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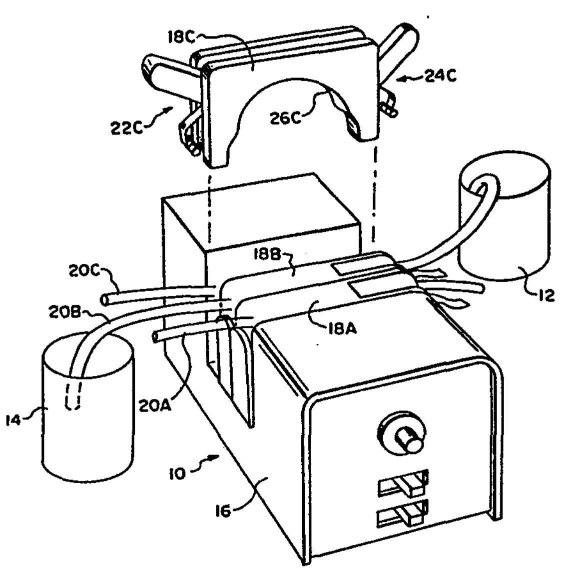
(54) Peristaltic pump.

(57) To increase precision of flow in multiple channels of a peristaltic pump, a plurality of spring biased cassettes (18A, 18B, 18C) are mounted to cooperate with a spool (38) having a plurality of elongated rollers (36A–36C) which orbit about its center so that each elongated roller in succession compresses a plurality of flexible tubes (20A–20C) in the channels against corresponding cam surfaces (108, 110) in the cassettes (18A–18C) spaced from the rollers (36A–36C) by surfaces (107) of the cassettes which are in contact with the rollers (36A–C) In each cassette (18A–C), the cam (108, 110) is mounted between side plates (52–54) against which the rollers (36A-36C) roll, which are spring biased against the rollers (36A-36C) and hinged at a center location to provide precision determined only by the precision of the cam (108, 110) to side plate edge dimension. The cam is shaped to reduce pulses during roller lift-off from the cam surface (108, 110) to provide for pulsefree flow.



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PERISTALTIC PUMP

This invention relates to peristaltic pumps.

Peristaltic pumps are known such as that disclosed, for example, in United States Patent 3,366,071 to Dutler granted January 3, 1963, which have a plurality of rollers that are orbited about a central driving shaft and compress a tube, with the rollers rolling against a bearing surface to control the amount of compression of the flexible tube.

In a prior art unit of this type, the rollers are in the form of cylinders, each having two steps of diameter. The inner step of the roller cylinders is radially compliant, fits within a substantially circular cross-sectional compartment and is traction driven by a central axle to follow an orbit along the roughly circular path. The outer step of the roller cylinders extends into a circumferential slot in the roughly circular cross-sectional compartment and compresses the flexible tube therein to pump the fluid.

This type of peristaltic pump has several disadvantages such as: (1) it is difficult to machine the radially compliant rollers with sufficient precision; (2) it works best as a single-channel pump and is clumsy to use as a multiple-channel pump; and (3) it is difficult to adjust the pump to different size conduits or for different pumping configurations.

Another type of peristaltic pump includes a plurality of cassettes rigidly holding tubes to rollers and having gearing on the rollers to provide forced backspin for preventing stretch of the tube from the drive of the orbiting rollers, for reducing the tendency of the tube to crawl through the cassette and for reducing pulses due to the stretching. This prior art pump has the disadvantage of being expensive to make with the tolerances necessary for: (1) low fluid pulsation; (2) long tubing life; and (3) pressure capability limited only by the strength of the tubing.

Other prior art peristaltic pumps orbit rollers about a central shaft but do not include a support for the rollers that is independent of the drive and which controls the tube. This type of prior art peristaltic pump has several disadvantages such as: (1) the flow rate and fluid pressure change with temperature and wear; (2) it is difficult to manufacture for precision flow rate and cancellation of fluid pulsation because the cumulative effect of machining tolerances extend from the center of the drive shaft to the rollers, the flexible tube and the fixed support for the tube; and (3) for similar reasons, it is difficult to match a plurality of channels.

Accordingly, it is a task of the invention to provide an inexpensive technique for controlling compression of peristaltic pump tubes for the purpose of reducing tube creep, pulsations and providing more ready adjustment to different size tubes.

The peristaltic pump of this invention is characterized by a tube holding means which has a cam surface mounted to it and which is adapted to receive a tube fixed in position with respect to the cam surface. A spring biased holder mounts the tube holding means to the peristaltic pump. The cam surface is spaced from the rollers by a guide incorporated in the tube holding means.

Advantageously, the tube holding means is characterized by spring biased pivotable hinge means for biasing said inlet and outlet tube holding means apart. The cam surface and plurality of rollers have dimensions such that successive rollers contact at least one-eighth of the total guide surface and less than three-quarters of the total guide surface whereby said tube is not completely compressed until just before it begins releasing the tube near said outlet end. The biasing springs and hinge enable the cassette to have multiple degrees of freedom of motion with respect to the rollers, whereby the cassette contacts multiple rollers regardless of small errors in the dimensions of the cassette and in the location of the rollers.

The above noted and other features of the invention will be better understood from the following detailed description when considered with reference to the accompanying drawings in which:

FIG. 1 is a simplified, fragmentary perspective view, partly exploded, illustrating an embodiment of the invention;

FIG. 2 is a fragmentary, exploded perspective view illustrating the embodiment of FIG. 1 in greater detail;

FIG. 3 is an elevational view illustrating a portion of the embodiment of FIG. 1;

FIG. 4 is a developed view illustrating the operation of the embodiment of FIG. 1; and

FIG. 5 is an elevational view illustrating another embodiment of a portion of FIG. 1.

