

April 8, 1969

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HYPERBARIC HEART PUMP OXYGENATOR WITH HYPOTHERMIA

Filed Jan. 4, 1965

Sheet 2 of 2

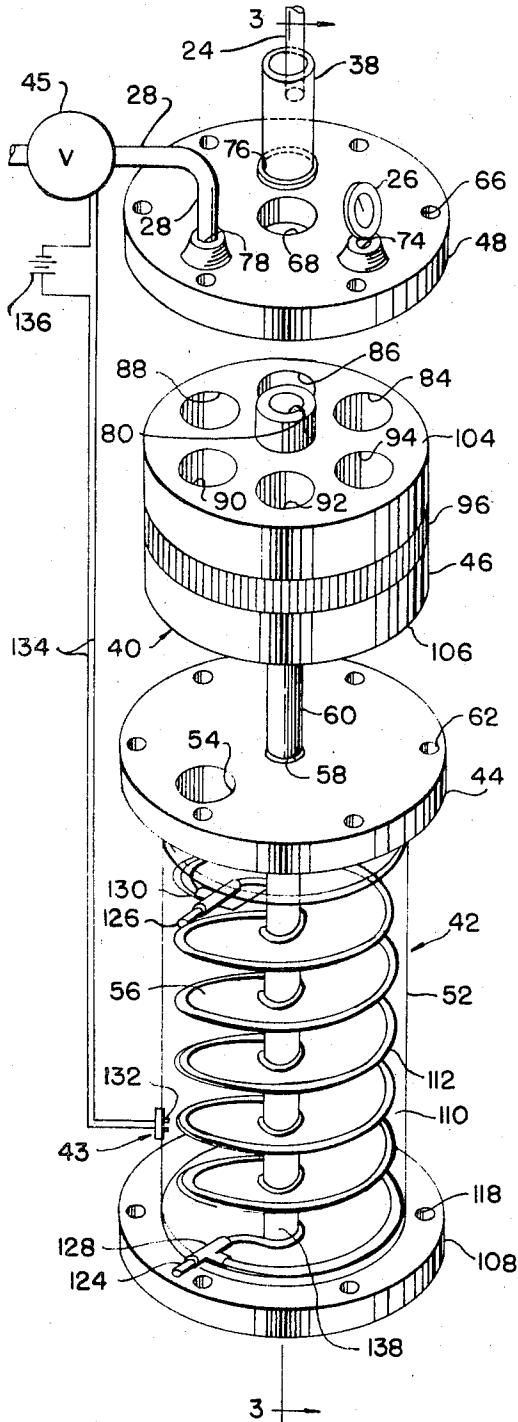


FIG. 2

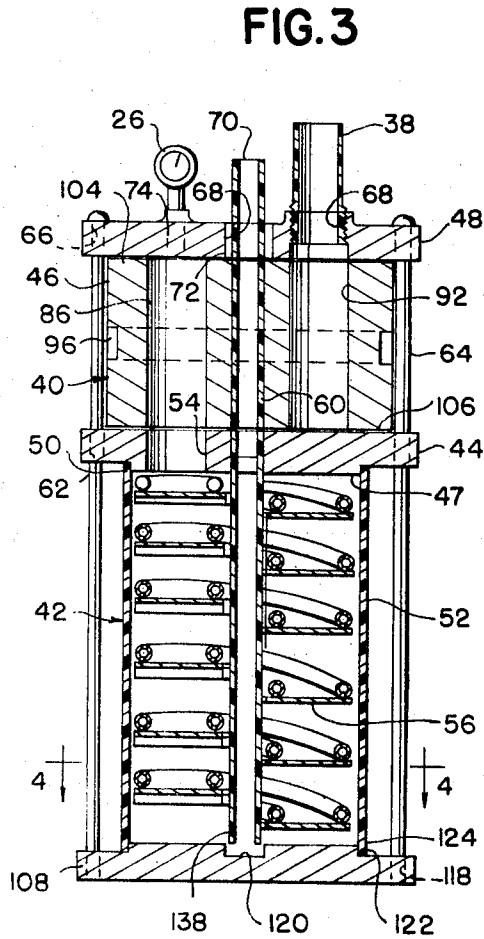


FIG. 3

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HYPERBARIC HEART PUMP OXYGENATOR WITH
HYPOTHERMIA

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Filed Jan. 4, 1965, Ser. No. 423,052

