PUMP

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FIG. 1

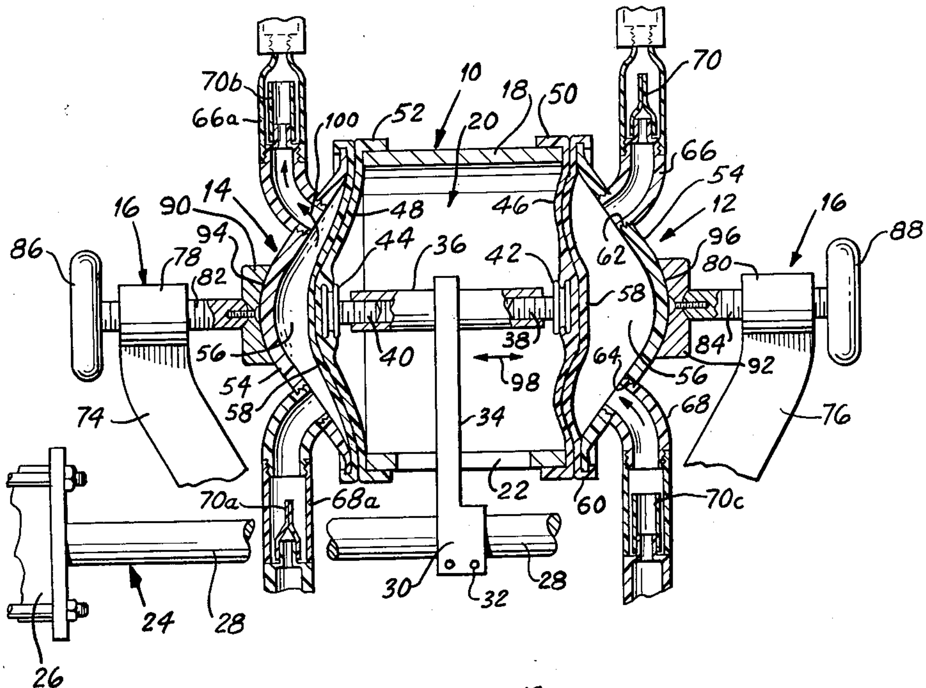

FIG. 2

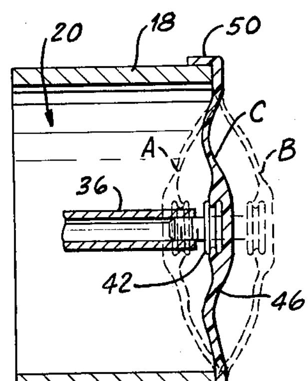

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FIG. 3

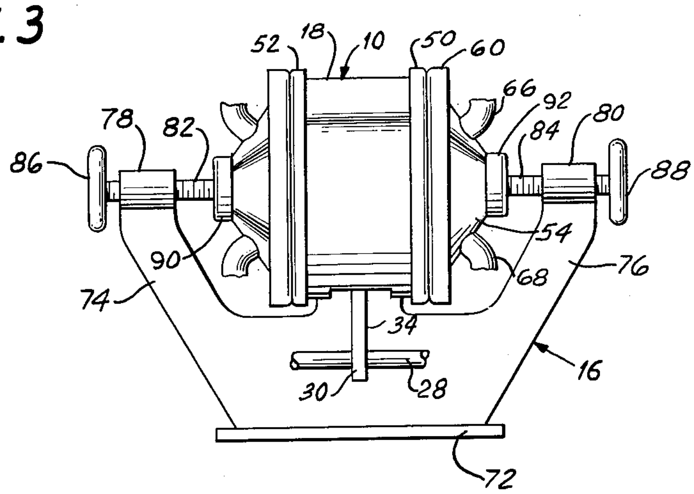
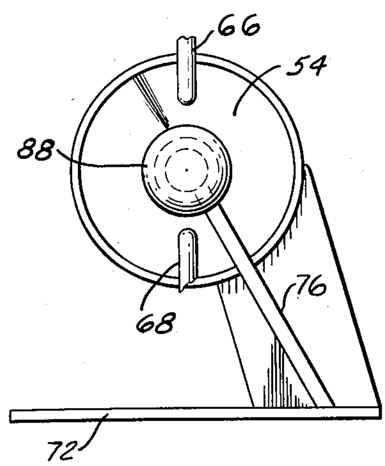


FIG. 4



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This invention relates to pump arrangements and structures and, in general, to devices for imparting movements to mediums such as fluids.

