

Sept. 21, 1954

C. GOBEL
BLOOD PUMP

2,689,565

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4 Sheets-Sheet 1

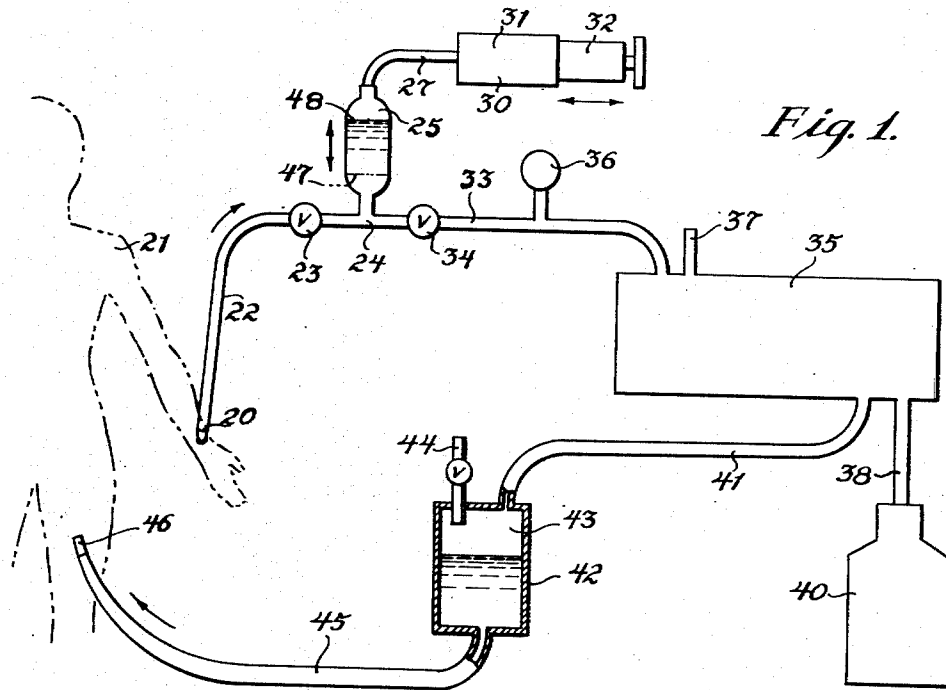


Fig. 1.

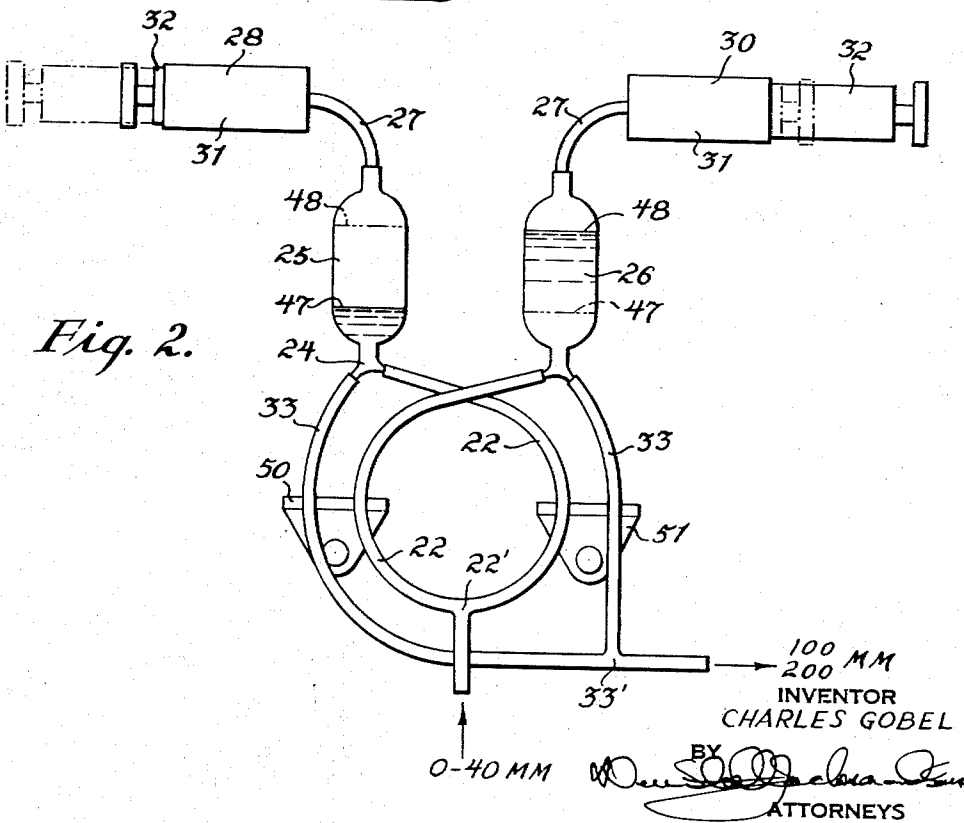
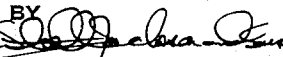


