Nov. 10, 1970 A. J. ANDREWS ET AL 3,539,277

BELLOWS PUMP

Original Filed Aug. 1, 1968 2 Sheets-Sheet 1

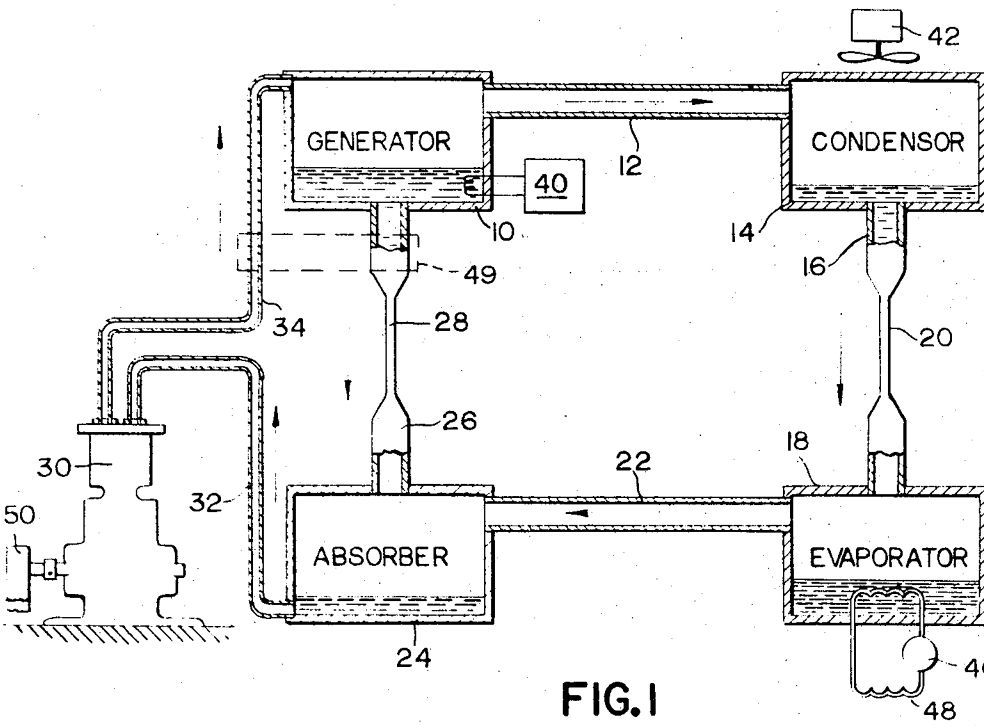


FIG. 1

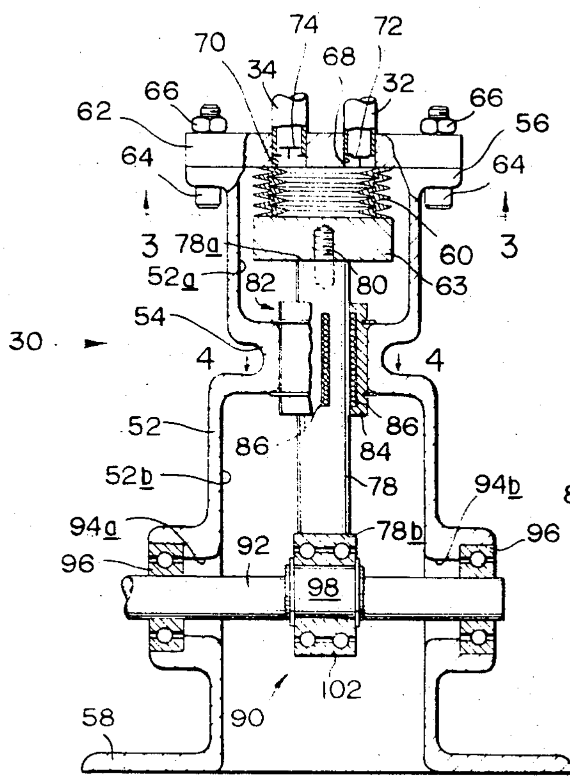


FIG. 2

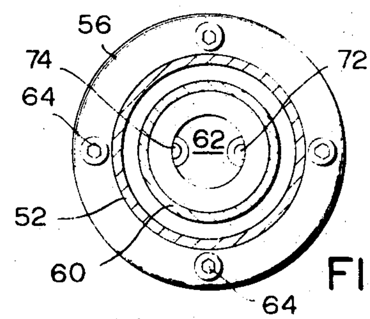


FIG. 3

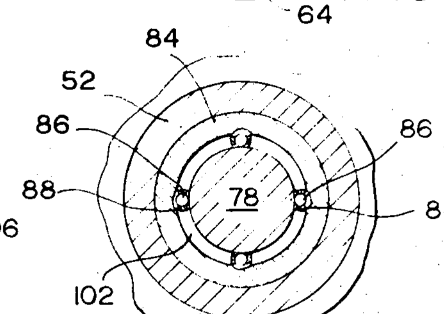


FIG. 4


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Original Filed Aug. 1, 1968 2 Sheets-Sheet 2

