

Aug. 14, 1962

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EXTRACORPOREAL BLOOD CIRCULATION SYSTEM
AND A SAFETY FEATURE THEREFOR
Filed Nov. 3, 1959

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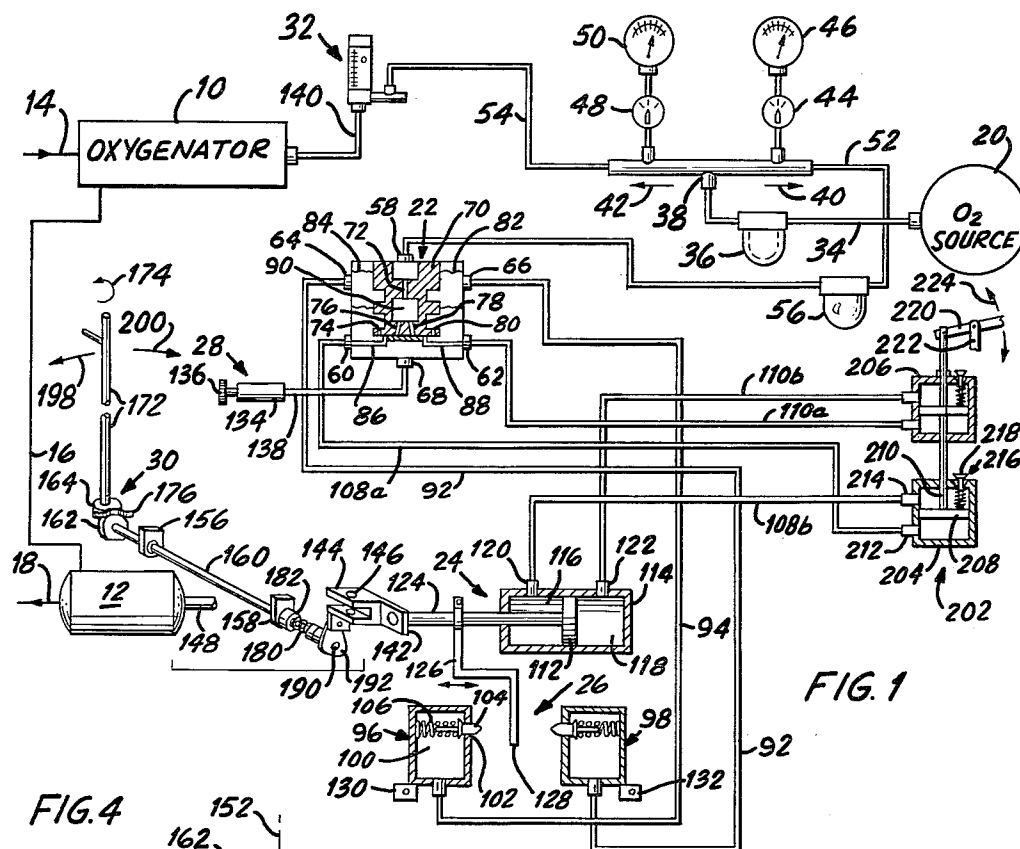


