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APPARATUS FOR UTILIZING ENERGY DERIVED FROM EXPLOSIONS.

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936,677. Patented Oct. 12, 1909.

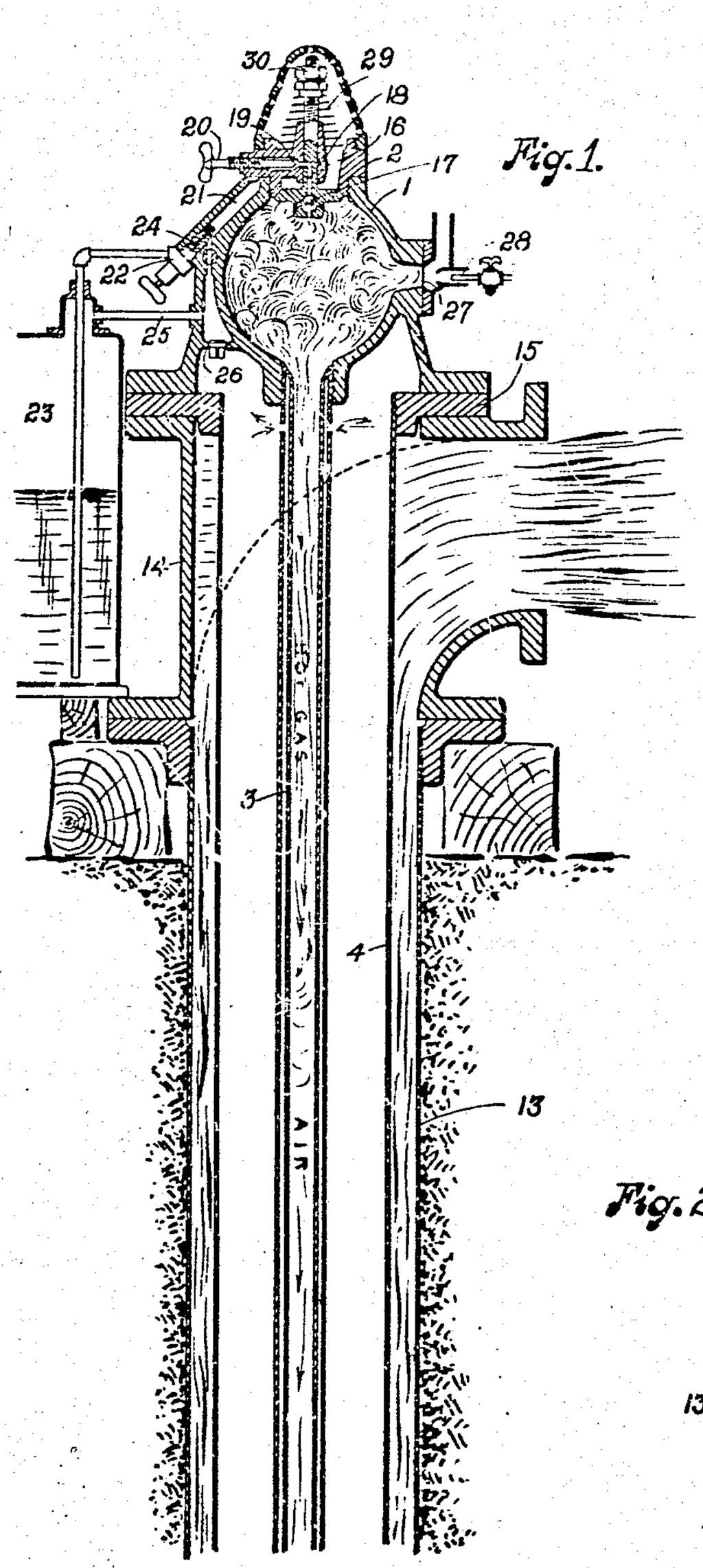

Fig. 1.

