United States Patent [19]

Spinosa et al.

[11] **3,927,955**

[45] **Dec. 23, 1975**

[54] **MEDICAL CASSETTE PUMP**

[75] Inventors: **Dominic Spinosa**, Wantagh; **John Varga**, Bayville, both of N.Y.

[73] Assignee: **East/West Medical Products, Inc.**, Hauppauge, N.Y.

[22] Filed: **July 9, 1973**

[21] Appl. No.: **377,677**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 174,019, Aug. 23, 1971, abandoned.

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

[51] **Int. Cl.²** **F04B 43/08**; F04B 43/12; F04B 45/26

[58] **Field of Search** 417/474, 475, 476, 477

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Primary Examiner—William L. Freeh
Assistant Examiner—Richard E. Gluck

[57] **ABSTRACT**

A medical cassette pump is provided, especially adapted for acting upon disposable fluid-carrying tubing in a manner such that the tubing can easily be inserted and removed from the fluid-pumping assembly. The pump includes a drive motor which rotates a fluid-pumping assembly about a principal axis. The fluid pumping assembly including pumping means engaging the fluid-carrying tube and advancing fluid along the tube in response to rotation of the fluid-pumping assembly, and displaceable cassette means for releasably engaging the fluid-carrying tube against the pumping means.

33 Claims, 16 Drawing Figures

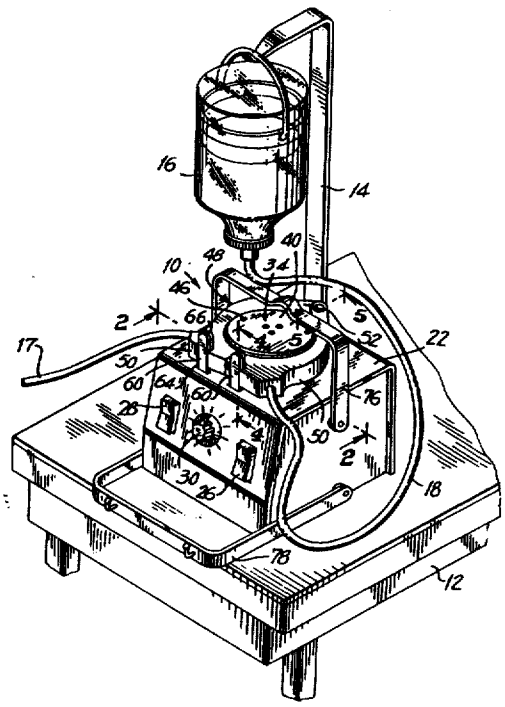


FIG. 2

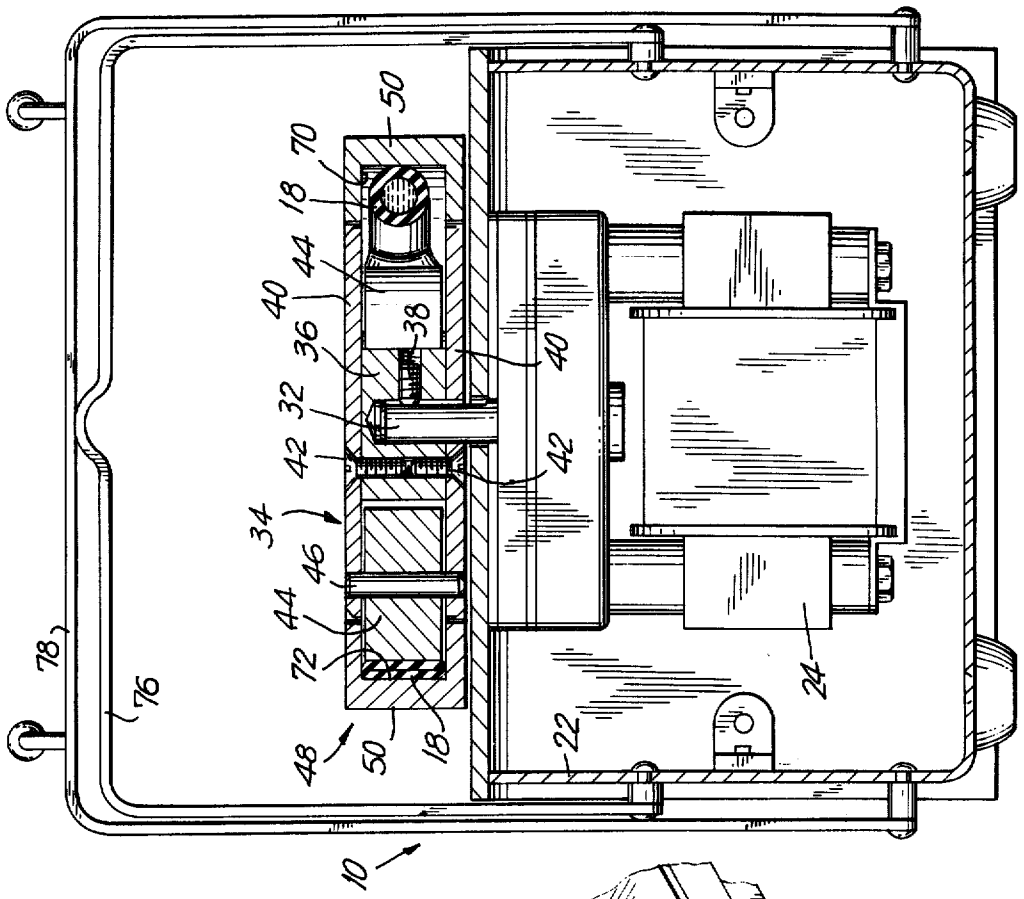
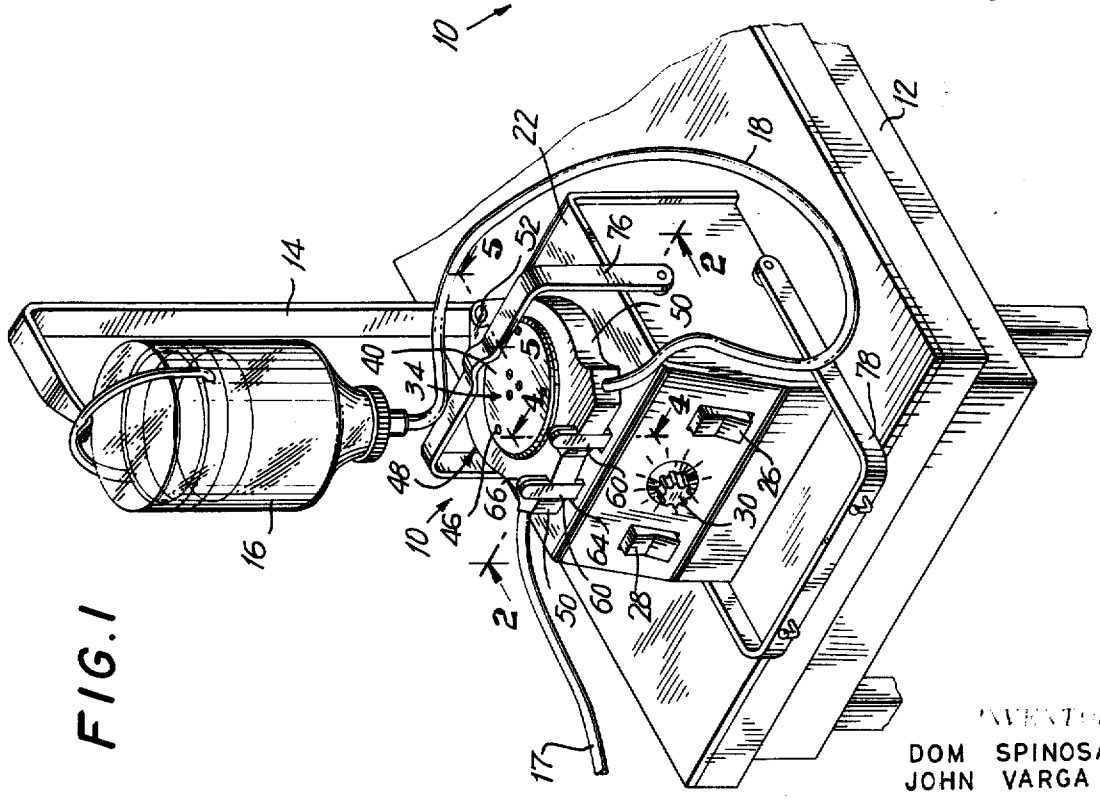