DETAILED DESCRIPTION

In FIG. 1 there is shown a simplified perspective view of a pumping system including a peristaltic pump 10, a first container 12 and a second container 14 arranged so that the pump 10 may pump a liquid from one of the containers to the other or may draw fluid out of one of the containers through one end of the tube and hold it until that end is moved to another container and the pump reversed for expelling it.

The pump 10 includes a cabinet or housing 16, three cassettes 18A-18C, one of which is shown removed and three tubes 20A-20C positioned within the pump 10. The cabinet 16 encloses programmable control circuitry, a motor and pump drive circuitry which cooperate with the cassettes 18A-18C and the tubes 20A-20C in programmed pumping operations. The cabinet 16, motor and drive mechanisms are not part of this invention and are typical of equivalent devices in the prior art.

The cassettes 18A-18C are identical and include a spring biasing means shown at 22C for cassette 18C on one end and a second spring biasing means 24C on the other end. The spring biasing means 22C and 24C bias a cam surface means 26C downwardly against the rollers to control the amount the tubes 20A-20C are squeezed in a programmed manner which reduces pulsations.

In FIG. 2 there is shown a simplified, fragmentary, exploded perspective view of a portion of the pump 10 having a motor 30, a transmission 32, a spool 38 and the cassettes 18A-18C. The cassettes 18A-18C are shown positioned to cooperate with respective ones of the tubes 20A-20C (not shown in FIG. 2 but shown in FIG. 1) and the spool 38. The spool 38 is driven by the motor 30 through the transmission 32 which in turn drives the axle 34 of the spool 38.

The spool 38 includes a plurality of rollers, three of which are shown at 36A-36C, each of the rollers being rotatably mounted to a different one of two spool flanges, one of which is shown at 40. The spool flanges are mounted for rotation with the axle 34 that is driven through the transmission 32 by the motor 30. The rollers such as 36A-36C are mounted to the flanges for orbiting about the axle 34 and rotating within the spool flanges so as to cooperate with the flexible tubes 20A-20C (not shown in FIG. 2 but shown in FIG. 1).

To hold the flexible tubes 20A-20C (not shown in FIG. 2 but shown in FIG. 1) over the spool 38 so that the rollers such as those shown at 36A, 36B and 36C can compress them to force fluid therethrough, the cassettes 18A-18C each have parts which are adapted to flexibly mount over the spool 38. Only the cassette 18A will be described in detail but the cassettes 18B and 18C are identical and the corresponding numbered parts on the cassettes 18B and 18C are identical to those on cassette 18A but are adapted to cooperate with different ones of the flexible tubes 20A-20C (not shown in FIG. 2 but shown in FIG. 1).

To flexibly mount over the spool 38, the cassette 18A has a hinge boss 48A, a hinge pin 50A, pairs of parallel inlet side plates 53A and 52A and outlet side plates 55A and 54A, inlet and outlet side locking levers 56A and 58A respectively, and inlet and outlet side latching springs or side latches 60A and 62A respectively. The side plates 53A, 52A, 55A and 54A are pivotally mounted by the pin 50A passing through the hinge boss 48A and spring biased in a manner to be described hereinafter. When the cassettes 18A-18C are placed over the spool 38, the locking levers 56A-56C, 58A-58C and the side latching springs cooperate together to hold the cassettes in place and provide properly controlled camming surfaces for rollers 36A-36C (others are shown in FIG. 3) and for the flexible tubes 20A-20C (not shown in FIG. 2 but shown in FIG. 1).

To hold the cassettes 18A-18C in place over the spool 38, the inlet side springs and the outlet side latching springs such as those shown at 60A and 62A-62C each have mounted at their end a corresponding one of the cassette pin latches 64A, 66A, 66B and 66C. On opposite sides of the spool 38, there are mounted to the cabinet 16 of the pump 10, cassette clip keepers, one of which is shown at 68 adapted to receive and hold the cassette pin latches. The two cassette clip keepers are identical and only the cassette clip keeper 68 will be described in detail.

The cassette clip keeper 68 includes a base 72, tangentially-extending spring slots 74A-74C and a cross slot 76. The base 72 extends radially outwardly from the spool 38 (horizontal in FIG. 2) and the tangentially extending spring slots 74A-74C are positioned to extend orthogonal to the axis of the cassettes 18A-18C respectively. They extend part way through the base 72 to receive the inlet side latches 62A-62C. The slots have a dimension parallel to the axle 34 which is sufficient to accommodate the side latching springs 62A-62C respectively but not sufficient to accommodate the pin latches 66A-66C respectively. The cross slot 76 is orthogonal to the spring slots 74A-74C and intersects them to form a keeper slot capable of receiving the ends of the latch pins 66A-66C to be held in place by outstanding fingers formed in the base 72 by the slots 74A-74C and the cross slot 76.

In FIG. 3 there is shown an elevational view of a portion of the cassette 18C mounted on the spool 38. Only 52C of the two parallel inlet side plates 53C-52C and 54C of the two outlet side plates 54C is shown to permit a clearer illustration of the manner in which the flexible tube 20C is compressed by the rollers 36A-36F as the spool 38 rotates to force fluid through the flexible tube 20C.

Although only one cassette 18C is shown, the other cassettes cooperate in the same manner with the spool 38 to: (1) provide self-adjustment between the rollers 36A-36F and the inlet side plate 52C and outlet side plate 54C for uniform action against all of the flexible tubes with all of the cassettes at all times by automatic adjustment of pressure; and (2) to provide a controlled sequence of the degree of squeezing of the tube 20C by the rollers 36A-36F based on their position and thus reduce pulsations.

