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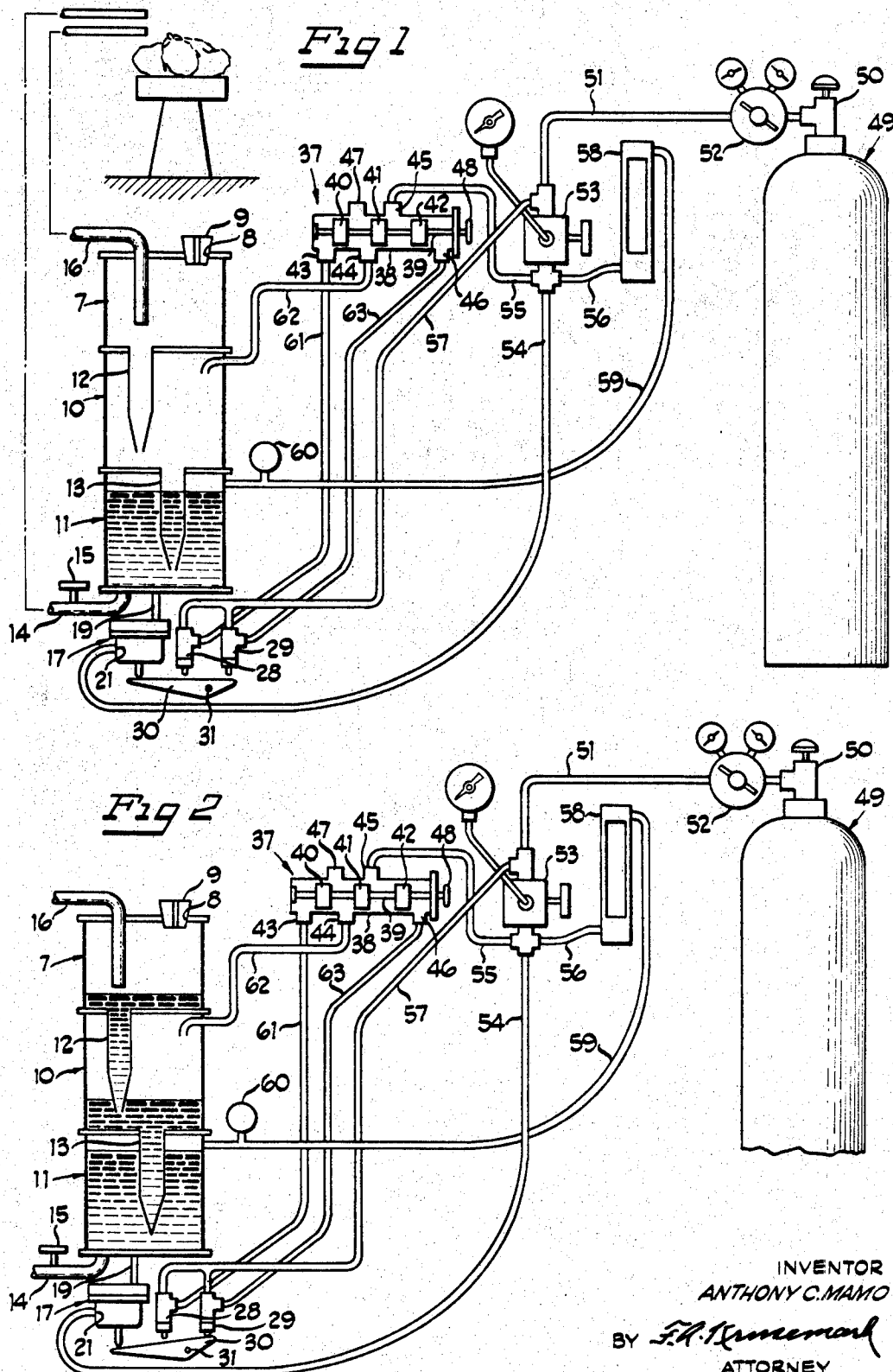
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3,407,748

