

- [54] **IMPLANTABLE LINEAR MOTOR
PROSTHETIC HEART AND CONTROL
SYSTEM THEREFOR**
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- [52] U.S. Cl. 3/1, 3/DIG. 2, 417/412
- [51] Int. Cl. A61f 1/24
- [58] Field of Search 3/1, DIG. 2; 128/1 D, 1 R,
128/DIG. 3, 419 R, 419 D, 419 B; 417/412

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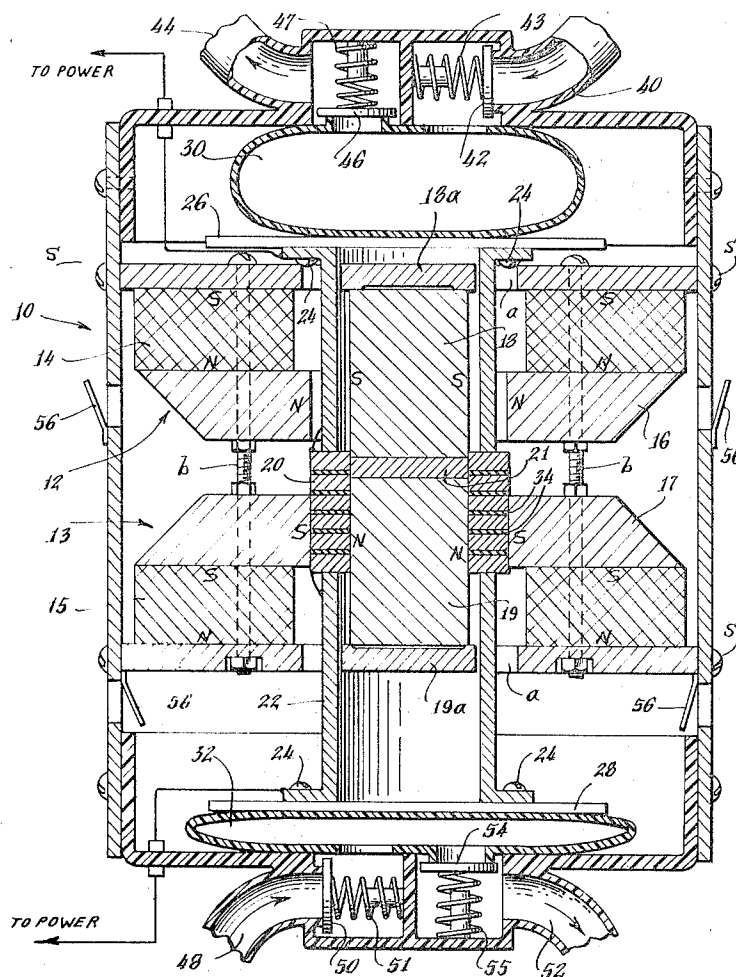
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[57] **ABSTRACT**

Linear drive pump and control means provide pulses of fluid of desired wave form into one or two conduits. The wave forms in two conduits may be the same or different, and controlled if desired by preprogrammed means. If employed as a half or whole heart sensing means disposed within the circulatory system or the artificial heart may be used to provide data for modifying preprogrammed data and scanning and monitoring means and means for recharging a power source implanted in a body may be provided.

7 Claims, 10 Drawing Figures



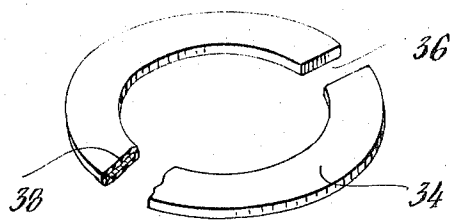
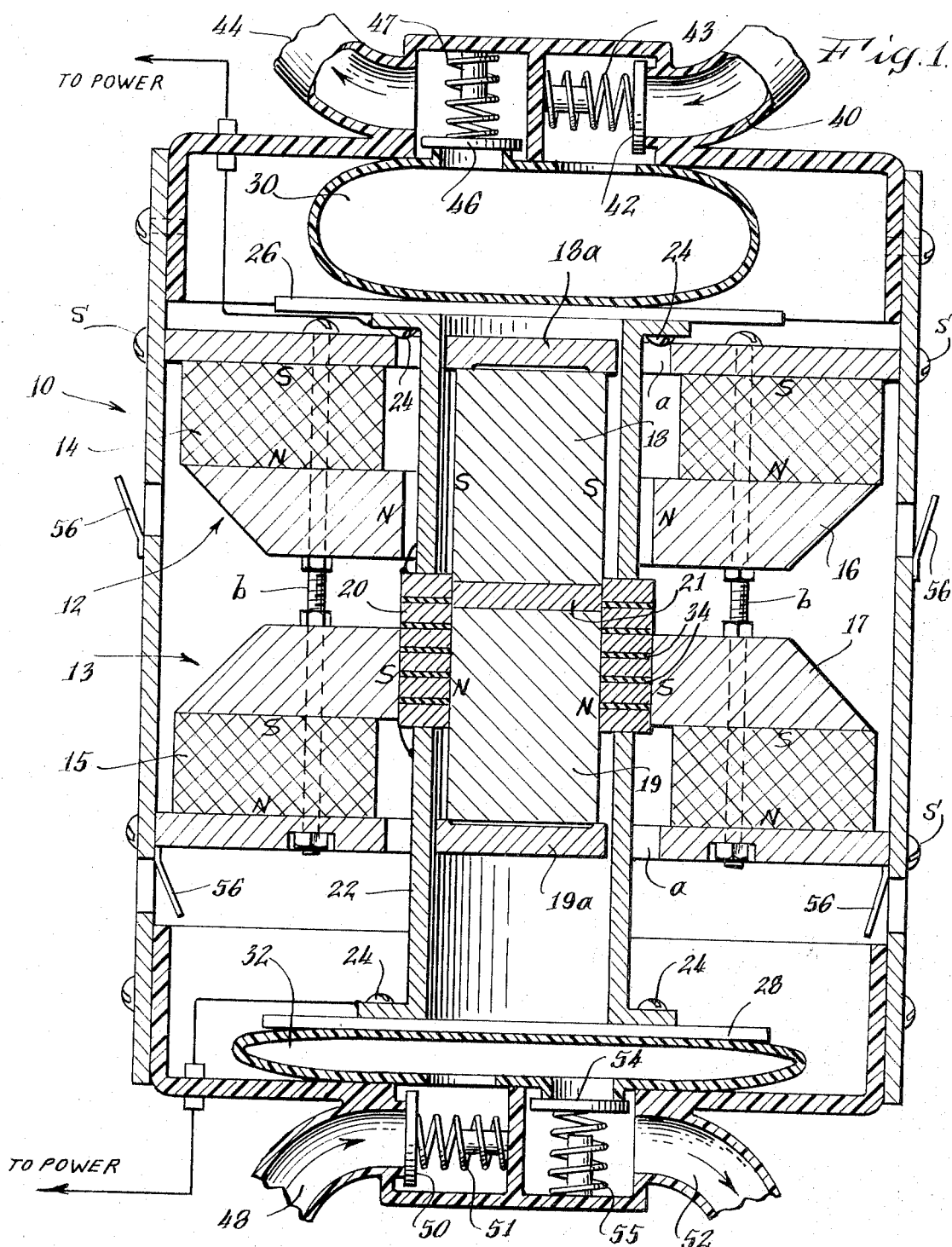


