H. A. HUMPHREY.

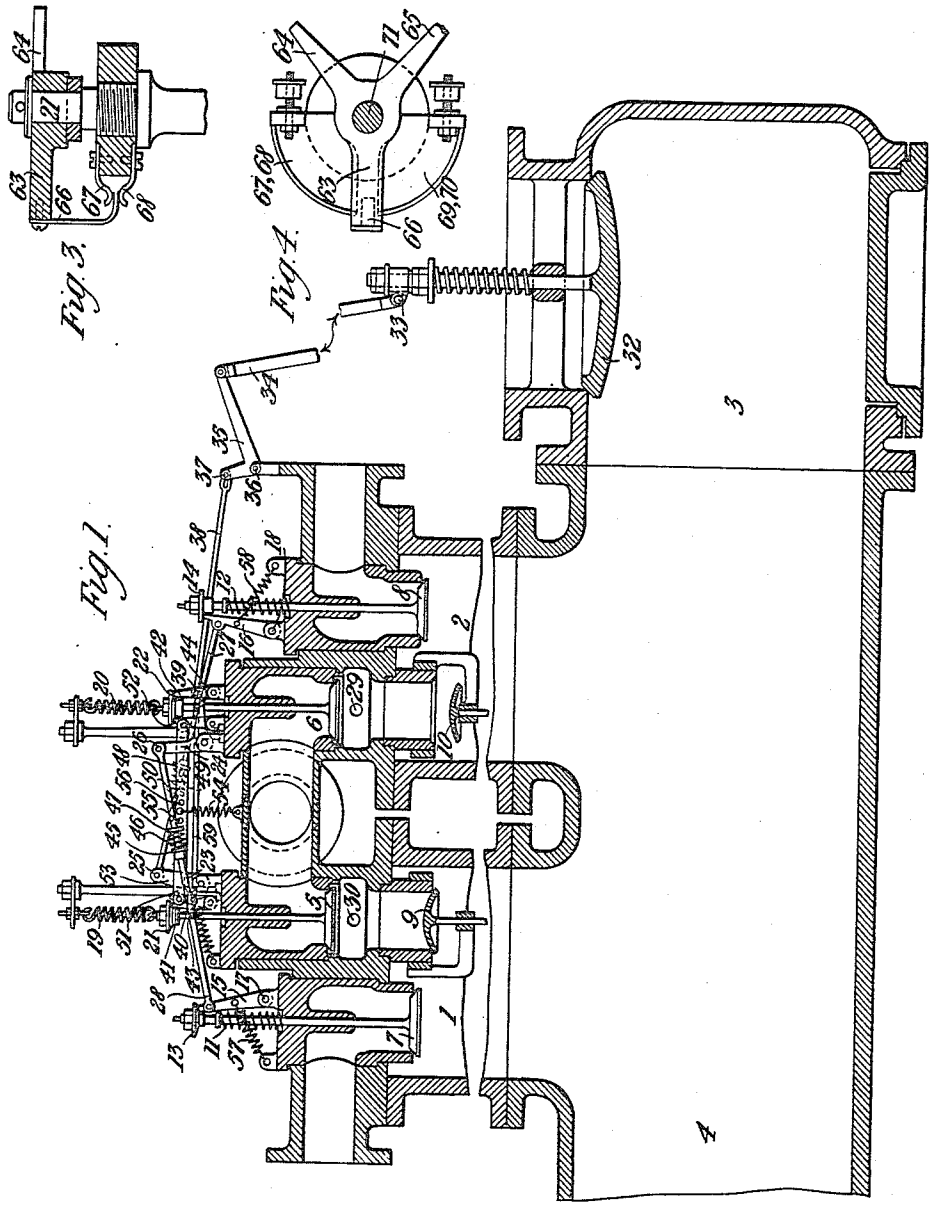
APPARATUS FOR RAISING OR FORCING LIQUIDS.

APPLICATION FILED FEB. 12, 1910. RENEWED FEB. 9, 1917.

1,265,784.

Patented May 14, 1918.

3 SHEETS—SHEET 1.



Witnesses:

