Dec. 19, 1967 L. R. WORTH ET AL 3,358,609

FLUID PUMP

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Fig 1

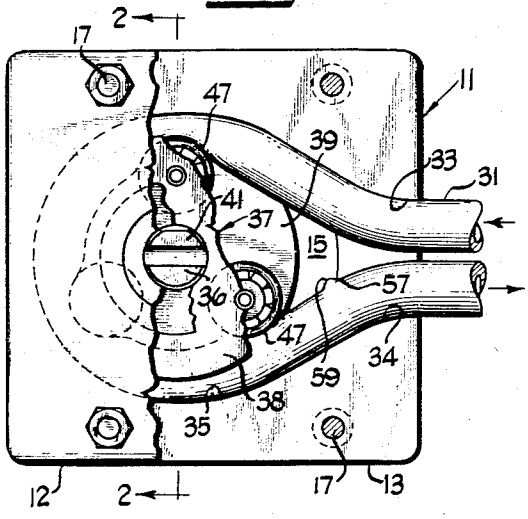
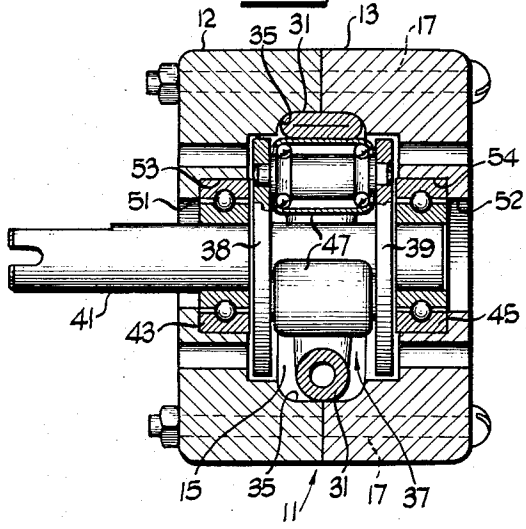


