Sept. 8, 1953 P. M. W. BRUCKMANN 2,651,264

FLUID PUMP

Filed Feb. 10, 1951 2 Sheets-Sheet 1

Fig. 1

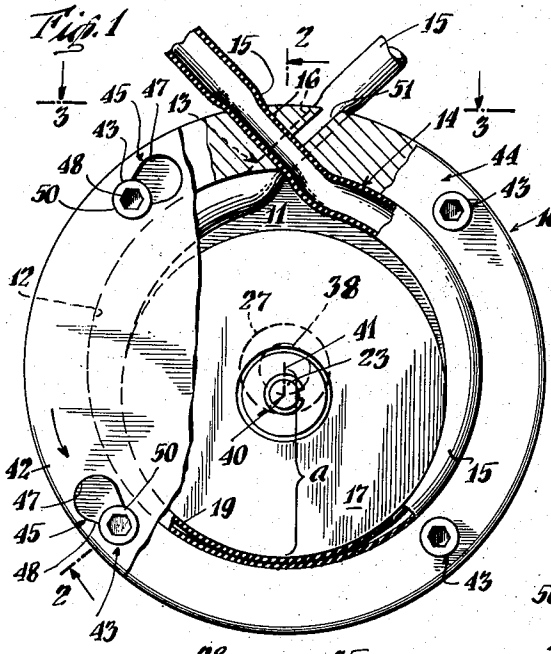


Fig. 2

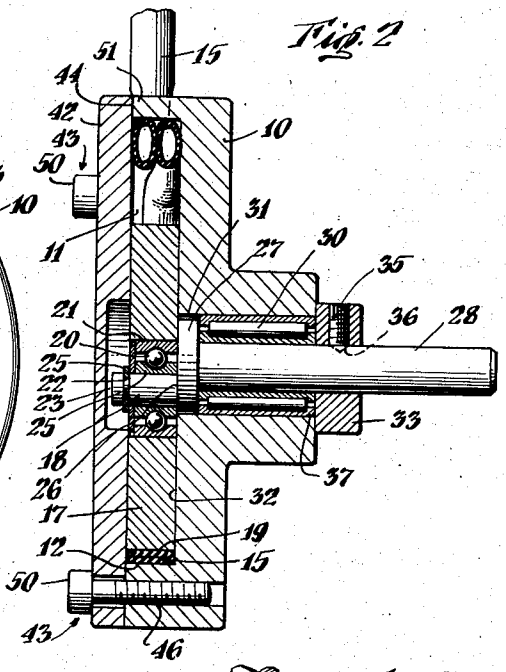


Fig. 3

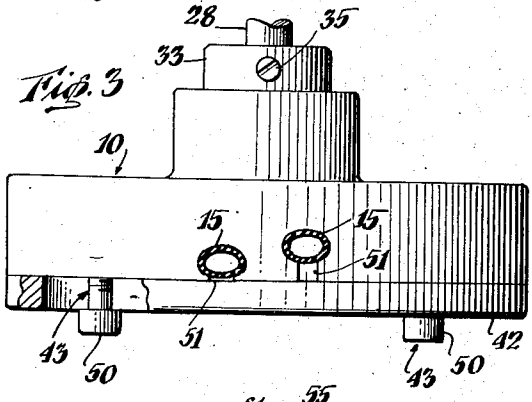


Fig. 5

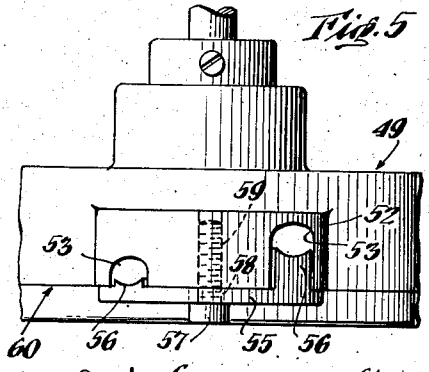


Fig. 6

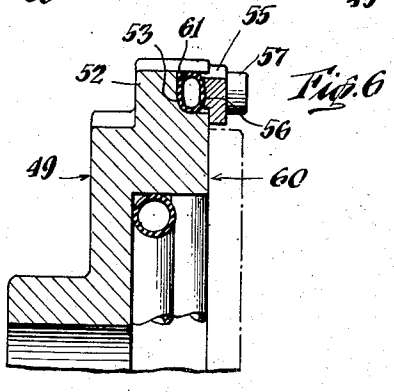
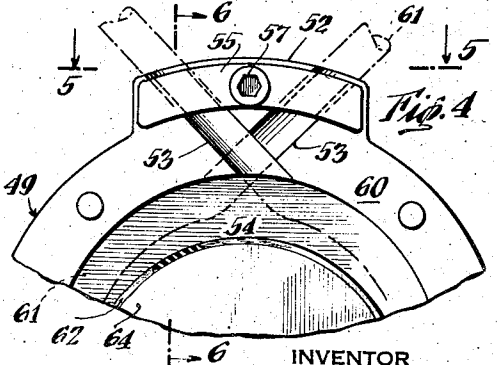


Fig. 4



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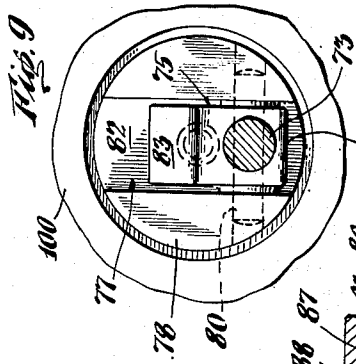