To provide for self-adjustment of pressure, the biasing means includes three biasing means, a first of which includes the inlet side locking lever 56C and the inlet side latching spring 60C, a second of which includes a first pin 78, a second pin 80 and a center leaf spring 82 and a third of which includes the outlet side locking lever 58C and outlet side latching spring 62C.

To support the leaf spring 82, the pins 78 and 80 extend orthogonally to the inlet side plate 52C and outlet side plate 54C respectively. The pins 78 and 80 are positioned near the corners of the side plates, distant from the hinge pin 50C and the spool 38 but toward the hinge pin from the locking levers 56C and 58C. They extend between the two parallel inlet side plates, only one of which is shown at 52C in FIG. 3, and the outlet side plates, only one of which is shown at 54C in FIG. 3, and hold the two inlet side plates and outlet side plates in parallel relationship to encompass within them the locking levers and springs.

To provide a center biasing force to bias the side plates away from the spool 38 when releasing side plates from the spool 38 and to bias against the inlet side spring 60C and the stiffer outlet side spring 62C when they are holding the side plates against the spool 38,the center leaf spring 82 extends parallel to the inlet and outlet side plates 52C and 54C with its center resting on the top of the hinge pin 50C, one end extending underneath the pin 78 and the other underneath the pin 80. This center spring 82 provides a biasing force to rotate the side plates about the hinge pin 50C away from the spool 38 and to bias their outer ends upward against the stronger forces of the inlet side spring 60C and outlet side spring 62C when the cassettes are mounted to the spool 38.

To lock the cassette 18C against the rollers in the spool 38, and squeeze the flexible tube 20C, the inlet and outlet sides utilize the locking levers and springs in the same manner so that only the inlet side will be described in detail with the understanding that the outlet side includes corresponding parts which lock in the same manner.

The inlet side locking lever 56C has a pin 84C at its lower end about which it pivots and the outlet side locking lever 58C has a similar pin 86C at its lower end for similar pivoting. The levers are generally bifurcated at their lower ends and have their respective inlet and outlet side springs 60C and 62C, lying within the bifurcation of the levers, pivotally mounted at one end about pivot pins 88C and 90C with the levers having an angle in them to form a toggle about that point. The angle is obtuse in the outward direction away from the spool 38 and of approximately 135 degrees. The levers may pivot toward the hinge pin 50C until the top portions are vertical and rest against the pins 78 and 80 respectively or pivot downwardly so their top portion is pointing down from a horizontal line so as to be almost tangential in direction with the spool 38.

To form toggles, the inlet side spring 60C and the outlet side spring 62C are each bent at approximately a right angle to itself in a direction that causes: (1) the pivot pin 88C and latching pin 64C at opposite ends of the inlet side spring 60C to be bent close to each other on the side facing spool 38; and (2) similarly the pivot pin 90C and the latch pin 66C are closer to each other on the side facing spool 38.

To bias the locking lever 56C with its top portion against the pin 78 with the spring 82, the pivot pin 84C is positioned in a line with the cassette clip keeper 70 and the pivot pin 88C so that when the upper end of lever 56C is rotated to its most vertical position, the pivot pin 88C is closer to the spool 38 and beyond the vertical line between the pivot pin 84C and latch pin 64C within the cassette clip keeper 70.

Similarly, when the lever is pulled downwardly so that it rotates counter-clockwise about the pivot pin 84C shown in FIG. 3, the inlet side spring 60C, once the pin 88C passes to the left of the line between the pivot pin 84C and the pin 64C within the cassette clip keeper 70, is pulled downwardly to loosen the lock.

The latch works in the same manner on the opposite side of the cassette 18C so the levers may be rotated together about the spool 38 with the latch pins 64C and

66C within the cassette clip keepers 68 and 70 and be locked in that place to resiliantly bias the inlet side plate 52C and the outlet side plate 54C about the spool 38. When the locking levers are rotated away from each other, they loosen the spring so as to loosen the toggles that bias the cassette against the spool 38.

To provide precision in the amount of squeezing of the flexible tube 20C as the rollers 36A-36C rotate with the cassette in place, each half of the cassette has two surfaces of differing radii which cooperate with the rollers 36A-36F of the spool 38 to control the amount of tube squeezing. The first surface rests upon the rollers and controls the space between the rollers and the second surface. The second surface provides a bearing support for the tubing to cooperate with the rollers for controlling the amount of squeeze of the flexible tube 20C.

In the embodiment of FIG. 3, the surface is made up of 107 and 107R, which is formed by the bottom edges of the inlet and outlet side plates 52C and 54C. The first surface is biased by the springs into a close engagement with the rollers to maintain the position of the first surface against the rollers. The second surface is provided by the face 108 of the inlet side cam 92 and the face 110 of the outlet side cam 94.

To hold the inlet and outlet side cams 92 and 94 and the inlet and outlet side plates 52C and 54C in close relationship, the hinge pin 50C passes through a conforming aperture in the outlet side plate 54C and the inlet cam 92. The inlet side plate 52C has the second surface, the curved portion 108 of cam 92, fastened to it so that it is mounted for rotation about the hinge pin 50C in the outlet side plate 54C. Thusly, the curved portion 108 conforms to a second surface about the hinge pin 50C. The outlet cam 94 has a curved portion 110 conforming to a curved second surface around the hinge pin 50C in the inlet cam 92.