Fig 2



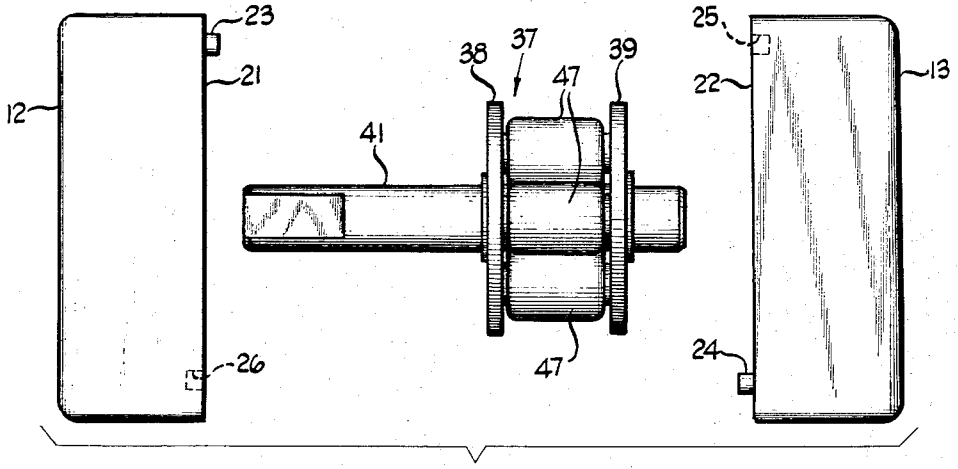


Fig 3

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Fig 4

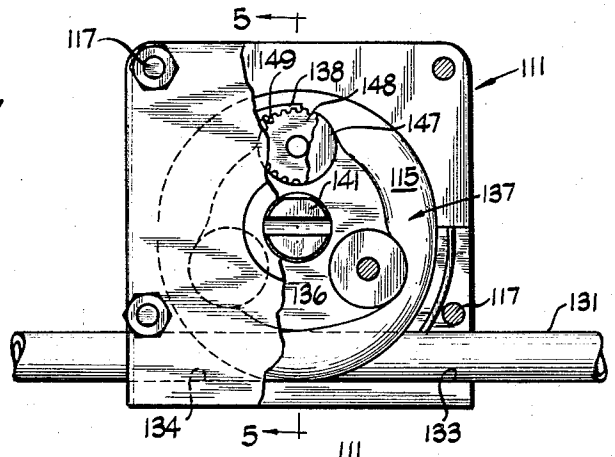
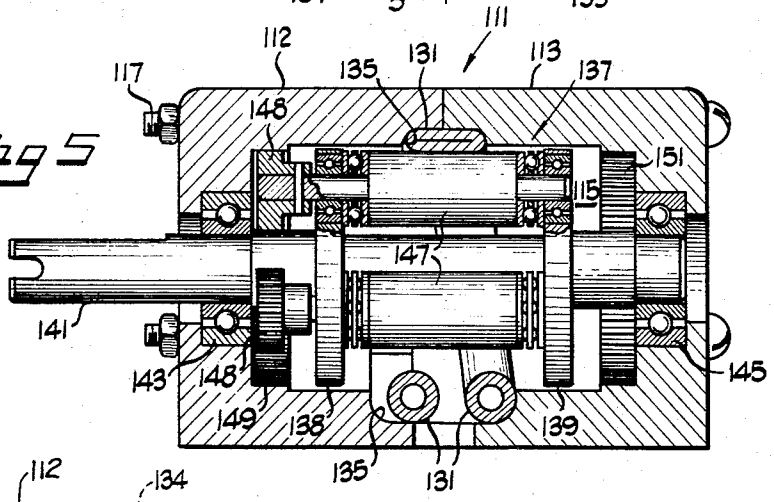


