Nov. 7, 1961 W. S. CHILDS 3,007,416

PUMP FOR CELLULAR FLUID SUCH AS BLOOD AND THE LIKE

Filed Aug. 13, 1958 2 Sheets-Sheet 1

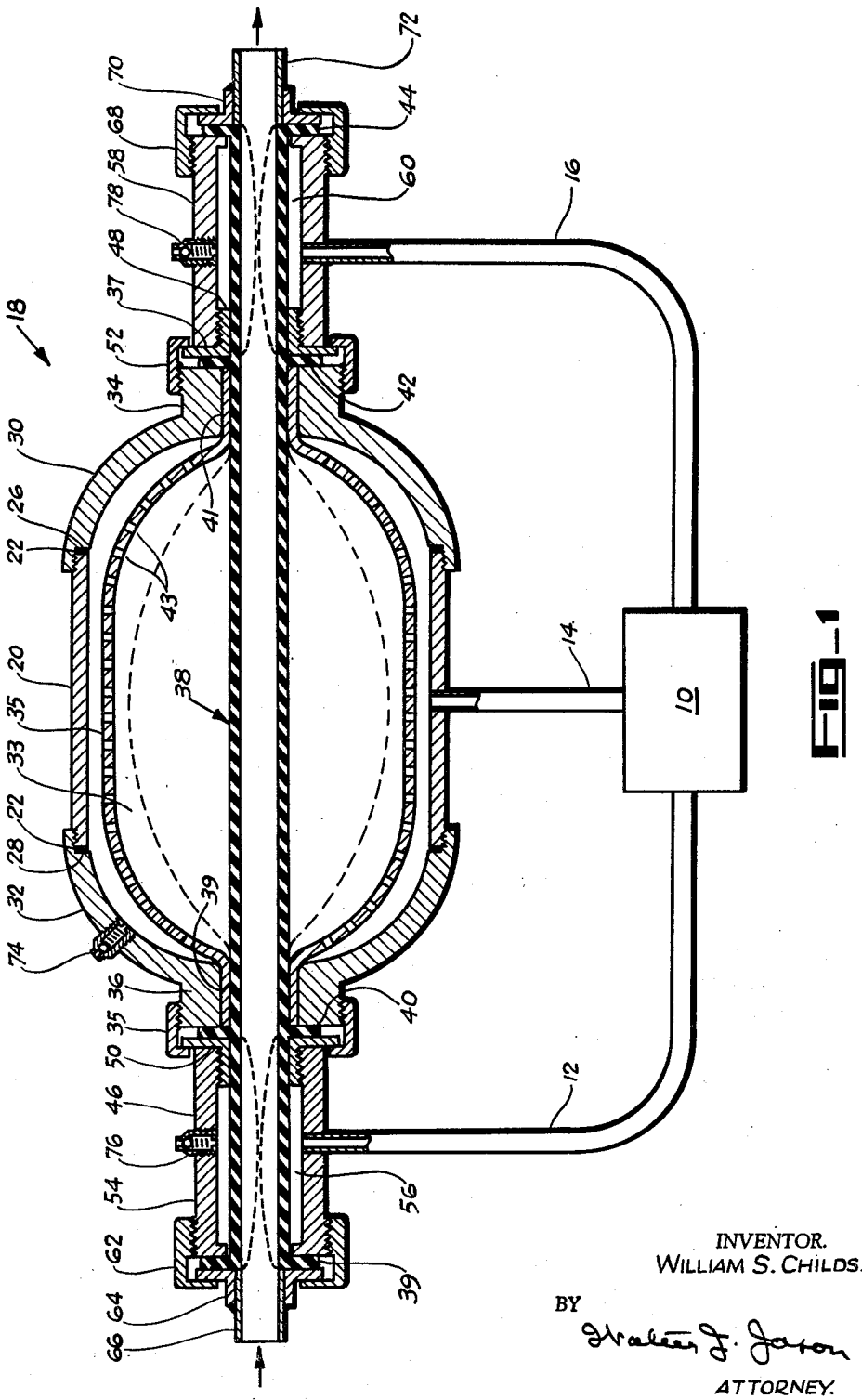

FIG-1

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PUMP FOR CELLULAR FLUID SUCH AS BLOOD AND THE LIKE

Filed Aug. 13, 1958 2 Sheets-Sheet 2

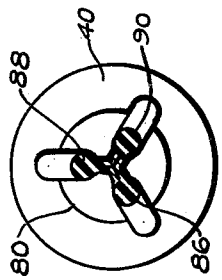

FIG. 6

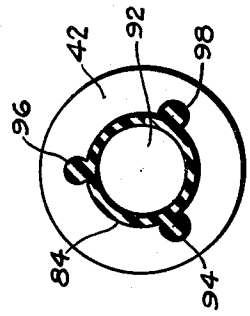

FIG. 5

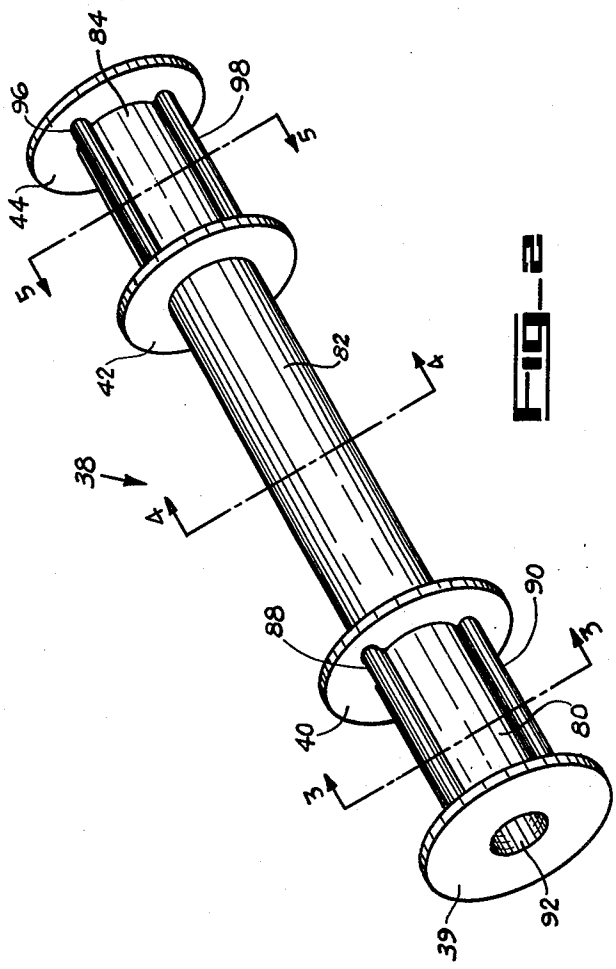

FIG. 2

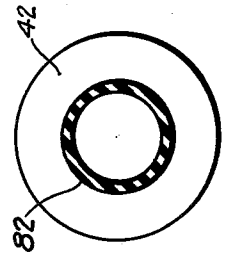

FIG. 4

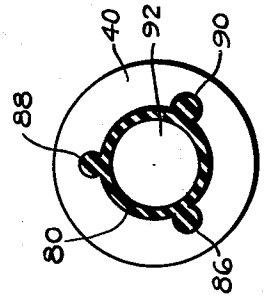

FIG. 3

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PUMP FOR CELLULAR FLUID SUCH AS BLOOD AND THE LIKE

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This invention relates to fluid pumps generally and more particularly to a pump capable of simulating the action of a human heart in pumping blood through the human system.

Heretofore heart pumps used to pump blood to bypass the blood around the living heart had distinct disadvantages. For example, such heart pumps, not only produced turbulence and stagnation of the blood, but in addition, at slow pumping rates, produced backflow or regurgitation of the blood, resulting in low efficiency fluid transfer. Moreover, at rapid pumping rates, damage to the blood by hemolysis took place due to the rapid and excessive forces applied in the pumping and valving operations. Other pumps, not only incorporated the above disadvantages, but in addition, were so constructed as to pump the blood in violent spurts, which also resulted in damage to the blood.