Fig. 2.

100 MM
200 MM
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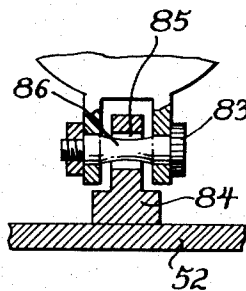
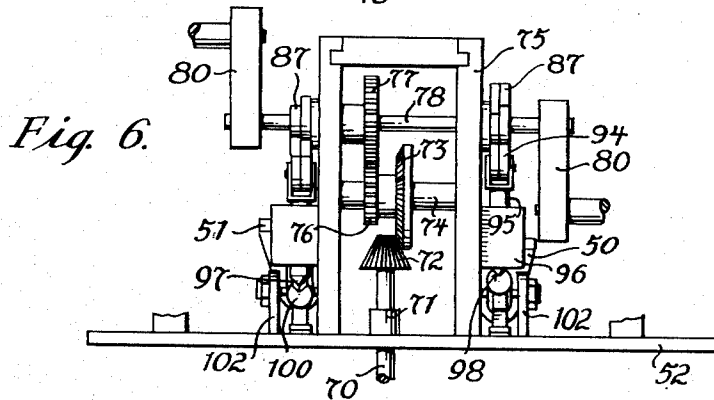
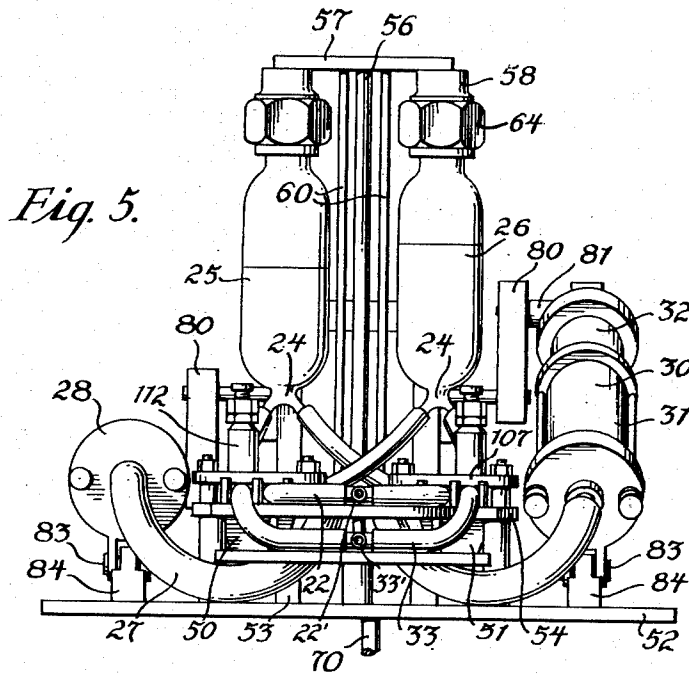
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4 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

2,689,565

BLOOD PUMP

Charles Gobel, Philadelphia, Pa.

Application December 8, 1952, Serial No. 324,687

14 Claims. (Cl. 128-214)

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The present invention relates to pumps, particularly of the character used in the pumping of blood in medical treatment.

A purpose of the invention is to permit the circulation of blood from the body of a living patient without damage to the blood.

A further purpose is to substitute a mechanical pump for the animal or human heart during cardiac surgery.

A further purpose is to aid the functioning of the human heart in medical treatment by making available an additional source of pumping pressure to circulate blood.

