of such expansion of the contained gases and restored to its normal temperature.

In applying my invention I prefer to use an engine such as illustrated and described in my pending application herein referred to, and accordingly I will in this application illustrate and describe such an engine and the manner in which it is operated; but before doing so I wish to explain more in detail the manner in which I modify the physical conditions of the liquid air.

Instead of using the liquid air from a closed or sealed vessel I place it in an open vessel surrounded, except at the orifice at the upper end, with a vacuum, so that the only point at which heat of the surrounding atmosphere can combine with or be absorbed by the liquid air to any great extent is through said opening or orifice at the upper end of the receiver or reservoir, at which point the nitrogen is permitted to freely escape, and as the escaping nitrogen at its low temperature comes in contact with the atmospheric air the latter is cooled or refrigerated to such an extent as to retard, if not altogether prevent, its entrance within the receiver or reservoir, and owing to the relative specific gravities of the components of liquid air the oxygen will tend to segregate below the nitrogen and may be drawn off in desired quantities from such locality and mingled in suitable proportions with the liquid hydrocarbon in the explosive-chamber of the engine and there duly expanded, ignited, and exploded, as will be presently explained.

It will be understood that when considered as a source of power liquid air of necessity represents the equivalent amount of force required for its production. In other words, a given amount of liquid air contains an amount of energy equal only to the force exerted in

the production of the liquid air; but said air represents concentrated energy, and hence an amount of force adequate for a given purpose can be carried in much more compact form and in less bulk than it would be possible to carry the apparatus required to produce the liquid air, and consequently my improved method may be utilized with very great advantage for driving engines employed to move vehicles of all kinds, such as the ordinary automobile, in which the motive power should be of limited weight in proportion to the capacity. For instance, if liquid air or ordinary compressed air be employed expansively as a motive force, it becomes necessary in the case of liquid air to use very strong and heavy cylinders to contain the same, and in the case of the ordinary compressed air it is necessary that the containing cylinders or reservoirs should not only be very heavy and strong, but that they should be of large capacity or size, so that it will be seen, as hereinbefore explained, in the employment of my improved method I am enabled to carry a large amount of motive force within a comparatively-limited space, and that by reason of the open condition of the liquid-air cylinder or containing vessel said vessel need not be made strong and heavy, as would be the case if the liquid air were sealed or confined.

I will now proceed to describe the details of engine best fitted for the use of my improved method, referring by letters and figures to the accompanying drawings, in which—

Figure 1 is a perspective view of an engine embodying my invention. Fig. 2 is a horizontal section on the line 2 2 of Fig. 3. Fig. 3 is a vertical section on the line 3 3 of Fig. 6. Fig. 4 is a section on the line 4 4 of Fig. 6, showing the piston to the extreme right. Fig. 5 is a horizontal section on the line 5 5 of Fig. 6, showing the piston in the position as shown in Figs. 2 and 10. Fig. 6 is a section on the line 6 6 of Fig. 2, the piston being in the position shown in Fig. 9. Fig. 7 is a horizontal section of the cylinder broken away at each end. Fig. 8 is a detail sectional view showing the means for regulating and controlling the supply of liquid air and hydrocarbon. Figs. 9, 10, 11, and 12 are horizontal sectional views showing, respectively, the position of the radial wing and box-valve at the time of explosive impact, extreme left throw, second or reverse impact, and extreme right throw. Fig. 13 is a top or plan and partial section on two horizontal planes, the first section being through the box-valve and its seat and the second lower down and centrally through the cylinder and piston, the latter being shown partially in plan and with the supply-pipes omitted at one side. Fig. 14 is a vertical section on the line 7 7 of Fig. 13. Fig. 15 is a similar section on the line 8 8 of Fig. 13; and Fig. 16 is a diagrammatic view in perspective, showing the liquid-air and hydrocarbon tanks and the conduit-pipes

leading therefrom to the explosion-chambers of the engine.

Similar letters and numerals of reference denote like parts in the several figures of the drawings.