FIG. 1

FIG. 4

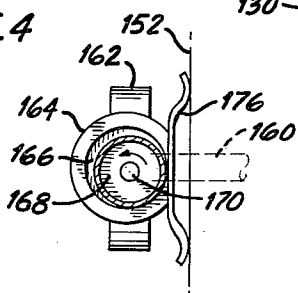


FIG. 2

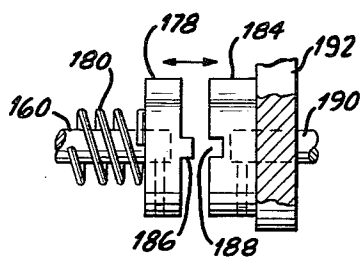
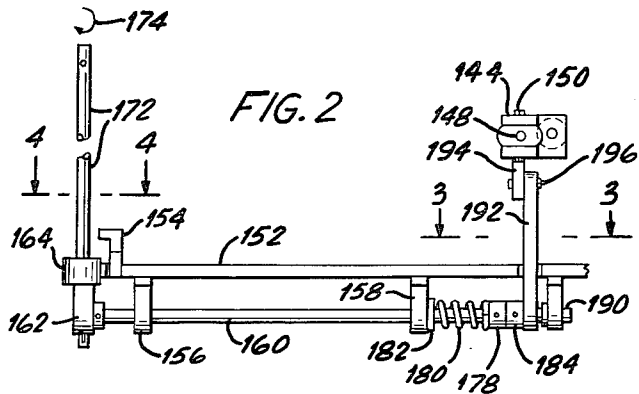


FIG. 3

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EXTRACORPOREAL BLOOD CIRCULATION SYSTEM AND A SAFETY FEATURE THEREFOR

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Filed Nov. 3, 1959, Ser. No. 850,720
13 Claims. (Cl. 128-214)

This invention relates to extracorporeal blood circulation systems and, more particularly, to safety apparatus to provide alternate sources of power therefor. The invention also relates to pump arrangements and pressure medium drives.

Extracorporeal surgical techniques are known whereby for surgical processes the functions of the heart and lungs are performed externally of the body. Generally, this involves tapping blood from the body, oxygenating the blood and returning the oxygenated blood to the body by means of a simulated pulse. This invention is principally concerned with the means employed for pulse simulation and with features assuring the continuous operation of pulse simulating equipment.

In those types of surgery involving the above surgical techniques, it is imperative that the surgery be effected as an uninterrupted procedure and that the extracorporeal simulation of the heart and lung functions be continuous. It is an object of the invention to provide an improved extracorporeal system capable of uninterrupted pulse simulation.

A further object of the invention relates to pump arrangements for pulse simulators and the like and it is contemplated, in this regard, that a pump arrangement be provided with selectively operable sources of power, one of which can be substituted for the other in the event of failure.

In accordance with one preferred embodiment of the invention, a piston and cylinder arrangement is employed as a reciprocating main drive for a pump and a manually-operated drive is provided as an alternate for the piston and cylinder arrangement. Since the piston and cylinder arrangement constitutes the main drive for the system, this arrangement is coupled in permanent manner to the pump, the manual drive being selectively connectable to the pump.

A consequence of having a main drive permanently coupled to a pump is that, when the alternate or safety drive is operated, the main drive constitutes a load thereupon. For example, in the above noted system employing the piston and cylinder arrangement, the manual drive in operating the pump would, at the same time, have to displace the piston which is permanently connected to the pump. This means that the medium in the associated cylinder would have to be compressed or else some remedial step taken to avoid this load.

Stated more generally as an object of the invention, it is contemplated that, in a pump system having a main drive connected in permanent manner and an auxiliary drive which is selectively connectable, provision be made to assure that the main drive does not constitute a load on the auxiliary drive when the latter is actuated.

With regard to another aspect of the invention, provision is made for facilitating the starting of the alternate drive. In fact, if the main drive were to become inoperative for any reason whatsoever, it would be essential to pick up the pulse with no delay. Accordingly, an object of the invention is to provide for initiating an auxiliary drive with minimum movement and effort.

A feature of the invention consists of the specific provisions which are made with respect to the auxiliary drive and particularly with respect to the engagement and disengagement thereof.

Other objects and features of the invention will be found

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in the following detailed description of a preferred embodiment thereof as illustrated in the accompanying drawing in which:

FIGURE 1 diagrammatically illustrates an extracorporeal blood circulation system having a safety feature provided in accordance with the invention;

FIGURE 2 is a front view of a manually-operated portion of the apparatus;

FIGURE 3 illustrates a detail of FIG. 2; and

FIGURE 4 is a view in the direction of arrows 4 in FIG. 2.

The system illustrated in the drawing conventionally comprises an oxygenator 10 and a pump or ventricle means 12. The oxygenator 10 may be a conventional oxygenator such as, for example, illustrated in Patent No. 2,693,802 of November 9, 1954, or in Patent No. 2,702,035, of February 15, 1955. The oxygenator functions to receive blood from the body and to expose this blood to oxygen for oxygenating the same. The pump or ventricle means serves to receive the oxygenated blood from the oxygenator and to simulate a pulse for purposes of returning the oxygenated blood to the body and circulating the blood therein.

