No. 671,542. Patented Apr. 9, 1901.

C. N. DUTTON.

HYDRAULIC IMPACT ENGINE.

(Application filed Sept. 18, 1899.)

(No Model.)

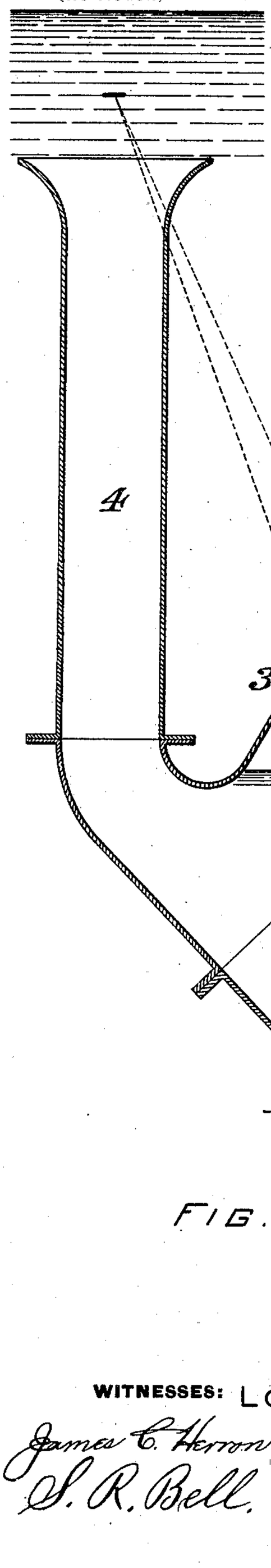

FIG. 1.

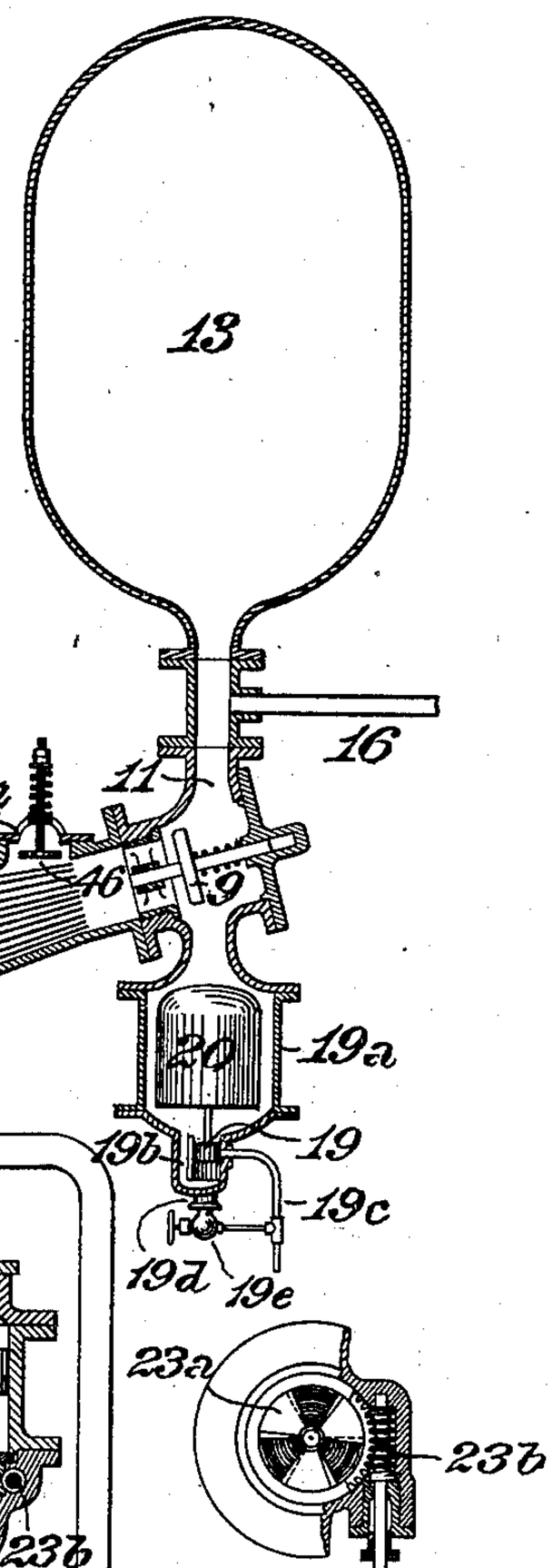

FIG. 2.

