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Minissian

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[54] **PERISTALTIC PUMP**

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[51] **Int. Cl.**³ **F04B 43/08**

[52] **U.S. Cl.** **417/477**

[58] **Field of Search** 417/477, 475, 476

[56] **References Cited**

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[57] **ABSTRACT**

A peristaltic pump has facing half shells defining a pumping cavity and circular tube access grooves entering the cavity. Rotor apparatus includes a cylinder having concave, semi-spherical end surfaces rotatably supporting roller balls therein. The pumping cavity has a tube supporting substantially semi-annular, semicircular seat. Spring loaded roller bearings in rotor axial bores communicate with the roller balls adjacent the concave surfaces. The roller bearings engage the roller balls urging a central crescent shaped occlusion of the tubing.

In operation, tubing is inserted in the access openings. The impeller rotation and frictional forces transmitted by the roller balls forces the tubing about the semicircular seat and out the opposing access groove. The roller balls impinge the tubing normal to a nominal tube axis to cause an occlusion deforming the tubing to a crescent configuration. As the roller balls traverse a toroidial configuration, the crescent shaped occlusion moves along the tube advancing fluid forward while creating a rearward vacuum.

5 Claims, 6 Drawing Figures

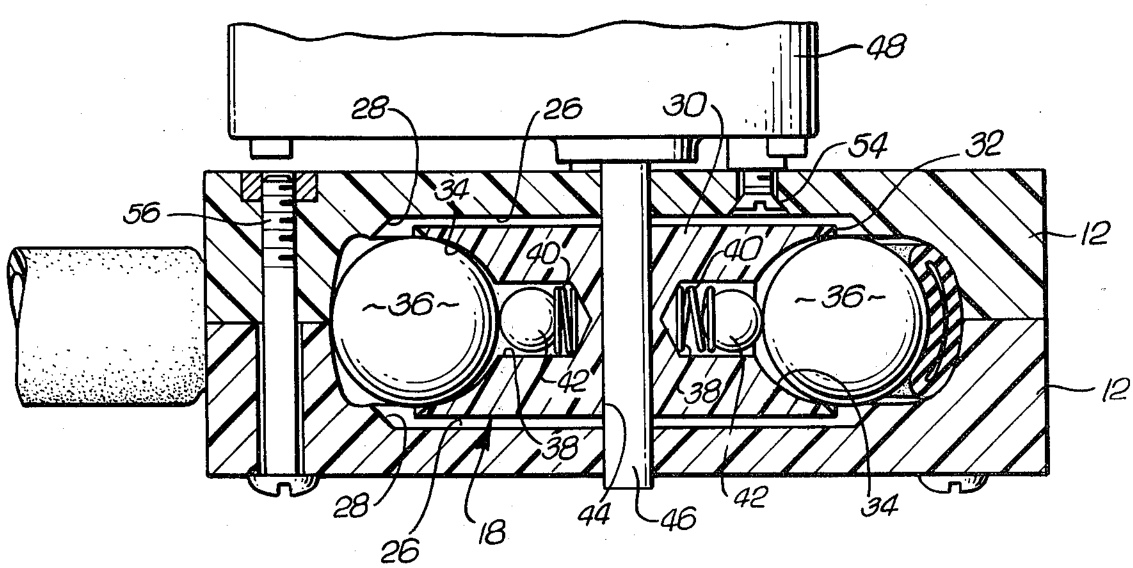

FIG. 1

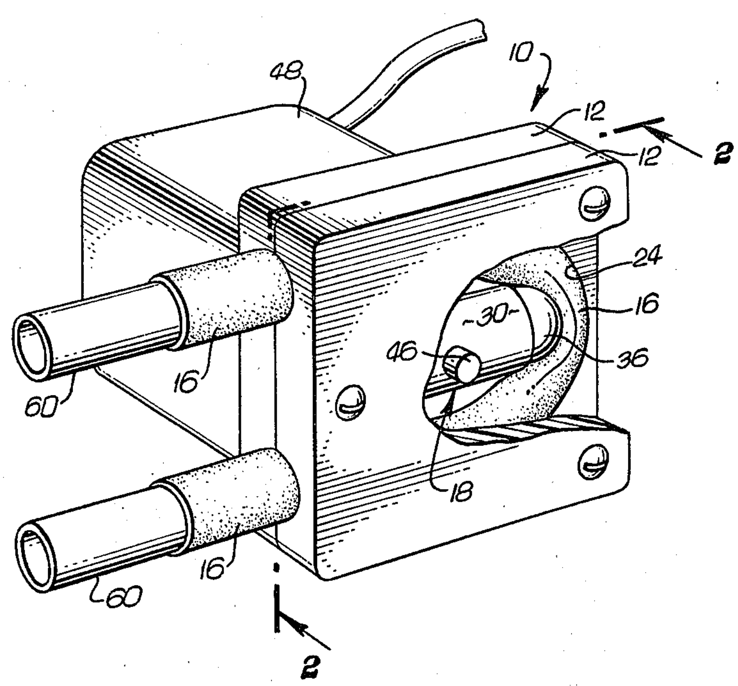
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FIG. 2

