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NASA CASE NO. MSC-20,907-1

PRINT FIG. 11

15P.

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(NASA-Case-MSC-20907-1) MULTI-PATH PERISTALTIC PUMP Patent Application (NASA) 15 p CSCL 13K

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MSC-20907-1
Serial No. 927992
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Patent

AWARDS ABSTRACT

MSC-20907-1

MULTI-PATH PERISTALTIC PUMP

The instant invention is directed to a peristaltic pump for critical laboratory or hospital applications requiring precise flow rates over an extended period of time.

Within the cylindrical barrel pump housing 10 is a single-piece, molded, elastomeric, cylindrical liner 30 with a multiplicity of flattened helical channels 31 created therein from one end of the liner to the other. Three cylindrical rollers 25 rotate about the center axis of the pump around the inside surface of the liner selectively compressing the liner, and hence the helical channels between the rollers and the barrel housing, creating a pumping action by forcing trapped fluid in the helical channels axially from one end of the liner to the opposite end.

The novelty of the invention appears to lie in the provision of the special liner with multiple helical channels as the pumping chamber, rather than the standard single elastomeric tubing which is squeezed repeatedly by rollers to move the liquid through a typical peristaltic pump. Large, repeated deflections on the standard tubing causes a permanent "set" in the tubing, thus either changing the flow rate, or requiring a new section of tubing to be positioned in the pump head. Further, this configuration minimizes the amount of outflow pulsation which is characteristic of a typical single tubing peristaltic pump.

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Description

Multi-path Peristaltic Pump

Origin of the Invention

The invention described herein was made by an employee of the United States Government and may be manufactured and used by or for the Government of the United States of America for governmental purposes without payment of any royalties thereon or therefore.

Background of the Invention

This invention relates to pumping methods and apparatus, and more particularly relates to improved peristaltic pumping methods and apparatus and the like.

It is well known that a peristaltic pump is a device having a flexible conduit or the like interconnected to carry a fluid, and further provided with external means for contorting or manipulating the conduit to cause the fluid therein to move through the pump. More particularly, means are included within the pump to repetitively compress and release a portion of the fluid-filled conduit, in order to squeeze the fluid progressively through the conduit. It is also well known that a peristaltic pump is especially useful for applications wherein fluids are required to be discharged or dispensed in small but very precise quantities or at very precise flow rates.

A typical peristaltic pump will generally comprise a pump drive, a pump head having a compression surface within its cavity, and a length of elastomeric tubing extending through the pump head to serve as a fluid flow channel. In addition, the pump will include a rotor compression subassembly disposed within the pump head for repeatedly compressing the tubing against the compression surface to force fluid through the tubing by peristaltic action. The rotor compression subassembly conventionally includes a rotor which is attached to the pump drive by means of a drive shaft, and one or more roller members attached to the periphery of the rotor.

In the peristaltic pumps of the prior art, a single length of plastic or elastomeric tubing provides a single flow path for the pumping of fluid through the pump. The tubing extends through the pump head and is placed circumferentially adjacent and between the rollers and the compression surface. The pump drive turns the drive shaft which rotates the rotor, which thereby rotates the rollers. These rotating rollers act to repeatedly and momentarily compress a portion of the tubing against the compression surface within the pump housing, in order to develop the peristaltic pumping action necessary to move a fluid along a flow path.

It will be apparent that a peristaltic pump differs from other types of pumps, in that it tends to deliver fluid in a pulsating manner rather than in a constant flow. In some applications, such as where it is sought to dispense fluid in discrete drops or other quantities of precise magnitude, this pulsation characteristic may be used to an advantage. In other applications, however, this pulsation characteristic of a peristaltic pump is an undesirable feature where the objective is to produce fluid flow at very precise flow rates. On the other hand, where the compression subassembly is composed of two or even three rollers, this pulsation characteristic is reduced if not eliminated.