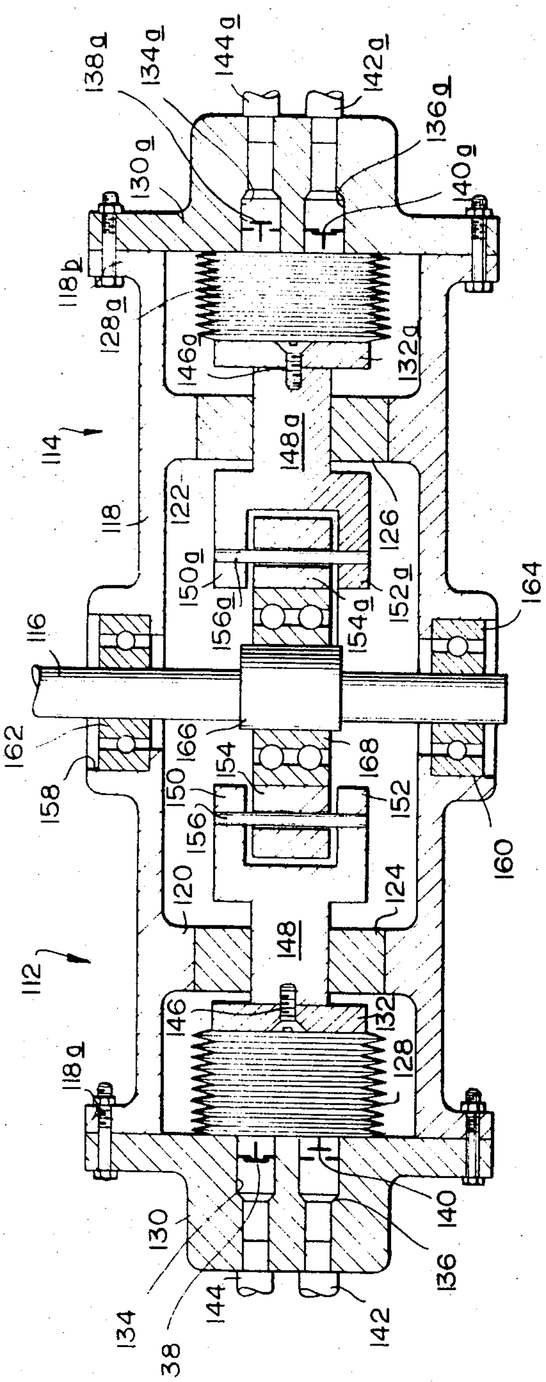


FIG. 5

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# 3,539,277
# BELLOWS PUMP

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Original application Aug. 1, 1968, Ser. No. 749,403, now Patent No. 3,473,347, dated Oct. 21, 1969. Divided and this application Apr. 9, 1969, Ser. No. 814,602
Int. Cl. F04b 43/00
U.S. Cl. 417—473 3 Claims

