United States Patent [19]

Holman, Jr.

[11] **3,720,485**

[45] **March 13, 1973**

[54] **ARTIFICIAL HEART**

[76] Inventor: **Norman W. Holman, Jr.,** 104 Hemlock Drive, Auburn, Ala. 36830

[22] Filed: **July 1, 1971**

[21] Appl. No.: **158,925**

[52] **U.S. Cl.** **417/413,** 417/475, 417/479, 3/1, 3/DIG. 2

[51] **Int. Cl.**........**F04b 43/08,** F04b 43/12, A61f 1/00

[58] **Field of Search**......417/412, 413, 474, 475, 479, 417/394, 430; 3/1, DIG. 2

[56] **References Cited**

UNITED STATES PATENTS

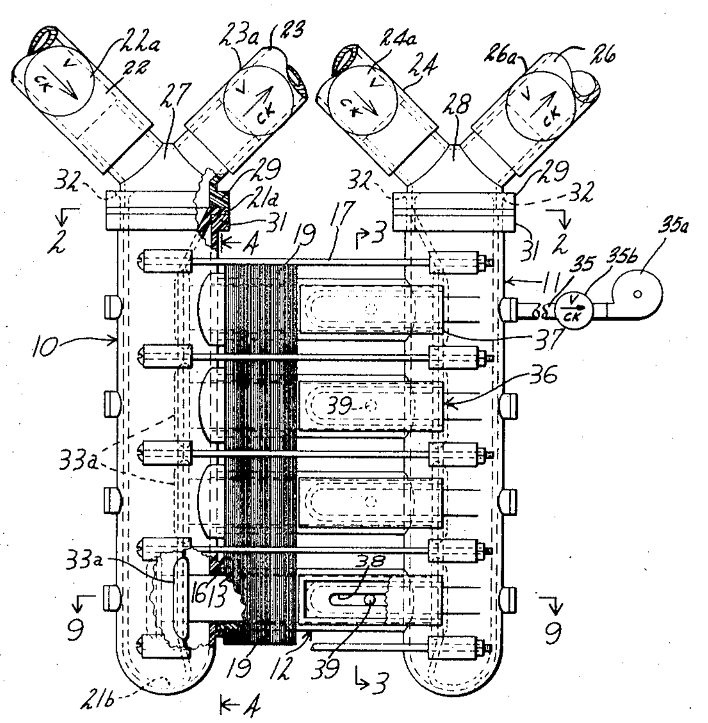
1,922,196	8/1933	Butler	417/475
3,653,267	4/1972	Jacobson	417/412 UX
3,180,272	4/1965	Broadfoot	417/475
3,633,217	1/1972	Lance	3/DIG. 2
3,518,702	7/1970	La Russa	3/1
3,171,360	3/1965	Walton	417/474

Primary Examiner—Carlton R. Croyle
Assistant Examiner—Richard E. Gluck
Attorney—Jennings, Carter & Thompson

[57] **ABSTRACT**

A pump, the construction of which makes it suitable for implantation in the human body, comprising a pair of pumping chambers of flexible material in the form of tubes having one closed end and one open end. A plurality of solenoids is arranged sequentially and alternately, starting adjacent the closed ends of the tubes, inwardly to distort the tubes, thus expelling fluid from the open ends. The solenoids and tubes are encased in a fluid tight housing maintained under subatmospheric pressure so that atmospheric pressure acts on fluid in the tubes, thus to return the tubes to expanded position, drawing a fresh supply of fluid after each pumping cycle. Circuitry and switches are provided to operate the solenoids in proper order.