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HYDRAULIC IMPACT-ENGINE.

SPECIFICATION forming part of Letters Patent No. 671,542, dated April 9, 1901.

Application filed September 18, 1899. Serial No. 730,824. (No model.)

To all whom it may concern:

Be it known that I, CHAUNCEY N. DUTTON, of Yonkers, in the county of Westchester and State of New York, have invented a certain new and useful Improvement in Hydraulic Impact-Engines, of which improvement the following is a specification.

The object of my invention is to provide improved facilities for pumping water or effecting the compression of air by the impact of falling water; and to this end my improvement consists in certain novel combinations of mechanical devices hereinafter fully set forth.

The application of hydraulic impact to the pumping of water has been familiar to engineers and mechanics for upward of one hundred years. Its use for compressing air is of later date; but notwithstanding the fact that the utility of the principle and the practicability of its application have been so long known no engine in which the application of this principle is essayed is, so far as my knowledge and information extend, so designed as to utilize all the known principles or natural laws which control the flow and impact of fluids. The well-recognized principles which are for the first time applied in engines of the class referred to under my present invention are as follows:

(*a*) It is well known to engineers that a fluid discharging through an opening suffers a contraction known as the *vena contracta*, which reduces the effective discharging capacity of the opening to less than two-thirds of the theoretical or full discharge through a similar opening were there no such phenomenon as the *vena contracta*. It is known also that the complete immersion of the discharge-opening in water reduces the effect of the *vena contracta* nearly one-half, the reduction of the discharge in air being about thirty-six per cent. and under water about twenty per cent. Further, it is well known that the discharge can be increased, so as to equal or even to exceed the theoretical discharge, by affixing to the discharge-opening a suitably-formed "diffuser" or conically divergent discharge-section. In order that a diffuser may function to increase the discharge to one hundred per cent., more or less, of the theoretical discharge of the conduit, it must be "conically divergent"—that is to say, its transverse discharging area must increase in a suitable regular ratio from that of the conduit to twice or three times as much.

(*b*) The second principle which my invention utilizes for the first time in such an engine is the variation between hydrostatic and hydraulic pressure—that is to say, between the pressure which obtains in a closed pipe connected with a reservoir of fluid and the less pressure which obtains therein when it is discharging. Hydraulic or hydrodynamic pressure at any point in a pipe is less than the hydrostatic pressure which obtains there when the pipe is closed by the amount of "head" or fall necessary to give the fluid the velocity with which it may be moving plus the head necessary to overcome the friction of the fluid in the pipe between said point and the reservoir. This phenomenon is that commonly designated as "hydraulic gradient" or "hydraulic grade-line"—to wit, that if a pipe have a full vent at a point considerably below the surface of the reservoir with which it connects, and if the profile of said pipe be developed on a plane surface and a straight line be drawn from a point slightly below the surface of the water in the reservoir to the opening or discharge of said pipe, then the pressure at any point in the length of said pipe is measured by the length of a vertical line joining the center of said pipe and the hydraulic grade-line. All points in the pipe which are below the grade-line are subjected to pressure above atmosphere, and at all points in said pipe above the hydraulic grade-line the pressure is below atmosphere.

(*c*) The third principle applied for the first time in such engines under my invention is the principle of the draft-tube. This while really involved in or as may be said a "corollary" of the above-named principle is yet of sufficient practical importance to warrant separate notice and elucidation. The draft-tube is commonly used in connection with turbine wheels. Its principle is that the outflowing water exerts a suction in the pipe above the discharge-opening within the practical limit of twenty feet or thereabout, which renders it practical without loss of power to raise the turbine wheel, or in this case to raise the point at which the power is utilized con-

siderably above the discharge-opening. The practical utility of this principle depends upon the fact that most watercourses which are practical sources of power are liable to floods, which raise the water-level in the tail-bay and drown the apparatus, if it be located at the lowest point practical and economical in normal stages of water. A hydraulic engine, such as the ram or impact air-compressor, will not operate if it be submerged, and heretofore in setting such engines, a draft-tube not being applied to them, the engines have been located above the high-water plane and there has been considerable loss of power at normal stages of water. The application of a draft-tube to such an engine enables me to raise it as the turbine wheel is raised above the flood plane without material loss of power.

