No. 671,541. Patented Apr. 9, 1901.

C. N. DUTTON.

HYDRAULIC IMPACT ENGINE.

(Application filed Apr. 12, 1898.)

(No Model.) 10 Sheets—Sheet 1.

FIG. 2.

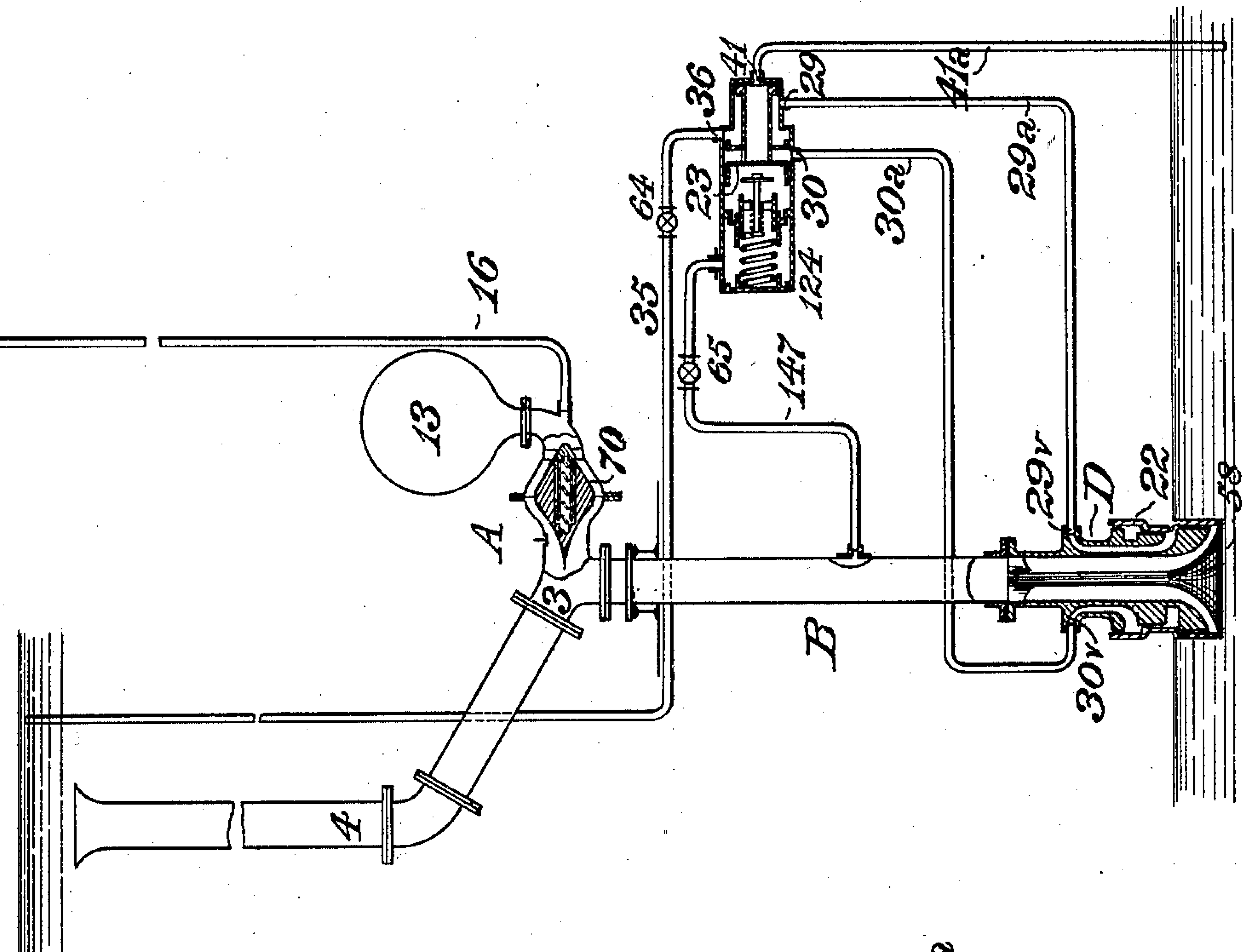

FIG. 1.

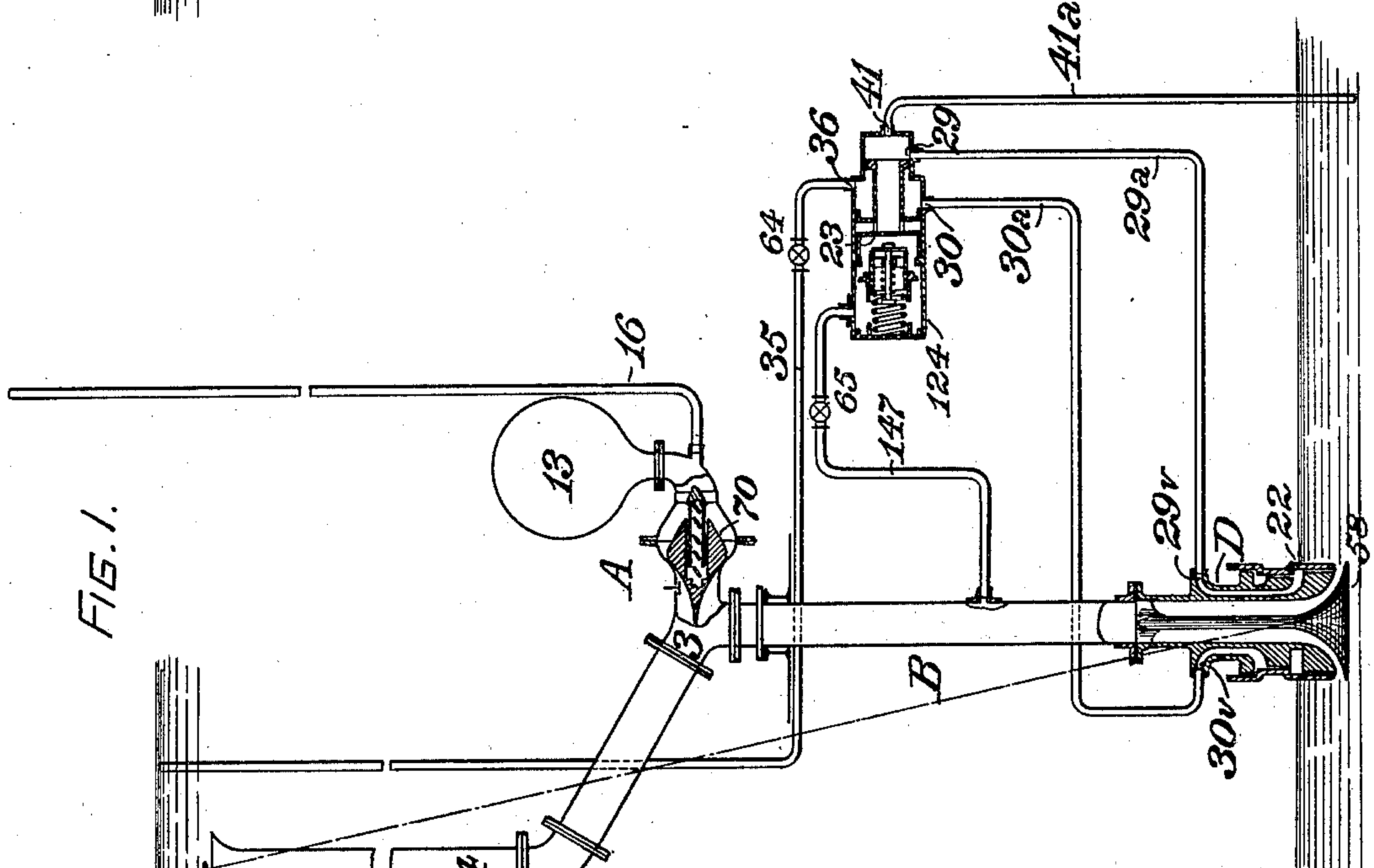

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FIG. 4.

