H. A. HUMPHREY.

METHOD OF COMPRESSING AN ELASTIC FLUID.

APPLICATION FILED JUNE 1, 1909. RENEWED JUNE 19, 1917.

1,254,693. Patented Jan. 29, 1918.

4 SHEETS—SHEET 1.

Fig. 1.

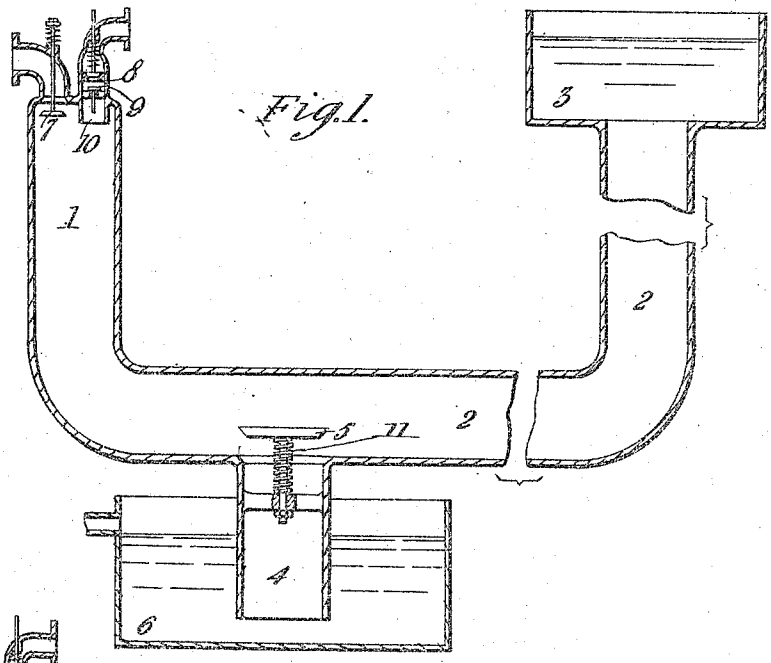
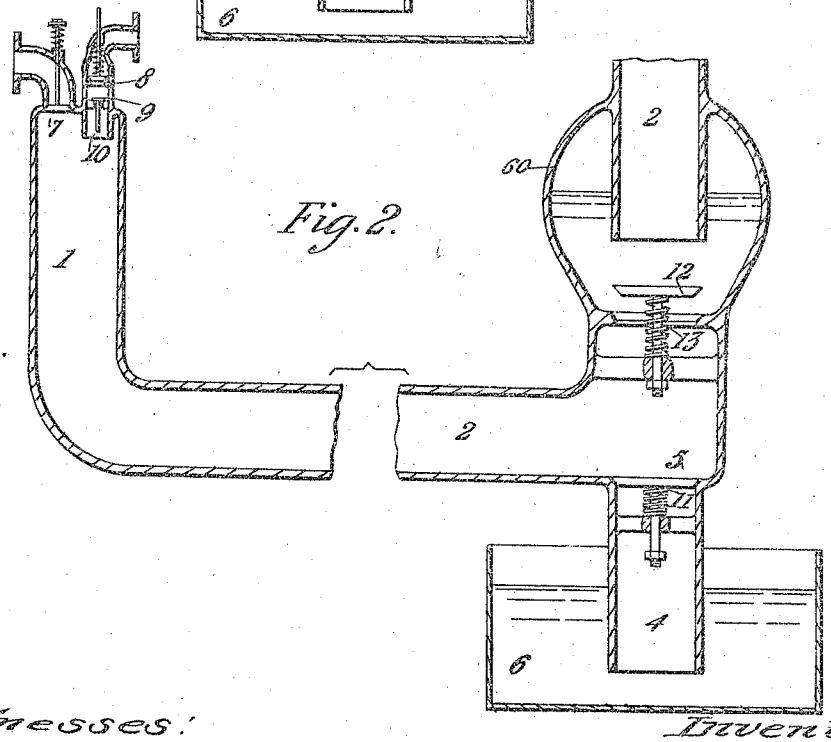


Fig. 2.



Witnesses:

Inventor
Herbert A. Humphrey
By
James L. Norris.
Atty.

H. A. HUMPHREY.

METHOD OF COMPRESSING AN ELASTIC FLUID.