FIG. 1



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FIG. 3

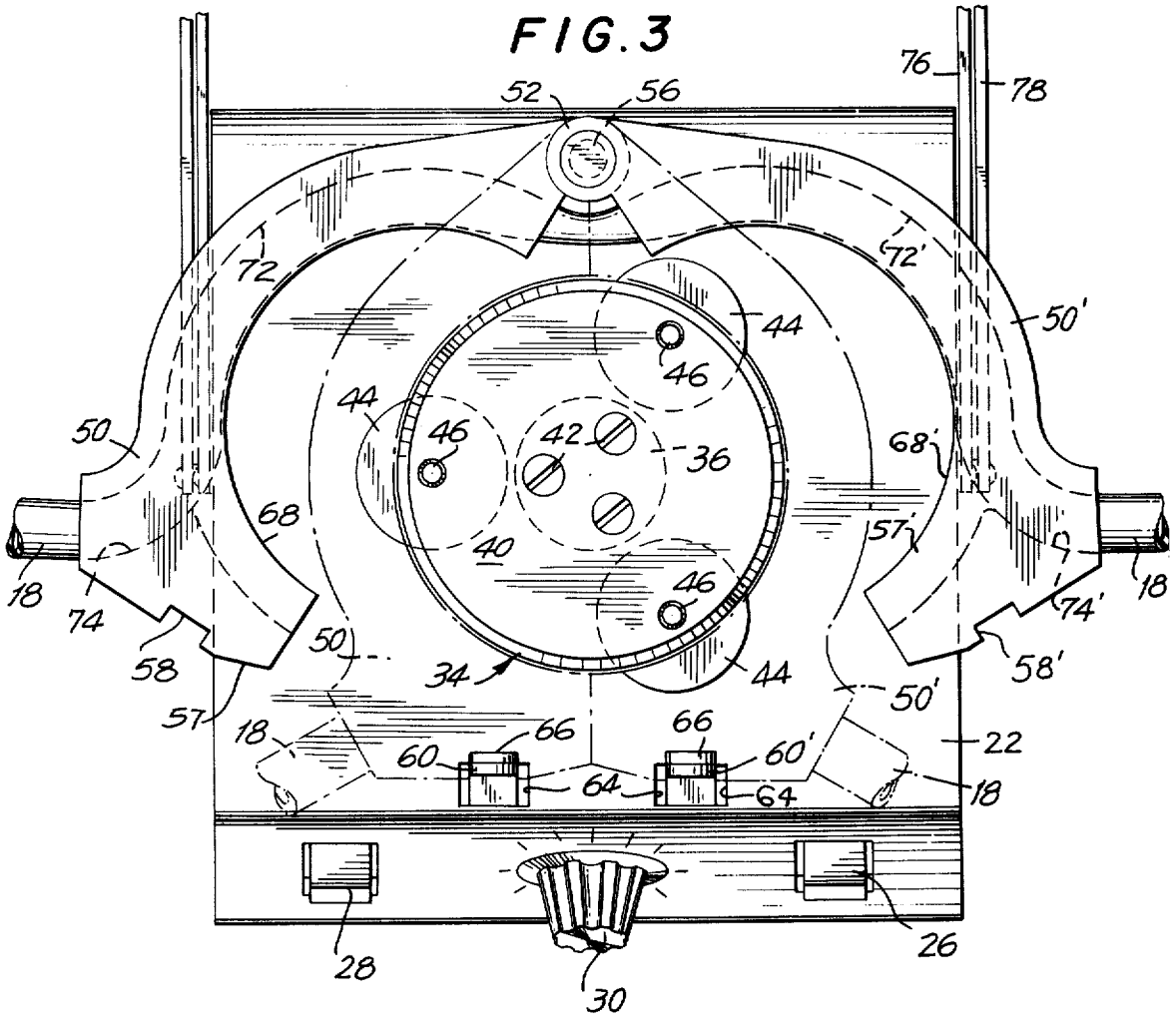


FIG. 4

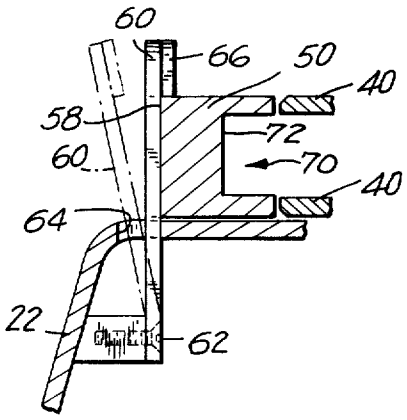
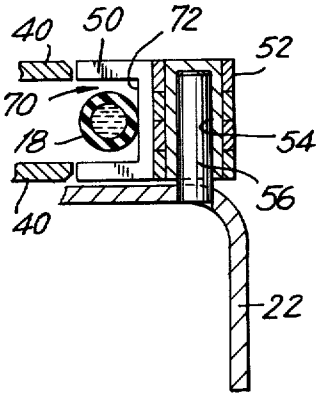


FIG. 5



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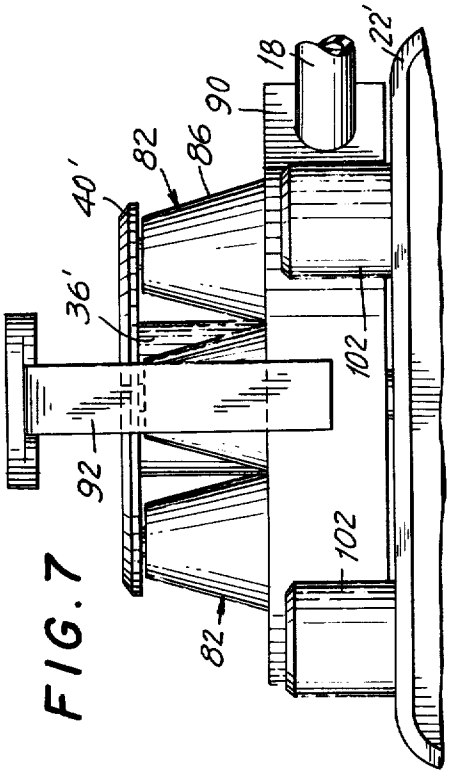