BLOOD CIRCULATING APPARATUS

Filed Feb. 17, 1967

3 Sheets-Sheet 1



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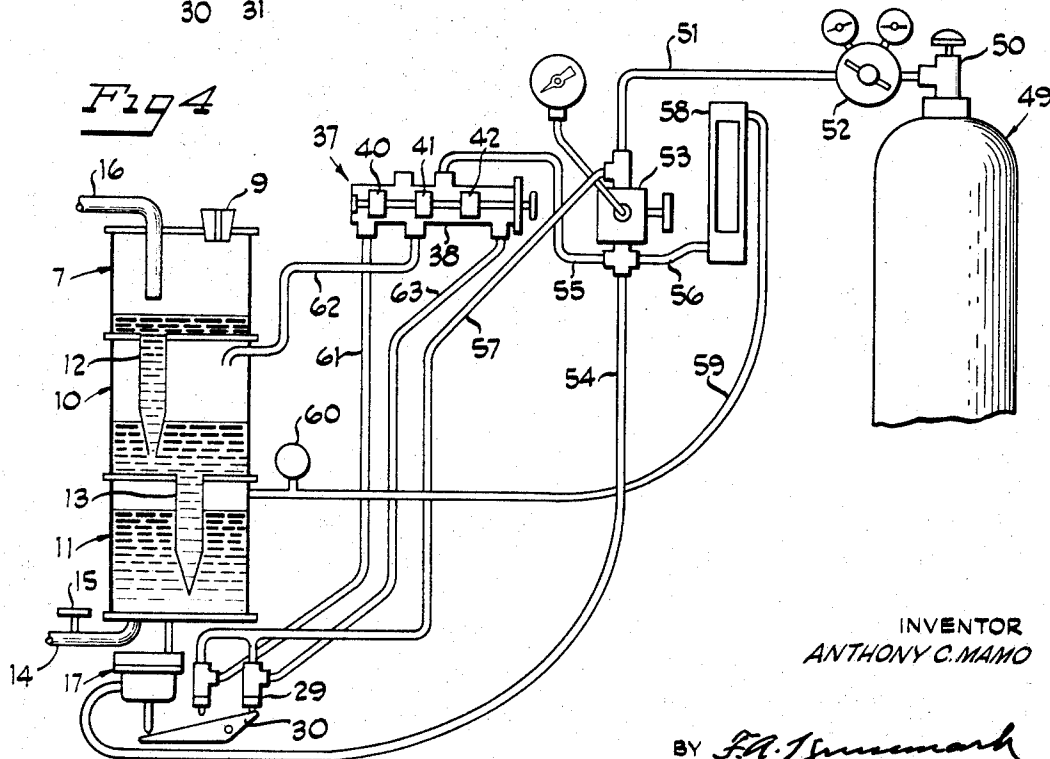
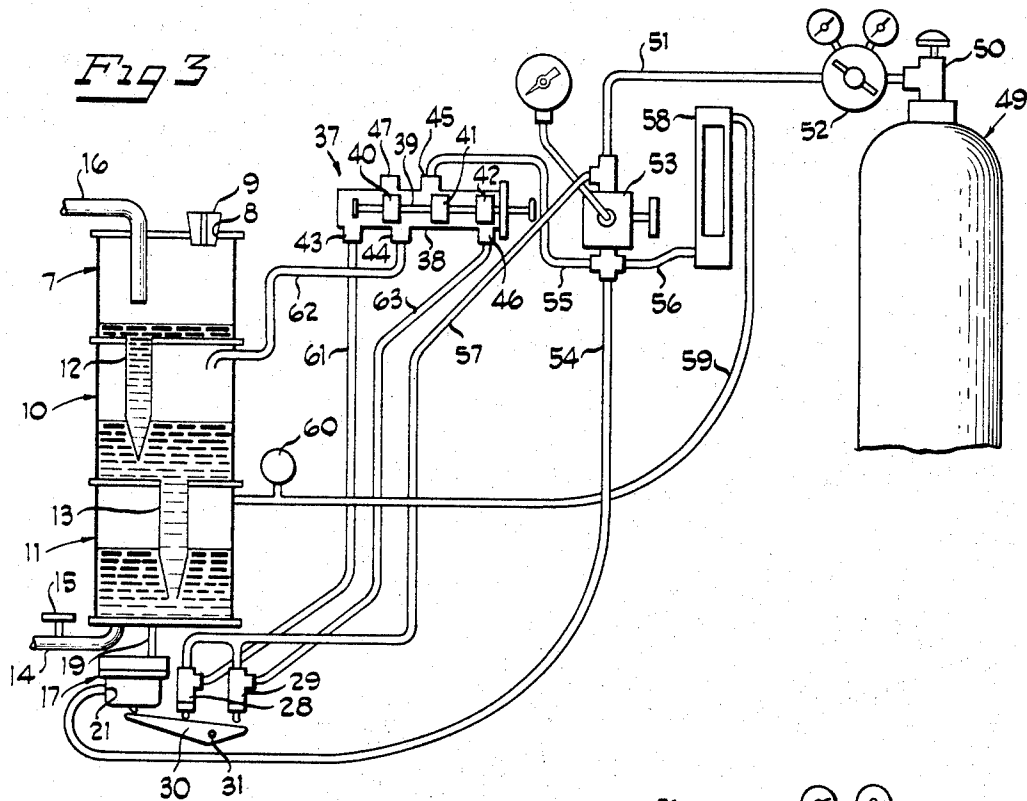
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3 Sheets-Sheet 2



