Aug. 11, 1931. E. W. SWARTWOUT 1,818,767

ROTARY BLOWER AND PUMP

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Fig. 1.

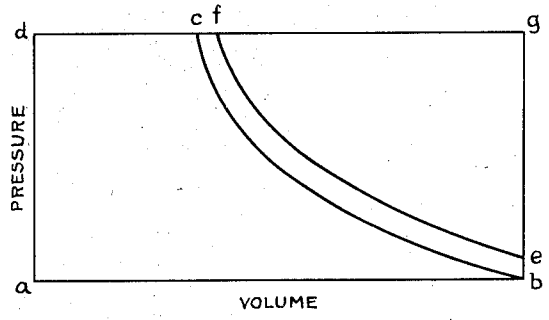


Fig. 2.

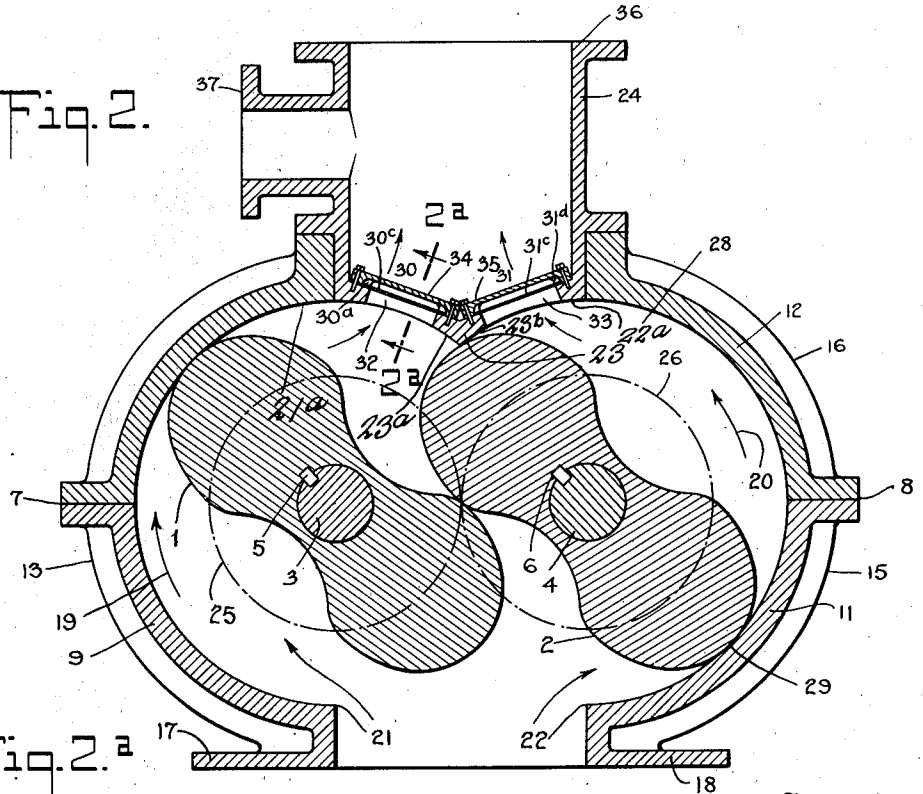
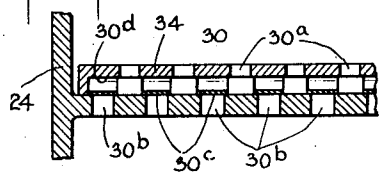


Fig. 2a



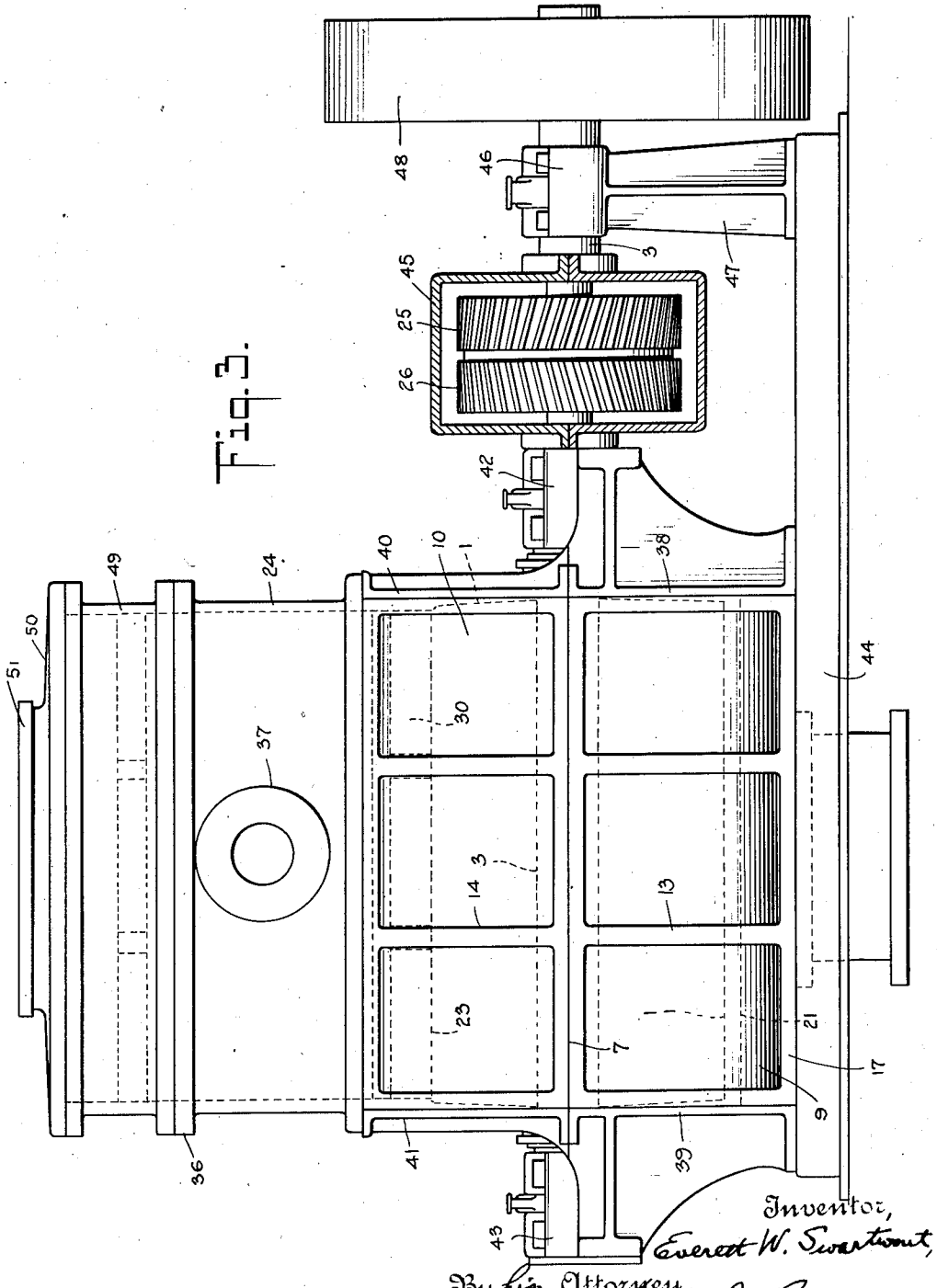
Inventor,
Everett W. Swartwout,
By his Attorney,
Henry J. Locke.