Rotary peristaltic action is used for a variety of low pressure, low volume positive displacement pumping actions to create the movement of fluids. Although all positive displacement pumps produce some pulsation in the outflow, tubing pumps usually produce greater pulsation than is desired for efficient operation. It has been determined that the amount of pulsation in peristaltic pumps can be minimized by using three rollers in the pump head or by utilizing a flow integrator.

Many different types of peristaltic pumps have been designed and constructed to meet various purposes and uses. In particular see the devices and techniques described and taught in the prior art exemplified by U.S. Patent No. 4,365,728(Tokorozarva, et al.) wherein a peristaltic pump is provided with a discharge apparatus utilizing a single length of elastic tubing wherein means are included to squeeze and release a section of the tubing to produce peristaltic pumping action. Likewise, other single-tube peristaltic-type pumps have also been devised as shown in U.S. Patent No. 4,446,993(Tokorozarva); U.S. Patent No. 4,296,875 (Borglum); U.S. Patent No. 4,334,640(Van Overbruggen et al), U.S. Patent No. 3,877,609(Cullis); and U.S. Patent No. 2,955,543 (Daniels). Manually-actuated peristaltic type pump action utilizing a single tube for fluid flow, for the dispensing of liquids, is illustrated in U.S. Patent No. 4,232,828 (Shelly) and U.S. Patent No. 4,271,988(Clausen).

Although all of such peristaltic pumps have been useful for particular applications and purposes, they have also tended to be subject to another problem which limits their effectiveness to dispense precise quantities of fluid, or to dispense fluids at a precise flow rate, over an extended period of time. In particular, there is a tendency for the flexible or plastic conduit to eventually lose elasticity as a result of being repeatedly squeezed and released over an extended period of time. When this occurs, there is a decrease in either the flow rate of the pump, or a decrease in the magnitude of fluid being discharged with each pumping cycle, whereby the very purpose of a device of this type is substantially negated.

More particularly, there is a tendency for the plastic tube or conduit to acquire a permanent "set" after being repeatedly subjected to large deflections or deformations during only a short period. In those situations, such as where the pump is used in critical laboratory or hospital applications, the tubing must be repositioned in the pump at frequent intervals making a fresh section of tubing available for compression, whereby the pump will accordingly perform as required.

Large deformations of the tubing by the rollers, and especially when repeated over a period of time, tend to cause a permanent "set" to develop in the tubing due to fatigue occurring in the elastomeric material from which the tubing is formed. A change in the flow rate of fluid through the tubing results from the development of the "set" in the tubing.

Where the pump is used in critical laboratory or hospital applications which require fluid flows to be maintained within precise limits, it thus becomes necessary that the tubing be repeatedly repositioned in the pump after only short periods of operation, due to this "set" which changes the flow rate of the pump. More particularly, this causes great inconvenience because the pump must be stopped and disconnected from the system at frequent intervals, so that the tubing can be manually pulled through the pump to position a new section of tubing adjacent the rollers, in order to maintain the correct flow rate for fluids being transferred or dispensed by the pump.

These and other disadvantages of the prior art are overcome with the present invention, however, and novel peristaltic pumping methods and apparatus are provided for dispensing fluids in precise quantities over an extended operating interval.

Summary of the Invention

In a preferred embodiment of the present invention, a peristaltic pumping mechanism is provided with a flexible liner having a plurality of helical passages in its wall portion, and is further provided with a plurality of rollers which each constrict the liner so as to compress portions of these helical passages, whereby fluid is forced through the liner ahead of such constrictions in the liner. As the rollers move over the liner, the passages open elastically to draw in fluid from the intake portion of the pump and thereby make such fluid available when the rollers return to the liner.

It is desirable for purposes of the present invention, that each passage in the liner be closed by one of the rollers to prevent backflow. Accordingly, it is a feature of the present invention that the angle between the rollers preferably be less than the helix angle of the passages in the liner. It is also a feature of the present invention that the passages in the liner be sized and shaped to minimize fatigue stresses in the material from which the liner is formed, whereby the liner will not acquire or develop a noticeable "set" even after extended periods of operation.