Fig. 1a

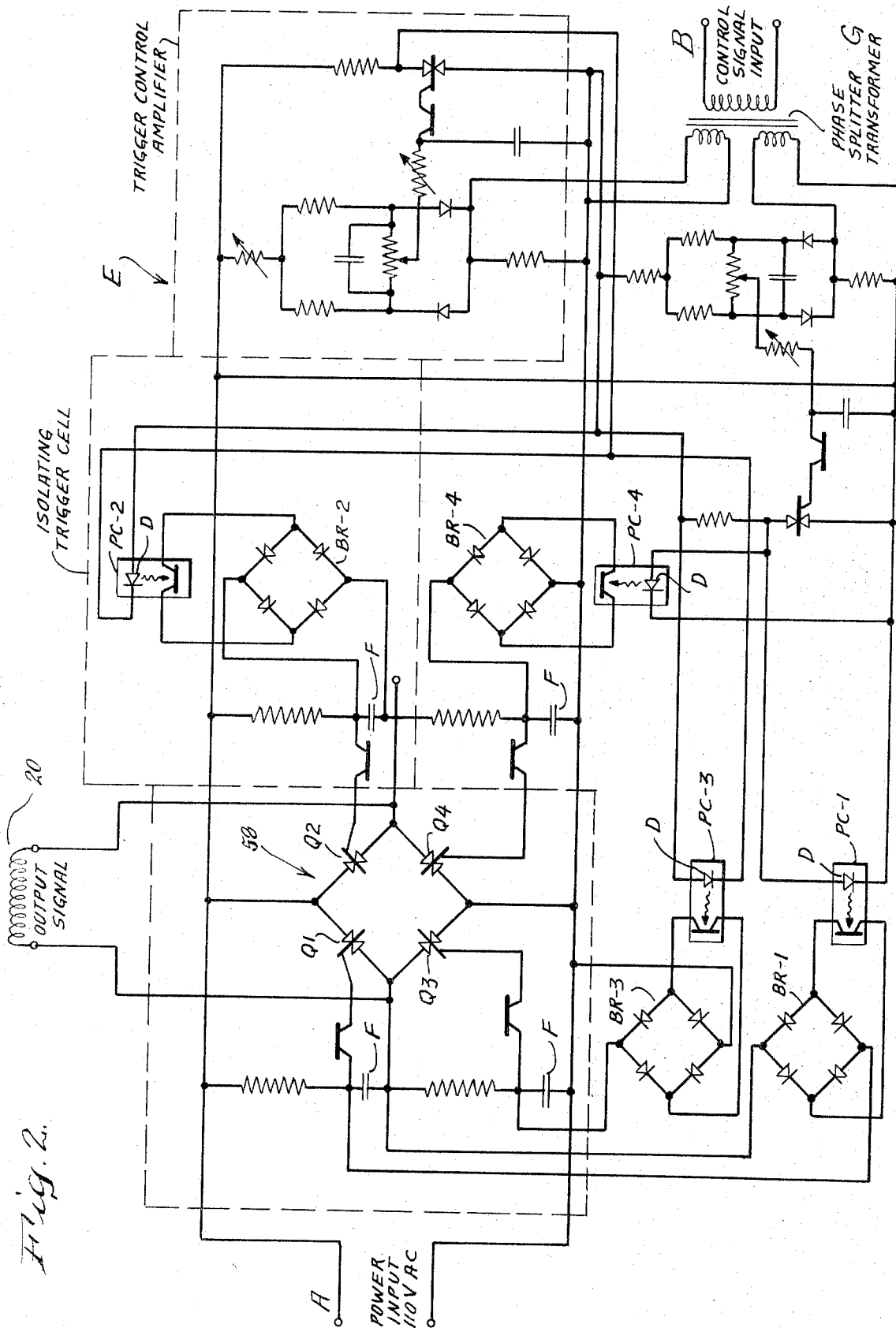


Fig. 3.

