April 13, 1926. 1,580,479

B. FRANKENFIELD

DIAPHRAGM PUMP

Filed Dec. 27, 1924 2 Sheets-Sheet 1

Fig. 1.

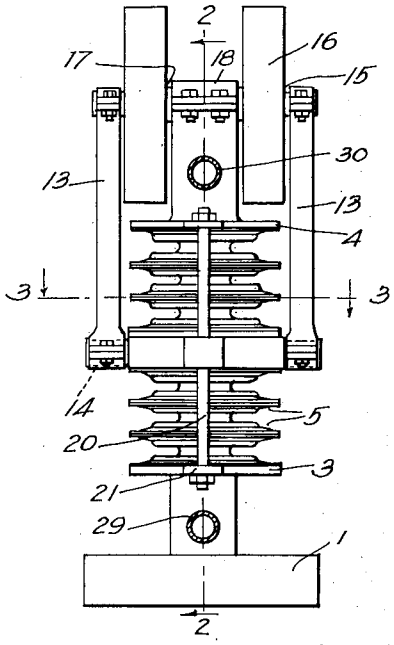
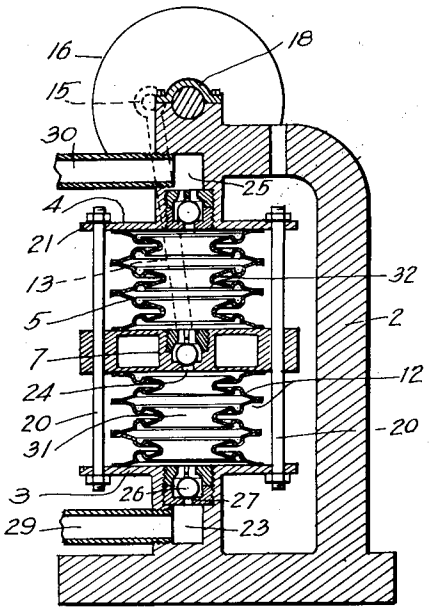


Fig. 2.



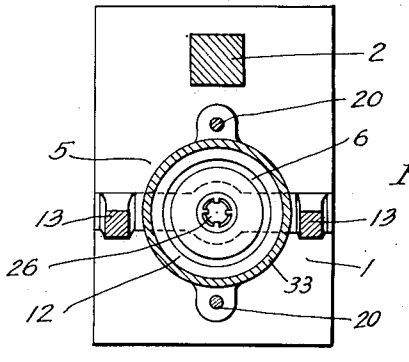


Fig. 3.

Fig. 4

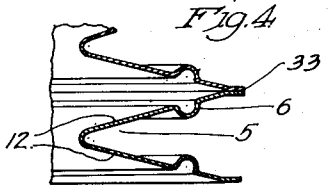
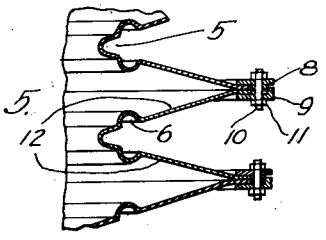


Fig. 5.



INVENTOR.
Budd Frankenfield,
BY Arthur P. Knight
ATTORNEY.

April 13, 1926.

1,580,479

B. FRANKENFIELD

DIAPHRAGM PUMP

Filed Dec. 27, 1924 2 Sheets-Sheet 2

Fig. 6.

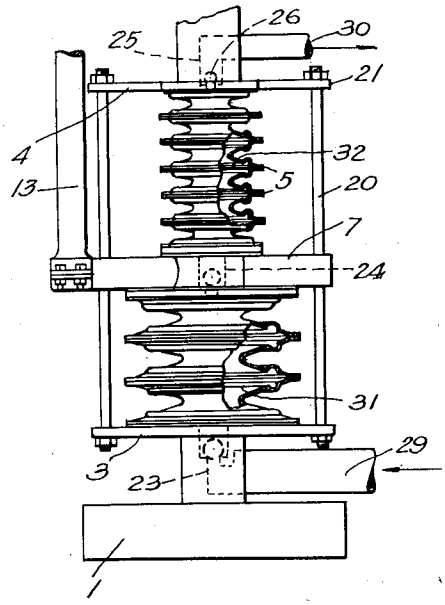


Fig. 7.