Fig 5



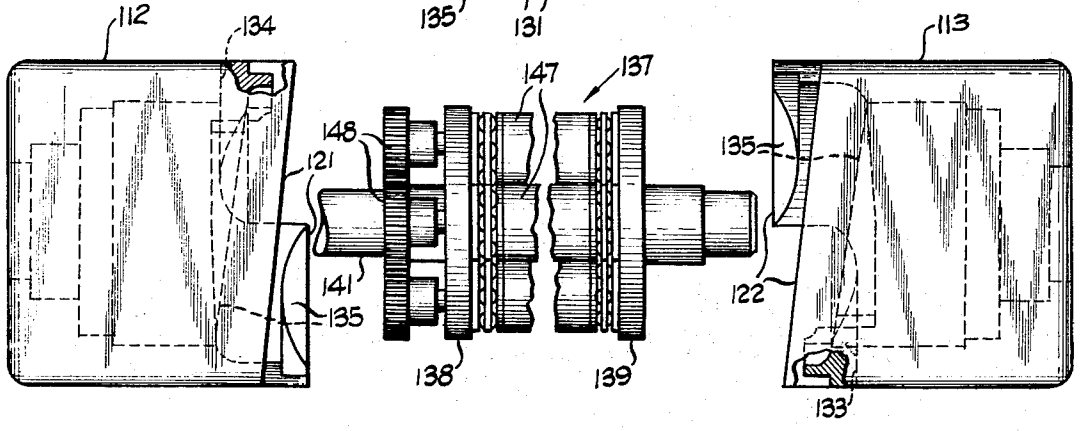


Fig 6

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FLUID PUMP

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Fig 7

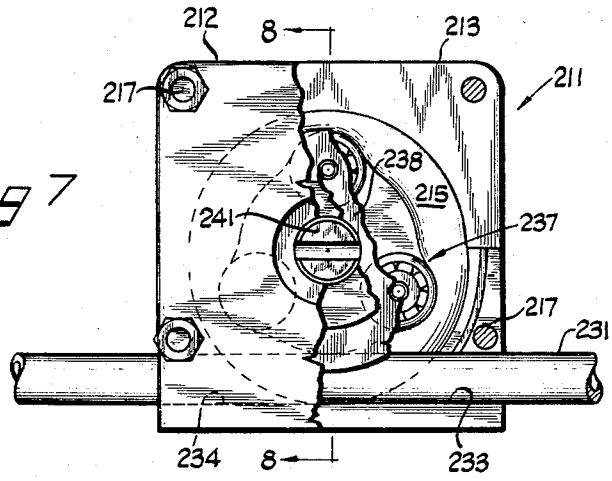


Fig 8

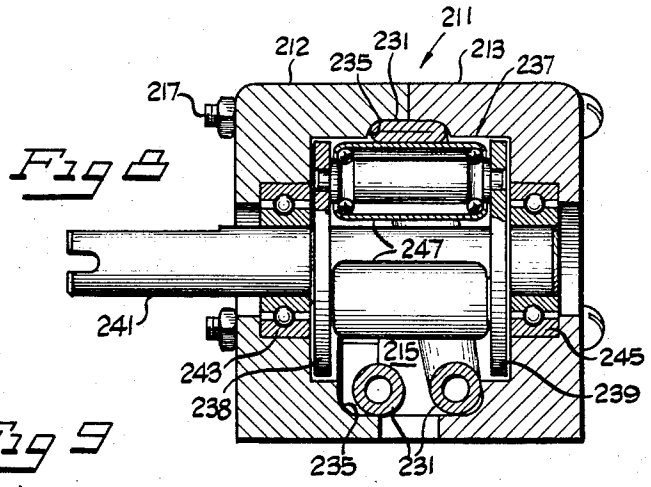
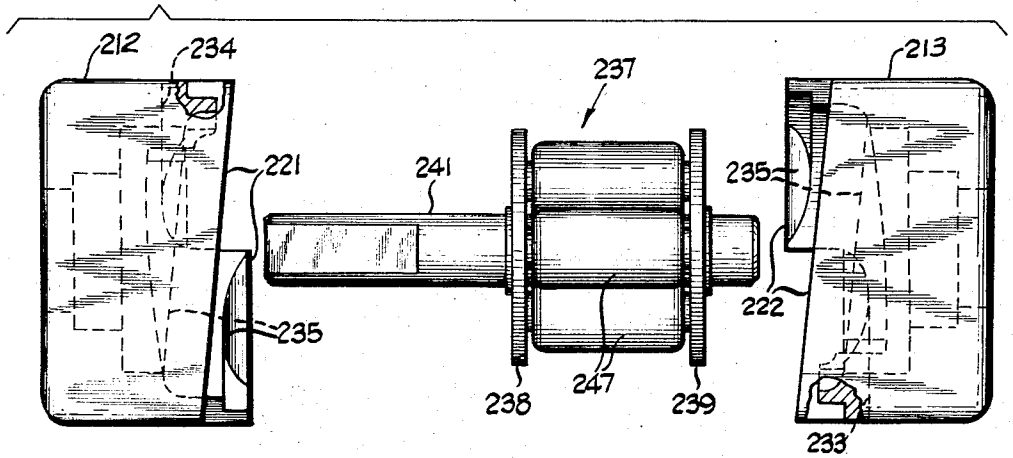


Fig 9



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3,358,609

FLUID PUMP

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ABSTRACT OF THE DISCLOSURE

A peristaltic pump is described which includes a housing with a fluid conducting tube having a portion disposed therein forming a loop. Rotary means disposed in the housing are supported by bearing means supported in the housing. The rotary means engage the tube to compress same and produce a peristaltic action therein. The housing is formed in identical halves having mating surfaces extending transversely of the axis of rotation of the rotary means.

This invention relates to fluid pumps and, more particularly, to a peristaltic pump of improved constructions.

There are a number of different types of peristaltic pumps, all of which operate to provide a moving region or moving regions of compression along the length of a compressible fluid conducting tube. The movement of the compressed region forces fluid ahead of it, and the action of the tube in returning to its uncompressed form provides a partial vacuum to cause fluid flow in behind the compressed area in the tube. In some such pumps, the tube extends in a straight line; however, in the pump of the present invention, the tube is enclosed in a housing and forms a loop therein. The particular form of peristaltic pump within which the invention is concerned generally includes a rotating structure having at least one portion which engages the tube in a manner to provide the desired moving regions of compression. Peristaltic pumps have varied uses, and are especially applicable where it is desired to provide a measured fluid flow which is capable of close regulation, such as in certain laboratory applications.