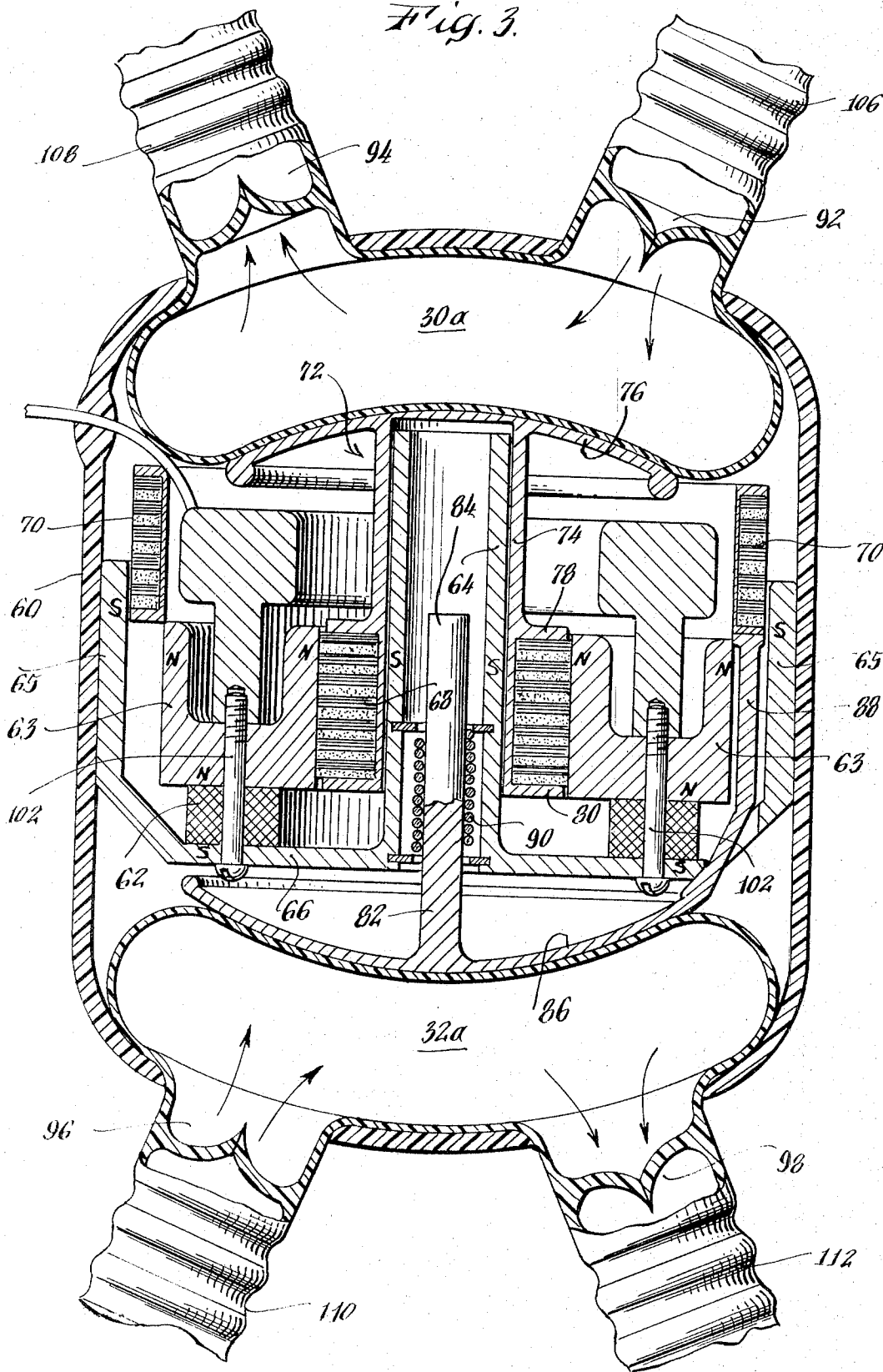
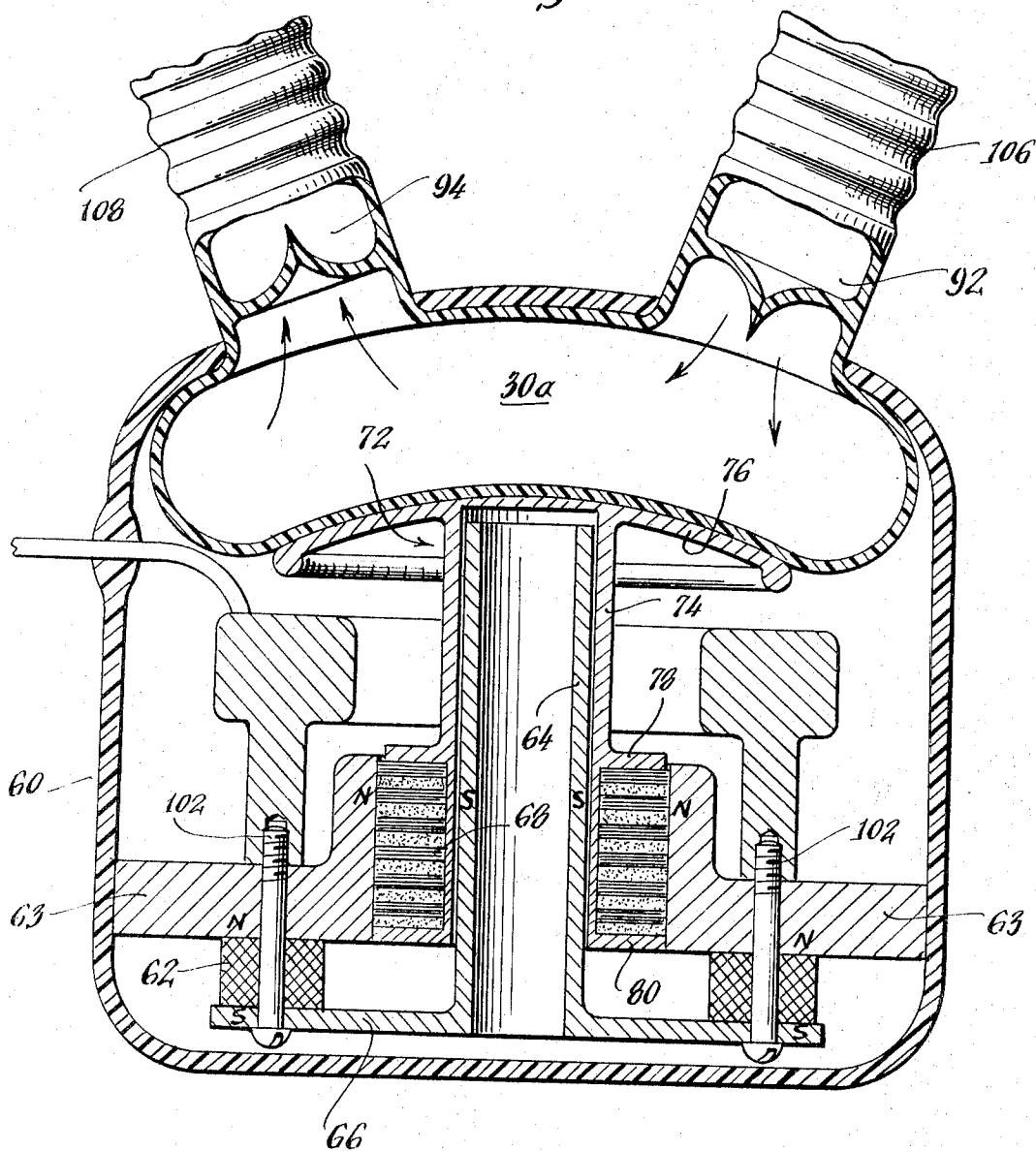
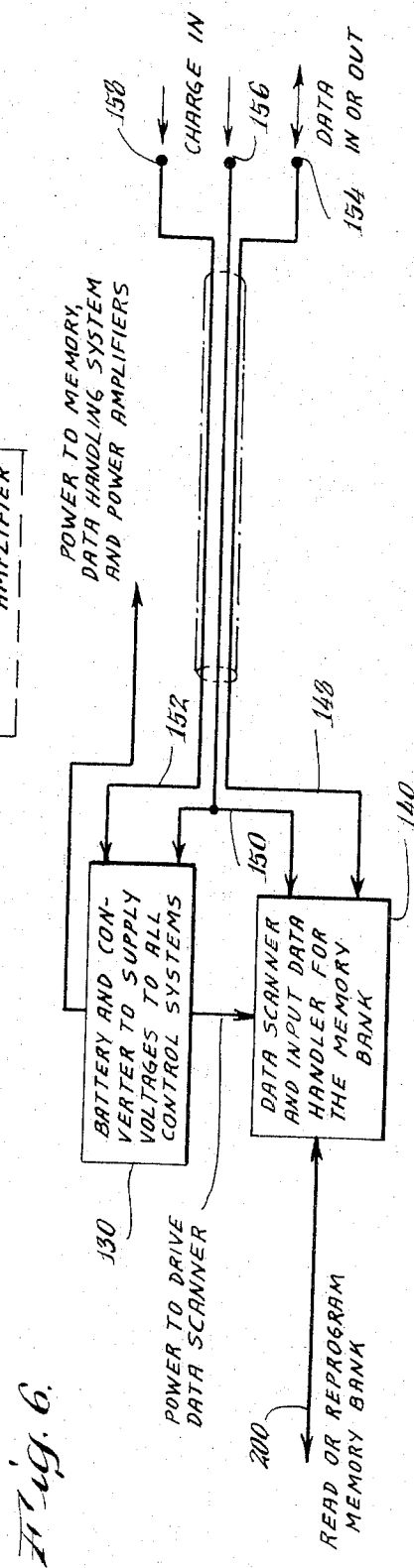
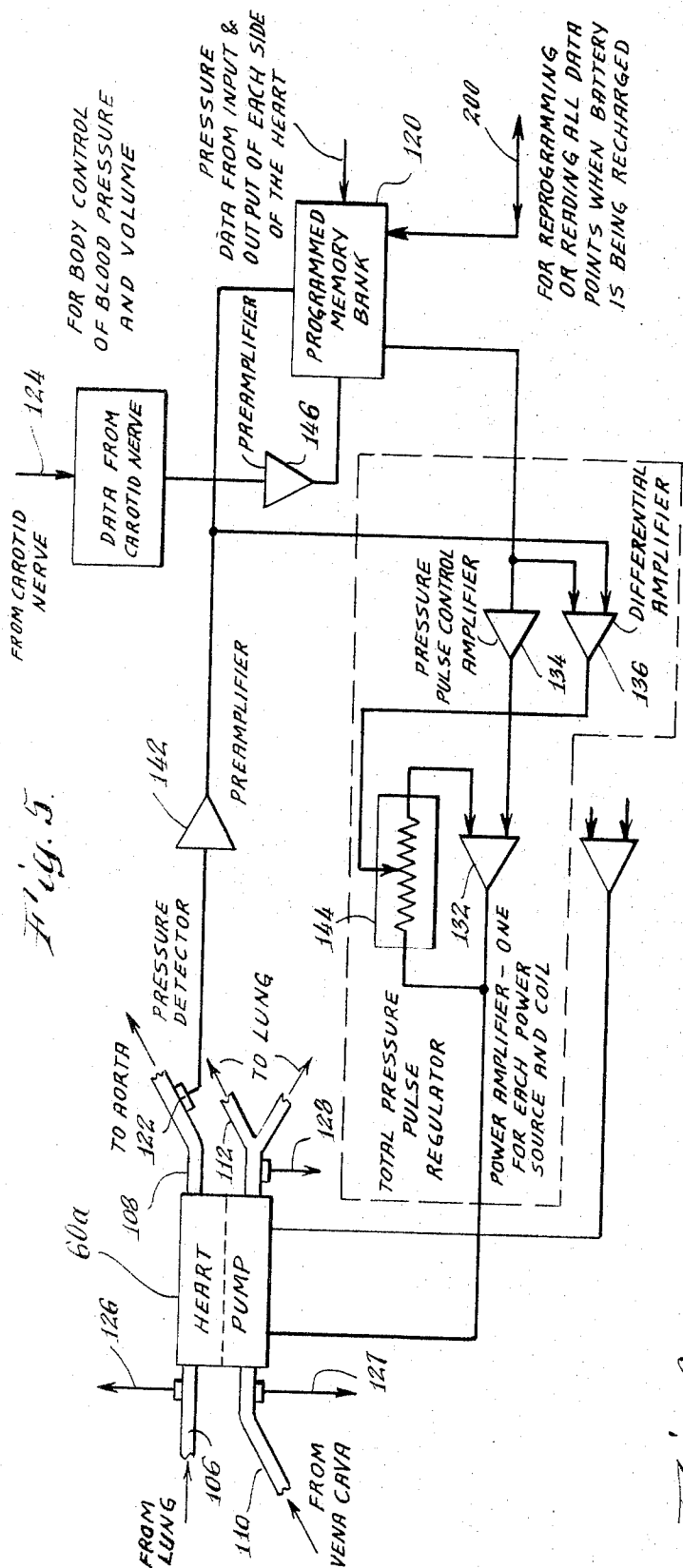