## ABSTRACT OF THE DISCLOSURE

A pump comprises a bellows having one end sealed to a header and communicating with intake and outlet valves in the header. The other end of the bellows is closed and is moved toward and away from the header by a shaft driven by an eccentric. The drive mechanism is bearing mounted and designed to move the bellows only parallel to the longitudinal axis of the bellows. These factors minimize the stresses on the pump elements and enable the pump to run much faster and for longer periods than prior pumps used for this purpose. Also, the pump can operate with a very low suction head.

## RELATED APPLICATION

This application is a division of our copending application Ser. No. 749,403, filed Aug. 1, 1968, now Pat. No. 3,473,347.

## BACKGROUND OF THE INVENTION

This invention relates to an improved pump for circulating working fluids through systems such as a refrigeration system. It should be understood, however, that the pump can also be used as a compressor or vacuum pump to move liquids and gases.

Some refrigeration systems have four basic sections, to wit, a generator, a condenser, an evaporator and an absorber, connected together in a closed loop. Working fluids are circulated between the different sections to obtain the refrigeration effect.

For best results, the refrigeration system should meet the following three requirements. First, the system should be completely leakproof. This is because its working fluids are usually corrosive or toxic. Secondly, the system should have a long, useful life and require a minimum amount of maintenance under a variety of operating conditions. Specifically, the system should be able to function effectively even at temperatures below 30° F. Finally, the cost, size and weight of the refrigerator should be kept to a minimum.

There are several available absorption refrigeration systems which are superior with respect to one or another of the above criteria. However, none of them exhibit superior performance with respect to all of these factors. This is due in large part to the means used heretofore to circulate the working fluids in the system. More particularly, conventional systems rely on a piston pump or a diaphragm pump to circulate the fluids around the refrigeration loop. The piston pump is unsatisfactory because its seals tend to leak after a relatively short time due to exposure to the corrosive working fluids. The diaphragm pump, on the other hand, which is most commonly used in these systems, must be operated at relatively low speeds, i.e. on the order of 100–300 r.p.m. Consequently, it tends to deliver the fluid in pulses, with the result that it must be followed by an accumulator to average out these fluid pulses. Further, because it is a low speed device, the diaphragm pump requires either a

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separate drive system or elaborate gear reduction from its usual power takeoff at the main high speed circulating pump used in these systems. Of course, all of these extra components increase the cost, size and weight of the overall refrigerator.

The diaphragm pump has another serious drawback in that it requires a certain minimum positive pressure head, on the order of 10 p.s.i.g., at the input side of the pump. This minimum pressure head is needed to return the pump diaphragm after each pressure stroke to ready it for the next pressure stroke. The inability of the diaphragm pump to operate with a low suction head, in turn, limits the refrigeration effect which can be obtained from the system as a whole. This is because the refrigeration effect increases as the pressure at the low pressure side of the refrigeration loop (i.e. at the suction side of the pump) decreases. Since present day diaphragm pumps limit this suction head to 10 p.s.i.g., they also limit the refrigeration effect which can be obtained from a given amount of refrigerant. More specifically, they prevent the refrigerator from working effectively when the ambient temperature falls below 30° F. because, at this temperature, the pressure at the pump inlet becomes less than 10 p.s.i.g.

## SUMMARY OF THE INVENTION

Accordingly, an object of the present invention is to provide an improved solution pump for an absorption refrigeration system which minimizes the overall cost of the system.

A still further object of the invention is to provide a fluid-tight, positive displacement pump for pumping corrosive and toxic fluids.

Another object of the invention is to provide a circulation pump which can operate at relatively high speeds.

A still further object of the invention is to provide a pump which can operate effectively with a relatively low suction head.