4 Claims, 11 Drawing Figures



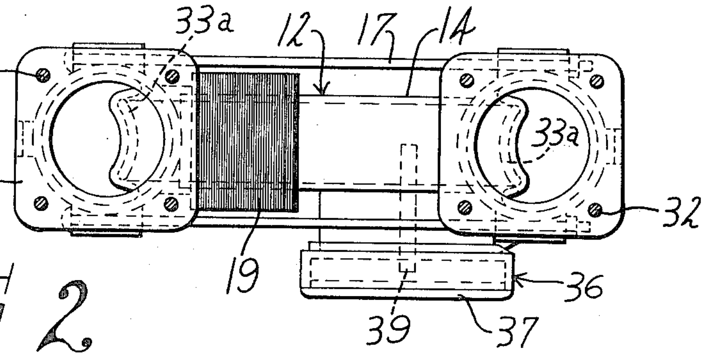


Fig 2

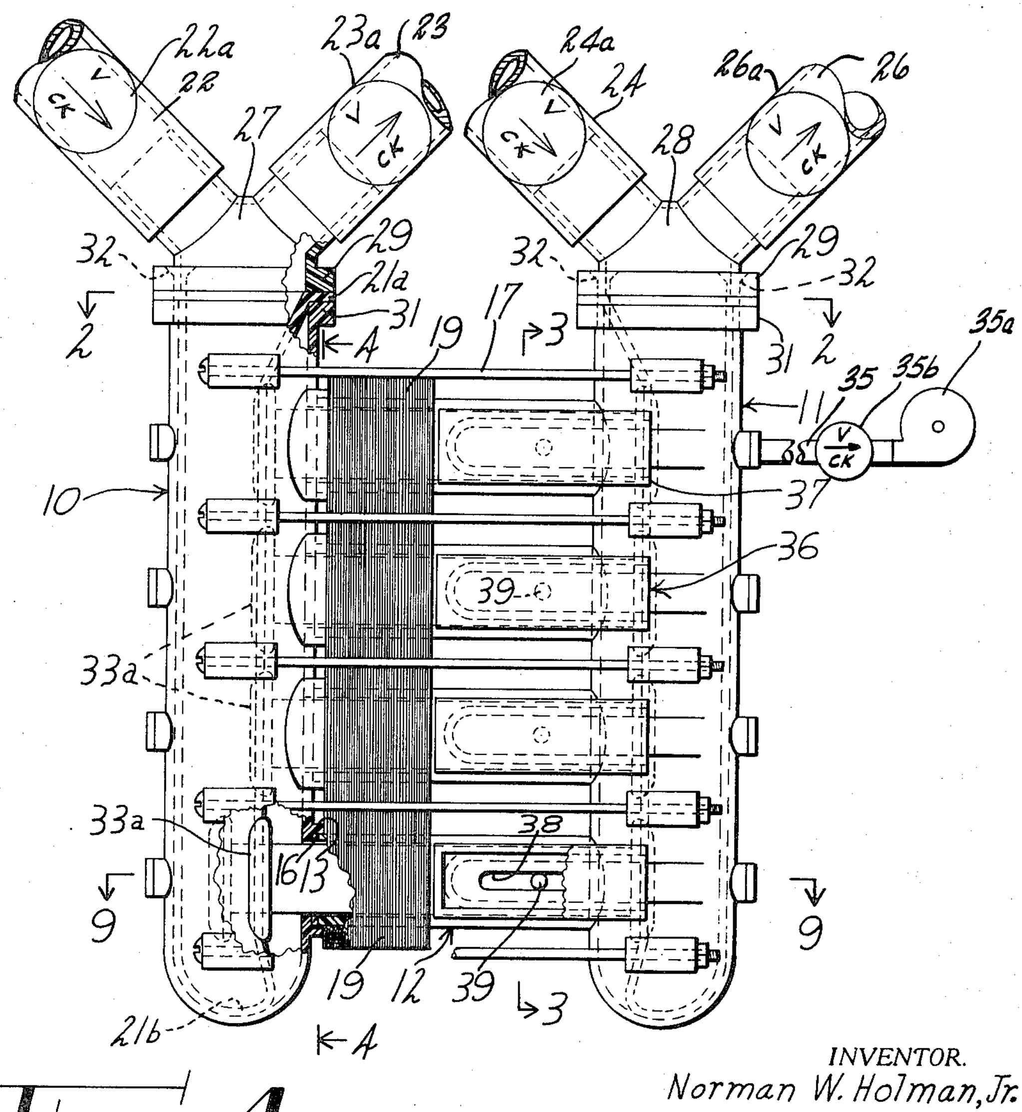


Fig 1

INVENTOR.
Norman W. Holman, Jr.
BY
Jennings, Carter & Thompson
Attorneys

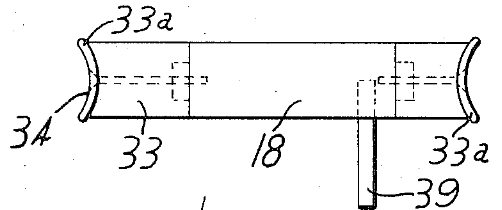


Fig 6

Fig 5

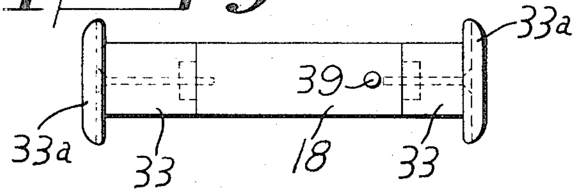
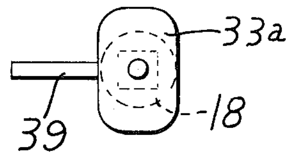