Fig. 9

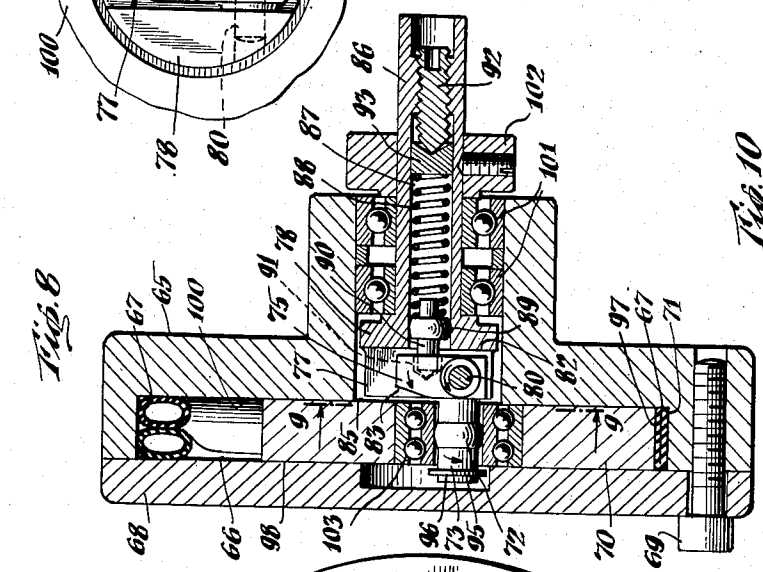


Fig. 8

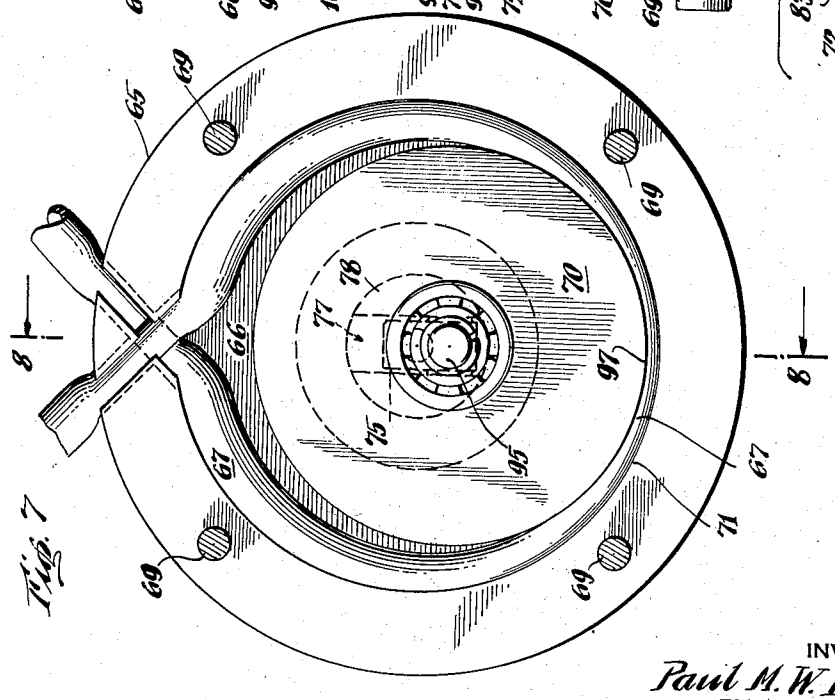


Fig. 7

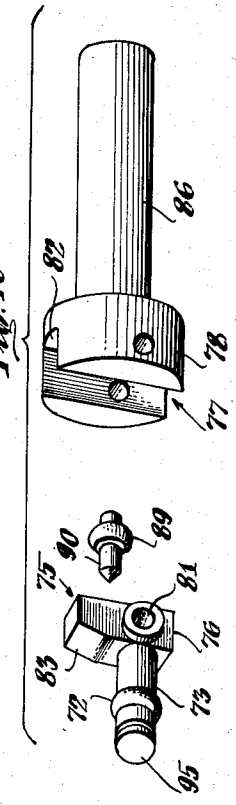


Fig. 10

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FLUID PUMP

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Application February 10, 1951, Serial No. 210,403

4 Claims. (Cl. 103—149)

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This invention relates to pumping apparatus and is more particularly concerned with an apparatus which may be readily disposed between the ends of a flexible tube to pump a fluid in either direction through the tube. The apparatus is so constructed that it may be operatively connected or disconnected without the necessity of disturbing either end of the tube.

The pumping device to which reference is made are those of the type in which a loop of tubing is disposed in a cylindrical chamber and the pumping action is obtained by compressing successive contiguous areas of the tubing between at least one rotating member and the wall of the chamber.

During the operation of such pumping devices, the tube is caused to creep. To counteract this creeping action, certain prior devices have sought to anchor the tube against the cylindrical wall of the chamber. Special tubes have been used which were provided with flanges or projections adapted to be received in suitable recesses in the cylindrical wall of the housing. Therefore, in order to use such pumping devices, it was necessary to employ tubing which was specifically designed with projections formed thereon; standard round tubing would not be suitable.

Also, in order to remove the tubing from prior devices, it was generally necessary to disconnect one of the ends of the tubes so that it could be threaded through the entrance and exit holes formed in the wall of the chamber housing. In threading the end of the tube through the housing, dirt or other foreign matter, almost inevitably, would get into or on the end of the tube so that the tube would have to be sterilized before it could be used for pumping any liquid which required sterile conditions.

Other devices have made the tubing an integral part of the pump, being connected inside the housing adjacent the inlet and outlet ports. Pumps of this type require additional tubing at the outside of the housing to carry the fluid into and out of the pump. Furthermore, it will be appreciated that when such devices were used to pump fluids, such as blood, water, milk or other liquids under sterile conditions, it was necessary to disassemble the pump completely in order to clean and sterilize the tube and the inlet and outlet ports, properly for such use.

The prior devices also made no provision for irregularities in the thickness of the tube wall and therefore incomplete compression could result which caused loss of vacuum and poor pumping action.

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Furthermore, the prior devices were limited to a specific diameter tube which they could receive.

An important object of the present invention is to provide a device in which a standard flexible tube may be used.

Another object of the invention is to provide a device which can be connected to, and disconnected from, the tube without disturbing the ends of the tube or otherwise contaminating the inside of the tube.

A still further object of the device is to provide means which will substantially eliminate the creeping of the tube during operation.

An additional object is to provide a device in which tubes having a range of diameters may be used.

Another object of the invention is to compensate for irregularities in the thickness of the tube wall to insure complete compression and improved pumping action.