As illustrated in the drawing, there is coupled to oxygenator 10 a line 14 which is adapted to have its free end inserted into the body undergoing surgery for the supply of blood to the oxygenator 10. The oxygenated blood is fed via line 16 to the pump 12 whereat as noted above a pulse is simulated so that the blood can be returned via the line 18 to the body.

The system further comprises an oxygen source 20, a distributing means 22, a main drive 24 for the pump 12, a first control 26 for controlling the length of the stroke delivered to the pump 12, a second control 28 which controls the speed of the stroke, an auxiliary drive 30 for safety purposes, and means 32 for delivering oxygen to the oxygenator 10.

The oxygen source 20 is any conventional source of oxygen conventionally found in an operating room or may be instead a tank of oxygen under pressure. The source 20 discharges oxygen under pressure into the line 34 in which is inserted a filter 36. The filter 36 is provided to filter out solids and moisture and may be any commercially available filter which will serve this purpose. It may comprise, for example, a porous bronze element or a Monel wire screen of, for example, 200 mesh.

Line 34 is connected to a T-connection 38 wherefrom the oxygen flows in either of two directions as indicated by arrows 40 and 42.

The pressure of oxygen flowing in the direction of arrow 40 is controlled by pressure regulator 44 as indicated on a dial 46. The oxygen flowing in the direction of arrow 42 is regulated by a pressure regulator 48, the pressure being indicated on a dial 50.

The oxygen following the path indicated by arrow 40 travels through a line 52 whereat its pressure may be regulated between zero and full line pressure. Preferably this pressure is kept to 100 pounds per square inch maximum. The pressure in line 54 which is coupled to T-connection 38 may also be regulated between zero and full line pressure and is also preferably kept below a 100 pounds per square inch maximum.

The oxygen flowing through line 52 is employed as a pressure medium to drive a pneumatic or hydraulic system of the nature which will be described hereinafter. Accordingly, oxygen source 20 not only constitutes a source of oxygen under pressure but may also be considered as constituting simply a source of a pressure medium.

Connected in line 52 is a lubricator 56, the function of which is to provide lubrication for the elements which follow in the system. The lubricator 56 may be any

conventional lubricator which provides an inert non-oxidizable oil such as fluorine or silicone oil which will be carried by the pneumatic medium through the line 52 to the elements which follow.

Line 52 is connected to the distributor 22 which is provided with an input port 58, supply ports 60 and 62 and control ports 64 and 66. Oxygen received under pressure via line 52 passes into the distributor 22 via input port 58. The distributor functions to distribute this oxygen selectively through one or the other of supply ports 60 and 62. Whether the oxygen is fed through port 60 or port 62 is determined by the pressure balance in the distributor 22 due to the operation of ports 64 and 66. A discharge port 68 is also provided in the distributor 22.

Actually, the distributor is a four-way valve which may be any one of a number of commercially available types. Details of one such four-way valve are illustrated in the drawing in a very schematic manner. According to the schematic showing of the details of distributor 22 this part of the system comprises an internal movable member 70 having openings 72, 74, 76, 78 and 80. One side of the movable member 70 is operatively associated with control port 66 in a hermetically sealed manner by means of a baffle 82. The other side is operatively associated with control port 64 in a like manner by means of a baffle 84.

Assuming that one of the control ports 64 or 66 is open, the pressure of oxygen arriving via input port 58 will drive the movable member 70 towards that side of the distributor 22 provided with the open port. Movement of the movable member 70 will selectively register one of openings 74 or 76 with the supply port 60 via channel 86 and one of the openings 78 or 80 with the supply port 62 via channel 88.

