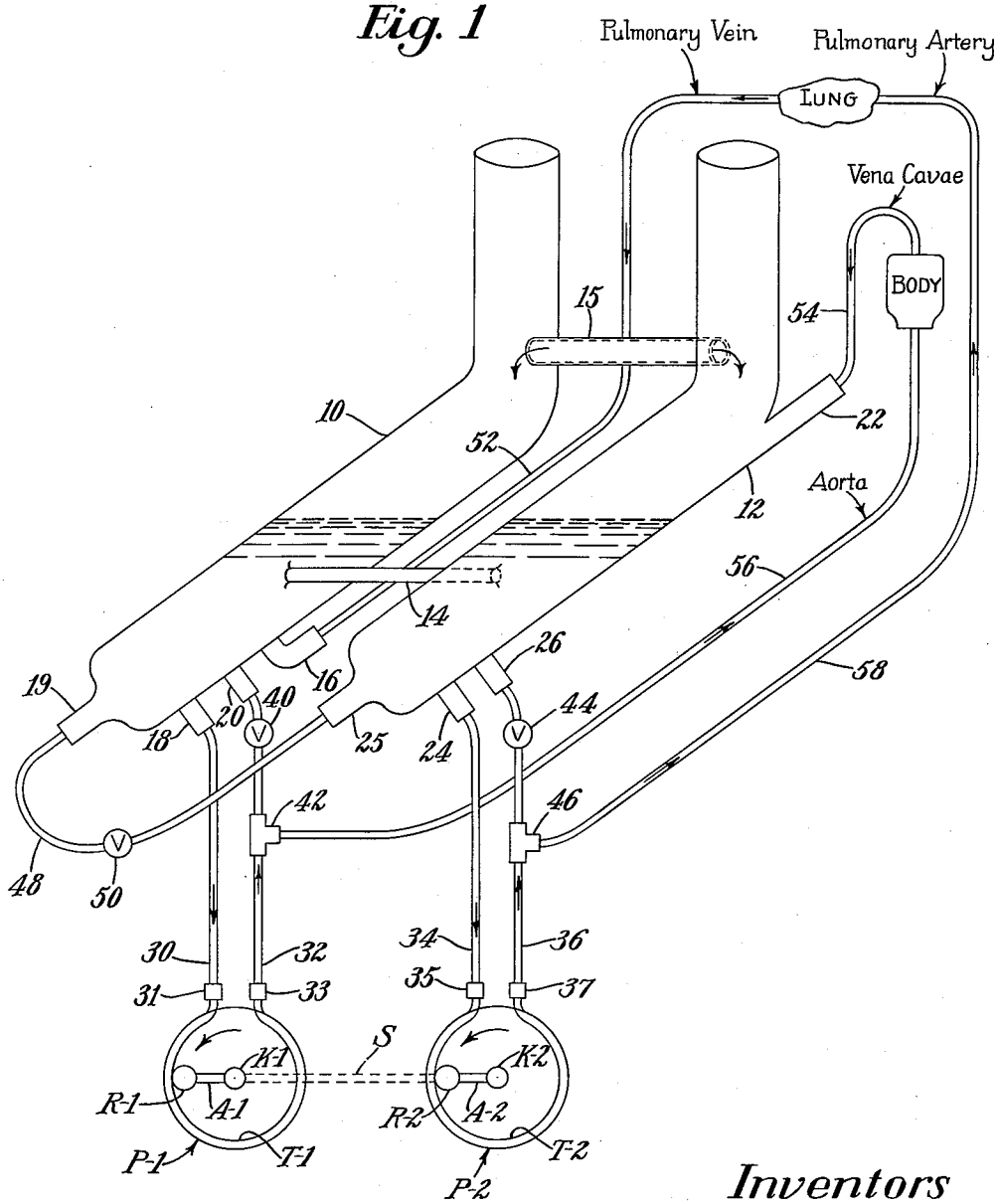
June 13, 1961 A. C. D'ARCEY ET AL 2,988,001