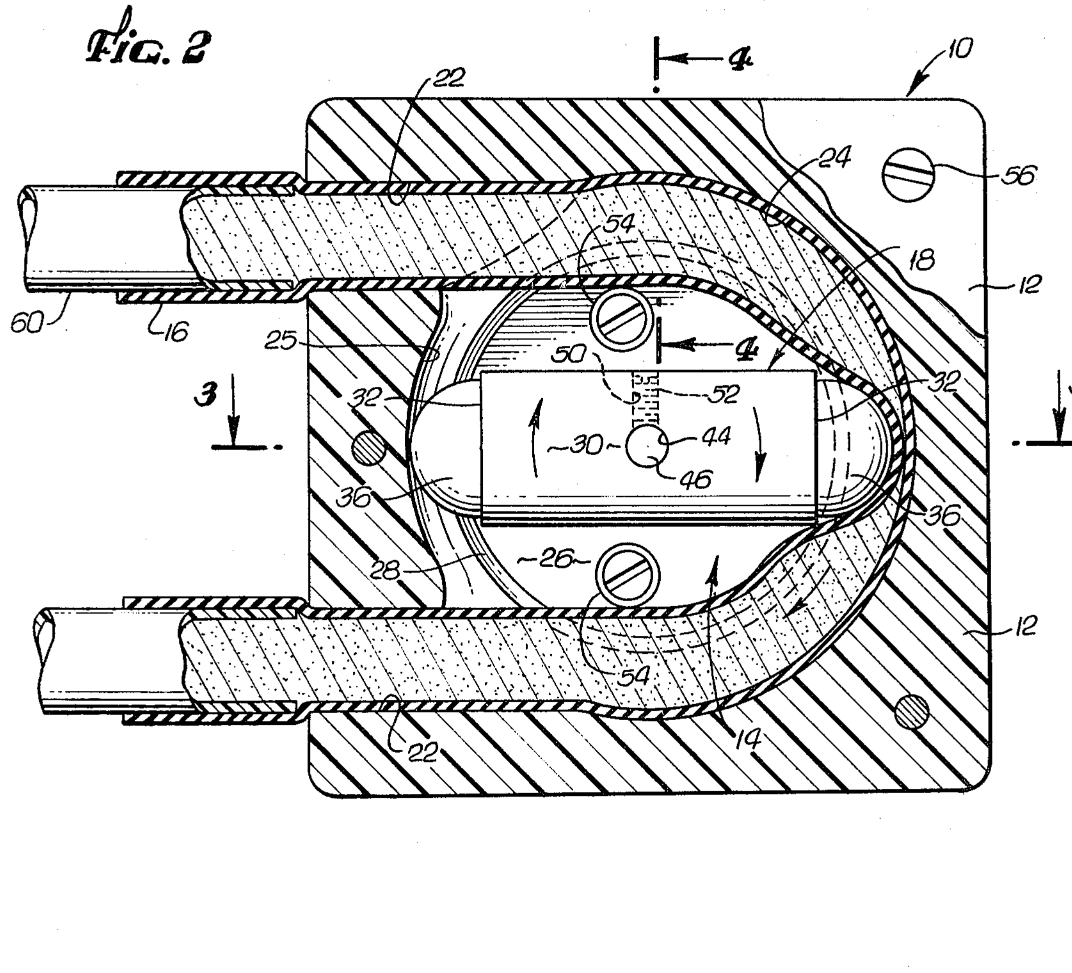
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FIG. 3