Fig. 4.





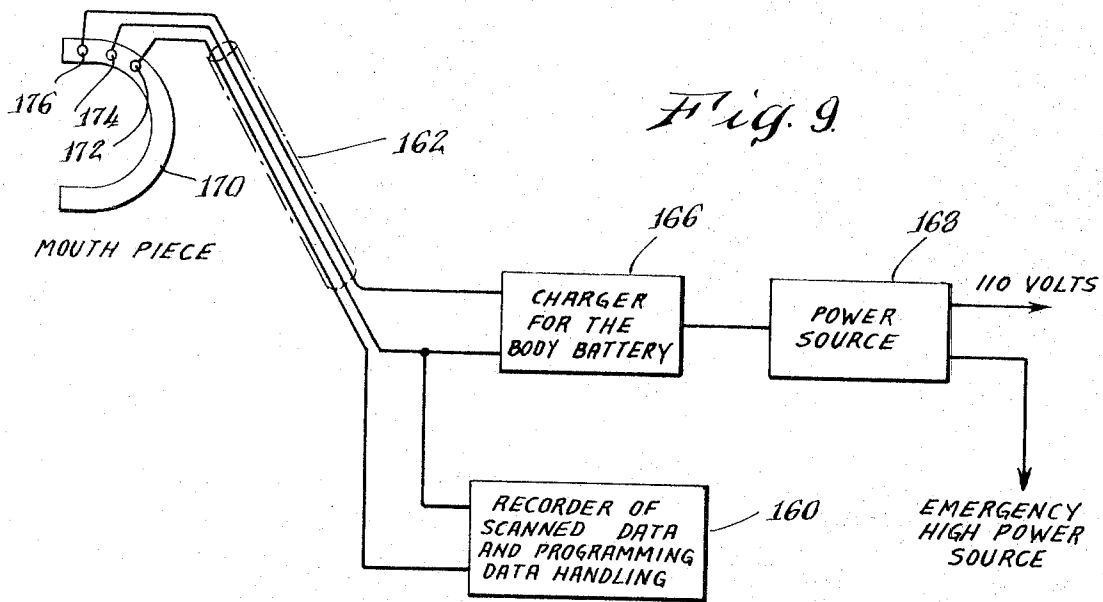


Fig. 7.