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ROTARY BLOWER AND PUMP

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Fig. 5.



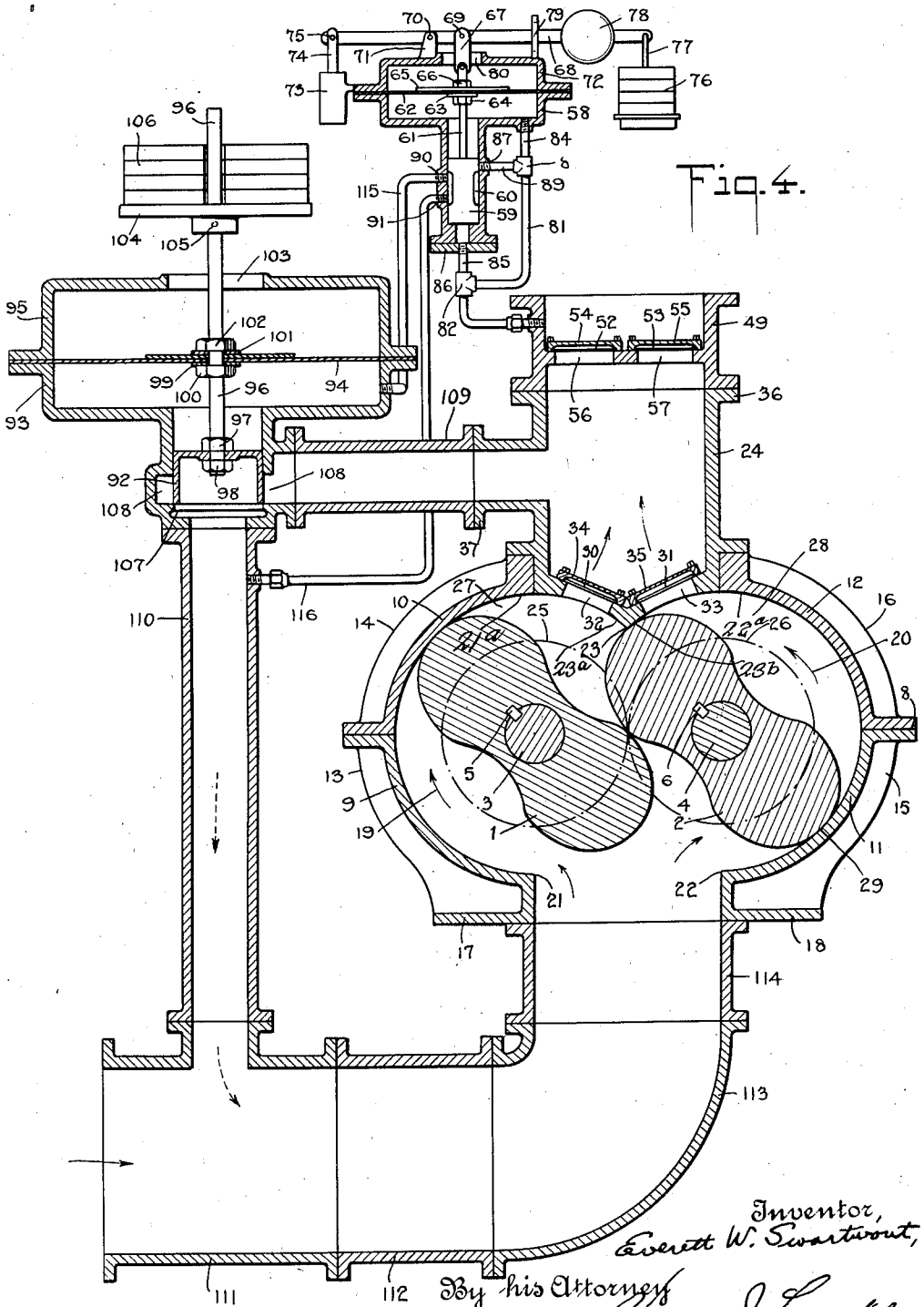
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ROTARY BLOWER AND PUMP

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Fig. 4.