APPLICATION FILED JUNE 1, 1909. RENEWED JUNE 19, 1917.

1,254,693. Patented Jan. 29, 1918.

4 SHEETS—SHEET 2.

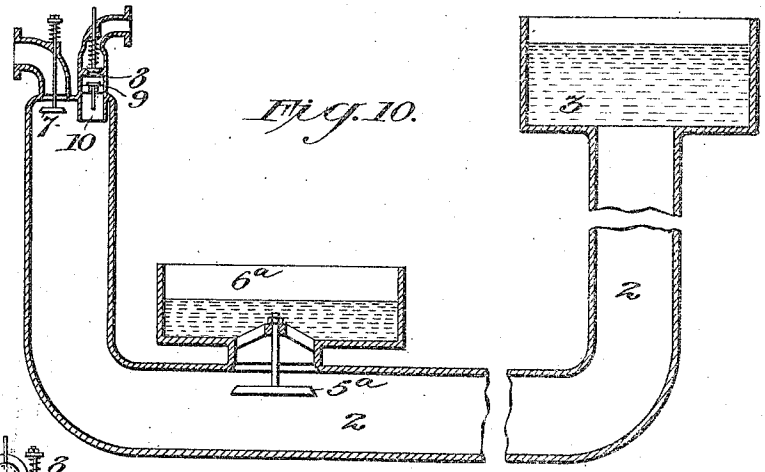


Fig. 10.

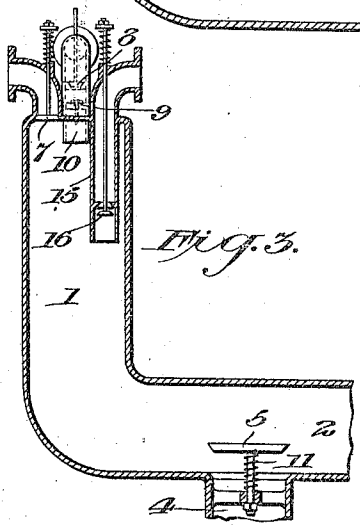


Fig. 3.

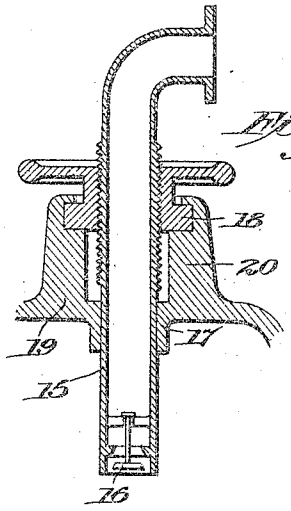


Fig. 8.

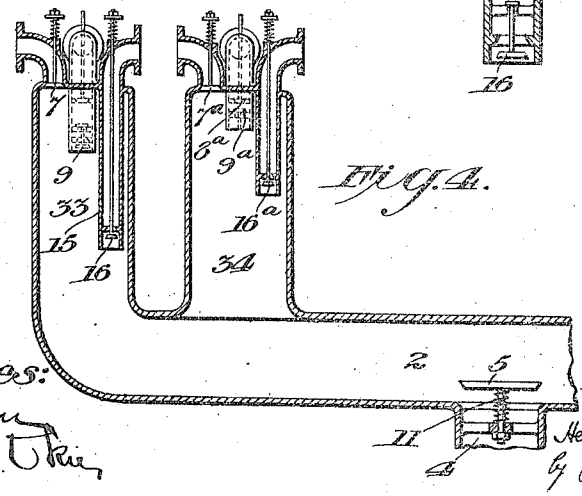


Fig. 4.

Witnesses:
Mae Hofmann
Howard J. Ulrich

Inventor:
Herbert A. Humphrey
by Wm. P. Broasdale
his attorney

H. A. HUMPHREY.

METHOD OF COMPRESSING AN ELASTIC FLUID.

APPLICATION FILED JUNE 1, 1909. RENEWED JUNE 19, 1917.

1,254,693. Patented Jan. 29, 1918.

4 SHEETS—SHEET 3.

Fig. 5.