Generally, peristaltic pumps which provide accurate flow rates, long life and reliability have tended to be relatively expensive. Such pumps have also often had a problem of the looped tube therein "snaking" around in the housing due to the longitudinal forces exerted thereon by the portion of the rotating structure which engages it. In addition, such pumps have sometimes encountered a problem in that the moving elements therein interfered with the fluid flow by engaging and pinching the tube.

It is an object of this invention to provide a peristaltic pump of improved construction and operation..

Another object of the invention is to provide a peristaltic pump which is low in cost and reliable of operation.

Still another object of the invention is to provide a peristaltic pump which is simple to maintain and wherein parts may be replaced with relative ease.

A still further object of the invention is to provide an improved peristaltic pump which is fully reversible in its operation.

Other objects, and the various advantages of the invention will become apparent to those skilled in the art from the following description taken in connection with the accompanying drawings wherein:

FIGURE 1 is an end view, with part broken away, of a peristaltic pump constructed in accordance with the invention;

FIGURE 2 is a sectional view taken along the line 2—2 of FIGURE 1;

FIGURE 3 is an exploded top view of the pump of FIGURES 1 and 2;

FIGURE 4 is an end view, with part broken away, of another embodiment of the invention;

FIGURE 5 is a sectional view taken along the line 5—5 of FIGURE 4;

FIGURE 6 is an exploded top view of the pump of FIGURES 4 and 5;

FIGURE 7 is an end view, with part broken away, of a still further embodiment of the invention;

FIGURE 8 is a sectional view taken along the line 8—8 of FIGURE 7; and

FIGURE 9 is an exploded top view of the pump of FIGURES 7 and 8.

In accordance with the invention, the peristaltic pump thereof comprises a housing with bearings supported therein. A portion of a fluid conducting tube is disposed in the housing and forms a loop. A rotary structure is disposed in the housing supported by the bearings and has at least two portions engageable with the tube to compress same and produce a peristaltic action therein. The rotary structure has an axis of rotation extending through the loop formed by the tube. The housing is formed in identical halves having mating surfaces lying in planes extending transversely of the axis of rotation.

Each of the halves of the pump housing may be provided with engaging portions on the mating surfaces which are adapted to align the halves in a predetermined relation. The looped portion of the tube may be disposed in a groove extending around the inner surface of the housing. When the rotary structure includes a plurality of rollers extending between a pair of axially aligned discs as shown in the drawings, the groove prevents engagement of the discs with the tube when the tube is compressed. Inlet and outlet holes are provided in the housing and the outlet hole may be directed to provide a bend in the tube which is generally opposite to the bend of the loop formed thereby to prevent longitudinal movement of the tube. The outer race of each of the bearings which support the rotary structure in the housing is shrunk fit into an opening in the housing.

Referring now more particularly to FIGURES 1–3, a peristaltic pump constructed in accordance with the invention is shown. The pump includes a housing **11** formed in identical halves **12** and **13**. The housing is constructed of a transparent plastic, preferably an acrylic resin, such as Plexiglas. The interior of housing **11** has a pumping chamber **15** therein and is held together by bolts **17**. The halves **12** and **13** of the housing separate along mating surfaces **21** and **22** and such surfaces contain projections **23** and **24** respectively, which fit into corresponding recesses **25** and **26** for aligning the halves **12** and **13** in a predetermined relation to each other. The projections **23** and **24** and the recesses **25** and **26** are in identical places on the respective halves **12** and **13** such that, as mentioned before, the halves are identical.

Fluid is conducted through the pump in a fluid conducting plastic tube **31**. Tube **31** is deformable and has a memory, that is, it will return to its original shape after being deformed. As is well known in the art of peristaltic pumps, if a moving region or moving regions of compression are provided along the length of the tube **31**, the action of the compressed regions pushing the fluid ahead and the action of the tube in returning to its original uncompressed shape provide a vacuum to cause fluid flow in the tube according to the direction of movement of the regions of compression. Tube **31** extends through an inlet hole **33** and forms a loop in the cavity **15** before extending outwardly of the housing through an outlet opening **34**. The tube is positioned in housing **11** by means of an annular groove **35** formed in the interior wall of

the housing. The axis of the left hand part of groove **35** (as viewed in FIGURE 1) corresponds to the axis of rotation of shaft **41**, whereas the axis of the right hand part is designated as point **36**. The plane of surfaces **21** and **22** extends exactly through the middle of groove **35** such that the identical nature of the halves **12** and **13** is achieved.