A is the bed of the engine, and it is adapted to be bolted or secured in place in any suitable manner.

B is the cylinder, formed with or secured to the bed A, and C C are the cylinder-heads, secured in place upon the flanges of the ends of the cylinder by bolts D. The cylinder B is formed with an exhaust-port E at the bottom, communicating with an outlet F through the bed A.

G G are lateral openings or wells surrounded by circular walls H H, and I I are screw-caps for closing the wells G and constituting bearings for diametric shafts J J.

K is an upwardly-projecting box inclosed by a cover L, secured to the box by bolts M. The interior side walls of the box K are inclined or converge, as shown at Fig. 6, and constitute a seat for the inclined sides of a wing valve-box N, the sides of which are each formed with a port or passage O, adapted to register with ports P in the side walls of the box K, which ports P lead to or communicate with explosion-chambers Q in the said box.

R R are two valve-carriers or seats, which are screwed into the box K on opposite sides and communicate with the two explosion-chambers Q. These valve-seats are each provided with two longitudinal channels S to constitute conduits for liquid air and hydrocarbon, respectively, as will be presently described, and stem-valves T, with beveled valve-heads, are located in the channels S and held in operative position by spiral springs U, washers V, and screw-nuts W, as clearly shown at Fig. 6.

Lateral projections a (shown in vertical section at Fig. 3) extend on each side from the box K and are formed with right-angled or curved liquid-air conduits or chambers b and hydrocarbon chambers or conduits c, which communicate when the valves T are open with the longitudinal channels S in the valve-carriers R in an obvious manner.

d d are branch tubes, which are screwed into the opposite sides of the valve-carrier R. A liquid-air-supply pipe e extends from a suitable liquid-air reservoir or receptacle and connects with one of the branch pipes d, and another supply-pipe f extends from a hydrocarbon reservoir or receptacle and connects with the other branch pipe d. These branch pipes d are formed with two vertical piston-channels adapted to receive reciprocating pistons or valves g g'. The partition or wall between the piston-channels is provided with a communicating passage h, (clearly shown at Figs. 3 and 8,) and the outer pistons g are formed with a passage or channel through the upper end, adapted when in proper position to register with the channel h, so that the charge of liquid air and hydrocarbon received, respectively, within the upper end of the pis-

tons *g* may be forced through the channels *h* into the chambers *b* and *c*. This action is produced through the following instrumentalities:

- 5 The upper ends of the pistons *g* are bored out to receive a solid platen or disk *i*, having a stem *k* rigidly connected therewith and passing through a suitable stuffing-box in the upper side of the branch pipe and threaded
- 10 at *l* in order that it may be adjusted within the thread in the seat *m*. The extreme outer end of the stem *k* is provided with an operating-handle or hand-wheel *n*. The upper bored-out end of the piston *g* is closed by a
- 15 screw-plug *o*, through which the stem *k* passes, and by means of the handle *n* the platen or disk *i* is so adjusted with reference to the under side of the plug *o* as to leave the space or channel *p*, before referred to, of any suitable
- 20 proportion in cross-section, which will, when the pistons are in their elevated position, register with and receive a charge of liquid air and a charge of hydrocarbon, respectively, from the conduit-pipes *e* and *f*. As the pis-
- 25 tons descend the solid or plugged heads will first cut off the flow of air and hydrocarbon, and then, approaching the immovable platen or disk *i*, the air and hydrocarbon will be squeezed between the plugs *o* and the platens
- 30 *i* and forced through the channel *h* into the chambers *b* and *c* over the heads of the pistons *g g'*. By this construction I am enabled to control the quantity or supply of liquid
- 35 air and hydrocarbon injected into the explosion-chamber, because by the rotation of the stem *k* through the threaded seat *m* the space between the plug or head *o* and the upper face of the disk *i* may be decreased or increased or entirely closed. Consequently when trav-
- 40 eling slowly and when comparatively-small power is required the supply of liquid air and hydrocarbon may be reduced by contracting the space between the disk *i* and plug *o*, and in traveling downgrade, where power may be
- 45 entirely dispensed with, the space between the plug and disk may be entirely closed and the supply of air and hydrocarbon entirely cut off. In order that this action may take
- 50 place simultaneously in all of the supply-pipes, I provide each of the stems *k* with a fixed lever or arm 5 and connect the several levers or arms by link-rods 6, so that by oper-
- 55 ating the hand wheel or lever before referred to and which may be secured to any one of the stems *k* all of the stems may be rotated simultaneously, and consequently the supply from the liquid-air and hydrocarbon tanks or reservoirs may be obviously controlled or entirely cut off.
- 60 The lower ends of the pistons *g g'* are secured, as shown, in the upper face of a cross-head *p'*, having an elliptical opening *q*, adapted to receive an eccentric *r* on each of the
- 65 shafts *J*, and, as will be obvious, when the cross-head *p'* is raised by the eccentric *r* the pistons *g g'* will be raised, and when the cross-head is drawn down by the eccentric the pis-

