Nov. 19, 1968 C. P. E. VON WRANGELL ET AL 3,411,448

HUMAN FLUID PUMPING APPARATUS

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Fig. 1.

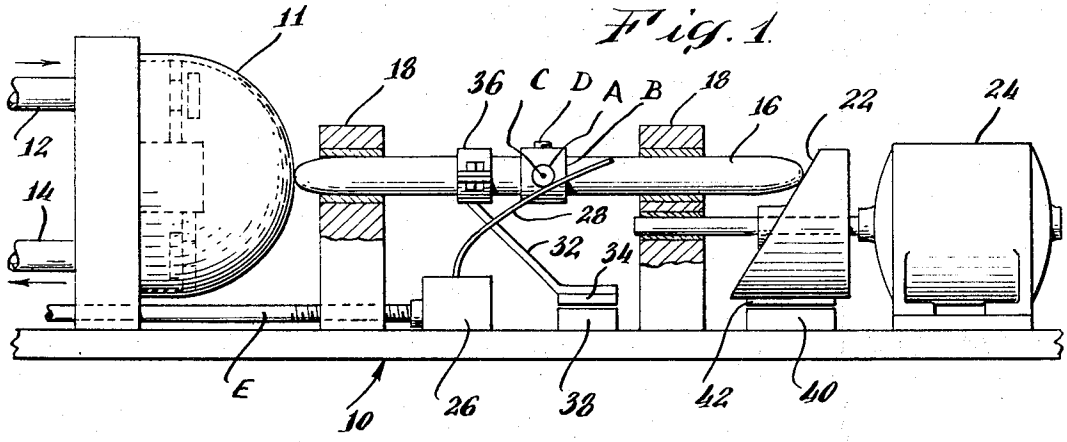


Fig. 2.

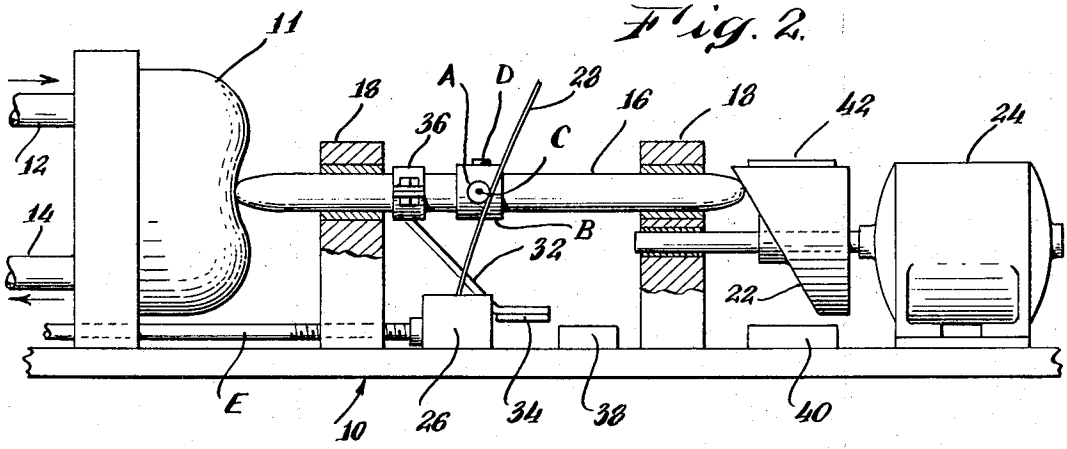


Fig. 3.