The general and characteristic features of an engine embodying my invention, in which the above-stated principles, as well as those heretofore applied in apparatus of this character, are utilized for practical operation, may be briefly described as follows:

A suitable conduit is provided to conduct the water from the reservoir to the engine, the working chamber of which is located above the flood plane. A discharge-tube leads from the working chamber, said tube being preferably a draft-tube descending to a plane lower than the low-water plane in the tail-bay, so that the discharge-opening is always immersed. The bottom of the draft-tube is provided with a diffuser the discharge-passage of which is conically divergent, its transverse area increasing in a proper ratio from its junction with the conduit to its discharge-opening, and which is alternately opened and closed by a movable main valve. When the discharge-passage is opened, the water flows through the conduit and hydraulic pressure obtains in the conduit—that is to say, the water establishes its lower hydraulic grade-line—and when said passage is closed the parts are subjected first to the pressure of impact and immediately thereafter to hydrostatic pressure, which raises the grade-line to the plane of the water-surface in the reservoir. An apparatus is thus provided in which there is a variable hydraulic grade-line, and advantage is taken of this variation of the hydraulic grade-line, or of the alternations between hydraulic and hydrostatic pressures, or alternate pressures and suctions, or of the variations in the total pressures obtaining, including atmospheric pressure in different parts of the pipe, to obtain absolutely positive action, which has not heretofore been accomplished in apparatus of such general character. To this end I provide means for alternately and automatically opening and closing the discharge-passage, such means consisting of a movable abutment adapted to be actuated in alternately opposite directions by the alternations between hydrostatic and hydraulic pressures or alternate pressure and suction in the draft-tube or elsewhere in the conduit, as may be most desirable, and a connecting device or mechanism through which the movements of said movable abutment are operatively transmitted to the valvular device or mechanism which controls the discharge-passage. The operative connection between the movable abutment and the discharge-passage-controlling mechanism may be either a mechanical or a hydraulic one, the former type being employed in the instance herein exemplified. The movable abutment is located above the lower hydraulic grade-line and below the plane of the reservoir-surface, so as to be subject to internal hydrostatic pressure when the discharge-passage is closed and to hydraulic pressure or to pressure less than that of the atmosphere or to "suction" when the discharge-passage is opened, in which event any force exterior to the conduit acting on the movable abutment—as, for example, atmospheric pressure—will overcome the hydraulic pressure acting thereon from within and force it inward. The alternate action of pressure and suction upon the movable abutment or of hydrostatic pressure and hydraulic pressure less than the exterior force—*e. g.*, that of the atmosphere thereon—effects the traverse thereof in alternately opposite directions, the movable abutment through the interposed operative connection coincidently and correspondingly actuating the discharge-controlling device. When the discharge-passage is thereby opened, water flows through the supply-pipe and discharges through said passage, speedily acquiring the maximum velocity due to the available head. When such velocity is acquired, the movable abutment is subject to suction, by which it is moved in direction to effect the closure of the discharge-passage. The water in the supply-pipe is by the closure of the discharge-passage diverted into the working chamber of the engine, where it performs work by its impact. Immediately thereafter the pipes and movable abutment are subject to hydrostatic pressure, by which the movable abutment is traversed in direction to effect the opening of the discharge-passage, thereby beginning another cycle of operations, which are thus made truly automatic and positive. The impact of the water may be utilized to lift water to a great height, as in the hydraulic ram, or to compress air for commercial uses, as in hydraulic air-compressors.

In the accompanying drawings, Figure 1 is a vertical central section through an apparatus illustrating an embodiment of my invention as a hydraulic air-compressor; and Fig. 2, a view, partly in plan and partly in section, showing the regulating-valve of the movable abutment.