tons will be lowered into the position shown at Fig. 3, in which position, as will be seen, communication between the chambers *b* and *c* and the liquid-air and hydrocarbon pipes *e* and *f* is absolutely cut off.

After the chambers *b* and *c* have been loaded to a sufficient extent by the described movement of the pistons *g'* the action of the pistons *g g'* in their upward movement against the air and hydrocarbon will cause the valves *T* to open against the action of the coil-spring *U* and permit a charge of air and a charge of hydrocarbon to enter the explosion-chamber *Q*, and as the pistons descend the coil-springs *U* will cause the valves to close the communication between the channels *S* and the explosion-chamber. At the same time that the pistons descend through the action of the shaft *J* and eccentric and have established a perfect cut-off a radial arm *s*, secured to the shaft *J*, passes between and contacts with insulated plates *t t'*, which are connected by suitable wires *u* with an electrode secured within the box *K* and projecting into the explosion-chamber, and consequently a spark will be made and the air and hydrocarbon exploded. It will be seen that the radial arms *s*, which complete the circuits and cause the sparks, are diametrically arranged on the two shafts *J*, and consequently explosions will be made alternately in the chambers *Q* on opposite sides of the box *K*.

The diametric shafts *J* are caused to rotate through the medium of diametric peripheral arms *v*, secured to the reciprocating and rotative piston *A'* and cranks *w* with an intermediate universal joint, such as described in the pending application hereinbefore referred to. Either or both of said shafts may be utilized as driving shafts. The piston *A'* is formed with a central diametric web *B'*, having a pocket therein to receive one end of a radial wing *C'*, which is housed within the box-valve *N*, as clearly shown at Figs. 2, 4, and 6, and a spring *D'*, located between the bottom edge of the wing and bottom of its pocket, holds the upper edge of the wing in close gas-tight contact with the inner side of the top of the box-valve.

The motions of the piston, wing, and box-valve are all such as fully described in the application herein referred to, viz: The piston reciprocates longitudinally and oscillates upon an imaginary longitudinal axis, accordingly as the motive agent exerts its force upon the heads of the piston or on each side of the radial wing *C'*, and the relation of the ports and the reciprocating and rotative action of the piston are such that the pistons may be started from any point of rest and no dead-centers have to be overcome, all as fully described in the application referred to.

To start the engine, I provide a sprocket-wheel 7, journaled on a short shaft 8, extending from a bridge or bracket 9, and the sprocket-wheel is provided with a suitable handle 10 for rotating it. On another shaft

11, journaled in a lower bridge or bracket, are located a sprocket-wheel 12 and a mutilated gear 13 in fixed relation to each other, and upon the collar of the eccentric r is secured a gear-wheel 14, adapted to mesh with the teeth upon the mutilated gear 13. A sprocket-chain 15 traverses the upper and lower sprocket-wheels 7 and 12.