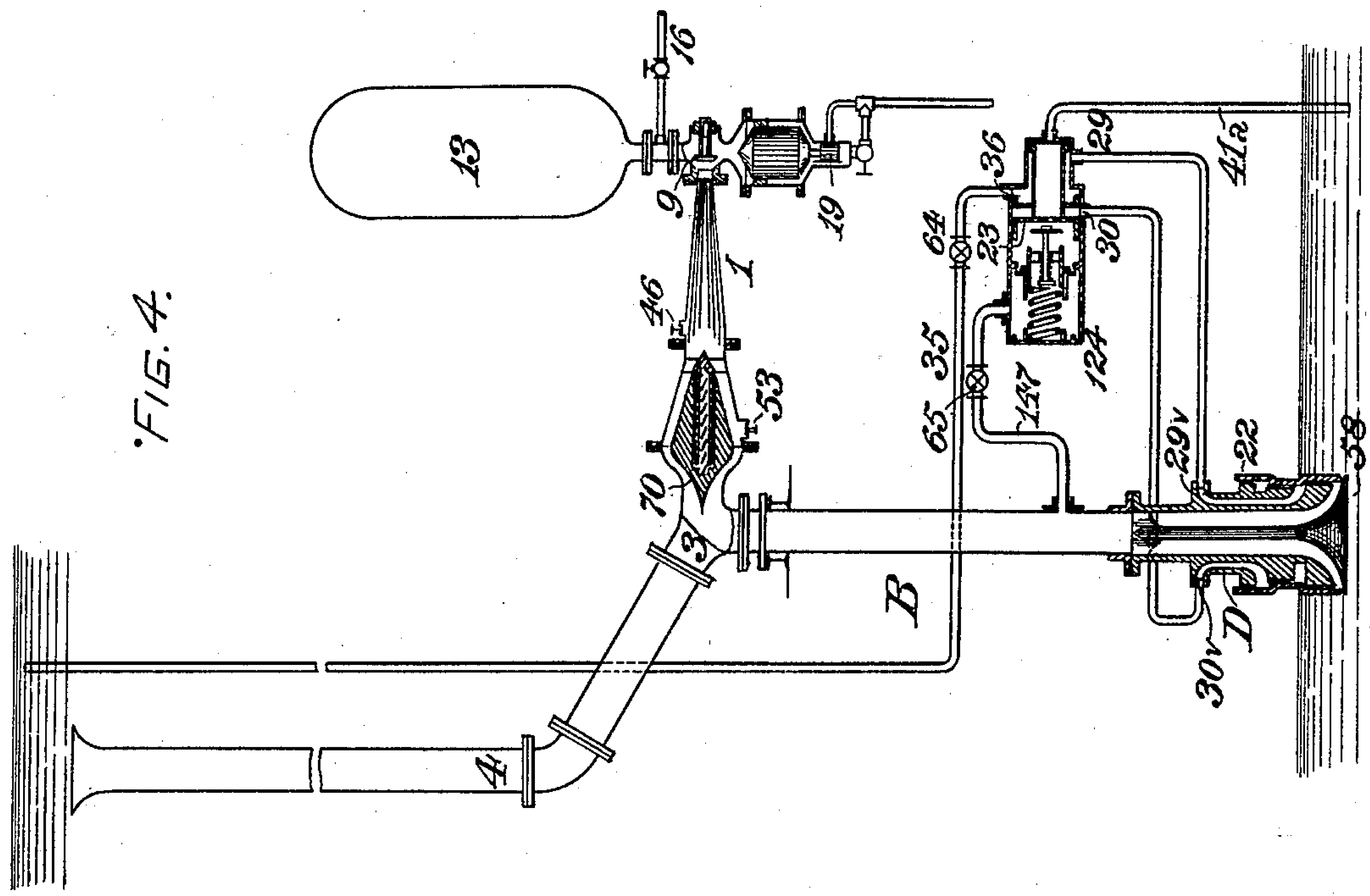
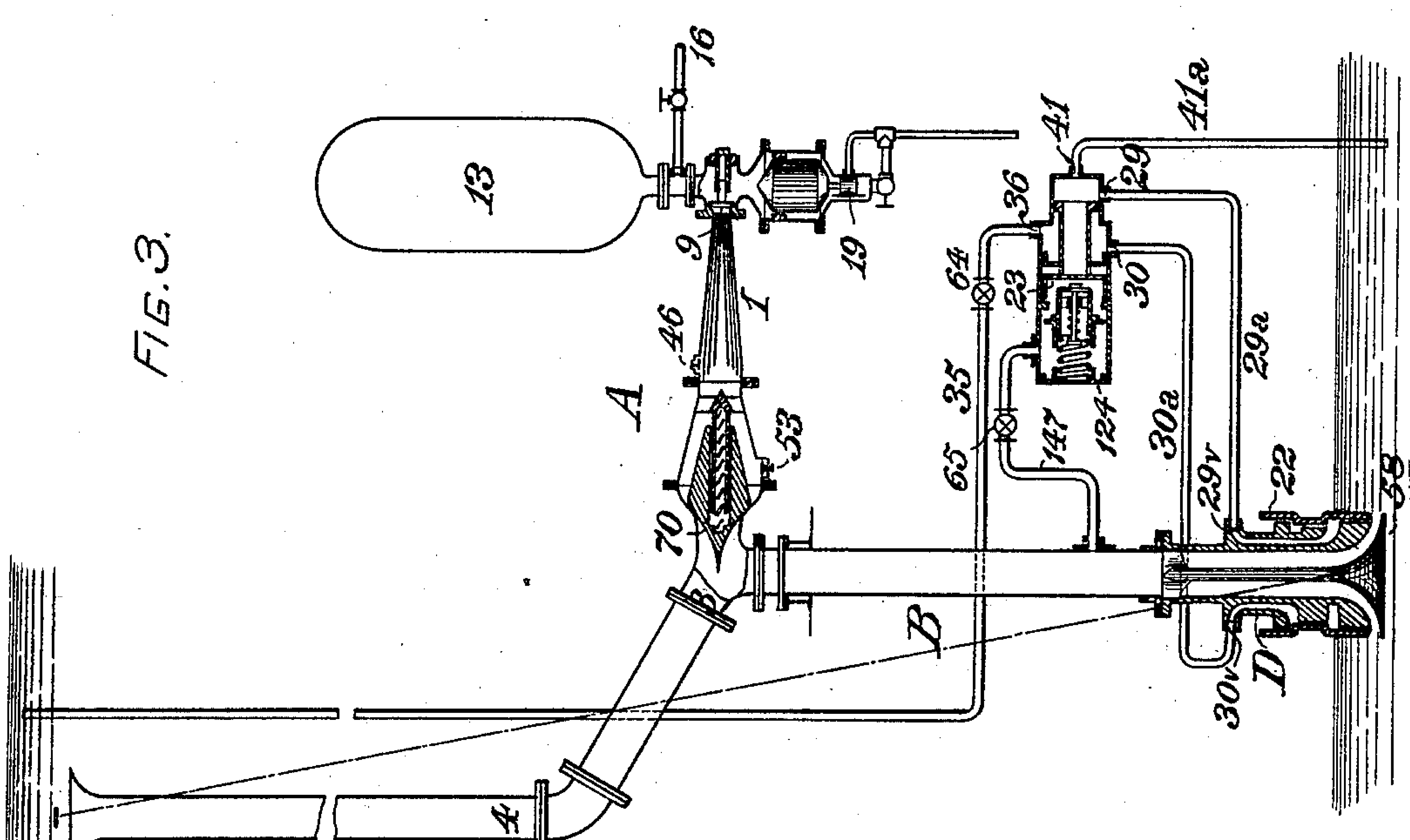


FIG. 3.



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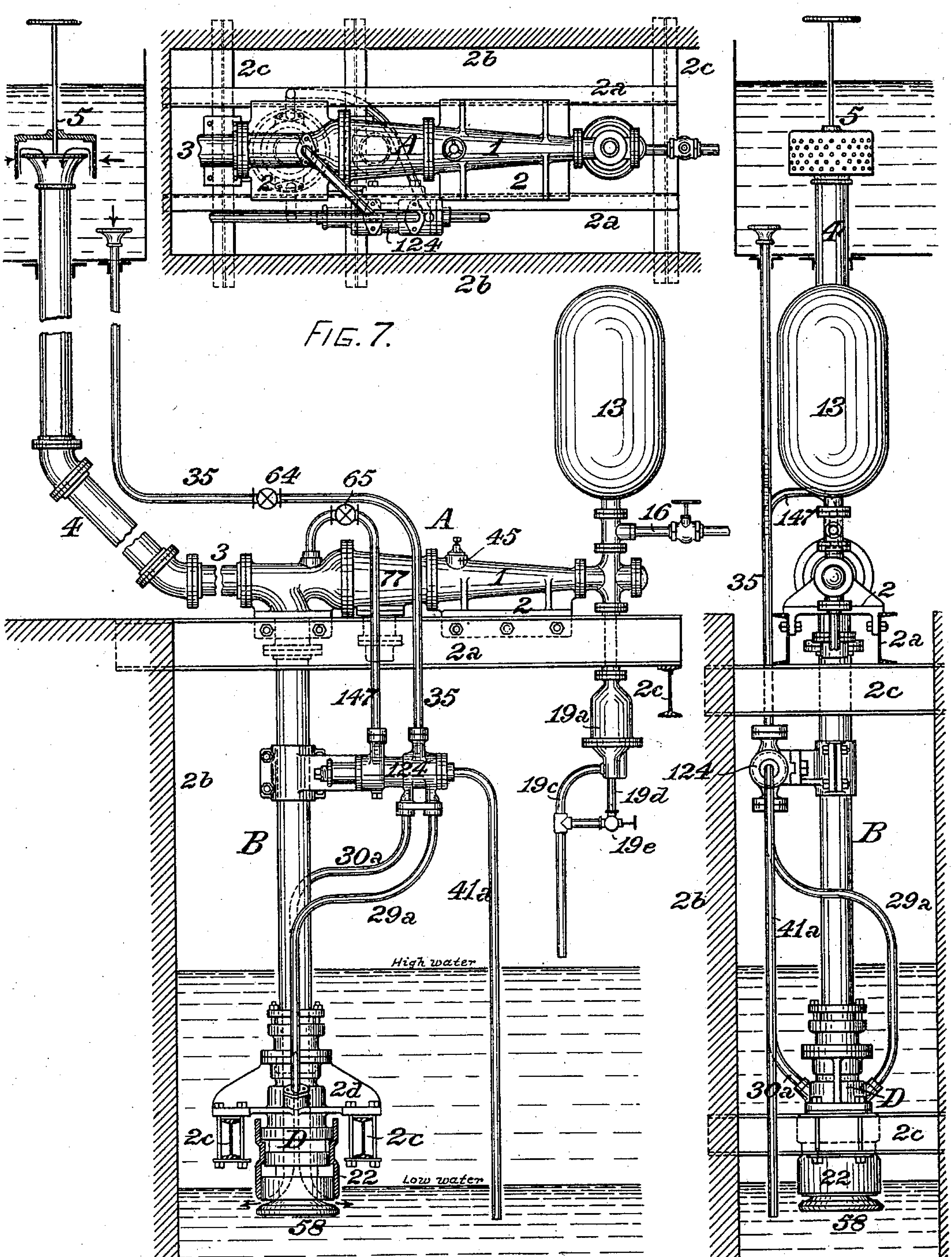

FIG. 7.

FIG. 5.

FIG. 6.

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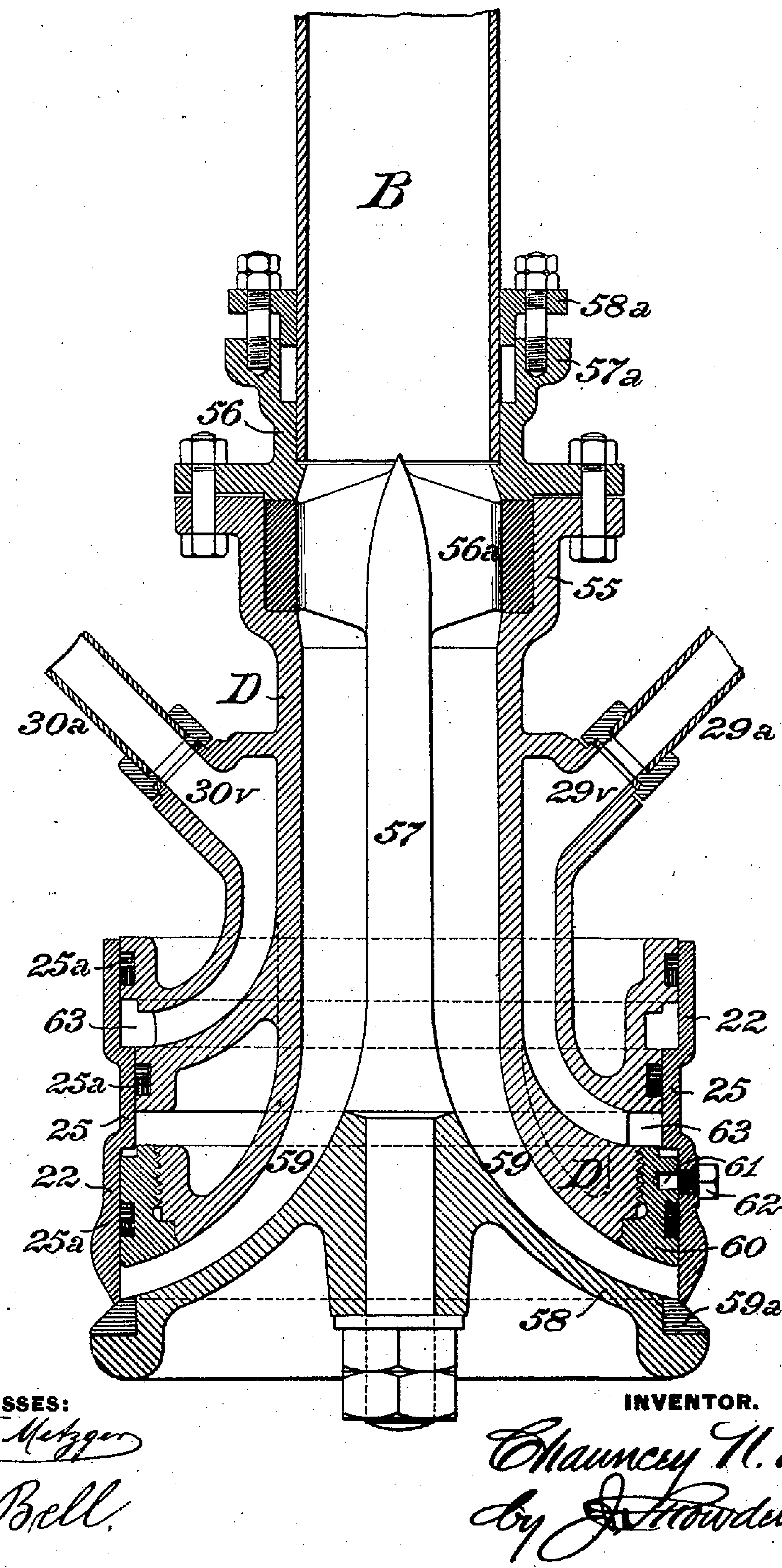
FIG. 8.