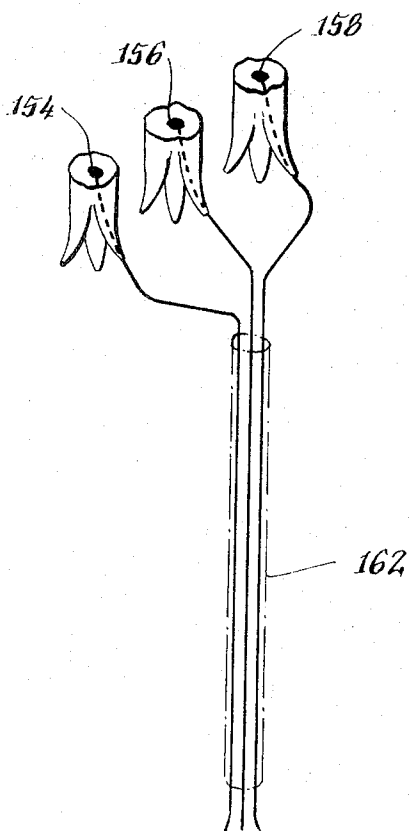
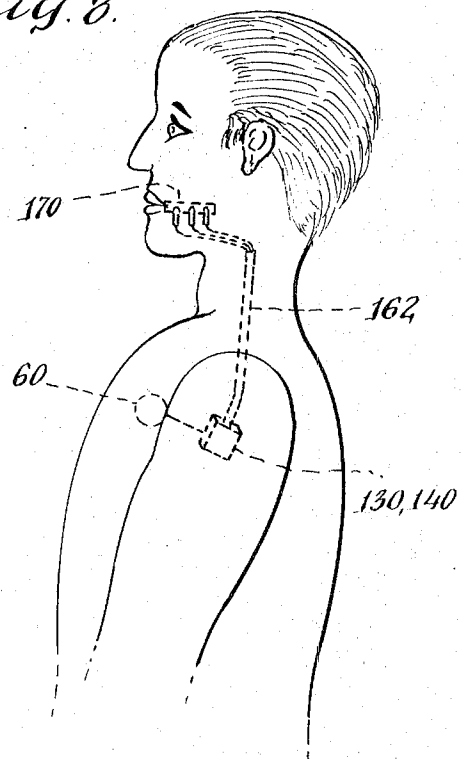


Fig. 8.



IMPLANTABLE LINEAR MOTOR PROSTHETIC HEART AND CONTROL SYSTEM THEREFOR

FIELD OF THE INVENTION

The invention relates to a compact and efficient pump adapted to provide pulses of fluid into a conduit or a plurality of conduits. Pulse flow into two conduits may be provided alternately or in any timed relation, and the wave shape of either series of pulses may be modified as desired. The flow in the two conduits may be the same or different fluids and the flow in either conduit may be started or stopped without effecting the flow in the other conduit.

The operation of the pump may be programmed for optimum operating, and changes in the wave form or the shutting off or starting of flow in either or both conduits may be accomplished automatically.

The operation of the pump may be scanned and the pressure and/or duration of the pulses in either conduit may be read and any variance from optimum operating conditions may be remedied.

In addition to its commercial uses the pump, when made of suitable materials, is adapted for use as a prosthetic heart, or half heart, which can be implanted in an animal or human body, and for such use compact power and control means, which can also be implanted in an animal or human body, are disclosed together with means whereby leads may be inserted into the body without leaving openings into the body subject to infection. Contact means are provided whereby the leads may be connected to means outside the body for recharging the power source within the body and for monitoring the operations of the heart.

SUMMARY OF THE DISCLOSURE

The invention may be embodied in a single or a double piston pump. In its single piston form the pump may have one or two fluid chambers. In each case a coil carried by a piston-like member is energized causing the coil and member to reciprocate to alternately open and close the chamber or chambers. In each form fluid is expelled from one chamber or a pair of chambers in pulses of controlled wave form.

The fluid chambers may be spaces at the ends of a pair of opposed cylinders, the spaces being opened to receive fluid and closed to discharge fluid, by reciprocating piston heads. As shown herein in its form using a single piston-like member to open and close one or two chambers a coil carrying piston-like member is reciprocable within a magnetic field. Both the field and the coil are constructed in a way to increase their strength and efficiency. Preferably two magnetic fields of opposite polarity act simultaneously on a coil mounted on a reciprocating piston-like member. A source of electrical power fed to a pulse generator connected to the coil continually changes the polarity of the coil causing reciprocation of the coil carrying piston-like member. One or both ends of the piston-like member are extended laterally and attached in any suitable manner to the opposed face or faces of the collapsible chamber or chambers. Each of the chambers has an inlet port and a discharge port each controlled by a check valve. As a chamber is collapsed by the movement of the piston-like member fluid is expelled from it through its discharge port into a communicating conduit, and in its two chamber form, the other chamber

is expanded and fluid is drawn into the other chamber through its inlet valve. If desired the reciprocation of the piston-like member may be controlled so that its stroke in one direction is not the same as its stroke in the other direction, thus providing flow of different wave form in the conduits.

In the double piston embodiment of the invention two separate coil carrying piston-like members are provided extending in opposite directions and with their rod portions preferably disposed concentrically to conserve space. In this embodiment both piston-like members are reciprocable within the same magnetic field and their heads are respectively attached to opposed surfaces of a pair of collapsible chambers but the coils which are mounted on the piston-like members respectively are separately powered and controlled so that the time and frequency as well as the speed and duration of the stroke of one piston-like member may be different from that of the other and modified as may be required.

If a device embodying the invention is to be used as a substitute for all or one-half of a living heart the materials used, particularly for the interior of the collapsible chambers, must be compatible with blood. The development or identification of such materials forms no part of this invention. A vast amount of work has been done to provide such materials and the results of this work may be found in many reference sources including for example:

U.S. Pat. No. 3,449,767, June 17, 1969 and long list of artificial hearts and chambers set forth therein; U.S. Pat. 3,409,913, Nov. 12, 1968 and references therein to arterial graft sections for attachment to the open ends of auxiliary ventricular means, and to connector means described therein, including connector means made of Medical Silastic 372 supplied by Dow Corning Corporation, Midland, Mich.; also Transactions Of The Americal Society Of Artificial Internal Organs; also references cited during prosecution of U.S. Pat. No. 3,327,322, June 27, 1967; also pamphlet of Avco Everett Research Laboratory, "Development of Blood - Compatible Elastomers, Theory, and Practice And In Viro Performance," by Emery Nyilas.