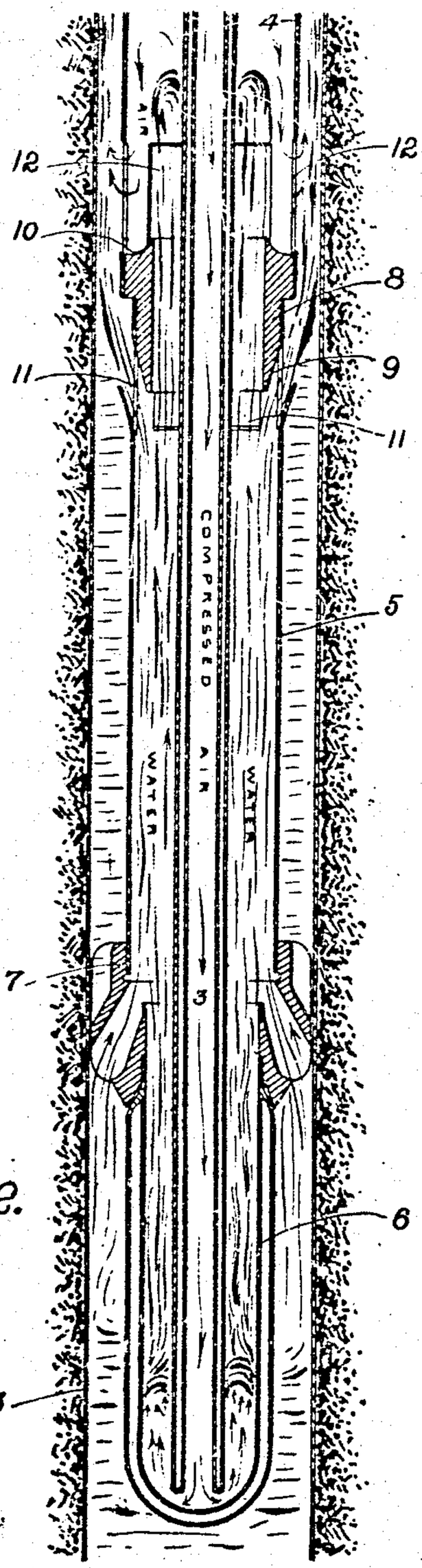

Fig. 2.

Witnesses:

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UNITED STATES PATENT OFFICE.

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APPARATUS FOR UTILIZING ENERGY DERIVED FROM EXPLOSIONS.

936,677. Specification of Letters Patent. Patented Oct. 12, 1909.

Application filed July 25, 1904. Serial No. 218,115.

To all whom it may concern:

Be it known that I, WILLIAM H. SMYTH, mechanical engineer, citizen of the United States, residing in the city and county of San Francisco and State of California, have invented certain new and useful Improvements in Apparatus for Utilizing Energy Derived from Explosions; and I do hereby declare the following to be a full, clear, and exact description of the same.

In the new type of device for the utilization of explosive energy to which the present invention relates, conditions are present, which make it desirable to eliminate to the greatest extent possible, mechanically operated or metallic moving parts. As one of the fundamental objects of this type of apparatus is to transform and store up in a form available for use at will, energy derived from successive explosions within the period of time occupied by heat conduction through metallic walls; it is apparent that if mechanical or metallic moving parts be employed in the operative functions, these parts will be compelled to perform their functions at extreme speeds or in periods of time measurable only in small fractions of seconds and consequently under adverse conditions. Again, as the material selected in the present expression of the invention, as the medium through the movement of which explosive energy is transformed, namely a water piston, is characterized by the qualities of incompressibility and inertia or mass in a high degree, it is desirable that the apparatus be so constructed as to present the least possible obstruction and deviation in the path of its motion. As the apparatus used herein to illustrate the invention is for lifting or moving water, the mechanical devices to control the operative functions and the movement of the material operated upon naturally would take the form of valves. The desirable elimination suggested would consequently be the omission of some or all of the water controlling valves. This therefore may be stated to be one of the objects of the present invention.

As further illustrating the extent and scope of the invention underlying the construction herein set forth, reference is here made to application filed October 13, 1902 for a new method or process under the title of utilizing heat energy, Serial No. 127,172 and an application for an apparatus of the same general type provided with submerged valves filed October 13, 1902 under the title of "Utilizing heat energy," Serial No. 127,173.

Besides its peculiar desirability in the present form, the omission of valves is desirable in any pump and particularly valves beneath the water. Such location renders valves subject to disarrangement by gravel, etc., and also makes them difficult of access or repair. Fortunately the qualities which, under the circumstances of the present disclosure, renders the presence of valves peculiarly undesirable, provide also, conditions which render them unnecessary. That is to say, the incompressibility and inertia of water may be utilized by proper mechanical provisions to take the place of valves. Further, as the operative functions in this device occupy such short spaces of time, the intervals between successive impulses are in a sense waste time, or at least, a failure to fully realize the mechanical capability of the apparatus.

Another object therefore of the present invention is to provide such a construction as will permit the operative impulses to follow each other with the greatest possible rapidity.

These and other objects, more readily understood from a description of the apparatus and its operation than from a mere general statement, are accomplished by the devices illustrated in the accompanying drawings.

Referring to these drawings;—Figure 1 is a sectional elevation of the upper part of the apparatus. Fig. 2 is a similar elevation of the lower or submerged part.

1 represents an explosion chamber provided with an inwardly opening valve 2, also fuel controlling and introducing devices and an igniter all of which will be more fully described hereinafter. A pipe 3 of comparatively small diameter extends from the lower part of the explosion chamber 1 downwardly into the well or other source of water supply. It may be provided with a non-conducting covering. This is illustrated in the drawings as a second pipe of somewhat larger diameter surrounding it, making an annular air space around pipe 3 the whole of its length. Surrounding the pipe 3 is an-

other pipe 4 of considerably larger diameter forming an air space or chamber. The upper portion of this air-chamber may wholly inclose the explosion chamber 1, or partly, as shown in the drawings. At the lower extremity of the air chamber and preferably forming a continuation thereof is a length of pipe 5 which I designate a drive pipe. It is preferably of a diameter somewhat smaller than the air chamber. Below the drive pipe is still another length of pipe 6 preferably closed at its lower end, constituting with pipe 5 an expansion space. This lower pipe 6 may be surrounded in a similar manner as pipe 3 is with a non-conducting covering. Pipe 6 is preferably of smaller diameter than pipe 5. Its bottom is near the bottom of pipe 3. The upper edge of pipe 6 is adjacent to the lower opening of pipe 5 leaving an annular space between the two pipes as an entrance for water. This part may be made, as illustrated, to constitute an injector device either by suitably shaping the adjacent ends of these pipes or by a coupling piece 7 to which both are attached.