APPARATUS FOR USE IN THE EXTRACORPOREAL CIRCULATION OF BLOOD

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Fig. 1



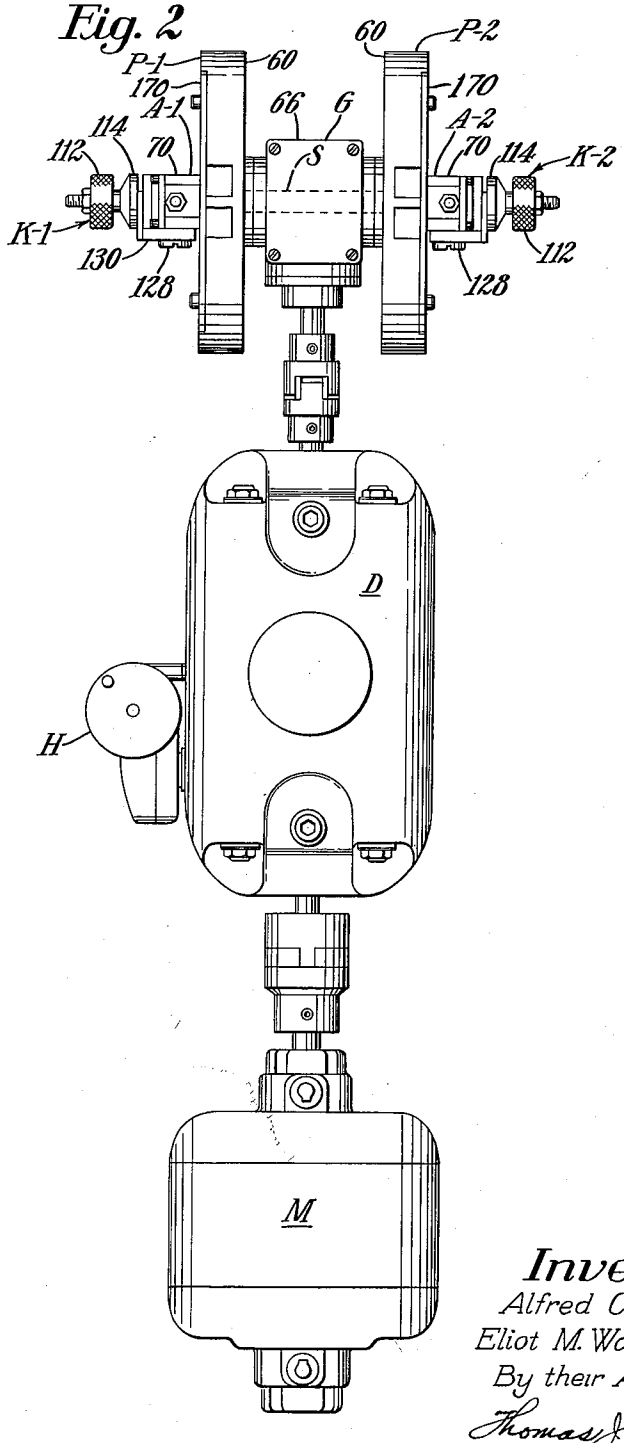
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APPARATUS FOR USE IN THE EXTRACORPOREAL CIRCULATION OF BLOOD