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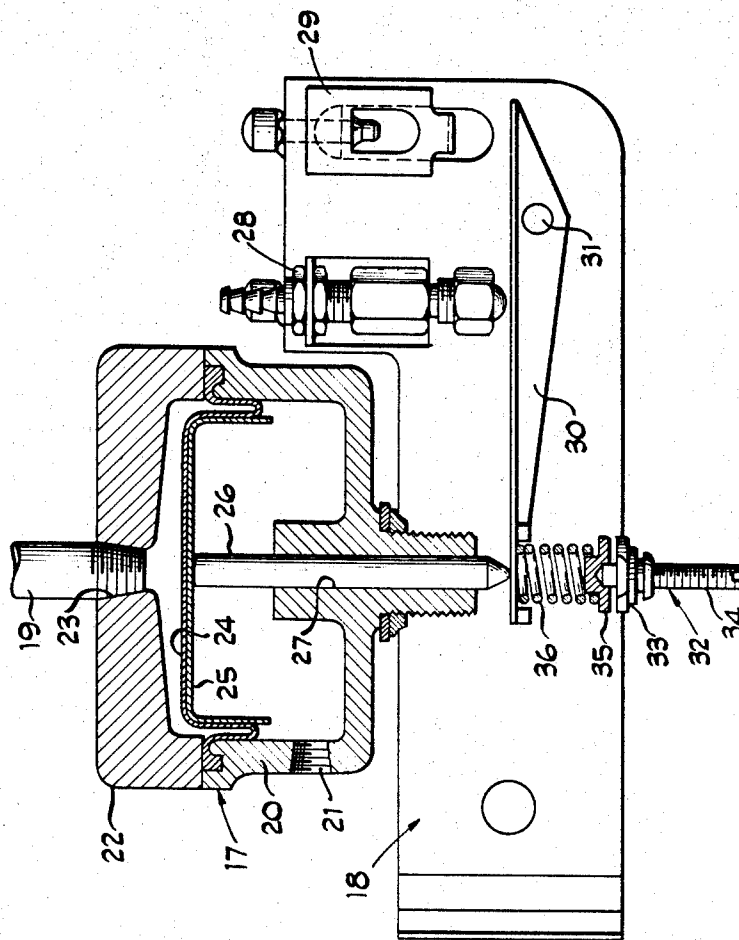
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Fig 5



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BLOOD CIRCULATING APPARATUS

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ABSTRACT OF THE DISCLOSURE

An apparatus comprising an upper compartment, an intermediate compartment and a lower compartment vertically disposed with respect to each other for conveying blood to a patient and a pressurized gas cylinder communicable with the lower compartment and selectively communicable with the intermediate compartment by gas conduit means.

Background of the inventions

Description of the prior art.—Patent No. 3,204,631 by L. J. Fields, shows a multiple compartment apparatus, vertically disposed, and a source of gas pressure which operates a pump to convey blood to the patient. In the present invention, there is an important distinction in that a pump as such is not used to convey blood to a patient but instead, by virtue of the arrangement of its components, blood is conveyed to the patient by gas under pressure supplied by the pressurized cylinder. Another patent, No. 3,075,524, by L. C. Clark, Jr., has a number of compartments arranged horizontally instead of vertically as in the present disclosure and conveys blood to the patient by virtue of alternate application of a vacuum and a pressure to one of the compartments. In the present disclosure, the means which causes the flow of blood to the patient is gas pressure applied to the bottom compartment. The blood supply for the bottom compartment is by gravity from the other compartments. Pumps as such, including pulsating types, are not required in the operation of this invention, hence, minimal damage occurs to the red blood corpuscles in its operation as compared with currently available blood pump devices.