It is an object of the invention to provide an improved means for selectively applying pressures to fluids in such a manner as to cause a flow of the same.

It is also an object of the invention to provide an improved pump having a minimum of parts which are readily assembled and taken apart in order to facilitate manufacture and maintenance.

A further object of the invention is to provide an improved pump having a minimum of frictionally engaged parts in order to provide for maximum longevity and minimum repair requirements.

Another object of the invention is to provide an improved pump requiring minimum priming.

Still another object of the invention is to provide an improved pump for processing fluid mediums transporting materials susceptible of being destroyed or injured by the application of pressure thereto.

Also included among the objects of the invention is the provision of a pump capable of producing or being adapted to produce complex pressure wave forms.

Further, it is an object of the invention to provide an improved means for imparting movements to fluids and the like while handling the same in a hygienic, sterile and antiseptic manner.

Along similar lines, it is an object of the invention to provide an improved pump including pump units which are readily demounted for purposes of cleaning.

Still another object of the invention is to provide a pump structure susceptible of being designed to avoid positive pumping displacements in order to apply pressure gently to the fluid being processed.

Yet another object of the invention is to provide an improved pump adapted for employing replaceable pumping units of different capacity.

Briefly, a pump provided in accordance with the invention may comprise a unit wherein a relatively rigid member and a resilient member cooperatively define a pump chamber, special means being provided, preferably in detachable relationship with said unit, to operate said resilient member to perform a pumping action.

Pumps provided in accordance with the invention have been very well received in the medical and surgical fields and, in this regard, it is an object of the invention to provide an improved artificial ventricle or pump adapted for simulating the action of the heart.

Moreover, in this regard, it is an object of the invention to provide an improved means for creating an artificial pulse for the handling of blood in an extra-corporeal blood circulation system and to assure that the blood is handled in an antiseptic manner.

Still further, inasmuch as blood cells are readily damaged by the application of pressure, it is an object of the invention to provide for processing blood without damaging the same. In other words, pumps of the invention are atraumatic with respect to blood and the like.

Other objects, features and advantages of the invention will be found in the following detailed description of a preferred embodiment thereof as illustrated in the accompanying drawing in which:

FIG. 1 is a front view, partially in section, of a pump provided in accordance with a preferred embodiment of the invention;

FIG. 2 is a sectional view of a component of the structure of FIG. 1 taken on the vertical axis of symmetry thereof;

FIG. 3 is a front view of the pump illustrating the outer appearance thereof; and

FIG. 4 is an end view of the pump structure shown in FIG. 3.

The pump illustrated in the drawing comprises generally a central section **10** having at its opposite extremities pump units **12** and **14** held thereagainst by means of an assembly unit **16**.

The central section **10** comprises a generally cylindrical casing or housing **18** having an opening **20** extending therethrough and provided at its lowermost section with an opening or slot **22**.

Operatively associated with the pump is a source of reciprocating or oscillatory power **24**. Power source **24** may comprise, for example, a double-acting piston and cylinder arrangement **26** of conventional construction, of which the piston is connected to a rod **28** which is given a linear reciprocating motion by the action of said piston and cylinder arrangement.

On the rod **28** is mounted a collar or bracket **30** by means of clamping bolts **32** or by mean of any conventional connecting arrangement, the bracket **30** supporting an arm **34**. Arm **34** is, of course, given the reciprocating movement provided by the rod **28**.

On the arm **34** in the opening **20** is mounted a rigid body **36** which is illustrated as a hollow metallic sleeve which is internally threaded. Extending from opposite ends of this body are two members **38** and **40** which are threadably and thereby adjustably engaged with the body **36** and which respectively include heads **42** and **44**.

The housing **18** is a rigid body faricated from a metal such as stainless steel, aluminum or the like, or, alternatively, from a synthetic material having substantial axial strength, the need for which will become apparent hereinafter. On the housing **18** at the opposite open extremities thereof are affixed flexible diaphragms **46** and **48**. These flexible diaphragms may be made of a synthetic material such as, for example, neoprene or may be of a heavy duty rubber capable of being repeatedly stretched and manipulated without tearing or being harmfully affected by the oscillating motion imparted thereto by body **36**. Preferably flexible diaphragms **46** and **48** are resilient and are formed with flanges **50** and **52** which snap over the housing **18** to constitute a unit therewith. It is to be noted that these diaphragms conveniently surround heads **42** and **44** which are molded therein.