Interposed between the pipe 5 and the air chamber 4 is a somewhat peculiar device 8, which I term a splitting nozzle. It is preferably of annular form and concentric to the various pipes mentioned. Its internal diameter is smaller than the pipe 5 and approximates that of pipe 6. Its lower part is chamfered or sharpened inwardly to its smaller diameter, to present an annular splitting edge 9 to a body of water flowing upward through pipe 5. The upper part of 8 is formed with a concave or recurved surface 10 forming a splitting inner edge and an upwardly curved outer edge. For constructive convenience, the splitting nozzle is made to serve as a coupling between the pipes 4 and 5 as shown. An opening 11 is provided at the upper end of pipe 5 and an opening 12 at the lower end of pipe 4 respectively on each side of the splitting nozzle 8. These openings are shown as holes arranged around their respective pipes.

A pipe or casing 13 surrounds and incloses the already mentioned pipes and serves both as a supply and a discharge pipe. In some cases, it may, as shown in the illustration, be the well casing. Its upper end may be provided with a head 14 having a discharge opening or elbow as shown. This head 14 may form a base or support for the already described construction as shown in Fig. 1.

It is a convenient method to have the air chamber with its described attachments provided with a separate flange 15. The explosion chamber 1 and pipe 3 also should be independently attached. By this construction which is clearly shown in Fig. 1, the various pipes etc., which are within the casing are readily and separably removable, a matter of some practical importance.

As the cycle of this device is not essentially dependent upon any particular heat generating means, it will, I think, conduce to clearness to describe its operation before describing in detail the means which I prefer to employ for producing and igniting explosive charges. Assuming then the device placed in position, its lower end submerged to some distance below the water level, the following conditions will exist:— Water will have entered through the injector nozzle 7 and by its flow cut off the air below, contained in 6, from the air above the water inlet. The air in 6 will be forced downward ahead of the inflowing water and compressed into the pipe 3 and chamber 1 in proportion to the submergence. The water will also have risen in the device and compressed the air in the air chamber to the pressure due to the submergence. If now suitable hydro-carbon or other fuel be introduced into the chamber 1 in suitable volume to form with the air therein an explosive mixture and this be ignited, the following described effects will take place:— The inflaming gases will expand with explosive rapidity, travel down the pipe 3 driving the air therein before them and displace the water in 6 and drive it with great velocity into 5 putting the water therein also into motion of high speed, constituting the water in 6 and in 5 a water piston of comparatively small mass. The upward displacement of the water in 6 and 5 will relieve the water in the casing below the nozzle 7 of pressure. The head or gravity will consequently cause it to enter through the annular opening between the pipes 5 and 6 with a velocity due to the combined effects of the injector principle and gravity. The uprushing water in 5 encounters the splitting nozzle 8 and a large amount of it separated and deflected outward through the openings 11. The remaining annular core continues upward and expends the energy and kinetic inertia imparted to it by the explosion in compressing the air in the air-chamber. This water core being of smaller diameter than the air-chamber permits a current of water and compressed air around its exterior to be displaced and forced downward and out of the air-chamber. In its downward flow, this current meets the concave deflecting surface 10 and is thus deflected outward and upward assisted and accelerated by the direct action of the upflowing water separated by the lower splitting edge. The expanding gases in 1 drive and follow the upflowing water in 6 and 5 till the expansion pressure falls to or below atmospheric pressure. At this point, the valve 2 opens and atmospheric air sweeps into 1, down through 3, up the pipes 6 and 5 into the still increasing space from which the water has been and is being displaced. Thus this space

is filled with air at atmospheric pressure. Water still continues to enter through the aperture at 7 due to the head and its acquired kinetic inertia assisted doubtless by the uprushing atmospheric air. The effect of explosive energy having been expended and the uprushing water piston having been arrested by the resilient cushion of the air chamber, a reaction now takes place. The resilience of the air in the air-chamber forces the water therein downward through the nozzle 8 into 5. The splitting action of the upper surface of 8 separates and deflects a portion of it outward and upward. At this time in the drive pipe 5 there is an upwardly ascending annular body of water surrounding a core of atmospheric air. This air of course extends from 5 wholly filling the spaces 6, 3 and 1. By the downward rush of the water through the nozzle 8, this air is compressed back into 3 and 1 to a degree of compression commensurate with the energy of the reaction. The valve 2 of course closes as the first effect of the reaction. The proportion of the chamber 6 is such that no water enters the pipe 3. Again a highly unstable equilibrium of the contending forces is reached with the water piston at the limit of its back journey and the air in 1 heavily compressed. The air remaining in 6 and 5 is rapidly ascending with the water still flowing in by gravity and kinetic inertia through the entrance. At this instant, another charge is ignited and the cycle repeated.