Fig 7



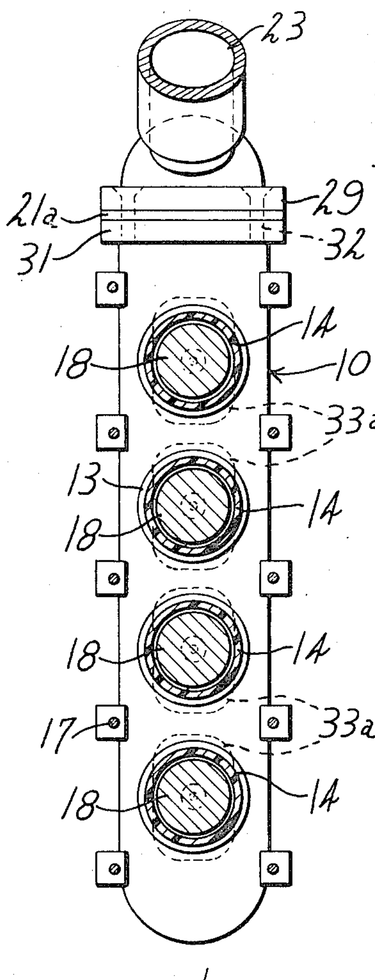


Fig 3

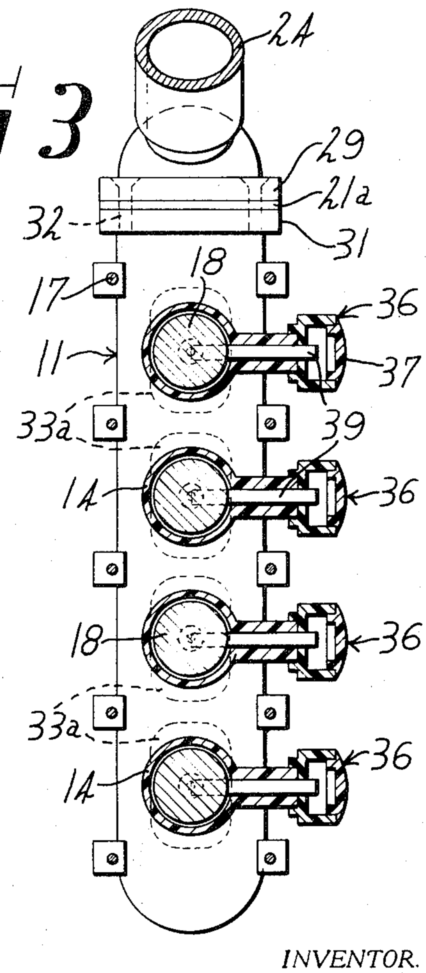


Fig 4

INVENTOR.
Norman W. Holman, Jr.
BY
Jennings, Carter & Thompson
Attorneys

3,720,485

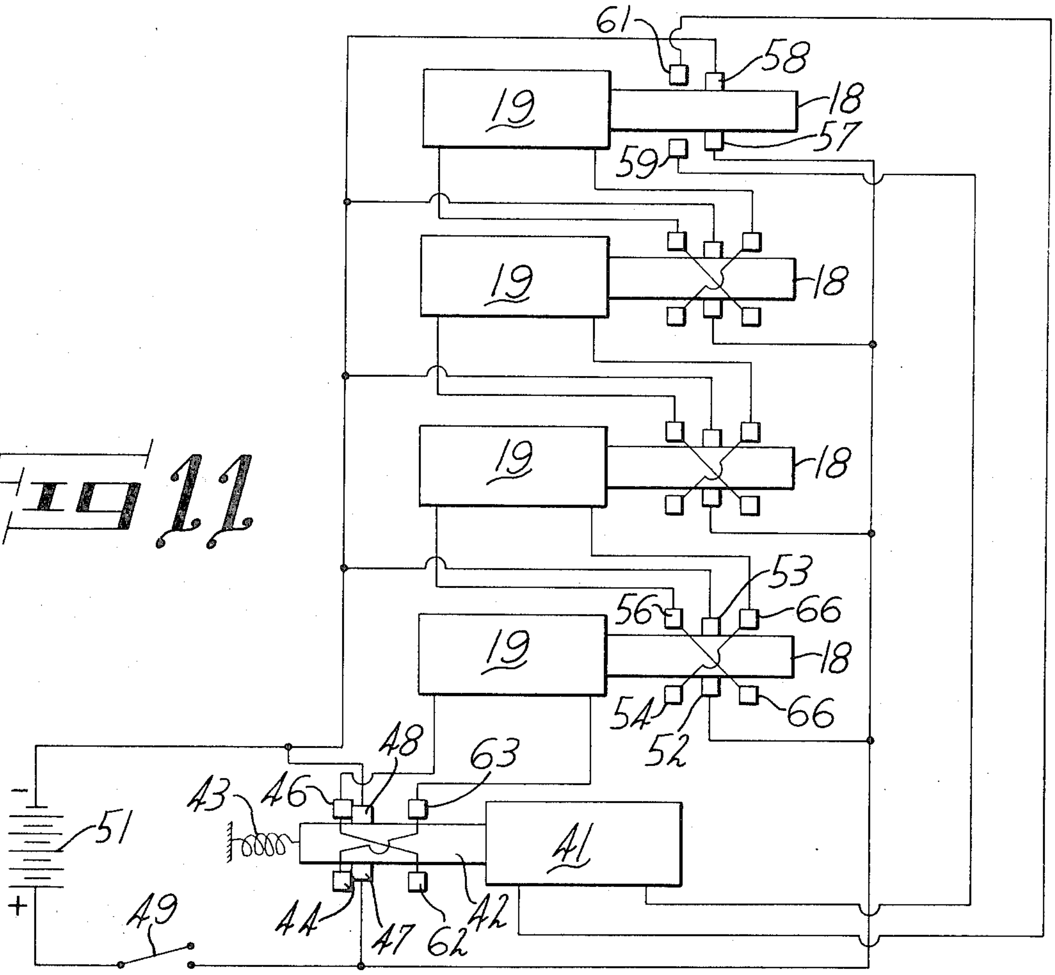
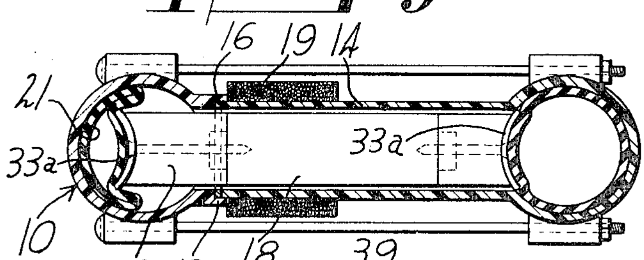


Fig 11

Fig 9



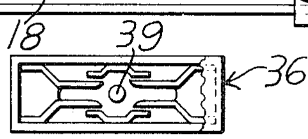
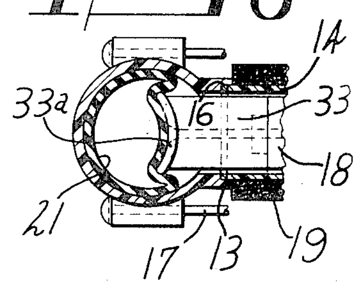


Fig 10

Fig 8



INVENTOR.
Norman W. Holman, Jr.
BY
Jennings, Carter & Thompson
Attorneys

ARTIFICIAL HEART

My invention relates to pumps and particularly to a pump which may be implanted in a human body for replacement of the natural heart.

In the field of endeavor to which this invention relates there is a need for a simple, compact, lightweight, reliable, low energy requirement pump having the capability of closely approximating the pumping ability of the normal human heart. Such pump not only must correspond functionally as nearly as possible with the natural heart, but also must be of a shape, size, configuration and weight to permit it to be implanted. Such pump must be of material to eliminate rejection by the host body. Of equal importance, the blood passing through the pump should not contact any rotating, sliding or other moving parts which have the effect of subjecting the blood to undue working or stress. Along similar lines, the intake stroke of such pumps should be accomplished by differential in pressure between the pumping chambers proper and their immediate surroundings, thereby to eliminate fixed mechanical connections between the pumping chambers and the drive means therefor. Still further, such pumps should be of the double chamber type with such chambers operatively related to a common drive means, thereby reducing the required number of driving devices or motors.