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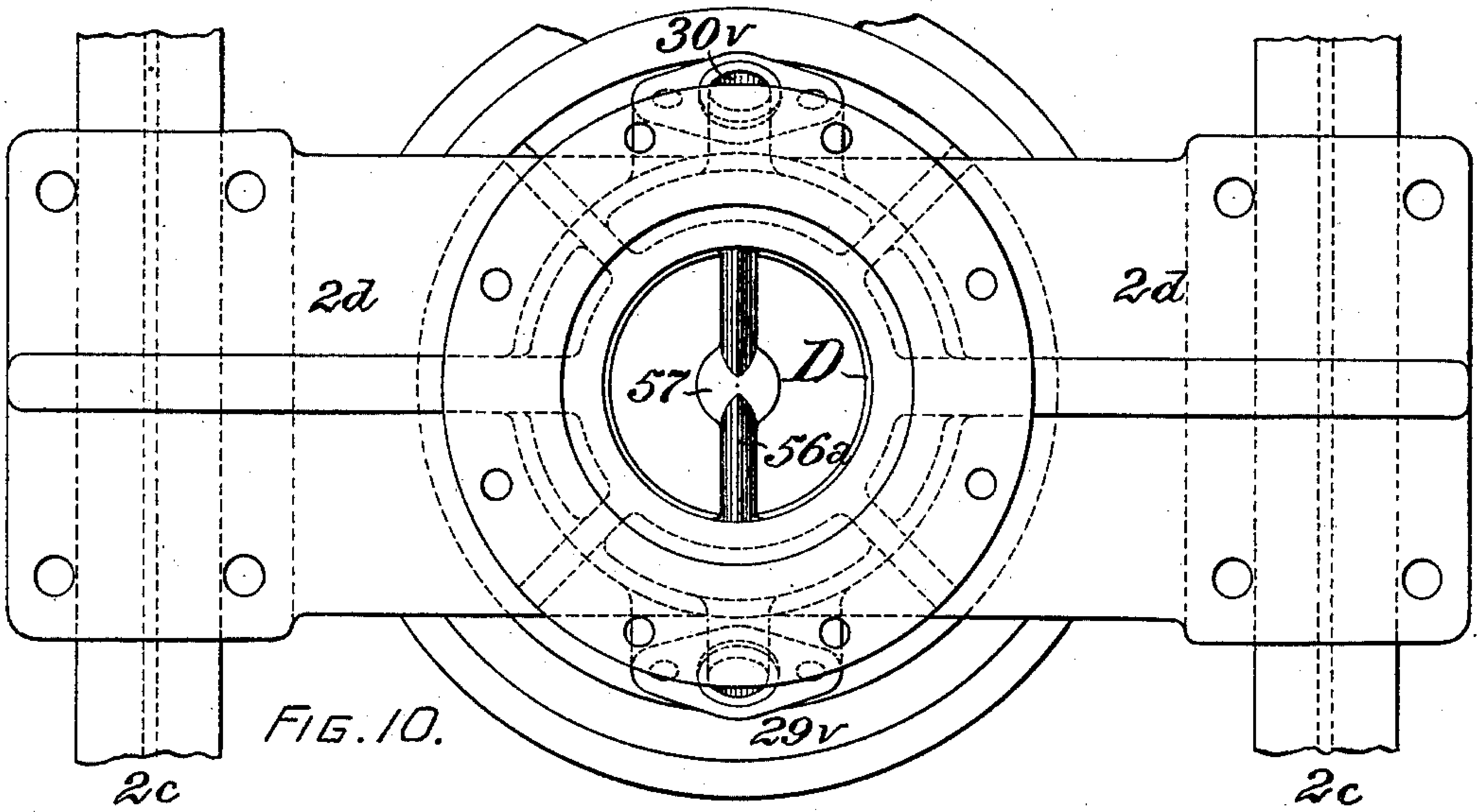

FIG. 10.

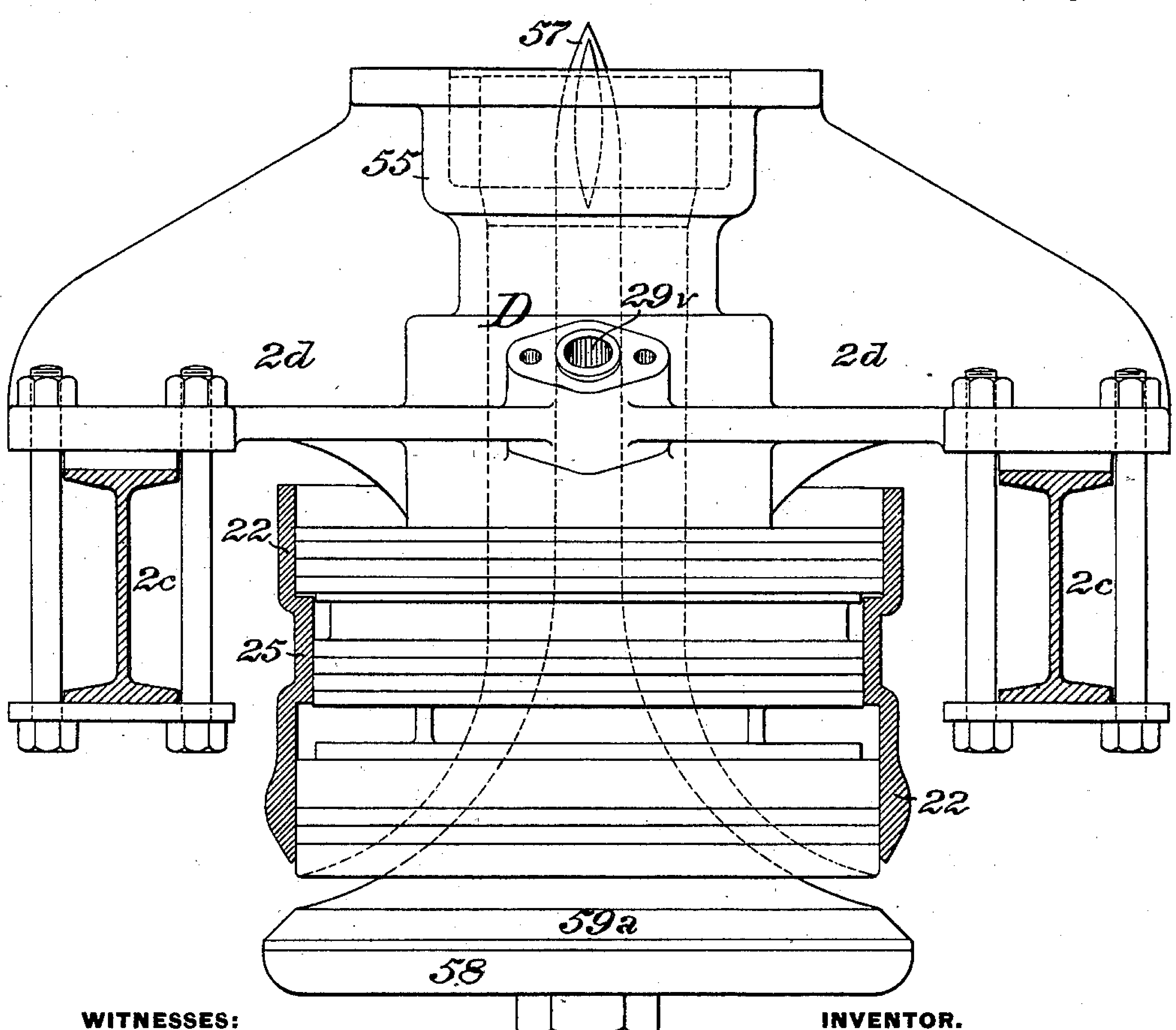

FIG. 9.

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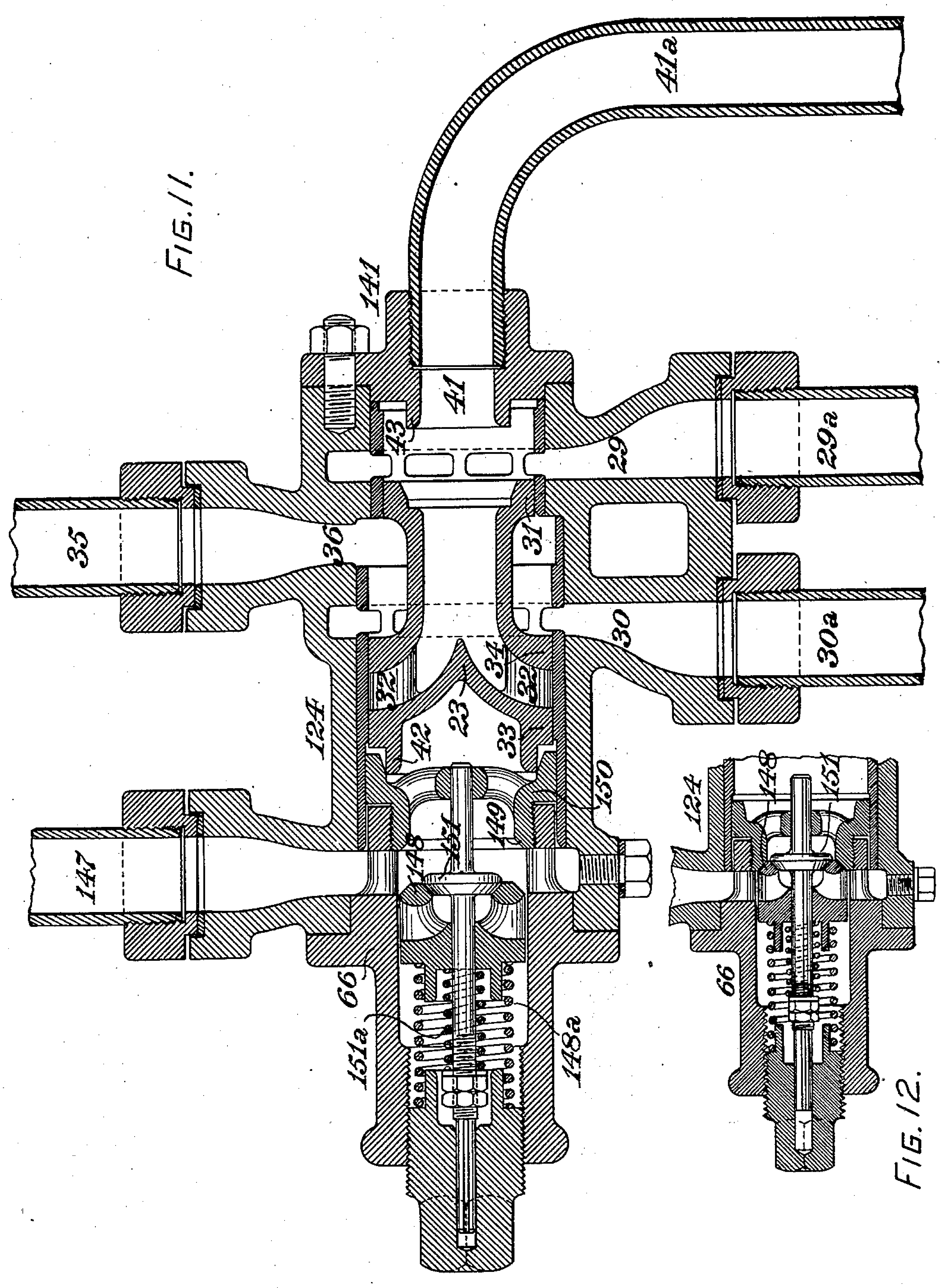