The pump units **12** and **14** are detachable from the central section **10**. These units are, in fact, simply held in abutting relationship therewith. Each of these units comprises a recessed shell or substantially rigid member **54** which, in the preferred embodiment of the invention, is of concave shape. This rigid member defines an inner opening or recess **56**, there being provided a resilient diaphragm **58** which confines the opening **56** in order to provide a variable-volume pumping chamber.

The shell 54 is preferably made of a material sufficient to resist deformation due to thrusts applied thereagainst by means of the assembly unit **16**. Metals may, of course, be employed for this puropse, but certain plastics also have sufficient strength, and one particularly suitable plastic is polypropylene.

The resilient diaphragm **58** is formed with a flange **60** for peripherally engaging the outer extremity of the associated shell **54**. A separate band may be employed if desired to lock the diaphragm and shell together, although this has not been found necessary if the flange of the resilient diaphragm is properly designed. The shall **54** and diaphragm **58**, as will be seen, constitute an integrated unit forming a sub-assembly of the pump structure.

Each shell 54 is provided with threaded openings 62 and 64, by means of which are engaged the threaded extremities of tubes 66 and 68 (specific ones of which are hereinafter designated by a letter suffix). These tubes constitute the outlet and inlet tubes associated with each unit. In each tube is provided a one-way or unidirectional valve 70 (also hereinafter specifically distinguished by letter suffixes).

As noted above, the pumping units 12 and 14 are held in abutting relationship with the central section 10 by means of the assembly unit 16. This sandwiches the resilient diaphragms against the flexible diaphragms (there is no mechanical connection between these diaphragms) and expels the air from between the diaphragms which in turn causes the diaphragms to adhere together with a suction-like effect. For this purpose, the assembly unit 16 is provided with a base 72 (FIGS. 3 and 4) provided with arms 74 and 76. At the extremities of these arms are internally threaded collars 78 and 80 through which extend threaded members 82 and 84 provided respectively with handles 86 and 88 which urge blocks 90 and 92 against the pump units 12 and 14. The blocks 90 and 92 are conveniently provided with concave recesses 94 and 96 in order to accommodate readily the shells 54 of pump units 12 and 14.

In operation, the body 36 is given a reciprocating motion as indicated by arrow 98 to flex diaphragms 46 and 48 between the extreme positions illustrated by dotted lines at A and B in FIG. 2. It is seen, in FIG. 2, that in the median position of the diaphragm 46, as illustrated at C, the diaphragm has an undulated or flexed shape due to the fact that its effective area exceeds the cross-sectional area of the opening 20 of housing 18. This enables an undulating or wave-like deformation to be imparted to the diaphragms 46 and 48 and thus to the resilient diaphragms 58 of units 12 and 14.

With the flexible diaphragms being thus operated, a pumping condition is established in units 12 and 14, and, while the resilient diaphragm of one of these units is being forced towards the associated shell, the resilient diaphragm in the other of said units withdraws from its associated shell. This causes the fluid in one unit to be forced outwardly therefrom via the associated outlet tube while fluid is drawn into the other unit through the inlet tube associated therewith.

More specifically, in FIG. 1, flexible diaphragm 48 is being driven into pump unit 14. Fluid cannot flow out through inlet tube 68*a* inasmuch as the one-way valve 70*a* is closed. However, fluid is forced out of the unit 14 in the direction indicated by arrow 100 since the valve 70*b* in the outlet tube 66*a* readily yields to the pressure of the fluid.

At the same time, flexible diaphragm 46 releases its pressure on resilient diaphragm 58 in pump unit 12 and withdraws this resilient diaphragm from the shell 12. Fluid cannot flow via outlet tube 66 back into the unit 12 since the valve 70 acts to shut off this tube. However, fluid is drawn into unit 12 from a fluid source or reservoir (not shown) via tube 68 due to the opening of valve 70*c*.

The units 12 and 14 repeatedly interchange functions and are reciprocally filled and exhausted as the operation of power source continues. Accordingly, a constant supply of fluid is assured alternatively via outlet tubes 66 and 66*a* and a supply of fluid is continuously draw into pump units 12 and 14 via inlet tubes 68 and 68*a*.