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Fig. 2



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APPARATUS FOR USE IN THE EXTRACORPOREAL CIRCULATION OF BLOOD

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Fig. 3

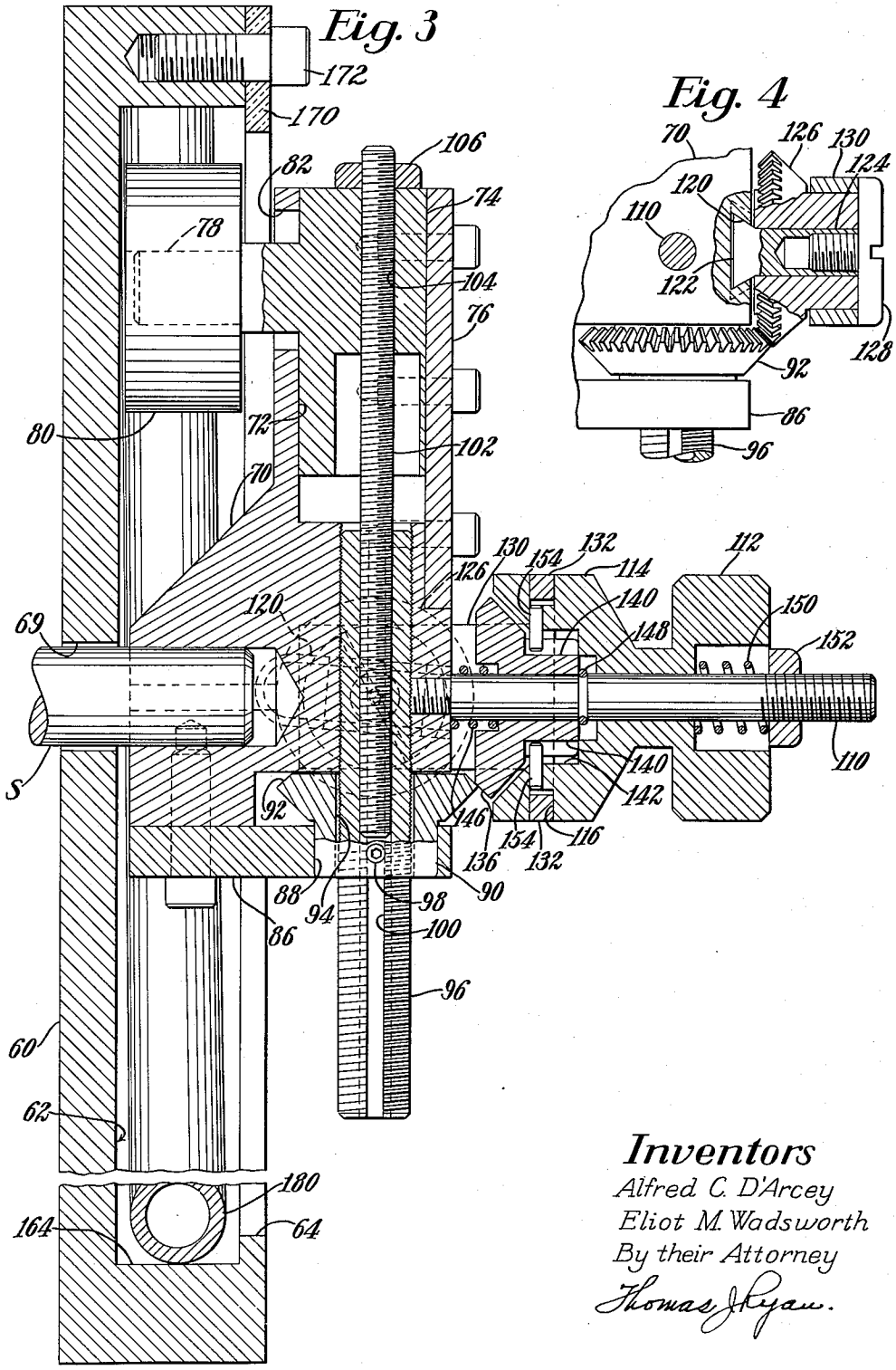


Fig. 4

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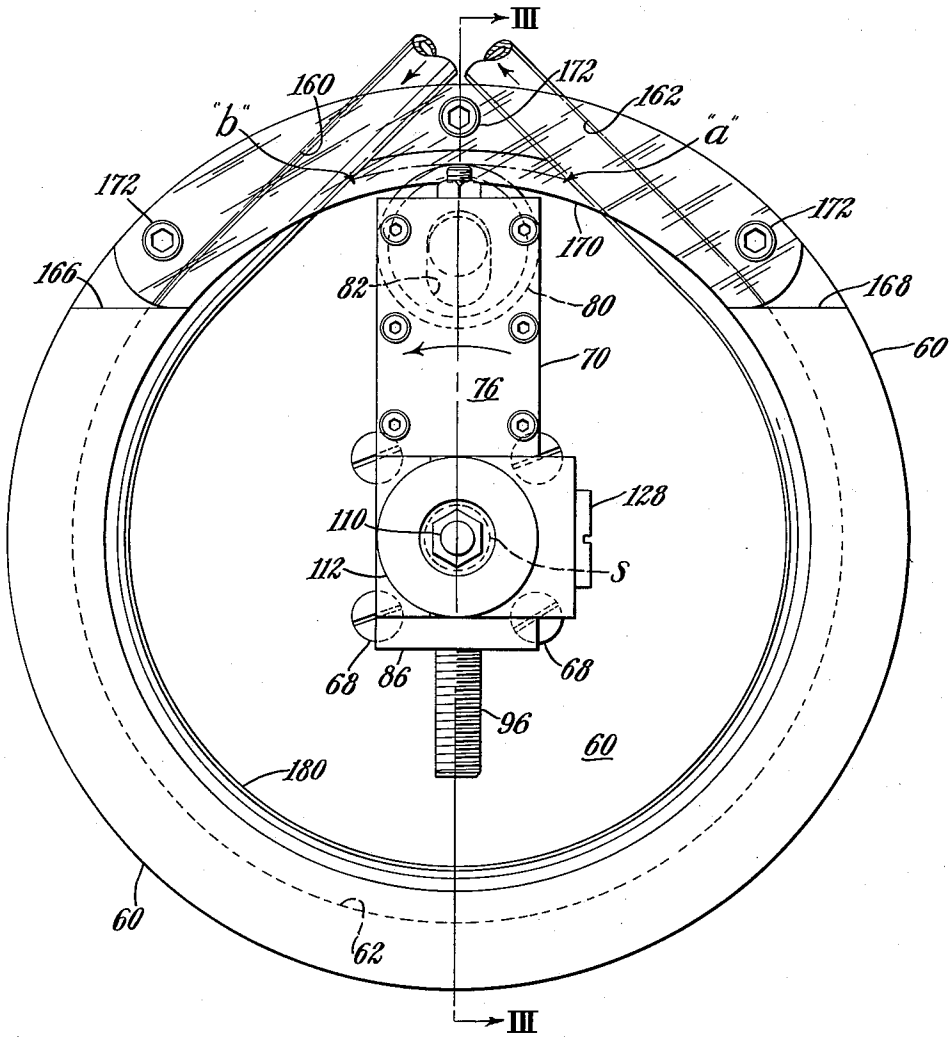
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APPARATUS FOR USE IN THE EXTRACORPOREAL CIRCULATION OF BLOOD

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Fig. 5



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2,988,001

APPARATUS FOR USE IN THE EXTRACORPOREAL CIRCULATION OF BLOOD

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8 Claims. (Cl. 103—4)

This invention relates to apparatus for use in the extracorporeal circulation of blood and is herein illustrated as embodied in a novel and improved pump of the compressible tube-rotary impeller type.

As will be appreciated by those skilled in the art, it has been hitherto proposed to provide pumping means located exteriorly of the body for taking over, respectively, the pumping actions of the right and left sides of the heart, thus making it possible entirely to by-pass the heart during surgical repair thereof which is very greatly facilitated by the "dry field" obtained as a result of relieving the heart of its usual task of circulating the blood of the patient. Obviously, a prime requisite of a pump of this type is complete dependability, while other important characteristics include simplicity of construction, and ease of operation and control. In addition, it is most imperative that the arrangement be such that the introduction of air into the blood stream is effectively avoided and the danger of damage to the blood corpuscles, trauma or hemolysis, substantially eliminated. It is, therefore, a principal object of this invention to provide a novel and improved pump for use in the extracorporeal circulation of blood in which all of these essential characteristics are obtained.