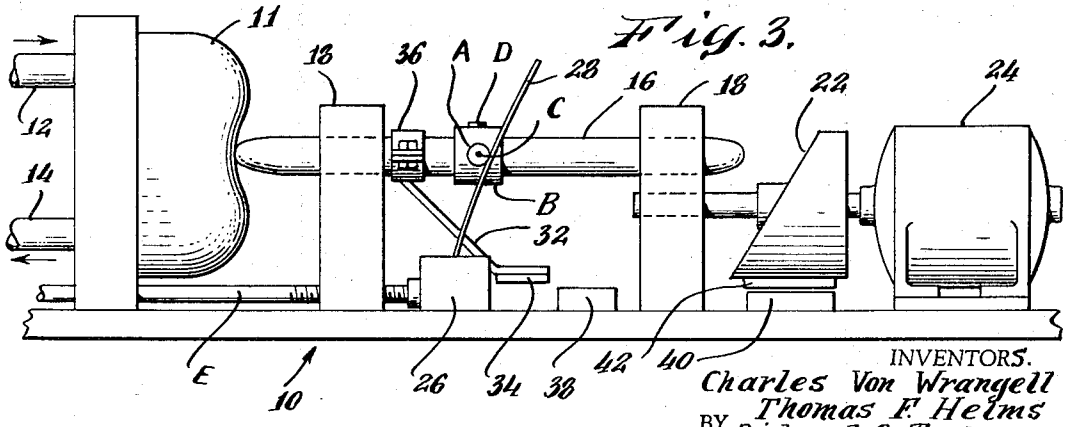


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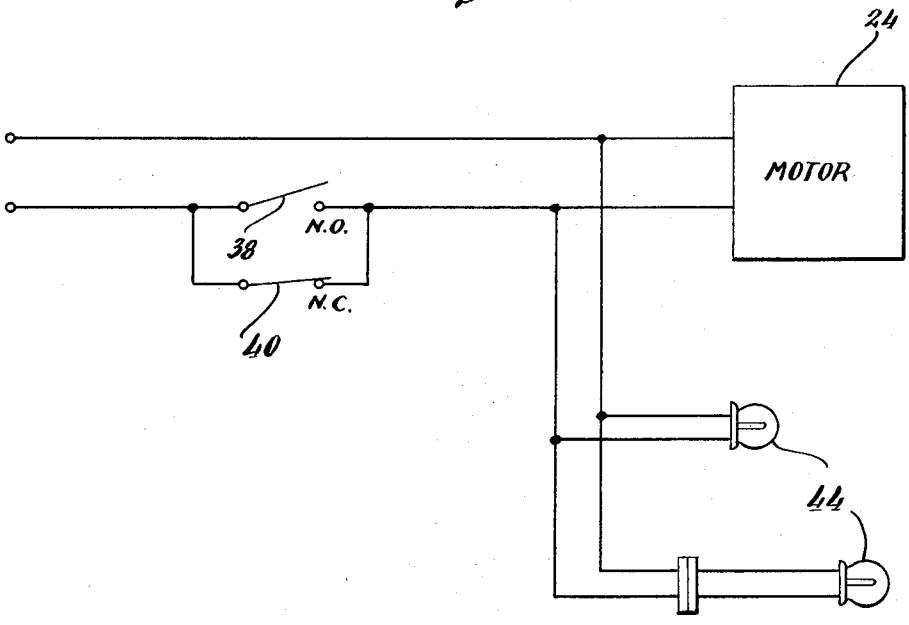
Fig. 4.

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# HUMAN FLUID PUMPING APPARATUS

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9 Claims. (Cl. 103—38)

## ABSTRACT OF THE DISCLOSURE

A pumping apparatus for a body fluid carried system wherein human fluid is removed from one position of the body and infused into the body at a second position. The pump comprises a compressible chamber compressed by a cam operated reciprocating rod on which is located an adjustable force means for maintaining a counterforce on the chamber.

*Background of the invention*

This invention has particular application to a pumping apparatus in a system for removing the human fluid from one position of the body and infusing the fluid into the body at a second position. In the process of removing and infusing the human fluid, it is necessary to cause the fluid to be removed under a pressure which is compatible with the body functions. In order to provide such conditions in the handling of a human fluid, there has been a need for a pump or other means for removing and transferring a human fluid outside the body safely and efficiently without any destruction or harm to the parts of the body from which the fluid may be removed and into which the fluid may be infused. According to the present invention, such a pumping apparatus is provided which can be adjusted to remove and transfer the different human fluids under various conditions compatible with the natural functions and characteristics of the body. That is, the pumping apparatus according to this invention, may safely remove a human fluid from the body at any predetermined position and transfer and cause the fluid to be infused into a second position of the body under pressures and flow rates completely compatible with the natural body functions at the respective removal and infusion positions of the body.