From the construction it will be seen that when the upper sprocket-wheel 7 is rotated it will, through the medium of the chain 15, cause the lower sprocket-wheel 12 to rotate, and with it the mutilated gear 13, and when the teeth of the latter mesh with the gear-wheel 14 said gear-wheel will rotate and carry with it the shaft J and eccentric r , and such movement of the shaft and eccentric, as hereinbefore explained, will cause the liquid air and hydrocarbon to be supplied to the explosion-chambers and ignited by a spark from the electrodes. The rotation of the shaft J will cause the piston to move, and with it the wing C' and box-valve, into such position that the several ports will be in proper relation, and the engine will thus be set in motion. The purpose of forming the gear 13 with a mutilation is in order that when the engine has been started the gears 13 and 14 will run out of mesh, and consequently the starting mechanism will come to a state of rest.

I will now proceed to describe the particular arrangement of ports through the medium of which the rotative and reciprocating motions are imparted to the pistons, and its four-way motion is converted into the rotary motion of the driving shaft or shafts J.

Assuming that the engine is at a state of rest and that the piston and box-valve are in the position shown in Figs. 6 and 9 and that it is desirable to start the engine forwardly or in the direction indicated by the arrows in Figs. 1 and 9, the engineer grasps the lever 10 and turns it to the right or in the reverse direction to the desired movement of the piston, the sprocket-wheel 7 will, through the medium of the chain 15, cause the sprocket-wheel 12 and the mutilated gear to mesh with the sprocket-wheel 14 on the driving-shaft J and will cause the latter to rotate to the left or in the reverse direction, and by reason of the connection between the crank w on the shaft J and the radial arm v on the piston A' the latter will be moved in the direction of the arrows referred to, and at the same time, as hereinbefore explained, the movement of the cross-heads p' through the action of the eccentrics r will cause the reciprocation of the pistons $g g'$ on both sides of the engine, and consequently the liquid air and hydrocarbon will be forced into the explosion-chambers Q and the electrodes will alternately spark at each half-revolution of the shafts J, and obviously the charges of liquid air and hydrocarbon will be exploded. Should the first charge of air and hydrocarbon forced into either of the explosion-cham-

bers Q fail to explode by reason of the temperature of the chambers or from any other cause, the continued movements of the shaft J will cause additional charges of air and hydrocarbon to be introduced and sparks to be made until the conditions are such as to secure the desired explosion, and as soon as an explosion takes place on either side of the valve-box N the port P from the explosion-chamber Q and the port O on the side of the valve-box will register and the wing C' will bear the relation to said ports as shown in Figs. 6 and 9. The explosive force will thus be exerted against the side of the wing C' and cause it to be vibrated toward the center of the valve-box, and when it has reached the center line, carrying with it the piston A', as shown at Fig. 10, the piston will have reached the limit of its reciprocating stroke, as shown at Fig. 5, this initial reciprocating movement of the piston being effected through the medium of the crank w on a shaft and its connection with the shaft v , extending radially from the periphery of the piston (which latter has been partially rotated on an imaginary longitudinal axis and reciprocated to the end of its stroke) will have as a resolution of the stated movements of the piston traveled in a path represented by one-fourth of a true circle. Just as the wing C' reaches the center line, as shown at Fig. 10, and the piston has completed its reciprocating stroke the degree of rotative movement of the said piston has brought the port 16 of the piston into initial register with the space in the valve-box between the wing C' and the side of the box from which the said wing has traveled, as shown at Fig. 10, (it being understood that the valve-box is open at the bottom, as described in the pending application hereinbefore referred to.) The force of the explosion and the expansion of the gases generated continue to vibrate the wing C' into the position shown at Fig. 11, and as the piston A' is correspondingly rotated the port 16 is progressively brought into full register with the space in the valve-box, and from the time of the initial register of the port 16 with the valve-box until full and complete register is made and during its continuance the expansive force of the gases traverses through the said port and thence through the longitudinal passage communicating with port 16 to the space between the head of the piston and the head C of the cylinder and causes the piston to travel coincidently with and in the same direction as the valve-box, as shown at Fig. 11. During the rotation and reciprocation of the piston which takes place while the wing C' moves from the position shown at Fig. 10 to that shown at Fig. 11 it has traveled a path similar to that made in traveling from the position shown at Fig. 9 to that shown at Fig. 10, and consequently has completed a movement of half a true circle. When the wing C' has reached the position shown at Fig. 11 (which is exactly reverse to that shown at Fig.