As herein illustrated the improved pump includes two units each having an inlet and an outlet associated with a pair of reservoirs, preferably formed of glass or other transparent material, and having an open upper end, a closed lower end, and a separate inlet connection. The inlet and outlet of each pumping unit is connected to a reservoir by means of suitable conduit means, and located in each of the conduit means extending from a pumping unit outlet is a normally closed valve means. Leading from each of the mentioned conduit means, in a location between the pump outlet and the mentioned normally closed valve is a connection for a conduit means adapted to deliver blood to the patient, while two other conduit means are similarly associated, respectively, with the inlet connections of the reservoirs for receiving blood from the patient. As will presently appear, the four conduit means for delivering and receiving blood are so cannulated to arteries and veins of the patient that one of the pumping units is connected to a reservoir for receiving venous blood from the venae cavae and this pumping unit forces the blood into the pulmonary artery and thence to the lungs, this pumping unit thus functioning to perform the pumping action of the right auricle and right ventricle of the patient's heart, while the other pumping unit is connected to the other reservoir which receives arterial blood from the pulmonary vein, and this pumping unit forces the blood into the aorta and thence through the patient's body, this pumping unit thus functioning to perform the pumping action of the left auricle and left ventricle. Referring again to the two reservoirs which, as suggested above, are preferably formed of transparent material, these provide receptacles open to atmospheric pressure for receiving blood from the patient before this blood enters the pumping units. Preferably, and as herein illustrated, these two reservoirs are connected at their lower ends by a suitable conduit in which there is a normally closed valve means adapted to be opened for by-passing blood from one reservoir to the other.

Although there are several well-known types of blood circulating pumps which possibly could be used with the apparatus outlined above, the compressible tube-rotary impeller type which is herein illustrated affords certain very definite advantages, especially when constructed in the novel and improved manner about to be explained and in accordance with features of this invention. In a pump of this type, a compressible tube is supported in a circular shape so as to be progressively compressed by the rotary impeller which is usually mounted on an arm extending radially from the drive shaft. By arranging this tube so that its circular shape is somewhat less than a full circle, the action of the impeller on the tube is interrupted once during each revolution of the drive shaft, thus causing the pump to have a cyclic action which simulates, at least in a general manner, the pulsations of the heart. As suggested above, the two pumping units of the novel apparatus of this invention take over, respectively, the pumping actions of the right and left heart. It therefore may be desirable, during use of the apparatus to circulate the blood of a patient, to change the cyclic rate of the two pumping units and/or to vary the pumping action of one or the other of the two pumping units. For this purpose, and in accordance with features of this invention, the two pumping units are associated with a common drive shaft, the speed of which may be varied to change the cyclic rate of the two pumping units, while the rotary impeller of each pumping unit is mounted on an associated drive shaft arm for radial adjustment thereon for varying the action of the impeller on the compressible tube and hence the pumping action of the unit. More particularly, with reference to the radial adjustment of the rotary impeller, novel adjusting mechanism is provided which includes a control member readily accessible to, and adapted to be seized by an operator, and which is arranged by movement axially of the drive shaft in one direction or the other to effect radial adjustment of the rotary impeller in the desired direction in response to rotation of the drive shaft.

The above and other objects and features of the invention will become apparent from the following detailed description of the embodiment thereof which is illustrated in the accompanying drawings, and will be pointed out in the claims.

In the drawings,

FIG. 1 is a diagrammatic view of the novel apparatus of this invention;

FIG. 2 is a plan view of an improved pump used in the novel apparatus shown in FIG. 1, this view also showing mechanism for driving the pump;

FIG. 3 is a view in end elevation, at an enlarged scale and with parts shown in vertical section substantially on line III—III of FIG. 5 and looking in the direction of the arrows, of the left-hand portion of the improved pump shown in FIG. 2;

FIG. 4 is a view in side elevation of a part of the pump shown in FIG. 5 with certain parts omitted or broken away and others shown in vertical section; and

FIG. 5 is a view in side elevation of the portion of the pump shown in FIG. 3.

Referring to these drawings, the apparatus which is illustrated in part schematically in FIG. 1 comprises two reservoirs 10 and 12 formed of glass or other transparent material, and of the shape shown. Each of these reservoirs has an open upper end and a closed lower end and the two reservoirs are physically connected by means of two cross struts 14, 15, the latter of which is preferably formed of a tubular member, while the former is a solid rod. The upper end of each reservoir is disposed at an angle to the body portion thereof so that when the reservoirs are supported with their open upper ends extending

substantially vertically, their body portions slope downwardly to their closed ends in the manner illustrated in FIG. 1. The reservoir **10** has formed thereon an inlet connection **16** and three other connections **18**, **19** and **20**, while the reservoir **12** has an inlet connection **22** and three other connections **24**, **25** and **26**.