FIG. 7

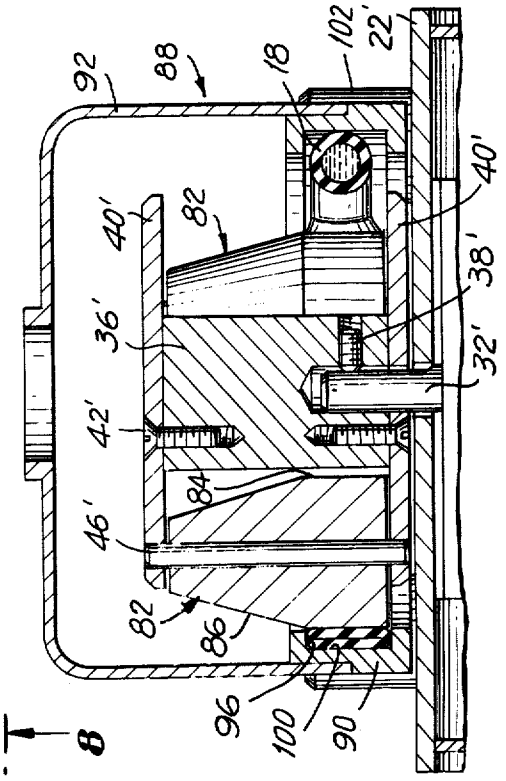


FIG. 8

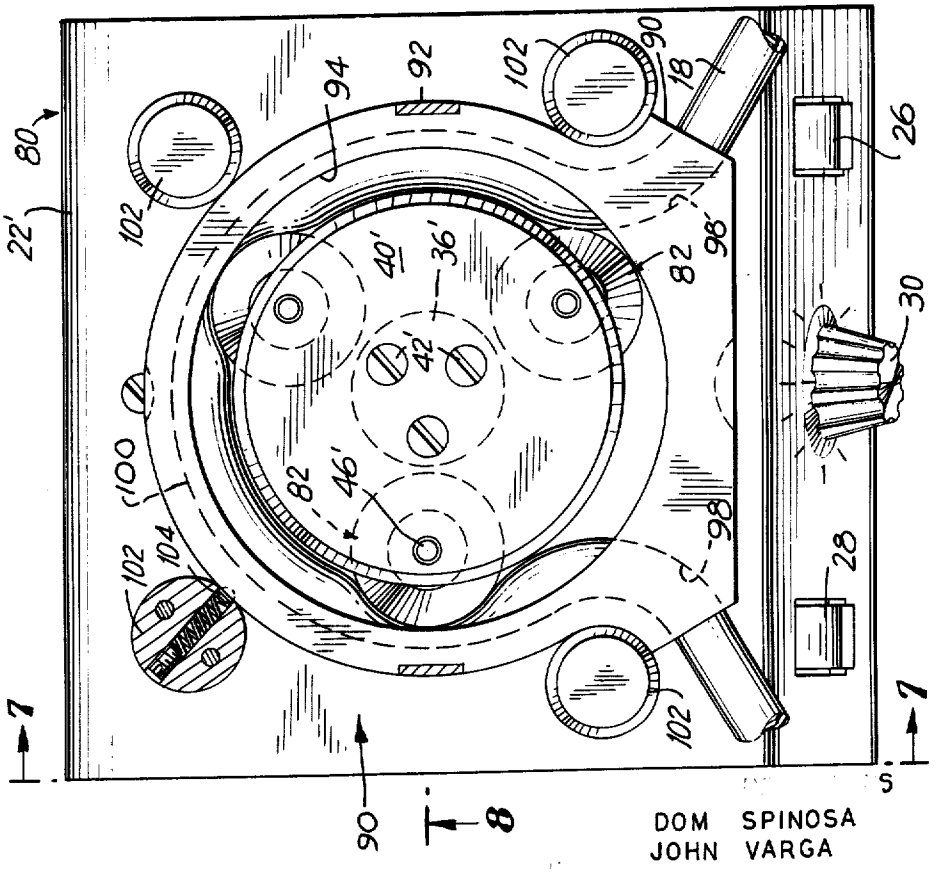
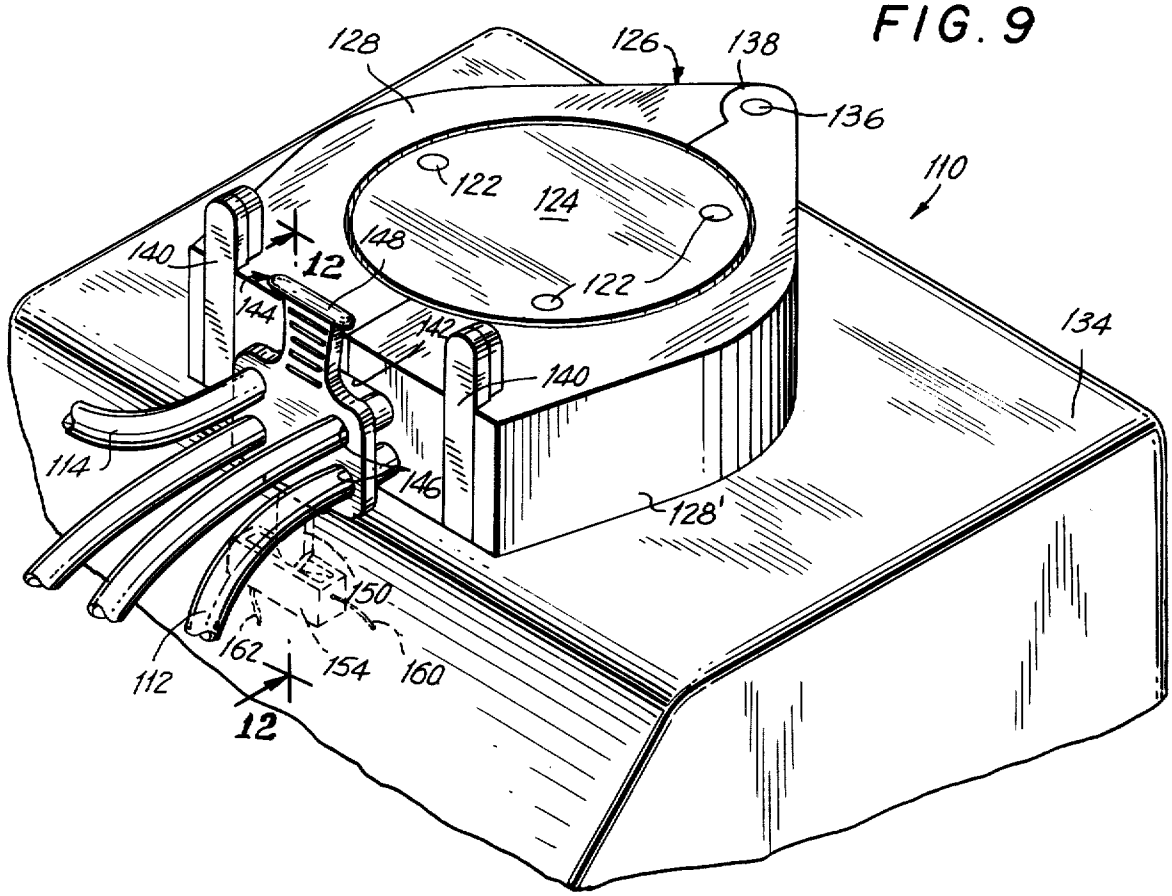


FIG. 6

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FIG. 9



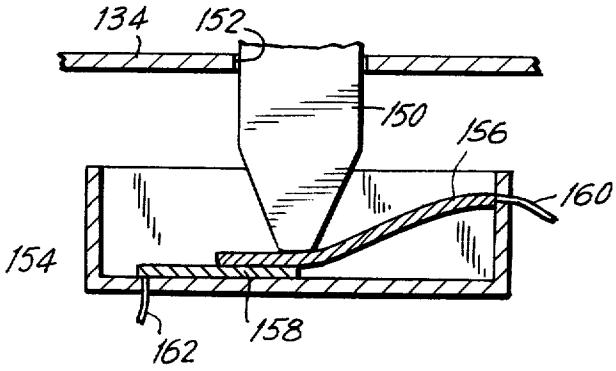


FIG. 12

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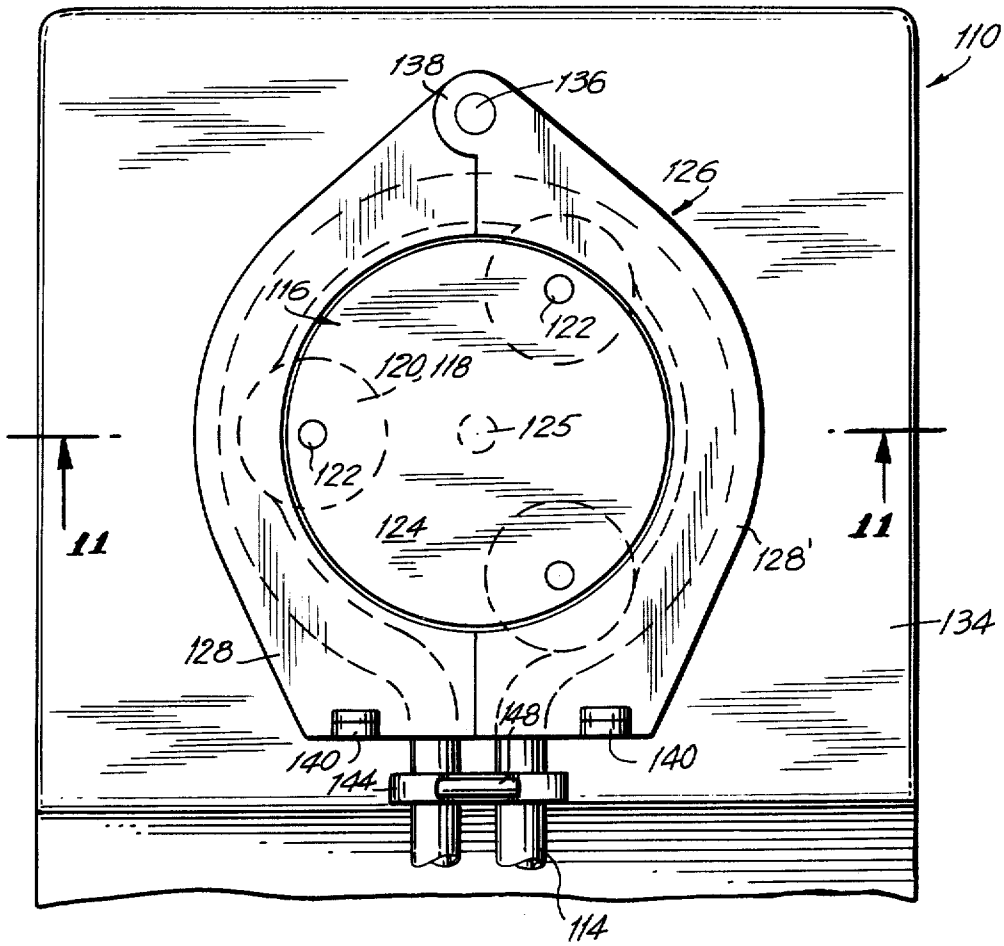