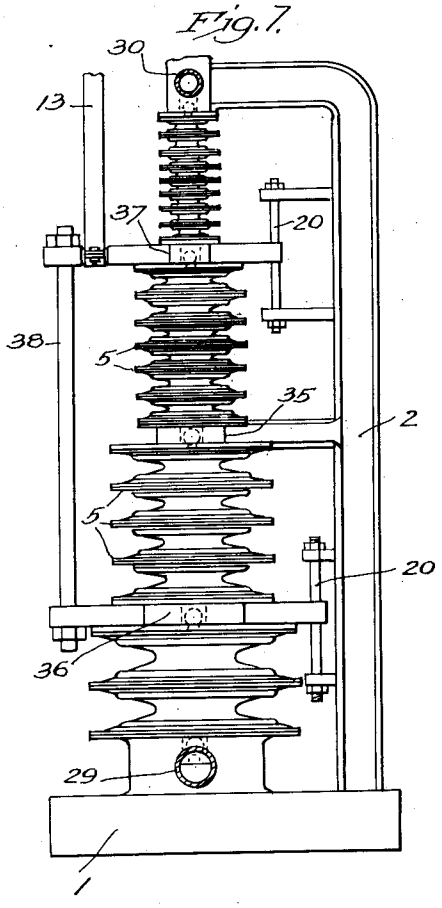


Fig. 8.

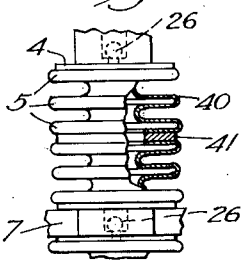


Fig. 10.

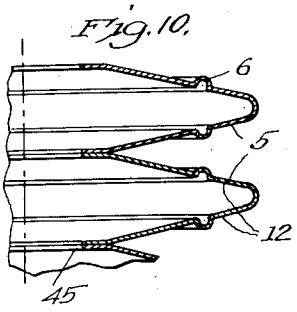


Fig. 9

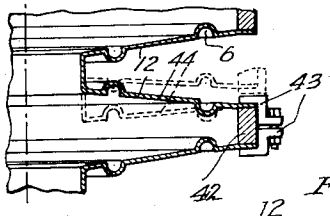
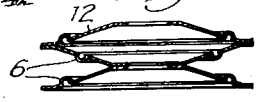


Fig. 11.



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Patented Apr. 13, 1926. 1,580,479

UNITED STATES PATENT OFFICE.

BUDD FRANKENFIELD, OF LOS ANGELES, CALIFORNIA.

DIAPHRAGM PUMP.

Application filed December 27, 1924. Serial No. 758,349.

To all whom it may concern:

Be it known that I, BUDD FRANKENFIELD, a citizen of the United States, residing at Los Angeles, county of Los Angeles, State of California, have invented a new and useful Diaphragm Pump, of which the following is a specification.

This invention relates to pumps for liquids or gases and particularly to pumps of the type in which a closed working chamber is alternately expanded and compressed by means of the movement of a flexible diaphram forming a part of the wall of said chamber. The object of my invention is to provide a pump of this type which possesses all of the inherent advantages of such pumps and is at the same time free from certain disadvantages which have been found in pumps of this type heretofore used.

One of the main advantages of diaphragm pumps in general is that no lubrication is required at any points exposed to the working chamber. In many types of pumps that have been devised there is need for lubrication between the moving and fixed parts at points exposed to the working chamber. For example, in a pump of the piston type a lubricant must be applied to the inside cylinder walls to reduce the friction between the piston and the cylinder. Most rotary pumps are subject to the same objection as it is necessary to maintain a lubricant between the impellers or rotary members and the surfaces over which they pass. Pumps of the centrifugal type, while they are free from close fitting working surfaces, nevertheless require the use of oil or other lubricants in the bearings adjacent the working chamber. The use of such lubricants is often-times undesirable, as it contaminates the liquid or gas being pumped. This is in many cases a very series objection for example in refrigerating plants in which a working fluid is first compressed and then expanded, the introduction of lubricants into the working fluid seriously impairs the effective and economical operation of the apparatus.