It will thus be seen that a violent, but controlled, surging or pendulum like oscillation of the water piston takes place, alternately against the resilient cushion of the air-chamber and the resilient air cushion in the charge chamber. This is a most highly desirable condition as the piston alternately gives and receives energy with practically no loss. Thus the increments of energy due to explosive action is wholly liberated to effect the upward movement of the water in the casing. This upward movement, by the form of the apparatus, is facilitated and backward movement is made to react also in an upward direction. There is thus effected a continually ascending flow of water in the casing against which the whole force of the explosive impulses is expended. In consequence of the small mass of the water piston, relatively to the water in the well, it is put into violent upward motion with practically no backward disturbance to the water beneath the chamber 6. It will be noticed also that with each explosive impulse, a large volume of air is induced to enter the upflowing water. A portion of this air finds its way into the air-chamber. The water therein will thus be displaced till the level of the air in the air-chamber is down to the upper edge of the opening 12. Thereafter at every impulse, a volume of air will enter, and a like volume displaced from the air-chamber and forced upward into the annular space between the air-chamber 4 and casing 9 by the water split from the ascending stream in drive pipe 5. This increment of air of course reduces the gravity of the ascending column and renders the column resilient and thus adds to the capacity of the air-chamber for absorbing the energy of explosion without shock to the apparatus. It may also be observed that in consequence of the non-conducting covering to the pipes 3 and 6, the hot gases do not come in contact with any surfaces cooled by the water of the well till they have expanded down to a comparatively low temperature. As these air spaces around the pipes may be in free communication with the air-chamber, any heat which is conveyed through the walls will reappear in work by expanding the air in the air-chamber. The arrangement of the expansion space 6 in relation to the pipe 3 avoids any change in direction of the inert and incompressible water piston, the unavoidable change of direction being transferred by this construction from the piston to the more fluid and resilient element, the expanding gases and air.

As stated heretofore the introduction of air into the ascending column, adds to the capacity of the air chamber, that is to say, it serves with the air chamber as a resilient cushion to receive the impact of the explosion. The proportion of this function or effect thrown upon the resilient discharge column or upon the air chamber is left largely to the judgment of the constructor, guided by the circumstances of the situation in which the invention is to be operated. It may be stated in this connection that under some circumstances, it will be found that the resilient column of the discharge water will give all of the cushion that is necessary to the effective working of the device so that under such circumstances, the air chamber may be entirely dispensed with. It may be found desirable when operating the device under these latter conditions to provide some simple means such as a hand air pump to inject air into the column during the first few impulses in order to start the column into motion and render it sufficiently resilient to perform its function as a cushion. So that when the term air chamber, resilient cushion or the like expressions are used herein, they are to be understood to mean either the inclosed chamber containing air or merely the air or other gas introduced into the water or discharge pipe in such form as to cushion the explosive blow.

It should be understood that the description heretofore, of the action of the gases and fluids during the operation, will vary with the proportion which the air chamber

bears to the resilient column and with other variable factors, such as submergence, head and position of explosion chamber with reference to the expansion chamber, etc. It however may be stated with certainty that in a device built in accordance with this invention, the explosive gas will expand in proportion to the resistance to be overcome and a volume of water proportionate to the work expended by the expanding gases, will issue from the discharge aperture.