In order to provide the moving area or areas of compression along the length of the compressible fluid conducting tube **31**, a rotary structure **37** is disposed in the cavity **15**. Rotary structure **37** includes a pair of axially spaced discs **38** and **39** mounted on a drive shaft **41**. Drive shaft **41** is supported for rotation in housing **11** by means of metal ball bearings **43** and **45**. A plurality of ball bearing supported rollers **47** extend between discs **38** and **39** and the axis of rotation of each of rollers **47** is parallel to and displaced from the axis of rotation of shaft **41**.

Each of rollers **47** has an outer surface adapted to engage the tube **31** as the structure **37** rotates about the axis of shaft **41** in response to rotation of shaft **41** by suitable driving means, not shown. As may be noted from FIGURE 1, the axis of rotation of shaft **41** is displaced a distance to the left of the axis of the annular groove **35** (indicated in FIGURE 1 as point **36**). Accordingly, when a roller is in the left hand portion of the cavity **15**, as viewed in FIGURE 1, it will operate to compress the tube **31** against the housing **11** and flatten the tube out as shown in cross section in the upper part of FIGURE 2. This forces fluid ahead of the compressed region. When the tube **31** returns to its normal shape once the roller **47** has passed by, a vacuum will be produced in the tube tending to draw fluid therethrough in the desired direction.

The bearings **43** and **45** are secured in the respective halves **12** and **13** of housing **11** in a manner which is simple and which affords reliable and sturdy construction. Halves **12** and **13** are provided with openings **51** and **52** therein, respectively. A slightly wider opening is provided in each of halves **12** and **13** between the respective openings **51** and **52** and the chamber **15**. These slightly wider openings are designated as **53** and **54** respectively. Openings **53** and **54** are each of a diameter which is equal to or less than the outer diameter of the outer race of antifriction bearings **43** and **45**. The housing **11** is heated to cause expansion of openings **53** and **54** to a diameter which will accommodate the outer races of the respective bearings **43** and **45**. Bearings **43** and **45** are then positioned in the openings **53** and **54** and the housing **11** is permitted to cool whereby the opening in which the bearing is disposed shrinks to the given diameter and secures the bearing in the housing. The shrink fit thus provided secures the metal bearing in the plastic housing without the need for additional structural elements such as screws, brackets, etc. This reduces production time and costs and greatly simplifies the product.

A number of other advantages accure from the invention. The construction of the housing **11**, in identical halves separable along surfaces lying in planes transverse to the axis of shaft **41**, lowers production costs in that each half of the pump housing is made in the same production operation. This type of construction also facilitates the stocking of replacement parts, and its simplicity affords sturdy construction and reliability. The transparent nature of the housing provides an attractive and saleable product and permits a user of the equipment to observe the condition of the tube **31**. Where the tube is transparent, fluid flow may also be observed. The groove **35** spaces the tube **31** from the discs **38** and **39** to eliminate the danger of tube pinching. The groove **35** and the loop of tube **31** therein are symmetrical on either side of a plane through the axis of rotation of structure **37**, thereby permitting rotation of the rotary structure **37** in either direction for effecting immediate reversal of fluid flow. Such a feature enables a single pump to be utilized, for example, to both fill and empty a tank of liquid chemicals.

Because of the rotation of rotating structure **37**, and despite the fact that rollers **47** are free to roll on the surface of tube **31**, and do so due to frictional forces, forces are still applied to tube **31** which may have a tendency to cause the tube to "snake" or slide around longitudinally in groove **35**. In the pump of the invention, such an undesirable occurrence is prevented by making openings **33** and **34** of substantially the same outer diameter as the tube **31** and by disposing openings **33** and **34** such that tube **31** is bent opposite to the bend of the loop which tube **31** forms in chamber **15**. Tube **31** is deformable due to its flexible nature and, when structure **37** is rotated counterclockwise (as viewed in FIGURE 1), any tendency for structure **37** to force tube **31** through opening **34** is prevented by the corner **57** at the edge of opening **34** which will engage the tube **31** and cause the tube to deform and provide a small bulge **59**. This bulge prevents tube **31** from being urged through opening **34**. A similar bulge occurs at opening **33** when the rotation of structure **37** is reversed.