Summary of the invention

A preferred embodiment of this invention as shown in the drawings comprises three vertically disposed compartments; viz, an upper compartment, an intermediate compartment and a lower compartment connected by flapper valves. The upper compartment is provided with a port serving as an inlet for blood from the patient, and a filler plug for initial priming. The lower compartment has a discharge fluid conduit for the passage of blood to the patient. Initially blood is introduced through a filler opening as a priming step, in volume, such that the lower compartment is filled to a predetermined level. After the priming step has been completed, the valve of the pressurized gas cylinder is opened, whereby gas pressure is introduced into the lower compartment which thereby causes blood to flow to the patient. Control valves are provided to regulate the pressure and a number of fluid conduits are suitably connected with respect to a directional control valve, a diaphragm sensor and a pair of trigger valves in a manner such that automatic performance is acquired. It is apparent that the flow of blood to the lower compartment is by gravity by way of the upper and intermediate compartments. Regulated gas pressure introduced into the lower compartment above the blood level by conduit means serves to transmit the blood to the patient.

This invention consists of the novel constructions, arrangements and devices to be hereinafter more fully described and claimed for carrying out the novel features of

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the invention as will be apparent from the following description of a preferred form of this invention, illustrated with reference to the accompanying drawings, wherein;

FIGURE 1 is a schematic view of this invention showing, in block form, the sensing device for the operation of the directional control valve;

FIGURES 2, 3 and 4 are similar views as shown in FIGURE 1, the difference residing in showing the variation of blood levels in the compartments during the various stages of operation; and

FIGURE 5 is a view of the sensing device shown in detail.

Referring now to FIGURES 1, 2, 3 and 4, it will be seen that the apparatus comprises an upper compartment 7 provided with a priming filler port 8 and a cap 9, an intermediate compartment 10 and a lower compartment 11, which are interconnected by check valves 12 and 13 respectively, which selectively provide communication between the upper compartment 7 and the intermediate compartment 10, and the intermediate compartment 10 and the lower compartment 11, respectively. These two check valves, preferably, are of a rubber flapper type. The lower end of the lower compartment 11 has a blood conduit 14, leading to the patient, which is provided with a variable restrictor valve 15. The upper compartment 7 has connected thereto a blood return conduit 16 which serves as a means for conveying blood from the patient to this compartment which, at a certain stage of operation serves to store the blood as hereinafter more fully explained. It should be observed that conduit 16 and check valves 12 and 13 are extended to prevent foaming and hemolysis.

A liquid level sensing device 17, shown in block form is connected to a ground 18 and is in fluid communication with the lower end of the lower compartment 11 by a blood conduit 19.

The liquid level sensing device 17 is shown in detail in FIGURE 5 which comprises a housing 20 having an intake port 21 therein and a cover 22 provided with a port 23 to which the blood conduit 19 is connected. A diaphragm 24 is carried in the housing 17 and is provided with an annular member 25 carrying a depending rod 26 which is slidably operable in a bore 27 in the lower end of the housing 20.

Two currently available trigger valves 28 and 29 are mounted on the ground 18 and are operably associated with the depending rod 26 of the liquid level sensing device 17 by means of an arm 30 pivoted at one end thereof on a pivot pin 31 connected to the ground 18 below the trigger valves 28 and 29. The other end of the arm 30 is positioned between the depending rod 26 and a level adjustment device 32, which is connected to the ground 18 and comprises a body 33 through which an adjusting screw 34 is threaded. A cap 35 is carried at the upper end of the adjusting screw 34 which has a compression spring 36 interposed between it and the other end of the arm 30.

A directional control valve 37 operably associated with the intermediate compartment 10 and the trigger valves 28 and 29, comprises a housing 38 having operable therein a spool 39 provided with first, second and third lands 40, 41 and 42 respectively, which are operably associated with first, second, third and fourth ports 43, 44, 45 and 46 respectively and a vent 47. The spool 39 is also provided with a knob 48 for manual operation use.