In the practice of my invention the apparatus is located so as to be conveniently supplied with water under pressure from a reservoir or other source by a conduit 4, which

may be controlled by a suitable valve and which connects with a supply-tube 3. The supply-tube 3 connects with the functioning portion or working chamber of the apparatus A and with a draft-tube B, which descends to a plane lower than the low-water plane in the tail-bay and is there provided with a diffuser D, the specific form of which is not of the essence of my invention. As herein shown, it is a casting, the body of which is flanged at top for connection to the lower end of the draft-tube B, adjacent to which it is of cylindrical bore and forms the seat of an annular main valve 22, which controls the passage for the discharge of water from the draft-tube. The casting is flared outwardly at its bottom, which is adapted to be supported on a suitable foundation and contains a central mushroom or deflector 58, above and around which is formed an annular discharge-passage 59, which should enlarge in transverse area from the axis of the diffuser toward its peripheral outlet in the proper ratio to secure the desired diffuser action, which is to increase the volume of water which an apparatus of a given size will discharge with a given head in a given time and to correspondingly increase the amount of work which will be done by an engine of a given size and cost. The diffuser may, if desired, be connected to the draft-tube through the intermediation of an expansion-joint, as set forth in my application, Serial No. 677,370, filed April 12, 1898, and it may be varied substantially as to its details of construction without departure from the spirit and operative principle of my invention.

Vertical movement in alternately opposite directions is imparted to the main valve 22 to alternately open and close the discharge-passage 59 by a movable abutment 23, in this instance in the form of a piston, which is fitted to traverse in a cylindrical casing 124, located at any desired point below the plane of the supply of water and above the hydraulic grade-line which obtains when water is flowing through the discharge-passage of the diffuser. The casing 124 is suitably supported, either upon the apparatus itself, as shown, or otherwise, as the exigencies of the case may determine as most suitable, and is connected below the abutment 23 with the water-supply pipe by a passage 147, which may either lead into the draft-tube B, as shown, or into the supply tube 3, as convenience may dictate. A port 41 is formed in the cap 124^a of the casing 124, from which port a compensation suction-pipe 41^a leads into the lower level or tail-bay, into which it opens below the low-water level. The supply of water to the lower side of said abutment may be controlled by a regulating-valve 23^a, which is herein shown as of the register type and as rotatable below a ported partition at the upper end of the passage 147. Movement about its axis is imparted to the regulating-valve to effect the adjustments desired by a worm 23^b engaging a worm-gear on the periphery of the valve. When located as above set forth, it will be seen that the lower side of the movable abutment 23 is subjected to hydrostatic pressure above atmosphere when the discharge-passage 59 is closed by the main valve 22 and is subjected to hydraulic pressure less than atmosphere or suction when said discharge-passage is opened by said valve. The suction will vary with the stage of water in the tail-bay, diminishing as the water rises therein and increasing as the water falls therein. The suction in the pipe 41^a obviously increases and decreases in the same ratio, and the variation in the suction in the draft-tube, which tends to move the abutment 23, is compensated by the variation in the suction in the tube 41^a. It will be seen, therefore, that the constant force tending to move the abutment is opposed by a constant force, and the variable force tending to move it is opposed by force varying in the same ratio, and therefore such variable forces can be made to compensate, so as to give any desired nicety in the operation of the abutment.

Movement of the abutment 23 in each direction is imparted to the main valve by any suitable intermediate operative connection, various forms of which, both direct and indirect, are familiar to those skilled in the art and which is not in and of itself an essential of my present invention. In the instance exemplified the connecting means is a positive and direct one, consisting of a rod or stem 30^a, which is secured at its opposite ends to the abutment 23 and to the main valve 22, which controls the discharge-passage 59, respectively. The casing 124 of the abutment 23 is in such case, preferably as shown, located in line axially with the seat of the valve 22 in the body of the diffuser D.