Basically, a pump of the above construction comprises a relatively rigid member such as the shell 54 having an inlet and an outlet opening with a relatively deformable and resilient member confining with said shell a variable-volume pump chamber, means being positioned externally of this chamber in engagement with the resilient member for oscillating the same towards and away from the rigid member to create a pumping action in the chamber. In its more refined form, however, the invention contemplates that two such pumping units be provided so that a continuous flow of fluid is assured, one unit complementing the action of the other, so that one unit is always being charged while the other is being discharged.

As will be noted from the above description, the means provided to apply forces to the resilient member of each unit is actually separate from the same and engages this member essentially in abutting relationship with suction-like forces. Moreover, it will be noted, for example, that the flexible diaphragms 46 and 48 first apply pressure against the associated resilient diaphragms in the direction in which the resilient diaphragms are urged towards the associated shells. The resilient diaphragms then move away from the associated shells in response to the movement of their respective flexible diaphragms.

An important feature of the invention which should be noted is that the curved shapes of the diaphragms cause them to protrude generally into the associated shells. This cuts down the normal volumes of these shells and minimizes the priming fluid required to initiate a pumping operation under certain circumstances. Further, the shapes of the diaphragms facilitate employing shells which are conical or similarly shaped, and are thus best suited to absorb the physical forces applied to them by blocks 90 and 92.

The effective areas of the flexible members 46 and 48 have been discussed above and it has been noted that these effective areas exceed the corresponding cross-sectional areas of the housing 18 so as to impart a wave-like pattern of motion to the flexible diaphragms. It is also to be noted that the flexible diaphragms engage the resilient diaphgragms in a positive manner only along limited areas since the areas of heads 42 and 44 are substantially less than the effective areas of resilient diaphragms 58. This means that pumping units 12 and 14 do not have positive displacements as would be employed, for example, in a conventional piston and cylinder type pump, since those areas of diaphragms 58 which are not positively subjected to pressure by heads 42 and 44 are yieldable.

It is also clear from the above description that units 12 and 14 are readily detachable from the remainder of the pump structure and this is especially valuable with respect to maintenance and repair. This feature, moreover, facilitates initial assembly and additionally permits the substitution of shells 54 of different sizes so as to permit an adjustment of basic pump capacity.

It has been mentioned above that pumps of the invention have been found especially adaptable in connection with medical and surgical techniques. More specifically, pumps of the invention have been found especially suitable for use in extracorporeal blood circulation systems wherein they are employed to constitute artificial ventricles for simulating pulses.

In the handling of blood, it is essential to avoid the crushing of the blood cells which are readily destroyed when subjected to mechanical pressure. Accordingly, it is especially advantageous to avoid a positive displacement by permitting a yielding of diaphragms 58 as noted above. Moreover, in a preferred embodiment of the invention the resilient diaphragms 58 are preferably made of a low durometer material having a smooth surface and a durometer constant of 40 (A scale) and preferably less than 20. Conventional rubbers are generally not of such a low durometer except when foamed and amongst the suitable materials found useful for this application is a synthetic known as silicone rubber. The use of low durometer, resilient materials as resilient diaphragms in structures of the invention have enabled the processing of blood with far less damage to blood cells in plasma than has been the case with known types of pumps. Accordingly, pumps of the inventon may be considered as being atraumatic as regards blood cells and the like.

It is noted that the threaded engagement of members 38 and 40 with rigid body 36 is adapted to permit an adjustment of oscillation stroke independently of the operation of piston and cylinder arrangement 26. Generally heads 42 and 44 are so arranged as to permit the resilient diaphragms 58 to be at all times spaced from shells 54 even at the extremities of oscillation. This adds to the atraumatic characteristic of the pump as has already been indicated.

As noted above, the shells 54 and diaphragms 58 constitute separable pumping units. The materials indicated above for these elements are all non-toxic and capable of being exposed to high temperatures for sterilizing operations such as autoclaving. Accordingly, after a surgical operation it is possible to remove units 12 and 14 and sterilize the same as a whole without any complicated mechanical procedure so that the units may be readily used over and over again. The wave form imparted to resilient diaphragms 58 by means of flexible diaphragms 46 and 48 is complex. The character of such resilient members is comparable to the resilient character of the muscle tissues of the heart so that pumps of the invention can be used to simulate the operation of the ventricle in the human body. This provides a use which enhances the value of the invention.

With the above structure, the invention achieves its objective of providing an improved means for selectively applying pressure to fluids so as to cause a flow of movement thereof. It is obvious from the above that a pump has been provided having a minimum of parts which are readily assembled and disassembled. It should be further clear from the above description that an improved pump has been provided having a minimum of frictionally engaged parts so as to provide for improved operation.