While the oxygen arriving via input port 58 is functioning to position the movable member 70 properly in co-operation with control ports 64 and 66, a portion of the oxygen is also flowing via channel 72 into a central chamber 90 which opens into passages 76 and 78. Depending on which of these passages is coupled to the associated channel 86 or 88, one of the supply ports 60 and 62 will be provided with oxygen under pressure. This means that the lines connected to these supply ports will be conveying oxygen under pressure.

At the same time as one of the ports 60 and 62 is connected as aforesaid to the line 52, the other of these two ports is connected via one of the openings 74 and 80 to the discharge port 68.

The above details of the distributor 22 are exemplary only of the commercially available devices which are available to perform the same functions. Thus any suitable valve system or distribution means may be substituted for the arrangement described above.

Connected to control ports 64 and 66 are the lines 92 and 94, respectively. These lines are connected at their free extremities to poppet valves 96 and 98.

Since each of the poppet valves is of similar construction, the poppet valve 96 alone will be next described by way of example. This valve comprises simply a chamber 100 having an opening 102 in which seats a valve member 104 which is loaded by a spring 106. The spring 106 operates through the valve member 104 to maintain opening 102 normally closed. This condition exists until the valve member 104 is physically displaced into the chamber 100. Thus it is seen that control ports 64 and 66 can be connected to ambient atmosphere by physical displacement of the valve members comprised by the poppet valves 96 and 98.

Connected to the supply ports 60 and 62 are the lines 108a and 110a respectively, these lines being connected to the main drive provided for the pump 12 which drive is an oscillating or reciprocating drive means.

Actually pump 12 may be any conventional blood pump, such as, for example, that shown in Patent No. 2,689,565 of September 21, 1954, and is preferably a

pump which is mechanically driven by means of an oscillating or reciprocating mechanical force.

To this end, the drive 24 comprises a piston and cylinder arrangement constituted by a double acting piston 112 slidably accommodated within a cylinder 114. Piston 112 divides cylinder 114 into two chambers 116 and 118 which are connected respectively via ports 120 and 122 to lines 108b and 110b. A rigid rod 124 is connected to the piston 112 and transmits the oscillating or reciprocating motion of the latter to the pump 12 which constitutes a ventricle means and operates to simulate a pulse.

From what has been set forth above it will be obvious that a supply of pressure to chamber 118 via port 122 will drive piston 112 to the left, whereas a supply of oxygen to chamber 116 via port 120 will drive the piston 112 to the right. Thus, the selective supply of oxygen via ports 60 and 62 of the distributor 22 will control the operation of reciprocation of the piston 112. Moreover, as will be discussed in greater detail hereinafter, the discharge of oxygen from chambers 116 and 118 via lines 108 and 110 and through the distributor 22 wherefrom the oxygen leaves via discharge port 68 will control the speed of reciprocation or travel of the piston 112.

Connected to the rod 124 is an arm 126. This arm is rigid with the rod 124 and has a free extremity 128 having a path of movement parallel to that of the path of movement of the piston 112. With respect to this extremity 128, the poppet valves 96 and 98 are positioned along the path of travel thereof so as to have their valve members contacted by the extremity 128 when it is desired to reverse the direction of stroke of the piston 112. The positions of poppet valves 96 and 98 are adjustable and for this purpose there are provided adjustable mounting brackets 130 and 132.

A brief indication has been given above as to how the length of stroke of the piston 112 is controlled. The speed of the stroke of piston 112 may be controlled by means of the control 28. For this purpose the control 28 which comprises a regulator 134 and a dial 136 is connected to the discharge port 68 of the distributor 22 by means of the line 138.

Before reference is made to the auxiliary drive of the system, the operation of the main drive mechanism heretofore described will next be given.

Oxygen caused to flow via line 52 into the distributor 22 by means of the pressure existing in oxygen source 20, will cause the movable element 70 in the distributor 22 to move to the left or right depending upon which of poppet valves 96 or 98 is opened due to the position of the arm 126. Line 52 will therefore be connected selectively to one of lines 108 or 110 and oxygen under pressure will therefore flow into one of chambers 116 or 118. This will cause the piston 112 to move in the direction of the chamber to which oxygen under pressure is not being fed. Whatever oxygen is in this latter chamber will be discharged via the associated one of the lines 108 and 110, the oxygen flowing via discharge port 68 and line 138 through the regulator 134 into the ambient atmosphere. The adjustment of regulator 134 will control the speed of this discharge and consequently the speed of the piston 112.