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Patented Aug. 11, 1931

1,818,767

UNITED STATES PATENT OFFICE

EVERETT W. SWARTWOUT, OF WHITE PLAINS, NEW YORK

ROTARY BLOWER AND PUMP

Application filed September 13, 1927. Serial No. 219,225.

My invention relates to rotary blowers and pumps.

More particularly, my invention relates to rotary blowers and pumps taking at the suction side air, gases, or liquids, either singly or as mixtures, and which deliver against a desired differential pressure with improved pressure regulation at any operating speed, with variable capacity when operating at any constant speed and with improved efficiency.

According to the prior act, the principal advantages of machines or rotary blowers and pumps of that type in which there are two parallel shafts carrying mating lobed impellers in a cylinder, are that the capacity per revolution is constant after the losses due to slip at the various operating pressures have been deducted; that the total net capacity is large; and that no lubrication within the cylinder is required and therefore delivering a product which is unpolluted by oil. The disadvantages of these prior types are that the efficient compression range is limited to small differential pressures due to the fact that a compression of air, or the fluid or other medium being compressed, what is termed instantaneous compression, is brought about by the return flow of the medium from the delivery line at the delivery line pressure back into the cylinders of the unit. Such return flow produces a hammer blow on the impellers immediately upon the impellers making a communication between the delivery line and the compartment in the impeller cylinder containing the medium to be compressed for delivery, thus causing a periodic momentary tendency to reverse the direction of rotation of the impellers and resulting in the uneven wearing of the operating and timing gears, and giving rise to continuously increasing noise of the gears, and finally effecting incidental damages resulting from the improper timing of the impellers and causing them to strike and wear, accompanied by decreased efficiency due to the larger clearances and consequently greater slip or leakage from the delivery side back to the suction side, heating at the suction with relatively high temperature at the delivery pressure, heating up of the machine, reduction in the net capacity of the machine, and other mechanical disturbances due to the expansion of some parts more than others due to the progressively increasing temperature of the medium at the suction side and within the machine.

In machines of the prior type employing instantaneous compression, the full differential pressure is continuously across the machine which gives rise to a substantial slip, or leakage from the high pressure side to the low pressure side of the machine, resulting in reduced volumetric efficiency, loss of capacity and reduced overall efficiency. When operated at constant speed and with constant differential pressure, the delivered capacity of machines of the prior type may only be varied by wasting the unwanted compressed air by relieving it into the atmosphere, or by expanding the excess compressed gas from the delivery side of the machine back to the suction side of the machine through a throttling valve controlled by a diaphragm pressure regulator or the like, causing heating at the suction side and saving no power as compared with that required when the machine is operated at full delivered capacity.

According to my invention, I employ rotary machines of any type, but preferably of that type having two parallel shafts carrying mating lobed impellers in a cylinder, comprising variable capacity means by what is termed unloading during periods when more of the compressed medium is delivered than is wanted or needed to maintain a substantially constant delivery pressure. Means are also provided for checking and preventing the escape or expansion of the compressed medium from the delivery pipe into the suc-

tion side of the machine, means for interconnecting and disconnecting the suction and delivery sides of the machine prior to the delivery pipe so that only periodically, or continually as needed, the medium is being compressed and delivered against the delivery pressure. When unloaded, the medium is not compressed at all but is merely circulated through the machine and back to the suction side at the suction pressure, therefore requiring no work and thus increasing the efficiency and reducing the total power required by the machine in proportion to the time unloaded and the time of periodically compressing the delivering.

To further improve the volumetric efficiency, to improve the efficiency of compression, to produce smooth operation at high speeds, and for the purpose of expanding the commercial uses for machines of the rotary type, I provide means for producing substantially gradual or adiabatic compression which eliminates the popping back into the machine and the other disadvantages incidental to instantaneous compression and which makes machines adapted for efficient operation at relatively high differential pressures. According to my invention, the compressed medium is held in the delivery pipe after it is delivered and is precluded from rushing back into the machine; furthermore, the full delivery pressure is attained by gradually increasing compression within the cylinder and the full delivery pressure is impressed upon the compressing elements of the machine only during a relatively short portion of each cycle from the suction side to the delivery side, thereby reducing the slip or leakage through the machine, as this is a function of the differential pressure and time. According to my invention machines are provided which are not only well adapted, but highly efficient, when used as vacuum pumps or as gas boosters operating with relatively high differential and high ratio of compression.

Though many new and useful applications of my invention will be perceived by those skilled in the art, my invention is especially useful and advantageous to the manufactured gas industry. One application of my invention is in the pumping of manufactured gas at variable rates to supply the fluctuating demands of various communities, utilizing as motors for driving these gas pumps, electric motors of the standard constant speed squirrel cage induction type. Motors of this type are especially valuable in that they do not cause sparking, and therefore the danger of explosions is eliminated. By the use of directly connected motor driven gas pumps operated at constant speed, the capacity may be varied to suit the needs, much power is saved, and should the electric power supply suddenly fail, a reverse flow of the gas is prevented and the gas pumps are protected from being rotated in the reverse direction as gas motors at excessively high speeds.

The accompanying drawings show certain representative embodiments of my invention. The principles may be applied to compressors, blowers and pumps of types differing from the specific type illustrated and variations may be made without departing from the principles of the invention, as comprehended in the scope of the appended claims.