The invention includes a pumping apparatus for moving the fluid through a flexible tube such as a standard round rubber tube by compressing successive contiguous areas along a length of said tube during each pumping cycle. The apparatus may consist of a chamber having a cylindrical wall along which the flexible tube may be disposed, at least one opening formed in the wall sufficiently large to permit two portions of the tube to extend therethrough, said opening being slightly smaller than the diameter of the tube in at least one direction or having means associated with the opening for adjustably crimping the tube. A cylindrical pump member having a diameter smaller than the cylindrical wall of the chamber may be rotatably mounted and be provided with means for moving it in a path about the axis of the cylindrical wall, so that successive areas of the periphery of the pumping member are moved into engagement with and compress successive contiguous areas along the length of the tube against the cylindrical wall during each cycle of the pumping member in the said path about the axis of the cylindrical wall. The tube is arranged in a loop around the cylindrical wall. The two portions of the tube which pass through the opening in the wall cross each other in different planes so that the loop of tube is substantially continuous around the wall; therefore, as the pumping member completes one cycle it simultaneously commences another pumping cycle. By this means, it is possible to obtain a substantially continuous flow, and the pulse which usually occurs in a pumping action is practically eliminated. The pumping member

may be provided with means for compensating for irregularities in the thickness of the tube wall to insure complete compression.

For a more complete description of the invention, reference is made to the drawing wherein:

Fig. 1 is a plan view of a pumping apparatus embodying the invention;

Fig. 2 is a sectional view taken along the line 2—2 in Fig. 1;

Fig. 3 is a side view taken along the line 3—3 in Fig. 1;

Fig. 4 is a plan view, with parts omitted, of the pumping apparatus showing a modified means for crimping the tube;

Fig. 5 is a side view taken along the line 5—5 in Fig. 4;

Fig. 6 is a sectional view taken along the line 6—6 in Fig. 4;

Fig. 7 is a plan view of a modified form of the invention;

Fig. 8 is a sectional view taken along the line 8—8 in Fig. 7;

Fig. 9 is a detail plan view taken along the line 9—9 in Fig. 8; and

Fig. 10 is an exploded perspective view of the cranking mechanism shown in Figs. 7 to 9, inclusive.

The pumping apparatus includes a housing 10 which has a chamber 11 defined by a cylindrical wall 12. An opening 13 is formed in the wall 12 to receive two portions of the tube 15 and to permit the positioning of a loop 14 of tube 15 in the chamber. The tubing 15 is disposed adjacent the wall 12. Channels 16 extend from the opening 13 in the cylindrical wall diagonally through the housing 10 as shown in Fig. 1. The portions of the tube 15 extending through the opening 13 cross each other at different levels and are carried off in diverging directions by the channels 16 extending at substantially right angles to each other. The channels 16 may be disposed substantially tangent to the cylindrical wall 12.

The channels 16 may be of a diameter slightly smaller than the diameter of the tubing 15 so that the tubing is crimped or constricted slightly as it passes through the housing 10. The channels 16 may converge to form a single opening 13 in the wall 12 or may have two separate openings.

A cylindrical pumping or compressing member 17 may be mounted in the chamber 11 for rotation about its axis on shaft 18. Suitable friction reducing means, such as ball bearings 20, may be disposed in raceways 21 provided on the member 17 and the shaft 18, respectively. The pumping member 17 may be maintained in rotatable position on the shaft 18 by forming an annular recess 22 adjacent the end 23 of the shaft and by positioning a removable resilient retaining ring 25 in said annular groove.

The end 26 of the shaft 18 is eccentrically fixed on a disc 27 to form a crank. The disc 27 in turn is fixed on a shaft 28 extending through the housing 10. The disc 27 and the shaft 28 are fixed in coaxial relationship to each other, the shaft 28 operating as a crankshaft for the crank formed by the shaft 18 and disc 27. The shaft 28 may be suitably mounted in the housing in a friction reducing bearing, such as roller bearings 30, shown in Fig. 2. The disc 27 is positioned in a cylindrical recess 31 formed in the floor 32 of the chamber 11. Axial movement of the shaft 28 in one direction is restricted by the collar 33 which is releasably attached to the shaft 28, on the outside of the housing 10, by means of the screw 35 tapped through the collar 33 extending into a recess 36 provided in the shaft. The axial movement of the shaft 28 is restricted in the other direction by abutment of the disc 27 against the block 37 containing the roller bearings 30.