Still another object of the invention is to provide a positive displacement pump whose components suffer a minimum amount of stress and wear in use.

Other objects of the invention will in part be obivous and will in part appear hereinafter.

The invention accordingly comprises the features of construction, combination of elements, and arrangement of parts which will be exemplified in the constructions hereinafter set forth, and the scope of the invention will be indicated in the claims.

Briefly, a refrigeration system comprises a generator, condenser, evaporator and absorber arranged in a closed loop. A positive displacement, welded bellows solution pump is connected between the generator and the absorber to pump the working fluids from the absorber at a low pressure, generally atmospheric pressure, to the generator at the high pressure side of the loop.

The solution pump comprises a housing having upper and lower compartments. A welded bellows is situated in the upper compartment. One end of the bellows is sealed to a header forming the top wall of the upper compartment and inlet and outlet check valves in the header communicate with the interior of the bellows. The other end of the bellows is closed and is free to move.

A vertical shaft having one end secured to the bellows end extends down through a bearing-lined bushing into the lower compartment. The lower end of the shaft rides on a bearing encircling an eccentric carried by a transverse drive shaft journaled in the sidewalls of the lower compartment. The drive shaft is driven, in turn, by a source of rotary power. Thus, when the drive shaft turns, the vertical shaft moves up and down.

On the upstroke of the vertical shaft, the bellows is compressed so that any fluid inside the bellows is pumped out through the outlet valve in the header and thence to the generator. Preferably the expansion of the bellows is not due directly to the downward movement of the vertical shaft. Rather, the bellows itself functions like a compression spring. That is, the bellows is still under some compression when the vertical shaft is in its full down position. Consequently, the free end of the bellows follows the shaft on its downward stroke, rather than being forceably pulled down by shaft. When this occurs, fluid is drawn from the absorber into the bellows through the inlet valve in the header.

This process repeats itself during each revolution of the drive shaft so that the working fluids are forceable and continuously pumped from the absorber to the generator.

The employment of this bellows solution pump enables the overall refrigeration system to function effectively even when the ambient temperature is below 30° F. This is because the pump does not require a minimum positive pressure head at its suction side. In fact, present pump will work satisfactorily even with a small negative suction head.

Also, the elements of the pump are all designed to minimize stresses on the bellows and also to minimize frictional losses within the pump. Accordingly, the pump can operate at greater speeds for a longer period than can conventional bellows pumps which are presently being used for other purposes. The fact that the present pump can operate at high speed produces two distinct advantages. First, the pump can be driven via a direct belt drive from the high speed water circulating pump used in these systems. This eliminates costly speed-reducing equipment which contributes to the weight and bulk of the overall system. Also, fluid pulses in the output from the present pump are much less pronounced than is the case with prior comparable solution pumps. Consequently, the present system does not require an accumulator to average out pulses in fluid being pumped to the generator. This also results in a concomitant decrease in the cost and size of the overall refrigeration system.

While the pump is primarily used as a compression pump it can also be used as a vacuum pump.

## BRIEF DESCRIPTION OF THE DRAWINGS

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description taken in connection with the accompanying drawings, in which:

FIG. 1 is a schematic diagram of an absorption refrigeration system using our improved pump;

FIG. 2 is a vertical section with parts in elevation and other parts cut away of our pump;

FIG. 3 is a sectional view along line 3—3 of FIG. 2;

FIG. 4 is a sectional view along line 4—4 of FIG. 2; and

FIG. 5 is a vertical section with parts in elevation of another pump embodiment employing the principles of the invention.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1 of the drawings, the present system comprises a generator **10** connected by way of a pipe **12** to a condenser **14**. A pipe **16** communicates between the bottom of condenser **14** and the top of evaporator **18**. Pipe **16** has a restriction at **20** provided by an expansion valve. A pipe **22** connects the top of evaporator **18** to the top of an absorber **24**. Further, a pipe **26** connects the top of absorber **24** to the bottom of generator **10**. Pipe **26** also has a restriction **28** similar to restriction **20** in pipe **16**. Thus, the generator, condenser, evaporator and absorber are arranged in a closed fluid-tight loop.