The functional portion A of the apparatus, which is illustrated in the drawings as one which is desirably adapted for application where it is desired to employ the waterfall for compressing air for commercial purposes, is not in and of itself an essential of my present invention, and other means of utilizing the impact of the falling water as applied through and by the essential elements of my invention may be substituted in the discretion of the constructor. Said functional portion, as well as another form thereof, is fully set forth in my application, Serial No. 677,370, aforesaid and need not therefore be herein fully and at length described. In the construction illustrated herein the conduit 4, draft-tube B, and supply-tube 3 are so disposed relatively to the compressing-chamber 1 of the functional portion A of the apparatus that when the discharge is in full action through the discharge-passage 59 the hydraulic grade-line will always pass through the supply-tube 3 below the horizontal plane of its junction with the compressing-chamber 1 and above the horizontal plane of its junction with the conduit and draft-tube.

The operation of the apparatus in compress-

ing air is as follows: When the main valve 22 is in full open position, as shown in the drawings, water discharges through the discharge-passage 59 until it attains the full velocity of the available head, whereupon the exterior force—*e. g.*, atmospheric pressure—on the upper side of the abutment 23 acting against the hydraulic pressure or induced suction on the inner side thereof forces the abutment 23 downward and through the connection 30ª closes the discharge-passage 59 by the main valve 22. When the discharge is in full action, the hydraulic gradient falls, its exact location depending on the stage of water in the lower level or tail-bay, but in a properly-designed apparatus will always at such times pass above the plane of the junction of the draft-tube with the conduit and below that of its junction with the compressing-chamber. Therefore the hydraulic head or pressure in the conduit at the junction of the supply-tube when the discharge is in full action will be such that any water in the compressing-chamber 1 will drain into the supply-tube and a column of water will be sustained in the supply-tube and seal it against the indraft of any air to the conduit. When the discharge-passage 59 is closed by the main valve 22, the water is diverted through the supply-tube 3 into the compressing-chamber 1, in which it compresses a charge of air which has entered the chamber through an opening controlled by an air-supply valve 46. As soon as the pressure in the compressing-chamber 1 exceeds the pressure in the reservoir 13 the reservoir check-valve 9 unseats and the compressed air is forced into the reservoir 13, from which it may be drawn as needed through the service-pipe 16, which is controlled by a suitable cock or valve in the ordinary manner. The hydrostatic pressure which is exerted in the conduit, supply, and draft tubes thereupon acts on the lower side of the abutment 23, raising said abutment and through the connection 30ª unseating or opening the main valve 22. When the main valve 22 is opened, the hydraulic grade-line falls, and as soon as it has fallen so far that the junction of the compressing-chamber with the supply-tube is above it the water drains back from the compressing-chamber 1 to the supply-tube 3 and a column of water is sustained therein which seals it against indraft of air, as above stated.

I claim as my invention and desire to secure by Letters Patent—

1. In a hydraulic impact-engine, the combination of a working chamber in which water may act intermittently, by impact, upon a fluid to which it delivers its momentum, a conduit adapted to supply water under pressure, a discharge-passage, mechanism for closing and opening the discharge-passage, and operating means, operatively connected with the closing and opening mechanism, and actuated alternately by hydrostatic pressure when the discharge-passage is closed, and by a force exterior to the conduit when the discharge-passage is opened and hydraulic pressure obtains in the apparatus.

2. In a hydraulic impact-engine, the combination of a working chamber in which water may act intermittently, by impact, upon a fluid to which it delivers its momentum, a conduit adapted to supply water under pressure, a discharge-passage, mechanism for closing and opening the discharge-passage, and operating means, operatively connected with the closing and opening mechanism, and actuated alternately by hydrostatic pressure when the discharge-passage is closed, and by atmospheric pressure when the discharge-passage is open and hydraulic pressure less than that of the atmosphere obtains on the inner side of the said operating means.

3. In a hydraulic impact-engine, the combination of a working chamber in which water may act intermittently, by impact, upon a fluid to which it delivers its momentum, a conduit adapted to supply water under pressure, a discharge-passage, a main valve controlling the discharge-passage, a movable abutment, open on one side to the supply-conduit, and adapted to be actuated alternately by hydrostatic pressure when the discharge-passage is closed, and by a force opposite to and greater than the hydraulic pressure acting on its inner side when the discharge-passage is open and the conduit is discharging fully, and an operative connection from the movable abutment to the main valve.