Returning now to constructive detail; in Fig. 1 is represented a simple and effective means for introducing liquid hydro-carbon into the explosion chamber in the form of spray or vapor, and an igniting device for inflaming the resulting mixture. The particular object in view in this form of introducing device is that the fuel shall not be permitted to enter the explosion chamber except when the valve 2 is closed and further that it shall commence to enter practically simultaneously with the closing of this valve. These requirements look toward that other and more fundamental object already referred to of curtailing the interval between the explosive impulses to its shortest possible duration. With these purposes in view, the valve 2 is itself made to control the time for the admittance of the vaporous fuel. This is accomplished by providing a longitudinal passage 16 in the stem of the valve 2 opening inwardly to the explosion chamber and outwardly to the periphery of the valve stem as shown. This passage is provided with a suitable check valve, shown as a ball valve 17 closable by pressure within the chamber 1. A circumferential groove 18 is provided in the valve stem guide communicating with passage 16 only when the valve 2 is closed. A passage 19 communicating with groove 18 is also provided. This passage is preferably controlled by a valve 20 as shown A mixing or vaporizing chamber or passage 21 is provided communicating with passage 19 and also with a source of air pressure and a liquid fuel supply by suitable valve controlled passages. In the form shown, the vaporizing chamber 21 is connected by a pipe controlled by a valve 22, with an air tight fuel tank 23. It is also connected with the air chamber by a passage controlled by a valve 24 shown as a plug valve in section. The fuel tank is connected above the level of the fuel with the air chamber by a pipe or passage 25 controlled by a non-return valve 26. I have indicated an igniting-device as consisting of a thin sheet or plate 27 covering an aperture in the wall of the explosion chamber. Means for heating plate 27 are represented as a Bunsen burner 28 arranged to project a flame upon the plate 27. It might be noticed that the valve 2 is provided with a closing spring 29 and nuts 30 on the valve stem to adjust the tension of the spring. The operation of this portion of the device is as follows:—It should be understood that the pressure in the fuel tank 23 is equal to the highest pressure attained in the air-chamber, which during the operation of the device is higher than the pressure in chamber 1 except during the period of explosion. Of course when starting up for the first time, or in the event of the pressure in 23 escaping, from any cause, it could be renewed by any of the ordinary means as for example, a hand air pump. Assuming then pressure in 23 and the plate 27 heated, the device may be started by merely opening the valve 20. This permits liquid fuel and air from the tank to escape into the passage 21, and be there vaporized, and so on through passage 19 and passage 16 to the chamber 1 where this rich vapor is mingled with the air till the combined mixture reaches explosive conditions. It is ignited by contact with the hot plate and an explosion results. The excess of pressure in chamber 1 causes the valve 17 to close the passage 16, and the heretofore described operations of the device takes place. As soon as the pressure reaches that of atmosphere, the valve 2 opens and consequently shuts off the supply of fuel vapor until the valve 2 is again closed in the performance of its more direct function, when fuel is again admitted and the various operations which have been described are repeated indefinitely.

It will be observed that in the operation of this device, certain novel, interesting and valuable conditions and functions are present and utilized. The first and most striking is the pendulum like or surging action of the water piston in its unrestricted reciprocation against oppositely disposed resilient cushions. This utilizes and makes practically effective a condition in which bodies of large mass may be kept in motion with a minimum expenditure of energy, thus is brought about a condition in which practically the whole of the explosive increment of energy is liberated for the accomplishment of effective work or in other words raising the mechanical efficiency of the transforming apparatus to practically theoretical perfection. Another condition is that involved in the fact that the path of the water moved is practically without change of direction. From a practical point of view also, the valveless character of the device is important. As therefore this disclosure introduces in useful expression such broadly novel principles, functions and effects for the utilization of the energy of explosive action and their application to the raising and moving of water, it is not desired that the invention be limited to the forms, proportions or arrangements of the parts as herein illustrated or any particular mechanical expres-

sion thereof, but I desire to claim the invention or inventions herein, in the broadest manner as a pioneer invention.

What I claim is:—

1. In an apparatus of the named type, the combination of a drive pipe having a chamber at each of its ends in free and uncontrolled communication therewith, said chambers being of suitable character to contain an elastic fluid, means for introducing into one of said chambers fuel and commingle it with the fluid therein to form an explosive charge, means to ignite the charge, and a freely movable body acting as a piston in the drive pipe and in advance of the charge.

2. In an apparatus of the named type, the combination of a drive pipe having a chamber at each of its ends in free and uncontrolled communication therewith, said chambers being of suitable character to contain an elastic fluid, means for introducing into one of said chambers fuel to form an explosive charge, means to ignite the charge and liquid acting as a piston in the drive pipe in advance of the charge.

3. In an apparatus of the named type, the combination of a drive pipe having a chamber at each of its ends in free and uncontrolled communication therewith, said chambers being of suitable character to contain an elastic fluid, means for introducing into one of said chambers fuel and commingle it with the fluid therein to form a succession of explosive charges, means to ignite the charges, and a freely movable body acting as a piston in the drive pipe and in advance of the charges.

4. In an apparatus of the named type, the combination of a drive pipe having a chamber at each of its ends in free and uncontrolled communication therewith, said chambers being of suitable character to contain an elastic fluid, means for introducing into one of said chambers fuel to form a succession of explosive charges, means to ignite the charges and liquid acting as a piston in the drive pipe in advance of the charges.

5. In an apparatus of the named type, the combination of an explosion chamber, an expansion chamber, an unobstructed pipe or passage of relatively small diameter connecting the two chambers, and a freely movable body in the expansion chamber acting as a piston.

6. In an apparatus of the named type, the combination of an explosion chamber, an expansion chamber, an unobstructed pipe or passage of relatively small diameter connecting the two chambers, a drive pipe, an air-chamber, the drive pipe and air-chamber being in free and uncontrolled communication with the expansion chamber and a freely movable body in the expansion chamber acting as a piston.

7. In an apparatus of the named type, the combination of an explosion chamber, an expansion chamber, an unobstructed pipe or passage of relatively small diameter connecting the two chambers and liquid in the expansion chamber acting as a piston.

8. In an apparatus of the named type, the combination of an explosion chamber, an expansion chamber, an unobstructed pipe or passage of relatively small diameter connecting the two chambers, a drive pipe, an air-chamber, the drive pipe and air-chamber being in free and uncontrolled communication with the expansion chamber and liquid in the expansion chamber acting as a piston.