A fluid circulating pump **30**, to be described in detail later, is connected between absorber **24** and generator **10**. Specifically, a pipe **32** communicates between the bottom of absorber **24** and the suction side of pump **30** and a pipe **34** leads from the pressure side of pump **30** to the top of generator **10**. Thus, restrictions **20** and **28** (and pump **30**) divide the loop into a high pressure side comprising generator **10** and condenser **14** and a low pressure side comprising evaporator **18** and absorber **24**.

The system uses two working fluids. A refrigerant fluid, such as ammonia, is circulated clockwise in various phases all around the loop, while an absorbent liquid such as water circulates only between generator **10** and absorber **24**. The purpose of the absorbent liquid is to enable pump **30** to return refrigerant vapor from absorber **24** to generator **10** after each evaporation cycle.

During operation of the system, a rich aqua-ammonia solution in generator **10** is heated by any suitable means indicated by an electric heater **40**. Ammonia is boiled off and passes through pipe **12** to condenser **14** as a vapor. In condenser **14**, the ammonia vapor is cooled by suitable external cooling means indicated by a fan **42**. The vapor condenses and the condensate passes through restriction **20** to the low pressure side of the loop. Specifically, the liquid ammonia flashes into evaporator **18** and cools water-carrying chiller coils **44** located therein. A pump **46** circulates the cold water from coils **44** to external cooling coils **48** which then cool the space around them. The coils **44** and **48** and pump **46** form a closed loop and pump **46** is normally driven at a high speed on the order of 3600 r.p.m.

From evaporator **18**, the ammonia vapor passes through pipe **22** into absorber **24**. At the same time, water from generator **10** at a high pressure, is forced through restriction **28** in pipe **26** into absorber **24**, maintained at a lower pressure. The ammonia vapor is dissolved in the water and the rich aqua ammonia mixture settles to the bottom of the absorber. Pump **30** then pumps the rich aqua ammonia solution from the absorber back to the generator **10** under high pressure, and the cycle commences again.

To further maximize the efficiency of the system, pipes **26** and **34** may be placed in heat exchange relationship as indicated by a heat exchange shell **49** shown in dotted lines. In this way, the heated water flowing to absorber **24** is used to preheat the cool aqua ammonia solution being pumped to generator **10**.

Pump **30**, to be described shortly, can operate at high speeds, on the order of 900–1200 r.p.m. Therefore, pump **30** can be driven through a conventional speed reduction belt drive **50** directly off high speed pump **46**. Consequently, the FIG. 1 device does not require a separate drive means or speed reducer which would add to its cost and size. Moreover, because it operates at high speeds, the pump **30** delivers fluid to generator **10** relatively uniformly so that there is no need for an accumulator to smooth its output as is the case with solution pumps in other comparable systems.

Referring now to FIG. 2, pump **30** comprises an upstanding generally cylindrical housing **52** which is formed with a restriction **54** dividing the housing into upper and lower open-ended compartments **52*a*** and **52*b***, respectively. The upper end of housing **52** is outwardly flanged at **56** and the lower end of the housing is flanged at **58**. Flange **58** serves as a base by which pump **30** can be secured to a suitable support.

An open-ended welded bellows **60** is situated in upper compartment **52a**. One end of bellows **60** is sealed to a discoid header **62** which closes off the top of compartment **52*a***. The other end of the bellows is sealed to a circular plate **63**. Header **62** is coextensive with upper flange **56** and is secured thereto by a series of threaded bolts **64** extending through the flange and header. Correspondingly threaded nuts **66** are turned down on the bolts to maintain a fluid-tight joint between flange **56** and header **62**. Suitable gasketing may be provided there, if needed.