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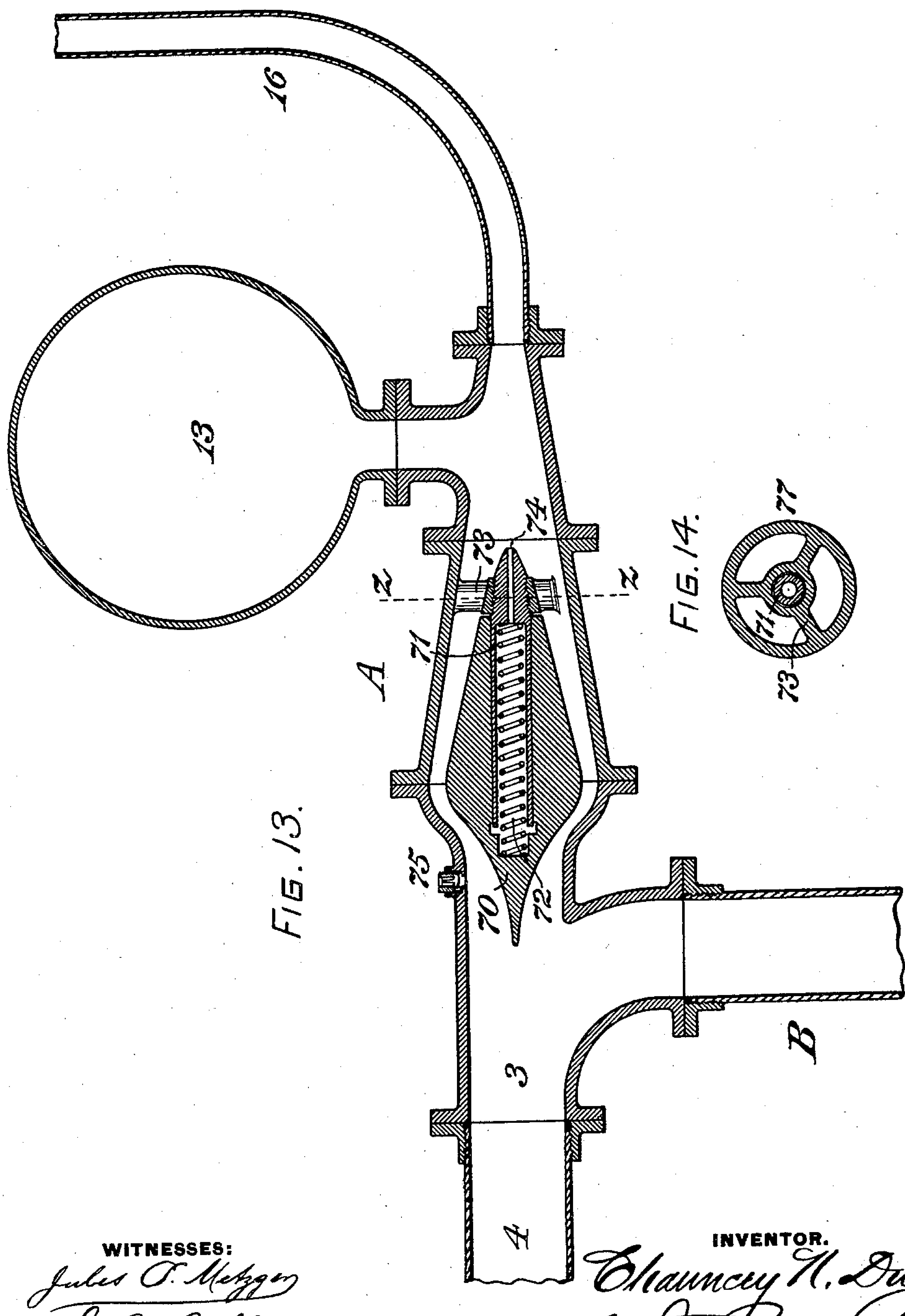

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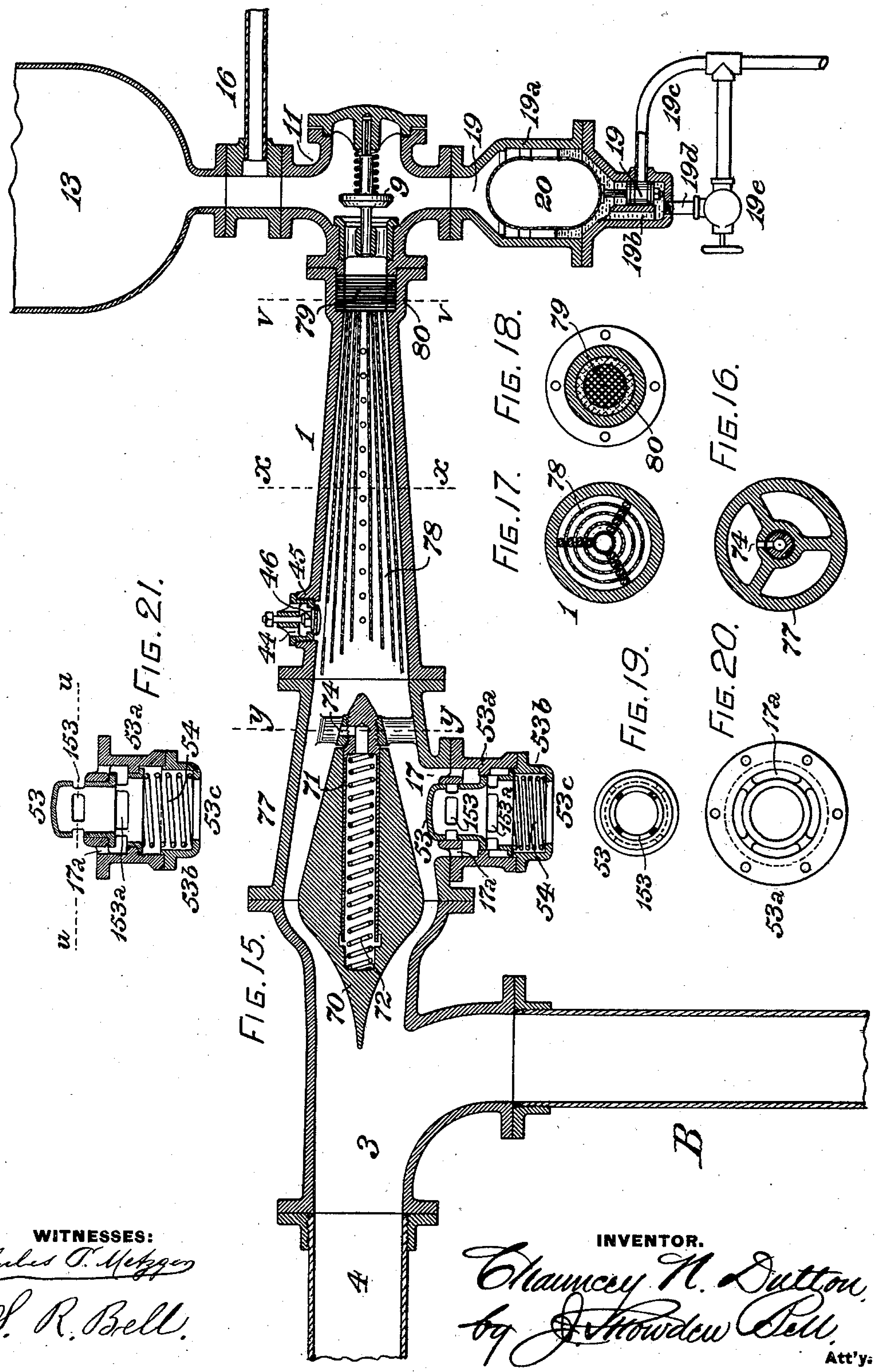

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FIG. 23.