FIG. 10

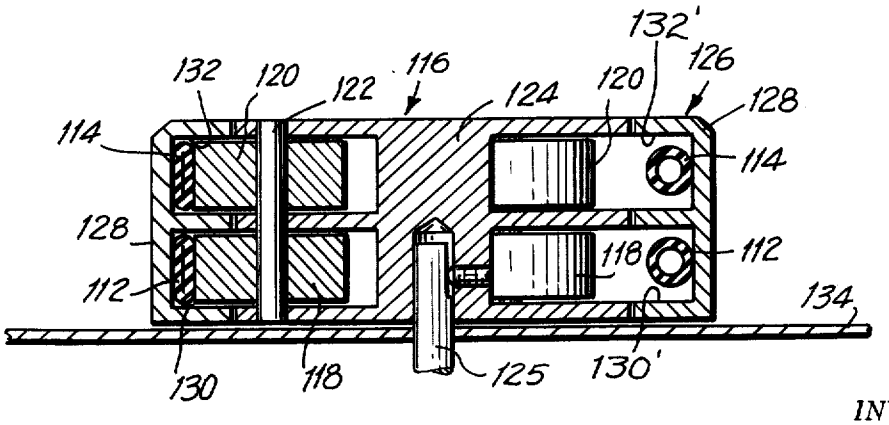


FIG. 11

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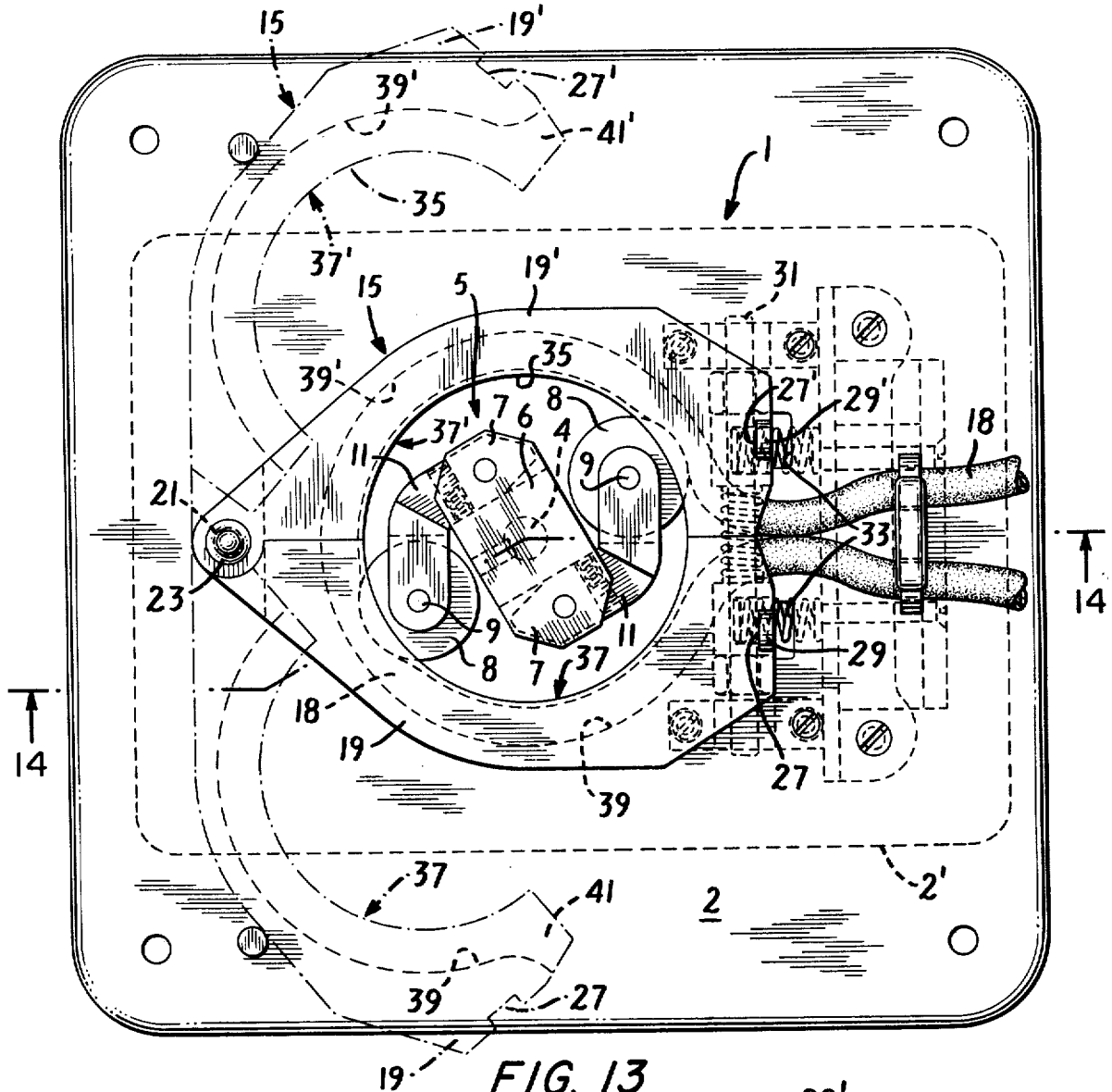

15
19'
39'
27'
41'
35
37'
1
5
31
11
21
23
9
8
7
6
4
29'
18
33
29
27
14
2'
2
39

FIG. 13

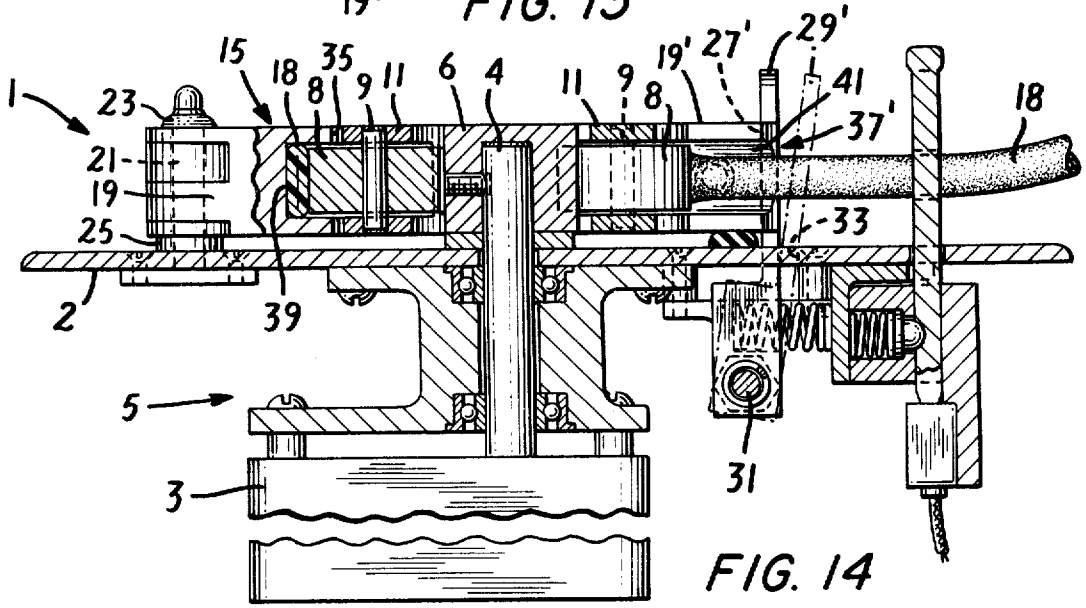

1
15
18
35
9
11
6
4
19'
27'
29'
41
37'
23
21
19
25
33
2
39
5
3
31

FIG. 14

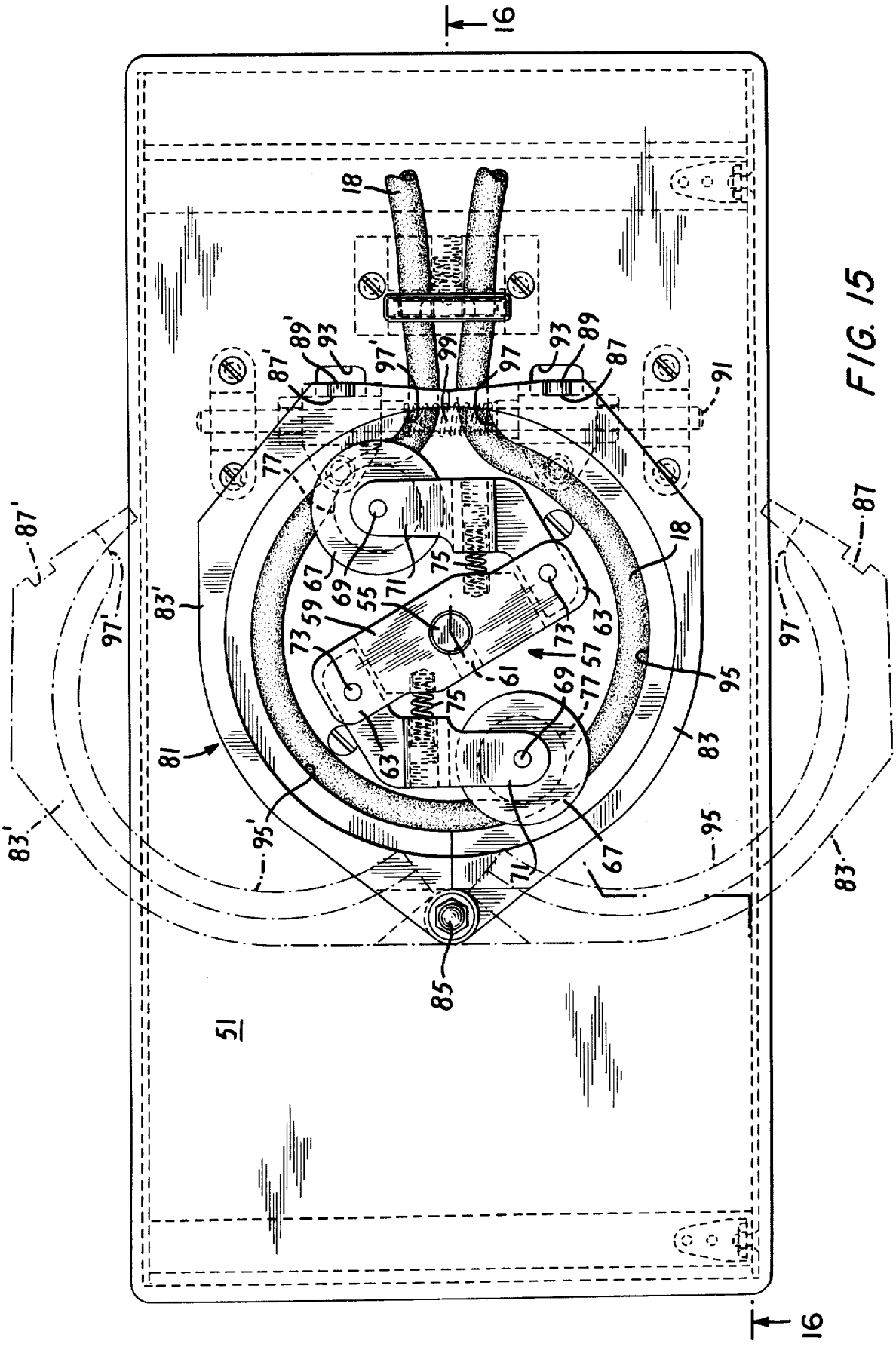

16
18
87'
89'
93
97'
99
97
93
89
87
91
77
83'
97'
87'
59
67
69
55
71
75
73
63
61
57
95
81
95'
85
51
16