A further purpose is to avoid regurgitation in the pumping of liquids and especially of blood during medical treatment.

A further purpose is to facilitate cleaning and especially sterilizing of pumps, particularly blood pumps.

A further purpose is to simplify the mechanism required for pumping blood in medical treatment.

A further purpose is to connect positive displacement piston pumps to the tops of respective reservoirs and to connect elastomer inlet and outlet tubes to the bottoms of the respective reservoirs and to pinch the tubes to make them function as valves under conditions which are nontraumatic to the blood.

A further purpose is to open and close the inlet tube of one reservoir and the outlet tube of another reservoir by the same depressor.

A further purpose is to delay the opening of the outlet tube of a particular reservoir when the inlet tube of the other reservoir is opening, desirably by an auxiliary depressor so that the outlet tube will not open until the discharge structure of the pump has built up a pressure at least equal to that in the discharge tube beyond the valve.

A further purpose is to mount those parts of the pump which require sterilization, particularly the reservoirs and the valves, on a readily removable plate suitably carrying anvils against which the depressors act.

A further purpose is to use an extremely thin curved edge on the depressor to avoid the likelihood of crushing red corpuscles of the blood.

A further purpose is to vary the point of beginning and ending of valve closure by adjustment of the dwell of cams.

A further purpose is to avoid damage to the fragile pumps by pivoting the same on rocking pivots.

A further purpose is to accomplish a seal to

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the tops of the reservoirs without the necessity of providing bulges or ground glass edges on the reservoirs.

Further purposes appear in the specification and in the claims.

In the drawings I have chosen to illustrate one only of the numerous embodiments in which my invention may appear, selecting the form shown from the standpoints of convenience in illustration, satisfactory operation and clear demonstration of the principles involved.

Figure 1 is a simplified diagram of the pump of the invention showing only one cycle.

Figure 2 is a diagram of the two cycle pump but omitting the connections to the dialyzer and to the patient.

Figure 3 is a side elevation of the preferred embodiment of the pump of the invention.

Figure 4 is a top plan view of the pump of Figure 3.

Figure 5 is a front elevation of the pump of the invention.

Figure 6 is a fragmentary rear elevation of the pump of the invention showing the drive but omitting the structure at the front.

Figure 7 is a fragmentary section on the line 7-7 of Figure 3.

Figure 8 is a fragmentary section on the line 8-8 of Figure 4.

Figure 9 is an enlarged fragmentary section on the line 9-9 of Figure 4.

Figure 10 is an enlarged fragmentary section on the line 10-10 of Figure 3.

Figure 11 is an enlarged fragmentary elevation of the cam and follower.

Describing in illustration but not in limitation and referring to the drawings:

The pump of the invention has other applications and can be used for pumping other liquids, but it is especially suited for pumping blood to a mechanical kidney, or as a heart pump. As the difference from the standpoint of the pump is merely one of size, it will be sufficient to illustrate the device applied to the mechanical kidney.

The mechanical kidney is primarily used in treatment of injuries and diseases which have caused temporary malfunctioning of the kidneys, where it is desired to minimize the effects of uremia and thus prolong the life of the patient until such time as his kidneys may regain proper function. Such temporary malfunctioning may be due to ingestion of poisons, shock, transfusion of mismatched blood and severe trauma, such as is seen in battle casualties. The condition is

referred to as "acute renal failure," "acute anuria" or "lower nephron nephrosis."

The dialyzer has a semi-permeable membrane which permits the transfer of soluble blood components other than protein materials to the opposite side of the membrane, and the transfer of electrolytes such as sodium chloride either way, depending on the relative concentrations on the two sides of the dialyzer. The dialyzer thus is an effective way of removing poison from the blood, and of readjusting the salt content of the blood. The dialyzer also can act as a filter to remove excess water from the blood and thus relieve edema.

A number of blood pumps have been developed which draw off blood from the body and pass it through the dialyzer and return it to the body. They have, however, in the past been subject to several difficulties of which the following are examples:

1. Blood is an extremely fragile material, as any impacting or crushing during pumping has a traumatic or destructive effect upon red corpuscles, with disastrous consequences to the patient.