Fig. 1 is a diagram of three compression cycles.

Fig. 2 is a vertical central section of Fig. 3, illustrating a simplified form of my invention.

Fig. 2*a* is a sectional elevation on line 2*a*—2*a* of Fig. 2.

Fig. 3 is a side elevation of Fig. 2.

Fig. 4 is a vertical central sectional elevation of a complete assembly, embodying my invention.

Referring to Fig. 1, the diagram, *abcd*, represents a pressure volume cycle of the ideal adiabatic character as will be understood by those skilled in the art. The diagram, *abegfcd*, represents a pressure volume cycle of the instantaneous compression character and which is the cycle which characterizes the operation of positive pressure lobed impeller type of unit as constructed according to the prior art. The diagram, *abefcd* represents a pressure volume cycle of approximate adiabatic form and which is the compression cycle obtained when operating machines according to my invention. It will be understood that when pumping liquids which are devoid of compressible gases, the pressure volume representation will be of the rectangular form with qualification, as will be understood. It is also understood that the efficiencies of the respective cycles, and also the power input of machines operating on these respective cycles, are in proportion to the areas of the respective compression cycles.

In the adiabatic cycle, *abcd*, the period of gradual compression takes place under the portion of the diagram represented by the curved line, *bc*, and the period or relative length of time during which delivery occurs against the delivery pressure is represented by the length of the line, *cd*.

In the positive pressure instantaneous compression cycle, *abegfcd*, compression is instantly effected by the rushing back of the gas from the delivery side at the delivery or discharge pressure, into the compression compartments of the machine, as is represented by the line, *beg*, of the diagram, *abegfcd*. The relative length of time at which the delivery pressure is across the machine, and the time during which slip, or leakage due to the full differential pressure occurs, is represented by the length of the line, *gfcd*, of the diagram, *abegfcd*.

According to my invention, when compressing gas free from condensed liquid, there may be a slight instantaneous compression caused by the popping over of the compressed gas left in the compression compartment, after delivery into the discharge has ceased, into the compartment on the suction side of the machine filled with gas at inlet pressure, thus slightly increasing the pressure of the mixture above the inlet pressure as represented by the line, *be*, of the diagram, *abefcd*, thus producing an effect somewhat similar to supercharging a compressor at its suction side. Adiabatic compression will then take place under the line, *ef*, and gradually increasing the pressure, followed by delivery against the discharge pressure, and for a duration of time represented by the length of the line, *fcd*, of the diagram, *abefcd*. It will be understood that when a considerable quantity of condensed liquid is present in the gas, as when handling mixtures of gas and liquor such as is encountered in the operation of filter presses and the like, enough of the liquor will continuously remain in the machine over the impellers to seal them against leakage and to cause whatever gas is present in the mixture to be compressed solely according to the adiabatic compression cycle, thus improving the power consumption and the efficiency of these machines considerably when compared with machines of the prior art types.

When complete unloading is effected as provided for in my invention, machines of any type will merely continuously circulate gas at the suction pressure, or liquid in any proportion, from the suction side of the machine through the machine and its discharge chamber back to the suction side, and such cycle is repeated during the time when so unloaded; such cycle is represented by the line, *ab*, of the three superimposed cycles represented by the diagrams of Fig. 1.

Referring to Fig. 2, the impellers 1, 2, shown in cross section, are mounted upon their respective shafts 3, 4. The impellers may be made according to any curved form such as the involute, the cycloidal, or other curves which make their lobes interengage mesh and mate in their various angular relationships with each other when rotated in opposite directions on parallel shafts, without contact between the impellers or with the surrounding casing, but with relatively small clearances. Though the impellers 1, 2 are preferably shrunk onto the shafts 3, 4 the keys 5, 6 may be employed to insure rigid relationship between the respective impellers and shafts. The casing comprises two heads at the respective ends of the cylinder. The cylinder may be made solid, or may be divided into halves, split horizontally along the lines 7, 8, thus making the cylinder quarter sections 9, 10, 11, 12, which are given rigidity by the ribs 13, 14, 15, 16, respectively. The arrow 19 shows the direction of rotation of the impeller 1 and the arrow 20 shows the direction of rotation of the impeller 2. The line 21 of the cylinder section 9, and the line 22 of the cylinder section 11 shows the lines at which the impellers 1, 2 close the suction side of the medium to be handled. The line 23 of the delivery compartment 24 shows the common line past which the impellers 1, 2 sweep. The impellers 1, 2 are driven and maintained in timing relation by the pair of gears 25, 26. The volume 27 formed between the impellers 1, 2, the cylinder section 10 and the delivery compartment 24 is what is left following delivery from the delivery compartment and is the volume of gas at the delivery pressure which is mixed with the volume of gas 28 at the inlet pressure formed between the impeller 2 and the cylinder sections 11, 12 and the delivery compartment 24. Upon rotation of the impellers 1, 2, beyond their positions as shown in Fig. 2, the impeller 2 will pass the line 23 thus making communication between the volumes 27 and 28, and initiate compression adiabatically of the enclosed gas. It will be noted that the impeller 2 rotates from the line 22 of the cylinder section 11 to the line 29 of the section 11 with no differential pressure between the suction opening and the gas volume 28 and therefore there is no slip past the impeller 2 and the cylinder section 11 while rotating from the line 22 to the line 29. A corresponding region of no slip occurs in the rotating of the impeller along the wall of the cylinder section 9 beginning at the line 21.