9) and the piston A' has moved accordingly, as described, the port O on the opposite side of the valve-box is in register with the port P of the explosion-chamber Q on the opposite side of the box K, and this chamber having been supplied with charges of denitrogenized liquid air and hydrocarbon said charge is exploded by the spark from the electrode in said chamber, and the explosive force is exerted against the wing to force it in a reverse direction and to the center, as shown at Fig. 12, in which position the wing C' has traveled a path equal to three-quarters of a circle, the piston at such time having completed a full half-stroke and brought the port 17 of the piston into initial register with the space between the wing and the side of the valve-box N and in the same relation thereto as the port 16 occupied to the valve-box when the ports were in the position shown at Fig. 10. As the port 17 of the piston communicates with a longitudinal passage leading to the head of the piston opposite that to which the passage from the port 16 leads, it will be seen that the piston will be forced in the reverse direction, while the wing C' continues its vibrating movement until it reaches or returns to the initial position illustrated at Fig. 9 and completes a path of movement represented by a full circle.

By observing the ports 16 and 17 and their relation to the spaces each side of the wing C' it will be seen that the gases between the wing and the sides of the valve-box are alternately exhausted through said ports as they alternately change from live to exhaust ports in an obvious manner, and at the same time that they become exhaust-ports the reciprocation and rotation of the piston brings the longitudinal passages communicating with the ports 16 and 17 alternately into register with the port E of the cylinder, so that the exhaust from the valve-box, as well as from the spaces between the piston-heads and the heads of the cylinder, may escape and be discharged through the outlet F.

By special reference to Figs. 10 and 12, which represent the extreme reverse reciprocating movement of the valve-box and accordingly also the extreme reciprocating movements of the piston, as shown at Figs. 5 and 4, respectively, it will be seen that just as the exhaust of the motive force between the cylinder and the approaching cylinder-head has been completed the ports 17 and 16 respectively close, and the gases remaining between the wing and the side of the box-valve toward which the wing is traveling are confined and compressed slightly and until the ports O and P begin to register and when communication is established with the explosion-chamber Q, and the partially-compressed gases then mingle with the gases arising from the admixture of the hydrocarbon and denitrogenized liquid air in the explosion-chamber. The combined gases are then all further compressed and until the ports O and P

are slightly past the central line of register, thus giving greater effective force to the explosion.

As will be readily seen by reference to the drawings, the ports O and P and explosion-chamber Q on opposite sides of the engine bear such relation to the movement of the piston and the valve-box, as well as the devices which operate to change the explosion-chambers, that the supply of liquid air and hydrocarbon is forced into said chambers sufficiently in advance of the time when the spark is made to secure the proper conditions for successful and effective explosion.

After the engine has been started and continues to run the successive and alternate explosions which take place in the chambers Q on opposite sides will raise the temperature of said chamber to such a degree as to facilitate the expansion of the denitrogenized liquid-air charge and to gasify the charge of hydrocarbon, and consequently the combined gases resulting from the mixture of the denitrogenized liquid air and carbon will be in condition to give off the most effective explosive force. It will be readily understood from the construction shown and described that, as heretofore stated, I am enabled to determine the speed and power of my improved engine by controlling the supply of denitrogenized liquid air and hydrocarbon injected into the explosion-chambers, thus enabling me to use the motive force with great economy. It will also be seen that the instrumentalities employed for controlling the supply are such that all accidental explosions either within or outside of the explosion-chambers are prevented, because the igniting-spark cannot be made until the explosion-chambers have been properly loaded and absolutely and positively cut off from the supply-chambers b and c, and all communication between the latter and the supply-pipes e and f and the liquid-air and hydrocarbon tanks or reservoirs has likewise been positively closed.