The piston 112 is thus caused to move in one of its two directions of oscillation and carries along with it the arm 126 which alternately depresses the valve member of one of the poppet valves 96 and 98 so as to connect lines 108 and 110 alternately either to the input line 52 or to the discharge line 138.

It will be appreciated that engagement of extremity 128 with the valve member of one of the poppet valves causes a reversal of movement of the piston 112. The position at which this reversal of movement is effected corresponds to the relative position of valves 96 and 98 and this may be selected as desired through the intermediary of adjustable brackets 130 and 132.

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Thus the speed of movement of the piston 112 is controlled by regulator 134 and the length of stroke of the piston 112 is controlled by the positions of the valve members of poppet valves 96 and 98. These main drive parameters control the movement of rod 124 and thus the operation of pump 12 which as noted above, is a ventricle means simulating a pulse.

As noted above a portion of the oxygen is transmitted via line 54. In line 54 as noted above is positioned a means 32 for the delivery of oxygen to the oxygenator 10. This means 32 is in effect a conventional flow meter which distributes part of the oxygen via line 140 to the oxygenator 10 under the desired pressure or flow rate. This flow rate is generally somewhat less than 65 liters of oxygen per minute and is controllable within the range, for example, of from 0 to about 20 liters per minute. Thus, the oxygen from the source 20 is not only employed to drive the pump 12 but is further employed to provide oxygen to the blood in the oxygenator 10.

Attention is next directed to the auxiliary drive 30, some of the details of which are additionally illustrated in FIGURES 2 to 4.

Shaft 124, which is reciprocated by main drive 24, terminates in a bracket 142 rigidly affixed to said shaft. Bracket 142 includes a U-shaped portion 144 having an opening 146 therein to accommodate a pin. Shaft 148, which is directly connected to the pump 12 (as is shown partially broken away in FIGURE 1) is connected to bracket 142 by means of a pin arrangement 150 (FIGURE 2) which is accommodated in opening 146. Preferably, there is no play in the above noted connection of shafts 124 and 148 so that a movement of either of these shafts is transmitted to the other of these shafts.

Unit 30 is mounted on a table or chassis 152, or the like, having an end member 154. Beneath table 152 are suspended brackets 156 and 158 which accommodate a rod 160 which is capable of both rotational and axial displacement in the brackets 156 and 158.

Rigidly connected to an end of the rod 160 is a disc or collar 162 and superposed with respect thereto is a ring 164 having an internal circular opening 166 within which is accommodated an eccentric 168 connected to the disc 162 by a pin 170 to which the eccentric 168 is affixed for rotation. The pin 170 is rotatable with respect to the disc 162 so that the disc maintains a substantially constant attitude relative to the table 152. Connected to the pin 170 is a control lever 172 which is adapted to rotate the pin 170 as indicated by the arrow 174.

As will be seen hereinafter, ring 164 is urged towards table 152, and is braced thereagainst by means of a leaf spring 176. Rotation of the control lever 172, due to rotation of the eccentric 168 in the opening 166, causes a displacement of the disc 162 towards or away from the table 152 and therefore results in an axial displacement of the rod 160.

On the rod 160 is positioned a clutch member 178, a spring 180 being mounted on the rod 160 between the clutch member 178 and a collar 182 on the rod 160. Spring 180 urges the clutch member 178 toward the right in FIGURES 2 and 3. The force of spring 180 is, however, normally overcome due to the position of the eccentric 168 in the ring 164 so that the clutch member 178 is normally disengaged from clutch member 184, as illustrated in FIGURE 3.

Clutch members 178 and 184 constitute a one-tooth dog clutch including a tooth 186 engageable in a groove 188. Rotation of control lever 172, by approximately $\frac{1}{4}$ of a rotation, causes a sufficient displacement of disc 162 and thereby of rod 160, to result in a penetration of tooth 186 into groove 188. Tooth 186 and groove 188 have a fixed relationship so that an axial displacement of rod 160 will always result in an engagement of clutch members 178 and 184.