Furthermore in pumps of the above mentioned types there is generally more or less leakage of the fluid being pumped between the moving and fixed parts, for example, between the piston and cylinder walls of a piston pump or around the impellers of a rotary pump. Another objection to such pumps is that in many of their embodiments it is necessary to provide stuffing boxes to prevent leakage of the fluid being pumped around the shafts or other moving parts. Such stuffing boxes are objectionable not only due to the added friction introduced but also because of the frequent inspection and adjustment and renewal of packing which are required in order to maintain a tight stuffing box.

Pumps of the diaphragm type are well-known and are free from the above mentioned objections namely, leakage of fluid being pumped, contamination of said fluid with lubricants, and necessity of maintaining tight stuffing boxes. In spite of these inherent advantages of diaphragm pumps their use has been very limited due primarily to their small capacity which in turn is due to the relatively small amount of motion of which a single diaphragm is capable. I have found that this objection may be overcome by providing a plurality of alternately disposed connected diaphragms constituting a plurality of bellows elements so as to increase to any desired extent the total motion which may be obtained and thus greatly increase the capacity of the pump. Another objection to pumps of the diaphragm type heretofore devised is that either the inlet or the outlet connection of many of said pumps is formed in or connected to a movable member, and a flexible connection must therefore be provided at this point. Such flexible connection is obviously undesirable and an important object of my invention is to provide a pump of the diaphragm or bellows type as above set forth in which no flexible connections are required. This object I accomplish by providing a plurality of bellows elements with fixed inlet and outlet means at the respective ends thereof and with a reciprocating or movable cross-head at an intermediate point in the series of bellows elements and serving to divide the interior of said bellows elements into two working chambers in such manner that the reciprocating movement of the cross-head causes alternate compression and expansion of said working chambers, suitable valve means being provided at the inlet and outlet means and in the movable cross-head

for permitting the desired motion of the fluid being pumped. In this manner I not only obviate the necessity of flexible connections, but also obtain a multi-stage pumping action, which makes possible the production of higher pressure than with a single stage. Furthermore, I decrease the size of the bellows elements or working chambers from the inlet to the outlet of the pump, and thus provide a pump of the compound type, so that in pumping a gas provision is made for the decrease in volume which occurs as the gas is compressed in the successive stages. In some cases the number of stages may be greater than two, for example, there may be four or more stages. The pump with decreasing size of bellows elements may also be used with liquids, to obtain a steady pumping action by delivering liquid on both strokes of the pump.

The accompanying drawings illustrate embodiments of my invention and referring thereto:

Fig. 1 is a side elevation of a diaphragm pump of the type to which this invention relates.

Fig. 2 is a vertical section on line 2—2 in Fig. 1.

Fig. 3 is a horizontal section on line 3—3 in Fig. 1.

Fig. 4 is an enlarged partial vertical section of a pair of bellows elements suitable for use in my invention.

Fig. 5 is a view similar to Fig. 4 showing a modified method of securing the bellows elements together.

Fig. 6 is a side elevation, partly broken away, of one embodiment of my invention.

Fig. 7 is a side elevation of another embodiment of my invention.

Fig. 8 is a partly sectional side elevation showing a modified form of bellows elements.

Figs. 9, 10 and 11, are partial vertical sections of adjacent bellows elements showing possible modifications in the construction thereof.

The apparatus shown in Figs. 1 to 3 comprises a suitable supporting frame having base 1 and standard 2. Said frame may be provided with a pair of opposing end plates or face plates 3 and 4 between which are mounted a series of interconnected bellows elements 5. Each of said bellows elements constitutes a pair of oppositely disposed diaphragm means 12 provided with suitable means indicated at 6 for permitting flexure thereof. At an intermediate point, and preferably substantially midway between the two face plates 3 and 4 is provided a reciprocating cross-head 7, which divides the series of bellows elements into two bellows means, and cooperates with said bellows means to define two working chambers or pumping units 31 and 32. The bellows elements 5 are secured to one another and to the face plates and crosshead in any suitable manner, for example as shown in Fig. 4, said elements may be brazed or welded together as at 33; or as shown in Fig. 5 suitable clamping means such as rings 8 and 9 may be used for this purpose, said rings being adapted to fit over the edges of the adjacent bellows elements and being provided with suitable fastening means such as bolts 10 and nuts 11. Said clamping rings are preferably made in sections to permit their being assembled around the bellows elements and it is also preferable to break joints in connecting said clamping means so as to cause said means to be firmly held in place.