4. In a hydraulic impact-engine, the combination of a working chamber in which water may act intermittently, by impact, upon a fluid to which it delivers its momentum, a conduit adapted to supply water under pressure, a discharge-passage, a main valve controlling the discharge-passage, a movable abutment, open on one side to the supply-conduit, and on the other to the atmospheric pressure, and an operative connection from the movable abutment to the main valve, the movable abutment being placed so as to be subjected to the hydrostatic pressure obtaining in the conduit when the discharge-passage is closed, and to hydraulic pressure less than that of the atmosphere when the discharge-passage is open and the conduit is discharging fully.

5. In a hydraulic impact-engine, the combination of a conduit adapted to supply water from a supply-level or forebay, a draft-tube extending into and having a discharge-passage beneath the level of the water in a discharge-level or tail-bay, a working chamber, in which water may act intermittently, by impact, upon a fluid to which it delivers its momentum and which is connected with the conduit, mechanism for closing and opening the discharge-passage, and operating means, operatively connected with the closing and opening mechanism, and adapted to open said mechanism by hydrostatic pressure when the

discharge-passage is closed, and to close said mechanism when the discharge-passage is open and the conduit is discharging fully, by a force opposite to and greater than the hydraulic pressure to which said operating means is at such times subjected.

6. In a hydraulic impact-engine, the combination of a conduit adapted to supply water from a supply-level or forebay, a draft-tube extending into and having a discharge-passage beneath the level of the water in a discharge-level or tail-bay, a working chamber, in which water may act intermittently, by impact, upon a fluid to which it delivers its momentum, and which is connected with the conduit, mechanism for closing and opening the discharge-passage, and operating means, operatively connected with the closing and opening mechanism, and adapted to open said mechanism by hydrostatic pressure when the discharge-passage is closed and to close said mechanism when the discharge-passage is open and the conduit is discharging fully by atmospheric pressure.

7. In a hydraulic impact-engine, the combination of a conduit adapted to supply water from a supply-level or forebay, a draft-tube extending into and having a discharge-passage beneath the surface of the water in a discharge-level or tail-bay, a working chamber in which water may act intermittently, by impact, upon a fluid to which it delivers its momentum, and which is connected with the conduit, a valve adapted to close and open the discharge-passage of the draft-tube, and a mechanism located below the plane of the higher water-level and above the hydraulic gradient which obtains during full discharge, said mechanism being operatively connected with said valve and actuated by the alternations in pressure due to the closing and opening of the discharge-passage.

8. In a hydraulic impact-engine, the combination of a conduit adapted to supply water from a supply-level or forebay, a diffuser on the discharge end thereof, having a conically-divergent discharge-passage, the transverse area of which enlarges toward the discharge-opening, a working chamber in which water may act intermittently, by impact, upon a fluid to which it delivers its momentum, and which is connected with the conduit, mechanism for closing and opening the discharge-passage, and operating means, operatively connected with the closing and opening mechanism, and adapted to open said mechanism by hydrostatic pressure when the discharge-passage is closed, and to close said mechanism when the discharge-passage is open and the conduit is discharging fully, by a force opposite to and greater than the hydraulic pressure to which said operating means is at such times subjected.

9. In a hydraulic impact-engine, the combination of a conduit adapted to supply water under pressure from a supply-level or forebay, a diffuser on the discharge end thereof, having a conically-divergent discharge-passage, a working chamber in which water may act intermittently, by impact, upon a fluid to which it delivers its momentum, and which is connected with the conduit, mechanism for closing and opening the discharge-passage, and operating means, operatively connected with the closing and opening mechanism, and adapted to open said mechanism by hydrostatic pressure when the discharge-passage is closed and to close said mechanism when the discharge-passage is open and the conduit is discharging fully, by atmospheric pressure.