Located adjacent to these two reservoirs is a pump comprising two pumping units, shown schematically in FIG. 1, and indicated generally by reference characters P–1 and P–2. Each of these pumping units includes a compressible tube T–1 (T–2) and a cooperating rotary impeller R–1 (R–2) mounted on a radially extending arm A–1 (A–2). As is illustrated in FIG. 2 of the drawings, the arms A–1 and A–2 are mounted on the opposite ends of a common drive shaft S which is arranged to be rotated, through suitable speed reducing gearing G, by means of the output shaft of a variable speed drive D driven by a motor M and having a control handle H. As will presently be explained, there is associated with each of the arms A–1 and A–2 an adjusting mechanism adapted to be controlled by means of a hand knob K–1 (K–2) for causing radial movement of the rotary impeller to vary the action of the rotary impeller on the compressible tube. The inlet and outlet of the pumping unit P–1 are connected to the two connections **18** and **20** of the reservoir **10** by conduit means comprising tubes **30**, **32**, and connecting glass tubes **31**, **33**, while the inlet and outlet of the pumping unit P–2 are connected to the connections **24** and **26** of the reservoir **12** by conduit means comprising tubes **34**, **36** and connecting glass tubes **35** and **37**. Associated with the tube **32**, which is connected to and leads from the outlet of the tube T–1 of the pumping unit P–1, is a valve means comprising a clamp device **40** and a branch connection **42** which is located between the mentioned valve means and the outlet of the tube T–1. In a like manner, there is associated with the tube **36**, which is connected to and leads from the outlet of the tube T–2, a valve means comprising a clamp device **44** and a branch connection **46** which is located between the last-mentioned valve means and the outlet from the tube T–2. Extending between the connections **19** and **25** is a tube **48** which provides a by-pass conduit means in which there is a normally closed valve means comprising a clamp device **50**. Suitable conduit means **52**, **54**, **56** and **58** are associated respectively with the inlet connections **16** and **22** and the branch connections **42** and **46**.

The two pumping units P–1, P–2 of the pump are of identical construction, one being a mirror image of the other, so that a detailed description of one of these units, for example the one which is illustrated on the left in FIGS. 1 and 2 of the drawings, will be sufficient for a complete understanding of the construction and mode of operation of the double unit pump arrangement of this invention. Referring to FIG. 3 of the drawings, this pumping unit comprises a housing **60** shaped to provide a circular recess **62** having adjacent to its open end an annular flange **64**. This housing is secured to a portion of a housing **66** associated with the speed reducing gear G, FIG. 2, by means of screws **68**, **68**, FIG. 5, and is provided with a bore **69** through which one end of the common drive shaft S projects, this shaft being square with the housing **60**, FIG. 3 and concentric with the recess **62**, FIG. 5. Fastened to this shaft within the recess **62** is a radially extending arm **70** (corresponding to the arms A–1 and A–2 of FIG. 1) which is grooved as indicated at **72** to receive a sliding block **74**, held in the groove by means of a cover **76**. Formed integrally with this block is a trunnion **78** on which a roll (corresponding to the rolls R–1 and R–2 of FIG. 1) which serves as a rotary impeller, is journaled. The trunnion **78** projects through a clearance slot **82** formed in the arm **70** as shown in FIG. 3.

Secured to the arm **70** is a member **86** having a bore **88** therein for rotatably receiving the hub **90** of a bevel gear **92**. This gear has a clearance hole **94** through which there passes a hollow lead screw **96** which is threaded into the arm **70** and to which the aforementioned bevel gear is drivingly connected by means of a set screw **98** and keyway **100** formed in the screw **96**. The lead screw **96** is internally threaded to receive a second lead screw **102**, of the same hand as the screw **96**, which is threaded through a bore **104** in the block **74** and secured thereto by a locknut **106**. The lead of the screw **96** is different from that of the screw **102** for a purpose which will presently appear.

For rotating the bevel gear to effect radial adjqustment of the roll **80**, the following arrangement is provided. Secured to the arm **70**, coaxially of the shaft S, is a stud **110** on which there is rotatably and slidably supported an adjusting knob **112** (corresponding to the knobs K–1 and K–2 of FIGS. 1 and 2) having an enlarged hub portion **114** which is provided with a circumferential groove **116** (FIG. 3). Formed in the arm **70** is a V-groove guideway **120**, see FIG. 4, which is inclined downwardly and outwardly, as indicated in FIG. 3, in which there is slidably mounted a block **122** from which there projects a stud portion **124**. Journaled on this stud portion is a bevel gear **126**, held in place by means of a headed screw **128**. Surrounding the hub of the gear **126** is the body portion of a yoke member **130** having a pair of arms **132**, **132** which are received within the annular groove **116** of the hub portion of the adjusting knob **112**. Also rotatably and slidably mounted on the stud **110** is a bevel gear **136** the hub of which is grooved as indicated at **140**, **140** and projects into a recess **142** formed in the hub portion **114** of the adjusting knob **112**. This gear is normally held yieldingly in the position shown in FIG. 3, by a spring **146**, with its hub engaging a stop ring **148** on the stud **110**. A relatively lighter spring **150**, seated against an adjusting nut **152** on the stud **110**, yieldingly holds the knob **112** and its hub portion **114** in the position shown in FIG. 3 with the bottom of the recess **142** in engagement with the end of the hub of the gear **136**. The hub portion **114** is drivingly connected to the gear **136** by means of pins **154**, **154** which are received within the groove **140**, **140**.