The pump of my invention attains the foregoing physical and functional characteristics by the provision of a pair of elongated pumping chambers of flexible material having one open and one closed end. These chambers are mounted in a fluid tight housing in such fashion that when the interior of the housing is maintained under sub-atmospheric pressure the return strokes are the result of such differential in pressure. For driving the pump I employ a plurality of solenoids spaced along the lengths of the chambers. The armatures of the solenoids are disposed to engage and partially collapse the chambers, alternately, and operate in sequence relative to each chamber starting at the closed ends of the same. With their open ends properly connected to the blood vessels and properly valved, blood is pumped from one chamber while the other, due to such differential pressure, is returning from partially collapsed to fully expanded position. Therefore, the solenoids constitute the drive for the two chambers and they are under control of a simple, sequencing circuit. My improved pump thus is quite compact and light in weight, and power drain is within practical, acceptable values.

A pump illustrating features of my invention is shown in the accompanying drawing forming a part of this application in which;

FIG. 1 is a side elevational view, certain parts being broken away and in section;

FIG. 2 is a view taken generally along line 2—2 of FIG. 1;

FIG. 3 is a detail sectional view taken generally along line 3—3 of FIG. 1;

FIG. 4 is a detail fragmental sectional view taken generally along line 4—4 of FIG. 1;

FIG. 5 is a detail view showing one of the armatures of one of the solenoids together with the chamber compressing members on each end;

FIG. 6 is a plan view of the solenoid and compressor members shown in FIG. 5;

FIG. 7 is an end elevational view of the armature and compressor shown in FIG. 5;

FIG. 8 is a detail fragmental sectional view showing the relative disposition of one of the pumping chambers and one of the solenoid compressor members, when the solenoid is in unenergized or neutral position.

FIG. 9 is a view taken generally along line 9—9 of FIG. 1 and showing the position of one of the armatures relative to pumping chambers when its solenoid is energized to move the armature to pumping position;

FIG. 10 is a detail view of one of the switches which may be employed in sequencing the solenoids; and,

FIG. 11 is a wholly diagrammatic wiring diagram.

Referring now to the drawings for a better understanding of my invention the housing of my improved pump may comprise essentially three sections. First, there are the pumping chamber housing sections **10** and **11** and a second central section **12** which houses the drive means for the pumping chambers proper. In practice I may make the entire housing of "-plastic," such as the material sold under the trade names "PLEXIGLASS" or "LUCITE." However, the housing parts may be made of any material which by experience has been found to be acceptable to a host body in which the pump is to be implanted, and so long as it has adequate physical strength to withstand a fair amount of internal sub-atmospheric pressure as will presently appear.

In practice, the parts **10** and **11** may be cast, molded, or otherwise fabricated as separate units. In similar manner the central portion **12** may comprise individual tube-like members. As best shown in FIGS. **8** and **9** the members **10** and **11** are provided with bosses **13** which are recessed to receive the individual tubes **14** forming the central portion **12** of the housing. A suitable gasket **16** may be inserted in the bores of the bosses so that when tie rods **17** are drawn up the entire inside of the housing becomes fluid tight.

Mounted for rectilinear sliding movement within each of the tubes **14** is the armature **18** of a solenoid. The windings **19** of the solenoids are placed about the tubes **14** and as best shown in FIGS. **1** and **2** these windings are off set to one side, that is, they are closer to one of the housing portions, for instance **10**, than they are to the housing portion **11**. The importance of this will later appear.

Disposed in each of the housing sections **10** and **11** is a pumping chamber **21**. Each of these chambers may be in the form of a test tube-like member of flexible material such as rubber or an appropriate one of the synthetic elastomers. The members **21** may be provided with flanges **21*a***, at their open ends, and the bottoms thereof are closed, in test tube-like fashion as indicated at **21*b***.