Inventor

Herbert A Humphrey

James L. Norris

Atty

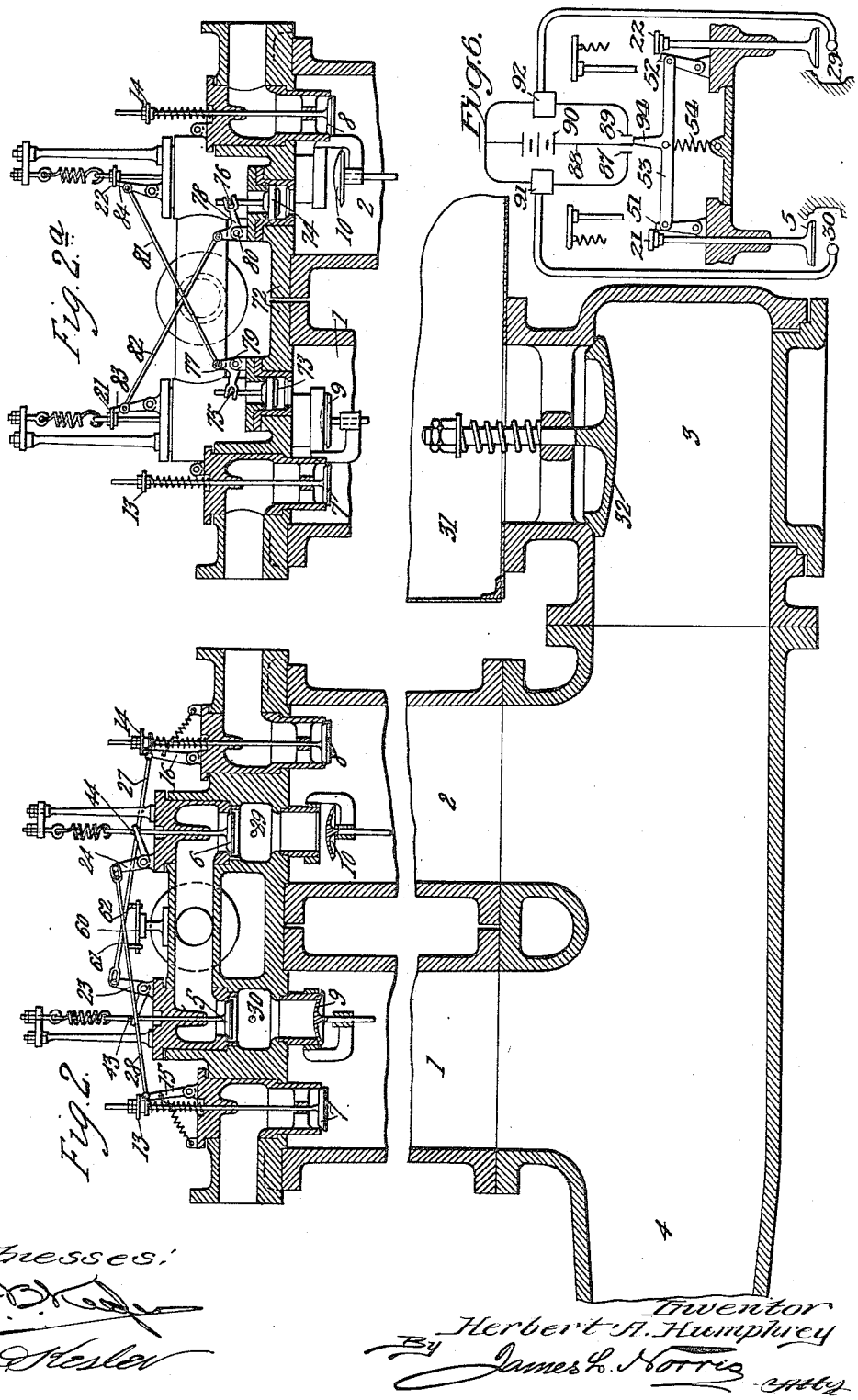
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3 SHEETS—SHEET 2.



Witnesses:

Inventor
Herbert A. Humphrey
By James L. Norris
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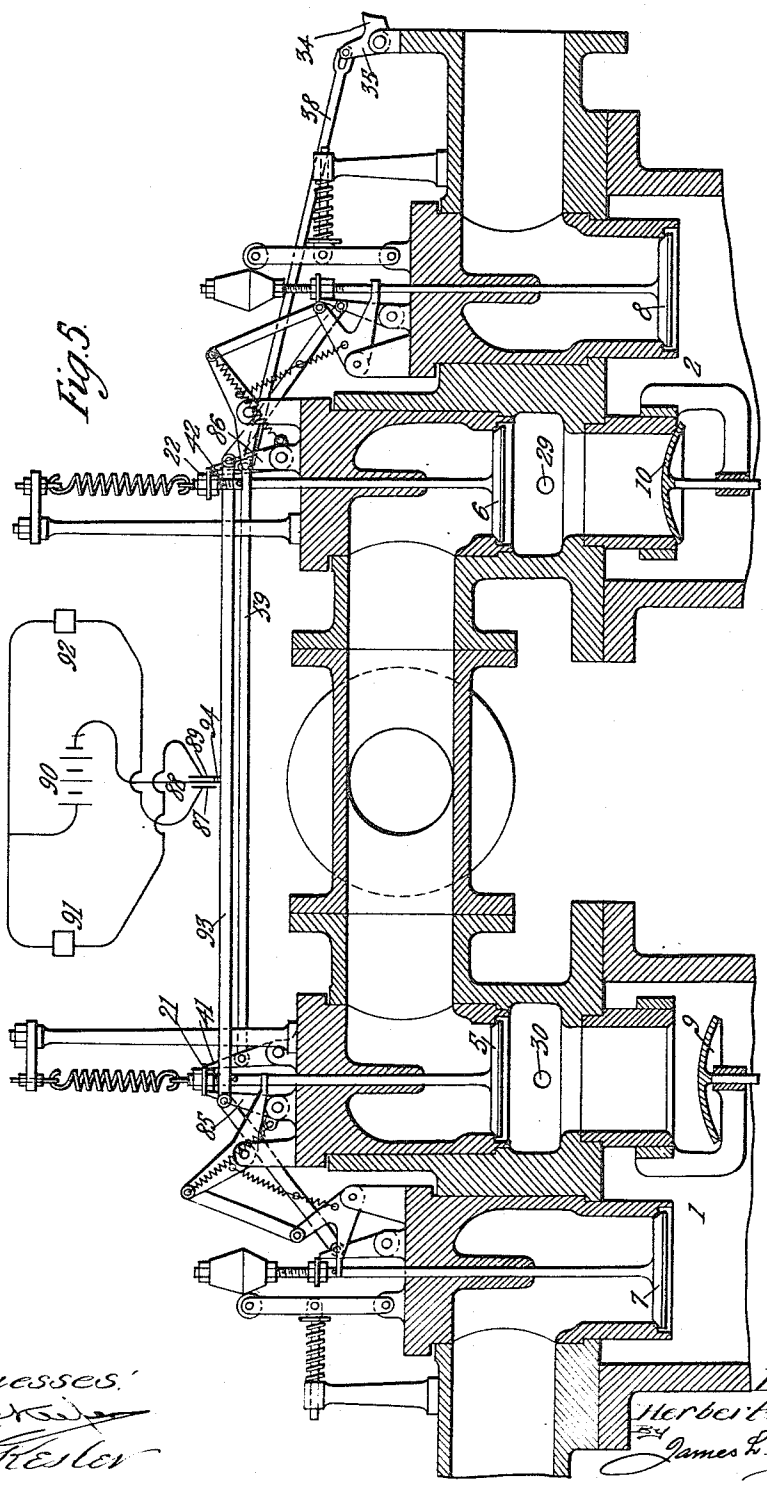
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3 SHEETS—SHEET 3.