9. In an apparatus of the named type, the combination of an explosion chamber, an expansion chamber, an unobstructed pipe or passage of relatively small diameter connecting the two chambers and means for introducing liquid in the expansion chamber to act as a piston.

10. In an apparatus of the named type, the combination of an explosion chamber, an expansion chamber, an unobstructed pipe or passage of relatively small diameter connecting the two chambers, a drive pipe, an air-chamber, the drive pipe and air-chamber being in free and uncontrolled communication with the expansion chamber and means for introducing liquid in the expansion chamber to act as a piston.

11. In an apparatus of the named type, the combination of an explosion chamber, an expansion chamber, an unobstructed pipe or passage of relatively small diameter connecting the chambers, means for introducing into the explosion chamber air and fuel and commingling them to form a succession of explosive charges, means to ignite the charges and of a freely movable body acting as a piston in the drive pipe in advance of the charges.

12. In an apparatus of the named type, the combination of an explosion chamber, an expansion chamber, an unobstructed pipe or passage of relatively small diameter connecting the chambers, means for introducing air into the explosion chamber, means for introducing fuel into the explosion chamber and commingling it with the air therein to form a succession of explosive charges, means to ignite the charges and liquid acting as a piston in the drive pipe in advance of the charges.

13. In an apparatus of the named type, the combination of an explosion chamber, an expansion chamber, an unobstructed pipe or passage of relatively small diameter connecting the two chambers, and an injector device for introducing liquid, between the expansion chamber and drive pipe.

14. In an apparatus of the named type, the combination of an explosion chamber, an expansion chamber, an unobstructed pipe

or passage of relatively small diameter connecting the two chambers, a drive pipe, an air-chamber, the expansion chamber, drive pipe and air chamber being in free and uncontrolled communication, a freely movable body in the expansion chamber acting as a piston and a splitting nozzle between the expansion chamber a d drive pipe.

15. In an apparatus of the named type, the combination of an explosion chamber, an expansion chamber, an unobstructed pipe or passage of relatively small diameter connecting the two chambers, a drive pipe and an air-chamber, the drive pipe and air-chamber being connected by a splitting nozzle and liquid introduced in the expansion chamber acting as a piston.

16. In an apparatus of the named type, the combination of an explosion chamber, an expansion chamber, an unobstructed pipe or passage of relatively small diameter connecting the two chambers, a drive pipe, an air-chamber, the drive pipe and air-chamber being in free and uncontrolled communication with the expansion chamber, means for introducing liquid in the expansion chamber, and a discharge pipe.

17. In an apparatus for applying energy derived from explosion, the combination with an explosion chamber of means for admitting an explosive charge thereinto, means for igniting said charge, an expansion chamber located beneath the surface of the water, having an aperture directed substantially in the direction of desired flow and a discharge conduit.

18. In an apparatus of the named type, the combination with an explosion chamber, an expansion chamber, an unobstructed pipe or passage of relatively small diameter connecting the two chambers, a freely opening valve in the explosion chamber for the admission of air provided with a substantially central opening for fuel to form an explosive charge, means to ignite the charge and liquid in the drive pipe acting as a piston.

19. In an apparatus of the named type, the combination with an explosion chamber, an expansion chamber, an unobstructed pipe or passage of relatively small diameter connecting the two chambers, an inwardly opening valve in the explosion chamber for the admission of air provided with a tension device and means for adjusting the tension of said device, means for introducing fuel into the explosion chamber and commingling it with the air therein whereby a succession of explosive charges are formed, means to ignite the charges and liquid in the expansion chamber acting as a piston.

20. In an apparatus of the named type, the combination with an explosion chamber, an expansion chamber, an unobstructed pipe or passage of relatively small diameter connecting the two chambers, a drive pipe connected with the expansion chamber, an inwardly opening valve in the explosion chamber for the admission of air and a passage for fuel controlled by said valve.

21. In an apparatus of the named type, the combination with an explosion chamber having a suitable igniter, an expansion chamber, an air chamber, means for admitting water thereinto, a fuel tank suitably connected with the air chamber whereby the pressure therein forces liquid fuel into the explosion chamber to form an explosive mixture therein.

22. In an apparatus of the named type, the combination of an explosion chamber, an expansion chamber, an unobstructed pipe or passage of relatively small diameter connecting the two chambers, a drive pipe, an air-chamber, the drive pipe and air-chamber being connected by a splitting nozzle provided with a splitting top and bottom edge and a curved deflecting upper surface and liquid introduced in the expansion chamber acting as a piston.

23. In an apparatus of the named type, the combination of an explosion chamber, an expansion chamber, an unobstructed pipe or passage of relatively small diameter provided with a non-conducting covering, connecting the two chambers and liquid in the expansion chamber acting as a piston.

24. In an apparatus of the named type, the combination of an explosion chamber, an expansion chamber, an unobstructed pipe or passage of relatively small diameter connecting the two chambers, a drive pipe, an air-chamber and a splitting nozzle located between the air chamber and drive pipe with an opening above it from the air chamber and an opening below it from the drive pipe.