The improved heart pump herein disclosed utilizes a flexible element of readily deformable material having a passage for passing blood or other cellular fluid, positioned in a housing such that it extends through and divides the housing into separate chambers. One end of the flexible element is adapted to be connected to a suitable source of fluid, and the other end is connected to the proper receiver of the fluid. The chambers are adapted to be connected to a source providing positive and negative fluid pressures such that the pressures are applied to portions of the element in a predetermined sequence to produce flow of the fluid through the element.

It is therefore an object of this invention to provide an improved pump which pumps blood or other cellular fluid with high efficiency.

Another object is to provide an improved pump which pumps blood or other cellular fluid gently by maintaining at a minimum the number and severity of the pumping and valving operations and prevents regurgitation, turbulence and stagnation of the fluid.

A further object is to provide an improved pump which pumps blood safely to prevent air embolism or brain damage caused by mechanical failure.

Still a further object is to provide a pump which simulates the action of the human heart.

A final object is to provide a pump which maintains the pumped fluid at a constant temperature.

Other objects and features of the present invention will be readily apparent to those skilled in the art from the following specification and appended drawings wherein is illustrated a preferred form of the invention and in which:

FIGURE 1 is partly a cross-section side view and block diagram of the pump structure embodying the invention.

FIGURE 2 is a perspective view of the flexible element of the pump structure of FIGURE 1.

FIGURE 3 is a cross-section view of a portion of the flexible element of FIGURE 2 in its normal uncollapsed state taken along the lines 3—3.

FIGURE 4 is a cross section view of another portion of the flexible element of FIGURE 2 in its normal unexpanded state taken along the lines 4—4.

FIGURE 5 is a cross section view of still another portion of the flexible element of FIGURE 2 in its normal uncollapsed state taken along the lines 5—5.

FIGURE 6 is a cross section view of the portion of FIGURE 3 in its collapsed state.

Referring now to the drawings wherein like reference characters designate like or corresponding parts throughout the several views there is shown generally in FIGURE 1 a periodic pressure generator 10 which controls and operates the pumping device 18 by providing a source of regulated positive and negative pressures through a fluid transmission medium, preferably a liquid having a predetermined temperature.

The pressure generator 10, the details of which are not shown, may be of any well known construction, such as a plurality of cylinders having pistons mounted therein for reciprocating movement and adapted to be periodically actuated by means of a driven rotary cam arrangement such that pressures generated by the pistons are transmitted through a fluid medium in the cylinders and conduits 12, 14 and 16 to the pumping device 18, in a predetermined sequence, hereafter to be described in greater detail. Conduits 12, 14 and 16 can be attached to the pumping device in any well known manner such as by coupling or force fitted as shown. The temperature of the pressure transmitting fluid can be controlled, as by a regulated mixing of hot and cold water, or other suitable means may be employed. This maintains the pressure transmitting liquid at a desired temperature, thus providing, in addition to a pressure transfer medium, a thermal transfer medium for regulating the temperature of the conveyed fluid.

The pumping device 18 comprises a center cylindrical portion 20 threadedly positioned at both ends within end members 30 and 32 to abut seals 22 and 24, respectively, the seals being adapted to rest in shoulders 26 and 28, respectively, of end members 30 and 32. The end members 30 and 32 are of hollow semi-spherical construction, and together with the cylindrical portion 20 form a chamber 33 therebetween. The end members 30 and 32 are provided with outwardly extending outer threaded portions or necks 34 and 36, respectively. A rigid perforated tubular member 35 having perforations 43 and having reduced diameter end portions 39 and 41 is adapted to be placed within the chamber 33 such that the reduced portions 39 and 41 are positioned within openings in the portions 34 and 36. A flexible or resilient walled tubular element 38, preferably of rubber, having collars 39, 40, 42 and 44 surrounding the ends and intermediate portions of the tubular element, is positioned within and extends through the member 35 such that the inner faces of the collars 40 and 42 are in abutting engagement with the ends of necks 36 and 34 and the ends of portions 39 and 41. A tubular member 46 having a flange portion 50 is adapted to be positioned around the tubular element 38 such that its inner face abuts the outer face of collar 40. An internally threaded cap 35 engages the threaded portion 36 to securely fasten the portion 50 and collar 40 to the end of neck 36. A similar cap 52 engages the neck 34 to secure the collar 42 and a tubular member 37 to the end of neck 34. Cylindrical elements 54 and 58 are each internally threaded at one end for engagement with members 46 and 48, respectively, and are positioned in surrounding spaced relationship with the respective ends of the element 38 to abut collars 39 and 44 at their other ends to form chambers 56 and 60. Cylindrical element 54 is provided with a threaded cap 62 which fluid tightedly secures a flange 64 of a fluid supply conduit 66 and the collar 39 to the end of cylindrical element 54. A cap 68 similar to cap 62 secures the collar 44 and a flange 70 of a fluid delivery conduit 72 to the end of cylindrical element 58. The fluid supply conduit 66 is adapted to be connected to a source of fluid to be conveyed and the conduit 72 is connected to a suitable receiver of the pumped fluid. Check valves 74, 76 and