Clutch member 184 is mounted on a rod 190 upon

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which is mounted a lever 192. Lever 192 is connected with an arm 194 mounted on the bracket 142. Specifically, this connection is effected by means of a pin 196 arranged in a lost motion assembly so that the arc described between upper extremity of lever 192 does not apply irregular forces to the shaft 148.

With the clutch members 178 and 184 engaged, a pivotal movement of control lever 172 as illustrated by arrows 198 and 200, will impart to the shaft 148 a reciprocating motion adapted for driving pump 12 in the same manner as provided for by main drive 24.

It will be seen from what has been described above that a simple rotation of control lever 172 causes an engagement of the auxiliary or safety drive 30 with the pump 12, whereupon a working of the lever 172 in a pivotal manner causes the pump 12 to be driven.

It will be appreciated that movement of the lever 172 is transmitted via shaft 124 to the piston 112. With a pressure medium, however, trapped in chambers 116 and 118, the movement of piston 112 in cylinder 114 would normally be resisted. This would be reflected as a load upon control lever 172 which, under certain circumstances, would be impossible to operate. Accordingly, the invention contemplates the provision of further means 202 which avoids the possibility that drive 24 will constitute a load on lever 172.

More particularly, lines 108a and b and 110a and b do not connect distributor 22 directly to cylinder 114. Instead, there are interposed in each of lines 108 and 110 control chambers 204 and 206, respectively. Control chamber 204 divides line 108 into two sections, 108a and 108b, and control chamber 206 divides line 110 into sections 110a and 110b.

Control chambers 204 and 206 are substantially identical and thus only one chamber, 204, will be described in detail. This chamber includes a slidable member 208, to which is connected a control rod 210. Chamber 204 is provided with an input port 212 connected to line 108a and an output port 214 connected to line 108b. Member 208 is positionable in chamber 204 so that ports 212 and 214 are directly connected, or so that these ports are isolated from one another.

Chamber 204 is also provided with a venting or exhaust port 216 in which is positioned a spring-loaded valve member 218.

Valve member 218 is positioned so as to be displaced by slidable member 208 when the latter has moved into position to isolate ports 212 and 214. Displacement of valve member 218 opens chamber 204 to ambient atmosphere and thus connects the cylinder 114 to exhaust. The piston 112 is, with the cylinder 114 open to ambient atmosphere, freely movable within said cylinder. The piston 112, under these conditions, constitutes absolutely no load on the control lever 172 which is free to reciprocate shaft 148 with the only load being constituted by the pump 12.

Control chambers 204 and 206, therefore, represent a means for establishing two conditions for the cylinder 114 and therefore the drive 24: a first condition whereat the drive 24 is operative and capable of driving pump 12 and a second condition wherein drive 24 is inoperative and incapable of imposing a load upon the auxiliary drive 30.

The slide members of control chambers 204 and 206 are both rigidly connected to control rod 210, to which is pivotally connected a control lever 220 mounted on a fixed bracket 222 and pivoted in the directions indicated by arrows 224. Operation of lever 220 serves to effect the control functions noted above with respect to rendering drive 24 operative and inoperative.

It will be appreciated from what has been stated above that levers 172 and 220 are readily operated members which, in the event of an emergency, are readily employed to provide the safety feature of the invention. Thus an extracorporeal blood circulation system has been provided

by the invention wherein an auxiliary manually-operated means is selectively connectable to a drive shaft 148 to substitute for the main power source 24. In general, this main power source has two operational conditions, in one of which it is capable of driving shaft 148 and thus pump 12, and in the other of which it is ineffective to drive shaft 148, but does not constitute a load on auxiliary drive 30.

It will be recognized that the invention contemplates not only an improvement in extracorporeal blood circulation systems, but as well improvements in pump systems in general.