In the past, there have been several pumping apparatus or other means which could effect the removal and the infusion of certain human fluids, such as the lymph fluid, of the body. The main disadvantage of those pumping apparatus, is that they could not completely regulate the removal and transfer of the various human fluids according to the requirements of the natural body functions, and therefore, could only be used for the handling of certain fluids. Hence, there has been a need for a pumping apparatus that could be adjusted to regulate the conditions under which various human fluids could be removed from the body safely and effectively. Such a pumping apparatus is provided by the present invention, which is completely adjustable to regulate the conditions under which various human fluids can be removed from the body and infused thereinto.

The pumping apparatus according to this invention can effectively handle various human fluids under the required conditions of the body by virtue of the arrangement and structure of its component parts. The function and importance of each component part of the improved pumping apparatus are described in the description of the preferred embodiments hereinbelow.



*Summary of the invention*

According to our invention, an improvement is provided in a pumping apparatus for a body fluid carried system wherein a human fluid is removed from one position of the body and infused into the body at a second position. Such human fluid being characterized by a natural availability determined by the natural body functions and flowing at an average rate and under a pressure limit to safely maintain flow thereof. The pumping apparatus has an elastic collapsible chamber for removing and holding a volume of the human fluid. The chamber having an inherent and limited elasticity to expel the fluid when compressed and to create therein an elastic force proportional to the degree that it is compressed. The elastic force is sufficient to inflate the chamber to cause a pressure to induce flow thereinto and to remove the human fluid from the body at the first position. The chamber having extended therefrom a valved inlet and outlet. Positioned near the elastic chamber is provided compressing means to reciprocate to compress the chamber to expel the human fluid therefrom. Drive means are provided to actuate the compressing means to compress the chamber at a rate so that the fluid is expelled at a pressure compatible with the natural body pressure of the second body position. The improvement in the pumping apparatus comprises an adjustable force means for maintaining a counterforce on the chamber sufficient to adjustably regulate the rate at which the chamber expands to remove the fluid from the human body at the first body position at a pressure compatible with the natural body pressure of the fluid at such position. In addition, control means are provided for actuating the drive means only when the chamber is inflated.

In another aspect of our invention, the compressing means may be a freely reciprocal rod and the drive means includes in part a rotatable nutating cam surface to actuate the rod, with the adjustable force means acting directly on the rod to maintain the same always in contact with the elastic chamber. The adjustable force means may be a torsion spring mechanism which constantly urges the rod toward the chamber to impose a counterforce on the chamber equal to the elastic force created therein.

According to another aspect of our invention, there is provided a lightweight portable pumping apparatus for use with a body fluid carried system wherein the human fluid is removed from one position of the body and infused into the body at a second position. Such fluid being characterized by a natural availability determined by the natural body functions and flowing at an average rate and under a pressure limit to safely maintain flow thereof. The pumping apparatus comprises a support base, an elastic collapsible chamber mounted on one end of the base for removing and holding a volume of the human fluid. The chamber having an inherent and limited elasticity to expel the human fluid therefrom when compressed and to create therein an elastic force proportional to the degree that it is compressed. The elastic force being sufficient to inflate the channel to cause a pressure to induce flow therein and remove the human fluid from the body at the first position. Extended from the chamber are a valved inlet and outlet. Positioned parallel to the base with one free end transverse to the surface of the chamber is a freely reciprocable push rod to compress the chamber to expel the human fluid therefrom. Adjustable force means are provided for maintaining a counterforce on the chamber sufficient to adjustably regulate the rate at which the chamber expands to remove the fluid from the human body at the first position at a pressure compatible with the natural body pressure of the fluid at such position. Mounted on the base adjacent to the other free end of the push rod are drive means to actuate the push rod to

compress the chamber at a rate so that the fluid is expelled at a pressure compatible with the natural body pressure of the second body position. Control means are provided for actuating the drive means only when the channel is inflated. The adjustable force means may be a torsion spring mechanism which constantly acts on the rod to maintain the contact of the rod with the elastic chamber. The drive means may include in part a nutating cam surface positioned adjacent to the other free end of the rod, whereby one rotation of the cam actuates the rod sufficient to compress the chamber.