78 are positioned in the walls of the members 32, 54 and 58, respectively, to provide a means for filling the chambers 33, 56 and 60, respectively (with a suitable pressure transmitting liquid, such as a sterile saline solution, prior to the operation of the pumping device.

Referring now to FIGURES 2–6, there is shown in greater detail the construction of the flexible pumping element 38 comprising portions 80, 82 and 84 and having a passage 92 extending throughout its length. The inner wall surfaces of portions 80 and 84 are of generally circular cross section in their normal uncollapsed state. The outer wall surfaces of the portions 80 and 84 are provided with substantially parallel elongated bulbed surface portions 86, 88, 90 and 94, 96, 98, respectively, which, under the influence of positive fluid pressure, produce a collapsing of the walls of the portions 80 and 84 to restrict the passage 92, thereby preventing flow of fluid therethrough. As illustrated, the bulbed surface portions 86, 88 and 90 are substantially equally spaced with respect to each other around the portion 80 and extend between the collars 39 and 40. The bulbed surface portions 94, 96 and 98 are similarly positioned on the portion 84 and extend between collars 42 and 44. The collapsed state of the portion 80 is shown in FIGURE 6 wherein it can be seen that the walls assume a complete state of collapse, under the influence of uniform fluid pressure applied thereto, with the result that passage 92 completely closes. The portion 84 collapses in a manner comparable to that of portion 80 upon application of the proper fluid pressure. FIGURE 4 shows the cross section configuration of portion 82 in its normal unexpanded state which is generally of circular configuration.

The operation of the pump is as follows:

Upon actuation of the pressure generator 10, a positive fluid pressure generated thereby, is transmitted through the fluid in the conduit 16 and the chamber 60 to act upon the surface of portion 84 of the flexible element 38 to contract the walls of the portion to thereby restrict the passage 92. Next, while maintaining the passage 92 in the portion 84 closed, a negative fluid pressure is produced by the generator 10 throughout the fluid contained in the conduit 14 and chamber 33, which results in a withdrawal of the pressure transmitting fluid in the chamber 33 and an expansion of the portion 82 of the flexible element 38. The expansion of the portion 82 gently draws the fluid to be conveyed through the conduit 66 and into the portion 82 in a quantity which is equal to the quantity of pressure transmitting fluid withdrawn from the chamber 33 by the generator 10. When the quantity of fluid has been drawn into the portion 82, a positive fluid pressure generated by generator 10 is applied through the conduit 16 to the portion 80 of the flexible element 38 to close the passage 92 therein. Next the generator 10 withdraws fluid from the chamber 60 to relieve pressure on the portion 84 which resumes its normal state and thereby opens the passage 92. An application of positive pressure through the fluid in conduit 14 and chamber 33 by the generator next contracts the portion 82, thus expelling the quantity of fluid to be conveyed drawn therein through the passage 92 and out the conduit 72 to its destination. The generator 10 then relieves the pressure in the chamber 56 and thus allows the portion 80 to assume its normal uncollapsed state and prepares the pump for a repetition of the above recited cycle.

It will be apparent to those skilled in the art that instead of a single pumping device 18, as described above, a plurality of similar pumping devices can be arranged to have their inlets and outlets commonly connected and arranged to be alternately actuated by generator 10 to provide discharge of fluid by one while the other is filling.