The engine may be readily stopped at any time by either shutting off the supply of oxygen and carbon in the manner described or by cutting the electrodes out by a suitable switch.

Having described the construction and operation of my improved engine from the standpoint of continuous movement in one direction and of controlling the speed and power of the same, as well as a complete stoppage thereof, I will now explain the manner in which it may be promptly and readily reversed.

The box-valve N is provided with lateral ports 24 and 25 (see Fig. 13) on each side adapted to register, respectively, with the passages 26 and 27 alternately, which passages 26 and 27, as shown, are in the cylindrical wall of the piston and diametrically opposite to each other and lead, as clearly shown in Fig. 13, to the center of each head of the piston, which is bored and countersunk to re-

ceive a rotative disk 28, provided with a radial wing 29, adapted to be vibrated within a chamber lateral to the space occupied by the disk 28, as clearly shown in Figs. 14 and

15. After the disks 28 have been properly located they are secured in position by plugs 30, which are secured by screw-bolts 31, which constitute the pivot or axis upon which the disks 28 rotate, the countersink in the heads of the pistons being stepped, as clearly shown in Fig. 5, to form an annular shoulder against which the plugs are held by the screw-bolts 31, while leaving the disks 28 free to rotate. The plugs are formed with passages 32 to register with and form continuations of the passages 16 and 17, and the disks 28 are formed with diametric passages 33, designed to alternately register with said passages 16 and 17 and the passages 32, accordingly as said disks are rotated in one or the other direction.

Looking at Fig. 13 and assuming that an explosion has taken place in the upper explosion-chamber Q and the impact and expansive force of the gases has forced the wing C' into the position shown and the piston A' has traveled to the end of the cylinder, the box-valve N has reciprocated accordingly, and the port 24 in passing the passage 26 permitted the gases to enter the latter and travel to the end of the piston and against the wing 29 of the disk 28, rotating the latter into the position shown at Fig. 14 and establishing free communication between the passage 16 in the piston and the space between the head of the piston and the adjacent ends C of the cylinder B, and at the same time the vertical portion of the passage 16 of the piston begins to register or open into the space between the wing C' and the side walls of the box-valve, while at the same time the passage 17, which has been the exhaust, is being closed and remains closed when the wing C' is moving from the position indicated at Fig. 11 and until it assumes the position shown in Fig. 12 after it has been subjected to the action of the explosion which has occurred in the second or opposite explosion-chamber Q. When said passage 17 becomes live and the passage 16 is the exhaust as the piston continues its reciprocation in the direction indicated by the position of the box-valve as shown in Fig. 12, the port 25 of the valve-box registers for a time with the passages 27 on the same side, and the force of the gas is admitted against the wing 29 to rotate the disk 28 into the position shown at Fig. 15, thus establishing the proper relation between the several ports and passages heretofore described to secure the continuous movement of the engine in the direction in which it was started. Now if it be desired to reverse the movement of the engine after it has of necessity been brought to a stop the hand-lever 10 is turned in a direction reverse to that which was given it for the movement heretofore described, and as a consequence the piston is reciprocated and rotated so that the initial explosion oc-

curs on the opposite side of the wing to that previously described, and consequently the disks 28 are reversely operated upon to set the ports and passages in proper relation for the continuous reverse movement of the engine. It will thus be seen that after the piston is started in either direction desired by the starting-lever 10 the relations of the parts are established automatically to secure the continuous movement of the engine in the desired direction, and as I am not aware that it has ever before been suggested to reverse the ports of an engine by the direct action of the motive force employed to run the engine I do not wish to be confined to the specific means shown and described for accomplishing this result, as many changes in construction may be devised and suggested without departing from the spirit of my invention, which in this particular rests in the generic idea of utilizing the motive force to change the relation of the ports of an engine and through such change to automatically establish the direction of movement.