The inlet cam 92 is rigidly mounted to the inlet side plate 52C by pins 96 and 98 and the outlet cam 94 is mounted to the outlet side plate 54C by orthogonal pins 100 and 102. Alternatively, cams 92 and 94 may each be respectively molded in one piece with the side plates 52C and 54C. The bottom sides of the inlet and outlet cams 92 and 94 are shaped to provide different amounts of squeezing to the flexible tube 20C and are sufficiently wide so that the tube 20C may rest and be compressed between the rollers 36A-36F and the cams 92 and 94 while remaining between the side plates on both sides of each cam. For this reason, there is a relatively wide surface on the inlet cam 92 between the parallel inlet side plate

52C and its parallel inlet side plate 53C not shown in FIG. 3 and a relatively wide surface on the outlet cam 94 between the outlet side plate 54C and its parallel outlet side plate 55C not shown in FIG. 3.

The positioning of the rollers a controlled distance from the second surface formed by inlet and outlet cams 92 and 94 by the first surface formed by the edge of the side plates 52C and 54C permits precision because there are only two immediately-connected surfaces to be controlled with respect to each other. This is true because the three degrees of freedom provided by the spring biasing means maintain the first surfaces 107L and 107R of the inlet and outlet side plates 52C and 54C against either two or three of the rollers and only the distance between the first-surface edge of the side plates to the tube-bearing second surfaces 108 and 110 of the inlet and outlet cams 92 and 94 controls the amount of squeezing of the tube.

The amount of squeezing of the tube is controlled so that on the inlet side, the rollers start to contact the tube 20C and the first surface at a location such as 104 which is less than 90 degrees from the hinge. The corresponding point on the outlet side, on the other side of the hinge, is also less the 90 degrees from the hinge. Thus, no more than three rollers can contact the first surface and the tube at a time, and the three available degrees of freedom of motion of the cassette insure that no roller inadvertantly leaves the surface and puts an incorrect squeeze on the tube. As many rollers can simultaneously contact the first surface of the cassette as there are degrees of freedom of motion of the cassette.

The roller compresses the tubing against the inlet cam 92 at its inner surface 106 approximately 63 degrees from the hinge pin 50C and barely occludes the tube against the cam surface 108 of the inlet cam 92. At this location the distance between the guide (first) surface and the cam (second) surface is equal to twice the thickness of the walls of the tube to form a liquid light seal provided the pressure difference across the occlusion is very small.

The difference in the dimensions between the first and second surfaces varies with the amount of pressure and for a pumping pressure of 30 psi (pounds per square inch) twice the thickness of the tube walls is approximately 126 mils; and the distance between the cam surface and the edge of the side plates closes 25 percent more than this to approximately 94 mils at a point of 59 degrees. This super-occlusion or compression of the elastomeric walls of the tube remains until approximately 5 degrees beyond the hinge point 50C where the tube is compressed against the surface 110 of the outlet cam 94 and then the roller begins a controlled release which reduces pulsations by providing compensation for volume until it is approximately 64 degrees of arc beyond the hinge pin 50C.

The end-to-end symmetry of the means for mounting the cassette onto the rest of the pump provides versatility. Each of the cassettes can be taken off the pump, turned end-to-end and remounted on the pump. The cassette, in one embodiment, has the lower pulsation at the end with cam 94, which is described above as being the outlet. If one of the cassettes is reversed, the inlet of the cassette has the lower pulsation. If the direction of rotation is reversed, then the reversed cassette has the lower pulsation at its outlet and the unchanged cassettes have the lower pulsation inlets.

In FIG. 4 there is shown a developed view or graph 126 illustrating the number of angular degrees through which a roller rotates as plotted against the distance between the first and second surfaces, which determine the amount of compression of a flexible tube in the peristaltic pump. This is expressed by the multiply-curved program line in FIG. 4.

Although it is not described in the foregoing part of the specification, it may be assumed for simplicity that the rollers have backspin forced upon them by some conventional means. Assuming this, no extra compensation in stretching and the extra pulsation due to stretching is necessary. The ordinate at 204E indicates the point a roller contacts a tube prior to being adjacent to a cam surface and the ordinate 228 is where it presses the tube to occlusion between the roller and the cam (second) surface. This period of controlled compression reduces tubing wear and strain on the drive and motion. However, it is not slow enough to eliminate pulsation on the inlet side.

Between the ordinates 228 and 206 a roller proceeds to super-occlude the tube to allow pumping against any head pressure up to 30 psi. At ordinate 206, the tube is flattened and compressed and it remains compressed to point 222 at which time it begins a controlled release from ordinate to ordinate 220. Some pressure is built up between two rollers against the cam surface before the leading roller reaches ordinate 220 to provide for a controlled pressure release while the roller moves further away from the cam surface to ordinate 224, at which time the tube is fully opened. This provides very low pulsation at the end of the tube corresponding to ordinate 207, but not the other end corresponding to ordinate 204F.

Thus, the spacing of an occluded tube which occurs at point 106 is, for many 1/16 inch wall thickness tubes, 0.094 inch or 94 mils and this spacing is maintained to ordinate 222. From ordinate 222 to ordinate 220, the spacing between the rollers and the cam is increased to 0.125 inch gradually and linearly and then it is increased still further to the full outer diameter of the tube which is 0.250 inch.

The distance between the rollers and the cam surface cannot be greater than twice the thickness of the membrane making up the tube and preferably is between twice the thickness and fifty percent of the thickness. In the preferred embodiment, it is approximately one and one-half times the thickness. The distance between two adjacent rollers should be at least one-quarter of the length on each side of the hinge connecting the segments of the cam surface and no greater than the total cam length.

The line 209 in FIG. 4 illustrates a method for compensation of the displacement, due to stretching of the tube, between two simultaneously occluding rollers. Stretching occurs if there is no backspin forced on the rollers as is the case with the design illustrated in FIG. 2. In the region between ordinate 207 and 211, the rollers super-occlude the tubing by more than the amount necessary to develop the maximum pressure provided by the pump.