For use as an artificial heart the one way valves of a collapsible chamber or chambers will respectively communicate through suitable connectors to veins and arteries of the animal or human body which have been severed when removing the original, damaged heart. In a full prosthetic heart the inlet valve of one chamber will communicate with the vein bringing the blood back from all parts of the body to the heart, and the outlet valve of the chamber will communicate with the artery leading from the heart to the lungs. The inlet valve of the other chamber will communicate with the vein bringing the blood from the lungs to the heart, and the outlet valve of the chamber will communicate with the artery (aorta) which carries and distributes the blood from the heart to all parts of the body.

The source of power illustrated herein for each coil employed is a storage battery preferably implanted in the body adjacent the implanted pump which is the artificial heart, and connected to the coil power and control circuitry, preferably housed in the same casing as the pump, by leads also within the body. Each battery may be recharged from time to time from means outside the body through leads disposed within the body. Such leads may also be employed for reading and re-

cording the operation of the heart pump and conditions within the body such as blood pressure at selected points, and for the input to a programmed memory bank of further instructions to correct or improve the recorded operations. Preferably the leads extend through tooth root canals of the animal or human being, to contacts provided as fillings or inlays. Three such contacts are provided in this way with a pair of said leads extending from the contacts to the power source, and a pair of said leads extending to scanning means, preferably disposed within the power source housing.

An inter-connector means is provided which can be readily inserted into and removed from a subject's mouth and is adapted to fit over the teeth having the contact forming fillings or inlays, the inter-connector means in turn having contacts adapted to register with the teeth supported contacts and to be connected to monitoring means as well as to a power supply for recharging the battery means within the body. When this connector means is placed over the contact forming inlays or fillings the battery means within the body may be recharged and the operation of the artificial heart may be monitored as well as certain conditions within the body for which detector means connected with the power control system have been provided, and commands may be transmitted to the control means within the body to change or modify the control means and thereby overcome malfunctions or deficiencies disclosed by the monitor.

The invention will be best understood if the following description is read in connection with the drawings in which;

FIG. 1 is an elevational view partly in cross section of a single piston two chamber pump in which the piston-like member carries a specially constructed coil which is reciprocated through a specially devised magnetic field,

FIG. 1a is a detail of one of the iron shims used singly or in groups, between successive portions of the coil winding to improve the strength of the field and so that a more efficient magnetic coupling is made.

FIG. 2 shows schematically drive and control means for the single piston pump,

FIG. 3 shows a two chamber and double piston pump which when made of suitable material may be used as a heart pump, comprising two coils carried by the piston-like members respectively and reciprocated independently within the same magnetic field,

FIG. 4 is similar to FIG. 3 but shows a single chamber and single piston pump which may be used as one-half a heart,

FIG. 5 is a schematic view of a control system for the pumps shown in FIGS. 3 or 4 including means for modifying and adjusting coil driving power in response to data from detector means disposed at selected points, and/or in response to data from a recording or preprogrammed memory bank,

FIG. 6 is a schematic view of a power supply and distribution system for energizing the power transmitting, modifying and adjusting means as shown in FIG. 5 including connections through which the power source may be recharged and data may be transmitted from data scanning to recording means, and input data may be supplied to a memory bank.

FIG. 7 is a detail schematic view showing teeth inlay contacts and leads extending from them within the body,

FIG. 8 is a side elevation showing relative location of artificial heart, battery and tooth supported contact means within a human body, and

FIG. 9 is a schematic view of a mouth piece interconnector, adapted when inserted in a subject's mouth to fit over the teeth contacts, and of connections from the interconnector to battery recharging means, and to means for recording and sequentially reading data from data scanner means and for handling input data for the memory bank.

DESCRIPTION

In FIG. 1 a reciprocating single piston pump is shown and in FIG. 3 a double piston pump is shown and in FIG. 4 is shown a single chamber and single piston pump which is adapted to serve as one-half a heart.

In the embodiment of the invention shown in FIG. 1 a casing 10 encloses a pair of spaced stationary magnetic field assemblies, 12 and 13, comprising respectively, an annular magnet 14 and two field portions 16 and 18 which are spaced apart and in contact respectively with the two poles of magnet 14 so that portions 16 and 18 are of different polarity, and an annular magnet 15 and two field portions 17 and 19 which are spaced apart and in contact respectively with the two poles of magnet 15 so that portions 17 and 19 are of different polarity. As shown, portion 16 is in contact with the north pole of magnet 14, and portion 18, through its laterally extended base portion 18a, is in contact with the south pole of magnet 14, and portion 17 is in contact with the south pole of magnet 15, and portion 19 is in contact with the north pole of magnet 15 through its laterally extended base portion 19a.

Portions 18 and 19 are axially and concentrically disposed within the open centers of magnet 14 and field portion 16, and magnet 15 and field portion 17 respectively, and radially spaced from their inner surfaces sufficiently to leave space between them and it within which a piston-like member 22, which may comprise four parallel spaced rods, and a coil 20, which is wound around it and carried by it, may be axially reciprocated. Base members 18a and 19a are apertured at a to provide spaces through which the rods comprising member 22 may reciprocate. Portions 18 and 19 of the two magnetic fields are spaced apart by a non-magnetic spacing member 21.

Portions 16, 18 and 18a, and 17, 19 and 19a, are made of iron to provide a strong magnetic field.

The piston-like coil support means 22, spaces apart and interconnects collapsible chambers 30 and 32, which are made of material selected on the basis of being suitable for, and compatible with, the fluid passing through them. The ends of the member 22 may be attached, as by screws 24, to piston cross members or heads 26 and 28 which in turn are attached in any suitable way as by adhesive to the opposed surfaces of members 30 and 32.

The coil 20 is made up of a series of coils separated by magnetic laminations. Discontinuous shim-like members 34, preferably in bundles of three to 10 members depending upon the shim thickness, are inserted between at evenly spaced intervals between turns of the coil to increase magnetic coupling when the coil is energized. The shim-like members 34 are made of soft

magnetic iron with an insulating coating. The members 34 are made with radially extending gaps 36 to avoid short circuiting the coil or creating an induced voltage as it moves through the magnetic field.

As shown in FIG. 1 collapsible chamber 30 communicates with a conduit 40 through intake check valve 42, normally held in closed position by spring 43, and communicates with a conduit 44 through discharge check valve 46, normally held in closed position by spring 47.

Similarly collapsible chamber 32 communicates with intake conduit 48 through check valve 50, normally held in closed position by spring 51, and communicates with discharge conduit 52 through discharge check valve 54 normally held in closed position by spring 55.