Extending outwardly from the recess **62** are two grooves **160**, **162**, FIG. 5, which are disposed at substantially right angles to each other and extend generally tangential to the outer wall of the recess **62**, indiciated in FIG. 3 by the reference character **164**. A portion of the annular flange **64** is cut away, as indicated at **166**, **168** in FIG. 5 of the drawings to provide a recess for a keeper plate **170**, preferably formed of a plastic or other transparent material, which is held in place by screws **172**, **172**, **172**. When this keeper plate is removed, a single loop of a compressible tube **180**, formed of rubber or suitable plastic material, may be placed in the recess in engagement with the outer wall **164** thereof and with its opposite ends extending outwardly through the grooves **160**, **162** which are of a width substantially equal to the normal outside diameter of the tube. The grooves **160**, **162** are of the same depth as the recess **62** and inasmuch as the axial distance of the bottom of this recess to the inside of the flange **64**, which is just sufficient to accommodate the tube when it is fully flattened by the roll **80**, is somewhat less than twice the diameter of the tube, the ends of the tube, as they project outwardly beyond the housing **60**, are deflected slightly away from each other out of the central plane of this housing.

As will be readily apparent when the shaft S is rotated, the tube **180** (corresponding to the tubes T–1 or T–2 of FIG. 1) will be progressively compressed by the roll **80**, which acts as a rotary impeller, so that liquid in the tube will be subjected to a pumping action and caused to flow in the direction of the arrows in FIGS. 1 and 5 of the drawings. This pumping action is interrupted once

during each revolution of the shaft S, while the roll **80** travels from a position "*a*" on one end of the loop of the tube to a position "*b*" on the other end of the loop. The output of the pump can be varied in two different ways, e.g., by increasing or decreasing the amount the tube **180** is compressed by the roll **80** and/or by increasing or decreasing the speed of rotation of the shaft S. As will be apparent, the latter also has the effect of varying the cyclic rate of the pump, i.e., the rate at which the pumping action is interrupted as above explained.

When the parts are in the positions in which they are shown in FIG. 3 of the drawings, the gear **136** is out of mesh with the gears **92** and **126**, while the gear **126** is partially meshed with the gear **92**. Now, if the operator wishes to cause the roll to move radially outwardly along the arm **70**, thereby to increase the pumping action, he grasps the knob **112** and pulls it outwardly, i.e., to the right FIG. 3, on the stud **110**. As a result of this movement of the knob **112** and its hub portion **114**, the gear **126** is moved downwardly completely in mesh with the gear **92** and outwardly into mesh with the gear **136**, which latter gear is being held against axial movement by ring **148** and against rotation by the operator through the action of the pins **154**, **154** on the grooves **140**, **140**. Therefore, as the arm **70** revolves in the direction of the arrow in FIG. 5 of the drawings, the gear **126** will be driven in a clockwise direction as viewed in FIG. 3, thus driving the gear **92** and screw **96** in a direction to cause the screw **96** to move upwardly wtihin the arm **70**, as viewed in FIG. 3. At the same time, the screw **96** tends to draw the screw **102** downwardly, in a manner which will be apparent. Inasmuch as the lead of the screw **96** is greater than the lead of the screw **102**, the net result will be a movement of the block **74** and roll **80** upwardly at a very slow rate. For example, with a lead on the screw **96** of $\frac{1}{32}$" and a lead on the screw **102** of $\frac{1}{36}$", the block **74** will be moved upwardly, i.e., radially outwardly along the arm **70**, approximately .0035" for each revolution of the gear **97**. As soon as the operator releases the knob **112** it is returned to the position shown in FIG. 3 by the spring **150** and radial movement of the roll **80** will cease. In order to effect radial movement of the roll in the opposite direction, thereby to reduce the pumping action, the operator grasps the knob **112** and pushes it inwardly, i.e., to the left as viewed in FIG. 3. This causes the gear **136** to be engaged with the gear **92**. Inasmuch as the gear **136** is held against rotation by the operator, in the manner explained above, as the arm **70** revolves in the direction of the arrow in FIG. 5, the gear **92** will be driven in a direction to effect radial movement of the roll **80** radially inwardly along the arm **70** toward the axis of the shaft S at the rate indicated above, i.e., approximately .0035" for each revolution of the gear **92**. During this rotation of gear **92**, the gear **126** turns idly. As will be apparent, the adjusting mechanism which has been described above provides a very sensitive adjustment of the roll **80** and as a result affords an extremely accurate control over the pumping action of the unit. In order to adjust screws **96** and **102**, relatively to each other, the nut **106** is removed and the screw **102** is threaded out of the screw **96** and the block **74**. Now, the screw **96** may be adjusted by manual rotation, after which, with the block **74** held in the desired location and the screw **96** held against rotation, the screw **102** may be rethreaded into the screw **96** and block **74** and the nut **106** replaced. As will be apparent, when the roll **80** is being adjusted outwardly, to increase the pumping action, the screw **96** travels upwardly toward the block **74**. Thus, by suitable adjustment of the screws **96** and **102**, the outward limit of movement of the roll can be so determined that complete closure of the tube **180** is prevented and the possible damage to the corpuscles which might occur in this way avoided.