At ordinate 207, the pressure in the liquid trapped ahead of a lagging roller is increased before the over-squeeze necessary for sealing against head pressure is released by the leading roller. The tube on the inlet side already has been closed by the lagging roller at ordinate 206 after the leading roller has passed ordinate 213 where the tube has only enough squeeze to seal against the head pressure, and before the leading roller reaches ordinate 222 where the tube squeeze starts to decrease from an amount sufficient to seal against head pressure.

FIG. 5 illustrates a way of making a peristaltic pump cassette with four degrees of freedom so up to four rollers may be in contact with its first surface at one time. The fourth degree of freedom is the sliding in-out motion allowed by elongated hole 551C around hinge pin 550C. Coiled tension spring 583 biases the cassette halves together as well as against springs 560C and 562C. The spool 538 of this pump carries light rollers 536A through 536M, spaced 45 degrees apart, so the program line is compressed with respect to the angular scale shown in FIG. 4. This allows the programmed circumferential length along the first and second surfaces to extend up to any amount less than the distance between five adjacent rollers. This is sufficient to provide a program resulting in very low pulsation at both ends of the tube simultaneously. The developed view or graph of such a program is not difficult to produce, and is more symmetrical than that of FIG. 4. If the rollers have forced backspin, segment 209 will not be required and the programmed space between ordinates 204E and 206 will be similar to a mirror image view of the programmed space between ordinate 222 and an ordinate slightly beyond ordinate 224. The programmed length is sufficient to include the stretch-compensation segment 209(shown in FIG. 4) since the program line is compressed on the actual program (not shown in FIG. 5).

Generally, the number of degrees of freedom of motion relates to the number of directions of motion permitted for the parts of the cassette with respect to the rollers. This number may be increased by increasing the number of joints in the cassette or the direction of motion at each joint. By increasing the number of degrees of motion, the number of rollers in contact with the cam is continuously increased.

From the above description, it can be understood that the peristaltic pump of this invention has several advantages, such as: (1) it is relatively simple in construction; (2) it can provide relatively pulse-free operation; and (3) it provides a uniform output between different channels of the pump even though they may use the same rollers. It should be understood that the embodiment of FIG. 4 can provide substantially pulse-free operation at the outlet when the roller spool is run in one direction and substantially pulse-free operation at the inlet when the rotor spool is run in the opposite direction. The embodiment of FIG. 5 can provide substantially pulse-free operation at both the inlet and outlet simultaneously, regardless of the direction of roller spool rotation.

Although a preferred embodiment of the invention has been described with some particularity, and two other equally advantageous embodiments have also been described, many modifications and variations of the described embodiments are possible in the light of the above teachings. Therefore, it is to be understood that within the scope of the appended claims, the invention may be practiced other than as specifically described.

CLAIMS

1. A peristaltic pump comprising a drive shaft (34), (Figs. 2, 3 and 5), a plurality of rollers (36A - 36F) mounted to said drive shaft (34) for orbiting thereabout; and a plurality of tube holding means (18A, 18B, 18C), characterized in that each of said tube holding means (18A, 18B, 18C) has a separate cam surface (108, 110) mounted to and is adapted to receive a tube (20) fixed in position with respect to the cam surface (108, 110) with a spring biased holder (e.g. 22C, 24C; Fig. 1) for mounting said tube holding means (18A - 18C) to said peristaltic pump; and the cam surface (108, 110) spaced from said rollers (e.g. 36A) by a guide (e.g. 107, 107R) incorporated in the tube holding means (e.g. 18A).

2. A peristaltic pump in accordance with claim 1 in which each of said tube holding means (18A, 18B, 18C) includes inlet and outlet holders characterized by spring biased pivotable hinges (e.g. 50C, 82) for biasing said inlet and outlet holders apart.

3. A peristaltic pump in accordance with either claim 1 or 2 characterized in that said cam surfaces (108, 110) and plurality of rollers (e.g. 36) have dimensions such that successive rollers contact at least one-eighth of the total guide surface lengths and less than three-quarters of the total guide surface lengths whereby said tube is not completely compressed until just before it begins releasing the tube near said outlet end.

4. A cassette for a peristaltic pump according to claims 1 - 3 characterized by spring biasing means (e.g. 60C, 62C) for biasing said cassette against said rollers (36); at least first and second surfaces; one of said surfaces spacing the other from said roller; and the other of said surfaces being a shaped cam surface adapted to bear against a flexible tube.

5. A cassette according to claim 4 characterized in that spring biasing means (e.g. 60C, 62C) is releasable.

6. A cassette in accordance with claim 5 characterized in that said cassette includes first

mounting (e.g. 53A, 52A) and second mounting means (e.g. 55A, 54A); said first and second mounting means being pivoted at a central location (48A), and biased apart; and said spring means including means for resiliantly and releasably biasing said first and second means against said rollers.

7. Apparatus comprising according to any of claims 1 - 6 characterized in that said cassette includes means for providing multiple degrees of freedom of motion for the cassette with respect to the rollers (36), whereby the cassette contacts multiple rollers (36) regardless of small errors in the dimensions of the cassette and in the location of the rollers.

8. Apparatus in accordance with claim 7 characterized in that the means for providing includes means for providing two degrees of freedom of motion whereby the cassette contacts at least two rollers simultaneously despite small errors in dimensions and locations.

9. Apparatus in accordance with claim 7 characterized in that the means for providing includes

means for providing three degrees of freedom of motion whereby the cassette contacts at least three rollers (36) simultaneously despite small errors in dimension and location.