Suitable operating or driving means are provided for effecting reciprocating motion of the cross-head 7, said operating means comprising for example connecting rods 13 engaging wrist pins 14 on said cross head and mounted eccentrically as at 15 on driving wheels 16. The shaft 17 of said driving wheels may be mounted to rotate in suitable bearing means 18 at the upper end of standard 2 and any suitable means may be provided for effecting rotation thereof, for example one or both of said driving wheels may constitute a pulley adapted to be driven by a belt or one or both of said driving wheels may be provided with gear teeth adapted to engage with suitable gears for effecting rotation thereof. Suitable guide means for the cross-head 7 are preferably provided, said guide means comprising for example guide rods 20 mounted at either end on outwardly extending portions 21 of face plates 3 and 4.

Suitable valve controlled passage means are provided for controlling the passage of fluid through the pump, said passage means comprising for example inlet passage 23, intermediate passage 24 between the two working chambers 31 and 32, and outlet passage 25. Each of said passage means is provided with suitable valve means, preferably check valves. Said check valves may be of any well-known type, for example, they may comprise ball valves 26 adapted to engage or cooperate with valve seats 27. Said check valves are adapted to be opened in an upwardly direction by means of pressure from below and are adapted to be closed by gravity or otherwise upon the release of such pressure. Inlet and outlet pipes 29 and 30 may be connected respectively to the inlet and outlet passage means 23 and 25.

In the diaphragm pump shown in Figs. 1 to 3 the bellows elements 5 are of substantially the same diameter throughout the length of the pump and the working chambers 31 and 32 are therefore substantially equal in volume.

In order to provide for multistage com-

pression in the case of a gas, or for discharge during both strokes in the case of a liquid, the bellows elements 5 of the pumping unit 31 near the inlet end are, according to my invention, of substantially greater diameter than the bellows elements of the pumping unit 32 near the outlet end of the pump, as shown in Fig. 6. The working chamber of the latter pumping unit is thus smaller in volume than that of the former so as to provide for compression or decrease in volume of the gas upon increase in pressure as is customary in compound pumps. As it is desirable that the length of each bellows element should be approximately proportional to its diameter in order to provide for the proper shape of the diaphragm means, and as the total length of the stroke is equal in the two chambers, I also prefer to provide a greater number of bellows elements of relatively lesser unit length in the high-pressure pumping unit 32 and a smaller number of bellows elements of relatively greater unit length in the low pressure pumping unit 31. As shown in Fig. 6. The pump is in this case provided as in the form first described, with suitable driving means, guide means, and valve controlled passage means substantially as above described.

In the operation of the pump as shown in Fig. 6 the driving means is set in moton, causing the cross head 7 to reciprocate or travel up and down on the cross-head guides 20. Each of the working chambers 31 and 32 is thus alternately compressed and expanded. During the expansion of the chamber 31 brought about by the upward motion of the cross-head, communication is closed through intermediate passage 24 due to excess pressure from above operating upon the check valve therein, and the fluid to be pumped is drawn in through inlet pipe 29 and inlet passage 23 into said working chamber, the decreased pressure within said chamber causing the check valve in passage 23 to be opened. At the end of the upward stroke of the cross-head the bellows elements comprising chamber 31 are therefore expanded to the maximum volume and said chamber is filled with the fluid being pumped. During this same stroke of the pump the upper working chamber 32 is being compressed in volume and the fluid is therefore forced from said chamber through the outlet passage 25 and outlet pipe 30. During the reverse stroke of the cross-head the check valves are operated in such manner that fluid is forced from the first or low pressure working chambers 31 into the second or high pressure working chamber 32. Fluid is therefore drawn into the pump and discharged therefrom at a higher pressure upon each complete up and down stroke of the cross-head.