25. In an apparatus of the named type, the combination of an explosion chamber, an expansion chamber, an unobstructed pipe or passage of relatively small diameter provided with a non-conducting covering, connecting the two chambers, a drive pipe, an injector nozzle located between the expansion chamber and drive pipe for admitting liquid, an air chamber connected with the drive pipe by a splitting nozzle, an inwardly opening valve in the explosion chamber for the admission of air controlling a passage for the admission of fuel, an igniter and a discharge pipe.

26. In apparatus of the named type, the combination of an explosion and expansion chamber, a body of material in the expansion chamber to act as a piston, an air chamber against which the piston expends its energy, a splitting nozzle in the path of the piston, and a pipe to receive the material driven from the expansion chamber.

27. In an apparatus of the named type, the combination of an explosion and expan-

sion chamber, a body of material in the expansion chamber to act as a piston, and an air chamber against which the piston expends its energy, an injector nozzle, a splitting nozzle in the path of the piston, a drive pipe interposed between the injector and splitting nozzles and a pipe adapted to receive the material driven from the expansion chamber.

28. In an apparatus of the named type in combination an explosion and expansion chamber and means for introducing water thereinto, a free piston in the expansion chamber, and a resilient cushion against which the piston expends a portion of its energy; an annular nozzle in the path of the piston arranged to permit the passage of the piston therethrough and deflect water accompanying the piston laterally and a pipe adapted to receive the deflected water.

29. In an apparatus of the named type in combination an explosion and expansion chamber and means for introducing water thereinto, a free piston in the expansion chamber, and a resilient cushion against which the piston expends a portion of its energy; an annular nozzle in the path of the piston arranged to permit the passage of the piston therethrough and deflect water accompanying the piston laterally and a pipe adapted to receive the deflected water and means for introducing a resilient fluid into the water in the pipe.

30. In an apparatus of the named type, the combination with an explosion chamber having a suitable igniter, an expansion chamber, means for admitting water thereinto, an air chamber in the path of the water expelled from the expansion chamber, a discharge pipe, a discharge opening from the expansion chamber and a discharge opening from the air chamber for the exit of fluid respectively from these chambers to the discharge pipe.

31. In an apparatus of the named type, the combination of an explosion chamber, means for introducing fuel thereinto, an igniter, a pipe of relatively small diameter extending from the explosion chamber arranged and adapted to be submerged beneath the surface of water, and an expansion chamber inclosing the submerged end of the pipe and rising above it.

32. In an apparatus of the named type, the combination of an explosion chamber, meahs for introducing fuel thereinto, an igniter, a pipe of relatively small diameter extending from the explosion chamber arranged and adapted to be submerged beneath the surface of water, an expansion chamber inclosing the submerged end of the pipe and rising above it, and an air chamber associated with the expansion chamber to receive the impact of the explosion upon its contained air

33. In an apparatus of the named type, the combination with an explosion chamber having a suitable igniter, an expansion chamber, means for admitting water thereinto, an air chamber, a fuel tank and means to maintain pressure in the fuel tank higher than the normal pressure in the air chamber.

34. In an apparatus of the named type, the combination with an explosion and expansion chamber having a suitable igniter, means for admitting water thereinto, an air chamber, a fuel tank connected with the air chamber by a valve controlled passage.

35. In an apparatus of the named type, the combination with an explosion and expansion chamber, means for introducing fuel thereinto to form an explosive charge, means for compressing the charge prior to ignition, an air chamber and a freely movable body of material acting as a piston interposed between the expansion chamber and the air chamber, a hot-surface-igniter to the explosion chamber and means for heating the igniter.

36. In an apparatus of the named type, the combination with an explosion and expansion chamber, means for introducing fuel thereinto to form an explosive charge, means for compressing the charge prior to ignition, an air chamber and a body of liquid acting as a piston interposed between the expansion chamber and the air chamber, a hot-surface-igniter to the explosion chamber and means for heating the igniter.

37. In an apparatus of the named type, the combination with an explosion and expansion chamber, means for introducing fuel thereinto to form an explosive charge, means for compressing the charge prior to ignition, an air chamber and a body of liquid acting as a piston interposed between the expansion chamber and the air chamber, a hot-surface-igniter to the explosion chamber and means for heating the igniter, and a discharge pipe.

38. In an apparatus of the named type, in combination, an explosion chamber and a freely movable body of material acting as a piston, an air valve opening inward to atmospheric pressure, a fuel supply and a passage therefrom communicating with the explosion chamber and controlled by the air valve.

39. In an apparatus of the named type, in combination, an explosion chamber and a body of liquid acting as a piston, an air valve opening inward to atmospheric pressure, a fuel supply and a passage therefrom communicating with the explosion chamber and controlled by the air valve.

40. In an apparatus of the named type, in combination, an explosion chamber and a body of liquid acting as a piston, an air valve opening inward to atmospheric pressure, a fuel supply and a passage therefrom communicating with the explosion chamber

and controlled by the air valve, and a discharge pipe.