2. Standard hospital practice requires that the blood pump be sterilized after each use, and some of the prior art blood pumps have been so complicated that the cleaning and sterilizing requires a day, thus restricting the availability of the equipment.

3. Many of the prior art devices have required the use of very extensive rubber components which have not been capable of withstanding the repeated autoclaving. Complexity and high expense has been a common difficulty in such prior art devices.

The device of the present invention has the advantage that it is not traumatic, is very simple and inexpensive to produce, is easy to clean and sterilize, and can quickly be made available for the next use.

The device of the invention was first used successfully in connection with the mechanical kidney to save the life of a patient who had already begun apparently fatal convulsions at the University of Pennsylvania Hospital on July 30, 1952. Careful tests for evidence of traumatic effect were made and the device has proved to be free from damage to the blood.

Figure 1 illustrates a typical set-up in connection with the mechanical kidney, only one phase of the pump being shown. An artery tube 20 is connected into an artery of the patient 21 and this leads through inlet tube 22 and inlet check valve 23 to T connection 24 at the bottom of one of the pump reservoirs 25 or 26. The top of each pump reservoir is connected by tube 27 to one of the positive displacement piston pumps 28 or 30 having cylinders 31 and pistons 32. The pumps are suitably glass hypodermic syringes, as well known in the art. An outlet tube 33 extends through check valve 34 to dialyzer 35. A pressure gage 36 is connected to the outlet.

The dialyzer has an inlet tube for fresh dialyzing solution 37 and a discharge connection 38 for dialyzate to waste 40. Dialyzed blood passes from the dialyzer through tube 41 to air trap 42 which maintains an air space 43 to allow any entrapped or entrained air to float out and prevent its entry into the body, and the trap has a valve controlled tube 44 at the top to determine the desired blood level in the trap. From the bottom of the trap blood passes by tube 45 to venous catheter 46, which returns the blood to the body of the patient 21.

It will be evident for an understanding of the device, that during pumping the blood ranges in each reservoir between a lower level 47 which is achieved at the end of the discharge stroke and an upper level 48 which is achieved at the end of the suction stroke, and that the space in the tubes 27, in the pumps 28 and 30 and in the reservoirs above the blood level 48 is filled with air, the pumping being accomplished by the change in liquid level due to the air pumped by the syringes. In the actual device shown, the pump is of two cycle construction, but it will be evident that the pumping can be carried out less desirably on a single cycle basis and also more desirably on a multicycle basis.

The piston pumps as seen in Figure 2 operate alternately at any suitable speed desired, approximately 6 R. P. M. having been found to be a desirable speed in blood pumping. When one pump is on the suction stroke the other is on the compression stroke and vice versa.

The inlet tubes 22 branching at T 22' and the outlet tubes 33 joining at T 33' are of elastomer such as soft rubber or synthetic rubber, and the valves are produced by depressors 50 and 51 which act alternately. The inlet tube of one reservoir is carried beside the outlet tube of the other reservoir and the same depressor closes the inlet tube of one reservoir and the outlet tube of the other reservoir at approximately the same time and opens the two tubes together. However, as later explained, it is very desirable that the outlet tube should not open until slightly after the inlet tube has opened.

The structure of Figures 3 to 11 inclusive embodies the device of Figures 1 and 2 in a convenient form. Base 52 mounts legs 53 which support a bodily removable plate 54 by Allenhead screws 55 extending into the legs. The plate mounts a standard 56 which at the top carries a cross arm 57 and at opposite ends the cross arm carries fittings 58 which engage and support the respective reservoirs 25 and 26. Pipes 60 extend up through the plate to the cross arm 57 and at the bottom are connected to tubes 27 from the respective pump 28 or 30. At the top the cross arm has a separate passage 61 on each side connecting to the appropriate tube 60 to communicate with a male threaded hollow tubular portion 62 of the fitting 58. The male threaded portion at its lower end has a comparatively thin tubular portion 63.

A hollow female threaded cap 64 engages the male threaded portion 62 and has an inwardly extending flange 65 at the lower end which has an interior bore in line with the bore of the tubular portion 63.