As appears in Figs. 2 and 2*a*, the port of the delivery compartment 24 is provided with a valve constructed to pass air, gas or other medium in one direction solely. Preferably, the delivery compartment for a two lobe impeller is provided with two sets 30, 31 of such uni-directional valves, comprising the spaced slots 30*a* of the valve 30, arranged in alternate spaced relation with respect to the slots 30*b*, the valve strips 30*c* being disposed to be displaced in one direction only relative to the discharge openings of the slots 30*b*, or the equivalent whereby upon the pressure in the delivery compartment 24 slightly exceeding the pressure in the delivery line 23, each valve 30*c* is moved in its slot 30*b* to effect communication through the valve slots. Like parts of the valve 31 are designated by like reference characters, 31, 31*b*, 31*c*.

As is indicated hereinabove, and as is illustrated in detail in Figs. 2 and 4, the delivery compartment is provided with the respective openings 32, 33 and comprises the central abutment having the arcuate faces 23*a*, 23*b* and further comprises the arcuate faces 21*a*, 22*a*, co-operating with the respective impellers 1, 2, thereby forming compression chambers between the respective impellers

and the co-operating parts of the delivery compartment at successive stages of relative motion and resulting "squeezing" action in the spaces between the impellers 1, 2, and the aforesaid arcuate parts.

Heretofore in pumps and compressors having inter-engaging lobed impellers operating in the cylinder, the delivery is devoid of valve means and accordingly as the respective lobes approach the delivery substantially no compression of the gas takes place.

Pursuant to my invention, arcuate extensions 21*a*—23*a* and 22*a*—23*b*, see Fig. 2, of the walls of the cylinder meet at or near the common line 23 and thus co-operate with the respective impellers to form spaces for the delivery of the gas without extending the dimensions of the cylinder, and serving also to prevent the return of the gas previously compressed and delivered into the delivery line. My invention provides the further co-acting means in the form of uni-directional valves, opening outwardly of the casing into the delivery line, whereby the distinctive characteristics graphically depicted in the pressure-volume diagram of Fig. 1 are attained; structurally stated, my improved machine comprises essentially a pump or compressor capable of sucking in at inlet pressure the volume *ab*, succeeding which is a partial compression period in which the pressure of the gas is suddenly increased solely and wholly within the compressor along line *be*, after which the gas is adiabatically compressed along the line *ef*, following which the compressed gas is delivered into the discharge line for the volume *fd*, at the discharge pressure represented by the line *ad*.

In prior types and uses of inter-engaging lobed impellers the work required on compression—which is of sudden compression—is represented on the diagram Fig. 1 at *abegfcd*. In this diagram the gas is sucked into the machine in a volume and at an inlet pressure represented by the line *ab*. At the point *b*, the tips of the respective impellers pass the cylinder at the points 21*a*, 22*a*, respectively, thus permitting the discharge line pressure to shoot back into the compartment opened by the respective movements of the two impellers. This causes the pressure which was formerly at the suction pressure to instantly arise along the line *begc* until the discharge line pressure immediately becomes the pressure in these compartments, whereby the discharge line pressure therefore compresses the gas which was present at the suction pressure. After this the co-operating movement of the two impellers delivers the compressed gas into the discharge line along the line *gfcd* at the pressure *da*.

As distinguished from piston pump machines or compressor, the movement of each piston of a multiple piston machine in one direction causes gas to be sucked into the cylinder at the suction pressure *ab*, and in volume represented by *ab*. The reversal of the direction of the piston causes its inlet valve to close, thus preventing the entrapped charge from returning to the inlet pipe. As the pressure within the cylinder is at the suction pressure, and as there are discharge valves which prevent communication between the discharge pipe and the interior of the cylinder, the gas in the cylinder is gradually or adiabatically compressed along the curve *bc*, until the pressure within the cylinder is slightly greater than the delivery pressure, thus overcoming the resistance of the delivery pressure against the spring valves and overcoming the frictional resistances of these valves. The compressed air is then delivered for the volume *cd*, at a pressure *ad*, after which the cycle is repeated.

After the gas has been adiabatically compressed it is delivered through the valves 30, 31, the ports 32, 33 and the valve bonnets 34, 35 of the delivery compartment 24. When the requirements are for compressed gas at constant capacity, the discharge line is connected directly with the delivery compartment 24, as at the flange 36, while if a by-pass of any kind is desired, it may be connected with the delivery compartment 24 as at the flange 37. Thus, it will be noted, that whatever medium is delivered from the volumes 27, 28 into the delivery compartment 24 there is no slip back into the machine, and, also, all of the medium taken in at the suction side, excepting the slip, is positively delivered into the delivery compartment 24, resulting in high volumetric efficiency and low power consumption.

Referring to Fig. 3, like numerals designate like parts as are illustrated and described in Fig. 2. The bottom head section 38 and the bottom head section 39 are attached to the respective ends of the cylinder section, 9, 11. The top head plate sections 40, 41 are attached to the bottom head sections 38, 39, and to the cylinder sections 10, 12. The bearings 42, of which two are shown, are supported in the head-plate 38, while the bearings 43, two in number, are supported by the headplate section 39. The two duplicate, intermeshing, synchronizing and timing gears 25, 26, respectively, are respectively mounted upon the shafts 3, 4 and are disposed within the housing 45, preferably remote from the cylinder, so that the gears can be fully protected from dust and dirt and run in a bath of oil, to maintain the impellers 1, 2 in proper relation to each other, and transmit half of the power. Depending upon which of the two shafts 3, 4 is the drive shaft, one of these shafts terminates in the double outer bearing 46, while the other shaft continues through the double outer bearing 46 upon which the pulley 48 is mounted; or

the drive may be connected to the driving shaft in any other suitable means. The double outer bearing 46 is mounted upon the pedestal 47 which, together with the head plate sections 38, 39 and the cylinder sections 9, 11 at the feet 17, 18 are preferably mounted upon the one piece bed plate 44 forming the base of the machine. When unloading is used the check valve 49 is mounted upon the delivery chamber 24 and the pipe plate 50 is mounted upon the check valve 49 thus providing the flange 51 for a suitable connection for the discharge piping.