As best seen in FIGS. 2 and 3, a pair of vertical openings **68** and **70** are formed in header **62** which communicate with the interior of bellows **60.** Opening **68** contains an inlet valve in the form of a conventional check valve **72** which allows fluid to flow into, but not out of, bellows **60**; opening **70** contains a similar check valve **74** which is arranged to allow fluid to flow only out of bellows **60.** The ends of pipes **32** and **34** (FIG. 1) are screwed into openings **68** and **70,** respectively, and thus communicate through the valves with the interior of bellows **60.**

A vertical cylindrical shaft **78** is secured at one end **78***a* to plate **63** by means of a double-ended, threaded stud **80** prior to securing header **62** to housing **52.**

As best seen in FIGS. 2 and 4, shaft **78** extends down into lower compartment **52***b* through a bushing **82.** Bushing **82** comprises an open-ended sleeve **84** which is secured to housing **52** within restriction **54** so that its longitudinal axis is aligned with the longitudinal axis of bellows **60.** Vertical arrays of ball bearings **86** in cages **88** are distributed around the inside of sleeve **84** to provide low friction bearing surfaces for shaft **78.**

Referring again to FIG. 2, shaft **78** is moved up and down along the axis of bellows **60** by means of a drive unit indicated generally at **90** in lower compartment **52***b* of housing **52.** Drive unit **90** comprises a horizontal drive shaft **92** extending through flanged openings **94***a* and **94***b* on opposite sides of compartment **52***b*. Specifically, drive shaft **92** is journaled in conventional double race ball bearing units **96** mounted in openings **94***a* and **94***b*. Also, one end of drive shaft **92** is coupled to belt drive **50** (FIG. 1).

As shown in FIG. 2, drive shaft **92** carries an eccentric **98** which is positioned directly below bushing **82.** Also, a cam-follower **102** in the form of a double race ball bearing unit encircles eccentric **98** with the inner race being keyed to the eccentric. Shaft **78** extends down into compartment **52***b* so that its lower end **78***b* normally rides on cam-follower **102.**

When shaft **92** is rotated, shaft **78** is moved up and down by eccentric **98** through cam-follower **102,** thereby actuating bellows **60.** Thus, as eccentric **98** moves toward its up position, shaft **78** compresses bellows **60,** thereby forcing any fluid in the bellows out through valve **74** and into generator **10** (FIG. 1). During this time, the inlet valve **72** is closed. Then, as eccentric **98** moves toward its down position, bellows **60,** which is under compression, pushes against shaft **78** so that the shaft follows the eccentric. During this part of the pump cycle, inlet valve **72** opens, drawing in more fluid from absorber **24,** while outlet valve **74** remains closed. Thus, fluid is drawn into and pumped out of bellows **60** during each revolution of drive shaft **92.**

It is important to note that all of the potential wear surfaces of the moving elements **78** and **92** are supported in ball bearing elements, i.e. bushing **82** and bearing units **96** and **102.** Therefore, these elements suffer a minimum amount of wear. For the same reason, pump **30** is able to operate at relatively high speeds as mentioned previously.

It should be emphasized also the pump components are arranged to keep the stresses on its different elements to a minimum. Thus, bellows **60,** shaft **78** and eccentric **98** are all disposed along the very same vertical axis. Also, shaft **78** is loose and rides on cam-follower **102.** Consequently, drive unit **90** does not transmit any appreciable sidewise forces to shaft **78** as would tend to cock it. Moreover, shaft **78** itself is constrained by bushing **82** so that it can only move along the axis of bellows **60.** Consequently, no appreciable sidewise forces are imparted to the bellows as would tend to unduly stress or distort it with the result that bellows **60** is able to operate at high speeds for relatively long periods without breaking.

Bellows **60** is still under some compression in its fully



open condition. Therefore, it is able to operate properly even though the pressure on the suction side of the pump, i.e. in pipe **32,** drops to a relatively low value. In fact, the present pump works effectively with suction heads as low as −½ p.s.i.g. Resultantly, the FIG. 1 system cools efficiently even when the ambient temperature drops below 30° F.