The upper end of the reservoir has a straight glass tube 66 which is surrounded and firmly engaged by a resilient rubber or other elastomer collar 67 which fits immediately inside the tubular portion 63 of the fitting part 62 and also inside the flange 65 of the fitting cap 64. An annular radially extending flange 68 on the collar intermediate its ends extends between and is gripped by the end of the tubular portion 63 of the male fitting and the upper portion of the flange 65 of the female fitting. By pinching the flange 68 by tightening the metallic parts 62 and 64, pressure on the collar is applied to seal the top of the reservoir. The reservoir is thus effectively connected and sealed to the fitting 58 and supported by the cross arm 57.

A main drive shaft 70 journaled at 71 on the base carries a bevelled pinion 72 which engages bevel gear 73 on cross shaft 74 journaled in drive

housing 75 mounted on the back of the face plate 52. Cross shaft 74 also carries speed reduction gear 76 which intergears with gear 77 on crank shaft 78 carrying cranks 80 at the opposite ends, which cranks are 180° out of phase. The cranks pivotally connect at 81 with extensions 82 on pump pistons 32 to manipulate the pistons back and forth. The individual pump barrels or cylinders are pivoted at 83 on pivot lugs 84 extending up from the base plate 52. Because of the fragile (glass) character of the pumps in the preferred form, the danger of slight misalignment which would cause cracking of the parts is considerable, and a rocking pivot is provided at 83. This is accomplished by providing an enlarged opening 85 (Figure 7) across the lug 84, and reducing the section of the pivot pin at 86 from both sides so that there is wide clearance for rocking in the opening 85.

The crank shaft 78 carries, 180° out of phase thereon, adjustable cams 87. Each of the cams consists of a cam hub 88 which is keyed or otherwise fastened to the shaft, a cam segment 90 engaging one face of the hub 88 and surrounding the shaft and a cam segment 91 engaging one face of the cam segment 90, and surrounding the shaft. An arcuate slit 92 is provided in each of the cam segments 90 and 91, and a cam screw 93 passes through both slots and is threaded into ring 88 to lock the cam segments in a predetermined position. Thus the beginning and end of the cam dwell can be changed on either cam to determine the exact setting desired. The segments of course extend radially beyond the ring.

The dwell portion of the composite cam on each side engages a follower roller 94 pivoted on a follower pin 95 which is guided in a holder 96 secured on the side of the housing 75. Pointed ends 97 of the followers 95 engage in longitudinal slots 98 on the upper sides at the ends of valve depressor levers 100 pivoted intermediate their ends at 101 on journals 102 on the base. The opposite ends of the depressor levers carry depressors 50 or 51 which extend upwardly through slots 103 in the removable plate 54. Leaf springs 104 under the rearward ends of the levers 100 cause them to retract and keep the followers against the cams. The springs are anchored at 105 to the base.

The form of the upper ends 106 of the depressors is important. While they should not be absolutely sharp knife edges, they should definitely be very narrow curves, so that they will not crush blood in closing the valve and cause trauma. Each depressor passes immediately under the inlet tube of one reservoir and the outlet tube of the other reservoir. The depressors operate against anvils 107 which are mounted by bolts 108 and spacer washers 110 on the removable plate so that the appropriate inlet tube 22 and the outlet tube 33 of the opposite phase pass between the depressor 50 or 51 and the anvil above.

In order to prevent the outlet from opening as quickly as the inlet, an auxiliary depressor plunger 111 (Figure 9) is mounted in a cylinder 112 above the outlet tube 33 in line with the depressor in the preferred embodiment. The auxiliary depressor 111 is spring urged toward the tube 33 by spiral compression spring 113 and the limit of movement of the auxiliary depressor downwardly is controlled by screw 114 and adjustment nuts 115 and 116 which engage on the top of the cylinder 112. In the form shown in Figure 9 the outlet tube is smaller than the inlet

tube, so that more advance of the auxiliary depressor is needed to prevent the outlet tube from opening when the inlet tube opens, but this can be readily adjusted with respect to the size of the tubes by adjusting the nuts 115 and 116 and screws 114.