A pressurized gas cylinder 49 is provided with a shut-off valve 50 having a first gas conduit 51 provided with a reducer valve 52 and connected to a gas flow regulator 53. Second, third, fourth and fifth gas conduits 54, 55, 56 and 57 respectively, interconnected the gas flow regulator 53 with the intake port 21 of the liquid level sensing means 17, the third port 45 of the control valve 37, a gas flow meter 58 and the trigger valves 28 and 29, respec-

tively. A sixth gas conduit 59 provided with a priming valve 60, interconnects the gas flow meter 58 with the upper end of the lower compartment 11. Seventh, eighth and ninth gas conduits 61, 62 and 63 respectively, interconnect the ports 43, 44 and 46, respectively, with the trigger valve 28, the intermediate compartment 12 and the trigger valve 29, respectively.

Generally speaking, the reducer valve 52 is used initially to provide a certain pressure of gas flow to the gas flow regulator 53 which serves to control the pressure. The gas flow meter 58 serves as a means for determining the rate of gas flow and therefore provides a means to accurately set the flow regulator 53. The variable restrictor valve 15 serves to regulate the volume of blood flowing to the patient.

It is usual that an oxygenator is provided in blood pump systems, and therefore it should be noted that one of the compartments may be provided with an oxygenator without interfering with its normal operation.

Operation

FIGURE 1 shows the priming phase in the operation of the blood circulating apparatus according to this invention. More specifically, the priming valve 60 is opened to permit air to escape as blood is introduced manually through the priming filler port 8 to a certain level as shown in the lower compartment 11, after which the priming valve 60 is closed. The cap 9 serves to close the filler port 8 to prevent contamination but leaving a vent for the passage of air.

The directional control valve 37 is in a position which seals off any communication between the intermediate compartment 10 and the pressurized gas cylinder 49 as shown in the drawing, but leaves the eighth gas conduit 62 open to vent 47, thereby venting to atmosphere the intermediate compartment 10.

It is therefore apparent that in the priming operation blood introduced manually through the priming filler port 8 will pass on the lower compartment 11 through the check valves 12 and 13.

After the priming phase has been completed, the shut-off valve 50 is opened, thereby providing gas pressure to the lower compartment 11 by way of the first, third and sixth gas conduits, 51, 56 and 59 respectively, which closes valve 13 as shown in FIGURE 2, thereby causing the flow of blood from compartment 11 through blood conduit 14 to the patient, and blood from the patient flows through the blood return conduit 16 into the upper compartment 7 and thence into intermediate compartment 10 through valve 12, by virtue of gravity. The blood levels at this stage being simulated as shown in FIGURE 2.

At this stage, pressure is also passed on the liquid level sensing device 17 against the diaphragm 24 by means of the second gas conduit 54 which is equal to the pressure in lower compartment 11, however, the weight of the blood therein, overcomes the resistance of the level adjusting device 32 thereby causing the arm 30 to move downwardly on the pivot pin 31 and trips the trigger valve 29 thereby establishing communication with the ninth gas conduit 63 which is connected to the fourth port 46 of the directional control valve 37 whereby pressure is exerted against the third land 42, thus retaining the initial position of the directional control valve 37. It should be noted that pressure is also exerted against the opposite face of the land 42 by gas pressure delivered by the third gas conduit 55 which balanced the pressure in the directional control valve 37 and maintains it in its initial position. When the level of the blood in the lower compartment 11 drops to a level approximately as shown in FIGURE 3, the valve of the compression spring 36, overcomes the depleted weight of the blood in compartment 11, whereby the arm 30 is moved upwardly on its pivot pin 31 against the trigger valve 28 which thus closes fluid communication between the fifth conduit 57 and the ninth gas conduit 63 and opens communication between the fifth gas conduit 57

57 and the seventh gas conduit 61, whereby gas pressure is exerted against the face of the first land 40 of the directional control valve 37 which closes the vent 47 and provides communication between the third gas conduit 55 and the eighth gas conduit 62, which thereby pressurizes the intermediate compartment 10 equal to that of the lower compartment 11 thus causing the check valve 12 of the intermediate compartment 10 to close and the check valve 12 of the lower compartment 11 to open. This is so, because the upper compartment 7 is at atmospheric pressure and the pressures in intermediate compartment 10 and lower compartment 11 are balanced. At this stage of operation, it is apparent that the upper compartment 7 serves as a storage means for the blood received from the patient during the period when the check valve 12 is closed.