Int. Cl. A61m 1/00

U.S. Cl. 23—258.5

15 Claims

ABSTRACT OF THE DISCLOSURE

A heart pump comprising a blood reservoir, a blood storage chamber, an output conduit extending from the bottom of the blood storage chamber, a source of pressure, a pair of plates, aligned openings in the plates between the source of pressure and blood storage chamber, and means for transferring blood from the blood reservoir between the plates to the aligned openings between the source of pressure and blood storage chamber. A spiral ramp is provided in the blood storage chamber for oxygenation of blood delivered thereto and heat exchanger means are provided in the blood storage chamber for controlling the temperature of blood in the storage chamber. A blood level responsive switch, is also provided in the storage chamber for turning off the source of pressure on the blood level falling below a predetermined level.

The invention relates to surgical equipment and refers more specifically to heart pump apparatus for use in a cardiopulmonary bypass or the like which incorporates hypothermia structure and structure for hyperbaric oxygenation of blood.

In the past separate heart pumps, blood oxygenators and heat exchangers have usually been used during heart surgery. Prior heart pumps, blood oxygenators and heat exchangers have often been complicated and expensive as well as being inefficient in the use of operating personnel and personnel for maintaining the separate apparatus in sterile condition.

In addition prior heart pumps, such as sigma motor or peristaltic type pumps and roller or DeBakey type pumps which progressively squeeze tubes closed along the length thereof to pump blood are traumatic to blood cells and cause eventual hemolysis thereof. The length of time prior heart pumps may be used during an operation is therefore limited. Other disadvantages of prior heart pumps include the physical size thereof, the difficulty of setting the pumps up and complicated control thereof. The large priming capacity required and relatively limited output range of prior heart pumps and the possibility of pumping dry are further disadvantages of prior heart pumps.

It is therefore a purpose of the present invention to provide improved heart pump apparatus.

Another object is to provide a combination heart pump, blood oxygenator and heat exchanger.

Another object is to provide portable, disposable heart pump apparatus which incorporates hypothermia and hyperbaric oxygenation of blood.

Another object is to provide heart pump apparatus which is non-traumatic to the cells of blood pumped thereby.

Another object is to provide heart pump apparatus which has wide output capacity.

Another object is to provide heart pump apparatus including a heat exchanger which may be connected directly to the mixing valve or a temperature gage on a water faucet.

Another object is to provide heart pump apparatus

which may be remotely controlled, is portable, easy to set up and automatic in use.

Another object is to provide heart pump apparatus which includes visual means for indicating the fluid in the patient and means for preventing dry pumping.

Another object is to provide heart pump apparatus which is simple in construction, economical to manufacture and efficient in use.

Other objects and features of the invention will become apparent as the description proceeds, especially when taken in conjunction with the accompanying drawings, illustrating a preferred embodiment of the invention, wherein:

FIGURE 1 is a perspective view of heart pump apparatus including combined pump, blood oxygenator and heat exchanger structure constructed in accordance with the invention connected to a patient in a cardiopulmonary bypass.

FIGURE 2 is a partly exploded perspective view of the heart pump apparatus illustrated in FIGURE 1.

FIGURE 3 is a longitudinal section view of the assembled heart pump apparatus illustrated in FIGURE 1 taken substantially on the line 3—3 in FIGURE 2.

FIGURE 4 is a transverse cross section of the heart pump apparatus illustrated in FIGURE 1 taken substantially on the line 4—4 in FIGURE 3.

With particular reference to the figures of the drawings, one embodiment of the present invention will now be considered in detail.