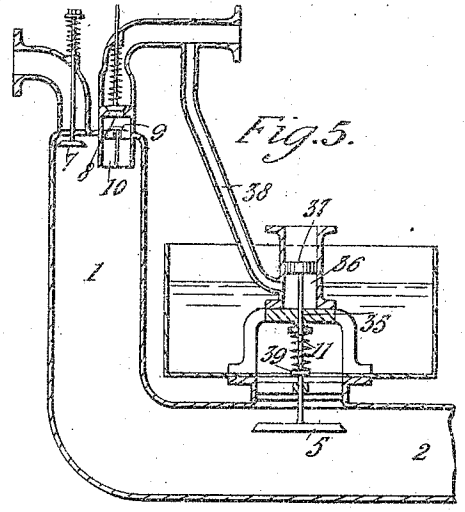
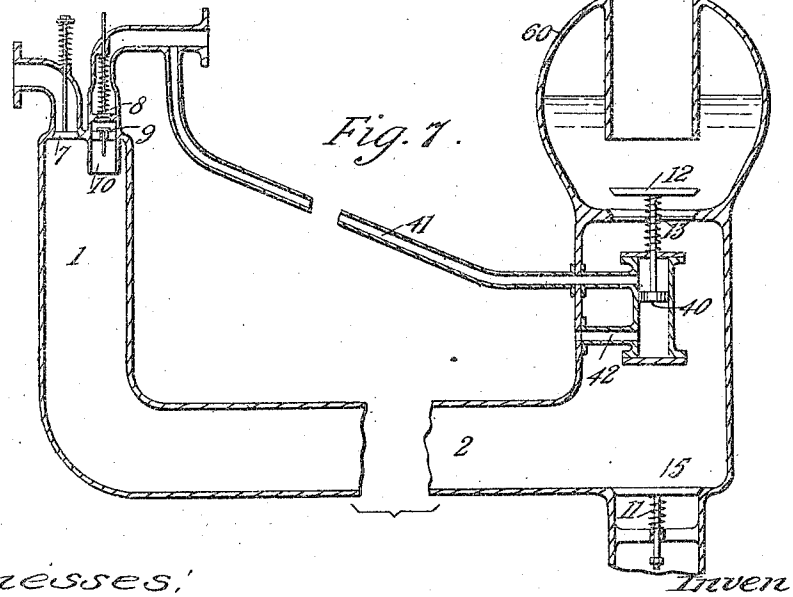


Fig. 7.



Witnesses,

W. B. Keesler

A. D. Kesler

Inventor

Herbert A. Humphrey

By

James L. Norris.

Atty

H. A. HUMPHREY.

METHOD OF COMPRESSING AN ELASTIC FLUID.

APPLICATION FILED JUNE 1, 1909. RENEWED JUNE 19, 1917.

1,254,693. Patented Jan. 29, 1918.

4 SHEETS—SHEET 4.

Fig. 9.

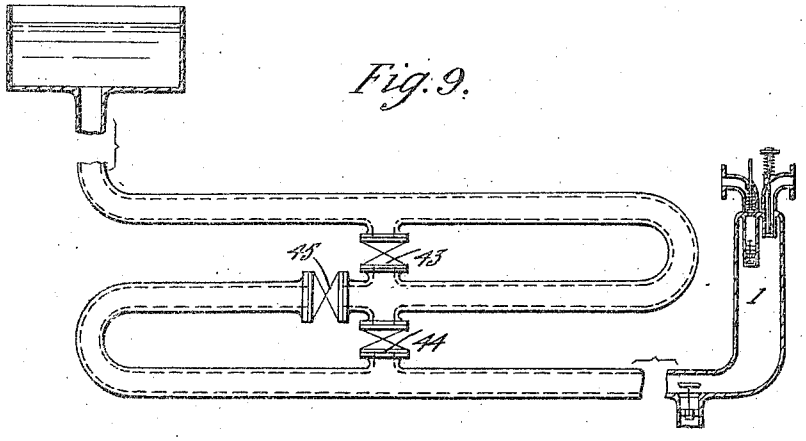
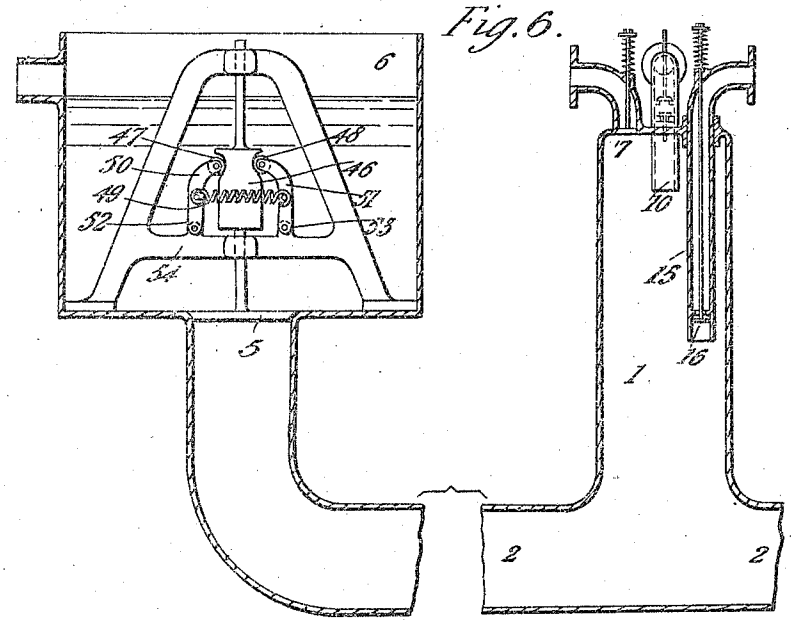