FIG. 15

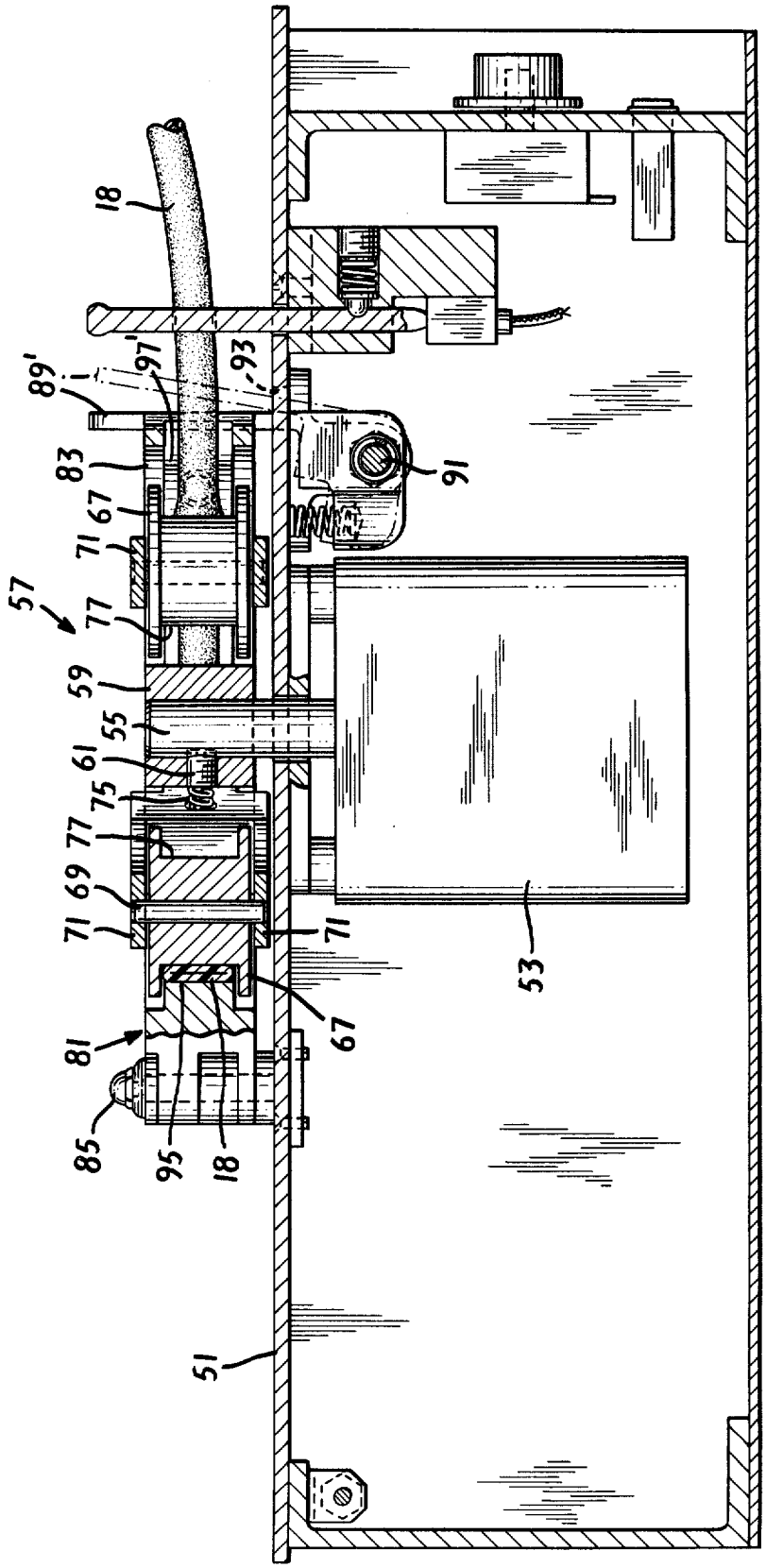

18
89'
97'
93
91
83
67
71
57
77
59
55
61
75
77
69
71
71
53
67
81
85
95
18
51

FIG. 16

MEDICAL CASSETTE PUMP

This application is a continuation-in-part of Ser. No. 174,019, filed Aug. 23, 1971, and now abandoned.

Pumps are frequently used for the delivery of fluids to and removal of fluids from patients where cavities of the body are to be washed out, such as the stomach, bladder or uterus, or where fluids are to be pumped from the body. Medical applications in which pumps are used include infusion, dialysis, hemoperfusion, constant irrigation, and the suction method of abortion. The fluid being delivered to or from the patient via the pump should move through a path in which it does not come into contact with any of the pump parts, in order to maintain the sterility of the fluid delivered to the patient, and to avoid contamination of the fluid taken from the patient. If the pump parts come in contact with the fluid being processed, it is necessary to clean and sterilize these parts between uses, which is an expensive and slow procedure.

Peristaltic pumps have been put to medical uses, but they have required threading of the fluid-carrying tube through intricate paths in the pump, which has made it difficult to replace the tubes between uses, and also raise the possibility of contamination of the tube during the threading operation.

In accordance with the invention, a peristaltic pump is provided in which a fluid-carrying tube is held against the pumping means by a readily displaceable cassette, which can be moved between a first position in which the fluid-carrying tube is held against the pump means for pumping of fluid through the tube, and a second position in which the fluid-carrying tube is exposed and can be freed from such engagement, and removed. Thus, merely by movement of the cassette between two positions the tube can be inserted, put in a pumping position for engagement by the pumping means, and replaced in a simple quick operation, without interference with the sanitary interior of the tube. No special equipment or tools and removal and replacement of bolts or screws is required.

The medical cassette pump of the invention comprises, in combination, a drive means; a fluid-pumping assembly operatively coupled to the drive means, for rotation thereby about a principal axis, said fluid pumping assembly including a pumping means rotatable about the principal axis; cassette means movable between a first position towards and a second position away from the pumping means; means defining at least one wall of a channel for reception of a fluid carrying tube, the wall restraining the tube from movement away from the pumping means, and retaining the tube in a path corresponding to the rotational path of the pumping means in close proximity to the pumping means in a manner such that the tube is collapsed by the pumping means against the wall; the cassette means in the first position retaining the fluid-carrying tube in the channel and in a position to be collapsed by the pumping means, and in the second position releasing the tube from such engagement to permit insertion of the tube in the channel or removal of the tube from the channel, and the pumping means in said first position of the cassette means being always in engagement with the tube at some portion of its length, and moving the collapsed portion along the tube for pumping of fluid through the tube upon rotation of the drive means.

The cassette means may comprise one or several cassette members describing segments of the arc of a circle or approximately circular shape and mounted for relative pivotable movement towards and away from the pumping means. A pair of cassette half-members each describing an approximately 180° arc can be pivotably mounted at one end, in a manner such that when brought together they extend through an approximately 360° arc about the fluid drive assembly. They engage the fluid-carrying tube against an inside wall thereof, which describes a circular channel about the fluid drive assembly. The cassette means can also be in the form of a disc, pivotably mounted at one side with the channel extending about one side of the disc, and enclosing the circular path followed by the pumping means.

The pumping means is coupled to the drive means for rotation thereby about its axis, in an arc corresponding to the channel, and in close proximity thereto, spaced therefrom by a distance equal only to the diameter of a fluid-carrying tube when collapsed and therefore closed off by the pumping means against the channel restraining wall. Thus, where the pumping means engages the tube, it closes off the tube to fluid flow against the interior wall of the cassette means, and by its rotation about the principal axis advances the fluid along the tube in response to the rotation of the fluid drive assembly.

The medical cassette pump can be formed with a frame and the cassette means may be releasably mounted on the frame for simultaneous removal of the cassette and fluid-carrying tube. The channel can be attached to the frame, or to the cassette means, or to the pumping means, or any combination of these alternatives. Thus, the pumping means can comprise grooved rollers or a grooved cam, with the channel being the groove, and the restraining wall thereof can be an internal peripheral wall of the cassette means.

The cassette means can be formed with one or two holes, slots, or other forms of openings therethrough, in a side thereof, for reception of the fluid carrying tube, so that it can enter the channel, each of the openings communicating with the channel.

The cassette means can be pivotably mounted on a shaft upstanding from the frame, which shaft is adapted to retain the cassette means secured to the frame. Bias means mounted on the frame can be provided, for biasing the cassette means into the first position, holding the fluid-carrying tube in engagement with the pumping means. The bias means can for instance take the form of a spring, such as a leaf or coil spring of the compression or tension type, or a magnet and magnetic member or pair of magnets.

Tab means can be provided, to act with a switch, the tab means engaging and preventing operation of the switch means operatively coupled to the drive means, to prevent the operation thereof unless the tab means is engaged by a tube.

The channel defines the loop described by the tube in traversing the inside wall of the cassette. This loop may extend over an arc that is greater or less than 360°. The only requirement is that a pumping means be continuously in engagement with the loop, during rotation of the pumping means about the principal axis, to ensure positive displacement of fluid along the loop.

Thus, if the loop be in excess of 360°, one pumping means will suffice, for advancement of fluid through the tube. If the loop be less than 360°, two pumping

means will suffice for this purpose, but more than two pumping means can be used, such as three, four or five, or even more, as desired. The spacing of the several pumping means from each other determines the volume of each pulse of fluid pumped through the tube, since each pulse is defined by the distance between adjacent pumping means of the fluid drive assembly. A large number, three, four or five, of pumping means give smaller relative pulses, but a more uniform pumped flow, along the tube.

The pumping means can take any desired form. The design and configuration of the pumping means in peristaltic pumps are conventional and form no part of the instant invention. Thus, for example, the pumping means can take the form of rollers, cams, fingers or spokes.