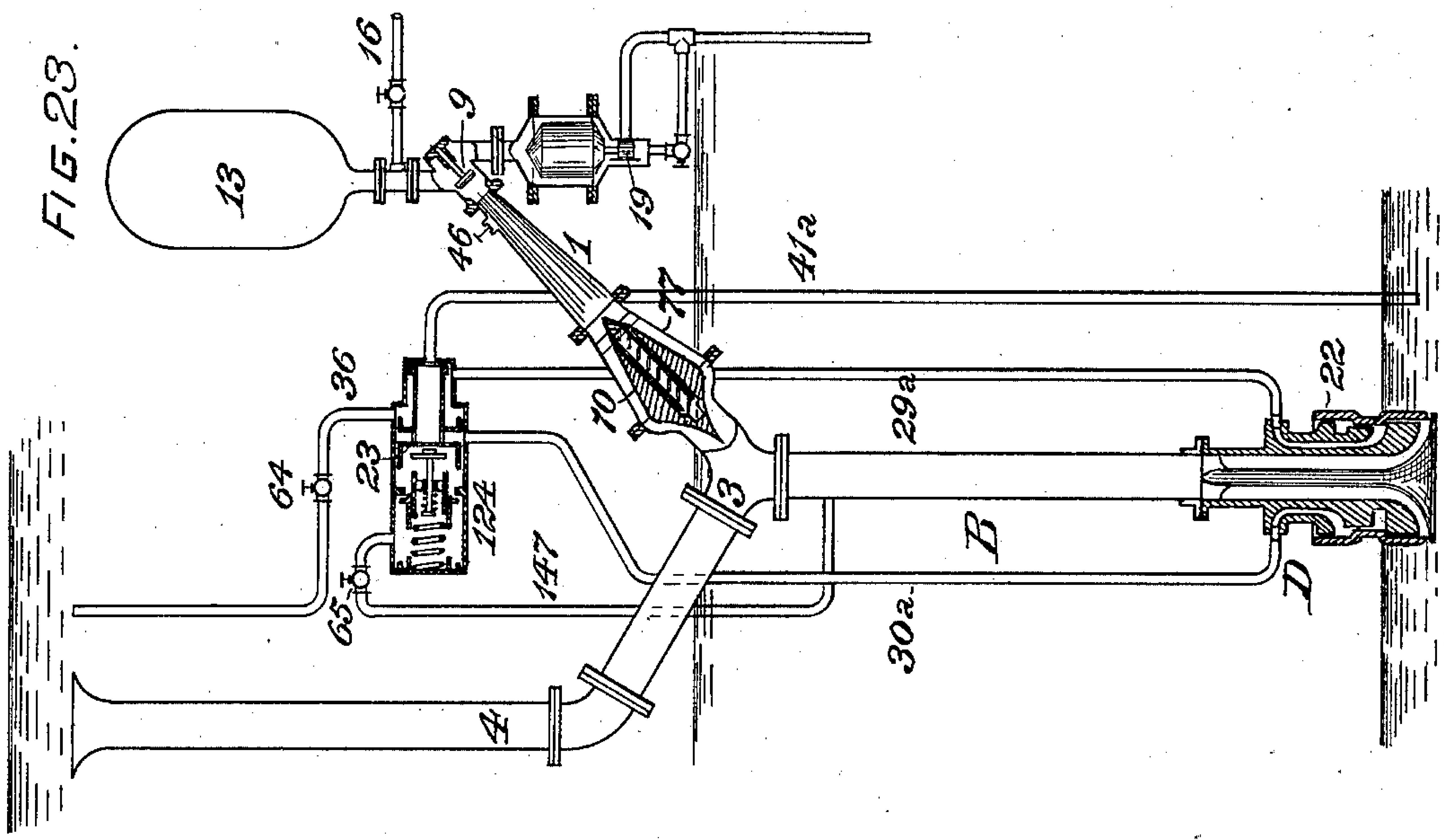

FIG. 22.

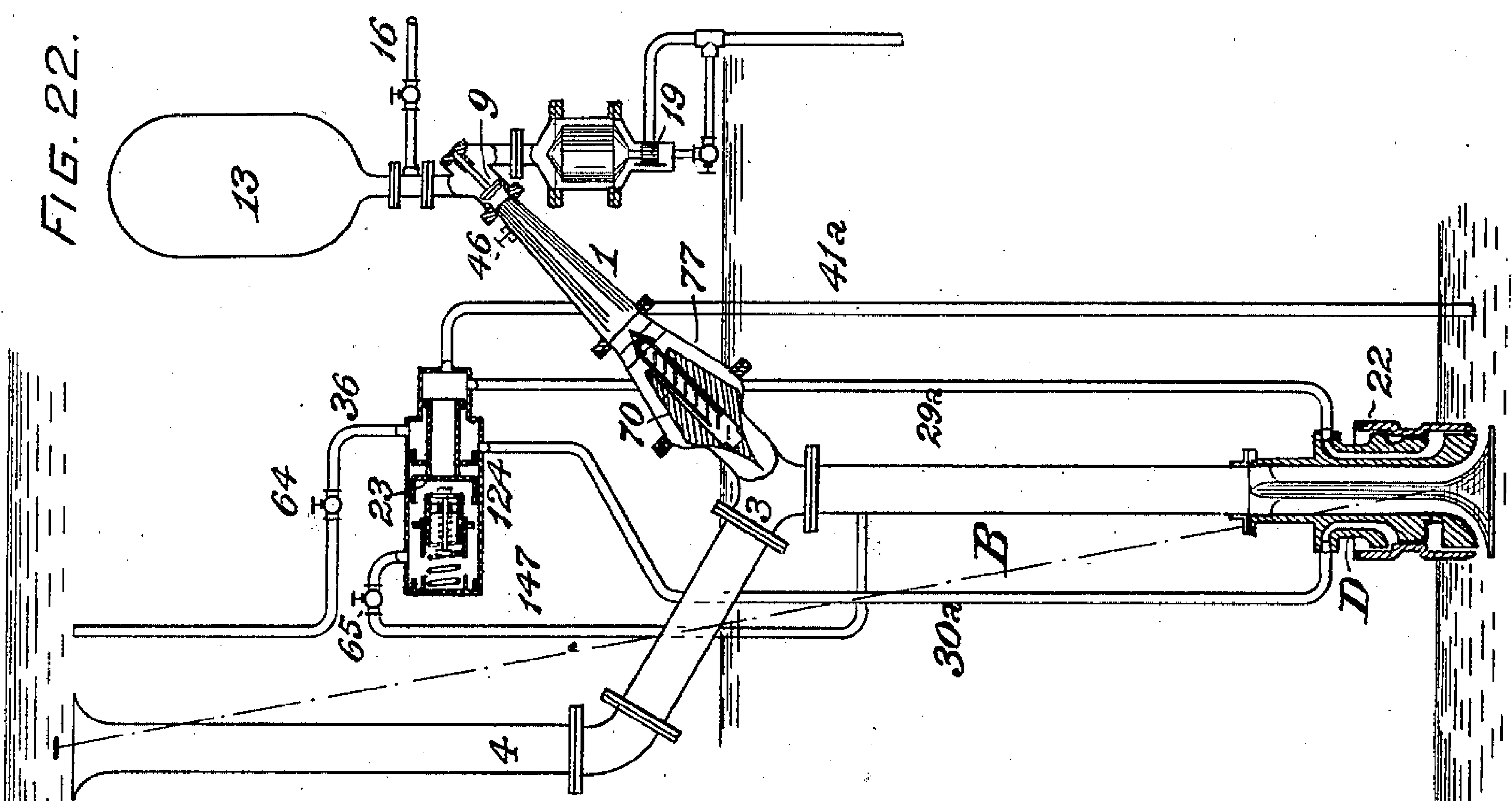

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FIG. 25

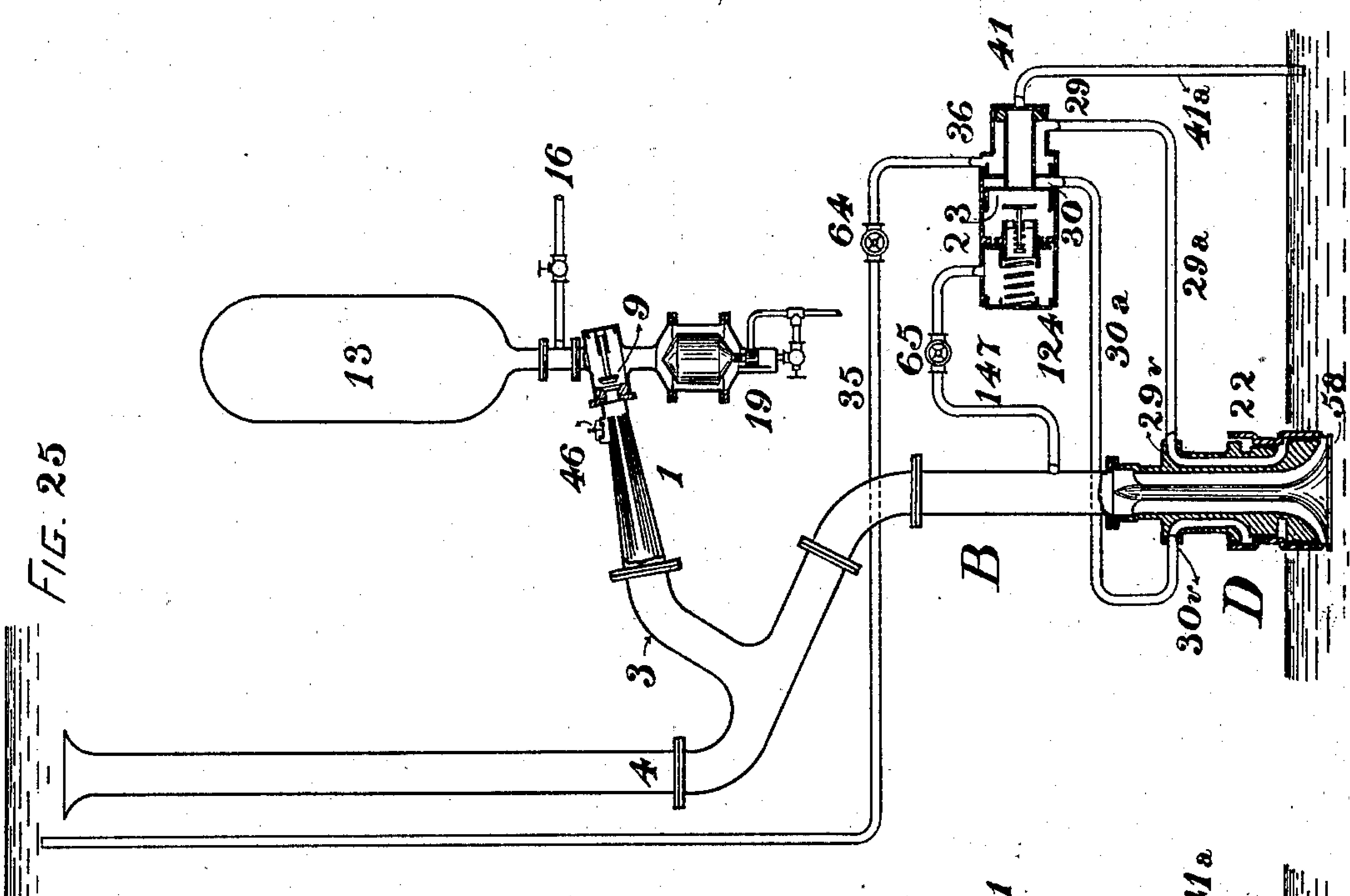
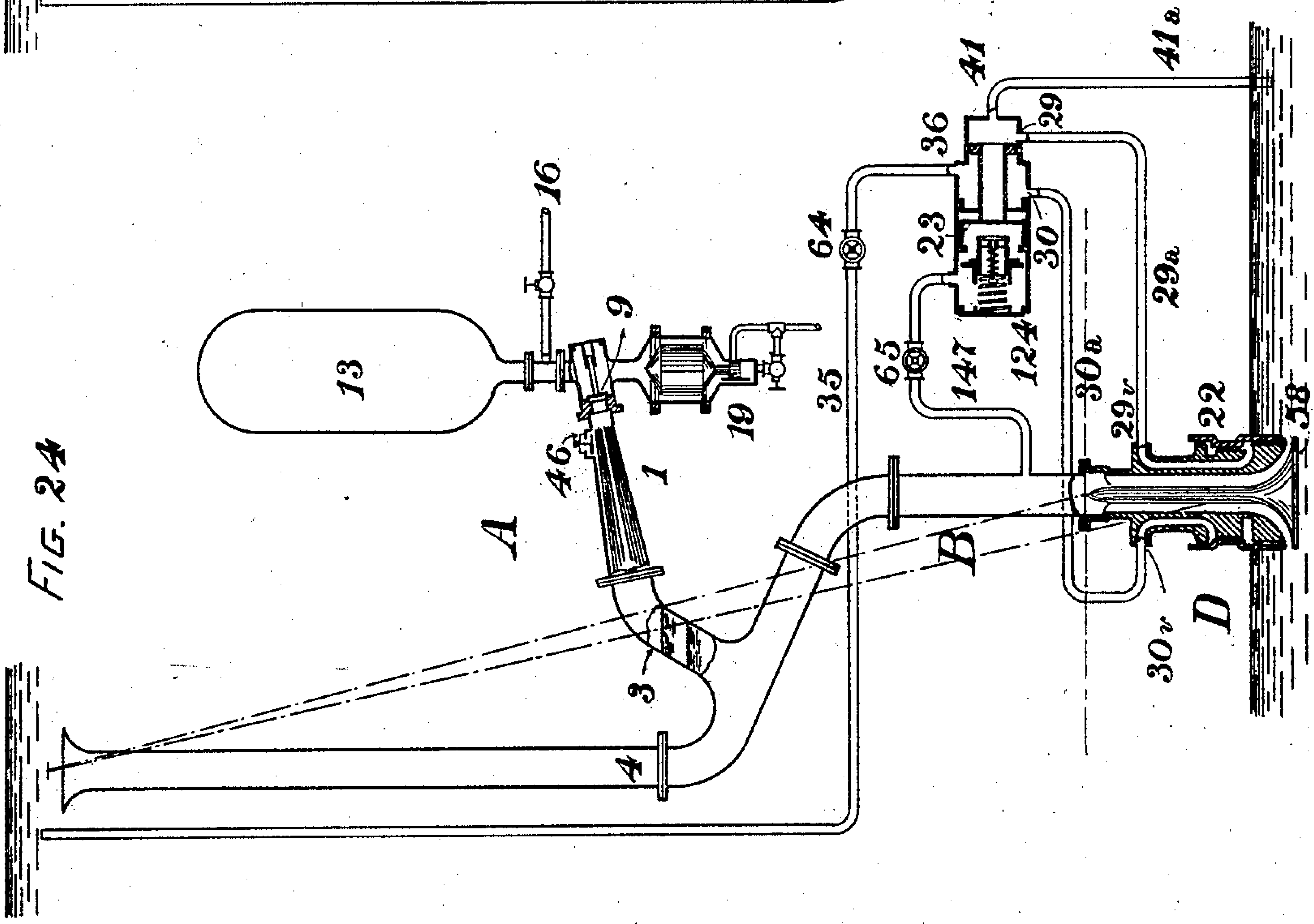