Fig. 6.



Witnesses:

Chas. Hesler

Inventor

Herbert A. Humphrey

By

James L. Norris

Atty

UNITED STATES PATENT OFFICE.

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

METHOD OF COMPRESSING AN ELASTIC FLUID.

1,254,693. Specification of Letters Patent. Patented Jan. 29, 1918.

Application filed June 1, 1909, Serial No. 499,339. Renewed June 19, 1917. Serial No. 175,705.

To all whom it may concern:

Be it known that I, HERBERT ALFRED HUMPHREY, a subject of the King of Great Britain, residing at 38 Victoria street, Westminster, in the county of London, England, consulting engineer, have invented a certain new and useful Method of Compressing an Elastic Fluid, of which the following is a specification.

My invention relates to a method of compressing air or other elastic fluid by means of liquid descending from a higher to a lower level or pressure wherein the column of liquid which compresses the air first attains velocity and then the energy acquired is utilized partly to deliver air under pressure and partly to store energy in an elastic cushion to produce a reverse movement of liquid at each cycle and thus cause a fresh charge of air to be entrained.

In one of the simplest forms of apparatus, suitable for carrying out the method referred to, a high level reservoir containing water or other liquid is connected by a long pipe with an air compressor chamber fitted with inlet and outlet valves for air. In a pending application for Letters Patent Serial No. 444,061, I have described improvements in apparatus for compressing air by means of the energy of expansion of an ignited combustible mixture, and the types of air compressor chamber and valves therein described, and such, for instance, as are illustrated in Figures 1 to 3 of said application, are suitable for use in connection with the present invention.

Referring to the drawings, which illustrate merely by way of example, apparatus for effecting my invention—

Fig. 1 is a vertical section of an air compressor chamber in communication with high and low level liquid reservoirs.

Figs. 2 to 6 are vertical sections of modified forms of the apparatus with the high level tank omitted.

Figs. 7 and 9 are vertical sections of other modified forms of the apparatus.

Fig. 8 is a vertical section of a part of the apparatus, and

Fig. 10 is a view similar to Fig. 1, except that the low level tank 6^a is shown as located above the horizontal portion of pipe 2 instead of below it.

Similar numerals refer to similar parts throughout the several views.

In Fig. 1 the air compressor chamber 1 communicates through a pipe 2 with a high level reservoir or tank 3 and through a pipe 4 controlled by valve 5 with a low level reservoir or tank 6. The compressor chamber is fitted with an inlet valve 7 which opens inward against the action of a light spring and with an outlet valve 8 which opens outward and may be controlled partly by a spring and partly by the pressure of the air delivered. The pipe in which this outlet valve is situated is continued downward past the top of the air compressor chamber to form a projecting portion 10, and it may contain another valve 9 which is normally open under the action of its weight and closes by impact and pressure of water upon it. Water valve 5 is normally kept open by a spring 11 or other equivalent device and is shut by the action of the water upon it due to the velocity of the water or by any known means capable of shutting the valve when the desired velocity of the water has been attained. The action of the apparatus is as follows:—