In order to cause a pumping effect, as will later appear, the arteries **22**, **23**, **24** and **26**, are attached as shown to Y-shaped valve carrying adaptors **27** and **28**. The adaptors **27** and **28** incorporate valves **22*a***, **23*a***, **24*a*** and **26*a*** to permit flow in accordance with the arrows as shown, into and out of the respective chambers. Further, the adaptors **27** and **28** are flanged as indicated at **29** so as to clamp the lips **21a** of the chambers **21** between such flanges and additional flanges **31** provided at the open ends of the chamber sections **10** and **11**. The parts are held together by screws **32** as illustrated.

On the ends of the armatures **18** are presser members **33**. As best shown in portions **5**, **6** and **7** the members

33 have end portion 33*a* which are elongated axially relative to the tube-like pumping chambers. Further, and as shown in FIG. 6 the sections 33*a* are concave as illustrated at 34 so that they generally conform to the circumference of the pumping chambers when the pumipng chambers are in fully expanded position as shown in the righthand side of FIG. 9. The inside of the chamber may be maintained under sub-atmospheric pressure by means of a tube 35 connected to the housing and leading outside the body in which the pump is installed, a pump 35*a* and one-way valve 35*b* being connected as shown in FIG. 1.

From what has been described it will be seen that the parts are dimensioned so that when assembled and with no current impressed on the windings 19 each, of the presser members 33 holds its pumping chamber partially compressed as shown in FIG. 8. However, when the armatures are energized to move the parts, say, to the left, as shown in FIG. 9, the pumping chamber 21 on the side 10 of the housing is distorted and partially collapsed as shown, while the one of the opposite side that is, in section 11, is fully open. Fluid is thus expelled by first energizing the solenoid nearest the closed end of the tube, then the next, and so forth. The method of controlling the solenoids for actuation of the chambers, in sequence, to effect pumping, will now be described.

Secured to the sides of the tubes 14 which house the armatures are switches indicated generally by the numeral 36. These switches are enclosed in outer housings 37 which are secured fluidtight to the tubes 14. As shown in FIG. 1, each of the tubes 14 is provided with an elongated slot 38 through which projects a switch actuating arm or member 39. Each of the switches 36 is provided with a double set of contacts adapted selectively to be closed, depending upon the position of the armatures, which, as stated, carry the pins or actuating arms 39.

Referring now particularly to FIG. 11 I will now describe a suitable circuit for actuating the several solenoids in proper sequence. It will first be noted that at 41 I show the coil of a control relay or solenoid having an armature 42. The armature 42 is spring biased to the left as shown in FIG. 11 by a spring 43 so that with no current applied to the coil 41, contacts 44 and 46 are closed by a set of contacts 47 and 48 carried, in effect, by switch arm 42. With the parts in the position shown in FIG. 11 and with the manual switch 49 closed, power is supplied from a battery 51 to the contacts 47 and 48, thence to contacts 44 and 46. This energizes the coil 19 of the solenoid located adjacent the closed ends of the pumping chambers 21, whereupon its armature 18 moves to the left as shown in FIG. 11. This motion connects movable contacts 52 and 53 with fixed contacts 54 and 56, which immediately energizes the solenoid located next immediately above the solenoid adjacent the lower ends of the tubes. This sequence progresses from the solenoid adjacent the closed ends of the tubes to the one adjacent the open ends of the tubes, whereby, the completion of a pumping cycle of the left hand side of the pump as viewed in the figure occurs when all of the solenoids are energized and the pumping chamber 21 in the left compartment 10 is compressed substantially to the position shown in FIG. 9, left side. At the same time the righthand most pumping chamber 21 housed in section 11 has expanded to open fluid filled position as shown in the righthand side of FIG. 9. As soon as the uppermost solenoid is energized, a pair of contacts 57 and 58 close on contacts 59 and 61, thus energizing the coil 41 of the relay. This immediately shifts contacts 47 and 48 to a set of contacts 62 and 63, whereby energy is supplied to the lowermost solenoid, but in opposite polarity to that previously described. This causes the solenoid adjacent the closed ends of the tubes to shift its armature 18 to the right, closing contacts 52 and 53 against contacts 64 and 66, thus energizing the next solenoid in opposite polarity, causing its armature to move to the right. This continues until all of the solenoids have again been energized. When the third solenoid of the series, starting at the bottom, moves to reversely energize the coil of the uppermost solenoid, its armature moves again back to the left, deenergizing the coil 41, permitting spring 43 to pull the armature switch arm 42 again to the left, thus completing a cycle.