In another aspect of our invention, there is provided a lightweight portable pumping apparatus for use in a fluid carried system wherein a fluid is transferred from one position to a second position under predetermined conditions of pressure and rate. The apparatus comprises an elastic collapsible chamber for holding a volume of the fluid. The chamber having an inherent and limited elasticity to expel the fluid when compressed and to create therein an elastic force proportional to the degree that it is compressed. The elastic force being sufficient to inflate the chamber to cause a sufficient pressure to induce flow therein and transfer the fluid from the first position. Extended from the chamber are a valved inlet and outlet. Positioned near the elastic chamber are compressing means to reciprocate to compress the chamber to expel the fluid therefrom. Adjustable force means are provided for maintaining a counterforce on the chamber sufficient to adjustably regulate the rate at which the chamber expels to remove the fluid from the first position at a predetermined pressure. Drive means are provided to actuate the compressing means to compress the chamber at a rate so that the fluid is expelled at a predetermined pressure sufficient to transfer the fluid to the second position. Control means are provided for actuating the drive means only when the chamber is inflated.

Other features and advantages of the present invention will be more apparent from the description hereinbelow of the best mode contemplated for carrying out the invention.

*Description of the drawings*

With reference to the accompanying drawings, the preferred embodiments of the invention are described hereinbelow. In the drawings:

FIGURE 1 is a side elevational view of a pumping apparatus embodying the present invention with the push rod fully retracted;

FIGURE 2 is a side elevational view of the pumping apparatus illustrated in FIG. 1 with the plunger advanced;

FIGURE 3 is a side elevational view of the pumping apparatus illustrated in FIG. 1 with the push rod held against the elastic chamber by the adjustable force means of this invention; and

FIGURE 4 is the electric circuitry of the present invention.

*Description of the preferred embodiments*

Referring to FIGS. 1 to 3, a pumping apparatus embodying the present invention is shown. The apparatus in its general arrangement comprises a base **10** which has mounted at one end an elastic collapsible chamber **11**. Extended from the chamber **11** are a valved inlet **12** and an outlet **14**. Compressing means, such as a freely reciprocal push rod **16** is slidably mounted on two supports **18** parallel to the base **10** with a free end near the chamber **11**. The push rod **16** is caused to move toward the chamber **11** (to the left) by the rotation of a nutating cam surface **22** driven by a motor **24** through a shaft **25**. The nutating cam **22** can be generally described as a truncated cylinder which is rotated about the longitudinal axis of the cylinder.

Mounted on a block **26** positioned on the base **20** is an adjustable force means, shown here as a torsion spring **28**. The spring **28** is U-shaped, and the two legs of which



bear against two rollers A, which are disposed on opposite sides of rod **16** and mounted in a block B which is adjustably mounted on the push rod **16**. The spring **28** by bearing against the rollers A, acts directly on the push rod **16**, thereby maintaining the rod **16** always in contact with the elastic chamber **11**.

Extended from the push rod **16** on the end of an arm **32** is a magnet **34**. The arm **32** is adjustably mounted on the rod **16** by a clamp **36**. When the magnet **34** is positioned over a normally opened reed switch **38**, the circuit of the motor **24** is closed (FIG. 4), thereby starting the motor **24** to rotate the cam **22**. The rotation of the cam **22** in turn causes the push rod **16** to move forward to the left to compress the chamber **10**, as shown in FIG. 2. A second reed switch **40** is provided to keep the motor in operation until the cam **22** completes one revolution. When the cam **22** completes one revolution, the normally closed second switch **40** is opened by the magnet **42** on the cam **22** positioned over it, FIG. 3. Thus, no current can pass to the motor **24** and it stops almost immediately due to the braking action of the indicating lamps **44**, as shown in FIG. 4. The function of indicating lamps **44** is described more fully hereinbelow.

The pumping apparatus illustrated in FIGS. 1–3 and described herein may be used in a body fluid carried system wherein the human fluid is removed from one position of the body at a second position. The fluid is characterized by a natural availability determined by the natural body functions and should be caused to flow at an average rate and under a pressure limit to maintain safe flow thereof. Such a system is disclosed in the co-pending application having Ser. No. 641,085, filed Apr. 7, 1967.