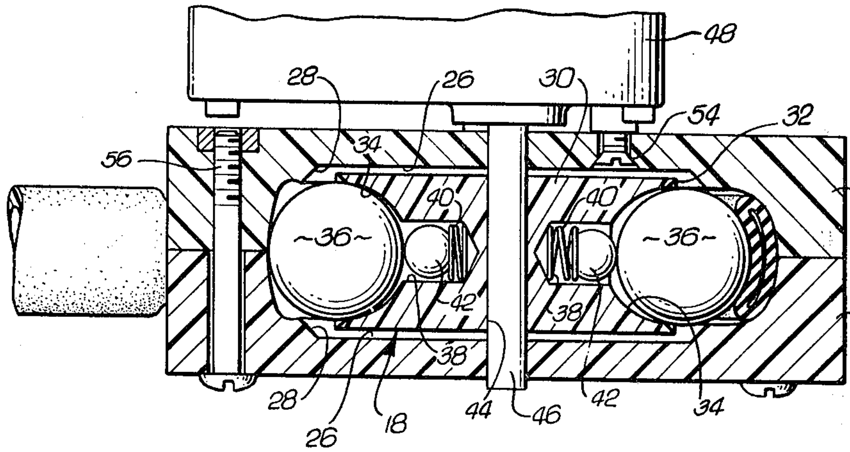


FIG. 4

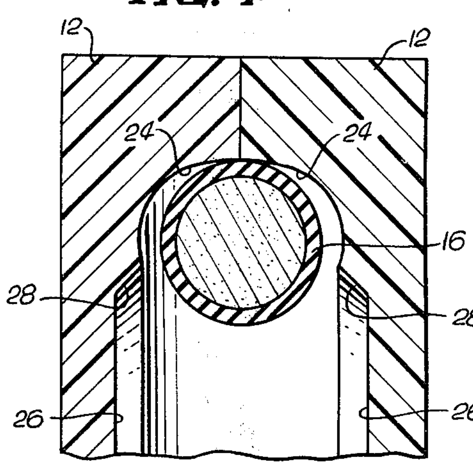


FIG. 5

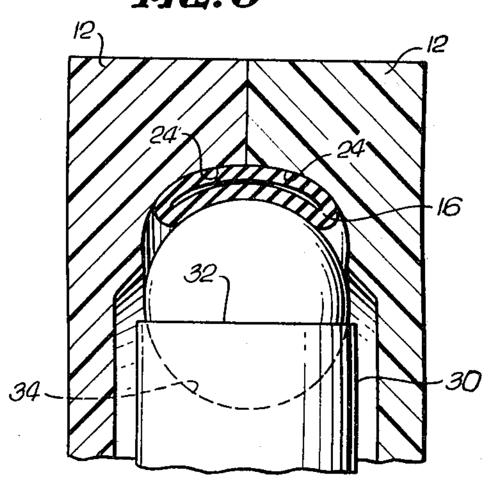
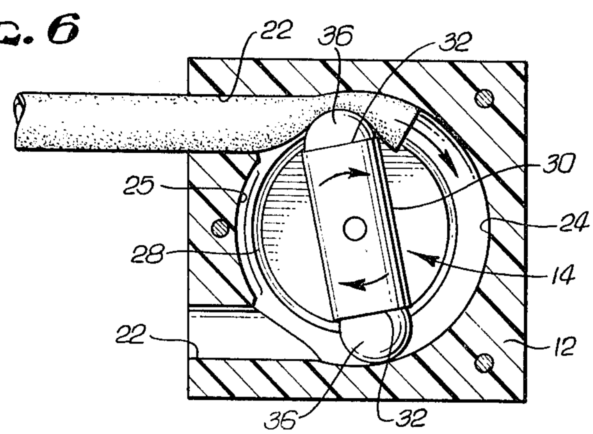


FIG. 6



PERISTALTIC PUMP

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention pertains to fluid pumping apparatus. Particularly, this invention pertains to peristaltic pumps in which a fluid is passed through a flexible tubing by moving occlusions of the tubing.

2. Description of the Prior Art

Peristaltic or tube pumps are used where it is desirable avoid pump contamination by the pumped fluid or contamination of the fluid pumped. They are used for pumping corrosive materials, in laboratories and in medical fields. No fluid contamination occurs since pumped fluid only contacts the insides of the tubing walls. The chemical resistance of the tubing, thus determines the limits of the resistance to contamination.