When the length of tube **31** within housing **11** becomes worn due to the frictional forces of the rollers **47** passing thereover, it is possible to easily provide a new portion of tube **31** in chamber **15** by grasping the outlet end of tube **31** and pulling thereon. The pulling force will stretch the tube **31** and eliminate the bulge **59** at corner **57**. By exerting a further pull on the tube **31**, the tube may then be drawn by hand through housing **11** until the desired unworn length of tube **31** is inside the housing. If this operation is performed before the worn portion of the tube ruptures, the fact that the tube is worn on its outer surface will not impair its ability to conduct fluid as required. Thus, the tube need not be replaced.

Referring now to FIGURES 4, 5 and 6, a further embodiment of the invention is shown. The major differences in this embodiment over the embodiment shown in FIGURES 1–3, is in the form of the loop in the fluid conducting tube and in the configuration and operation of the rotating structure in the housing which engages the tube. In the embodiment of FIGURES 4, 5 and 6, the pump comprises a housing **111** having identical halves **112** and **113**. As was previously the case, housing **111** is constructed of transparent plastic, preferably an acrylic resin. The two halves of housing **111** are held together by bolts **117** and a pump cavity **115** is formed in housing **111**. The parting or mating surfaces **121** and **122** are positioned such that each half **112** and **113** is identical, and are of a configuration which properly aligns the halves when the surfaces mate. A flexible tube **131** extends into cavity **115** through an opening **133** in housing **111**. Tube **131** forms a helical loop in cavity **115** and passes through an outlet opening **134** at the same level as opening **133** and on the opposite side of housing **111**. The looped portion of tube **131** is disposed in a groove **135** which is also helical in shape and is formed in the inner wall of housing **111**. Groove **135** maintains the tube **131** spaced from the rotary structure **137**. The axis of the upper part of groove **135** (as viewed in FIGURE 4) is the same as the axis of shaft **141**. The axis of the lower part of groove **135** is designated as point **136**. The upper and lower parts of groove **135** are joined by a flat corresponding to the distance between the axis of shaft **141** and axis **136**. The axis of the lower part of groove **135**, designated as point **136** in FIGURE 4, is displaced from the axis of shaft **141** of the rotary structure **137**. This allows expansion of tube **131** just prior to its entry into openings **133** and **134**. The displacement is selected such that this expansion is only partial, creating a nozzle effect at the outlet of the pump to maintain pressure in the section of tube **131** inside cavity **115**.

The rotary structure **137** operates as did the rotary structure **37** in the previously discussed embodiment to provide the moving area or areas of compression along the length of the compressible fluid conducting tube **131**.

Rotary structure **137** includes a pair of axially aligned discs **138** and **139** supported on a drive shaft **141**. Drive shaft **141** is supported for rotation in ball bearings **143** and **145**. Ball bearings **143** and **145** are supported in the respective halves **112** and **113** of housing **111** in the same manner as ball bearings **43** and **45** of the previously described embodiment were supported in halves **12** and **13**. Rotary structure **137** further includes a plurality of rollers **147** ball bearing supported between discs **138** and **139** for rotation about axes which are parallel to the axis of rotation of shaft **141**. Because of the 360° tube wrap and the nozzle effect previously described, pulsations are minimized and accurate metering of the fluid being pumped is possible.

In the previously discussed embodiment, the frictional force between the tube **31** and the rollers **47** causes rollers **47** to rotate as the structure **37** rotates. Under some circumstances, it may be desirable to reduce wear on the fluid conducting tube and avoid "snaking" caused by the rollers and, accordingly, in the present embodiment, the rollers **147** are positively driven. To achieve this, a planetary gear arrangement is provided including a plurality of planet gears **148** each drivingly attached through disc **138** to a respective roller **147**. Planet gears **148** engage an annular gear **149** at one end of cavity **115** and which is molded as an integral part of housing half **112**. The annular gear **149**, as an alternative, may be made separately and press fit into housing half **112**. As shaft **141** rotates rotary structure **137** about its axis, the annular gear **149** rotates each of planet gears **148** to drive rollers **147** at the desired rate.