Referring to Fig. 4 like numerals designate like parts as hereinabove illustrated, and description relative to these parts in Figs. 2 and 3 will suffice. Figure 4 further illustrates the following additions which comprises one embodiment of my unloading means. The check valve body 49 contains the valves 52, 53 disposed within the valve bonnets 54, 55, for the purpose of preventing a return flow of the medium through the ports 56, 57, under the valves 52, 53, into the delivery chamber 24. Unloading is accomplished automatically by a fluid pressure motor comprising preferably a pressure regulated pilot valve which controls the inflow and outflow of the medium at the discharge or delivery pressure, and which also controls the alternate inflow and outflow of the medium at the suction pressure, thus actuating a by-pass valve to full open or to full shut positions. When this by-pass valve is in its full shut position, none of the medium can return to the suction side. When unloaded, this by-pass valve is in its full open position and none of the medium is delivered into the discharge line, the check valve 49 preventing any return from the discharge pipe.

The pilot valve body 58 is shown in one embodiment of my invention and comprising the pilot valve 59, having the cut away ports 60, and further having its valve stem 61 connected to the diaphragm 62 by the plate 63 and the nut 64, all disposed within the body 58. The diaphragm 62 is also held to the valve stem 61 by the plate 65 and the nut 66. The valve stem 61 is connected by the link 67 with the lever 68 and the pin 69. The lever 68 has its fulcrum on the pin 70, supported by the bracket 71. The bracket 71 is mounted on the top of the body section 72. The diaphragm 62 is held in place by the body section 72. The lever 68 may be connected with a dash pot 73 by the link 74 and the pin 75. The weights 76, supported by the rod 77, attached to the lever 68, may be varied to balance the diaphragm action at any desired pressure with the aid of the slide weight 78 which may be set at different positions on the lever 68. The lever 68 is limited in its movement up and down by the slotted stop 79 disposed around the lever 68 and mounted upon the body section 72. The top of the diaphragm 62 is subjected to atmospheric pressure through the opening 80 in the body 72.

The pipe 81 connects the discharge pipe side of the check valve body 49 with the T 82 and with the T 83. The body 58 is connected with the discharge pipe by the pipe 84 and the pipe 85 at 86 from the T's 82 and 83, thus subjecting the lower side of the pilot valve 59 and the lower side of the diaphragm 62 to the discharge pressure. The valve body 58 has the port 87, connected by the pipe 89 and the T 83 with the discharge pressure through the pipe 81. The valve body 58 also has the spaced ports 90 and 91, both communicating with their cut away ports 60 of the pilot valve 59 when the pilot valve 59 is in its bottom position as shown, which occurs when the pressure in the discharge pipe is insufficient to raise the diaphragm 62 connected with the pilot valve 59.

The by-pass valve 92, disposed within the valve body 93 is connected with the diaphragm 94, and is held in place by the upper valve body section 95, by the valve stem 96, the nuts 97, 98, the plate 99, the nut 100, the plate 101, the nut 102, and extends through the opening 103 of the upper valve body section 95 where the shelf 104 is attached to the valve stem 96 by the pin 105. The weights 106 are placed upon the shelf 104 in the required number and size to insure the return of the by-pass valve 92 to its seat 107 when the pressure under the diaphragm 94 within the valve body 93 is the same as the suction pressure of the medium being pumped or compressed.

The valve body 93 having the ports 108, is connected by the pipe 109 with the discharge chamber 24 at the flange 37, and also, the valve body 93 is connected by the pipe 110, the T 111 of the suction main, the pipe 112, the elbow 113 to the pipe plate 114 at the suction side of the machine. The space between the diaphragm 94 and the valve body 93 is connected with the port 90 of the pilot valve body 58 by the pipe 115. The port 91 of the valve body 58 is connected with the suction pipe 110 by the pipe 116. Thus, it will be noted that during periods when the discharge pipe pressure is insufficient to raise the diaphragm 62 and the pilot valve 59, the port 87 will be closed from the discharge pressure by the pilot valve 59 while at the same time, the ports 90, 91 will be connected together through the cut away port 60 of the pilot valve 59, the result being that the suction pressure will operate against the bottom of the diaphragm 94, through the pipes 115, 116, and the force of the suction pressure operating over the diaphragm 94 will be insufficient to lift the valve stem 96 and the weights 106, and the by-pass valve 92 will be held on its seat 107, and as the by-pass valve

ports 108 will be closed, no gas or medium being pumped or compressed can by-pass, and the machine will deliver its full capacity into the discharge, and unloading will be entirely ineffective.

When an excess quantity of the medium is delivered by the machine into the discharge, the pressure will increase, and when the discharge pressure has increased sufficiently, the force operating upon the diaphragm 62 will be greater than the predetermined loading of the lever 68 and the stem 61, the result being that the pilot valve 59 will rise, the port 91 connected with the suction 110 through the pipe 116 will be closed, the port 87 connected with the discharge through pipe 81 will be opened, the port 90 will remain open, and the pressure under the diaphragm 94 will have been changed from suction pressure to discharge pressure, the weights 106 will be insufficient to hold the valve stem 96 down, and the by-pass valve 92 will become fully opened. The medium in the discharge pipe is prevented from returning through the closing of the check valves 52, 53, the discharge chamber 24 is connected with the suction 114 through the pipe 109, the open port 108, the pipes 110, 111, 112 and 113, there will be no increase in the pressure of the medium as it passes through the machine, the medium merely being recirculated at suction pressure requiring only sufficient power for driving to overcome the friction of the machine, and unloading is fully effective.