Referring again to the preferred embodiment of the present invention, the liner may be formed as a generally tube-like body within the pump assembly, and the rollers may conveniently be positioned to press outwardly against the interior surface of the liner as will hereinafter be described in detail. In an alternative embodiment of the invention, however, the rollers may be positioned to be urged against the exterior surface of the liner. In this alternative embodiment, the rollers may be gear-driven or belt-driven, rather than being driven directly by the shaft of a motor or the like, so that an inlet connection can be conveniently provided for the fluid or liquid to be pumped.

Accordingly, it is an object of the present invention to provide improved peristaltic pumping methods and means for precisely dispensing fluids over an extended operating interval.

It is also an object of the present invention to provide improved peristaltic pumping methods and apparatus for dispensing precise quantities of fluid over an extended operating interval.

It is further an object of the present invention to provide improved peristaltic pumping methods and apparatus for dispensing fluid at precise flow rates over an extended operating interval.

It is another object of the present invention to provide improved peristaltic pumping methods and apparatus employing a plurality of compressible helical passageways for progressively conducting fluid in discrete quantities and at precise flow rates.

It is a particular object of the present invention to provide an improved peristaltic pump comprising a housing, a rotor compression subassembly mounted in said housing, an elastomeric liner having a plurality of helical flow channels formed therein disposed between said housing and said rotor compression subassembly, and rotary drive means for rotation of said rotor compression subassembly.

It is also a particular object of the present invention to provide, in a peristaltic pump and the like having a compression surface defined by an internal cavity located between intake and outlet ports therein, the improvement in combination therewith comprising a flexible liner means disposed in said housing adjacent said compression surface and having a plurality of flow-channels interconnecting said intake and outlet ports therein, and compression means rotatably disposed in said housing adjacent said liner means transversely of said flow channels therein.

These and other objects and features of the present invention will be apparent from the following detailed description, wherein reference is made to the figures in the accompanying drawing.

In the Drawing

Fig. 1 is a longitudinal cross-sectional view of a preferred embodiment of the present invention taken along line B-B of Fig. 2.

Fig. 2 is a cross-sectional view of the present invention taken along line A-A of Fig. 1.

Detailed Description

Referring now to Fig. 1, there is illustrated a peristaltic pump 1, constructed in accordance with the teachings of the present invention, which generally comprises a cylindrical pump housing 10, a rotor compression subassembly 20 coaxially mounted within said pump housing, and a cylindrical, multi-path elastomeric liner 30 positioned within the annulus between the inner wall of the pump housing and the outer surface of the rotor compression subassembly.

Pump housing 10 includes a cylindrical pump barrel 11 having an end cap 12 attached to each end thereof, and an end cap bearing 13 coaxially mounted at the center of each end cap. Each end cap 12 details a fluid port 14 which communicates with a fluid reservoir 15, such reservoir extending annularly through end cap 12. Fluid ports 14 include threaded walls 16 which are advantageously utilized for the attachment of tubing or the like which serves as a communication means between a fluid source and a fluid discharge.

End cap bearings 13 provide support for a rotatively mounted rotor compression subassembly 20 in addition to providing a clamping surface for sealing fluid within pump housing 10. Through the engagement of threads 17, formed on the outer surfaces of each end of pump barrel 11, with threads 17a formed at the proximal ends on the inner surface of end cap 12, and further, by the engagement of threads 18, formed on the outer surface of the distal end of end cap bearing 13, with threads 18a formed on the inner surface of the distal ends of end caps 12, fluid is sealed within pump housing 10.