In case the fluid being pumped is a liquid there is of course no appreciable compression of such liquid. During the entire downward stroke of the cross-head liquid is therefore forced from the larger working chamber into the smaller chamber and due to the smaller capacity of the latter a part of this liquid is discharged through the outlet valve during the downward stroke. A further amount is discharged on the upward stroke, thus providing substantially continuous discharge. On the other hand when the fluid being pumped is a gas such gas is first compressed within the low pressure working chamber 31 during the first part of the downward stroke of the cross-head until the pressure in the two working chambers becomes equal and such gas is then forced into the high pressure working chamber during the remainder of said stroke. In the same manner, the gas in the high pressure working chamber 32 is first compressed and then discharged during the upward stroke of the cross-head.

I may in some cases provide a pump having more than two stages, for example as shown in Fig. 7, four of such stages may be provided. In this case the middle cross-head 35 is fixed for example by connection to the standard of the frame and two movable or reciprocating cross-heads 36 and 37 are provided between said middle cross head and the inlet and outlet ends of the pump respectively. The successive pumping units are each composed of a series of bellows elements as in the forms above described and suitable valve controlled passage means are provided between said pumping units as well as at the inlet and outlet ends of the pump. The reciprocating cross-heads 36 and 37 are provided with suitable guide means indicated at 20 and with suitable driving means comprising for example connecting rod 13 adapted to be driven in any suitable manner. Said cross heads may be provided with separate driving means if desired or they may be connected together in any suitable manner for example by means of tie rod 38 so as to enable connecting rod 13 to effect simultaneous movement of both of said cross-heads.

The bellows elements comprising the four pumping units may in this case also be made of progressively decreasing diameter in the successive pumping units from the inlet toward the outlet end of the pump. The effective volume of each working chamber is therefore less than the preceding one and the pump is therefore adapted for pumping gases. Also in order to maintain equal deformation in the diaphragms of all the bellows elements the length of each element is proportioned to its diameter, and the number of elements in each chamber is successively increased.

The operation of the above described four stage pump is substantially the same as that

of the corresponding two stage pump above described. The first and third working chambers will be compressed and expanded together and alternately with the second and fourth working chambers. The fluid being pumped is therefore drawn in at the inlet and is caused to pass through the successive working chambers and is discharged at a higher pressure at the outlet, said movement and increase in pressure of the fluid being accompanied by a corresponding reduction in volume in the case of gas.

It will be obvious that I may provide any even number of pumping units or working chambers, connected together in series and operated as above described, the alternate cross-heads being respectively fixed and reciprocating. My invention may therefore be said to comprise in general a plurality or series of pumping units or working chambers each preferably made up of a plurality of bellows elements, means interposed between said pumping units and cooperating therewith to define a plurality or series of working chambers, passage means connecting said pumping units in series and provided with check valves, and means for compressing and expanding each of said pumping units alternately with adjacent units, the bellows elements of successive pumping units being made of progressively decreasing diameter so that said pumping units and the working chambers enclosed thereby are of progressively decreasing effective volume, and the bellows elements of the successive pumping units decreasing in length and increasing in number in order to maintain the proper shape of the diaphragm or bellows elements while maintaining the stroke of each pumping unit the same throughout the pump.

I do not desire to be limited to any particular form or type of diaphragm or bellows elements, nor to any particular method of connecting said bellows elements together, for example as shown in Fig. 8, a number of said bellows elements may be formed in one piece as indicated at 40. A unit may thus be provided comprising, for example, three or more bellows elements. Each working chamber may in some cases comprise only one of said units or as shown in Fig. 7, two or more of said units may be connected in series to form a single working chamber, suitable reinforcing or stiffening means such as ring 41 being provided between said units if desired.