There will now be obvious to those skilled in the art many modifications and variations of the structure set forth above. These modifications and variations will not, however, depart from the scope of the invention if defined by the following claims.

What is claimed is:

1. An extracorporeal blood circulation system comprising an oxygenator adapted to oxygenate the blood, ventricle means coupled to said oxygenator to receive blood therefrom and simulate a pulse, a drive coupled to and actuating said ventricle means, a power source coupled to said drive for operation of the latter, and an auxiliary manually-operated means selectively connectable to said drive to substitute for said power source in the event of failure of the latter.

2. In an extracorporeal blood circulation system comprising an oxygenator adapted to oxygenate the blood, and a ventricle means coupled to the oxygenator to receive blood therefrom and simulate a pulse, said ventricle means being adapted to be operated by a reciprocating force; a drive comprising a piston and cylinder arrangement, coupling means, coupling said arrangement to said ventricle means for supplying the reciprocating force and driving the latter, means supplying a pressure medium to said cylinder for displacing the piston therein, manually-operated means coupled to said coupling means for selectively driving said ventricle means, and means for selectively venting said cylinder to avoid imposing a load on said manually-operated means due to said piston and cylinder arrangement.

3. In an extracorporeal blood circulation system: pump means to simulate a pulse, manually-operated means selectively connectable to said pump means for driving the same, pneumatic means permanently connected to said pump means for driving the same, and control means to render said pneumatic means inoperative to impose a load on said manually-operated means with the latter driving the pump means.

4. In an extracorporeal blood circulation system: pump means responsive to a reciprocating force for pumping said blood, a piston and cylinder arrangement coupled to said pump means for the supply of said force thereto, means for supplying a pressure medium to said cylinder to actuate said piston for supplying said force, and means coupled to the first said means to vent the same and render said arrangement ineffective to operate said pump means.

5. In an extracorporeal blood circulation system including a reciprocal pump to pump said blood: a piston and cylinder arrangement connected to said pump to drive the same, a source of pressure medium, a distributor coupled to said source, and control means connected to

said cylinder and distributor and adapted to selectively connect and isolate the same.

6. In the system claimed in claim 5, means in said control means to vent said cylinder to ambient atmosphere with the cylinder and distributor isolated.

7. A manual control for a pump system including a reciprocable shaft, said control comprising means coupled to said shaft to reciprocate the same, means selectively engageable with the first said means, and lever means coupled to the second said means, said lever means being adapted on rotation to engage the first and second said means and being pivotable with the latter said means engaged to reciprocate said shaft through the intermediary of the latter said means, said lever means comprising a lever and an eccentric on said lever; and the second said means comprising a collar having a circular opening accommodating said eccentric, a rod connected to the collar and thus displaceable by said eccentric, and a clutch member on said rod and displaceable therewith into and out of a position of engagement with the first said means.

8. A control as claimed in claim 7, wherein the first said means comprises a second clutch member engageable with the first said clutch member and means connecting the second clutch member with said shaft.

9. A control as claimed in claim 8, comprising a spring engaging the first clutch member and urging the same into engagement with the second clutch member, said eccentric normally maintaining the clutch members disengaged.

10. A control as claimed in claim 9, comprising a spring engaging said collar to urge the same against said eccentric and into a position whereat the clutch members are disengaged.

11. A system comprising a source of pressure medium, a distributor coupled to said source, a cylinder, a double-acting piston in said cylinder dividing the latter into two chambers adapted for being coupled to said distributor, first and second connecting members connecting the distributor to said chambers; each connecting member including a hollow casing, a displaceable member dividing the casing into two sections respectively connected to said cylinder and said distributor, a control for displacing the moveable member to connect the distributor to said cylinder, and exhaust means responsive to displacement of the displaceable member to vent said cylinder; a pump, and a rod connecting said piston to said pump for driving the latter, said distributor alternately connecting said source to said cylinder chambers to reciprocate said piston.

12. A system as claimed in claim 11, comprising a hand-operated lever selectively connected to said rod for driving said pump.

13. A system as claimed in claim 11, comprising one control member connected to both displaceable members for controlling the same simultaneously.

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