Thus, for example, a plurality of planetary rollers rotatably mounted in spaced relation to the principal axis and to each other can be used. The planetary rollers can be mounted at one side of a disc, or on spokes extending from a central hub attached to the drive shaft. A spoked wheel, the spokes serving as fingers, can be used, and a cam disc with cam-like protruberances can also be used, the tips or ends of the cams or fingers engaging and collapsing the tube in the manner described.

Two or more sets of pumping means can be provided, aligned in two planes, spaced along the principal axis, each engaging a separate fluid-carrying tube. The pumping means for each fluid-carrying tube can be arranged the same or differently, so as to engage and advance the fluid in each of the fluid-carrying tubes at the same or different times and in the same or different ways. The pumping means can be arranged to engage several or all of the tubes simultaneously, so as to pump fluid through such tubes at the same rate, although, optionally, not in the same direction, such as for example, in pumping fluid to and away from the body, to irrigate or flush a portion of the body.

In one embodiment of the medical cassette pump according to the invention, planetary rollers are provided composed of a cylindrical portion and a conical portion extending from one end of the cylindrical portion, in a manner such that the fluid-carrying tube rides along the conical portion for positioning and gradual compression until engagement by the cylindrical portion, at which point the tube is positioned for pumping operation.

The drawings illustrate preferred embodiments of the invention.

FIG. 1 is a perspective view of one embodiment of medical cassette pump according to the invention having a pair of cassette members, and three planetary rollers as the pumping means;

FIG. 2 is a sectional view taken along the line 2—2 of FIG. 1, and looking in the direction of the arrows;

FIG. 3 is a top plan view of the medical cassette pump of FIG. 1, showing the cassette half members in the open position;

FIG. 4 is a sectional view taken along the line 4—4 of FIG. 1, and looking in the direction of the arrows;

FIG. 5 is a sectional view taken along the line 5—5 of FIG. 1, and looking in the direction of the arrows;

FIG. 6 is a top plan view partially in section of a second embodiment of medical cassette pump according to the invention;

FIG. 7 is a fragmentary side elevation of the medical cassette pump of FIG. 6;

FIG. 8 is a sectional view taken along the line 8—8 of FIG. 6;

FIG. 9 is a fragmentary perspective view of a third embodiment of medical cassette pump according to the invention, having two planetary rollers as the pumping means;

FIG. 10 is a top plan view of the embodiment of medical cassette pump of FIG. 9;

FIG. 11 is a sectional view taken along the line 11—11 of FIG. 10;

FIG. 12 is a sectional view taken along the line 12—12 of FIG. 9;

FIG. 13 is a top plan view of a fourth embodiment of medical cassette pump according to the invention, having three grooved planetary rollers as part of the channel and the pumping means;

FIG. 14 is a sectional view taken along line 14—14 of FIG. 13;

FIG. 15 is a top plan view of a fifth embodiment of medical cassette pump according to the invention; and

FIG. 16 is a sectional view taken along the line 16—16 of FIG. 15.

The medical cassette pump indicated generally by 10 shown in FIGS. 1 to 5 is supported on a table 12, which also has a stand 14 mounted thereon. Hanging from the stand 14 is a fluid-dispensing bottle 16, to which is removably coupled a flexible resilient fluid-carrying tube 18, for delivery of fluid from the bottle to a patient by way of a catheter or other delivery device (not shown) attached to the end 17 of the tube 18. The end 17 of the fluid-carrying tube 18 can also be connected to a collection receptacle (not shown) in which case the pump can be arranged to draw fluid from the patient, and deliver it to the receptacle.

The medical cassette pump 10 includes a housing 22 within which is mounted an electric drive motor 24, best seen in FIG. 2. An on-off switch 26 and a reversing switch 28 mounted on the exterior of the housing 22 are operatively coupled in the electric circuit with the motor 24, so as to open and close the circuit and thus to turn the motor on and off, and also to control the direction of rotation thereof. Rheostat knob 30 mounted on the housing 22 turns a rheostat (not shown) and thus controls the speed of the drive motor. These components are conventional, and any design can be used. Timing and sequence controls permitting the automatic operation of the pump for predetermined periods, spaced by predetermined rest intervals, also can be provided. The drive motor is preferably noiseless and arc-less, so that it can be used in an oxygen environment.

The drive motor 24 rotates the drive shaft 32, which defines the principal axis of rotation of a fluid pumping assembly indicated generally by 34. As best seen in FIG. 2, the fluid-pumping assembly 34 is composed of a central hub 36, secured to drive shaft 32 by a set screw 38, and rotating therewith. A pair of spaced circular discs or plates 40 are mounted on each end of hub 36 by screws 42, for the rotation of the plates with the hub and drive shaft. Three spaced planetary rollers 44 are freely rotatably mounted between plates 40 upon roller shafts 46.

As best seen in FIG. 3, the three rollers 44 are circumferentially placed about the outer periphery of the plates 40, and are equally spaced from each other and the drive shaft 32. The three rollers 44 are carried in a circular path about the principal axis of rotation by the drive shaft 32.

A cassette **48** is provided, comprising a pair of cassette half-members **50, 50'**, joined at one end by a common hinge **52**, best seen in FIG. **5**. The hinge **52** is provided with an axial aperture **54** therethrough, engaging a post **56** projecting upwardly from the housing **22**. The post **56** serves as a pivot pin for the pivotal movement of the two cassette half-members **50, 50'** with respect to each other and the drive assembly, as well as positioning the cassette on the housing.

If the motor **24** is to be of the unidirectional type, the aperture **54** could be closed at one end by a wall, to prevent accidental reversal of the direction of fluid flow.

As shown in FIG. **3**, the two cassette half members are swung apart to open the cassette, and together to close the cassette. They also may be lifted off the post **56**, for removal from the housing. The other end **57, 57'** of each cassette half member **50, 50'** is provided with a notch **58, 58'**, which cooperates with a spring finger **60, 60'** as best seen in FIG. **4**. Each of the spring fingers **60, 60'** is mounted at one end to the housing **22** by a screw **62, 62'**, and each extends through an aperture **64, 64'** in the housing. The aperture permits the movement of the spring finger to the position shown in phantom lines in FIG. **4**, to permit the pivoting of the associated cassette halfmember **50**. A pad **66** at the end of each spring finger **60** engages the top surface of each cassette half-member **50, 50'** to prevent the upward displacement of the cassette half-members.

Each cassette half-member is formed with a substantially semi-circular inner peripheral wall **68, 68'**, dimensioned to extend about and receive plates **40**, and serving as a retaining wall for the tube **18**. In this embodiment, the portion of the inner peripheral wall **68, 68'** of each of the cassette half-members retaining the tube is formed as the base, **72, 72'** of a U-channel **70, 70'**, and is integral with the cassette half-member. The channel **70** can also be a separate component, pivotably mounted to the post **56** or frame **22**, and movable with the cassette half-member.

The two cassette half-members together describe an arc of 360° about the fluid-pumping assembly, each extending over about 180°. The channels, **70, 70'** extend over the same arc.

As best seen in FIG. **2**, the rollers **44** are dimensioned to extend into the channels **70**, to engage fluid-carrying tube **18** and thrust it in a flattened condition against the base wall **72, 72'**, of the channels **70, 70'**, as shown in the left portion of FIG. **2**. Channel **70** is dimensioned to loosely receive the fluid-carrying tube **18**, when the tube **18** is not in engagement by the rollers **44**, and to permit the flattening of the tube **18** against the inner wall **72** by the rollers **44**, closing off the tube at that point, and defining a pulse of fluid within the tube that is advanced along the tube by the rollers as they are rotated by the shaft **32** about their circular path.

Each of the cassette half-members is also provided with a curved bore **74, 74'** communicating with channels **70, 70'**, as best seen in FIG. **3**. The bores are spaced approximately 120° apart, so that the channels **70, 70'** extend over an uninterrupted arc of 240° and 120°.

In operation, the fluid-carrying tube **18** is threaded through the bores **74, 74'**, and received within the channels **70, 70'**, over the longer arc of approximately 240°. The cassette half-members **50, 50'** are then mounted on the post **56**, while in the open position as shown in FIG. **3**. Then, the two cassette half-members **50, 50'** are brought together into the position in phantom lines in FIG. **3**. When so positioned, at least two of the three rollers **44** at any given interval thrusts a portion of the fluid-carrying tube **18** against the inner wall **72, 72'** of the channels **70, 70'**, to effectively close the tube at that point. A pulse of fluid is defined between such two rollers, which pulse is advanced along the tube as the fluid-pumping assembly **34** is rotated. Before any roller **44** leaves contact with the tube at one end of the arc, the next-preceding roller **44** has engaged the tube at the other end of the arc, so that a pulse of fluid is always being advanced along the tube.

Each pulse of fluid is sequentially delivered to the outlet portion of the fluid-carrying tube located in the bore **74'**, while a new pulse of fluid at the inlet portion **74** is formed by the next roller, in sequence, and advanced along the section of the fluid-carrying tube and delivered to the outlet portion. In this manner a smooth and continuous flow of fluid is produced, in either desired direction of flow, without any of the moving parts of the pump being in contact with the fluid being transmitted.