41. In an apparatus of the named type in combination, a pipe, an air chamber at each of its extremities forming a resilient cushion, a body of liquid in said pipe, means for introducing fuel into one of the chambers to form a succession of explosive charges and means for igniting the same and means for introducing successive increments of air into both of the chambers.

42. In an apparatus of the named type in combination, a pipe, an air-chamber at each of its extremities forming a resilient cushion, a body of liquid in said pipe, means for introducing fuel into one of the chambers to form a succession of explosive charges and means for igniting the same and means for introducing and discharging successive increments of fluid.

43. In an apparatus of the named type in combination, a pipe, an air-chamber at each of its extremities forming a resilient cushion, a body of liquid in said pipe, means for introducing fuel into one of the chambers to form a succession of explosive charges and means for igniting the same and means for introducing and discharging successive increments of fluid and an inlet and a discharge for water.

44. In an apparatus of the named type, the combination of an explosion and expansion chamber, a body of fluid in the expansion chamber to act as a piston, an injector nozzle, an air chamber against which the piston expends its energy and an unobstructed pipe or passage between the injector nozzle and air chamber, and a discharge from the air chamber.

45. In an apparatus of the named type, the combination of an explosion and expansion chamber, a body of fluid in the expansion chamber acting as a piston, an injector nozzle, an air chamber against which the piston expends its energy, an unobstructed pipe or passage between the injector nozzle and air chamber, an inlet for air an inlet for water and a discharge.

46. In an apparatus of the named type, the combination of an expansion chamber, a body of fluid in the expansion chamber acting as a piston, an injector nozzle, an air chamber against which the piston expends its energy, an unobstructed pipe or passage between the injector nozzle and air chamber, an inlet for water and a discharge.

47. In an apparatus of the named type, the combination of an expansion chamber, a body of fluid in the expansion chamber acting as a piston, an injector nozzle, an air chamber against which the piston expends its energy, a drive pipe, the exit or nozzle of the drive pipe projecting into the air chamber, and a discharge from the air chamber.

48. In an apparatus of the named type, the combination of an explosion and expansion chamber, a body of liquid in the chamber acting as a piston, a submerged air chamber connected with the expansion chamber against which the liquid piston expends its energy and a discharge from the air chamber.

49. In an apparatus of the named type, in combination an explosion chamber, a submerged expansion chamber and a well casing forming a discharge pipe, an air chamber within the well casing in free communication with the expansion chamber and an inlet for water.

50. In an apparatus of the named type, the combination of an explosion and expansion chamber, a body of material therein to act as a piston, an air chamber connected with the expansion chamber against which the piston expends its energy, a discharge from the air chamber, the air chamber and the discharge being suitably connected and arranged to permit a volume of air being displaced from the air chamber into the discharge by the piston.

51. In an apparatus for raising or moving liquid, the combination of a pipe or the like adapted to conduct the liquid to be moved, means to introduce a resilient fluid into the liquid in the pipe, means acting subsequently to the last mentioned means to accumulate pressure greater than that in the pipe and means to introduce and apply a resilient fluid at a pressure greater than atmosphere to compress the lower portion of the fluid in the pipe.

52. In an apparatus for raising or moving liquid, the combination of a pipe or the like adapted to conduct the liquid to be moved, means adapted to introduce a resilient fluid into the pipe with the liquid, an explosion chamber communicating with the pipe in such manner that pressure therein is exerted upon the fluid in the pipe, a container connected with the chamber and means to effect pressure in the container greater than that in the pipe whereby a resilient charge is introduced.

53. In an apparatus of the named type, the combination of an explosion chamber, means for introducing fuel thereinto, an igniter, a pipe of relatively small diameter extending from the explosion chamber arranged and adapted to be submerged beneath the surface of water, and an expansion chamber adjacent to the submerged end of the pipe and rising above it.

54. In an apparatus of the named type, the combination of an explosion chamber, means for introducing fuel thereinto, an igniter, a pipe of relatively small diameter extending from the explosion chamber arranged and adapted to be submerged beneath the surface of water, an expansion chamber adjacent to the submerged end of

the pipe and rising above it, and an air chamber associated with the expansion chamber to receive the impact of the explosion upon its contained air.

55. In an apparatus for raising fluid, the combination of an explosion chamber, a confined expansion space freely communicating therewith, a discharge in communication with the expansion space, and means for admitting liquid into the expansion space, the said parts having such relative arrangement substantially as shown, that upon each explosion, gas is carried with the body of liquid beyond the expansion space to the discharge.

56. In an apparatus for raising fluid, the combination of an explosion chamber, an extension thereto provided with a confined expansion space freely communicating with the explosion chamber through the extension thereof, a discharge pipe communicating with the expansion space, and means for admitting liquid into the expansion space, the said parts having such relative arrangement substantially as shown, that upon each explosion, gas is carried with the liquid beyond the expansion space to the discharge.

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Witnesses:
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