FIG. 24



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UNITED STATES PATENT OFFICE.

CHAUNCEY N. DUTTON, OF YONKERS, NEW YORK.

HYDRAULIC IMPACT-ENGINE.

SPECIFICATION forming part of Letters Patent No. 671,541, dated April 9, 1901.

Application filed April 12, 1898. Serial No. 677,370. (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.

My present invention relates to apparatus of the same general class as and is an improvement upon that which constitutes the subject-matter of Letters Patent of the United States No. 609,087, granted and issued to me under date of August 16, 1898, and is further a specific structural embodiment of the governing and essential principles of that which is set forth in an application for Letters Patent filed by me September 18, 1899, Serial No. 730,824.

The object of my invention is, as in my application Serial No. 730,824 aforesaid, to provide improved facilities for pumping water or effecting the compression of air by the impact of falling water; and my improvement consists in certain novel combinations of mechanical devices hereinafter fully set forth.

The general and characteristic features of an engine embodying my invention 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 formed into a diffuser, which is submerged, and the main valve of the apparatus is there located, surrounding the diffuser in the form shown in the drawings and being movable, so as to open and close the discharge-opening. When the discharge-opening is opened, the water flows through the conduit and establishes its lower hydraulic grade-line, and when the opening 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 and of the varying pressures or alternate pressures and suctions 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 a means for closing and opening the discharge-opening of the diffuser, which is actuated alternately by the raising and lowering of the hydraulic gradient when the discharge-opening is closed and opened, respectively, and which effects through the intermediation of columns of water which it controls the movement of a discharge-governing device. Under my present invention the opening and closing means is in the form of a controlling-valve of the general character of those which are set forth in my Letters Patent No. 609,087 aforesaid and in my Letters Patent No. 609,089, dated August 16, 1898, and which is not in and of itself claimed as of my present invention. This controlling-valve is located above the lower hydraulic grade-line and below the plane of the reservoir-surface, so as to be subject to pressure less than the atmosphere or to "suction" when the diffuser is open and is subject to hydrostatic pressure when the diffuser is closed. The alternate pressure and suction operate the controlling-valve, which in its alternate motions opens ports and admits water alternately to opposite sides of an operating-piston on the main valve, thereby opening it and closing it. When the main valve opens, water flows through the supply-pipe and discharges through the diffuser, speedily acquiring the maximum velocity due to the available head. When such velocity is acquired, the controlling-valve is subject to suction, which reverses it, and thereby admits water to the opposite side of the main-valve piston and closes said main valve. When the main valve closes, the water in the supply-pipe is thereby diverted into the working chamber of the engine, where it does its work by impact. Immediately thereafter the pipes are subject to hydrostatic pressure, by which the controlling-valve is reversed and admits water under pressure to the proper side of the main valve to open it and again begin the cycle of operations, which are thus made truly automatic and positive. The impact of the water can 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 such as set forth in my Letters Patent No. 609,087, before referred to.

In the accompanying drawings, Figures 1 and 2 are diagrammatic views showing an apparatus embodying my invention as adapted to raise water and constituting, in fact, an improved hydraulic ram, Fig. 1 showing the main valve open and Fig. 2 the main valve closed and the apparatus in the act of utilizing the power. Figs. 3 and 4 are similar views showing my invention applied in a hydraulic air-compressor, Fig. 3 showing the main valve open and Fig. 4 showing the main valve closed and the apparatus in the act of compressing air. Fig. 5 is a general side view, Fig. 6 a general end view, and Fig. 7 a general plan, of the apparatus adapted for use as an air-compressor. Fig. 8 is a longitudinal central section through the lower end of the draft-tube, the diffuser, and the main valve. Fig. 9 is a view in elevation and on an enlarged scale of the diffuser with the main valve in section. Fig. 10 is a plan view of the diffuser. Fig. 11 is a longitudinal central section through the controlling-valve; and Fig. 12, a partial section through the same, showing the check-valve in a different position. Fig. 13 is a central section through the functional part of the apparatus adapted for use as a hydraulic ram, and Fig. 14 a section on the line *z z* of Fig. 12. Fig. 15 is a central section through the functional part of the apparatus adapted to act as a hydraulic air-compressor. Figs. 16, 17, and 18 are transverse sections on the lines *y y*, *x x*, and *v v*, respectively, of Fig. 15. Fig. 19 is a transverse section on the line *u u* of Fig. 21. Fig. 20 is a plan view of the drain-valve. Fig. 21 is a detached sectional view of the drain-valve when open. Figs. 22 and 23 are diagrammatic views similar to those of Figs. 3 and 4, showing a modified form of the apparatus which is detailed in Figs. 15 to 21, inclusive. Figs. 24 and 25 are similiar diagrammatic views showing another modification.

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 5 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 functioning portion having suitable bed-plates 2, which rest on beams 2^a, carried by the foundation 2^b and the transverse framing 2^c or in any other suitable manner. The diffuser D, which is shown on an enlarged scale in Figs. 8, 9, and 10, is preferably formed in a casting provided with lugs or arms 2^d for supporting it and attaching it to suitable beams or other means of support. I form an expansion-joint in the draft-tube, preferably made by a socket 55 on the upper end of the diffuser, provided with a flange to which is attached a nozzle 56, having a stuffing-box 57^a, with a gland 58^a, into which the end of the wrought part or pipe connection constituting the adjacent portion of the draft-tube B enters, so that settlement and expansion and contraction can take place without straining the joints. A spider 56^a is supported and swivels in the socket 55, said spider being formed on the upper end of a forged suspender 57, on the lower end of which is secured a mushroom or deflector 58. The tubular portion of the diffuser D is enlarged about the spider and suspender, so as not to restrict the flow, and the lower end is flared, so that the space between the suspender and deflector 58 and the inner surface of the diffuser forms the diffuser-passage 59, which passage enlarges in transverse area from the center toward the discharge-opening in the proper ratio to secure the desired diffuser action.

In order to secure the smooth surfaces and true curves desirable in such apparatus, the inner surface of the diffuser and the concentric surface of the suspender and deflector can be turned. For convenience of construction and in order to secure the nearest possible approximation to perfect action the main valve 22 is located at the lower end of the diffuser D. This valve is in the form of a cylinder, which is turned on the inside and provided with an inwardly-projecting piston 25 near its middle portion, so that it can be moved to and fro by admitting water alternately to the opposite sides of the piston, and it is packed by spring-rings 25^a, which lie in grooves turned in the enlarged end of the diffuser. When the main valve 22 is closed, it seats on a copper or other suitable ring 59^a on the deflector 58, and in order to slip it upon the diffuser the end thereof is provided with a removable ring 60 above the passage 59. After the valve 22 has been slipped upon the diffuser the ring 60 is entered into the end of the valve and screwed on the diffuser, there being sockets 61 formed in said ring and openings, subsequently closed by tap-bolts 62, opposite them in the valve, so that a spanner or other suitable means may be applied to screw said ring on the diffuser.

Water is admitted to the opposite sides of the piston 25 on the main valve 22 by passages 30^v 29^v, which communicate by pipes 30^a and 29^a with the delivery-ports of the controlling-valve 23, to be presently described. The main valve 22 automatically cushions its reciprocating motion at the limits of its stroke, itself choking the exhaust of the water which had operated it. To that end the supply-passages 29^v and 30^v open into annular grooves 63, the height of which is less than the stroke of the valve, so that as the valve approaches the limit of its stroke the piston 25 automatically throttles the exhaust from that end toward which the valve is moving. It will be seen that the pressure of the water in the diffuser will tend to draw the deflector 58 to a central position, and to this end the bearing-surface on the spider 56, on which it is suspended, may be made spherical.