Rollers are typically used to cause a deformation or occlusion of the tubing which rollers are advanced both to drive the fluid in the tubing forward, while creating a rearward vacuum suction behind the portion of the fluid being pushed forward. Each roller is typically a cylinder. The axis of the cylindrical roller is disposed transversely to the tubing. As the roller bears on the tubing, it exerts forces on the central portion of the tubing, but also causes a flattening of the edges. Ultimately, the tubing must be advanced through the pump to subject a fresh tubing segment to the rollers, or replaced as a result of the frictional forces on the tubing and repeated tubing deformation. Often this is not of significant concern when the pumping is used on an intermittant or occasional basis. However, where the pumping apparatus is fixed in a unit of machinery, it is often desirable to minimize pump maintenance.

SUMMARY OF THE INVENTION

A peristaltic pump in accordance with this invention generally comprises a housing for supporting a flexible resilient tubing. A rotor is disposed within the housing. The impeller has a concave arcuate surface facing and transverse to the tubing. The arcuate surface of the rotor is movable longitudinally to create a moving crescent shaped occlusion. This concave arcuate surface causes the tubing to deform centrally, without exerting significant forces at the edges of the tubing deformity. The limited forces exerted at the flattened sides of the tubing provide an enhanced tubal life while maintaining high flow capacity.

In a more specific example of the invention, the tubing is supported by semi-annular seat of semicircular cross-section within the housing. The rotor comprises a longitudinal shaft having concave spherical surfaces at either end. Roller balls are rotatably disposed within the semi-spherical concave surfaces of the shaft. The roller balls impinge normal to the tubing axis. Thus, rather than flattening the tubing, the tubing is allowed to retain a circular shape on the nonimpacted side of the tubing, while the impacted side of the tubing is pushed into a generally concave circular shape giving the occluded portion of the tubing a crescent configuration.

Additional features in accordance with this invention include longitudinal bores within the shaft for supporting biasing means to urge the roller ball against the tubing. Ball bearings disposed within each of the bores provide low friction rotating surfaces on which the roller balls can rotate. The support grooves have a radius of curvature somewhat greater than the tubing diameter to conform to a greater curvature of the tubing when occluded.

BRIEF DESCRIPTION OF THE DRAWINGS

A better understanding of the invention may be had by reference to the following description taken in conjunction with the accompanying drawings in which:

FIG. 1 is a perspective view with portions exposed and portions removed, of an example of a peristaltic pump in accordance with this invention;

FIG. 2 is a fragmented elevational view taken along lines 2—2 of FIG. 1 of the invention depicted in FIG. 1;

FIG. 3 is a cross-sectional view taken along lines 3—3 of the invention depicted in FIG. 2;

FIG. 4 is a fragmented cross-sectional view of the invention taken along lines 4—4 of FIG. 2;

FIG. 5 is a fragmented cross-sectional view of the invention depicted in FIG. 4 showing the rotor engaging a portion of tubing; and

FIG. 6 is a cross-sectional diagrammatic view of the invention as depicted in FIG. 2 showing the feeding of tubing into the pumping cavity in accordance with this invention.

DETAILED DESCRIPTION

With particular references to FIGS. **1**, **2**, **3**, **4** and **5**, a preferred example of a peristaltic pump in accordance with this invention generally comprises a housing **10** comprising facing half shells **12**, a pumping cavity **14**, tubing **16** and a rotor apparatus **18**.

Each half shell **12** is preferably injection molded of hard polyethylene and polyvinylchloride complex, Lexan or other generally non reactive material, and a reduced shell thickness may facilitate and reduce molding costs, as in known in the art. Transparent shells **12** are preferable as they allow inspection of the condition of the internal pumping apparatus. Each half shell **12** comprises a pair of parallel longitudinal semi-circular grooves **22**. The grooves **22** support the tubing **16** and provide access for inserting the tubing **16** into the pumping cavity **14**.

The pumping cavity **14** is defined by a substantially semi-annular tube support grooves **24** of generally arcuate cross-section and a pair of recessed circular surfaces **26**, each disposed in facing spaced apart relationship in each of the half shells **12**. As viewed in FIG. **4**, the semi-annular tube support grooves **24** each comprise a groove having a quarter-circle arc in cross-sectional in each of the facing half shells to provide a seat for the tubing **16** defining a nominal curvilinear tubing axis, when the half shells **12** are joined in facing relationship. The curvilinear tubing axis is disposed through the tubing **16**. The longitudinal grooves **22** open up to the support grooves **24**. A roller ball support groove **25** provides a rotor engaging surface in each half shell **12**. The roller ball support grooves **25** are disposed in facing relationship to the tube support grooves **24** to provide a tube simulation surface. These grooves **25** are also disposed about the axis of the circular surfaces **26**, about an arc of less than a half circle. The grooves **25** have a radius less than that of the support groove **24**, by approximately the thickness of an occluded tubing **16**. This results in support for the roller apparatus **18**, to simulate the thickness of an occluded tubing to assure that there is no imbalance during rotation. A bevelled ledge **28** separates the circular surfaces **26** from the semi-annular support grooves **24** and separates them laterally to prevent creep.