FIG. 5 shows a duplex pump made in accordance with the present invention. The FIG. 5 pump is utilized where higher flow rates are desired in the refrigeration loop or in applications requiring low flow rates, but more unifom fluid velocities.

The FIG. 5 pump comprises two identical pump sections indicated generally at **112** and **114.** The components of the two pump sections are all arranged in a straight line and both sections are driven in unison by a single drive shaft **116** between them. As with the FIG. 2 pump, the in-line construction minimizes stress and wear on the pump components.

The duplex embodiment comprises a generally cylindrical, open-ended housing **118.** The opposite ends of housing **118** are flanged at **118***a* and **118***b*. Also, housing **118** has reduced diameter portions **120** and **122** midway along the two pump sections in which are mounted similar bushings **124** and **126.**

A welded bellows **128** is situated in pump section **112** outwardly of bushing **124.** One end of bellows **128** is sealed to a generally circular header **130** which is bolted to flange **118**a, thereby closing off the open end of pump section **112.** The other end of bellows **128** is sealed to a circular plate **132.**

A pair of passages **134** and **136** extend through header **130** and communicate with the interior of bellows **128.** Passage **134** contains a check valve **138** which allows fluid to flow out of, but not into, bellows **128;** passage **136** contains a similar check valve **140** which only permits fluid to flow into the bellows. Pump section **112** draws fluid into bellows **128** from an inlet pipe **142** connected to passage **136** and pumps fluid out of bellows **128** through an outlet pipe **144** connected to passage **134.**

Plate **132** is secured by a threaded stud **146** to one end of a power transmitting shaft **148** received in bushing **124.** The opposite end of shaft **148** is bifurcated, forming a pair of spaced, parallel arms **150** and **152.** Shaft **148** is arranged so that arms **150** and **152** extend perpendicular to drive shaft **116.**

A rubbing member **154** is positioned between arms **150** and **152.** A pin **156** extends loosely through member **154** and is secured to arms **150** and **152.** Thus, member **154** is positioned between the arms, but can cock or pivot slightly above the pin.

Drive shaft **116** extends through flanged openings **158** and **160** in housing **118.** Specifically, shaft **116** is journaled in double race ball bearing units **162** and **164** positioned within openings **158** and **160,** respectively. Also, shaft **116** carries an eccentric **166** which is positioned directly opposite member **154.** Member **154** rides on a ball bearing cam follower **168** carried by the eccentric. Thus, when shaft **116** is rotated toward a position 180° from its position indicated in FIG. 5, shaft **148** is urged to the left, thereby compressing bellows **128.** This causes any fluid in the bellows to be pushed out through valve **138** and then to the outlet pipe **144.**

On the other hand, when the shaft is rotated toward the illustrated position, bellows **128** expands. The expansion of bellows **128** draws additional fluid from pipe **142** into the bellows through valve **140.** As mentioned previously, bellows **128** is still under some compression when shaft **148** has moved to the right as far as it can go. Therefore, the bellows does not require positive pressure in the inlet passage **136** to expand it.

The provision of the cocking member **154** minimizes the sidewise forces that might be transmitted from eccentric **166** to shaft **148.** Moreover, the shaft is constrained by bushing **124** to move only along the axis of bellows **128.**

Consequently, the bellows is not subjected to sidewise stresses which might tend to distort or break it, as fully described above in connection with FIG. 2.

The elements of pump section **114** are identical to those of section **112**. Therefore, we will not describe them again in detail. The section **114** components corresponding to those in section **112** carry the same identifying number followed by the letter *a*. It should be noted, however, that the pumping cycles of sections **112** and **114** are 180° out-of-phase. That is, when fluid is being pumped out of bellows **128** in section **112**, fluid is being drawn into bellows **128a** in section **114**.