Fig. 3.



Witnesses:

Inventor

Herbert A. Humphrey

By James L. Norris

Atty.

UNITED STATES PATENT OFFICE.

HERBERT ALFRED HUMPHREY, OF WESTMINSTER, LONDON, ENGLAND, ASSIGNOR TO HUMPHREY GAS PUMP COMPANY, A CORPORATION OF NEW YORK.

APPARATUS FOR RAISING OR FORCING LIQUIDS.

1,265,784. Specification of Letters Patent. Patented May 14, 1918.

Original application filed June 13, 1908, Serial No. 438,427. Divided and this application filed February 12, 1910, Serial No. 543,533. Renewed February 9, 1917. Serial No. 147,721.

To all whom it may concern:

Be it known that I, HERBERT ALFRED HUMPHREY, a subject of the King of Great Britain, residing at 38 Victoria street, Westminster, in the county of London, England, consulting engineer, have invented certain new and useful Improvements in Apparatus for Raising or Forcing Liquids, of which the following is a specification.

In my copending application No. 438427, filed June 13, 1908, resulting in Patent No. 1,085,865, dated Feb. 3, 1914, of which this forms a division, I have described a method of and apparatus for raising and forcing liquid, wherein a column of liquid is propelled outwardly from a combustion chamber by the energy of expansion of an ignited combustible charge, and in which a column of liquid flows inwardly toward the combustion chamber to expel products of combustion therefrom and to compress a fresh combustible charge in a second combustion chamber.

This invention also comprises improvements in valve gearing suitable for apparatus operated according to the method referred to, and will be described with reference to the accompanying diagrammatic drawings in which Figure 1 is a part vertical section of such apparatus with valve gearing, according to this invention, controlled by the liquid inlet valve of the apparatus: Fig. 2 is a similar view to Fig. 1 and shows the valve gearing in a simplified form resulting from the omission of that part of the gear which is controlled by the liquid supply valve; Fig. 2ª is a sectional elevation of the head of the combustion chamber showing additional locking gear applicable to Figs. 1 and 2: Figs. 3 and 4 are respectively a detail section and plan view of a switch shown in Fig. 2: Fig. 5 is a vertical section of the head of an apparatus similar to that in Fig. 1 but with another modified form of valve gearing, and Fig. 6 is a diagram of the ignition circuit and switch as applied to apparatus illustrated in Fig. 1.

In Fig. 1, 1 and 2 are combustion chambers shown broken across and much shortened vertically so as to permit the working parts to be drawn to a large scale. The combustion chambers communicate at their lower part with a supply pipe 3 and a discharge pipe 4, the latter being continued to a place of higher level or higher pressure. At the upper part of the combustion chambers are fitted admission valves 5 and 6 and exhaust valves 7 and 8, two other valves 9 and 10 are also shown below valves 5 and 6, the purpose of which will be explained later. The seatings of valves 7, 8, 9 and 10 are shown projecting some distance into the upper part of the combustion chambers with the object of forming a space in the latter in which an elastic cushion can be compressed to prevent shock from liquid which rises in the chambers striking the top of the chambers, and for other purposes presently explained.