10. In a hydraulic impact-engine, the combination of a conduit adapted to supply water from a supply-level or forebay, a draft-tube, a diffuser on the discharge end thereof, having a conically-divergent discharge-passage, the transverse area of which enlarges toward the discharge-opening, a working chamber in which water may act intermittently, by impact, upon a fluid to which it delivers its momentum, and which is connected with the conduit, mechanism for closing and opening the discharge-passage, and operating means, operatively connected with the closing and opening mechanism, and adapted to open said mechanism by hydrostatic pressure when the discharge-passage is closed, and to close said mechanism when the discharge-passage is open and the conduit is discharging fully, by a force opposite to and greater than the hydraulic pressure to which said operating means is at such times subjected.

11. In a hydraulic impact-engine, the combination of a conduit adapted to supply water from a supply-level or forebay, a draft-tube, a diffuser on the discharge end thereof, having a conically-divergent discharge-passage, a working chamber in which water may act intermittently, by impact, upon a fluid to which it delivers its momentum, and which is connected with the conduit, mechanism for closing and opening the discharge-passage, and operating means, operatively connected with the closing and opening mechanism, and adapted to open said mechanism by hydrostatic pressure when the discharge-passage is closed and to close said mechanism when the discharge-passage is open and the conduit is discharging fully, by atmospheric pressure.

12. In a hydraulic impact-engine, the combination of a working chamber in which water may act intermittently, by impact, upon a fluid to which it delivers its momentum, a conduit adapted to supply water under pressure, a discharge-passage, mechanism for closing and opening the discharge-passage, and operating means, operatively connected with the closing and opening mechanism and adapted to be actuated to close and open said mechanism, by the alternations of the total pressure of the water in the apparatus to which are due the raising and lowering of the hydraulic grade-line, when the discharge-passage is closed and opened.

13. In a hydraulic impact-engine, the combination of a working chamber in which water may act intermittently, by impact, upon a fluid to which it delivers its momentum, a conduit adapted to supply water under pressure, a discharge-passage, a main valve controlling the discharge-passage, a movable abutment, open on one side to the supply-conduit, and adapted to be moved alternately in opposite directions by the alternations of the total pressure of the water in the apparatus to which are due the raising and lowering of the hydraulic grade-line, when the discharge-passage is closed and opened, and an operative connection from the movable abutment to the main valve.

14. In a hydraulic impact-engine, the combination of a conduit adapted to supply water from a supply-level or forebay, a draft-tube extending into and having a discharge-passage beneath the surface of the water in a discharge-level or tail-bay, a working chamber, in which water may act intermittently, by impact, upon a fluid to which it delivers its momentum, and which is connected with the conduit, mechanism for closing and opening the discharge-passage, and operating means, operatively connected with the closing and opening mechanism, and adapted to be actuated to close and open said mechanism by the alternations of the total pressure of the water in the apparatus to which are due the raising and lowering of the hydraulic grade-line, when the discharge-passage is closed and opened.

15. In a hydraulic impact-engine, the combination of a conduit adapted to supply water from a supply-level or forebay, a diffuser on the discharge end thereof having a conically-divergent discharge-passage the transverse area of which enlarges toward the discharge-opening, a working chamber, in which water may act intermittently, by impact, upon a fluid to which it delivers its momentum, and which is connected with the conduit, mechanism for closing and opening the discharge-passage, and operating means, operatively connected with the closing and opening mechanism, and adapted to be actuated to close and open said mechanism, by the alternations of the total pressure of the water in the apparatus to which are due the raising and lowering of the hydraulic grade-line, when the discharge-passage is closed and opened.

16. In a hydraulic impact-engine, the combination of a conduit adapted to supply water from a supply-level or forebay, a draft-tube, a diffuser on the discharge end thereof having a conically-divergent discharge-passage the transverse area of which enlarges toward the discharge-opening, a working chamber in which water may act intermittently, by impact, upon a fluid to which it delivers its momentum, and which is connected with the conduit, mechanism for closing and opening the discharge-passage, and operating means, operatively connected with the closing and opening mechanism, and adapted to be actuated to close and open said mechanism, by the alternations of the total pressure of the water in the apparatus to which are due the raising and lowering of the hydraulic grade-line, when the discharge-passage is closed and opened.

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