Rotation of the shaft 28 in either direction imparts a cranking action to the shaft 18 which is eccentrically mounted on the disc 27. The axis 40 of the shaft 18 moves in a circular path 38, indicated by the dotted line in Fig. 1, about the axis 41 of the shaft 28, the radius of the circular path being the distance between the axis 40 and the axis 41.

A housing cover 42 may be provided to close the chamber 11, the cover 42 being removably maintained on the housing 10 by means of bolts 43 passing through slots 45 provided in the cover 42, the bolts 53 being secured in holes 46 tapped in the housing 10. The slots 45 may be of the form shown having an enlarged end 47 and a reduced end 48, the enlarged end 47 of each slot being sufficiently large to permit the head 50 of each bolt to pass therethrough and the narrow or reduced end 48 of each slot being sufficiently small to prevent the head 50 of each bolt from passing through at that end. Such an arrangement is desirable because it permits the removal of the cover by loosening the bolts 43 and rotating the cover in a direction indicated by the arrow in Fig. 1 to bring the heads 50 of the bolts 43 into line with the enlarged ends 47 of the slots 45. If desired, the bolts 53 may be held in position by set screws from the rear face of the housing so that the cover can be removed by rotating it as described, without loosening the bolts.

The channels 16, extending from the chamber 11 to the outside of the housing 10, are provided with narrow slots 51 which extend to the face 44 of the housing. The slots 51 are sufficiently wide to permit the tube 15 to be passed downward through said slots into the channels 16 by compressing the tube, but are sufficiently restricted so that the tube may not be readily displaced once it has been positioned in the channels 16.

In operation, a standard tube 15, which may be attached at one end to a vessel containing the fluid to be pumped, and with the other end attached to a receptacle for receiving the pumped fluid, may be connected to the pumping apparatus described in the following manner. The cover 42 is removed from the housing 10 by rotating the cover in the direction indicated by the arrow in Fig. 1, so that the heads 50 of the bolts 43 are in the enlarged ends 47 of the slots 45. The cover 42 may then be lifted from the housing 10. The tube 15 is looped and one portion of the tube passed through one slot 51 and another portion of the tube passed through the other slot 51 and the loop in the tube may be pressed down into the chamber 11 and disposed about the cylindrical wall 12 as shown in Fig. 1. In order to work the tube into position against the wall 12, it may be necessary to rotate the shaft 28 so that the member 17 completes one cycle around the circular path 38.

When the loop 14 of tube 15 is in position against the wall 12, the cover 42 is replaced; thereafter, the shaft 28 may be rotated in either direction to effect the pumping action which is obtained by milking or compressing successive contiguous areas of the tube. The rotation of the shaft 28 causes the shaft 18 to be moved in the circular path 38 about the axis 41 and causes portions of the periphery 19 of the pumping member 17 to compress the tube 15 against the

inner wall 12 of the housing 10. As the pumping member 17 is caused to move about the circular path 38, successive areas of the periphery 19 of the member 17 compress successive areas of the tube 15, the member 17 rotating about its own axis 40 while the axis 40 moves in the circular path 38 about the axis 41. The rotation of the member 17 results in the compressing action being effected by substantially stationary means; in other words, there is relatively no movement between the successive areas of the periphery 19 and the successive areas of the tube 15 with which they engage.

As the successive compressions are exerted on the tube 15 by the member 17, fluid in the tube 15, ahead of the point of compression, is forced forward through the tube in the direction in which the member 17 is rotating. If no liquid is in the loop 14 of the tube 15 at the beginning of the pumping operation, the movement of the pumping member 17 around the cylindrical wall 12 successively compressing areas of the tube 15 causes the air to be exhausted from the tube in front of the liquid in the tube, so that the liquid is drawn into and through the pump by syphoning action. The recovery characteristics of the tube, after compression, create sufficient vacuum to refill the loop so that a steady flow may be maintained by continuously rotating the member 17. It will be appreciated that liquid may be moved in either direction through the pump, the change in direction being effected merely by changing the rotational direction of the shaft 28.