When the movable coil 20 is energized it will move in one direction or the other depending upon the voltage polarity fed to the coil and because of the disposition of the magnetic polarity of the two magnetic fields it will be simultaneously pulled and pushed by said fields and thus can be moved with considerable force. When coil 20 moves toward chamber 30 between the annularly spaced north and south poles of the magnetic field 12, it causes the piston-like coil carrying means 22 to move with it thus opening valve 46 and collapsing chamber 30 and thereby forcing its contents, as a pulse of fluid, into conduit 44. During the collapsing of chamber 30 valve 42 remains closed. However upon the return stroke of the coil assembly, due to change in the polarity of the fed voltage the coil controlled by the driving power source, chamber 30 is opened, valve 46 closes, and valve 42 opens, and fluid from conduit 40 flows into chamber 30.

While chamber 30 is being expanded and filled with fluid, chamber 32 is being collapsed, valve 54 opens, and fluid within chamber 32 is discharged in pulse form into conduit 52, valve 50 being held in closed position during the collapsing of chamber 32 but opening again to admit fluid from conduit 48 into chamber 32 when the stroke of the coil assembly is again reversed.

It should be noted that by control of the power source the opposite strokes of the coil assembly may be made with the same force and timing thus delivering alternately into conduits 44 and 52 pulses of fluid having the same wave form, or the coil assembly may be made to move in one direction with greater force and speed than in the other direction by having a higher voltage pulse for one direction of travel. This result may be desired for example in installations where it is important to conserve space and weight and to deliver fluid through separate conduits in different wave form.

Flap valves 56 are provided in the wall of casing 10 to dissipate heat generated within the pump, and the liquid passing through chambers 30 and 32 may also serve to cool the interior of the pump.

The pump shown in FIG. 1 may be driven and controlled by the operation of the well known full wave SCR cycloconverter control system shown in FIG. 2 which is desirable because of its low cost to build and operate.

Power from a 60 Hz voltage power source is fed into the system at A, having the necessary voltage and current to match the impedance of the pump drive coil 20. The required frequency signal input is fed into the system at B, and the size and frequency of this signal may

be varied and programmed to produce the required pumping changes to give the required pressure pulse curve and rate. The power source is modulated to produce the necessary frequency and wave form by the action of the cycloconverter.

The cycloconverter comprises, a full wave bridge 58 comprising four triac bilateral solid state switches, Q1, Q2, Q3 and Q4; connected respectively to control bridges BR-1, BR-2, BR-3 and BR-4; photon couplers PC-1, PC-2, PC-3 and PC-4 each comprising a light emitting diode D; a trigger control amplifier E; a trigger capacitor F; and a phase splitter transformer G.

The triac switches Q-1Q-4 will be triggered in the proper sequence to convert a 60 Hz input wave into a low frequency wave form which will, with proper filtering, replicate the low frequency input signal. Triggering is accomplished through the photon couplers which receive their signals from the trigger control amplifier which receives its signal from the input of the phase splitter transformer G.

The light transmitting diode D of each photon coupler is normally "on" and causes a short circuit across its related trigger capacitor F which prevents the triac from triggering. When the light transmitting diode is turned off the capacitor will charge to 32 volts at which point the bilateral switch will change state and trigger the triac switch.

The trigger control amplifier E operates with a 0-6 volt signal. The signal will cause trigger on either the positive or negative half of the 60 hertz input voltage, depending upon the polarity of the input signal. Q1 and Q4 will trigger when the control signal and the 60 hertz signal are in phase, and Q2 and Q3 will trigger when the signals are 180° out of phase.

The phase splitter transformer G provides the proper polarity relationship between the input and output signals.

Pulsing the wave with a square wave form may be obtained using a d.c. on-off electronic switch, such for example as the cycloconverter, for low power consumption.

The double piston pump shown in FIG. 3 comprises a casing 60 enclosing a stationary annular magnet 62 and a magnetic field comprising the annular portion 63 which is in contact with the north pole of magnet 62, and a field portion 66 which is in contact with the south pole of magnet 62. From the base 66 portions 64 and 65 extend upwardly on opposite sides of field portion 63. Portion 64 is tubular and extends up from the center of base 66. Portion 65 is formed by an upwardly extending cup-shaped extension of base 66. Portions 64 and 65 are shaped and disposed so as to provide annular spaces between themselves and portion 63 within which a pair of coils 68 and 70, and the two piston-like members 72 and 82 by which they are respectively carried, may reciprocate.

The member 72 comprises a tubular portion 74 and the curved head portion 76 which is attached in any suitable manner to the opposed face of fluid chamber 30a. Projecting radially from tubular portion 74 in axially spaced relation are the flanges 78 and 80, and coil 68 is wound around the said tubular portion 74 between flanges 78 and 80. It will be noted that magnetic field portion 64 is tubular and is disposed within the tubular portion 74 of member 72. Coil 68 is thus disposed between magnetic field portions 63 and 64.

Member 82 comprises the rod portion 84 which is disposed for reciprocation within the concentrically disposed tubular field portion 64 and the surrounding piston-like member 74, and the central head portion 86 is attached in any suitable way to the opposed face of fluid chamber 32a. The head portion 86 is extended outwardly forming the cup-shaped flange 88 which extends close to chamber 30a and coil 70 is disposed around the rim of the flange, between portions 63 and 65 of the magnetic field. The rod portion 84 is guided for linear movement with magnetic field portion 64 by the bearing 90 disposed therein.

Circuitry for controlling the pump, such for example as is shown in FIG. 5, may be disposed within the pump, as in the annular housing 100 secured in place by means of screws 102 shown extending from magnetic field member 66 through the magnet 62 and field member 63.

Because of its flexibility and compactness the pump disclosed herein is adapted for many uses as for example to supply two liquids in unequal and variable amounts, or to administer two drugs at a changing rate controlled by a patient's temperature and heart rate. For such uses chambers 30a and 32a may be connected to inlet and outlet conduits in the manner shown for the collapsible chambers of the single piston pump shown in FIG. 1.

One of the uses particularly contemplated for the double piston pump is as a heart pump, a prosthetic substitute for a whole human or animal heart and in FIG. 3 the inlet and outlet of each chamber 30a and 32a is shown provided with connector means suitable for connecting the chamber to veins and arteries of a living body which were previously connected to the heart which has been removed. Chamber 30a is connected through inlet valve 92 and the connector 106 to the blood vessel which returns blood from the lungs to the heart; and is connected through outlet valve 94 and the connector 108 to the main artery, the aorta, which delivers blood from the heart to the rest of the body.

Similarly chamber 32a is connected through inlet valve 96 and the connector 110 to the blood vessel which returns blood from the body to the heart, and is connected through outlet valve 98 and the connector 112 to the main artery, which leads from the heart to the lungs.