Referring to FIGURE 1, the heart pump apparatus 10 is shown with an arterial line 12 connected from the pump output conduit 60 to a cannula in femoral artery 14 of a patient 16 in who a cardiopulmonary bypass has been effected. The heart pump apparatus 10 is also connected to a cannula 18 in the right atrium 20 of the heart 22 of patient 16 through a venous line 24. The pump apparatus 10 further includes the pressure relief mechanism 26 and the oxygen supply conduit 28. Pump apparatus 10 also includes a coronary perfusion tube 30 connected to the arterial line 12 and cardiotomy suction structure including a suction tube 32, a vacuum source conduit 34 and reservoir 36 draining into the main pump apparatus reservoir 38.

In operation of the pump apparatus 10, blood from the patient 16 is returned to the reservoir 38 of pump apparatus 10 by gravity flow, after which it is allowed to fall through the pump portion 40 of pump apparatus 10 into the oxygenator and heat exchanger portion 42 of the pump 10 where it is oxygenated and the temperature thereof controlled. Subsequently the blood is forced upward through the output conduit 60 of pump apparatus 10 and the arterial line 12 due to oxygen pressure in the oxygenator and heat exchanger portion 42 of the pump apparatus 10 supplied through the oxygen supply conduit 28. The pressure relief mechanism 26 is operable in conjunction with the rotating cylinder part 46 of the pump portion 40 of pump apparatus 10 to maintain required pressure in the oxygenator-heat exchanger portion 40 of the pump apparatus 10 while transferring oxygen under pressure and blood thereinto as will be considered subsequently. Blood level sensing structure 43 is provided to prevent dry operation of the pump apparatus 10.

More specifically, the pump portion 40 of the combined pump, blood oxygenator and heat exchanger pump apparatus 10, as best shown in FIGURES 2 and 3, includes the lower pump plate 44, the pump cylinder 46 and the upper pump plate 48.

The lower pump plate 44 is provided with a reduced diameter portion 47 thereon for receiving the upper end 50 of the transparent cylinder 52 of the oxygenator and heat exchanger portion 42 of the pump apparatus 10.

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An opening 54 through which blood is passed onto the helical ramp 56 of the portion 42 of the combined pump apparatus 10 extends through the lower pump plate 44. The pump discharge conduit 60 extends through the central opening 58 in the lower pump plate. The peripheral opening 62 through which connecting bolts 64 extend to secure the pump apparatus 10 in assembly are also provided in the lower pump plate 44.

The upper pump plate 48 includes the peripheral opening 66 extending therethrough to receive the bolts 64 along with the opening 68 positioned centrally thereof for receiving the upper end 70 of the pump discharge conduit 60 and the collar 72 of the pump cylinder 46. The upper pump plate 48 further includes the three angularly, equally spaced and flanged openings 74, 76 and 78 extending axially therethrough for receiving the pressure relief mechanism 26, the reservoir 38 and the oxygen supply conduit 28, respectively.

The pump cylinder 46 includes a central opening 80 therethrough aligned with the collar 72 thereon and six equally spaced axial openings 84, 86, 88, 90, 92 and 94 extending therethrough, as shown best in FIGURE 2. The openings 84, 86, 88, 90, 92 and 94 are positioned to align in sequence with the opening 54 in the lower pump plate 44 and the openings 74, 76 and 78 in the upper pump plate 48 on rotation of the pump cylinder 46.

The pump cylinder 46 is further provided with the annular rack 96 extending circumferentially therearound axially centrally thereof in mesh with the pinion 98 which is driven through the gear 100 by motor 102 to rotate the pump cylinder 46 as desired in accordance with the operation of the pump apparatus 10 to be considered subsequently.

The upper pump plate 48, the lower pump plate 44 and the pump cylinder 46 may be constructed of aluminum or suitable rigid plastic. The pump cylinder 46 is provided with thin Teflon sheets 104 and 106 on the top and bottom thereof respectively. The Teflon sheets on the pump cylinder 46 provide a bearing and sealing surface between the cylinder and the pump plates.

The oxygenator and heat exchanger portion 42 of the combined pump apparatus 10 includes an oxygenator bottom plate 108, the transparent cylinder 52, the helical ramp 56 and the heat exchanger conduits 112, together with the inlet and outlet connection structure 114 and 116 respectively for conduits 112.