It has been found desirable, as noted, to crimp or constrictively hold the portions of the tube 15 as they pass through the housing 10 so that there is a minimum of lengthwise or axial creep of the tubing as a result of the rotation of the compressive member 17. It is believed that the tendency of the tube to creep results from the fact that the circumference or periphery 19 of the member 17 has a smaller lineal length than the circumference of the circle described by the radius a; the difference in lineal length of the two circumferences is compensated for by different rates of rotation which causes the tube 15 to slip or creep as successive areas of the tube are compressed.

By holding the tube 15 in the constricted channels 16 the slipping is substantially eliminated.

It will be noted that an additional means of minimizing the slippage in the present invention has been to employ a pumping member 17 which has a relatively large diameter and therefore a periphery which has a lineal length not substantially smaller than the lineal length of the circumference described by the radius a. It will, therefore, be seen that by compressing the tube with a pumping member of relatively large radius, there is less inclination for the tube to creep. Furthermore, by a combination of the enlarged pumping member and the restricted openings, it has been possible to substantially eliminate the lengthwise creeping of the tube without the necessity of using a tube of special construction.

The use of a pumping member 17 having a relatively large diameter which is only somewhat smaller than the diameter of the cylindrical wall has the advantage of maintaining the portions of the loop 14 of the tube in position adjacent the wall in the areas in which it is not under compression.

An alternative means of constrictively holding the tube is illustrated in Figs. 4, 5 and 6 and may include a lug 52 extending outwardly from the housing 49, corresponding to housing 10 in Figs. 1–3. The lug 52 has formed in it diagonal channels 53 crossing each other at different levels in said lug, and each of said channels extending from the outside of the lug through the housing 49 and into the chamber 54, which corresponds to chamber 11 in Figs. 1–3. A plate 55 is adapted to be positioned on the lug 52, the plate 55 being provided with projections 56 which are adapted to extend into the channels 53 provided in the lug 52. The plate 55 is maintained in releasable and adjustable connection by means of bolt 57 extending through a hole 58 provided in the plate 55 and the hole 59 tapped in the lug 52. As shown in Fig. 6, a tube 61, which has been placed in the channels 53 of lug 52; may be constrictively held in said channels by screwing the plate 55 into position on the lug 52 so that the projections 56 constrictively engage the tube. The channels 53 extending through the housing 49 may be sufficiently large in diameter to receive tubes of various diameters, and the channels should be cut so that they extend upwardly to provide openings in the face 60 of the housing 49, thereby permitting the placing of the tube in the channels without the necessity of threading the tube through holes. The plate 55 is removed in order to permit the placement of the tube in the channels 53.

If tubes of different diameters are used, it is desirable to employ compressing or pumping members of different diameters. To permit substitution of the pumping member, the member 17 may be removed easily from its position in the chamber 11 by removing the retaining ring 25 and sliding the compressing member 17 off the shaft 18 and replacing it by a similar member of the deisred diameter and replacing the retaining ring in the annular groove 22.

As shown in Fig. 4, the pumping member 64 may be provided with a resilient surface 62 of suitable material, such as relatively soft rubber, on the compressing periphery of the member to give a more complete and effective compression of the tube, by presenting a resilient compressive surface to compensate for inconsistencies in wall thickness of standard tubing.

An alternative means of providing for resilient compression action by the pumping member, to compensate for irregularities in tube wall thickness and for slight variations in the diameter of the tube, is shown in Fig. 7 to 10, inclusive. The pump housing 65, cylindrical chamber 66, tube 67, cover 68, bolts 69 in Figs. 7 to 10 correspond to similar parts in Figs. 1–6. The modification resides in the mounting of the pumping member 70 so that it is resiliently pressed into engagement with the tube 67 which is positioned against the wall 71 of the chamber 66.

The pumping member 70 is rotatably mounted on the crowned collar 72 fitted on the shaft 73. The shaft 73 is fixed to the block 75 adjacent the end 76. The block is of a size which may be received in the slot 77 formed in the disc 78. The block 75 is pivotally mounted in the slot 77 on the pin 80, the axis of the pin being at right angles to the shaft 73 and extending through hole 81 in the block adjacent the end 76. The block 75 is thus held in the slot 77 slightly above the floor 82 of the slot to permit limited rotation of the block about the pin. The upper face 83 of the block, remote from the pin 80, is bevelled to permit limited pivoting of the block without en-

gaging the lower side 85 of the pumping member 70.