Any suitable means may be provided for permitting the necessary flexure of the diaphragm means or bellows elements for example as indicated at 6 in Figs. 4, 5, 9, and 10; such means may comprise inwardly or outwardly projecting ribs formed in said diaphragms. I may also provide in some cases for double flexure of the diaphragm means, that is to say, for motion of said means in both directions from a plane perpendicular to the axis of the pump as shown in Fig. 9. Suitable spacing rings 42 may be provided in such case and suitable clamping means indicated at 43 may be provided for securing the bellows elements to said spacing rings. With such a construction each of the diaphragm means may be flexed in either direction from the dead center position, as indicated at 44, thus providing for relatively large motion with a smaller number of diaphragms.

Each of the bellows elements may comprise a pair of outwardly flaring diaphragm means as indicated in Fig. 4, said bellows elements being in such case connected together at their outer edges or as shown in Fig. 10, each bellows element may comprise a pair of diaphragm means facing inwardly toward one another and in this case the bellows elements are connected together at their inner edges as indicated at 45. Furthermore if desired each bellows element may consist of two separate diaphragm means, or in other words the flexible walls of the working chambers may be made up of a series of independent alternately disposed diaphragm means 12 connected to one another at both their inner and outer edges, as shown in Fig. 11. Also, as shown in this same figure, in order to decrease the clearance and thus increase the efficiency of the pump, I may in some cases prefer to offset the flexure means or ribs 6 in adjacent or opposing diaphragms, so as to permit such diaphragms to be brought closer together without causing said ribs to strike or engage one another.

The diaphragms or bellows elements may be formed of any suitable flexible material, such as thin steel or other metal, or in some cases, for example in the form shown in Fig. 8, of more flexible material such as leather. Or they may be made partly of metal to provide strength at the points subjected to the greatest stress, and partly of leather or other more flexible material to provide the necessary flexibility.

The operation of the pumps above described is intermittent or pulsating when operating on a compressible fluid or gas, in that fluid is drawn in during only one half of the stroke and discharged during the other half of the stroke. In some cases such pulsating action may be objectionable and can readily be obviated by arranging a plurality of such pumps side by side and adapted to operate in the manner of duplex or triplex pumps of the piston type.

Furthermore while I have shown and described my invention only in connection with its use as a pump, its action is reversible, and by supplying suitable mechanically operated valves adapted to be opened at the

proper time a gas or liquid under pressure may be passed through the apparatus and the resulting motion of the reciprocating member may be used to deliver power in any suitable manner.

What I claim:

1. A pump comprising a series of bellows elements, inlet and outlet means provided with check valves at the respective ends of the series of bellows elements, a reciprocating member connected at an intermediate portion in said series of bellows elements and dividing the space within said bellows elements into two pump chambers, said reciprocating member being provided with a check valve controlled passage for controlling communication between said two pump chambers, and the bellows elements enclosing the pump chamber nearer the inlet means being of larger diameter and greater length but less in number than the bellows elements enclosing the pump chamber nearer the outlet means.

2. In a pump a plurality of pumping units each comprising a plurality of bellows elements, means interposed between said pumping units and cooperating therewith to define a plurality of working chambers and provided with valve controlled passage means connecting said working chambers, and means for compressing and expanding each of said pumping units alternately with each adjacent pumping unit, all the bellows elements of any one pumping unit being of the same diameter and unit length but said bellows elements being of successively lesser diameter and unit length and greater number in each successive pumping unit in the direction of fluid flow.

3. In a pump, two pumping units, each defining a working chamber and each comprising a plurality of bellows elements, reciprocating means connected between said two pumping units and provided with a valve controlled passage controlling communication between said working chambers, the outer ends of said two pumping units being fixed, and means for reciprocating said reciprocating means, the bellows elements of one of said pumping units being of greater diameter and unit length and of lesser number than the bellows elements of the other pumping units.

4. In a pump a series of pumping units each comprising a plurality of bellows elements, means connecting said pumping units in series and provided with check valve controlled passage means communicating with adjacent pumping units and adapted to permit fluid passage therethrough in one direction only, said connecting means being alternately fixed and movable, and means for reciprocating said movable connecting means, all the bellows elements of any one pumping unit being of the same diameter and unit length but said bellows elements being of successively lesser diameter and unit length and greater number in each successive pumping unit in the direction of fluid flow.

In testimony whereof I have hereunto subscribed my name this twelfth day of December 1924.

BUDD FRANKENFIELD.