The exhaust valves 7 and 8 in the present example open under the action of their own weight, and light springs 11 and 12 serve to limit their motion. On the valve stems are collars 13 and 14, and on the valve plugs are mounted pawls 15 and 16 turning about pivots 17 and 18 and capable of engaging under the collars so as normally to keep the exhaust valves closed. The admission valves 5 and 6, for combustible mixture, open against the action of light springs 19 and 20 which close the valve when the difference of pressure on the two sides of the valve becomes small enough. Admission valve 5 carries on its stem a fixed collar 21 and a pin 43, the former being constructed to engage with pawls 41 and 51 at certain parts of the cycle; the pin engages with one end of bell crank 23. Similarly valve 6 has on its stem a collar 22 capable of engaging with pawls 42 and 52, and also carries a pin 44 which engages with one end of bell crank 24. Bell crank 23 is attached through pin 25 to rod 27 the other end of which is pivoted to pawl 16, and bell crank 24 is attached by pin 26 to rod 28 which is pivoted to pawl 15. Thus, when admission valve 5 opens pin 43 on its stem turns bell crank 23 and rod 27 and pawl 16 are moved to the left, thereby disengaging the latter from collar 14, leaving the exhaust valve free to open. It will be seen that the inlet valve of chamber 1 releases the exhaust valve of chamber 2, and in a similar manner the inlet valve of chamber 2 controls the exhaust valve of chamber 1.

Rod 28 carries a fixed collar 45, a spring 46, and a loose collar 47, and rod 27 car-

ries a corresponding set of parts 48, 49, and 50. A link 53 connects pawls 51 and 52 and is of such length that the pawls cannot be engaged simultaneously with the collars 21 and 22 respectively. Link 53 carries two pins 55 and 56 capable of engaging with collars 47 and 50 respectively in such a way that the movements of rods 27 and 28 may be utilized to move the link 53 and pawls 51 and 52.

Attached to the stem of liquid supply valve 32 is a swivel 33 to which is fastened a rod 34 attached to bell crank 35 turning about pivot 36. This bell crank has a pin and slot connection 37 with rod 38, the other end of which is pivoted at 39 to pawl 42 and connection is carried to the pawl 41 by means of another rod 59 pivoted at 39 and 40. The length of rod 59 is such that pawls 41 and 42 may not be simultaneously engaged under the collars 21 and 22. Thus, when liquid supply valve 32 opens, rod 34 is drawn downward and pawls 41 and 42 are moved to the right leaving that admission valve free to open which is not otherwise kept shut by one of the pawls attached to link 53.

The action of the apparatus is as follows:—It is assumed that all the valves are in the position shown, that a compressed combustible charge is in the upper portion of chamber 2, and that liquid fills the whole of chamber 1 except for a small space in the top thereof which contains a compressed elastic cushion. Ignition now occurs in chamber 2, and for this purpose a sparking plug 29 is provided in a recess in the admission valve casting. Combustion starts in this recess and spreads past valve 10, so that the whole combustible charge is fired. The rise of pressure drives the liquid in combustion chamber 2 downward and outward from the combustion chamber along the discharge pipe. As the two chambers communicate the increased pressure of the liquid in chamber 2 is transmitted to the liquid in chamber 1 and the elastic cushion in the top of chamber 1 is further compressed. As the expansion in chamber 2 continues toward atmospheric pressure a moment arrives when the pressure of the liquid above and below valve 32 is the same, and further expansion causes this valve to open so that liquid from the supply tank 31 (Fig. 2) flows into the apparatus to follow the liquid moving in the discharge pipe. The movement of valve 32 releases pawl 41 from under collar 21 on the stem of admission valve 5. At this time the level of liquid in chamber 2 is lower than the liquid in chamber 1 and the pressure in chamber 2 cannot support the liquid in chamber 1, so that a downward motion of the liquid in chamber 1 occurs, drawing in a fresh combustible charge through the inlet valve 5 and past valve 9, the latter opening automatically under its own weight as soon as the pressure in chamber 1 is relieved. Valve 5 is shut by spring 19 when the charge has been drawn in.

The discharge pipe being sufficiently long to permit a considerable portion of the energy of combustion to be transformed into kinetic energy of the outwardly moving column of liquid in the discharge pipe, this column continues to move toward the place of higher level or pressure for some time after the pressure in the combustion chamber has fallen to that represented by the head or pressure to which the liquid is raised, so that expansion may be carried to atmospheric pressure. When admission valve 5 opened to admit the fresh combustible charge into chamber 1 the exhaust valve in chamber 2 was released in a manner already described, consequently when the pressure of expansion is low enough in chamber 2 valve 8 opens and some of the liquid from the supply tank is free to rise in chamber 2 and expel burnt products through the exhaust valve 8.

The cycle has now arrived at the point where in chamber 1 there is a fresh combustible charge, the inlet valve 5 and the exhaust valve 7 are shut, and the valve 9 is open. In chamber 2 there are some products of combustion in the upper portion of the chamber, liquid in the lower portion of the chamber, the inlet valve 6 is shut, but the exhaust valve 8 (which opened before valve 5 closed) and valve 10 are open.