The rotor apparatus **18** comprises a longitudinal cylindrical rotor **30** having opposing ends **32** and a concave semi-spherical surface **34** normal to the shaft axis at each end **32**. A pair of tube engaging roller balls **36** having a radius approximating that of concave semi-spherical surfaces **34**, though somewhat smaller to minimize frictional contact is disposed within each of the concave surfaces **34** at each end **32** of the rotor **30**.

The rotor **30** comprises longitudinal bores **38** along the shaft axis adjacent the concave spherical surfaces **34**. A spring **40** is disposed in each of the longitudinal bores **38** for biasing the roller ball **36** outwardly from the rotor **30**. This allows the use of tubing of irregular tolerance without creating excessive torque on a motor drive. In the example shown, a smaller roller bearing **42** is disposed at the end of each spring **40** and is urged outward from the bores **38** engaging the roller balls **36**. The smaller roller bearings **42** are allowed to rotate on the end of the springs **40**, which have a diameter just a bit less than that of the smaller roller bearings **42**. The diameter of the smaller roller bearings **42** is slightly smaller than that of the bores **38** so that the bearings may reside within the bores **38**. Use of these smaller roller bearings **42** in combination with the springs **40** is preferred as it reduces frictional forces which would otherwise be present from the greater surface area engagement of the roller balls **36** against the semi-spherical surfaces **34** of the rotor **30**. It should be recognized that the roller bearing **42** and the spring **40** need not be present for the pump to operate as lubrication may be sufficient. However, it is preferable to use the combination of the spring **40** and roller ball **42** as, in addition to reducing friction and torque on the motor, allows the use of various tubing **16** with some variation in tubing diameter.

The rotor **30** has a transverse bore **44**, disposed normal and axial to the circular surface **26** for receiving a transverse rotor shaft **46** of a motor **48**. A threaded aperture **50** extending normal to the transverse bore **44** and normal to the axis of the rotor shaft **46** extends through the transverse bore **44**. A set screw such as an allennut **52** mating with threaded aperture **50** affixes the rotor shaft **46** of the motor **48** to the rotor **30**.

Three countersunk apertures **54** transverse to one of the casing half-shells **12** are provided for rigidly affixing the housing **10** to a motor **48** or a motor mount. Housing apertures **56** are provided for joining the half shells **12** to one another.

By way of example, latex surgical tubing **16** may be used having an outer diameter of about 17 mm and an inner diameter of 10 mm. Typically the rotor **30** has a length of about 60 mm. Each roller ball **36** may have a diameter of about 20 mm.

In operation, the motor **46** is actuated causing the rotor **30** of the impeller apparatus **18** to rotate. As the rotor **30** rotates, it is retained within yet slightly spaced apart from the circular surface **26** and is prevented from climbing from the circular surface **26** by the bevelled ledge **28**. The roller balls **36**, however, are entrained by the concave semispherical surface **34** of the rotor **30** and by the semi-annular support grooves **24** and the inset grooves **25**. Lubrication allows the roller ball **36** to freely rotate as the impeller shaft **30** is rotated independently.

As shown in FIG. **6**, the tubing **16** is then placed through the cylindrical access opening defined by the grooves **22** of the facing half shells **12**. As the tubing **16** reaches the pumping cavity **14**, it is engaged by one of the roller balls **36**, thereby forcing further movement of the tubing **16** into the pumping cavity against the support grooves **24**. The tubing **16** is carried around the support grooves **24** and is forced out of the opposing access aperture **22**, as the free end tends to expand outwardly from the first axis of the tubing **16**.

A pair of connecting tubes **60** are then disposed on the tubing **16** adjacent the access openings to communicate the pumping fluid to a source, while preventing further movement of the tubing **16**, maintaining the tubing **16** within the pumping cavity **14**.