In the case where gear **149** is molded as an integral part of the housing, and where each of the housing halves **112** and **113** are made identical, a corresponding annular gear **151** is provided in housing half **113** and serves no purpose when the pump is in the configuration shown in FIGURES 4–6. In the event of wear or damage to annular gear **149**, the attitude of rotary structure **137** with respect to housing **111** may be reversed such that the planet gears **148** mesh with gear **151**. Thus, a replacement part is unnecessary. As was the case in the previous embodiment, the construction is symmetrical for easy reversal.

Referring now to FIGURES 7, 8, and 9, a still further embodiment of the invention is shown. In this embodiment, the fluid conducting tube is formed in a helical loop in the pump housing, as was the case in the embodiment of FIGURES 4–6, but the rotary structure is more similar to that utilized in the embodiment of FIGURES 1–3. The embodiment of FIGURES 7–9 includes a housing **211** which is constructed of clear plastic, preferably an acrylic resin. The housing is formed in identical halves **212** and **213** and defines a cavity **215**. The halves **212** and **213** are held together by bolts **217**.

A flexible plastic fluid conducting tube **231** enters the cavity **215** in housing **211** through an inlet opening **233**, forms a helical loop therein, and exits through outlet opening **234**. A helical groove **235**, formed in the inner wall of housing **211**, holds and guides the looped portion of tube **231** in the desired helical configuration. The axis of groove **235** (point **236** in FIGURE 7) is displaced from the axis of shaft **241** as was the case in the previously describe embodiments. Surfaces **221** and **222** extend transversely of the axis of shaft **241**, the axis of the groove **235** and the axis of the loop in tube **231**.

The halves **212** and **213** separate along mating surfaces **221** and **222** which are positioned such that each half is identical. Surfaces **221** and **222** are of a configuration to align the two halves **212** and **213** with respect to each other. As was the case in the previous two embodiments, the pump is symmetrical, enabling reversal.

Rotary structure **237** is comprised of ball bearing supported rollers **247** extending between axially aligned discs **238** and **239**. Discs **238** and **239** are secured to a drive shaft **241** which is supported for rotation in ball bearings **243** and **245**. Ball bearings **243** and **245** are secured in the respective halves **212** and **213** of housing **211** in the same manner as the ball bearings of the previous embodiments were secured in their housings. It will be noted from FIGURE 8 that the groove **235** is spaced a sufficient distance from the discs **238** and **239** such that the discs will not pinch the tube **231**. The advantages accruing from the device of the FIGURES 7–9 are similar to those found in the previous embodiments.

It will therefore be seen that the present invention provides an improved peristaltic pump which is low in cost and reliable of operation. The pump is easy to maintain and replacement of parts is facilitated by the simple construction. The pumps are capable of maintaining uniform fluid flow despite variation in pressure because of their positive displacement pumping. For example, pumps have been constructed in accordance with the invention which are capable of delivering 0.9 quart per minute at 600 r.p.m. and maintain such delivery at a relatively constant level from 0 to about 100 p.s.i. above atmospheric pressure. Various modifications and embodiments of the invention, other than those shown and described herein, will be apparent to those skilled in the art from this description and accompanying drawings. Such other modifications and embodiments, as well as those shown and described herein, are intended to fall within the scope of the appendant claims.

We claim:

1. A peristaltic pump comprising a housing having bearing means supported therein, said housing having a groove therein extending around the inner surface thereof, a fluid conducting tube positioned in said groove in said housing forming a loop, a rotary structure including a pair of axially spaced support members positioned on opposite sides of said groove, each support member being supported for rotation on said bearing means in said housing, said rotary structure including a plurality of rollers extending between said support members and engageable with said tube to compress same and produce a peristaltic action therein in response to rotation of said support members, said support members having their outer peripheries adjacent the outer peripheries of said rollers, said groove being of sufficient width and depth to accommodate said tube upon compression thereof and being spaced from said support members an amount sufficient to prevent engagement of said support members with said tube upon compression thereof.