The controlling-valve 23, which is shown on an enlarged scale in Figs. 11 and 12, accords substantially in general operative principle with that set forth in my Letters Patent Nos. 609,087 and 609,089, before referred to. It may be 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 diffuser and be suitably supported either upon the apparatus itself or otherwise, as the exigencies of the case may determine as most suitable. When located as above set forth, it is subject to hydrostatic pressure above atmosphere when the main valve 22 is closed and is subject to pressure less than atmosphere or suction when said valve is open. It is desirable that the supply of fluid to the controlling-valve shall be free from alternations of pressure, and it is therefore shown as provided with a separate supply-pipe 35, connecting it with the reservoir or water-supply, and with a valve 64 for controlling the supply. The movable members of the controlling-valve device are contained in a suitable tubular case 124, having at its smaller end an exhaust-port 41, which opens into a pipe 41^a, extending into the water of the tail-bay below the low-water plane. At the opposite end a pipe 147 connects the interior of the valve-case with either the supply-tube 3 or the draft-tube B, as convenience may dictate, said pipe being controlled by a valve 65. A valve 23 is fitted to reciprocate in the case 124, said valve having a hollow or tubular body, a piston 31, of small diameter, adjacent to the exhaust-port 41, a piston 33, of larger diameter, at the opposite end, an intermediate piston 34, and ports 32 between the pistons 33 and 34, which communicate with the bore of the valve. The supply-pipe 35 connects with a central supply-port 36 for admitting water from the reservoir to the valve between the pistons 31 and 34. A delivery-port 29 is formed between the supply-port 36 and the exhaust-port 41 and communicates by a pipe 29^a with the lower end of the main-valve cylinder, and a second delivery-port 30 is formed on the opposite side of the supply-port 36 and connects by a pipe 30^a with the upper end of the main-valve cylinder. The pistons on the valve are slightly wider than the delivery-ports, so that they can cover and close them, and the reciprocating motion of the valve is cushioned at the limits of its stroke by the functioning of projecting flanges 42 and 43, which at such times form chambers from which the exhaust of fluid is restricted, thus cushioning the motion. The port 41 is preferably formed in a cap 141, which closes the smaller end of the valve-shell, and the opposite end is closed by a cap 66, forming the valve-case for the main check-valve 148, which is shown open in Fig. 11 and closed in Fig. 12. The valve-seat 149 of the main check-valve 148 is preferably formed on a bushing 150, secured to the inner end of the cap 66. The second check-valve 151 has its seat on the main check-valve and is shown seated in Figs. 11 and 12. A spring 148^a normally holds the check-valve 148 seated, and a spring 151^a normally holds the check-valve 151 in contact with its seat on the larger check-valve 148. The two springs are preferably made adjustable, as indicated in the drawings, or in any other preferred manner, as the experience or judgment of the constructor may dictate.

The operation of the controlling-valve is as follows: When in the position shown in Fig. 11, the valve 23 is just completing its stroke from right to left, so as to connect the supply-port 36 with the delivery-port 30 and the delivery-port 29 with the exhaust-port 41, so that water will feed through the pipe 30^a and exhaust through the pipe 29^a to and from opposite sides of the piston 25 on the main valve 22 and close said main valve. The force which moved the valve 23 from right to left in the position shown was the suction exerted upon it by the water flowing through the draft-tube B and diffuser D, owing to the fact that the valve is located above the then obtaining hydraulic grade-line. This force was assisted by the water-pressure on the unbalanced area of the larger piston 34 of the valve and resisted by the elasticity of the spring 148^a and the suction of the column of water in the pipe 41^a. It will be obvious that when the pipe 41^a is full of water and the check-valve 148 is closed the motion from right to left of the valve 23 is resisted by the force of the spring 148^a and the weight of the column of water in the tube 41^a and that before the valve 23 can move, as aforesaid, from right to left the suction upon it must become great enough to overcome the elasticity of the spring 148^a and to unseat the check-valve 148, thus allowing the water to escape from between the valve 23 and the check-valve 148, and also that the force operating the valve 23 must at the same time lift a column of water in the tube 41^a, as otherwise the motion of said valve away from the exhaust-port 41 would create a vacuum in the tube 41^a or in the end of the valve-body adjacent thereto. The pressure of the supply of water on the pistons 31 and 34 is constant, as is also the elasticity of the spring 148^a. 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 valve, is compensated by the variation in the suction in the tube 41^a, or, in more precise language, the atmospheric pressure on the exhaust end of the valve 23 will be diminished proportionately to the height of the column of water which it sustains in the tube 41[a], through which alone the atmosphere can communicate with the exhaust end of the valve. It will be seen, therefore, that the constant force tending to move the valve 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 valve. When the valve has remained in the position shown for a sufficient time to cause the main valve 22 to be closed, the closure of said main valve causes the machine to function by the pressure of impact, and immediately thereafter the hydrostatic pressure obtains in the supply and draft tubes, which pressure is conveyed through the pipe 147 to the end chamber of the shell of the controlling-valve behind the check-valve 148, which is at such time seated, as shown in Fig. 12, and under the smaller check-valve 151. As soon as this pressure has become great enough to overcome the resistance of the spring 151[a] and raise the valve 151 the water from the pipe 147 transmits the hydrostatic pressure which then obtains in the apparatus to the large end piston 33 of the controlling-valve 23 and moves the valve from left to right, the small end piston 31 at such time passing over the delivery-port 29 and the intermediate piston 34 passing over the other delivery-port 30, so that the delivery-port 29 is connected with the supply-port 36 and the delivery-port 30 is connected with the valve-port 32 and through the central bore of the valve with the exhaust-port 41. When the valve 23 is in this position, the water-supply feeds through the port 29 and pipe 29[a] and exhausts through the pipe 30[a] and port 30 to and from the lower and upper sides of the piston 25 on the main valve, which is raised and opened, allowing water to flow through the draft-tube and diffuser and again instituting the cycle of operations.

The functional portion A of the apparatus (illustrated in fuller detail in Figs. 13 to 20, inclusive) is varied to adapt the machine for operation in the same manner in both cases, either as a hydraulic ram or as an air-compressor, the detail for hydraulic-ram operation being shown in Figs. 13 and 14, the essential parts shown in these views consisting in a supply check-valve 70, an air-chamber 13, and a lift-pipe 16. The supply check-valve, which is preferably made of hard rubber, slides on and is guided on a tubular central stem 71 and is seated by a spring 72 in said stem. The stem 71 may be secured in and supported by a spider 73. The preferred detail is similar to that shown in the drawings, so as to give easy and unbroken flow of water. The stem 72 should be provided with an inlet-passage 74 to admit water freely to its interior and prevent suction and resistance to the movement of the valve. The operation of this form of the apparatus is in all other respects similar to that of the common hydraulic ram. When the main valve 22 is closed, the pressure of water in the conduit 4 and supply-tube 3 unseats the check-valve 70 and compresses the air in the air-chamber 13. As soon as all the momentum of the water has been delivered to the compressed air the apparatus becomes subject to hydrostatic pressure, the check-valve 70 seats, and the water is forced up through the delivery-pipe 16 by the expansion of the air in the air-chamber 13, and the controlling-valve 23 is reversed, causing the main valve to open and again institute a cycle of operations. Air in desired quantity to replace that carried away by the water delivered through the pipe 16 can be supplied by a small supply-valve 75, located in front of the check-valve 70. While this valve 75 does the same duty as the ordinary snifter-valve, it is more positive in its action and easier to regulate, because air is forced through said valve into the supply-tube when the pressure obtaining therein is less than atmosphere, which condition obtains when water is discharged through the diffuser.

Figs. 15 to 21, inclusive, show a form of the apparatus preferred for use where it is desired to use the waterfall for compressing air for commercial uses. The supply check-valve 70 is carried on a tubular stem 71 similar to that above described, except that the port 74 does not extend in a straight line, but is turned upward, so that the cavity of the tubular stem 71 and valve 70 will be always full of water. Were it possible for air to enter them freely the force might be wasted in compressing the air in said cavities. As in my Letters Patent No. 609,087, before referred to, I provide a conical compressing-chamber 1, connected at its larger end with the casing 77, in which the supply check-valve 70 is carried, and at its smaller end with a casing 11, containing the reservoir check-valve 9 and connecting with the air-reservoir 13 and with a drain 19. As in said patent, I also provide for the entry of air into the compressing-chamber by an air-supply valve 46, opening inwardly and closing an air-supply port 44 in the compressing-chamber 1, and I also provide a passage 17 for draining the dead-water out of the compressing-chamber 1 by a drain-valve 53. The detail of these valves differs, however, from that shown in said patent, the air-supply valve 46 being made an assembling-unit, which can be screwed into a socket 45. The drain-valve 53, together with its shell, is also made into an assembling unit. To this end it is made tubular. Its seat is formed in a removable cylindrical shell 53[a], which is bolted at one end to the casing 77 and is provided at its opposite end with a detachable cap 53[b], having a central opening 53[c] for the discharge of the water, and inclosing a spring 54, which holds the drain-valve open, except when subject to pressure on its inner side. The drain-valve 53 is in the form of two connected cylinders of different diameters in order to economize space. When the valve is in its highest position, as shown in Fig. 21, its upper ports 153 open directly into the interior of the shell 77 and its lower ports 153^a connect therewith by the annular passage 17^a. In my Letters Patent No 609,087 reference is made to the cooling effect on the compressed air of the tapering walls of the air-compressor and the concentric deflector 40. As therein recited, it is well known that when air is compressed its latent heat becomes sensible heat and its temperature is raised, and unless such rise of temperature is counteracted by cooling the air a great loss of power results. Compression without cooling is termed "adiabatic." Compression with complete cooling is termed "isothermic" and is the economical method, but has not been perfectly done in any apparatus heretofore invented, so far as I am aware. Air being a non-conductor of heat and not radiating it, it is obvious that a particle of air can only be cooled by bringing it into intimate contact with a cold object. This, as set forth in said Letters Patent No. 609,087, is accomplished in some measure by the annular form of the compression-chamber, in which each particle of air would come into frequent contact with the cold walls of the chamber during compression and give up its heat to them to be subsequently carried away by the water. Improved apparatus for this purpose, which will attain isothermic compression more nearly than has heretofore been accomplished, is exemplified in Figs. 15 to 18, inclusive, in which a metal cooler 78, in the instance shown consisting of a plurality of concentric sheet-metal bodies, is located in the compressing-chamber 1. These can be of any suitable material—as, for example, sheet-brass—and can be either drawn or rolled in sections and suitably assembled into a unit, which can be inserted in the compressing-chamber when the apparatus is assembled. The sheets of metal constituting the cooler may be as many as desired and the spaces between them sufficiently small to insure frequent and intimate contact between each particle of air and a part of the cooler during compression, so that the heat previously latent will be absorbed immediately when it is set free. Where a very high temperature might be developed, an additional cooler may be provided in the form of disks of wire-cloth 79 or rings carrying cross-wires, which are inserted in an enlarged end 80 of the compression-chamber 1, adjacent to the shell 11, with which its smaller end is connected, and as close as may be to the check-valve 9, so that all the latent heat set free during compression will be absorbed either by the walls of the compressing-chamber, by the sheet-metal cooler 78, or by the additional wire coolers 79, such heat being absorbed and carried away by the water at the next stroke of the apparatus.