Rotor compression subassembly 20 includes a rotor 21 disposed within the cavity of pump housing 10, such rotor being attached at one end to a drive shaft 22 and to a bearing shaft 23 at the opposite end. Shaft 22 is rotatively supported and axially mounted at the center of one end cap bearing 13 for attachment to an external pump drive means (not shown) to provide rotary drive of the rotor compression subassembly 20 for operation of pump 1, while shaft 23 is rotatively housed within the other end cap bearing 13.

Longitudinal roller bar supports 24 are mounted to and disposed within, the periphery of rotor 21, and provide support for elongated, annular roller bars 25 which are concentrically mounted thereupon, such roller bars being free to rotate about their respective longitudinal axes. Preferably, three (3) roller bars 25 are attached to rotors 21 so as to provide optimal reduction of pulsation in fluid outflow while preventing the loss of flow capacity below practical limits.

As can be seen in Fig. 2, elastomeric liner 30 is of a single-piece, molded construction and includes a plurality of substantially flattened parallel flow channels 31, created in a helical path and formed therein to extend longitudinally along the length of liner 30 between fluid reservoirs 15 so as to provide multiple parallel flow paths therethrough.

In operation, conventional tubing members or the like are first attached to fluid ports 14 by means of male connectors to engage fluid port threads 16. The tubing members are then attached respectively to a fluid source and a fluid discharge. Drive shaft 22 of rotor compression subassembly 20 is operatively connected to an external rotor drive means to provide rotation of the rotor compression subassembly. As the drive means rotates rotors 21 and the attached roller bar supports 24, peristaltic action is initiated. Such action occurs when rotating roller bars 25 compress the inner surface of elastomeric liner 30, thereby selectively compressing the helically arranged flow channels 31 between the inner surface of the pump barrel and the roller bars 25 (Fig. 2) to create a pressure seal on the flow channels 31. Fluid is drawn into fluid port 14, and subsequently into the adjacent fluid reservoir 15, as roller bars 25 move from the compressed areas of the liner 30. This releasing action causes the flow channels 31 to expand, thereby creating a suction action. The continual rotation of roller bars 25 and the subsequent selective compression and release of the helically-arranged flow channels 31 causes movement of fluid through channels 31. Fluid trapped in the flow-channels is forced axially from one end of the liner 30 to the opposite end, and subsequently into reservoir 15 and fluid port 14 attached to the fluid discharge.

Referring again to the structures depicted in Figures 1 and 2, it will be noted that each of the several flow channels 31 in the flexible liner 30 are arranged to interconnect both fluid ports 14 separately and independently of each other. Accordingly, if the roller bars 25 act to compress one or more, but not all, of the channels 31 at any one time, the result will be that most if not all of the fluid in the compressed channels 31 will tend to be driven backward through the uncompressed channels 31, rather than forward through the peristaltic pump 1 as intended. Accordingly, it will be apparent that in order for the peristaltic pump 1 to function properly, it is necessary for all of the channels 31 to be compressed and closed any time any one of these channels 31 are sought to be compressed by the roller bars 25.

As may further be seen in Figures 1 and 2, the roller bars 25 are axially aligned as well as rotated about the longitudinal axis of the peristaltic pump 1, and therefore pumping is achieved with this mechanism because the ellipsoid-like channels 31 are helically arranged within the wall portion of the flexible liner 30. Thus, it will be apparent that closure is effected because the roller bars 25 tend to traverse the several channels 31 at an angle. More particularly, it will be apparent that the channels 31 must lie at an angle, relative to the axes of the roller bars 25, which is less than the helical angle of the channels 31 relative to the axis of the liner 30. This, in turn, is another reason why the peristaltic pump 1 illustrated in Figures 1 and 2 is preferably provided with at least three roller bars 25, inasmuch as the traverse angle would have to be greater than 360 degrees if the depicted pump 1 were provided with only a single roller bar 25.