If desired, cassette **48** may be assembled with the tube, and furnished as a unit, each such unit constituting a complete disposable cassette. This system can be sterilized as a unit, utilized as a unit, utilized as a unit, and disposed of as a unit. Whether or not the cassettes are disposable, a plurality of cassettes **48** may be provided, each of the cassettes engaging a separate tube, so upon completion of one operation, a pump may be immediately utilized for another operation by merely substituting a new cassette for the old one, including a fluid-carrying tube already threaded thereon. This substitution is readily and quickly made.

The pump is provided with a pair of handles **76, 78**, which permit the carrying of the pump, its mounting on a stand, or the selfsupport thereof.

The embodiment of medical cassette pump of FIGS. **6** to **8**, generally designated **80** in these Figures, comprises a drive shaft **32'**, with a hub **36'** mounted and held thereon by set screw **38'**. A pair of circular plates **40'** are secured to the hub by screws **42'**. In this embodiment, the planetary rollers **82**, which are freely rotatably mounted in circumferentially spaced relation on shaft **46'**, are formed with a cylindrical surface portion **84** and a conical surface portion **86**. The cassette **88** comprises a unitary cassette member **90** and a handle member **92**. The cassette member **90** is formed with an inner central opening **94**, the inner periphery of which defines a relatively shallow channel **96** (See FIG. **8**), the base wall **100** of which serves as a retaining wall for a tube **18**. The central opening **94** in the cassette member **90** is dimensioned to receive the cylindrical portion **84** of rollers **82**, with a close clearance between portion **84** and base wall **100**, so that a tube **18** in the channel is collapsed by the roller **82** against the wall **100** and closed off at that point.

The cassette member **90** is formed with a pair of curved bores **98, 98'** spaced approximately 120° apart and communicating with the channel **96**. The channel thus defines a 360° arc, with 120° and 240° portions between the bores **98, 98'**. The fluid-carrying tube **18** is threaded through the bores, around the 240° arc of the channel **96**. Since the channel is relatively shallow, portions of the fluid-carrying tube **18** project laterally out of the channel, but where in engagement with the cylindrical portion **84** of the rollers **82**, the tube **18** is compressed and flattened between the rollers and the

wall **100** of the channel **96**.

The cassette **88** is mounted on housing **22'** by four upstanding posts **102**, which project from the top of the housing. Each of the posts is provided with a spring-loaded detent **104**, which engages a corresponding recess in the cassette member **90**, to releasably retain the cassette member **88** in position. The cassette is mounted and removed by grasping the handle **92**, and moving the cassette along the principal axis defined by the drive shaft **32'** towards or away from housing **22'**.

The conical surfaces **86** of the rollers **82** permit the fluidcarrying tube **18** to ride therealong, and to be gradually compressed and released, and also serve as a centering device for the positioning of the cassette.

Alternatively, rollers **82** may be substantially cylindrical, but mounted for radial displacement relative to the principal axis of the drive shaft **32'**. In this embodiment, the pancake-shaped cassette member **90** would be positioned about the fluid-pumping assembly, and the rollers would be displaced outwardly into the channel **96**, to engage the fluid-carrying tube against the inner wall **100**, and locked in this position.

In another alternative embodiment, the fluid-pumping assembly can be formed integrally with the pancake-shaped cassette member **90**, the combination being keyed to and removably mounted on the drive shaft **32'**.

The cassette **88** may be disposable, and a plurality of such cassettes may be utilized, to permit the quick substitution of one cassette for another, as in the case of the embodiment of FIGS. **1** to **5**.

It will be apparent that the operation of this embodiment is the same as FIGS. **1** to **5**, and consequently, the operation will not be described.

The embodiment of medical cassette pump shown generally as **110** in FIGS. **9** to **12** is adapted for the simultaneous pumping of fluid in the same direction (but in fact in opposite directions in the fluid system) through two separate fluid-carrying tubes **112, 114**. As best seen in FIG. **11**, the fluid-pumping assembly shown generally as **116** is provided with two roller sets, each composed of three rollers, **118, 120**, one roller of each set being mounted on a common shaft **122** for free rotation thereabout. Each of the common roller shafts **122** are secured to a hub member **124**, which in turn is fixedly mounted on the drive shaft **125**, for rotation thereby. The hinged cassette **126** is provided with a pair of cassette half-members **128, 128'**, and extending along the portion of the inner peripheral walls thereof are channels **130, 130', 132, 132'** dimensioned to receive the corresponding pairs of rollers **118, 120**, and the fluid-carrying tubes **112, 114**. The cassette **126** is mounted on the housing **134** by the post **136**, extending through the hinge **138** joining the two cassette half-portions, and by the spring fingers **140**.

The cassette has four open slots **142**, which communicate with the channels **130, 130', 132, 132'**, and permit the insertion of the fluid-carrying tubes therein without threading the tubes through bores of the cassette. This permits permanent mounting of the cassette on the housing by means of the pin **136**.

In order to position and retain the fluid-carrying tubes, and to permit their easy insertion in and removal from the pump **110**, a tab member **144** (see FIG. **9**) is provided having four apertures **146**, positioned in two aligned spaced pairs opposite the slots **142**. Each of the fluid-carrying tubes **112, 114** is threaded through the two apertures, **146** of each pair, and about the channels **130, 130', 132, 132'** to define a 240° loop in each of the tubes in which at least two of the rollers **118, 120** engage the tubes **118, 120** at any given moment. Pivoting the cassette half-members **128, 128'** to the closed position shown in FIG. **10** brings the rollers **118, 120** into engagement with the tubes **118, 120** over this 240° loop. They are released for removal from the channels **130, 130', 132, 132'** by pivoting the half-members **128, 128'** away from this position.

Tab **144** is provided with a handle **148**, and is also adapted to serve a further safety switching function. For this purpose, tab **144** is provided with a projecting finger **150**, as best seen in FIGS. **9** and **12**. The finger projects through an aperture **152** in housing **134** into a switch block **154**. As shown in FIG. **12**, the finger **150** engages a displaceable switch member **156** against a switch member **158**, to close an enabling circuit, which when open will not permit the motor to operate. The circuit is connected by the leads **160, 162** to the drive motor of the pump. The displaceable contact **156** is in the form of a leaf spring, which will move to the open position when finger **150** of tab **144** is withdrawn. This ensures that the pump will only operate when the fluid-carrying tubes are properly positioned. A tab arrangement such as tab **144** can also be incorporated in pumps using only a single fluid-carrying tube.

The two-tube embodiment of FIGS. **9** to **12** permits the coordinated withdrawal and delivery of fluids from the body, and is particularly useful in flushing out cavities such as the stomach, intestine, and the like, and in particular in drug or poison cases, where the stomach must be washed out rapidly. The two sets of planetary rollers can also be mounted on separate hubs joined by a clutch mechanism, so that the two sets can be selectively operatively coupled to the drive shaft. This arrangement permits intermediate fluid delivery or withdrawal while maintaining continuous withdrawal or delivery, respectively.

The fluid-carrying tubes can also include concentric tubes, one within the other, for simultaneous delivery of two fluids at the same time. Two, three or more fluid-carrying tubes can be driven, if desired, simply by providing an adequate supply of pumping means. Closed disposable delivery and collection systems can be arranged for, with the fluid receptacle, fluid-carrying tube, and fluid passage means (such as a catheter) all formed as a unit. The medical cassette pump according to the invention provides a flexible efficient and sanitary pumping system, which can be utilized for a wide range of medical and other functions.

The medical cassette pump shown generally as **1** in FIGS. **13** and **14** includes a mounting plate **2** on which is mounted a drive motor **3**, best seen in FIG. **14**. The plate can mount the pump on a cabinet or table, the pump mechanism fitting within the cut-out portion. As on-off switch and a reversing switch (not shown) are operatively coupled to drive the motor **3** so as to turn the motor on and off and control the direction of rotation thereof. Means also can be provided to control the speed of the drive motor. Timing and sequence controls permitting the automatic operation of the pump for predetermined periods spaced by predetermined rest intervals also can be provided. The drive motor is preferably noiseless and arcless, so that it can be used in an oxygen environment.

The drive motor **3** rotates the drive shaft **4** which defines the principal axis of a fluid-pumping assembly **5**. The fluid-pumping assembly is composed of a central

hub 6 secured to drive shaft 4, and a pair of spaced wings 7 extend from hub 6 and are integral therewith for rotation of the wings with the drive shaft. Two planetary rollers 8 are freely rotatably mounted on wings 7 by roller shafts 9, cradled by arms 11.

As best seen in FIG. 13, the two rollers are circumferentially spaced 180° apart about the wings 7, and are equally spaced from the drive shaft 4. The two rollers are carried about the principal axis by rotation of the drive shaft 4.

A cassette 15 is provided comprising a pair of cassette half-members 19, 19' joined at one end by a pivot post 21 mounted on plate 2. The post 21 is provided with a cap 23 and a washer 25 on each side of the members 19, 19'. The post 21 serves as an axis for the relative pivotal movement of the two cassette half-members 19, 19', as well as serving to retain the cassette 15 in position on the housing 2.

The two cassette half-members are pivoted away from each other to open the cassette. The other end of each cassette half-member 19, 19' is provided with a notch 27, 27' which cooperates with a spring finger 29, 29', as best seen in FIG. 14. Each of the spring fingers is mounted at one end to the plate 2 by a screw 31, and extends through an aperture 33 in the plate. The aperture permits the displacement of the spring finger to the position shown in phantom lines in FIG. 14, to permit the pivoting of the associated cassette half-member 19, 19'.