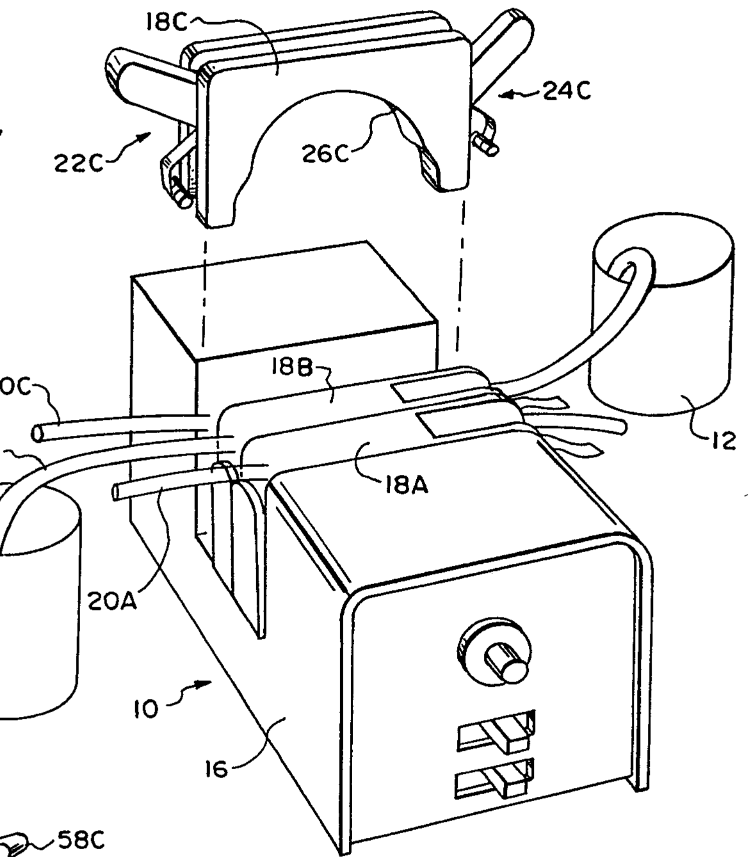
10. Apparatus in accordance with claim 7 characterized in that the means for providing includes means for providing four degrees of freedom of motion whereby the cassette contacts at least four rollers (36) simultaneously despite small errors in dimension and location.

11. Apparatus in accordance with claim 7 characterized in that the means for providing includes means for providing five degrees of freedom of motion whereby the cassette contacts at least five rollers (36) simultaneously despite small errors in dimension and location.

12. Apparatus in accordance with claim 7 characterized in that the means for providing includes means for providing multiple degrees of freedom of motion whereby it contacts as many rollers (36) as there are degrees of freedom despite small errors in dimension and location.

13. A peristaltic pump in accordance with claim 7 characterized in that the hinge means imparts a fourth degree of motion to the tube holding means, which is sliding away and toward the hinge to allow the cam surface to contact four rollers simultaneously.

14. A peristaltic pump in accordance with any of claims 1 - 7 characterized in that the inlet and outlet tube holding means impart two degrees of freedom to the tube holding means, which are up-down and side-to-side motion, and the hinge means impart a third degree of motion to the tube holding means, which is pivoting rotation about the hinge.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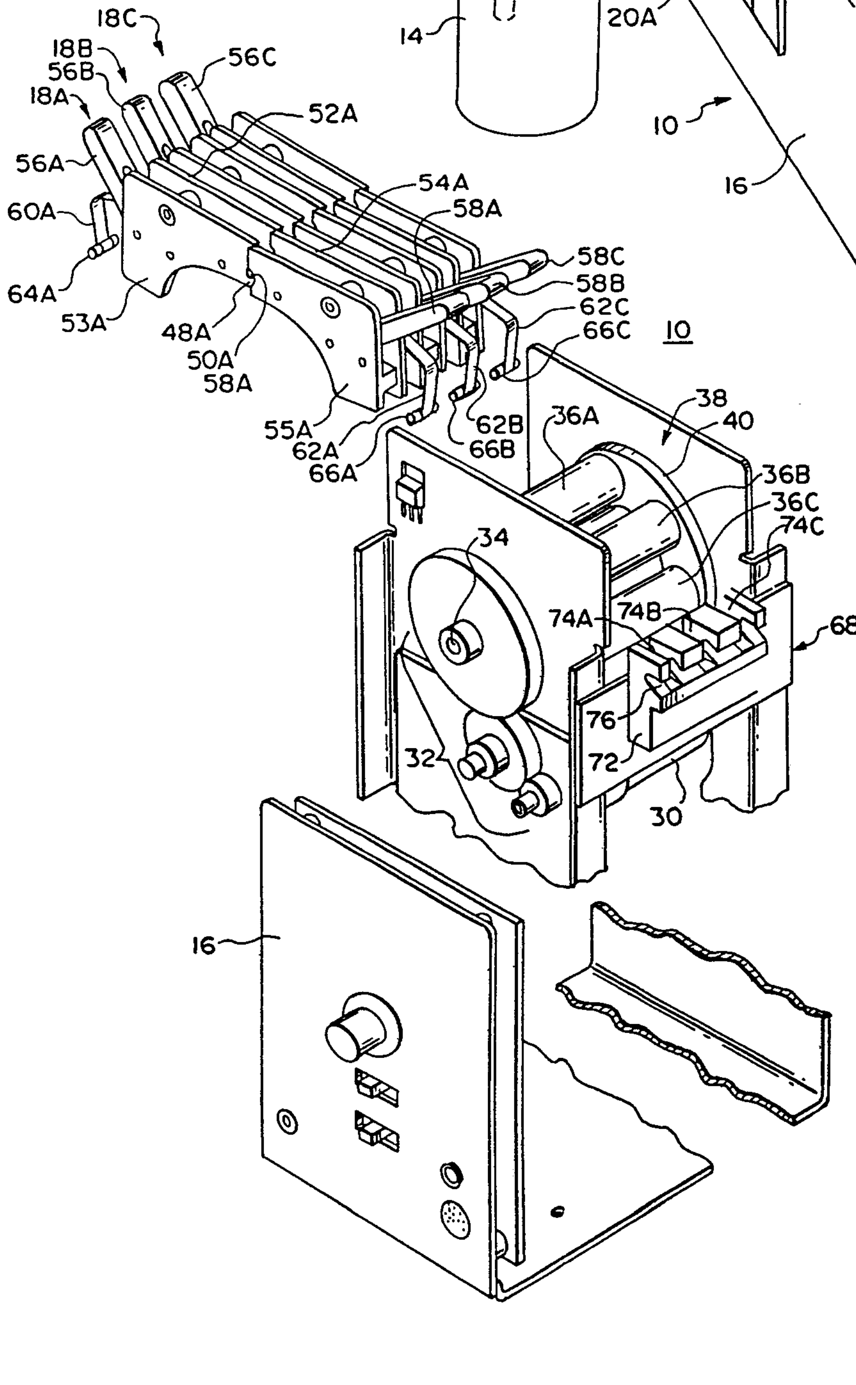
20C
20B
18A
12
14
20A
10
16