While a certain preferred embodiment of the invention has been specifically disclosed, it is to be understood that the invention is not limited thereto as many variations will be readily apparent to those skilled in the art and the invention is to be given its broadest possible interpretation within the terms of the appended claims.

What I claim is:

1. A fluid pump comprising a flexible tubular element, a plurality of flexible collars positioned on the outer surface of said tubular element in spaced relationship with each other and along the length of said tubular element to form therebetween first and second end portions, and a middle portion of said tubular element, said first portion being adapted to be connected to a source of fluid, said first and second portions each having a plurality of substantially parallel elongated bulbed surface portions extending between adjacent collars and arranged in spaced relationship with respect to each other around said first and second portions, housing means in engagement with said collars and in surrounding spaced relationship with said first, second, and middle portions to form first, second, and third chambers, respectively, means positioned in said third chamber for limiting expansion of said middle portion, and means for producing a predetermined sequence of positive and negative fluid pressures in said chambers to contract and expand said portions, said predetermined sequence of positive and negative fluid pressures being a positive fluid pressure in said second chamber, a negative fluid pressure in said third chamber, a positive fluid pressure in said first chamber, a negative fluid pressure in said second chamber, a positive fluid pressure in said third chamber, and a negative fluid pressure in said first chamber, said predetermined sequence being repeatable to produce continuous flow of said fluid through said tubular element.

2. A fluid pump comprising a flexible tubular element, a plurality of flexible collars positioned on the outer surface of said tubular element in spaced relationship with each other and along the length of said tubular element to form therebetween first and second end portions, and a middle portion of said tubular element, said first portion being adapted to be connected to a source of fluid, said first and second portions each having a plurality of substantially parallel elongated bulbed surface portions extending between adjacent collars and arranged in spaced relationship with respect to each other around said first and second portions, housing means in engagement with said collars and in surrounding spaced relationship with said first, second, and middle portions to form first, second, and third chambers, respectively, a rigid member positioned in said third chamber in surrounding spaced relationship with said middle portion to limit expansion thereof, said rigid member having perforations, and means for producing a predetermined sequence of positive and negative fluid pressures in said chambers to contract and expand said portions, said predetermined sequence of positive and negative fluid pressures being a positive fluid pressure in said second chamber, a negative fluid pressure in said third chamber, a positive fluid pressure in said first chamber, a negative fluid pressure in said second chamber, a positive fluid pressure in said third chamber, and a negative fluid pressure in said first chamber, said predetermined sequence being repeatable to produce continuous flow of said fluid through said tubular element.

3. A fluid pump comprising a flexible tubular element, a plurality of flexible collars positioned on the outer surface of said tubular element in spaced relationship with each other and along the length of said tubular element to form therebetween first and second end portions, and a middle portion of said tubular element, said first portion being adapted to be connected to a source of fluid, said first and second portions each having a plurality of substantially parallel elongated bulbed surface portions extending between adjacent collars and arranged in spaced relationship with respect to each other around said first and second portions, housing means in engagement with said collars and in surounding spaced relationship with said first, second, and middle portions to form first, second, and third chambers, respectively, said chambers each

containing a pressure transmitting liquid having a predetermined temperature, a rigid member positioned in said third chamber in surrounding spaced relationship with said middle portion to limit expansion thereof, said rigid member having perforations, and means for producing a predetermined sequence of positive and negative pressures on said liquid to contract and expand said portions, said predetermined sequence of positive and negative pressures being a positive pressure on the liquid in said second chamber, a negative pressure on the liquid in said third chamber, a positive pressure on the liquid in said first chamber, a negative pressure on the fluid in said second chamber, a positive pressure on the liquid in said third chamber, and a negative pressure on the liquid in said first chamber, said predetermined sequence being repeatable to produce continuous flow of fluid from said source through said tubular element.

4. a diaphragm adapted for use in a diaphragm pump comprising a flexible tubular element, a plurality of flexible collars on said element in spaced relationship with respect to each other and along the length of said element to form therebetween end portions and a middle portion

of said element, said end portions each having a plurality of substantially parallel elongated bulbed surface portions extending between adjacent collars and arranged in spaced relationship with respect to each other around said end portions.

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