As soon as withdrawals from the discharge line reduce the pressure under the diaphragm 62 sufficiently, the pilot valve 59 will return to the position shown, the pressure under the diaphragm 94 will again become the suction line pressure, the by-pass valve 92 will fully close, and no by-passing takes place. All of the medium which passes through the machine is delivered into the discharge pipe, and unloading will again be entirely ineffective, the alternate loading and unloading periodically becoming effective to maintain a substantially constant delivery line pressure, and reduction in power consumption in substantial proportion to the quantity of the medium delivered into the discharge pipe.

It will be understood by those skilled in the art, that the pilot valve means and the by-pass valve means illustrated in the drawings may be rearranged and modified to be responsive to any desired vacua in lieu of pressure. Also, in certain applications it may be preferable to have the pilot valve means, or the by-pass valve means, or both operated or controlled electrically, hydraulically, or pneumatically, either separately or in combination as desired. Though I have described valve means for preventing instantaneous compression, it will be understood that in extremely high speed machines with a large number of deliveries into the discharge per unit of time, the return flow of the gas into the compression compartments may be prevented by omitting the valves and restricting the port openings at the discharge side to an extent which will produce a movement of the gas solely in one direction.

It will be observed that my invention provides for the discharge of the compressor into the discharge line under conditions of pressure in the discharge line not exceeding any predetermined value, under which condition the by-pass between the discharge and inlet openings is closed; further, under the condition of the pressure in the discharge line exceeding such predetermined value, the discharge from the compressor is by-passed back to the inlet of the compressor. Preferably, as is illustrated and described hereinabove, the valve controlling my by-pass assumes in this operation either a fully open position or a fully closed position, in which event the discharge from the compressor is wholly prevented from going into the discharge line and is led back through the open by-pass valve to the inlet of the compressor.

Whereas, I have described my invention by reference to specific forms thereof, it will be understood that many changes and modifications may be made without departing from the spirit of the invention.

I claim:

1. The combination of a casing having an inlet and a discharge, said inlet being free of any valve, means including impellers disposed within said casing for compressing a fluid, driving means for said impellers, valve means for said discharge, fluid passage means communicating at its one end with said discharge of said casing between said valve means and said impellers and at its opposite end with said inlet for controlling the discharge through said discharge valve means, said fluid passage means including a valve responsive to discharge and inlet pressures and movable solely to fully opened and fully closed positions, and means for moving said valve solely to fully opened and fully closed positions.

2. The combination of a casing having an inlet and a discharge, said inlet being free of any valve, means including impellers disposed within said casing for compressing a fluid, driving means for said impellers, valve means for said discharge, fluid passage means communicating at its one end with said discharge of said casing between said valve means and said impellers and at its opposite end with said inlet for controlling the discharge through said discharge valve means, said discharge controlling means including a valve responsive to inlet and discharge pressures and movable solely to fully opened and fully closed positions, and means for

moving said valve solely to fully opened and fully closed positions.

3. The combination of a casing having an inlet and a discharge, said inlet being free of any valve, means including impellers disposed within said casing for compressing a fluid, driving means for the impellers, valve means for said discharge, fluid passage means communicating at its one end with said discharge of said casing between said valve means and said impellers and at its opposite end with said inlet for controlling the discharge through said discharge valve means, said discharge controlling means including a manually variable weight adjustable valve, responsive to inlet and discharge pressures and movable solely to fully opened and fully closed positions, and means for moving said valve solely to fully opened and fully closed positions.

4. The combination of a casing having an inlet and a discharge, said inlet being free of any valve, means including impellers disposed within said casing for compressing a fluid, driving means for the impellers, valve means for said discharge, and fluid passage means communicating at its one end with said discharge of said casing between said valve means and said impellers and at its opposite end with said inlet for controlling the discharge through said discharge valve means, said discharge controlling means including a device responsive to the pressure at the inlet and the discharge of said casing.

5. The combination of a casing having an inlet and a discharge, said inlet being free of any valve, means including impellers disposed within said casing for compressing a fluid, driving means for the impellers, valve means for said discharge, a delivery line communicating with said discharge through said discharge valve means, and fluid passage means communicating at its one end with said discharge of said casing between said valve means and said impellers and at its opposite end with said inlet for controlling the discharge through said discharge valve means, said discharge controlling means including a valve responsive to the pressure of said inlet and said delivery line.

6. The combination of a casing having an inlet and a discharge, said inlet being free of any valve, means including impellers disposed within said casing for compressing the fluid, driving means for the impellers, valve means for said discharge, a delivery line communicating with said discharge through said discharge valve means, and fluid passage means communicating at its one end with said discharge between said discharge valve means and said impellers and at its opposite end with said inlet for controlling the discharge through said discharge valve means, said discharge controlling means including a valve responsive jointly to the pressure in said discharge line and the pressure at said inlet.

7. The combination of a casing having an inlet and a discharge, means disposed within said casing for compressing a fluid, driving means, check valve means for said discharge, check valve means disposed in the discharge of said casing anteriorly of said first named discharge valve means, and means communicating at its one end at a location intermediate said first named and said second named discharge valve means and at its other end with said inlet for controlling the discharge of compressed fluid through said first named discharge valve means.