The outward flow of liquid in the discharge pipe having ceased, an inwardly moving column of liquid commences to flow under the action of its head or pressure. Liquid inlet valve 32 shuts automatically, and the inflowing liquid tends to rise in both chambers but as there is a free outlet for the burnt gases from the top of chamber 2 while there is no outlet for the combustible charge in chamber 1, the returning liquid rises at first only slowly in chamber 1 and more quickly in chamber 2. When the rising liquid strikes valve 10 and exhaust valve 8 it shuts these valves. Exhaust valve 8 is locked by means of pawl 16 which is pulled into position to engage under collar 14 by spring 58 and valve 10 is held up by the pressure of the rising liquid which compresses the elastic cushion, in this case consisting of a portion of the burnt products inclosed in the top of the chamber. This elastic cushion will expand again to some extent and the pressure will fall somewhat, but neither valve 6 nor valve 8 will open because the former has been locked by pawl 42 which returned to the position shown when valve 32 closed, and valve 8 is locked by pawl 16. The flow of liquid into chamber 2 having been checked, the liquid now rises farther in chamber 1, compressing the combustible charge therein until the kinetic energy of the column of liquid is expended and the liquid brought

to rest, having stored energy in the compressed combustible charge and the compressed elastic cushion. As the volume of the compressed combustible charge is such that the level of liquid in chamber 1 does not reach valve 9, this valve remains open and ignition now occurs by means of a sparking plug 30, and the cycle described commences afresh with the difference that this time the functions of the respective chambers are reversed.

When valve 5 opened and its pin 43 moved bell crank 23, releasing the exhaust valve on chamber 2, collar 50 on rod 27 engaged pin 56 on link 53, thus moving this link to the left and compressing spring 49. As valve 5 shuts before valve 8 the collar 14 engaging against the side of pawl 16 keeps rod 27 sufficiently toward the left while valve 5 shuts, and then link 53 completes its movement causing pawl 51 to engage under collar 21, thus locking valve 5 and at the same time releasing pawl 52 from under collar 22. Either of the positions of link 53 is rendered stable by spring 54, which tends to keep link 53 in its lowest positions. The spring 57 has a similar function to spring 58. These various movements are for the purpose of bringing all the valve gear into the right position for starting the new cycle as mentioned above.

In order that ignition may occur alternately in the two chambers, the movement of link 53 may be utilized to operate a switch, so that when link 53 is to the right ignition plug 29 is in circuit, and when the link is to the left ignition plug 30 is in circuit. See Fig. 6.

Fig. 2 shows the apparatus in a somewhat simplified form resulting from the omission of that part of the valve gear which is controlled from the liquid supply valve 32 together with link 53 and pawls 51 and 52 shown on Fig. 1, and the action of the apparatus with the simplified gearing will now be described:—

As before, it is assumed that the valves are in the position shown and that ignition occurs in combustion chamber 2 followed by expansion, the intake of fresh liquid through valve 32 to follow the liquid moving in the discharge pipe, and the intake of a combustible charge in chamber 1 through valves 5 and 9. When the outwardly moving column of liquid comes to rest and the inward flow of liquid commences, liquid from the supply tank 31 has risen in chamber 2 and valve 32 has shut again. The inwardly moving liquid now rises in chamber 2 expelling the products of combustion through valve 8 which was released by the opening of valve 5, by the action of pin 43, bell crank 23 and link 27 as in the case of Fig. 1. On arriving at valves 8 and 10 the liquid shuts them by impact. Valve 8 is at once locked by pawl 16, but in this construction there is no pawl to lock admission valve 6, consequently, when the products of combustion remaining in the top of chamber 2 are compressed by the rising liquid after valves 8 and 10 are shut, and then these products forming the elastic cushion expand imparting momentum to the liquid so that it falls below the level corresponding with atmospheric pressure, combustible mixture is drawn into chamber 2 through valves 6 and 10, both of these valves being opened by the suction. The opening of valve 6 releases pawl 15 from under collar 13 on exhaust valve 7, but as the inwardly flowing column of liquid is already compressing the combustible charge in chamber 1 valve 7 does not open and when valve 6 shuts again pawl 15 again engages under collar 13 and the inwardly flowing liquid now rises in both chambers until maximum compression has been attained in chamber 1 and a fresh cycle is started by the sparking at plug 30 producing ignition. The increased pressure produced by combustion propels the liquid from chamber 1 and causes further compression of the gaseous contents of chamber 2, and the energy stored in both chambers is then utilized in the outward propulsion of liquid. When expansion has proceeded far enough in chamber 1 the quantity of combustible mixture to make up the required charge is drawn into chamber 2 through valve 6, and the movement of valve 6 withdraws pawl 15 from under collar 13 and this time exhaust valve 7 falls. The inwardly moving column of liquid now drives out the products of combustion from chamber 1 and compresses the combustible charge in chamber 2, and a fresh cycle is started by the ignition of the charge in chamber 2.

In order that ignition may occur alternately in the two chambers there is shown in the case just described a switch 60 capable of being turned into two positions by projections 61 and 62 attached to rods 28 and 27, adapted to engage against switch arms 64 and 65. Details of the switch are shown in Figs. 3 and 4. There are four spring contact pieces in two pairs, 67 and 68 constituting one pair and 69 and 70 the other pair. These contact pieces of conducting material are insulated from one another and are so spaced that the two pieces forming one pair may be bridged by a metal tongue 66 carried by switch arm 63 rotating about pivot 71. In Fig. 4 where the parts are drawn in plan, the metal tongue 66 is in a central position and does not make electrical contact with any of the contact pieces, but a small movement in either direction closes the circuit between 67 and 68 or between 69 and 70, thus determining

which primary coil in the two ignition coils is to be energized when the ignition device, such as that described in my application No. 411304, operates the switch which times the ignition.