Additionally, it has been indicated that pumps of the invention are especially adapted for processing fluids without injuring the contents thereof and that these pumps are adapted for producing complex pressure wave forms for simulating the human pulse.

Moreover, it is clear that pumps of the invention are especially suited for hygienic, sterile and antiseptic techniques since units are included which are readily remounted for purposes of cleaning. This very same arrangement enables the ready substitution of pumping units of different capacities.

There will now be obvious to those skilled in the art many modifications and variations of the structures set forth above. These modifications and variations will not, however, depart from the scope of the invention if they are defined by the following claims.

What is claimed is:

1. A pump comprising a relatively rigid member having an inlet opening and an outlet opening, and defining an open chamber, valve means operatively associated with said openings to provide for a one-way flow therethrough, a relatively deformable and resilient member extending across said rigid member and confining said open chamber to form a variable-volume pump chamber, and means positioned externally of said chamber and in engagement with said resilient member, said means oscillating said resilient member towards and away from said rigid member to create a pumping action in said chamber, said means being separate from said resilient member and engaging the same in abutting relationship, said means and resilient member including diaphragms in face-to-face relation with air excluded from therebetween so as to provide a suction effect between the diaphragms.

2. A pump as claimed in claim 1, wherein said resilient member has a determinable effective area transverse to the direction of oscillation of said means, said means including a rigid portion for applying pressure to an area of said resilient member which latter area is substantially less than said determinable effective area whereby to avoid a positive displacement of the entire effective area of the resilient member into the pump chamber.

3. A pump as claimed in claim 1, wherein said valve means comprises uni-directional valves coupled to said inlet and outlet openings.

4. A pump as claimed in claim 1, wherein the first said rigid member and said resilient member are affixed to each other and detachable as a unit from said means.

5. A pump as claimed in claim 1, wherein the resilient member has a durometer of less than 40.

6. A pump as claimed in claim 1, wherein said means comprises a rigid support and an oscillatable member movable with respect thereto, comprising clamp means for holding said rigid and resilient members detachably against said support with said resilient member in a position to be engaged by said oscillatable member.

7. A pump as claimed in claim 1, comprising means for applying to the first said means an adjustable, linear stroke.

8. A pump comprising a rigid housing having an opening extending therethrough, a rigid movable member extending through said opening, means coupled to said movable member to oscillate the same in said opening, flexible diaphragms on said housing at opposite ends of said opening and connected to said movable member to be displaced thereby, and variable volume pump units against said flexible diaphragms to be operated thereby, said pump units each comprising a rigid recessed shell defining an open chamber a resilient diaphragm mounted on said shell to define a closed pump chamber, each shell having inlet and outlet openings, and valve means operatively associated with said openings to provide for a one-way flow therethrough said resilient diaphragm being mounted in abutting relationship with its associated flexible diaphragm.

9. A pump as claimed in claim 8, wherein the shell and resilient diaphragm of each pump unit are peripherally engaged, said units having only an abutting relationship with said flexible diaphragms, said pump further comprising assembly means for detachably holding said units against said housing with the flexible diaphragms sandwiched therebetween.

10. A pump as claimed in claim 9, wherein said valve means comprises unidirectional inlet and outlet valves connected to each unit.

11. A pump as claimed in claim 10, wherein said assembly means comprises a bracket including spaced arms and threadably adjustable and opposed members on said arms and holding the units and housing therebetween.

12. A pump as claimed in claim 10, wherein said movable member includes portions embedded in said flexible diaphragms.

13. A pump as claimed in claim 10, wherein said movable member includes a central main body and two members threadably adjustable on said body and in engagement with said flexible diaphragms.

14. A pump as claimed in claim 10, wherein said resilient diaphragms have a durometer of no more than about forty.

15. A pump as claimed in claim 10, comprising a double-acting piston connected to and driving said movable member.

16. A pump as claimed in claim 10, wherein said units are entirely of non-toxic autoclavable materials.

17. A pump as claimed in claim 10, comprising inlet and outlet tubes housing said valves and threadably engaged with said shells.

18. A pump as claimed in claim 10, wherein said housing has the shape of a cylinder.

19. A pump as claimed in claim 18, wherein said flexible diaphragms have areas exceeding the cross-sectional area of said cylinder so as to promote undulations in the flexible diaphragms during pumping operations.

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