Starting with valves 7 and 8 shut and a charge of air at atmospheric pressure in chamber 1 water from tank 3 flows through pipe 2 and past valve 5 to the low level or waste water tank 6. The difference of head between tanks 3 and 6 produces a flow past valve 5 the velocity of which increases until valve 5 shuts. By this time the column of water moving in pipe 2 has attained considerable kinetic energy and as there is no longer any outlet into tank 6 the water is forced to rise in chamber 1 and to compress the air contained therein. When the pressure of the air is able to lift valve 8 air is discharged until one of two things happen, either the energy in the moving column is converted into pressure energy and the column brought to rest before the water in chamber 1 reaches the lower end or lip of pipe 10, or the water rises past this lip so as to cause valve 9 to shut against the seat above it, in which case the air imprisoned

in the top of the chamber above the level of the lip of pipe 10 is still further compressed. In either case there remains in chamber 1, when the column of liquid comes to rest, a quantity of air under pressure exceeding the static head due to the height of the liquid in tank 3. This pressure causes a reverse flow of liquid so that the water descends in chamber 1 as the air therein expands. When the pressure in chamber 1 has sufficiently diminished valve 9 falls under the action of its weight and the non-return outlet valve 8 having previously closed prevents compressed air from the delivery pipe returning to the chamber. On reaching atmospheric pressure or thereabout the further expansion of the air in the chamber is prevented by the opening of valve 7 admitting fresh air as the water continues to fall. Valve 5 having shut under the action of velocity of the water continues to remain shut due to the pressure of the water upon it during the compression stroke and the expansion stroke in chamber 1, just described, but at some point during the downward flow of water in chamber 1 the pressure on the top side of valve 5 will be sufficiently decreased to enable spring 11 to lift the valve so that a free outlet into tank 6 is again provided. If the column of liquid moving along pipe 2 to tank 3 has not then come to rest water may flow from chamber 1 into tank 6 or pipe 2 thus drawing more air through valve 7 and then water may flow from tank 3 to tank 6 to commence a fresh cycle. As soon as the suction on inlet valve 7 ceases this valve shuts under the action of its spring and there is again a charge of air in chamber 1 ready to be compressed when valve 5 once more shuts under the action of the velocity of the water.

In Fig. 10 the positions of the low level tank 6^a and the water valve 5^a are above pipe 2. In this case if the reverse flow toward tank 3 has not ceased when the water, descending in chamber 1, reaches the level of the water in tank 6^a, water will be drawn in past valve 5^a to follow the column of water moving toward tank 3 until the column comes to rest so that some of the discharged water returns back into the apparatus.

In Fig. 2 there is an additional water valve 12 placed in the pipe between chamber 1 and high level tank to which pipe 2 leads. Valve 12 is normally held open by spring 13 and closes under the pressure due to velocity of the water. The action of the apparatus is as follows:

It is assumed that there is a charge of air at approximately atmospheric pressure in chamber 1 and that all the valves are in the position shown. Water flows from the high level tank past valve 12 to compress the air in chamber 1 and to store kinetic energy in the moving column of liquid. When the water has a certain velocity valve 12 shuts and the kinetic energy stored in the column of liquid between valve 12 and the chamber is utilized to compress further the air in the chamber, some of which is delivered and some of which is retained in the chamber to produce the reverse flow. When valve 12 is closed, the moving column of liquid in pipe 2 causes valve 5 to open so that water may flow from low level tank 6 past valve 5 to follow the moving column. Valve 5 remains open during the remainder of the compression stroke and on the cushion expansion stroke occurring in chamber 1 a reverse flow causes water to flow back past this valve until it is shut by the pressure thereon due to the velocity of the flowing liquid. As the moving water in pipe 2 cannot be suddenly arrested valve 12 is forced open so soon as valve 5 shuts, and thus communication is again established between chamber 1 and the high level tank for the cycle of operations to be repeated. In order to avoid shock an air vessel 60 is formed in pipe 2 above valve 12.