It is sometimes desirable to prevent the opening of the admission valve in that chamber in which the compressed elastic cushion has justly expanded without having resource to any mechanism actuated by the liquid supply valve 32. In this case advantage may be taken of the fact that when the elastic cushion expands in one chamber there is already a pressure in the other chamber set up by the returning mass of liquid which is flowing inwardly to compress the combustible charge. For this purpose there are fitted in the castings 72 which close the tops of the chambers two double seated piston valves 73 and 74, as shown in Fig. 2a, where both the valves are against their top seatings. On the stems of these valves are pins 75 and 76 engaging with the forked arms of bell cranks 77 and 78 rotating about pivots 79, 80 and connected with rods 81 and 82 pivoted to pawls 84 and 83 respectively. The weight of the moving parts may be so balanced that with a slight excess of pressure in chambers 1 and 2 above atmosphere piston-valves 73 and 74 take up the position shown, but when the pressure inside the chambers falls approximately to that of the atmosphere piston-valves 73 and 74 fall to their lower seats, thus actuating the bell cranks 77 and 78 and moving rods 81 and 82 to release pawls 84 and 83 from under the collars 22 and 21 on the stems of the admission valves. It will thus be seen that the admission valve 5 on chamber 1 cannot open when the pressure in chamber 2 exceeds the pressure at which piston valve 74 is adjusted to move against its upper seat, and consequently there can be no admission through valve 5 except at the end of the working stroke in chamber 2. The valve 6 on chamber 2 is similarly controlled by piston valve 73 on chamber 1. This arrangement as described in connection with Fig. 2a can be fitted in conjunction with other valve gears described in this specificaton in substitution for those parts of such gears that are for the purpose of preventing the combustible inlet valves from opening under suction at any time during the cycle except when there is suction upon one of the inlet valves in conjunction with low liquid pressure in the combustion chambers.

In application No. 438425 there has been described a valve mechanism in which the admission and exhaust valves mutually control one another, and the gear has been illustrated in reference to Fig. 2 therein. The same type of gear is applicable to the present invention but it is preferable to connect the two pawls 85 and 86 by an additional link 93 as shown in Fig. 5 of the accompanying drawings. These pawls engage with collars 21 and 22 on the stems of admission valves 5 and 6 respectively. In starting the apparatus it is necessary to see that the pawls are in their correct position according to which chamber is to produce the first working stroke, and then afterward the action will be automatic. Without the addition of link 93 the gear attached to the admission and exhaust valves of chamber 1 operates as follows:—

Admission valve 5 opens under suction, and in closing under the action of a spring, releases the exhaust valve 7, which is then free to open when the pressure within the combustion chamber falls to a suitable extent. The exhaust valve 7 is shut by impact of liquid upon it and in closing releases the admission valve 5, and the valves on shutting are locked until released aforesaid. The valve gear attached to chamber 2 acts in a similar manner.

The chief object in connecting together the two pawls 85 and 86 by link 93 is to allow only one admission valve to open at a time. The operation of the gear just described is somewhat modified by the introduction of this link in that it prevents the pawl attached to the admission valve on one chamber from engaging under the collar on the stem of this valve until the pawl controlling the opening of the exhaust valve on the other chamber engages under the collar attached to the stem of the last mentioned valve, and this action occurs when this valve shuts. To prevent the admission valves opening when the expansion of the elastic cushion occurs two additional pawls 41 and 42, engaging under the collars of the admission valves 5 and 6, may be added and operated by the link 59, slotted rod 38, bell crank 35, and rod 34 as explained with reference to Fig. 1, these parts being moved by the liquid supply valve. The arrangement described in connection with Fig. 5 is also applicable to this case.

It will be necessary, as in the previous examples, so to arrange the electrical ignition circuits that it is only possible to obtain sparks at ignition plug 29 when there is a combustible charge in chamber 2, or sparks at ignition plug 30 when there is a combustible charge in chamber 1. In the present example this is provided for by fitting link 93 with a projection 94 capable of making electric contact between a central contact strip 88 and one or other of the outside contact strips 87 or 89, according to whether link 93 is moved to the left or to the right. Thus, in the position shown projection 94 makes contact between 88 and 89. The electric circuits include a battery 90, and two sets of ignition apparatus 91 and 92, the

ignition plug 30 being electrically connected with 91, and similarly plug 29 with 92. This arrangement secures that when a charge is introduced into one chamber the ignition apparatus connected with this chamber is operative and the other ignition apparatus is inoperative, the movement of link 93 making the required changes for the alternate ignition in the two chambers.

Having thus described the nature of my said invention and the best means I know of carrying the same into practical effect, I claim:—

1. In apparatus for raising or forcing liquid having two combustion chambers each fitted with an admission valve for combustible mixture and an exhaust valve for burnt products, and a play pipe having free and uninterrupted communication with said combustion chambers wherein a column of liquid of sufficient bulk and path of travel to acquire useful momentum is propelled outwardly by the energy of expansion of an ignited combustible charge and a column of liquid flows inwardly toward the chambers to expel burnt products from one chamber and compress a fresh combustible charge in another chamber, and means whereby the admission valve in each chamber controls the exhaust valve in the other chamber.