As the roller ball **36** of the impeller apparatus **18** rotates, it impacts the tubing **16** after rotation within a half revolution. However, the roller ball **36**, begins impacting centrally and normally to the tubing **16** and the support groove **24**, causing the portions of the tubing **16** immediately adjacent the roller ball **36** to cave inwardly. This inward occlusion continues as the roller ball **36** travels about a toroidial arc defined by the rotor **30** travel. The advancement of the roller ball **36** then causes an occlusion of the tubing **16**. The occlusion, however, does not create a flattening of the tube but rather a crescent shape tube closure. Rather than applying substantial forces primarily at the sides of the tubing **16**, the forces are significantly directed centrally inward on the tubing **16**. These forces cause a slight outward bowing on the backside of tubing **16**. For this reason the semi-annular support grooves **24** have a curvature slightly greater than the tubing **16** radius prior to deformation by the roller balls **36**. This is best shown diagrammatically in FIGS. **4** and **5**. The movement of the roller balls **36** about its torroidial path forces liquid through the tubing **16** forwardly in the direction of torroidial movement of the roller ball **36** while creating a vacuum in the tubing **16** in the rearward region of the tubing **16** sending fluid into the tubing **16**. Compressive forces on the tubing required to cause occlusion tend to be less than the forces in the ordinary peristaltic pump, thereby creating an enhanced tubing life.

Lubication may be achieved by packing a lubricant in the bores **38** prior to assembly. It may also be maintained by injecting a lubricant through the access openings **22** adjacent the tubing **16**, which may then be carried by the roller balls **36** to the concave surfaces **34** of the impeller.

Part of the ability to create an effective vacuum in the rearward region is based on the resilience of the tubing **16**. That is aided because tubing **16** occlusion occurs without excessive compressive forces on the tubing **16** edges. Because of this, high pumping rates can be maintained over a significant tubing life, for a given rotor RPM. The use of roller balls about the shaft cooperates so that generally only one of the roller balls has caused the tubing **16** to occlude at one time, while preventing the necessity for needing any sort of check valves.

Thus, a peristaltic pump has been provided which is reliable, easy to maintain and may be used with corrosive fluids, yet is simple and reliable in its construction.

While the invention has been particularly shown and described with reference to preferred examples thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. A peristaltic pump comprising:

a housing having a substantially semi-annular seat for supporting a flexible tubing;

a flexible deformable resilient tubing disposed within the annular seat and defining a curvilinear tubing axis, the tubing having an outer surface and defining an outer radius, the seat having a radius of curvature slightly larger than the outer radius of the tubing to substantially engage the outer surface of the tubing when deformed;

a rotor having opposing ends, the rotor disposed and rotatable within the housing, a semispherical concave surface at either end of the rotor, and a roller ball disposed within each concave surface, the roller ball having a convex surface about a curvilinear axis parallel to the curvilinear axis of the tubing to cause significant central tubing deformation while limiting the deformation forces exerted at the tube edges, the rotor rotatable within the housing to cause the roller ball when the rotor is rotated to impinge normal to the tubing axis to deform the central region of the tubing, moving fluid through the tubing with the movement of the rotor and creating a vacuum rearward;

means for biasing the roller ball against the tubing to compensate for small variations in tubing outer diameter; and

ball bearing means for reducing rotational friction of the roller ball, the ball bearing means disposed intermediate the biasing means and the roller ball and bearing on the roller ball, the ball bearing means having a smaller diameter than the roller ball.

2. The invention as set forth in claim **1** and in which the housing comprises a pair of facing half shells.

3. The invention as set forth in claim **1** and in which the housing comprises a pair of facing recessed circular surfaces, the rotor rotatably disposed between the circular surfaces, and a circular beveled ledge surrounding each circular surface separating the circular surfaces from the annular seat, thereby providing clearance for the rotor to rotate avoiding creep of the tubing from the annular seat to adjacent the circular surfaces.

4. The invention as set forth in claim **1** and in which the housing comprises:

circular access apertures for receiving the flexible tubing; and

roller ball support means for engaging one of the roller balls of the rotor when opposite the tubing, the roller ball support means opposite the seat and having a radius of curvature, the seat having a radius of curvature, the radius of curvature of the roller ball support means less than the radius of curvature of the seat.

5. The invention as set forth in claim **3** and in which:

the means for biasing the roller ball against the tubing comprises a bore disposed normal to the rotational axis of the rotor and has a spring disposed therein; and

lubricant disposed within the bore for providing lubrication to the roller ball.

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