A simple means of altering the volume of air compressed per cycle is illustrated in Fig. 3 where, in addition to the parts already described, chamber 1 has another pipe 15 communicating with the atmosphere and projecting for a considerable distance into the chamber. This pipe contains a valve 16 which is normally open but is adapted to shut by the impact of water upon it. When the inflowing column of water shuts valve 5 the other valves are in the position shown in Fig. 3 and the water rising in chamber 1 expels air past valve 16 into the atmosphere until valve 16 is shut by impact. As the column of water has done no appreciable work between the shutting of the valve 5 and the closing of valve 16 it has still further gained in velocity due to the head under which it flows, (except in the case where valve 12, Fig. 2, is used and this valve has shut). The available energy is therefore greater, and the quantity of air acted upon is less, so that air may be delivered under greater pressure past valve 8 until valve 9 is shut by impact to compress the elastic cushion, whereupon the flow is reversed. By varying the length of the part of pipe 15 which extends into the chamber, the volume of air to be acted upon when valve 16 closes will be varied; the greater this length the greater may be the volume of air delivered and the lower the pressure of delivery, and vice versa. In Fig. 8 pipe 15 is shown extending through a gland 17 in the top of the chamber casting and fitted with a nut and hand wheel 18 adapted to turn in recesses in brackets 19, 20. As nut 18 is rotated pipe 15 is raised or lowered and the aforesaid length varied.

In application No. 438,427, I have described how a mixture of gas and air may be drawn into one chamber when the liquid in another chamber which communicates with the first chamber is driven downward, and this method of drawing in a gaseous mixture may be applied to the present invention for the purpose of drawing in a charge of air. The necessary modification is shown in Fig. 4, where there are two air compressor chambers 33 and 34 each fitted with the usual valves already described. Water flowing from the high level tank flows partly into one chamber and partly into the other, either of which may be made to act as an air vessel wherein an air cushion may be thus compressed. If in turn each of these chambers is made to act as an air vessel for the other chamber then the contained air cushion will drive down the liquid in that chamber, causing a return flow until the pressure is sufficiently reduced to allow the liquid in the other chamber to fall by gravity and so draw in a fresh supply of air.

In the said application No. 438,427, I have shown an interlocking valve mechanism between four valves, which secures an alternate action of the valves on the two chambers, and if a similar arrangement is adapted to the present case and applied to valves 7, 8, 7^a and 8^a the two chambers may be made to act as air compressor chambers or air vessels alternately. Thus when air is being compressed and delivered from chamber 33 valve 8^a is locked shut so that no air can be discharged past it and all the air between valve 16^a and the top of the chamber forms an air cushion. Since the air that is discharged from the two chambers may be connected to separate reservoirs it is obvious that the pressure at which the air is delivered from one chamber may differ from the pressure at which air is delivered from the other chamber and to illustrate this the pipes which project into the tops of the two chambers respectively are shown in Fig. 4 reaching to different levels.

The water valve 5 which is shut by pressure due to velocity may be automatically controlled by the air pressure with the object of limiting the fluctuations of pressure in the air discharged. One method of doing this is illustrated in Fig. 5 where the stem of valve 5 passes through a gland 35 into a cylinder 36 and is attached to a piston 37. A pipe 38 conducts air under pressure from the air discharge pipe to act upon the under side of a piston 37 or other equivalent device such as a diaphragm so as to give an upward thrust which partly neutralizes the downward thrust of spring 11 which presses on collar 39 fastened to the valve stem, the effect being to allow valve 5 to shut under the action of the velocity of the escaping water earlier than it would otherwise do. The moving column of water has therefore less velocity when valve 5 shuts and the available energy for compressing air is thereby reduced. It will be seen that if the pressure of air rises sufficiently to neutralize entirely the action of spring 11 and the weight of valve 5 and its attachment, the valve may be maintained shut and the action of the apparatus as a compressor will then cease until the pressure is again sufficiently reduced to allow valve 5 to move from its seat and allow water to escape, or until the apparatus is started again by forcibly opening valve 5 against the static head of water which will exist when the column has ceased to move.