As shown in FIGS. 1–3, the chamber **11** may be an elastic dome-shaped chamber having extended therefrom a valved inlet **12** and a valved outlet **14**. Both the inlet **12** and outlet **14** are normally closed, and they may be elastic. The valved inlet **12** and outlet **14** are adapted to have connective tubing extending therefrom. Such tubing is intended to form a fluid-tight connection with the body at a removal position and an infusion position thereof.

The chamber **11** should be made of such material as to have an inherent and limited elasticity to expel a human fluid therein when compressed and to create therein an elastic force which is proportional to the degree that it is compressed. The elastic force shoud be sufficient to inflate the chamber **11** to cause a pressure to induce flow thereinto and remove the human fluid from the removal position (not shown) of the body.

The normal position of the chamber **11** is fully extended as shown in FIG. 1. The chamber is compressed by the movement of the push rod **16** is to the left as shown in FIG. 2. The push rod **16** is caused to move to the left by rotation of cam **22** driven by the motor **24** through a shaft **25**. As the push rod **16** compresses the chamber **11**, the compression simultaneously shuts the valved intake **12** and expels the fluid in the chamber **11** through the valved outlet **14**. If the push rod **16** were reacted, the chamber **11** would be free to expand elastically to its normal position, limited only by the pressure admitted through the inlet **12** which has tubing connected to the removal position of the body, for example, the thoracic duct (not shown). However, by having the torsion spring **28** urge the rod **16** toward the chamber **11** by pressing against the rollers A, mounted thereon, a counter-force is maintained on the chamber **11** sufficient to adjustably regulate the rate at which the chamber **11** expands due to the elastic force created therein. By virtue of the adjustability of the counter-force on the elastic chamber **11** the fluid may be removed from the body at the removal position at a pressure that is compatible with the natural body pressure of the fluid in any particular patient at such position.

The elastic force of the diaphragm chamber is greatest when the diaphragm is fully compressed, FIG. 2. For

example, a silastic diaphragm of about one and a quarter (1¼) inches diameter can be fully compressed with the stroke of about one-third inch of the push rod **16** which creates a force therein of about 1.6 pounds per square inch when so compressed. Accordingly, the elastic force created in the chamber diminishes as the chamber **11** is allowed to expand and is zero when the elastic chamber **11** has regained its fully expanded position; FIG. 1.

The cam **22** has a nutating surface which during a rotation causes the push rod **16** to move a certain distance which is sufficient to fully compress the chamber **11**, thereby releasing the fluid therein. The push rod **16** does not return after the cam **22** has completed a rotation, but is held in contact with the chamber **11** by the torsion spring **28** and is caused to return its original retracted position only when and as the chamber **11** is inflated; FIG. 1.

The U-shaped spring **28** is adjustable and may be arranged to apply whatever force is necessary to counterbalance the elastic force of the chamber **11** to provide a fluid removal pressure compatible with that of the human fluid at the removal position of the body. As shown in FIGS. 1–3, the two legs of the U are forced backward into an arc and bear against the two rollers A, which are mounted by pins C on the block B secured to the push rod **16** by a set screw D. When the push rod **16** is fully retracted (FIG. 1) the legs of the spring **28** are bent back into a nearly horizontal position and thus bear against the bottoms of the rollers A. The spring force is thus directed upward, thus applying practically no force horizontally to oppose the elastic force of the chamber **11**. Conversely, when the push rod **16** is fully advanced (FIG. 2) the legs of the U-shaped spring **28** bear against the rollers A so as to exert a more nearly horizontal force on the push rod **16**. When the push rod **16** is in this fully advanced position, the spring **28** exerts a greater counterbalance force against the diaphragm **11**. Although the spring **28** is actually bent through a large arc when the push rod **16** is fully retracted, the horizontal component of force provided by spring **28** reaches a maximum net value when the push rod **16** is in its advanced position (FIG. 2), and this force diminishes as the push rod is brought back to its fully retracted position; FIG. 1. Thus, the push rod **16** exerts a force at all times equal and opposite to the elastic force of the chamber **11**.