8. The combination of a casing having an inlet and a discharge, means disposed within said casing for compressing a fluid, driving means, check valve means for said discharge, check valve means disposed in the discharge of said casing anteriorly of said first named discharge valve means, and means communicating at its one end at a location intermediate said first named and said second named discharge valve means and at its other end with said inlet for controlling the discharge of compressed fluid through said first named discharge valve means, said discharge controlling means including a pressure responsive device.

9. The combination of a casing having an inlet and a discharge, means disposed within said casing for compressing a fluid, driving means, check valve means for said discharge, check valve means disposed in the discharge of said casing anteriorly of said first named discharge valve means, and means communicating at its one end at a location intermediate said first named and said second named discharge valve means and at its other end with said inlet for controlling the discharge of compressed fluid through said first named discharge valve means, said discharge controlling means including a manually variable weight adjustable valve.

10. The combination of a casing having an inlet and a discharge, means disposed within said casing for compressing a fluid, driving means, check valve means for said discharge, check valve means disposed in the discharge of said casing anteriorly of said first named discharge valve means, and means communicating at its one end at a location intermediate said first named and said second named discharge valve means and at its other end with said inlet for controlling the discharge of compressed fluid through said first named discharge valve means, said discharge controlling means including a device responsive to the pressure at the inlet of said casing.

11. The combination of a casing having an inlet and a discharge, means disposed with-

in said casing for compressing a fluid, driving means, check valve means for said discharge, a delivery line communicating with said discharge through said discharge valve means, check valve means disposed in the discharge of said casing anteriorly of said first named discharge valve means, and means communicating at its one end to a location intermediate said first named and said second named discharge valve means and at its other end with said inlet for controlling the discharge of compressed fluid through said first named discharge valve means, said discharge controlling means including a valve responsive to the pressure of said delivery line.

12. The combination of a casing having an inlet and a discharge, means disposed within said casing for compressing a fluid, driving means, check valve means for said discharge, a delivery line communicating with said discharge through said discharge valve means, check valve means disposed in the discharge of said casing anteriorly of said first named discharge valve means, and means communicating at its one end at a location intermediate said first named and said second named discharge valve means and at its other end with said inlet for controlling the discharge of compressed fluid through said first named discharge means, said discharge controlling means including a valve responsive jointly to the pressure in said discharge line and the pressure at said inlet.

13. The combination of a casing, an impeller disposed within said casing for compressing a fluid, driving means for said impeller, discharge and inlet piping for said casing, passage means closed to the atmosphere interconnecting said discharge and inlet piping, a power operated valve for said passage means, a unidirectional valve for said discharge piping and means responsive to the pressure of said discharge piping and said inlet piping for controlling said passage means valve.

14. The combination with a compressor provided with inlet and discharge openings, and a discharge line, of means for controlling the discharge of fluid from said compressor into said discharge line, said controlling means comprising by-pass means communicating at one end with said discharge opening and at its opposite end with said inlet opening, a valve controlling said by-pass means and pilot valve means controlled by the pressure in said discharge line for operating said valve means alternately to fully open and fully closed positions.

15. The combination with a compressor provided with inlet and discharge openings, and a discharge line, of means for controlling the discharge of fluid from said compressor into said discharge line, said controlling means comprising by-pass means communicating at one end with said discharge opening and at its opposite end with said inlet opening, a valve controlling said by-pass means and power operated pilot valve means controlled by the pressure in said discharge line for operating said valve means alternately to fully open and fully closed positions.

16. The combination with a compressor provided with inlet and discharge openings, and a discharge line, of means for controlling the discharge of fluid from said compressor into said discharge line, said controlling means comprising by-pass means communicating at one end with said discharge opening and at its opposite end with said inlet opening, a valve controlling said by-pass means and valve means controlled by the pressure in said discharge line for operating said valve controlling said by-pass means alternately to fully open and fully closed positions, said valve means comprising a pilot valve member, a casing enclosing said pilot valve member and provided with a port, and a piping connecting said port with said discharge line.

17. The combination with a compressor provided with inlet and discharge openings, and a discharge line, of means for controlling the discharge of fluid from said compressor into said discharge line, said controlling means comprising by-pass means communicating at one end with said discharge opening and at its opposite end with said inlet opening, a valve controlling said by-pass means and valve means controlled by the pressure in said discharge line for operating said valve controlling said by-pass means alternately to fully open and fully closed positions, said valve means comprising a pilot valve member, a casing enclosing said pilot valve member and provided with a plurality of ports and piping respectively connecting said ports with said discharge line and said inlet opening.

18. The combination with a compressor provided with inlet and discharge openings, and a discharge line, of means for controlling the discharge of fluid from said compressor into said discharge line, said controlling means comprising by-pass means communicating at one end with said discharge opening and at its opposite end with said inlet opening, a valve controlling said by-pass means and valve means controlled by the pressure in said discharge line for operating said valve controlling said by-pass means alternately to fully open and fully closed positions, said valve means comprising a pilot valve member, a casing enclosing said pilot valve member and provided with a port, and piping connecting said port with said inlet opening.

19. The combination with a compressor provided with inlet and discharge openings,

and a discharge line, of means for controlling the discharge of fluid from said compressor into said discharge line, said controlling means comprising by-pass means communicating at one end with said discharge opening and at its opposite end with said inlet opening, a valve controlling said by-pass means and valve means controlled by the pressure in said discharge line for operating said valve controlling said by-pass means alternately to fully open and fully closed positions, said valve means comprising a pilot valve member, a casing enclosing said pilot valve member and provided with a port at which the pressure is maintained the same as that of said inlet opening.

In testimony whereof I have signed this specification this 10th day of September 1927.

EVERETT W. SWARTWOUT.