Fig. 7 shows a similar controlling device, having the like object of limiting the fluctuations of pressure in the air discharged, but applied to valve 12 of the apparatus described with reference to Fig. 2. The piston 40 is in this case attached to the stem of valve 12 and air from the delivery pipe of the compressor is conveyed through pipe 41 to press on the top side of the piston and so counteract the effect of the spring 13 to a greater or less degree according to the pressure of the air delivered. The cylinder in which the piston moves has a second connection 42 open to the atmosphere. It is evident that, as in the last case, when the pressure of the air discharged rises, greater pressure will be exerted on the top of piston 40 and the upward thrust of spring 13 will be further neutralized so that valve 12 will shut earlier than it would otherwise do. The moving column of water has then less available energy for compressing and delivering air.

In starting the compressor, the water valve may be forcibly opened against the static head which exists when the water is at rest in the apparatus. Another way is suddenly to release the pressure of the air contained in the compressor chamber by opening the communication between the chamber and the atmosphere. This may conveniently be done by forcing down the air inlet valve. The pressure on the water valve will thus be suddenly released and this valve will then open under the action of its spring and start the usual cycle of operations.

It is not always necessary that there should be a reversal in the direction of flow of the water between the chamber and the high level tank, as the varying volume of the air space in the chamber may be brought about by a difference in the rate of inflow and outflow of water. An example of this is given in Fig. 6 where pipe 2 from the air chamber passes to the left to the low level tank 6 to the right to the high level tank, not shown. The waste water valve 5 has a stem with a bottle shaped projection 46 on it; against the surface of which two rollers 47 and 48 are urged by means of a spring 49.

The rollers are mounted on arms 50 and 51 pivoted at 52 and 53 respectively and are carried on a frame 54 attached to the tank and serving also to act as guides to the valve stem. In the position shown the rollers 47 and 48 have been forced into the recess on the part 46 and thus serve to lock the valve in its shut position, so that it requires a pressure on the underside of the valve, exceeding the pressure at which compressed air is delivered, to force the valve upward against the action of the rollers. Spring 49 is adjusted so that the pressure at which valve 5 opens is the normal cushion pressure in chamber 1. It is assumed that the pipe between the chamber and the high level tank is a long one compared with the pipe between the chamber and the low level tank, and the action of the apparatus is as follows: After the long column from the high level tank has compressed a charge of air in the usual way, and cushioning occurs, valve 5 opens, its first movement on opening being to force the rollers from out of the recess and to lift the valve until the rollers are in contact with the approximately cylindrical portion of part 46. The action of the rollers has then no tendency to shut valve 5 and the valve remains open while the cushion-expansion occurs and water escapes past valve 5 causing a fresh charge of air to be taken into chamber 1. When the energy imparted to the column of water between the chamber and the low level tank has been expended the water level in tank 6, being higher than in the chamber, causes a flow from tank 6 to the chamber to take place, and, due to the action of this flow, valve 5 is shut again and held shut by the rollers entering into the recess on part 46, and the cycle is ready to be repeated. It will be observed that in this case there is no necessity for the column of liquid between the chamber and the high level tank to be reversed, since, if the flow is always from the high level tank to the chamber, the cushion energy is sufficient to cause a more rapid flow between the chamber and the low level tank when valve 5 opens and thus allows the air space in the chamber to increase while the fresh charge of air is drawn in. The reverse movement of water brought about by the cushion energy is in this case confined to the movement of water in the chamber and water in the pipe between the chamber and the low level tank.

So far, the air inlet pipe has been shown as open to the atmosphere from which the supply of air is taken, but it is obvious that a closed connection may be used and the apparatus worked as an exhauster. In such cases it is generally desirable to place tank 6 at a sufficiently low level to assist in producing the required degree of suction on the air inlet.

In applications Serial Nos. 438,425 and 438,426, there are descriptions of how air vessels communicating with the column of water may be used for altering the periodicity and the amount of energy available per cycle, and such means are applicable to the present invention. Also, the effective length of the column of liquid between the high level tank and the compressor chamber, or of any other column of liquid utilized for the purpose of this invention may be altered by cross connections between different parts of the pipe in which the water moves, so that by opening or shutting valves portions of the pipe may be cut off or added as desired. Thus, in Fig. 9 the pipe between the compressor chamber 1 and high level tank 3 is shown fitted with three valves. If valves 43 and 44 are open and valve 45 shut, water can pass by the shortest route from tank 3 as far as valves 43 and 44 and to the compressor chamber. If valves 43 and 45 are shut and valve 44 open, water flows around the right hand bend then as far as valve 44 through which it passes to the chamber. The longest route is formed when valves 43 and 44 are shut and valve 45 open, when the water has to traverse the whole length of the pipe. With the short route the column of water will attain its velocity more quickly but the available energy per cycle will be less, while with the long column the period of the cycle will be increased and the available energy will be also increased.