FIG. 1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56C
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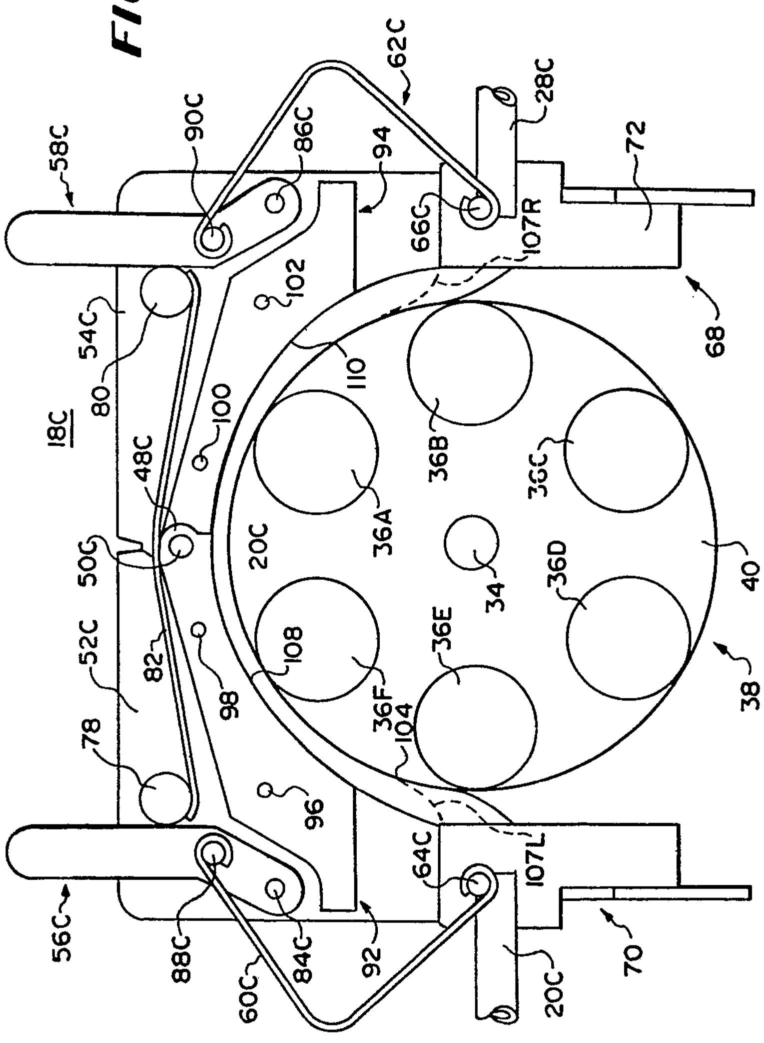
58A
62C
66C
10
55A
62A
66A
62B
66B
36A
38
40
36B
36C
74C
34
74A
74B
68
76
72
32
30
16

FIG. 2

FIG. 3



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56C
58C
52C
54C
78
80
48C
50C
82
88C
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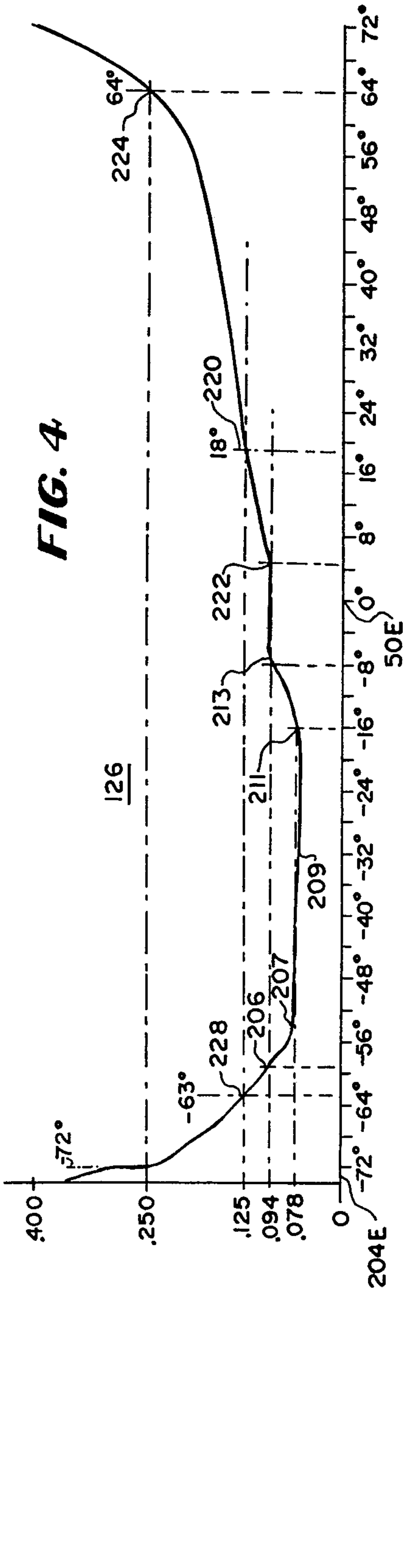
84C
86C
60C
62C
92
94
96
98
100
102
64C
66C
107L
107R
20C
28C
70
72
68
104
108
110
36A
36B
36C
36D
36E
36F
34
40
38