The oxygenator bottom plate 108 is provided with threaded peripheral openings 118 into which bolts 64 are threaded and the central recess 120 into which the pump output conduit 60 extends. The oxygenator bottom plate 108 further includes the reduced diameter portion 122 for receiving the end 124 of the transparent cylinder 52. The bottom plate 108 may be aluminum or plastic.

The transparent cylinder 52 is provided to give a visual indication of the quantity of blood in a patient since the blood in the patient is a function of the blood in the pump. The transparent cylinder 52 may be glass or clear plastic. The cylinder 52 as previously indicated is held in position over the reduced diameter portions 47 and 122 of the pump lower plate and the oxygenator bottom plate. Suitable seals therebetween may be provided if necessary.

The ramp 56 is a helically wound and axially extended flat member having high heat transfer qualities. Ramp 56 may be for example chrome plated brass. In operation the blood deposited on the ramp 56 at the top thereof runs down the helical ramp path in a wide thin stream into the blood storage chamber 110 formed by the cylinder 52, lower pump plate 48 and the oxygenator bottom plate 108. The blood thus is spread out over the large area provided by the ramp during its downward travel so that oxygenation thereof by oxygen under pressure in cylinder 52 between plates 44 and 108 is readily accomplished without foaming the blood and thus producing air bubbles therein.

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The tubes 112 of the heat exchanger and oxygenator portion 42 of the pump apparatus 10 are helically formed as illustrated best in FIGURE 2 and are connected to the inner and outer periphery of the helical formed ramp 56 to provide therewith a channel down which the blood deposited on the ramp 56 through the opening 54 in the lower pump plate 44 is passed. The inlet and outlet connection structure 114 and 116 for the tubes 112 include a single pipe 124 or 126 and the T-couplings 128 and 130 respectively.

In operation, cooling water is directed into the pipe 124 upwardly through the helical tubes 112 and out of the pipe 126. The pipe 124 may be connected to a water faucet mixing valve or a temperature control valve while the pipe 126 may be connected to a water drainage system. The temperature of the blood passing down the ramp 56 may thus be conveniently controlled.

As shown best in FIGURE 2, the blood level sensing structure 43 controlling the operation of the pump apparatus 10 in accordance with the height of blood in the transparent cylinder 52 includes a pair of electric contacts 132 positioned within the transparent cylinder 52 at a height above the oxygenator bottom plate 108 above which it is desired to maintain the level of the blood in the transparent cylinder 52. A pair of conductors 134 are provided connecting a source of electric energy 136 to the solenoid operated valve 45 in the oxygen supply line 28 through the contacts 132.

In operation, when the blood in the transparent cylinder 52 falls below the level of the electric contacts 132, the circuit to the solenoid operated valve 45 is broken so that the valve 45 closes, cutting off the supply of oxygen under pressure to the pump apparatus 10 through oxygen conduit 28. Further forcing of the blood remaining in the transparent cylinder 52 out of the output conduit 60 and into the patient is thus prevented whereby possible pumping of air directly into the patient, which of course would be fatal, is prevented.

In over-all operation of the combined pump, oxygenator and heat exchanger pump apparatus 10, it will be assumed that the pump apparatus 10 is connected to a patient 16 as illustrated in FIGURE 1. Thus the venous line 24 is connected to the cannula 18 to the right atrium 20 of the patient's heart 22, while the arterial line 12 is connected to a cannula 15 in the femoral artery 14 of the patient 16. It will further be assumed that the oxygen supply line 28 is connected to a supply of oxygen under pressure which may be regulated by convenient means to provide the proper blood flow through the patient 16 and that the pump apparatus 10 is primed with, for example, 400 cubic centimeters of appropriate fluid.

The motor 102 is then started to drive the gear 100 and the pinion 98. Pinion 98 in turn produces a rotation of the pump cylinder 46 about the Teflon pump output conduit 60. During the rotation of the pump cylinder 46 a single complete cycle of one of the openings 84, 86, 88, 90, 92 and 94 will be considered.