The disc 78 corresponds to the disc 27 in Figs. 1 and 2, and is fixed coaxially on the shaft 86. The shaft 86 acts as a crank shaft for the crank formed by the disc 78 and the shaft 73. A bore 87 is formed in the center of the shaft 86. Spring 88 is disposed in the bore 87. A pin 90 is positioned in the bore 87 at the end adjacent the disc 78. The pin 90 extends through the floor 82 of the disc and into a recess 91 formed in the bottom of the block 75. The pin 90 is pressed resiliently into the recess 91 to cause the block 75 to pivot slightly in the direction indicated by the arrow in Fig. 8, about the pin 80. The resilient pressure of the pin 90 may be increased or decreased by adjustment of screw 92 which is tapped in the bore 87. The screw 92 engages the sliding member 93 which in turn abuts the end 94 of the spring 88.

A crowned collar 89 may be provided on the pin 90 to permit the pin to move slightly out of axial alignment with the shaft 86 as the block 75 pivots slightly. Similarly, the crowned collar 72 permits the shaft 73 to move slightly out of axial alignment with the pumping member 70 as the shaft moves, in the direction indicated by the arrow in Fig. 8, when the block 75 pivots about the pin 80.

It will thus be understood that the spring-loaded pin 90 pressing resiliently against the block 75 causes the latter to pivot about the pin 80, thereby causing the upper end 95 of the shaft 73 to move outwardly toward the wall 71 of the chamber. As the upper end 95 of the shaft 73 moves toward the wall 71, the pumping member 70 is also moved toward the wall 71. In this manner the pumping member 70 is resiliently pressed against the tube 67 disposed around the wall 71, the resiliency compensating for slight irregularities in the size of the tube. The compressing periphery 97 of the pumping member 70 is maintained parallel to the wall 71 of the chamber 66 by the inside of the cover 68 and the floor 100 of the chamber 66 slidably engaging the upper face 98 and the lower face 85 of the member 70.

Suitable bearing rings 101 are interposed between the shaft 86 and the housing 65. The shaft 86 is maintained in proper axial position with respect to the housing 68 by the collar 102 which corresponds to the collar 33 in Figs. 2 and 3.

Bearings 103 may be provided between the shaft 73 and the pumping member 70.

Referring to Fig. 8, the retaining ring 96 on the shaft 73 corresponds to the retaining ring 25 shown in Fig. 2; however, some clearance is allowed between the ring 96 and face of the block for the bearings 103 to permit the described movement of the shaft 73.

The pumping member and the housing may be constructed of any suitable material, such as metal or plastic, and the pump may be used with any standard tube having sufficient wall resiliency to recover its shape between successive cyclic compressions.

It will be appreciated that the pump may be used effectively and will fulfill all the objects of the invention in many applications. However, it may be of interest to note that the pump has been found of particular use for the pumping of blood, especially in blood transfusions. The action of the pump does not result in any measurable amount of hemolysis, i. e. a destruction of the blood cells. A pump embodying the invention has been used for regular transfusions as well as for intraarterial transfusions. Present transfusion techniques require that some means be available in the operating room by which blood can be transfused rapidly into the patient. None of the various methods previously available had the same degree of simplicity and safety as this new pump which may be operated without priming, which may use standard tubing, and which does not require sterilizing before using because the blood being pumped through the tube does not at any time come in contact with the pump. Furthermore, the tube may be placed in the pump without disturbing the ends of the tube.

In accordance with the provisions of the patent statutes, I have herein described the principles of the operation of the invention, together with the elements which I now consider the best embodiments thereof, but I desire to have it understood that the structure disclosed is only illustrative and the invention can be carried out by other means. Also, while it is designed to use the various features and elements in the combinations and relations described, some of these may be altered and modified without interfering with the more general results outlined.