Thus, the two pump sections **112** and **114** can be connected together so that the overall device pumps fluid at twice the rate of the FIG. 2 pump. More particularly, outlet pipes **144** and **144a** can both be connected through a suitable T-coupling (not shown) to outlet pipe **34** (FIG. 1). Similarly, inlet pipes **142** and **142a** in the FIG. 5 pump can be connected through a T-fitting (not shown) to inlet pipe **32** (FIG. 1). Thus, when the pump is operated in this fashion, it delivers fluid at a very uniform velocity and with very little pulsing. Needless to say, also, the duplex pump has all the advantages described above in connection with the single action pump.

It will be appreciated that the same principles may be followed in constructing a pump having three or more such sections, all of which are driven from a single drive shaft. In this event, the eccentrics on the drive shaft would be arranged much like those on an automobile cam shaft to actuate the bellows in the various pump sections at the appropriate times. Also, the inputs and outputs to and from the various sections would be connected together as described above in connection with FIG. 5. Thus, the overall pump would be capable of delivering fluid at extremely uniform velocities and with practically no pulsing at all. This feature is useful in applications where extremely uniform and precise flow rates are desired.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained. Also, certain changes may be made in the above constructions without departing from the scope of the invention. For example, the pump may employ drive means between the drive shaft **92** or **116** and the bellows plates **63** or **132** which affords a positive linkage between those elements. Also, eccentricities **98** and **166** can be substituted for by axially rotated truncated cylinders whose ends function as the bearing surfaces for shafts **78** and **154**. Therefore, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

We claim:

**1.** A hermetically sealed pump comprising
(A) a hollow open-ended casing,
(B) a removable header closing off the top of said casing,
(C) a bellows secured at one end to said header, said bellows having a spring rate tending to maintain it in a fully extended condition so as to draw fluid into said bellows regardless of the presence of a positive pressure inside the bellows,
(D) inlet and outlet passages in said header and communicating with the interior of said bellows,



(E) check valves mounted in said passages,
(F) a closure sealed to the free end of said bellows,
(G) a power transmitting shaft having one end removably engaging said closure,
(H) a bushing
  (1) mounted in said casing, and
  (2) slidably receiving said shaft,
(I) a drive shaft
  (1) rotatively mounted in said casing, and
  (2) spaced opposite the free end of said transmitting shaft,
(J) an eccentric carried by said drive shaft opposite the free end of said transmitting shaft, and
(K) bearing means operative between said eccentric and said transmitting shaft as a cam-follower for said transmitting shaft so that when said drive shaft is rotated, said transmitting shaft follows the eccentric and moves only along the axis of said bellows so that no appreciable sideways forces are applied to said bellows.

**2.** A pump as defined in claim **1** and further including
(A) bearing units rotatively supporting said drive shaft in said casing, and
(B) bearing elements positioned in said bushing to minimize sliding friction with said transmittng shaft.

**3.** A hermetcally sealed duplex pump comprising
(A) an open-ended hollow casing, said casing including removable headers at opposite ends thereof,
(B) a pair of resilient bellows arranged along a common axis and having first ends sealed to said headers,
(C) a drive shaft rotatively mounted in said casing intermediate the ends thereof,
(D) an eccentric carried by said drive shaft and positioned on said axis,
(E) means defining inlet and outlet passages in each of said headers, and communicating with the interior of the corresponding bellows,
(F) a pair of plates sealed to the free ends of said pair of bellows,
(G) a pair of bushings mounted in said casing coaxially with said axis,
(H) a pair of power transmitting shafts slidably received in said bushings and extending from said pair of plates toward said eccentric,
(I) a pair of rubbing members pivotally mounted at the ends of said pair of transmitting shafts, and
(J) a bearing unit encircling said eccentric and engaging each of said rubbing members so that when said drive shaft is rotated, said bellows alternatively are compressed and then expand due to their own resilience without being subjected to any appreciable forces off said axis.


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