I claim—

1. The method of compressing an elastic fluid by means of liquid descending from a higher to a lower level or pressure, which consists in permitting a flow of said liquid until it attains velocity, then utilizing the momentum of the liquid partly to compress and deliver compressed elastic fluid, and partly to store energy in an elastic cushion to produce a reverse movement of the liquid and thus cause a fresh charge of elastic fluid to enter the region of compression.

2. The method of compressing an elastic fluid by the movement of liquid from a higher to a lower level, which consists in permitting a flow to waste until required velocity is secured, then interrupting the flow to waste and utilizing the momentum of the liquid to compress and deliver compressed elastic fluid, and also to compress an elastic cushion to reverse the movement of the liquid and utilizing the momentum to entrain fresh elastic fluid, varying the flow to waste and thereby controlling the velocity of the liquid in its compression movement.

3. The method of compressing an elastic fluid by the movement of liquid from a higher to a lower level, which consists in permitting a flow to waste until required velocity is secured, then interrupting the flow to waste and utilizing the momentum of the liquid to compress and deliver compressed

elastic fluid, and also to compress an elastic cushion to reverse the movement of the liquid and utilizing the momentum to entrain fresh elastic fluid, varying the effective mass of the liquid in the compression movement.

4. The method of compressing an elastic fluid by the movement of liquid from a higher to a lower level, which consists in permitting a flow to waste until required velocity is secured, then interrupting the flow to waste and utilizing the momentum of the liquid to compress and deliver compressed elastic fluid, and also to compress an elastic cushion to reverse the movement of the liquid and utilizing the momentum to entrain fresh elastic fluid, varying the effective mass of the liquid in the reverse movement.

5. A method of compressing air or other elastic fluid by means of liquid descending from a higher to a lower level which consists in causing a column of liquid which compresses the air to attain velocity and acquire energy, utilizing the energy partly to deliver air in part under pressure and in part at atmospheric pressure, so as to vary the volume of air to be delivered under pressure, and partly to store energy in an elastic cushion, and using the energy of the elastic cushion to produce a reverse movement of liquid and to cause a diminution of pressure and thus entrain a fresh charge of air.

6. In a method of compressing air or other elastic fluid by means of liquid descending from a higher to a lower level and which consists in causing a column of liquid which compresses the air to attain velocity and acquire energy, utilizing the energy partly to deliver air under pressure and partly to store energy in an elastic cushion, using the energy of the elastic cushion to produce a reverse movement of liquid and to cause a diminution of pressure and thus entrain a fresh charge of air, utilizing some of the air delivered under pressure to control automatically the velocity to be acquired by the column of liquid.

7. The method of compressing an elastic fluid by means of liquid descending from a higher to a lower level or pressure, which consists in permitting a flow of said liquid until it attains velocity, then utilizing the momentum of the liquid, acting upon two regions of compression alternately, one of them acting as air compressor and the other as a resilient cushion, partly to compress and deliver compressed elastic fluid, and partly to store energy in an elastic cushion to produce a reverse movement of the liquid and thus cause a fresh charge of elastic fluid to enter the region of compression.

8. The method which consists in reciprocating a column of liquid with a velocity sufficiently limited to preserve the coherence of the column and having sufficient bulk and path of travel to acquire useful momentum and permitting a gravity actuated movement of the liquid in one direction of its reciprocation until it acquires sufficient momentum to compress a primary medium.

9. The method of compressing an elastic fluid by a column of liquid of sufficient volume and path of travel to enable it to attain useful momentum, which consists in permitting a gravity actuated movement of the liquid until it attains velocity sufficient to acquire useful momentum, utilizing said momentum to compress the elastic fluid, and utilizing a portion of the energy of the compressed fluid to reverse the movement of the liquid.

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

HERBERT ALFRED HUMPHREY.

Witnesses:
J. MILLARD,
W. J. SKERTEN.

Copies of this patent may be obtained for five cents each, by addressing the "Commissioner of Patents, Washington, D. C."