Having thus described my invention, I claim:

1. A pumping apparatus for moving fluid through a flexible tube by compressing successive contiguous areas along a length of said tube formed in a loop during each pumping cycle, comprising, a flexible tube, a chamber having a cylindrical wall, a floor portion, and an open end, a cover adapted to be removably fixed on the open end, at least one opening formed in the cylindrical wall and having at least two channels extending from said opening in the wall, substantially at right angles to each other and substantially tangent to the cylindrical wall, said channels and said opening being of a size to constrictively hold two portions of the tube which is crossed upon itself and looped in the chamber and positioned adjacent the cylindrical wall, said opening and said channels extending upwardly to the open end of the chamber to permit the placing of the tube in the opening and channels by passing it in from the open end whereby the loop of tube may be placed in the pumping apparatus without disturbing the terminal ends of the tube remote from the loop, the wall of the chamber being of sufficient axial length to accommodate the tube when in compressed condition, a cylindrical pumping member having a diameter smaller than the cylindrical wall of the chamber, means for rotatably mounting the pumping member and means for moving the pumping member in a path about the axis of the cylindrical wall so that successive areas of the periphery of the pumping member compress successive contiguous areas along the length of the loop of tube against the cylindrical wall during each cycle of the pumping member in the path about the axis of the cylindrical wall, the tube being substantially continuous around the wall of the chamber so that the pumping member commences a new cycle upon the completion of the preceding cycle.

2. A pumping apparatus adapted for alternately using cylindrical pumping members of various diameters for moving fluid through flexible symmetrical tubes of various diameters by compressing successive contiguous areas along a length of a tube of selected diameter during each

pumping cycle, comprising, a flexible tube of selected diameter, a chamber having a cylindrical wall, a floor portion and an open end, a cover adapted to be releasably fixed on said open end, two channels formed in the cylindrical wall and adapted to receive tubes of the said various diameters, one of said channels extending from the open end to a point adjacent the floor of the chamber and the other of said channels extending part way to said floor, said channels intersecting on the face of the cylindrical wall and diverging at substantially right angles to each other as they extend through the wall, means fixed on the outside of the wall for adjustably and constrictively engaging two portions of the tube of selected diameter extending through said channels, the tube crossing itself at the intersection of the channels being looped in the chamber and positioned adjacent the cylindrical wall, said channels extending upwardly to the open end of the chamber to permit the placing of portions of the tube in the channels from the open end of the chamber, the wall of the chamber being of sufficient axial length adapted to accommodate tubes of the said various diameters when in compressed condition, a cylindrical pumping member of selected diameter interchangeable with cylindrical pumping members of various diameters each having a diameter smaller than the cylindrical wall of the chamber, mounting means for rotatably supporting the selected pumping member, means for moving the mounting means for the pumping member in a path about the axis of the cylindrical wall so that successive areas of the periphery of the selected pumping member compress successive contiguous areas along the length of the loop of the selected tube against the cylindrical wall during each cycle of the pumping member in the path about the axis of the cylindrical wall.

3. A pumping apparatus for moving fluids through a flexible tube by compressing successive contiguous areas along a length of said tube arranged in a loop during each pumping cycle, comprising, a flexible tube, a chamber having at least one cylindrical wall, at least one port in said wall, said port and said wall defining an opening through the top of the chamber whereby the tube may be placed in the chamber in looped condition and whereby two portions of the tube may extend outwardly from said chamber through said port, a cylindrical pumping member, means for mounting the pumping member for rotation about its axis and means for moving the axis of the pumping member in a circular path about the axis of the wall so that successive areas of the periphery of the pumping member resiliently compress successive areas along the length of the tube disposed in the chamber, the means for mounting the pumping member and resiliently pressing it into contact with the tube includes a drive shaft coaxial with the wall of the chamber, a crank shaft member connected to the shaft, a bell crank, one arm of which is provided with a crown collar on which the pumping member is rotatably mounted, the center of the bell crank being pivotally mounted in said crank shaft member for movement in a circular path about the axis of the chamber, the other arm of the bell crank being spring pressed by a spring means axially disposed with respect to the wall.

4. The apparatus of claim 3 with means for adjusting the resilient pressure of the spring means, including an adjustable member axially adjustable with respect to the axis of the wall of the chamber.

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