2. In apparatus for raising or forcing liquid having two combustion chambers each fitted with an admission valve for combustible mixture and an exhaust valve for burnt products, and a liquid supply valve, and a play pipe having free and uninterrupted communication with said combustion chambers wherein a column of liquid of sufficient bulk and path of travel to acquire useful momentum is propelled outwardly by the energy of expansion of an ignited combustible charge and a column of liquid flows inwardly toward the chambers to expel burnt products from one chamber and compress a fresh combustible charge in another chamber, means whereby the admission valve in each chamber controls the exhaust valve in the other chamber, and means whereby the liquid supply valve controls the said admission valves.

3. In apparatus for raising or forcing liquid having two combustion chambers each fitted with an admission valve for combustible mixture and an exhaust valve for burnt products, and ignition circuits for causing ignition in the chambers, and wherein a column of liquid is propelled outwardly by the energy of expansion of an ignited combustible charge and a column of liquid flows inwardly toward the chambers to expel burnt products from one chamber and compress a fresh combustible charge in another chamber, mechanism whereby the admission valve in each chamber controls the exhaust valve in the other chamber and means whereby the said mechanism also controls the ignition circuits for causing ignition in the chambers in turn.

4. In apparatus for raising or forcing liquid having a liquid supply valve, two combustion chambers each fitted with an admission valve for combustible mixture and an exhaust valve for burnt products, and ignition circuits for causing ignition in the chambers, and wherein a column of liquid is propelled outwardly by the energy of expansion of an ignited combustible charge and a column of liquid flows inwardly toward the chambers to expel burnt products from one chamber and compress a fresh combustible charge in another chamber, mechanism whereby the admission valve of each chamber controls the exhaust valve of the other chamber, means whereby the said mechanism also controls the ignition circuits for causing ignition in the chambers in turn, and is itself controlled by the liquid supply valve.

5. In apparatus for raising or forcing liquid having two combustion chambers each fitted with an admission valve for combustible mixture and a coöperating exhaust valve for burnt products, and wherein a column of liquid is propelled outwardly by the energy of expansion of an ignited combustible charge and a column of liquid flows inwardly toward the chambers to expel burnt products from one chamber and compress a fresh combustible charge in another chamber, means whereby the admission valve in each combustion chamber opens under suction and in automatically closing releases the coöperating exhaust valve which exhaust valve is then free to open when the pressure within its combustion chamber has fallen to a suitable extent, and is adapted to be shut by impact of liquid and in closing to release the coöperating admission valve, and means whereby each valve on shutting is locked until released as aforesaid.

6. In apparatus for raising or forcing liquid having two combustion chambers each fitted with an admission valve for combustible mixture and an exhaust valve for burnt products, and a play pipe having free and uninterrupted communication with said combustion chambers wherein a column of liquid of sufficient bulk and path of travel to acquire useful momentum is propelled outwardly by the energy of expansion of an ignited combustible charge and a column of liquid flows inwardly toward the chambers to expel burnt products from one chamber and compress a fresh combustible charge in another chamber, and means adapted to prevent the two admission valves being opened simultaneously.

7. In apparatus for raising or forcing liquid having two combustion chambers each fitted with an admission valve for combusti-

ble mixture and an exhaust valve for burnt products and a play pipe having free and uninterrupted communication with said combustion chambers wherein a column of liquid of sufficient bulk and path of travel to acquire useful momentum is propelled outwardly by the energy of expansion of an ignited combustible charge and a column of liquid flows inwardly toward the chambers to expel burnt products from one chamber and to compress a fresh combustible charge in another chamber, means adapted to prevent the two exhaust valves being opened simultaneously.

8. In apparatus for raising or forcing liquid having a liquid supply valve, two combustion chambers each fitted with an admission valve for combustible mixture and an exhaust valve for burnt products, and a play pipe having free and uninterrupted communication with said combustion chambers in which a column of liquid of sufficient bulk and path of travel to acquire useful momentum is propelled outwardly from a combustion chamber by the energy of expansion of an ignited combustible charge so as to take in fresh liquid through a liquid supply valve, and a column of liquid flows inwardly toward a combustion chamber to expel the products of combustion from one chamber and compress a fresh charge in another chamber, locking devices fitted to the admission valves and adapted to be operated by the liquid supply valve.

9. In apparatus for raising or forcing liquid having a liquid supply valve, two combustion chambers each fitted with an admission valve for combustible mixture and an exhaust valve for burnt products, and a play pipe having free and uninterrupted communication with said combustion chambers in which a column of liquid of sufficient bulk and path of travel to acquire useful momentum is propelled outwardly from a combustion chamber by the energy of expansion of an ignited combustible charge so as to take in fresh liquid through a liquid supply valve, and a column of liquid flows inwardly toward a combustion chamber to expel the products of combustion from one chamber and compress a fresh charge in another chamber, and means adapted to prevent the admission valve in each chamber from opening except near the end of the working stroke in the other chamber.