2. A peristaltic pump comprising a housing having bearing means supported therein, said housing having a groove therein extending around the inner surface thereof and further having inlet and outlet holes therein communicating with said groove, a fluid conducting tube having a portion disposed in said groove in said housing forming a loop, said tube extending through said inlet and outlet holes and being radially deformable and having, when not deformed, an outer diameter substantially equal to the diameter of said outlet hole, said outlet hole being directed to provide a bend in said tube which is generally opposite to the bend of the loop formed thereby such that longitudinal force exerted on said tube to urge same toward said outlet hole will cause said tube to deform at said outlet hole and prevent longitudinal movement of said tube, said deformity constituting the only resistance to longitudinal movement of said tube so that said tube may be pulled through said housing, and rotary means disposed in said housing and supported by said bearing means, said rotary means being engageable with said tube to compress same and produce a peristaltic action therein.

3. The combination of claim **2** wherein said housing is comprised of a transparent plastic and is provided with a pair of mutually aligned openings therein, and wherein said bearing means comprise a pair of anti-fraction bearings, each having an outer race which is shrunk fit into a respective one of said openings.

4. A peristaltic pump comprising a housing having bear-

ing means supported therein, a fluid conducting tube having a portion disposed in said housing and forming a loop, rotary means disposed in said housing and supported by said bearing means, said rotary means having at least two portions engageable with said tube to compress same and produce a peristaltic action therein, said rotary means having an axis of rotation extending through the loop formed by said tube and including a planet gear for rotatably driving said one portion, said housing enclosing a first annular gear secured thereto and engaging said planet gear for driving the same in response to rotation of said rotary means about said axis thereof, said housing enclosing a second annular gear secured thereto, said housing being formed in identical halves having mating surfaces lying in planes extending transversely of said axis of rotation between said first and second annular gears, whereby the disposition of said rotary means with respect to said housing may be reversed when said first annular gear becomes worn such that said second annular gear engages said planet gear for driving same in response to rotation of said rotary means.

5. A peristaltic pump comprising a housing having bearing means supported therein, said housing further having a spiral groove extending around the inner surface thereof, a fluid conducting tube having a portion disposed in said groove in said housing form a spiral loop, and rotary means disposed in said housing and supported by said bearing means, said rotary means being engageable with said tube to compress same and produce a peristaltic action therein, said rotary means having an axis of rotation extending through the loop formed by said tube, said housing being formed in identical halves, each half having an irregular mating surface extending transversely of said axis of rotation, said housing being divided on planes extending through said spiral groove such that the portions of said spiral groove in said identical halves are identical, said irregular mating surfaces being identical and being shaped to accurately position said halves with respect to each other.

6. The combination of claim 5 wherein said groove in said housing and said portion of said tube in said housing are symmetrical on either side of a plane passing through said axis of rotation.

7. A peristaltic pump comprising a housing having bearing means supported therein, said housing further having a generally helical groove extending around the inner surface thereof and having inlet and outlet openings, a fluid conducting tube passing through said inlet and outlet openings and having a portion disposed in said groove in said housing to form a generally helical 360° loop, and rotary means disposed in said housing and supported by said bearing means, said rotary means being engageable with said tube to compress same and produce a peristaltic action therein, said rotary means having an axis of rotation extending through the loop formed by said tube, said groove being shaped with respect to the axis of rotation of said rotary means to allow only partial expansion of tube just prior to its entering said outlet opening and create a nozzle effect to minimize pulsations.

8. The combination of claim 7 wherein said groove has a first part with a first axis corresponding to the axis of rotation of said rotary means, said groove having a second part adjacent said outlet opening, said second part having a second axis parallel with and displaced from said first axis whereby said groove defines an eccentric path for the 360° loop portion of said tube, said second axis being displaced from said first axis a distance such that said rotary means only partially relieves the compression on said tube adjacent said outlet opening to provide the nozzle effect.

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