The mode of operation of the apparatus will now be outlined with particular reference to FIGS. 1 and 2 of the drawings. The apparatus is set up in the operating room adjacent to the patient with the two reservoirs **10**, **12** mounted on a suitable stand, or other type of support, at a level somewhat below the patient and with the pump unit, see FIG. 2, located close by on the floor. In order to save valuable floor space, the pump unit may be supported on a suitable frame and in the vertical position shown in FIG. 2. Without attempting to explain the details of the surgical procedure involved, which forms no part of the present invention, the conduit means **52**, **54**, **56** and **58** are cannulated with appropriate blood vessels of the patient, as diagrammatically illustrated in FIG. 1, so that the patient's heart is entirely bypassed. Initially, each of the two reservoirs is partially filled with a saline solution, or with blood, and with the values **40**, **44** opened the pump is started. Now, as blood flows from the pulmonary vein into the reservoir **10** through the conduit **52** and from venae cavae into the reservoir **12** through the conduit **54**, these valves are gradually closed to cause the pump units to circulate the oxygenated blood which flows into the reservoir **10** through the body of the patient and the venous blood which flows into the reservoir **12** to the lungs of the patient.

The speed of rotation of the common drive shaft S of the pump is set, by means of the control handle H on the variable speed drive D, Fig. 2, so that the cyclic action of the two pumping units is comparable to the normal pulse of the patient, which this cyclic action of the pump simulates, while the pumping action of each pumping unit P–**1** and P–**2** is initially adjusted to approximate that required to take care of the blood which flows into the two reservoirs and to equalize the flow through the reservoir **10** with the flow through reservoir **12**. This state of equality of flow, or the lack thereof, is readily apparent to the operator by his observation of the level of the blood within these two reservoirs, which, as already indicated, are made of transparent material for this purpose. As will be apparent, the flow of blood through the reservoir **10** may be very quickly and accurately regulated by the operator through a suitable manipulation of the control knob K–**1**, while the flow through the reservoir **12** can similarly be regulated by means of the knob K–**2**. In this manner the action of the pump can be controlled in accordance with the requirements of the patient during the operation. In the event that such action should become necessary for any reason, the quantity of the blood in the two reservoirs may be very quickly balanced by temporarily opening the by-pass valve **50** located in the conduit **48**. The hollow strut **15** provides an automatic by-pass for preventing overflow of one or the other of the reservoirs **10** or **12** should the level of the blood therein rise to an unduly high level.

The cyclic rate of the pump, i.e., the simulated pulse, may be readily increased or decreased by varying the speed of rotation of the common drive shaft S in the manner explained above and this change will be the same for each of the two units which, as explained above, correspond to the right and left sides of the heart. After such a change in the cyclic rate of the pump it may be necessary for the operator to make a slight readjustment in the pumping action of the two units in order to maintain the desired quantity and equality of flow through the two reservoirs. This can, of course, be readily accomplished in the manner explained above.

As will be apparent, with the apparatus of this invention, a single operator is enabled to control the operation of the pump and to regulate the flow through the two reservoirs in any desired manner appropriate to conditions met during the operation. Moreover, the novel and improved pump is very dependable in action and, because of the simplicity of its construction, there is little, if any, likelihood of mechanical difficulties arising. The pump

tube 180 (T–1 or T–2) is very easily replaceable in the event of damage during use and, should mechanical failure of one or both of the pumping units occur during an operation, these tubes could be quickly removed and placed in another standby pump with only a very brief interruption of the circulation of blood. As explained above, the limit of outward adjustment of the pressure roll 80 may be such that the compressible tube used in each pumping unit can never be entirely closed by the roll. Thus danger of damage to the blood by squeezing of the corpuscles may be effectively avoided. In addition, the action of the rotary impeller in moving the blood through the compressible tube is an easy one and such that other damage to the blood is avoided.

After use, the various pieces of tubing which have been employed for the several conduits referred to above, as well as the two pieces of tubing used in the pumping units themselves, may be entirely discarded or, if desired, these pieces of tubing may be cleaned and sterilized for future use. The same is also true with respect to the two reservoirs which may be made of glass or of a suitable transparent plastic of a type which can be either sterilized or such as would warrant being discarded after use.

The two reservoirs are connected together by the struts to form one unit. As indicated above, this unit is mounted on a suitable stand at a level slightly below that of the patient. As the blood flows into these two reservoirs through the conduit means provided, a syphon effect is produced. This syphon effect may be increased or decreased by lowering or raising the two reservoirs, which is easily accomplished because of their simple construction, to facilitate or retard the rate of flow of blood from the patient into the reservoirs. As shown in FIG 1, the inlet 22 to the reservoir 12 which receives blood from the venae cavae is so located that the blood flows some distance down along the inner wall of the inclined body portion of the reservoir. This, it has been found, tends to avoid foaming of the blood and also provides a convenient visual indication of the rate of flow of blood from the patient. On the other hand, the inlet 16 to the reservoir 12, which receives blood from the pulmonary vein, is located well below the level of blood in that reservoir to avoil entrainment of air. By providing the connections 18, 20 and 24, 26 adjacent to the lower portion of their respective reservoirs, the operator can, by maintaining the level of blood in these reservoirs well above these connections, avoid any danger of air entering the circulating blood stream. Should occasion require, blood from a donor may be added to either one or both of the reservoirs through their open upper ends and an automatic gravity feed device may be provided for this purpose.