Referring again to the structures depicted in Figures 1 and 2, it will be noted that each of the helical flow channels 31 are aligned with each other but equally spaced apart throughout the wall portion of the flexible liner 30. If each of the roller bars 25 is arranged and sized to traverse a separate different group of the helical flow channels 31 at any one time, then such an arrangement will achieve constant fluid through-put irrespective of the number of different roller bars 25 included within the structures herein depicted.

In this respect, it should be further noted that a peristaltic pump can be provided according to the concept of this invention which is capable of separately but concurrently transferring a plurality of different types of fluids. More particularly, the pump housing 10 may be adapted to have three separate and different input ports in the end cap 12 adjacent the intake end of the pump 2, and three separate and different outlet ports in the other end cap 12 adjacent the discharge or opposite end of the pump 2. Each input port communicates with a selected one of the outlet ports by way of a selected one of a plurality of different groups of the flow-channels 31 in the liner 30, and thus such a pump 2 can effectively achieve a plurality of different through-puts at any one time.

It should also be noted, of course, that a peristaltic pump of this type which is capable of handling a plurality of separate through-puts, will have other uses besides transfer of separate different fluids. In particular, such a pump can also achieve a pressure build-up within a system, by having one outlet interconnected to another different input port, whereby the same fluid is recirculated back through the pump one or more times before being sent on to another location in a system. With each such recirculation cycle or step, however, there is an increase in flow-pressure whereby the subject fluid may ultimately be delivered to the overall system at a much enhanced pressure. The conduits by which the fluid is recirculated back through such a pump, may be external to the pump, or they may be built into the pump itself.

Referring again to the structures depicted in Figures 1 and 2, it should be noted that other alternative embodiments of the present invention may be provided having variations in the number of roller bars 25, and with corresponding variations in the number of groups of flow channels 31 in the liner 30. This, of course, may call for corresponding variations in the helix angle of the flow channels 31 relative to the axes of the roller bars 25 without departing from the spirit and scope of the present invention. Furthermore, in an alternative embodiment of the present invention the roller bars 25 could be relocated adjacent the outer surface of the liner 30 with an inner support for achieving compression of the liner 30. In such a configuration, the roller bars could be belt or gear-driven, rather than being directly driven by a drive shaft attached to an external pump drive, to permit connection of an inlet for fluid flow. Otherwise, the pumped fluid would be required to flow through the inner compression support after exiting the liner.

Further structural and sealing additions, modifications, substitutions, variations and deletions may be undertaken by those skilled in the art within the spirit of the present invention and are understood to be included within the scope of the present disclosure. Accordingly, the methods and apparatus hereinbefore described and depicted are intended as examples only, and are not intended as limitations on the scope of the present invention.

What Is Claimed Is:

Multi-path Peristaltic Pump

Abstract of the Disclosure

A peristaltic pump for propulsive movement of fluids requiring precise fluid flow regulation, said pump generally comprising a cylindrical pump housing having inlet and outlet fluid ports; a rotor compression subassembly coaxially mounted with said pump housing; a cylindrical elastomeric liner subject to compression by the rotor compression subassembly to achieve peristaltic action, said liner having a plurality of helical flow channels formed therein which extend longitudinally between the inlet and outlet fluid ports of said pump housing; and rotary drive means for rotation of said rotor compression sub-assembly.