In the position shown in FIGURE 2, the opening 84 would be in an intermediate position between the pressure relief mechanism 26 and the blood reservoir 38. The pressure in the chamber formed by the opening 84 and the upper and lower pump plates 48 and 44 with the cylinder in this position will be substantially atmospheric.

Subsequent rotation of the pump cylinder 46 into a position wherein the opening 84 is under the reservoir 38 permits a predetermined volume of blood to pass into the chamber formed by the opening 84 since the blood has collected in the reservoir 38 from the venous line 18. The opening 84 then passes into another position wherein the opening formed thereby is sealed.

The opening 84 will then pass into the position of the present opening 90 in FIGURE 2 wherein the opening 84 will be aligned over the opening 54 in the lower pump plate 44 and will simultaneously be aligned with the opening 78 into which the oxygen supply conduit 28 is con-

nected. In this position the blood in the opening 84 is dropped into the oxygenator and heat exchanger portion 42 of pump apparatus 10 by gravity force alone since the pressure in the oxygen supply conduit 28 and that in the cylinder 52 will be substantially equal.

The blood will then pass down the helical ramp 56 between the tubes 112 to the bottom of the oxygenator and heat exchanger portion 42 of the pump apparatus 10 to form a pool at the bottom thereof covering the contacts 132. On passage down the ramp 56 the blood is thinly spread out over a large area so that the blood is oxygenated by the oxygen under pressure within the cylinder 52 without bubbles being formed therein. In addition the temperature of the blood is controlled at this time as previously indicated by water at a selected temperature being passed upwardly through the tubes 112.

The blood is then forced out of the pump output conduit 60 by the pressure in the cylinder 52 forcing the blood in the bottom of the cylinder 52 into the end 138 of the conduit 60 and upward into the arterial line 12.

The empty opening 84 is then passed into the position beneath the pressure relief mechanism 26 wherein the pressure in the chamber formed by the opening 84 is neutralized. The opening 84 then passes into the position illustrated in FIGURE 2 to complete a complete cycle of a single opening 84 of the rotatable pump cylinder 46.

As previously indicated, should the level of the blood in the transparent cylinder 52 fall below the level of the contacts 132 the circuit to the solenoid operated valve 45 from the source of electric energy 136 will be broken, whereby the solenoid operated valve 45 will close to prevent maintaining pumping pressure in the blood storage chamber 110. Pumping of oxygen into the patient 16 is thus positively prevented.

The operation of the cardiotomy suction structure to provide blood in reservoir 36 which empties into reservoir 38 will be readily apparent. Thus the operation area may be drained of excess blood and the blood returned to the pump apparatus 10 through the reservoir 38. The coronary perfusion tube may be used to provide blood where desired during the operation.

As previously indicated, the combined pump, oxygenator and heat exchanger pump apparatus 10 is small, portable and disposable, as well as being easy to set up and to control by a single person. Further, the pump requires a particularly low priming volume, such as 400 cubic centimeters in contrast to perhaps 2 liters for known heart pumps and the heart pump apparatus disclosed is non-traumatic to blood cells so that they will not be hemolysed. Also, the pump apparatus 10 has a particularly wide output range, as for example from a few cubic centimeters to 6 liters per minute, cannot run dry and provides visual indication of the fluid in the patient as well as providing oxygenation and heat transfer with pumping action in a simple, economical and efficient structure.

While one embodiment of the present invention has been considered in detail, it will be obvious to those skilled in the art that other embodiments and modifications thereof are possible. It is the intention to include all embodiments and modifications of the pump apparatus disclosed as are defined by the appended claims within the scope of the invention.

What I claim as my invention is:

1. A heart pump comprising a first pump plate having an oxygen supply opening and a blood reservoir opening extending therethrough, means for supplying oxygen under pressure to the oxygen supply opening, a second pump plate positioned in spaced relation to the first pump plate having an opening therethrough aligned with the oxygen supply opening, blood translator means positioned between the first and second plates having at least one opening therein extending between the first and second plates positioned to sequentially align with the blood reservoir opening in the first pump plate and the oxygen supply opening in the first plate and the aligned opening

in the second plate on movement of the blood translator means, means defining a blood storage chamber in communication with the opening in the second plate and a pump output conduit extending from the blood storage chamber.