In FIG. 4 a single chamber pump is shown which is adapted for use as one-half of a human or animal heart. It will be seen that FIG. 4 is similar to the upper portion of FIG. 3 and for convenience like parts are identified by like numerals, but it will be understood that the single chamber may be connected in this manner as shown for either chamber of the pump shown in FIG. 3. The casing of the pump shown in FIG. 4 is identified by the numeral 60.

Since the optimum fluid pulse output of each chamber varies in accordance with the condition and needs of the body or other system in which the pump is used, each coil is connected to its source of power through a power amplifier or switching circuit, the output of which may be modified to provide great flexibility to the stroke of the piston it drives and thereby provide the desired output pulses of blood from the chamber controlled by that piston.

In FIGS. 5 and 6 means are indicated for driving a coil from a single storage battery source of power in accordance with prerecorded programmed data modified

by data signalled from various points within the body and within a prosthetic heart implanted therein. It will be understood that the circuitry will be repeated for driving a second coil. The prerecorded program data which supplies the basic control pressure wave form to the fluid and controls the rates of the pulses leaving the collapsible chambers 30a and 32a respectively, is shown supplied by a memory bank 120 which is part of a bidirectional multiple and monitoring system incorporated into the mechanical heart's electronic control system. Sensing means in the form of a detector 122 is disposed in the discharge conduit, which when the pump is used as a mechanical heart is the aorta, to supply a pressure data signal. A second detector 124 is shown in contact with the carotid nerve to provide command data to the memory 120. It will be understood that other sensing means may be disposed at other points, such as 126, 127 and 128, along the circulation system of a body in which the mechanical heart is implanted and at points within the pump itself to provide information as to the pressure, temperature or other conditions at such places, and that such data may be employed to modify the basic wave form and rate of the pulses delivered from the pump in response to the programmed controlled data.

As shown, power for driving a coil is supplied from a storage battery power source 130 to a power amplifier 132 and also to the data handling preamplifiers 134 and 136, and to programmer amplifier 138 and the data scanner 140.

Each coil is driven by a power amplifier 132 which is driven by the driver amplifier 134 and a feedback loop 144. The driver amplifier 134 controls the feedback loop 144 and is driven by the differential amplifier 136 with the data signal from the preprogrammed data signal modified by the pressure wave form supplied from the detector means 122 in the aorta through the pressure control pre-amplifier 142. In addition, the signal produced by the carotid nerve through detector 124 feeds into memory 120 through pre-amplifier 146 to adjust the memory signal in such a manner as to produce sufficient blood pressure for the brain of the patient.

The data scanner 140 is connected by leads 148 and 150 to contacts 154 and 156 through which connection may be made to means 160 for reading and recording data from the scanner 140 and through which new input data may be supplied to the memory 120.

As shown in FIG. 6 and 7 a third contact 158 is provided, and the power source 130 is connected through leads 150 and 152 to contacts 156 and 158 through which, as by the means illustrated in FIG. 9 the power source 130 may be recharged.

In FIG. 7 contacts 154, 156 and 158 are shown as inlays or fillings in three teeth of the user of the heart pump and the leads 148, 150 and 152 extend from the inlay contacts respectively through the root canals of the teeth and preferably within a teflon conduit 164 within the body, to the power source 130 and to the data scanner 140.

For convenience in connecting the inlay contacts 154, 156 and 158 to a battery charger 166 and to a means 160 for recording data from the scanner system and handling memory input data, an interconnecting means 170 may be employed, adapted to fit over the inlay contact carrying teeth and having contacts 172, 174 and 176 disposed to register with the inlay

contacts, the contacts of the interconnecting means being in turn connected with the battery recharger means 166 and the recorder and input data handling means 160.

What I claim is:

1. A prosthetic heart adapted to be implanted within the body of a human being or other animal, and a system for operating it, comprising, a single collapsible chamber, having inlet and outlet ports, adapted to be connected respectively to a vein and an artery, means for opening the chamber to receive fluid from a vein to which it is adapted to be connected, means for closing the chamber and expelling pulses of fluid from it into an artery to which it is adapted to be connected, means for controlling the expelling means so as to provide in the artery predetermined changes in pulse pressure, amplitude and frequency, a source of electric power adapted to be disposed within the body, and circuitry for connecting it to the prosthetic heart for operating it, a source of electric power to be located outside the body, and circuitry including, leads adapted to be implanted within the body, and connected to said source of power to be located within the body, leads connected to the source of power outside the body, and separable contact members connected to said leads respectively and adapted when physically brought together to connect the source of electric power outside the body directly to the source of electric power to be implanted within the body, to recharge the latter from the former, said separable contact members including at least a first set of contact members adapted to be disposed on teeth of the body, and another set of contact members are sized and shaped for mounting on teeth of the body adapted to carry said first set of contacts, and the said leads adapted to be implanted within the body are adapted to extend from said first set of contacts through the root canals of the teeth intended to carry said contacts, and the other set of contacts are connected to the said leads which are disposed outside the body and extend to the said source of power outside the body.

2. The device claimed in claim 1 in which one set of said contact members are adapted for mounting on teeth of the body and are connected by leads which extend to scanning means disposed outside the body.

3. The device claimed in claim 1 including a mouth piece adapted to fit over contact means adapted for

mounting on teeth of the body and having conductive means adapted to engage the contact means with means disposed outside the body.

4. A prosthetic heart adapted to be implanted within the body of a human being or other animal and the system for operating it which comprises, a single housing having therein two fluid chambers, separate movable piston-like members having heads connected to the walls of the chambers respectively, and separate coils mounted on said piston-like members respectively, a magnetic field in which each of said coils is disposed, and power and control means for energizing said coils and alternating their polarity separately, whereby the piston-like members are separately reciprocated and the force, amplitude and frequency of the strokes of said piston-like members may be the same or different, and the strokes of each of said piston-like member may be varied individually.

5. The apparatus claimed in claim 4 including a source of electric power adapted to be implanted within the body, circuitry for connecting the said source of power to said coils respectively, for implanting within the body, a source of electric power to be located outside the body, and circuitry including, leads adapted to be implanted within the body, and connected to the source of power to be located within the body, leads connected to the source of power outside the body and separable contact members connected to said leads respectively and adapted when physically brought together to connect the source of electric power outside the body directly to the source of electric power to be implanted within the body, to recharge the latter from the former.

6. The apparatus claimed in claim 4 in which the control means includes, program control means, pressure detector means and power amplifier means, all disposed within said prosthetic heart.

7. The apparatus claimed in claim 4 in which each piston-like member comprises a rod portion and a head portion, the rod portions extend in opposite directions and are concentrically disposed, one of said coils is supported around the rod portion of one of said piston-like members, and the head portion of the other of said piston-like members is cup-shaped and the other of said coils is mounted around the rim of said cup-shaped head portion.

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