While I have shown and described mechanism for causing a spark from an electrode in the explosion-chamber at a time when it has fully been charged and all communication with the supply-chamber pipes and reservoirs has been absolutely cut off, I desire it to be understood that I prefer that the spark should be made just after the piston has passed the exact central point of its movement, and it will be obvious that the positive and negative contact-wires *u u* may be duplicated, and the insulated plates *t t* may be divided vertically and insulated and either division of the said plates put in circuit by an automatic switch, so that as the contact-arm *s* traverses its path it will not make electrical contact until it has passed the vertical insulated center line of the plates *t t*.

Many other ways may be devised for accomplishing the result without departing from the spirit of my invention, which in this particular does not relate to the means by which the spark is made at any given time, but in the generic idea of sparking through any instrumentality at a predetermined time with reference to the movement of the piston.

I desire to call particular attention to the fact that the engine is provided with two shafts J J, the rotation of which through the medium of their connection with the piston causes the proper charging and explosion of the gases in the explosion-chambers Q on opposite sides of the piston-wing, and consequently either or both of said shafts may be utilized as a driving shaft or shafts, and that when both are used as drivers power may not only be applied economically on each side of the engine, but such application of power will steady and hold the engine firmly in all its bearings and thoroughly balance the same.

By reference to diagrammatic view shown at Fig. 16 it will be seen that the liquid-air reservoir is open at the top for the escape of the

nitrogen constituent and that the denitrogenized liquid air is drawn from the bottom of said reservoir and conducted directly to the explosion-chambers of the engine.

5 I desire to lay special stress upon the fact that I am enabled to take from the reservoirs predetermined quantities of denitrogenized liquid air and hydrocarbon, and consequently am enabled to use them with great economy and safety.

10 While I have described the employment of denitrogenized liquid air (or liquid air which has been deprived to a greater or less extent of the nitrogen mixed therewith) as one of the agents for producing the explosive force for driving an engine and have named naphtha as one of the best forms of carbon which of necessity must be mixed with the denitrogenized air, it will be understood that I do not wish to be limited as to the particular form of carbon which may be used, as the liquid air in its denitrogenized form will when mixed with any suitable or attenuated hydrocarbon accelerate and intensify the explosion resulting from the ignition of the combined gases.

25 Having described the construction, operation, and advantages of my improved engine and the manner in which I employ denitrogenized liquid air and hydrocarbon combined

as a motive agent for driving the same, what I claim as new, and desire to secure by Letters Patent, is—

1. The method herein described for driving the pistons of explosive-engines which consists in mixing with a closed chamber, opening to the piston, a predetermined quantity of liquid air deprived wholly or in part of its nitrogen constituent, and a predetermined quantity of hydrocarbon or equivalent agent, and exploding the gases resulting from such admixture, by the application of an electric spark or otherwise.

2. The method herein described for driving the pistons of explosive-engines, which consists in first depriving liquid air wholly or in part of its nitrogen constituent, second, mingling in a closed chamber opening to the piston, a predetermined quantity of the denitrogenized liquid air, with a predetermined quantity of hydrocarbon, and finally igniting and exploding the combined gases within said chamber.

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

JAMES C. ANDERSON.

Witnesses:

G. P. ROUTT,
J. G. BOOTH.

It is hereby certified that in Letters Patent No. 651,742, granted June 12, 1900 upon the application of James C. Anderson, of Highland Park, Illinois, for an improvement in "Method of Moving Pistons of Explosive Engines," an error appears in the printed specification requiring correction, as follows: In line 36, page 7, the word "with" should read *within*; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed, countersigned, and sealed this 19th day of June, A. D., 1900.

[SEAL.]

F. L. CAMPBELL,
Assistant Secretary of the Interior.

Countersigned:

WALTER H. CHAMBERLIN,
Acting Commissioner of Patents.