FIG. 4



.400
.250
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.094
.078
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204E
-72°
-64°
-56°
-48°
-40°
-32°
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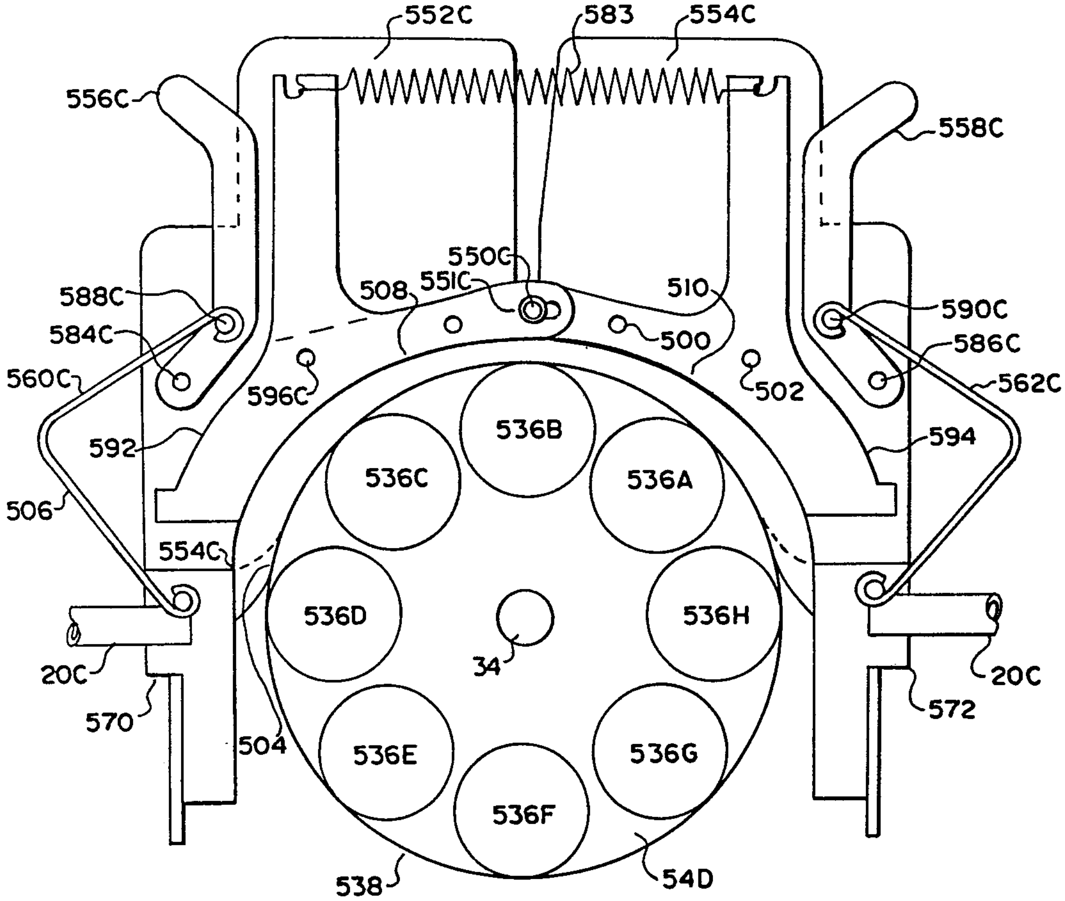
-16°
-8°
0°
8°
16°
24°
32°
40°
48°
56°
64°
72°
50E
126
228
-63°
206
207
209
211
213
222
220
18°
224

FIG. 5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502
562C
592
594
536B
536C
536A
506
554C
536D
536H
34
20C
20C
570
572
504
536E
536G
536F
538
54D

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DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
X	DD-A- 100 309 (MARR) * Whole document *	1,4,5, 7,9	F 04 B 43/12
A		3,8,10 -12	

X	FR-A-2 336 571 (MILES LABORATIES) * Page 5, line 25 - page 8, line 27; figures 1-9 *	1,4,5	
A		2,3	

A	GB-A-2 076 476 (WARNER-LAMBERT) * Page 1, line 92 - page 2, line 37; page 2, line 115 - page 3, line 45; figures 1,3,6,7 *	1,3-5	TECHNICAL FIELDS SEARCHED (Int. Cl.4)
	---		F 04 B
A	WO-A-8 200 498 (KLEINHAPPL) * Page 3, line 6 - page 6, line 24; figures 1-5 *	1-3	

D,A	US-A-3 366 071 (DUTLER) * Whole document *	1,3,4	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	05-09-1985	VON ARX H.P.

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