Having thus described our invention, what we claim as new and desire to secure by Letters Patent of the United States is:

1. A pump for use in the extracorporeal circulation of blood comprising a pair of pumping units each having a circular shaped compressible tubular pumping member, a support for each of said pumping members, a pump shaft extending through said supports and centrally located relatively to said circular pumping members, a pair of arms secured to said shaft, an impeller member mounted for radial adjustment on each of said arms and adapted to cooperate with one of the pumping members, and a separate means carried by each of said arms for radially adjusting the impeller member mounted thereon to vary the action of said impeller member on its associated pumping member during the operation of the pumping unit, and power-operated means for rotating said pump shaft.

2. A pump for use in the extracorporeal circulation of blood comprising a pair of pumping units each having a circular shaped compressible tubular pumping member, a support for each of said pumping members, a pump shaft extending through said supports and centrally located relatively to said circular pumping members, a pair of arms secured to said shaft, an impeller member mounted for radial adjustment on each of said arms and adapted to cooperate with one of the pumping members, a separate means carried by each of said arms and manually operable to effect radial adjustment of the impeller member thereon to vary the action of said impeller member on its associated pumping member during the operation of the pumping unit, and power-operated means for rotating said pump shaft.

3. A pump for use in the extracorporeal circulation of blood comprising a pair of pumping units each having a circular shaped compressible tubular pumping member, a support for each of said pumping members, a pump shaft extending through said supports and centrally located relatively to said circular pumping members, a pair of arms secured to said shaft, a rotary impeller member mounted for radial adjustment on each of said arms and adapted to cooperate with one of the pumping members, means carried by each of said arms and shiftable in directions extending axially of the pump shaft to effect radial adjustment of the impeller member thereon in response to rotation of the pump shaft to vary the action of said impeller member on its associated pumping member during operation of the pumping unit, and power-operated means for rotating said pump shaft.

4. A pump having a circular shaped compressible tubular pumping member, a support for the pumping member, a pump shaft extending through said support and centrally located relatively to the circular pumping member, an arm secured to said pump shaft, a rotary impeller mounted on said arm for radial adjustment and adapted to cooperate with the pumping member, means carried by the arm and shiftable in directions extending axially of said pump shaft to effect radial adjustment of said rotary impeller thereon in response to rotation of said pump shaft to vary the action of the impeller on the pumping member during the operation of the pump, and power-operated means for rotating the pump shaft.

5. A pump for use in the extracorporeal circulation of blood comprising a pair of pumping units each having a circular shaped compressible tubular pumping member, a support for each of said pumping members, a pump shaft extending through said supports and centrally located relatively to said circular pumping members, a pair of arms secured to said shaft, a rotary impeller member mounted for radial adjustment on each of said arms and adapted to cooperate with one of the pumping members, an adjusting knob carried by each of said arms and shiftable axially of said pump shaft, means controlled by said knob and operable to effect radial adjustment of the impeller member thereon in response to rotation of the pump shaft to vary the action of said impeller member on its associated pumping member during the operation of the pumping unit, and power-operated means for rotating said pump shaft.

6. A pump having a circular shaped compressible tubular pumping member, a support for the pumping member, a pump shaft extending through the support and centrally located relatively to said circular pumping member, an arm secured to said pump shaft, a rotary impeller mounted on said arm for radial adjustment and adapted to cooperate with the pumping member, an adjusting knob carried by said arm and shiftable in directions extending axially of said pump shaft, means controlled by said knob and operable to effect radial adjustment of the impeller thereon in response to rotation of the pump shaft to vary the action of said impeller on the pumping member during the operation of the pump, and power-operated means for rotating the pump shaft.

7. A pump for use in the extracorporeal circulation of blood comprising a pair of pumping units each having a circular shaped compressible pumping member, a support for each of said pumping members, a pump shaft

extending through said supports and centrally located relatively to said circular pumping members, a pair of arms secured to said shaft, a rotary impeller mounted on each of said arms for radial adjustment and adapted to cooperate with one of the pumping members, a differential screw associated with each arm for effecting radial adjustment of the impeller mounted thereon, a reversible drive mechanism carried by each arm for operating the screw associated therewith, an adjusting knob carried by each of said arms and shiftable in directions extending axially of said pump shaft for controlling the drive mechanism carried thereby to cause rotation of its screw in response to rotation of the pump shaft to effect radial adjustment of the impeller on said arm thereby to vary the action of the impeller on its associated pumping member, and power-operated means for rotating the pump shaft.

8. A pump having a circular shaped compressible tubular pumping member, a support for the pumping member, a pump shaft extending through the support and centrally located relatively to said circular pumping member, a rotary impeller mounted on said arm for radial adjustment and adapted to cooperate with said pumping member, a differential screw for effecting radial adjustment of the rotary impeller, a reversible drive mechanism for operating said screw, an adjusting knob carried by said arm and shiftable in directions extending axially of said pump shaft for controlling the drive

mechanism to cause rotation of the screw in response to rotation of the pump shaft to effect radial adjustment of said impeller on said arm thereby to vary the action of the impeller on the pumping member, and power-operated means for rotating the pump shaft.

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