In operation it will be evident that when one piston pump begins its suction stroke, the elastomer tubes which are its valves are adjusted so that the inlet tube is open and the outlet tube is closed due to the fact that the depressor engaging the inlet tube is down and the depressor engaging the outlet tube is up. The opposite condition applies to the other pump and reservoir and their valves. It is very desirable that the outlet valves close early and open late. If we consider reservoir 25 at the position in which its syringe is retracted at the end of its suction stroke, there is no superatmospheric pressure in the air compartment of that reservoir. When now the compression stroke starts, if the corresponding outlet valve were to open immediately, as soon as the inlet valve closes there would be regurgitation back through the outlet tubing since the outlet tubing is under a hydrostatic pressure of as much as 100 to 200 millimeters of mercury above atmospheric. It is therefore desirable that the outlet valve open later, the time lag being determined by adjustment of nuts 115 and 116 and screw 114 so that the pressure in the pump and reservoir can build up to at least the equal of the pressure in the outlet tubing beyond the outlet valve before the outlet valve opens.

The same feature to advantage will take place if a substantial pressure exists in the inlet, but since the inlet pressure is normally much lower, of the order of 0 to 40 millimeters of mercury below atmospheric, this is less important in the case of the inlet.

When the depressor moves down, the inlet tube opens first but the outlet tube remains closed for a small interval, and then opens when the pressures on either side of the depressor are equalized. On the closing cycle, when the depressor is moving up, the cam has been so shaped as to allow rapid upsweep of the depressor so that the inlet and outlet tubes are closed almost simultaneously. The cam, however, provides for lowering of the depressor more slowly so that the inlet tubes do not open at the same time.

The reason for desiring to avoid regurgitation in blood pumping is not only the desire to get greater efficiency in pumping and more rapid flow, but to avoid the possibility of detaching foreign material in the tubing and reservoirs such as minute fibrous clots, which might injure the patient.

It will be evident that the two depressors work oppositely, each opening and closing the inlet and outlet of a different reservoir.

The extremely narrow curved edge on each depressor prevents the possibility of trapping and squeezing blood and causing traumatic deterioration.

If the adjustment is not that desired, it is very easy to stop the pump and readjust the cam positions, changing either the beginning or the end of the dwell.

It has been found in service that the device can be used without danger of breakage of the syringe pumps, due to the rocking action at their pivots.

The pump of the invention has proved to be an improvement over more complicated devices since it appears less formidable to the patient

at the bedside and therefore is less likely to frighten him.

After the use on a particular patient has been completed, it is very simple to clean and sterilize the equipment. For this purpose the fittings 58 at the tops of the reservoirs are loosened, and then the screws holding the removable plate are released. The plate can readily be removed forward, after which the tubes 27 are detached from pipe 60. All the equipment which requires sterilizing is then supported on the removable plate and can be retained in this position during washing and during sterilizing including autoclaving.

The fitting using the rubber collar at the top of the reservoirs is very sanitary as the collars can be pulled off for separate sterilizing if desired after the fittings are loosened and the upper ends of the reservoirs being straight tubes do not have any interior recesses which are difficult to clean.

In view of my invention and disclosure variations and modifications to meet individual whim or particular need will doubtless become evident to others skilled in the art, to obtain all or part of the benefits of my invention without copying the structure shown, and I therefore claim all such insofar as they fall within the reasonable spirit and scope of my invention.

Having thus described my invention, what I claim as new and desire to secure by Letters Patent is:

1. In a blood pump, a reservoir, a positive displacement air pump connected to the top of the reservoir, an inlet valve connected to the bottom of the reservoir, an outlet valve connected to the bottom of the reservoir, a connection adapted to withdraw blood from the body of a living animal to the inlet valve, a connection adapted to return blood to the body of the animal from the outlet valve, means for opening the inlet valve and closing the outlet valve during the suction stroke and means for opening the outlet valve and closing the inlet valve during the discharge stroke, the means for opening the outlet valve becoming operative after the discharge stroke has commenced and built up a pressure sufficient to overcome the pressure in the outlet connection.

2. In a blood pump, a pair of pumping reservoirs, a pair of piston air pumps each connected to the top of a different reservoir, a pair of inlet valves each connected to the bottom of a different reservoir, a pair of outlet valves each connected to the bottom of a different reservoir, a connection adapted to receive blood from a living animal to both inlet valves, a discharge connection adapted to return blood to the animal connected to both of the outlet valves, means for opening each of the inlet valves and closing each of the outlet valves during the suction stroke of the corresponding pump, means for closing each of the inlet valves during the compression stroke of the corresponding pump, and means operative at a point after the beginning of the compression stroke of each pump for opening the corresponding outlet valve at a time at which the pressure above the reservoir has built up to a value at least equal to the pressure in the discharge connection.