2. Structure as set forth in claim 1 and further including means within the blood storage chamber for oxygenation of the blood delivered thereto.

3. Structure as set forth in claim 1 and further including heat exchanger means in the blood storage chamber for controlling the temperature of blood passing through the pump.

4. Structure as set forth in claim 1 and further including means connected to the blood storage chamber responsive to the level of blood therein for preventing connecting the blood storage chamber to the source of pressure on the blood in the blood storage chamber falling below a predetermined level.

5. Structure as set forth in claim 1 and further including a pressure relief opening in the first plate positioned to align with the opening in the second plate on movement of the blood translator.

6. A heart pump comprising an upper pump plate having an oxygen supply conduit opening, a pressure relief mechanism opening and a blood reservoir opening extending therethrough, an oxygen supply conduit connected into the oxygen supply conduit opening for supplying oxygen under pressure therein, a blood reservoir positioned on the upper pump plate over the blood reservoir opening therethrough and in communication therewith, a lower pump plate positioned beneath the upper pump plate and having an opening therethrough aligned with the oxygen supply conduit opening in the upper pump plate, a cylinder positioned between the upper and lower pump plates including at least one opening therein extending between the upper and lower pump plates positioned to sequentially align with the oxygen supply conduit opening in the upper pump plate and the opening in the lower pump plate, the pressure relief mechanism opening in the upper pump plate and the blood reservoir opening in the upper pump plate on rotation of the cylinder, means for rotating the cylinder, means defining a blood storage chamber in communication with the opening in the lower pump plate, a pump output conduit extending axially from the bottom of the blood storage chamber through the lower pump plate, the pump cylinder and the upper pump plate out of the pump, and means for securing the pump plates, the cylinder and means defining the blood storage chamber in assembly with each other.

7. Structure as set forth in claim 6 wherein the means for rotating the pump cylinder includes an annular rack positioned centrally on said cylinder, motor means and gear and pinion structure connected between said motor means and rack for rotating said cylinder an operation of said motor means.

8. Structure as set forth in claim 6 wherein the means defining the blood storage chamber includes a bottom plate aligned with and positioned below the lower pump plate, and a transparent cylinder extending axially between the lower pump plate and bottom plate for providing a visual indication of the amount of blood in the blood storage chamber.

9. Structure as set forth in claim 6 and further including means for preventing supply of oxygen under pressure in said oxygen supply conduit opening in response to blood in the blood storage chamber falling below a predetermined level.

10. Structure as set forth in claim 9, wherein the means for preventing supply of oxygen under pressure comprises a solenoid operated valve in the oxygen supply conduit, a source of electric energy, a pair of contacts within the blood storage chamber, and means for completing a circuit through the solenoid operated valve from the source of electrical energy through the contacts only when the contacts are covered with blood.

11. Structure as set forth in claim 5 wherein there are six openings extending axially through said cylinder equally spaced angularly therearound and the oxygen supply opening, pressure relief mechanism opening and blood reservoir opening through the upper pump plate are equally spaced angularly around the upper pump plate so as to be sequentially in axial alignment with the six openings through the cylinder on rotation of the cylinder.

12. Structure as set forth in claim 11 and further including heat exchanger structure within said blood storage chamber.

13. Structure as set forth in claim 6 and further including means within the blood storage chamber for oxygenating the blood in the blood storage chamber.

14. Structure as set forth in claim 13 wherein the means for oxygenating the blood comprises a helical ramp within the blood storage chamber positioned beneath the opening in the lower pump plate for receiving blood therethrough and providing a wide surface down which a thin layer of blood will pass under oxygen pressure.

15. Structure as set forth in claim 14 and further including heat exchanger means within said blood storage chamber comprising a pair of helically wound tubes posi-

tioned at the inner and outer periphery of the helical ramp, means for feeding a fluid at a predetermined temperature into the lower ends of the tubes, and means for withdrawing the fluid from the upper ends of the tubes to vary the temperature of the blood flowing down the ramp.

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U.S. Cl. X.R.

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