A very important feature of the counter-balancing force provided by the spring **28**, is that it can be adjusted so as to maintain a counter-force on the elastic chamber **11** sufficient to adjustably regulate the rate at which the chamber **11** expands to remove the fluid from the human body at a pressure compatible with the natural body functions at the removal position of the body. Thus, the removal of any fluid from the body can be accomplished safely without any harm or destruction to the walls of the conduit from which the human fluid may be removed.

The counter-force exerted by the spring **28** can be adjusted in one of two ways. One way is by moving the spring support block **26** with respect to the base **10**. The alternate way is by moving the roller block B with respect to the push rod **18**.

As shown in FIG. 1 the block **26** can be moved to the right or left by turning an adjustment screw E, extending to the block. If the support block **26** is moved to the left, the spring **28** will be flat for a greater portion of the push rod **16** travel, and, thus, a horizontal counter-force component of the spring **28** force will be decreased. Conversely, the shifting of the block **26** to the right will cause the spring **28** to bear against the rollers A so as to exert a more horizontally directed, and therefore stronger, counter-balancing force.

Alternately, the counter-force of the spring **28** can be adjusted by moving the roller block B to the left or right along the push rod **16** by first loosing the set screw D; FIGS. 1–3. If the block B is shifted to the left (toward the chamber **11**) the spring **28** will bear against the rollers A with a more horizontally directed force. If the block B is positioned more to the right (toward the cam **22**) the spring **28** will bear upon the rollers A with a force directed upwards for a greater portion of the plunger travel, and therefore the counter-force opposing the chamber expansion will be less.

As can be seen, by increasing or decreasing the counterbalance force of the spring, as described above, the expansion rate of the elastic chamber **11** can be regulated at any rate required for the safe removal of a human fluid from any part of the body. In other words, by regulating the rate of expansion of the chamber **11** the pressure under which a fluid is removed can safely be maintained as required by the natural body functions.

Referring to FIG. 4, an electrical circuit is shown which may be used for the controlled operation of the pumping apparatus. The respective reed switches **38** and **40**, the motor **24** and the indicating lamps **44** with the connective wiring are shown in their relative positions. There may be one or more indicator lamps **44** connected in circuit across the motor terminals which serve the function of quickly stopping the motor. Thus, when the source of electrical power is shut off by the opening of the normally closed reed switch **40** under the influence of the magnet **42** carried by the cam **22**, the indicator lamps **44** hasten the stoppage of the motor by producing a dynamic braking action. That is, the coasting motor momentarily acts as a generator and the indicator lamps **44** are an electrical load causing the rotational energy to be quickly dissipated, bringing the motor **24** to an almost immediate stop. The normally opened switch **38** is closed when the magnet **32** is brought over it while the second reed switch **40** which is normally closed is opened when the magnet **42** is directly over it; FIG. 1.

The power to operate the pumping apparatus may be derived from any source, such as a battery or an electrical output. It is preferred, however, that the power be supplied by a battery since the pumping apparatus is intended to be portable, i.e., worn by the patient. All that is necessary is that the power be available on demand when the pumping apparatus is to be put in operation to transfer a human fluid as required by the natural body functions.

Although the various features of the invention have been shown as applied to several embodiments of the invention, it will be evident that changes may be made in such details and certain features may be used without departing from the principles of the invention.

We claim:

**1.** In a pumping apparatus for a body fluid carried system wherein a human fluid is removed from one position of the body and infused into the body at a second position, such fluid being characterized by a natural availability determined by the natural body functions and flowing at an average rate and under a pressure limit to safely maintain flow thereof; wherein said pumping apparatus has:

(a) an elastic collapsible chamber for removing and holding a volume of said human fluid, said chamber having an inherent and limited elasticity to expel said fluid when compressed and to create therein an elastic force proportional to the degree that it is compressed, said elastic force being sufficient to inflate the chamber to cause a pressure to induce flow thereinto and remove said human fluid from said body at said first position, said chamber having extended therefrom a valved inlet and outlet;

(b) compressing means positioned near the elastic chamber to reciprocate to compress said chamber to expel the human fluid therefrom; and

(c) drive means to actuate said compressing means to compress the chamber at a rate so that said fluid is expelled at a pressure compatible with the material

body pressure of said second body position; wherein the improvement comprises:

(i) adjustable force means for maintaining a counterforce on said chamber sufficient to adjustably regulate the rate at which said chamber expands to remove said fluid from said human body at said first body position at a pressure compatible with the natural body pressure of said fluid at such position; and

(ii) control means for actuating said drive means only when said chamber is inflated.