3. In a blood pump, a pair of pumping reservoirs, a pair of piston air pumps each connected to the top of a different reservoir, a pair of inlet valves each connected to the bottom of a different reservoir, a pair of outlet valves each connected to the bottom of a different reservoir, a connection adapted to receive blood from a liv-

ing animal to both inlet valves, a discharge connection adapted to return blood to the animal connected to both of the outlet valves, common means for opening and closing the inlet valve of one reservoir and the outlet valve of the other reservoir and means for delaying the opening of the outlet valve of one reservoir behind the closing of the inlet valve of that reservoir to permit building up of air pressure on the compression stroke above the pressure of the blood in the discharging reservoir to prevent regurgitation from the discharge line.

4. In a blood pump, a pair of pumping reservoirs, a pair of piston air pumps each connected to the top of a different reservoir, a pair of inlet valves each connected to the bottom of a different reservoir, a pair of outlet valves each connected to the bottom of a different reservoir, a connection adapted to receive blood from a living animal to both inlet valves, a discharge connection adapted to return blood to the animal connected to both of the outlet valves, common means for opening and closing the inlet valve of one reservoir and the outlet valve of the other reservoir and means for accelerating the closing of the outlet valve of one reservoir ahead of the opening of the inlet valve of that reservoir to permit holding the pressure in the discharge connection on the suction stroke to prevent regurgitation from the discharge line.

5. In a blood pump, a pair of pumping reservoirs, a pair of piston air pumps each connected to the top of a different reservoir, a pair of inlet valves each connected to the bottom of a different reservoir, a pair of outlet valves each connected to the bottom of a different reservoir, a connection adapted to receive blood from a living animal to both inlet valves, a discharge connection adapted to return blood to the animal connected to both of the outlet valves, common means for opening and closing the inlet valve of one reservoir and the outlet valve of the other reservoir and means for delaying the opening of the outlet valve on one reservoir behind the closing of the inlet valve of that reservoir to permit building up of air pressure on the compression stroke above the pressure of the blood in the discharging reservoir to prevent regurgitation from the discharge line and means for accelerating the closing of the outlet valve of one reservoir ahead of the opening of the inlet valve of that reservoir to permit holding the pressure in the discharge connection on the suction stroke to prevent regurgitation from the discharge line.

6. In a pump, a pair of reservoirs, a pair of positive displacement pumps connected to the tops of the respective reservoirs, a resilient inlet tube connected to the bottom of each reservoir, a resilient outlet tube connected to the bottom of each reservoir, the inlet tube of one reservoir being positioned beside the outlet tube of the other reservoir, a pair of depressors each operating on the inlet tube of one reservoir and the outlet tube of the other reservoir and means for bringing the depressors into closing relationship of the respective tubes alternately.

7. In a pump, a pair of reservoirs, a pair of positive displacement pumps connected to the tops of the respective reservoirs, a resilient inlet tube connected to the bottom of each reservoir, a resilient outlet tube connected to the bottom of each reservoir, the inlet tube of one reservoir being positioned beside the outlet tube of the other reservoir, a pair of depressors each operating on the inlet tube of one reservoir and the outlet tube

of the other reservoir, means for bringing the depressors into closing relationship of the respective tubes alternately, and means for holding the outlet tube of a particular depressor closed during the initial stage of the opening motion of the depressor after the inlet tube has closed and then opening the outlet tube.

8. In a pump, a pair of reservoirs, a pair of positive displacement piston pumps connected to the tops of the reservoirs, a resilient inlet tube connected to the bottom of each reservoir, a resilient outlet tube connected to the bottom of each reservoir, the inlet tube of one reservoir being carried beside the outlet tube of another reservoir, means for manipulating the pistons alternately, depressors synchronized with the pistons and moving to close the inlet tube of one reservoir and the outlet tube of another reservoir and then to open the same, anvils engaging the opposite sides of the tubes from the depressors, auxiliary depressors mounted on the anvils engaging the outlet tubes and spring means urging the auxiliary depressors toward the outlet tubes so that the outlet tube remains closed after the inlet tube closes when the main depressor is retracted.