When the blood builds up to a certain level as shown in FIGURE 4, the same sequence of events as explained with respect to FIGURE 2 occur which is followed by the sequence of events shown in FIGURE 3, and thereafter the operational performance is that shown with respect to FIGURES 3 and 4 which continue to repeat in that order.

While this invention has been described in connection with certain specific embodiments thereof, such as calling for the use of blood in its operation with respect to a patient, it should be noted that this invention will operate with the use of other fluids with respect to other subjects and therefore it is to be understood that the embodiment of this invention is by way of illustration and not by way of limitation and the scope of this invention is defined solely by the appended claims which should be construed as broadly as the prior art will permit.

I claim:

1. A blood circulating apparatus for conveying blood to a patient including:

A. an assembly of three vertically disposed compartments, comprising an upper compartment, an intermediate compartment and a lower compartment,

(1) a port in said upper compartment for introducing blood thereto,

(2) first check valve means for selectively providing fluid communication between said upper compartment and said intermediate compartment,

(3) second valve means for selectively establishing fluid communication between said intermediate compartment and said lower compartment,

(4) a first blood conduit connected to said lower compartment serving as a means for conveying blood to the patient,

(5) a second blood conduit communicating with said upper compartment serving as a means for returning blood from the patient,

(6) means defining a directional control valve, and

(7) a source of gas pressure selectively communicable with said intermediate compartment by means of said directional control valve and means to continuously communicate gas pressure to said lower compartment, whereby pressure is provided to cause blood to be delivered to the patient from said lower compartment.

2. A blood circulating apparatus for conveying blood to a patient including:

A. an assembly of three vertically disposed compartments, comprising an upper compartment, an intermediate compartment and a lower compartment,

(1) a port in said upper compartment for introducing blood thereto,

(2) first check valve means for selectively providing fluid communication between said upper compartment and said intermediate compartment,

(3) second valve means for selectively establish-

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ing fluid communication between said intermediate compartment and said lower compartment,

- (4) a first blood conduit connected to said lower compartment serving as a means for conveying blood to the patient, 5
- (5) a second blood conduit communicating with said upper compartment serving as a means for returning blood from the patient,
- (6) a liquid level sensing device in fluid communication with said lower compartment, 10
 - (a) a diaphragm in said liquid level sensing device responsive to pressure in said lower compartment,
 - (b) a rod depending from said diaphragm,
 - (c) a pivotally mounted arm positioned between said rod and an adjusting means at one end thereof and operably associated with first and second trigger valves at the other end thereof, 15
- (7) a directional control valve operably in fluid communication with said first and second trigger valves, and 20
- (8) a source of gas pressure in continuous gas communication with said lower compartment, said liquid level sensing device and said directional control valve. 25

3. A blood circulating apparatus according to claim 1 wherein the said first blood conduit is provided with a variable restrictor valve.

4. A blood circulating apparatus according to claim 1 30 wherein the said means to continuously communicate gas pressure to said lower compartment is provided with a priming valve.

5. A blood circulating apparatus according to claim 1 wherein the said source of gas pressure is a pressurized gas cylinder. 35

6. A blood circulating apparatus according to claim 2 wherein:

- (1) first and second gas conduits interconnect the said source of gas pressure with the said liquid level sensing device, 40

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- (2) a third gas conduit is in communication with a third port in the said directional control valve and the said second gas conduit,

- (3) a fourth gas conduit is intercommunicable between the first, second and third conduits and a sixth conduit which is in communication with the said lower compartment,

- (4) a fifth gas conduit interconnects the said first gas conduit with the said first and second trigger valves,

- (5) a seventh gas conduit interconnects the said first trigger valve with the said first port of the said directional control valve,

- (6) an eighth gas conduit interconnects a second port of the directional control valve with the said intermediate compartment, and

- (7) a ninth gas conduit interconnects a fourth port with the said second trigger valve.

7. A blood circulating apparatus according to claim 6 wherein a gas flow regulator is interconnected with the said first and second gas conduit and wherein a gas flow meter with the said fourth gas conduit and the said sixth gas conduit.

8. A blood circulating apparatus according to claim 6 wherein the said first gas conduit is provided with a reducer valve.

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