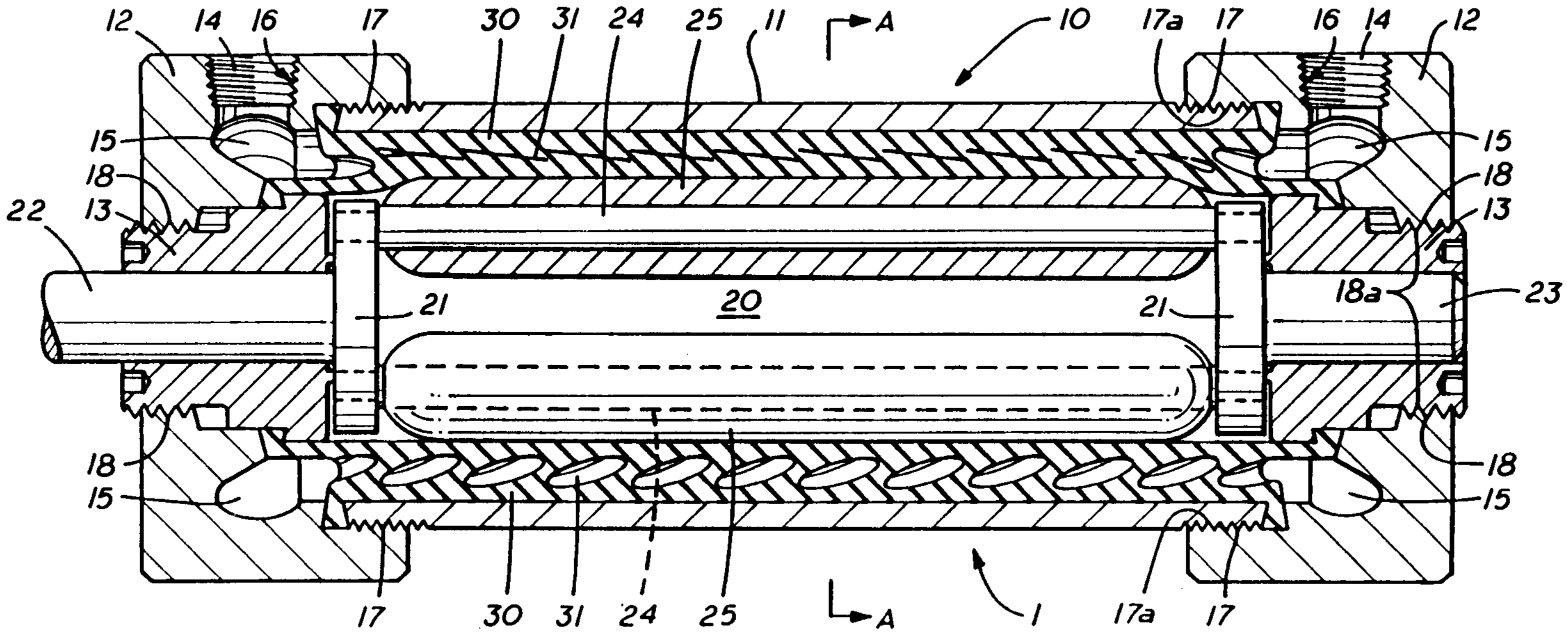
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FIG. 1

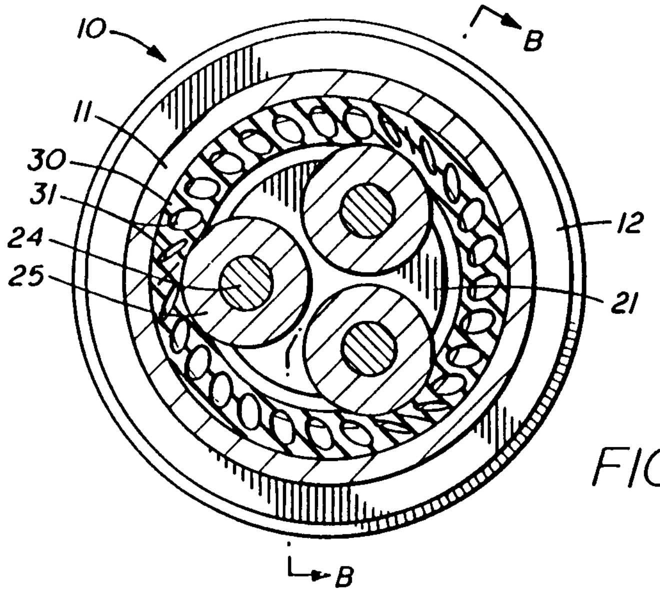
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FIG. 2