9. In a pump, a pair of reservoirs, a pair of positive displacement piston pumps connected to the tops of the reservoirs, a resilient inlet tube connected to the bottom of each reservoir, a resilient outlet tube connected to the bottom of each reservoir, the inlet tube of one reservoir being carried beside the outlet tube of another reservoir, means for manipulating the pistons alternately, depressors synchronized with the pistons and moving to close the inlet tube of one reservoir and the outlet tube of another reservoir and then to open the same, anvils engaging the opposite sides of the tubes from the depressors, auxiliary depressors mounted on the anvils engaging the outlet tubes, spring means urging the auxiliary depressors toward the outlet tubes so that the outlet tube remains closed after the inlet tube closes when the main depressor is retracted, and adjustments for the maximum strokes of the auxiliary depressors.

10. In a pump, a pair of reservoirs, a pair of positive displacement piston pumps connected to the reservoirs, means for driving the pumps in unison and opposite in phase, an elastomer inlet tube connected to the bottom of each reservoir, an elastomer outlet tube connected to the bottom of each reservoir, the inlet tube of one reservoir and the outlet tube of the other reservoir extending in side by side relation, depressor cams having dwell positions driven by the means for driving the pumps respectively out of phase and having adjustments of the beginning and end of the cam dwell position, and depressors operatively connected to the depressor cams, one of which engages and closes and opens the inlet tube of one reservoir and the outlet tube of the other reservoir while the other engages and opens and closes the inlet tube of one reservoir and the outlet tube of the other reservoir.

11. In a pump, a pair of reservoirs, a pair of positive displacement piston pumps connected to the reservoirs, means for driving the pumps in unison and opposite in phase, an elastomer inlet tube connected to the bottom of each reser-

voir, an elastomer outlet tube connected to the bottom of each reservoir, the inlet tube of one reservoir and the outlet tube of the other reservoir extending in side by side relation, depressor cams having dwell positions driven by the means for driving the pumps respectively out of phase and having adjustments of the beginning and end of the cam dwell position, depressors operatively connected to the depressor cams, one of which engages and closes and opens the inlet tube of one reservoir and the outlet tube of the other reservoir while the other engages and opens and closes the inlet tube of one reservoir and the outlet tube of the other reservoir, anvils engaging the opposite sides of the tubes with respect to the depressors and auxiliary depressors on the anvils engaging the opposite sides of the outlet tubes to maintain the same closed after the inlet tube is closed on the compression stroke.

12. In a blood pump, a pair of reservoirs, positive displacement piston pumps connected to the respective reservoirs at the tops, an inlet tube connected to the bottom of each reservoir, an outlet tube connected to the bottom of each reservoir, the inlet and outlet tubes of the opposite reservoirs being carried side by side, and depressors having very thin rounded edges extending across the pairs of inlet and outlet tubes and resiliently closing the same, the valves being non-traumatic due to the narrow compression face on each depressor.

13. In a blood pump, a pair of positive displacement piston pumps, means for driving the pumps in alternate phases, a base supporting the means for driving the pumps, a readily removable plate mounted detachably on the base, a pair of reservoirs mounted on the plate, a connection from the top of each reservoir to a different pump, elastomer inlet tubes extending over the plate and connected to the bottom of each reservoir, elastomer outlet tubes extending over the plate and connected to the bottom of each reservoir, the inlet tube of one reservoir being carried beside the outlet tube of the other reservoir, an anvil over the inlet tube of each reservoir and the outlet tube of the other reservoir in contact therewith and depressor means beneath the plate operatively connected to the driving means and acting on the tubes to make them function as valves against the anvil, the reservoirs and tubes being removable as a unit for sterilization.

14. In a pump, a pair of positive displacement piston pumps of fragile material, a rocking pivot supporting one end of each pump, crank means manipulating the pistons of the pumps out of phase, a pair of reservoirs, one connected at the top to each pump, an elastomer inlet tube connected to the bottom of each reservoir, an elastomer outlet tube connected to the bottom of each reservoir, and depressor means for closing the tubes and opening the same to permit them to function as valves.

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