The air-cooling devices above described are not claimed as of my present invention, and the same are set forth and claimed in a separate application filed by me May 16, 1898, Serial No. 680,816.

The drainage of entrained water out of the air-reservoir 13 is provided for by a valve 19, located below the same, said valve differing from that shown in Letters Patent No. 609,087 in the particular of being a balanced piston-valve lifted, as in said patent, by a float 20 when water accumulates in the chamber containing the float. To this end a passage 19^b extends from the float-chamber 19^a below the valve 19, so as to balance the pressures on its opposite sides. When the valve 19 is elevated by the float, water is discharged through a pipe 19^c. The discharge of exceedingly unusual quantities of water is provided for by a branch 19^d, controlled by a valve 19^e, which can be opened by hand at such times to discharge such quantities of water and to bring the water-level below the bottom of the float 20, so as to restore the initial volume of air therein at the same pressure as obtains in the reservoir 13, this device providing for maintaining the buoyancy of the float or restoring the same should it be impaired.

The operation of the apparatus in compressing air is as follows: When the main valve 22 is open, the check-valve 70 is closed by the pressure of the spring and atmospheric pressure upon the back of said valve. Water discharges through the diffuser D and draft-tube B until it attains the full velocity due to the available head, whereupon the controlling-valve 23 is reversed and water under pressure is admitted therefrom upon the top of the operating-piston 25 to the main valve 22 to close it. When the main valve is closed, the current of water is diverted, and unseating the check-valve 70 it enters the functioning portion or working chamber A of the machine, exerts pressure upon the drain-valve 53 and air-supply valve 46, by which said valves are closed, and compresses the air charge in the compressing-chamber 1. As soon as the pressure in the compressing-chamber 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 can be drawn as needed through the service-pipe 16. As the air is compressed it is forced from the large end of the compressing-chamber to the small end thereof and passes through the narrow spaces between the walls of the compressing-chamber and the cooler and between the bodies comprising the latter, which absorb the latent heat as soon as it is set free, attaining as nearly as possible the isothermic compression. After compression is effected the apparatus tends to attain a condition of equilibrium, in which all its parts are subjected to hydrostatic pressure, the check-valve 70 is seated, the controlling-valve 23 is reversed, and a new cycle of operations is begun.

In the form of air-compressor shown in Figs. 1 and 2 a considerable loss of power may result in some instances from the fact that the water from the compressing-chamber 1 after doing its work is drained out and falls from the elevation of the compressing-chamber and the drain-valve 53 to the water-surface of the tail-bay. Where the machine is intended to compress small volumes of air to high pressure by a high head of water, this loss would be so small as to be negligible; but in apparatus intended to compress large volumes to low pressures with a low head of water it might amount to a considerable percentage of the total available power. To obviate this loss, I provide a structural modification of the apparatus shown in Figs. 22 and 23, in which the compressing-chamber is upwardly inclined at a greater or less angle, preferably one of about forty-five degrees. The air-supply valve 46 is located at the small upper end of the compressing-chamber 1, and the compressing-chamber is drained through its large open end and the tube 3, the valve 70 remaining open for that purpose and the drain-valve 53 being dispensed with. In this construction the check-valve 70 is made lighter than water, so that when the chamber 77 is filled with water the valve 70 will float into its highest position and unseat and will remain unseated until nearly all the water has drained out of the chamber 77, when the valve will be seated by its own weight. The operation of this form of the apparatus is as follows: When the main valve 22 is open and the check-valve 70 seated, water from the reservoir flows through the draft-tube and diffuser and acquires the velocity due to the available head. The controlling-valve 23 then reverses and closes the main valve, which diverts the flowing water into the functional portion or working chamber A of the apparatus, unseating and lifting the check-valve 70 and compressing the air in the chamber 1, forcing it into the reservoir 13, as in the instance heretofore described. Immediately thereafter hydrostatic pressure obtains in the apparatus, the valve 23 reverses, the main valve is opened, and water flows out through the diffuser D. As the flow acquires velocity the hydraulic grade-line lowers until it falls below the point of junction of the supply-conduit 4, feed-pipe 3, and draft-tube B, at which time the water in the supply-tube 3, valve-chamber 77, and air-compressing chamber 1 exerts a greater pressure at the point of junction than is exerted by the water from the reservoir. The body of water, therefore, in said chambers will then drain out and will do useful work by aiding to give velocity to the water in the draft-tube, and when the water is almost drained out of the chambers the check-valve 70 will seat by its weight and water will begin to discharge from the reservoir, and the discharge will attain the full velocity due to the head, the valve 23 will reverse, the main valve will be closed, and a new cycle of operations will be begun.

Figs. 24 and 25 show a simpler form of apparatus for accomplishing the purposes accomplished by the construction just described. In this form of apparatus the check-valve 70 is omitted, its function being discharged by water which remains in the supply-tube 3. This is rendered practicable by disposing the conduit 4, draft-tube B, and supply-tube 3 in such a form that when the discharge is in full action through the discharge-opening 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 this type of the apparatus is as follows: 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 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 into the conduit. When the main valve 22 is closed, the water is diverted through the supply-tube 3 into the compressing-chamber 1, where it compresses air, as in the other forms of apparatus, and thereafter the hydrostatic pressure obtains for an instant. When the main valve 22 is again opened, the hydraulic grade-line falls, and as soon as it has fallen so that the junction of the compressing-chamber with the supply-tube 3 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, sealing it and preventing indraft of air into the conduit.

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

1. In a hydraulic impact-engine, the combination substantially as set forth, of a conduit for the supply of water a working chamber in which water may act intermittently by impact upon a fluid to which it delivers its momentum, and communicating with the supply-conduit, a draft-tube leading from the working chamber to a lower discharge-level, a valve for effecting the intermittent supply of water delivered by the supply-conduit, to the working chamber, and pipe connections through which the valve is actuated, in alter-

nately opposite directions, by pressure from a head of water and by suction in the draft-tube, respectively.

2. In a hydraulic impact-engine, the combination, substantially as set forth, of a conduit for the supply of water, a working chamber in which water may act intermittently by impact upon a fluid to which it delivers its momentum, and communicating with the supply-conduit, a draft-tube leading from the working chamber to a lower discharge-level, a main valve governing the discharge-opening of the draft-tube, a controlling-valve actuated in alternately opposite directions by fluid-pressure from a head of water and by suction in the draft-tube, and pipe connections, governed by the controlling-valve, through which fluid-pressure is applied to effect the alternate opening and closure of the main valve.

3. In a hydraulic impact-engine, the combination, substantially as set forth, of a conduit for the supply of water, a working chamber in which water may act intermittently by impact upon a fluid to which it delivers its momentum, and communicating with the supply-conduit, a draft-tube leading from the working chamber to a lower discharge-level, a controlling-valve located below the plane of supply to the conduit and above the hydraulic grade-line which obtains when the draft-tube is open for water-discharge, pipe connections through which the controlling-valve is actuated, in alternately opposite directions, by pressure from a head of water and by suction in the draft-tube, respectively, a main valve governing the discharge-opening of the draft-tube, and pipe connections, governed by the controlling-valve, through which fluid-pressure is applied to effect the alternate opening and closure of the main valve.

4. In a hydraulic impact-engine, the combination, substantially as set forth, of a conduit for the supply of water, a working chamber in which water may act intermittently by impact upon a fluid to which it delivers its momentum, and communicating with the supply-conduit, a draft-tube leading to a lower discharge-level, a main valve governing the discharge-opening of the draft-tube, a piston fixed to said main valve, a controlling-valve actuated in alternately opposite directions by fluid-pressure from a head of water and by suction in the draft-tube, and pipe connections, governed by the controlling-valve, through which fluid-pressure is alternately supplied to and exhausted from opposite sides of the main-valve piston.

5. In a hydraulic impact-engine, the combination, substantially as set forth, of a conduit for the supply of water, a working chamber in which water may act intermittently by impact upon a fluid to which it delivers its momentum, and communicating with the supply-conduit, a draft-tube leading to a lower discharge-level, a diffuser connected to the draft-tube, a main valve governing the discharge-opening of the draft-tube, a controlling-valve actuated, in alternately opposite directions, by fluid-pressure from a head of water and by suction in the draft-tube, and pipe connections, governed by the controlling-valve, through which fluid-pressure is applied to effect the alternate opening and closure of the main valve.

6. In a hydraulic impact-engine, the combination, substantially as set forth, of a conduit for the supply of water, a compressing-chamber communicating therewith, a draft-tube leading to a lower discharge-level, an air-supply passage opening into the compressing-chamber, a reservoir, a check-valve, controlling communication between the compressing-chamber and the reservoir, a main valve governing the discharge-opening of the draft-tube, a controlling-valve actuated, in alternately opposite directions, by fluid-pressure from a head of water and by suction in the draft-tube, and pipe connections, governed by the controlling-valve, through which fluid-pressure is applied to effect the alternate opening and closure of the main valve.

7. In a hydraulic impact-engine, the combination, substantially as set forth, of a conduit for the supply of water, a compressing-chamber communicating therewith, a draft-tube leading to a lower discharge-level, a supply check-valve controlling communication between the compressing-chamber and the supply-conduit, an air-supply passage opening into the compressing-chamber, a reservoir, a check-valve controlling communication between the compressing-chamber and the reservoir, a discharge-passage for the release of water from the compressing-chamber, a main valve governing the discharge-opening of the draft-tube, a controlling-valve actuated, in alternately opposite directions, by fluid-pressure from a head of water and by suction in the draft-tube, and pipe connections, governed by the controlling-valve, through which fluid-pressure is applied to effect the alternate opening and closure of the main valve.

8. In a hydraulic impact-engine, the combination, substantially as set forth, of a conduit for the supply of water, a compressing-chamber communicating therewith and inclined upwardly therefrom, so as to be drained into a draft-tube, an air-supply passage opening into the compressing-chamber, a draft-tube leading to a lower discharge-level, a reservoir, a check-valve controlling communication between the compressing-chamber and the reservoir, a main valve governing the discharge-opening of the draft-tube, a controlling-valve actuated, in alternately opposite directions, by fluid-pressure from a head of water and by suction in the draft-tube, and pipe connections, governed by the controlling-valve, through which fluid-pressure is applied to effect the alternate opening and closure of the main valve.

9. In a hydraulic impact-engine, the com-

bination, substantially as set forth, of a compressing-chamber, a drain-valve chamber communicating therewith by a central and lateral ports, a drain-valve fitting in said casing and having a tubular body, a portion of which fits the central port of the valve-chamber and another portion fitting a larger bore thereof, and lateral ports in each portion of its body, and an unseating-spring bearing on the drain-valve.

10. In a hydraulic impact-engine, the combination, substantially as set forth, of a draft-tube, a diffuser connected thereto, and having a tubular body, and external passages terminating in annular grooves at different levels thereon, a deflector suspended in the diffuser and having a conical body, and a cylindrical main valve, fitting on the body of the diffuser, and having an inner annular piston in position to be subjected, on opposite sides, to pressure from fluid in the external passages and annular grooves of the diffuser.

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Witnesses:
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