2. A pumping apparatus according to claim 1, wherein said compressing means is a freely reciprocable push rod and said drive means includes in part a rotatable nutating cam surface to actuate said rod, with said adjustable force means directly acting on said rod to maintain the same always in contact with said elastic chamber.

3. A pumping apparatus according to claims 1 and 2 wherein said adjustable force means is a torsion spring mechanism which constantly urges said rod toward said chamber to impose a counterforce on said chamber equal to said elastic force.

4. A lightweight portable pumping apparatus for use in a body fluid carried system wherein a human fluid is removed from one position of the body and infused into the body at a second position, such fluid being characterized by a natural availability determined by the natural body functions and flowing at an average rate and under a pressure limit to safely maintain flow thereof, said pumping apparatus comprising:

(a) a support base;

(b) an elastic collapsible chamber mounted on one end of said base for removing and holding a volume of said fluid, said chamber having an inherent and limited elasticity to expel said human fluid therefrom when compressed and to create therein an elastic force proportional to the degree that it is compressed, said elastic force being sufficient to inflate the chamber to cause a pressure to induce flow thereinto and remove said human fluid from said body at said first position, said chamber having extended therefrom a valved inlet and outlet;

(c) a freely reciprocable push rod positioned parallel to said base with one free end transverse to the surface of said chamber to compress the chamber to expel the human fluid therefrom;

(d) adjustable force means for maintaining a counterforce on said chamber sufficient to adjustably regulate the rate at which the chamber expands to remove the fluid from said human body at said first position at a pressure compatible with the natural body pressure of said fluid at such position;

(e) drive means mounted on said base adjacent to the other free end of said push rod to actuate said push rod to compress the chamber at a rate so that said fluid is expelled at a pressure compatible with the



natural body pressure of said second body position; and

(f) control means for actuating said drive means only when said chamber is inflated.

5. A pumping apparatus according to claim 4, wherein said adjustable force means is a torsion spring mechanism directly acting on said rod to maintain the same always in contact with said elastic chamber.

6. A pumping apparatus according to claim 4, wherein said driving means includes in part a nutating cam surface positioned adjacent to said other free end of said rod, said nutating cam surface in one rotation actuates said rod sufficient to compress said chamber.

7. A pumping apparatus according to claims 4 and 6, wherein there is included a second control means to cause said nutating cam to rotate only once when said elastic chamber is partially inflated.

8. A pumping apparatus according to claim 4, wherein said adjustable force means is a U-shaped torsion spring adjustably mounted on said support base with its two legs bearing on opposite sides of the push rod to maintain said rod always in contact with said elastic chamber.

9. A lightweight portable pumping apparatus for use in a fluid carried system wherein a fluid is transferred from one position to a second position under predetermined conditions of pressure and rate, said apparatus comprising:

(a) an elastic collapsible chamber for holding a volume of said fluid, said chamber having an inherent and limited elasticity to expel said fluid when compressed and to create therein an elastic force proportional to the degree that it is compressed, said elastic force being sufficient to inflate the chamber to cause a pressure to induce flow therein and transfer said fluid from said first position, said chamber having extended therefrom a valved inlet and outlet;

(b) compressing means positioned near the elastic chamber to reciprocate to compress said chamber to expel the fluid therefrom;

(c) adjustable force means for maintaining a counterforce on said chamber sufficient to adjustably regulate the rate at which said chamber expels to remove the fluid from the first position at a predetermined pressure;

(d) drive means to actuate said compressing means to compress the chamber at a rate so that said fluid is expelled at a predetermined pressure sufficient to transfer said fluid to said second position; and

(e) control means for actuating said drive means only when the chamber is inflated.

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ROBERT M. WALKER, *Primary Examiner.*