It will be noted that by maintaining the inside of the housing under sub-atmospheric pressure there is no need for a mechanical connection between the pressers 33 and the flexible pumping chambers themselves. As soon as the solenoids are activated to move the presser feet away from the tubes atmospheric pressure forces the tubes to expand, drawing in a new supply of blood, through the valves in the adaptors 27 and 28. In this connection it will be seen that even with all four solenoids energized to move their armatures to a common side there is left a passage for the blood to start flowing into the first collapsed tube as soon as the armature of the upper solenoid moves toward the other pumping chamber.

It will be seen that the energy requirement for operating my improved pump is clearly within acceptable values inasmuch as the only work done by the solenoids is on their pumping strokes. With the coils displaced to one end of the tubes which house the armatures, by reversing the polarity of the coils the armatures are caused to be drawn either into the coil or repelled therefrom, thereby obtaining the pumping stroke by a simple reversal of polarity on the coils themselves.

In view of the foregoing it will be apparent that I have devised an improved pump which is entirely suitable for implantation into a human body to take the place of the natural heart. While I have not shown the details of the valving required it is believed that the present state of the art is such that such valves are known to those skilled in the art. Further, while I have shown my improved pump as formed of separate parts it is entirely feasible to mold the same as a complete, integral unit with the parts in place therein, ready for operation. My improved pump lends itself to fabrication from materials which are known not to be rejected by the human body and in an actual implantation the only thing required would be to provide means for supplying current to the windings. While I contemplate that the control solenoid 41 would be housed in the pump itself, as will be seen it is quite feasible to locate it in a control box, outside of the body.

While I have shown my invention in but one form, it will be obvious to those skilled in the art that it is not so limited, but is susceptible of various other changes and modifications without departing from the spirit thereof.

What I claim is:

1. In a pump,

a. a pair of spaced apart elongated pumping chambers formed of resilient material closed at one end and open at the other, there being inlet and outlet check valves connected to the open ends of said chambers,

b. means to introduce fluid to be pumped into the open ends of said chambers,

c. motorized means between the chambers effective when energized for motion in one direction to inwardly distort one of said chambers in step-like fashion starting adjacent the closed end thereof, whereby fluid in said chamber is expelled from the open end thereof,

d. means to energize said motorized means for motion in another direction thereby to inwardly distort the other of said chambers in step-like fashion starting adjacent the closed end thereof, whereby fluid in said second chamber is expelled from the open end thereof,

e. means to return said chambers from distorted to expanded positions when said motorized means is out of operative engagement therewith, and

f. the maximum inward distortion of said chambers being such that there remain continuous passages through the length of the same filled with the fluid being pumped, whereby when said motorized means shifts from operative connection with one of said chambers to operative connection with the other, fluid is free to flow into the chamber from which the shift is being made.

2. A pump as defined in claim 1 in which the motorized means is a plurality of solenoids having their armatures spaced along and located between the chambers, and means to energize the solenoids individually in sequence relative to each of the chambers starting with the solenoid adjacent the closed ends of the chambers, thereby to accomplish the aforesaid expulsion of fluid from the chambers.

3. A pump as defined in claim 1 in which the flexible chambers and said motorized means are enclosed in a fluid tight housing in such fashion that the insides of the chambers are subject to atmospheric pressure, and means to maintain the inside of said housing under sub-atmospheric pressure, whereby the differential pressure thus resulting serves as means to return the chambers from distorted to expanded positions when released by the distorting means.

4. In an artificial heart,

a. a fluid tight housing of substantially rigid material embodying a central portion and pumping chamber receiving portions at opposed sides of the central portion,

b. a plurality of solenoids in the central portion mounted in stacked relation therein, the armatures of which are disposed for their ends to enter the pumping chamber portions when the coils thereof are appropriately energized,

c. pumping chambers in each of the pumping chamber housing portions in the form of tubes of flexible material having one closed and one open end, there being inlet and outlet check valves connected to the open ends of said tubes,

d. means securing the tubes in fluid tight relation to the housing adjacent the open ends thereof,

e. means to maintain the interior of the housing under sub-atmospheric pressure, and

f. means alternately to energize the solenoids sequentially starting with the solenoid adjacent the closed ends of the tubes, whereby the armatures inwardly distort first one tube and then the other starting adjacent the closed ends thereof, thus expelling fluid from the tubes through the outlet valves at the open ends thereof.

* * * * *