10. In apparatus for raising or forcing liquid having two combustion chambers each fitted with an admission valve for combustible mixture and an exhaust valve for burnt products, and a play pipe having free and uninterrupted communication with said combustion chambers in which a column of liquid of sufficient bulk and path of travel to acquire useful momentum is propelled outwardly from a combustion chamber by the energy of expansion of an ignited combustible charge and a column of liquid flows inwardly toward a combustion chamber to expel the products of combustion from one chamber and compress a fresh charge in another chamber, a puppet valve in each chamber automatically operated, and a locking device fitted to each admission valve and adapted to be operated by the piston valve of the other chamber.

11. Apparatus for utilizing an expansive force, comprising a play pipe for a body of liquid of sufficient bulk and path of travel to enable it to acquire useful momentum, a plurality of combustion chambers having free and uninterrupted communication with the play pipe, and provided with fuel inlet valves and exit valves for burnt products, and igniting means in said combustion chambers, the parts arranged and controlled whereby liquid is reciprocated freely in the play pipe to expel burnt products from one chamber and to entrain and compress fresh charge in another chamber.

12. Apparatus for utilizing an expansive force, comprising a play pipe for a body of liquid of sufficient bulk and path of travel to enable it to acquire useful momentum, a plurality of combustion chambers having free and uninterrupted communication with the play pipe, and provided with fuel inlet valves and exit valves for burnt products, and igniting means in said combustion chambers, the parts arranged and controlled whereby liquid is reciprocated freely in the play pipe, certain movements in the reciprocation being due to the expansive force and whereby the momentum of the moving liquid is utilized to entrain fresh liquid and fresh expansible charges.

13. Apparatus for utilizing an expansive force, comprising a play pipe for a body of liquid of sufficient bulk and path of travel to enable it to acquire useful momentum, a plurality of combustion chambers having free and uninterrupted communication with the play pipe, and provided with fuel inlet valves and exit valves for burnt products, and igniting means in said combustion chambers, the parts arranged and controlled whereby liquid is reciprocated freely in the play pipe, certain movements in the reciprocation being due to the expansive force and whereby the momentum of the moving liquid is utilized to entrain fresh liquid and fresh expansible charges and to compress said charges.

14. Apparatus for utilizing an expansive force, comprising a play pipe for a body of liquid of sufficient bulk and path of travel to enable it to acquire useful momentum, a plurality of combustion chambers having free and uninterrupted communication with the play pipe, and provided with fuel inlet valves and exit valves for burnt products,

and igniting means in said combustion chamber, the parts arranged and controlled whereby liquid is reciprocated freely in the play pipe, certain movements in the reciprocation being due to the expansive force whereby fresh liquid and fresh expansible charges are entrained and whereby the flow of the liquid into said chambers at each cycle to expel burnt products from one chamber and to compress a fresh charge in the other chamber.

15. Apparatus for utilizing an expansive force, consisting of a play pipe, a plurality of expansion chambers having free and uninterrupted communication with the play pipe, and said chambers having suitable inlet and outlet valves and suitable control therefor, and also igniting means whereby liquid is freely reciprocated in the play pipe, certain movements thereof being due to the expansive force and the momentum of the liquid is utilized in storing energy in expelling burnt products from one chamber and entraining and compressing a fresh charge in another chamber at each cycle..

16. The combination of a play pipe for the reciprocation of a body of liquid of sufficient bulk and path of travel to enable it to acquire useful momentum, a plurality of expansion chambers in free communication with the play pipe and having intake and discharge valves as means for causing an outstroke of the liquid by the force of an expansible charge in an expansion chamber and means for utilizing the kinetic energy of the outstroke to introduce a fresh expansible charge.

17. The combination of a play pipe for the reciprocation of a body of liquid of sufficient bulk and path of travel to enable it to acquire useful momentum, a plurality of expansion chambers in free communication with the play pipe and having intake and discharge valves as means for causing an outstroke of the liquid by the force of an expansible charge in an expansion chamber and means for utilizing the kinetic energy of a return stroke to expel burnt products from one chamber and to compress a fresh expansible charge in another chamber in the same cycle.

18. The combination of a play pipe for the reciprocation of a body of liquid of sufficient bulk and path of travel to enable it to acquire useful momentum, a plurality of expansion chambers in free communication with the play pipe and having intake and discharge valves as means for causing an outstroke of the liquid by the force of an expansible charge in an expansion chamber and means for utilizing the kinetic energy of the outstroke to introduce a fresh expansible charge and the kinetic energy of the return stroke to exhaust one chamber and to compress a fresh expansible charge in another chamber in the same cycle.

19. The combination of a play pipe for the reciprocation of a body of liquid of sufficient bulk and path of travel to enable it to acquire useful momentum, a plurality of expansion chambers in free communication therewith and having intake and discharge valves as means for causing an outstroke by the force of an expansible charge in an expansion chamber, and means for utilizing the kinetic energy of the return stroke to compress a fresh expansible charge in another chamber and to exhaust the first chamber, and means for utilizing the kinetic energy of the outstroke to introduce part of an expansible charge and the kinetic energy of another outstroke, due to the elastic cushion in one expansion chamber, to introduce the balance of the expansible charge.

In testimony whereof I have signed my name to this specification in the presence of two subscribing witnesses.

HERBERT ALFRED HUMPHREY.

Witnesses:
JOSEPH MILLARD,
WALTER I. SKERTEN.