Each cassette half-member is formed with a substantially semi-circular inner peripheral wall 35 dimensioned to extend about and receive wings 7. In this embodiment at least a portion of the inner peripheral wall 35 of each of the cassette half members is formed with a channel 37, 37' having a base wall 39, 39' serving as a retaining wall for a fluid-carrying tube 18.

As best seen in FIG. 13 the rollers 8 are dimensioned to extend into the channels 37, 37' to engage fluid carrying tube 18 against the base walls 39, 39' of the channels, as shown in the left portion of FIG. 14. The channels 37, 37' are dimensioned to loosely receive the fluid-carrying tube 18 when not in engagement by the rollers, and to permit the flattening thereof against the inner walls 39, 39' by the rollers 8, thus defining a pulse of fluid within the tube, that is advanced along the tube by the rollers 8 as they rotate about the drive shaft 4. Each channel 37, 37' of the cassette half members terminates in a curved slot 41, 41', as best seen in FIG. 13.

In operation, with the cassette half-members 19, 19' in the open position shown in phantom lines in FIG. 13, fluid-carrying tube 18 is placed in the channels 37, 37', extending through the curved slots 41, 41', and looping in an arc of approximately 320° about the drive assembly 5. Then, the two cassette half-members 19, 19' are brought together into the closed position shown in FIG. 13. When so positioned at least one and sometimes both of the two rollers 8 engage a portion of the fluid-carrying tube 18 against the inner wall 39, 39' of the channels 37, 37' to effectively close the tube. A pulse of fluid is defined before each roller engaging the tube, which pulse is advanced along the tube as the roller travels its circular path about the channels 37, 37' when the fluid drive assembly 5 is rotated.

Each pulse of fluid is sequentially delivered to the outlet portion 41' of the channel 37', while a new pulse of fluid is formed by the next roller 8, as it contacts the tube at inlet portion 41, of channel 37, and advanced in sequence along the fluid-carrying tube by the roller, and delivered to the outlet portion 41'. In this manner, a smooth and continuous flow of fluid in either direction is produced, without any of the moving parts of the pump being in contact with the fluid being transmitted.

The medical cassette pump shown in FIGS. 15 and 16 includes a housing 51 within which is mounted a drive motor 53. An on-off switch and a reversing switch are operatively coupled to drive the motor 53, so as to turn the motor on and off, and control the direction of rotation thereof. Means can be provided to control the speed of the drive motor. Timing and sequence controls permitting the automatic operation of the pump for predetermined periods spaced by predetermined rest intervals also can be provided. The drive motor is preferably noiseless and arcless, so that it can be used in an oxygen environment.

The drive motor 53 rotates the drive shaft 55 which defines the principal axis of a fluid-pumping assembly 57. The fluid-pumping assembly is composed of a central hub secured to drive shaft 55 by a set screw 61. A pair of wings 63 extend from and are integral with hub 59 for rotation of the plates with the drive shaft. Two planetary rollers 67 are freely rotatably mounted on roller shafts 69, which are cradled on arms 71. The arms 71 are pivotably mounted to the wings 63 by pins 73, and spring-biased outwardly relative to the drive shaft 55 by compression springs 75 attached to hub 59.

As best seen in FIG. 15, the two rollers 67 are circumferentially spaced 180° apart about the wings 63 and are equally spaced from the drive shaft 55. The two rollers are carried in a circular path about the principal axis of rotation by the drive shaft 55. Each roller has a central groove 77 which accommodates the fluid-carrying tube 18.

A cassette 81 is provided, comprising a pair of cassette half-members 83, 83' joined at one end by a pivot pin 85, best seen in FIG. 16. The pin projects upwardly from the housing 51. The pin serves as an axis for the relative pivotal movement of the two cassette half-members 83, 83', as well as serving to retain the cassette in position on the housing 51.

As shown in FIG. 15, the two cassette half-members 83, 83' are pivoted away from each other to open the cassette. The other end of each cassette half-member is provided with a notch 87, 87' which cooperates with a spring finger 89, 89' as best seen in FIG. 16. Each of the spring fingers is mounted at one end to the housing 51 by a screw 91, and extends through an aperture 93 in the housing. The aperture permits the displacement of the spring finger to the position shown in phantom lines in FIG. 16, to permit the pivoting of the associated cassette half-member 83, 83'.

Each cassette half-member is formed with a flat substantially semi-circular inner peripheral wall 95, 95' dimensioned to extend about and receive wings 63. In this embodiment, the groove 77 of each roller 67 serves as the channel for the fluid-carrying tube 18.

As best seen in FIG. 15, the grooves 77 are dimensioned to compress and flatten the fluid-carrying tube 18 against the inner walls 95, 95' of the cassette half-members 83, 83', as shown in the left portion of FIG. 15. The fluid-carrying tube 18 lies free and expanded when not in engagement by the rollers 67. Thus, the rollers 67 define a pulse of fluid within the tube before them, that is advanced along the tube by the rollers as they rotate along their circular path about the principal axis of the drive shaft 55. Each of the cassette half-

members **83, 83'** is provided with a curved end **97**, defining an opening **99** therebetween, as best seen in FIG. **15**. The members describe an arc of approximately 320° between the two sides of opening **99**.

In operation, with the cassette half-members in the open position shown in phantom lines in FIG. **15**, fluid-carrying tube **18** is placed in a loop of approximately 320° over the rollers **67**. Then the two cassette half-members **83, 83'** are brought together into the closed position in FIG. **15**. When so positioned, the ends of the tube **18** both pass through opening **99**, and at least one and sometimes two of the two rollers **67** engages a portion of the fluid-carrying tube against the inner walls **95, 95'** of the members **83, 83'**, flattening it so as to effectively close the tube there. One of the rollers **67** is always flattening the fluid-carrying tube against the wall at any given interval, and a pulse of fluid is defined ahead of such roller, which pulse is advanced along the tube by that roller as the fluid-pumping assembly **57** is rotated.

Each pulse of fluid is sequentially delivered to the outlet portion of the fluid-carrying tube located at opening **99**, while a new pulse of fluid is formed by the next roller, in sequence, and advanced along the section of the fluid-carrying tube by the roller as it moves about its circular path, and delivered to the outlet portion. In this manner, a smooth and continuous flow of fluid in either direction is produced, without any of the moving parts of the pump being in contact with the fluid being transmitted.

Having regard to the foregoing disclosure the following is claimed as the inventive and patentable embodiments thereof:

1. A medical cassette pump comprising in combination a driving means; a fluid-pumping assembly operatively coupled to the drive means for rotation thereby about a principal axis, said fluid-pumping assembly including a pumping means rotatable about the principal axis; cassette means movable between a first position towards and a second position away from the pumping means; means defining at least one wall of a channel for reception of a fluid-carrying tube; the wall restraining the tube from movement away from the pumping means and retaining the tube in a path corresponding to the rotational path of the pumping means in close proximity to the pumping means in a manner such that the tube is collapsed by the pumping means against the wall; the cassette means in the first position retaining the fluid-carrying tube in the channel and in a position to be collapsed by the pumping means, and in the second position releasing the tube from such engagement to permit insertion of the tube in the channel or removal of the tube from the channel, and the pumping means in said first position of the cassette means being always in engagement with the tube at some portion along the tube for pumping of fluid through the tube upon rotation of the drive means; said cassette means comprising a pair of cassette half-members each describing an approximately 180° arc and pivotably mounted at one end in a manner such that, when brought together, they extend through an approximately 360° arc about the fluid-pumping drive assembly and having an inside wall defining one wall of the channel.

2. A medical cassette pump according to claim **1** in which the cassette means comprises a plurality of cassette members each describing a segment of the arc of an approximately circular shape, and mounted for relative pivotable movement towards and away from the pumping means.

3. A medical cassette pump according to claim **1** in which the cassette means comprises a disc pivotably mounted at one side with the channel extending about one side of the disc, and enclosing the circular path followed by the pumping means.

4. A medical cassette pump according to claim **1** in which the pumping means is coupled to the drive means for rotation thereby about its axis, in an arc corresponding to the arc of the channel, and in close proximity thereto, spaced therefrom by a distance equal only to the diameter of a fluid-carrying tube when collapsed and therefore closed off by the pumping means against the channel restraining wall, so that where the pumping means engages the tube, it closes off the tube to fluid flow against the interior wall of the cassette means, and by its rotation about the principal axis advances the fluid along the tube in response to the rotation of the fluid drive assembly.

5. A medical cassette pump according to claim **1** comprising a frame with the cassette means releasably mounted on the frame, for simultaneous removal of the cassette and fluid-carrying tube.

6. A medical cassette pump according to claim **1** in which the channel is attached to the cassette means.

7. A medical cassette pump comprising in combination a driving means; a fluid-pumping assembly operatively coupled to the drive means for rotation thereby about a principal axis, said fluidpumping assembly including a pumping means rotatable about the principal axis; cassette means movable between a first position towards and a second position away from the pumping means; said pumping means defining at least one wall of a channel for reception of a fluid-carrying tube, the wall restraining the tube from movement away from the cassette means and retaining the tube in a path corresponding to the rotational path of the pumping means in close proximity to the pumping means in a manner such that the tube is collapsed by the cassette means against the wall; the cassette means in the first position retaining the fluid-carrying tube in the channel and in a position to be collapsed by the pumping means, and in the second position releasing the tube from such engagement to permit insertion of the tube in the channel or removal of the tube from the channel, and the pumping means in said first position of the cassette means being always in engagement with the tube at some portion along the tube for pumping of fluid through the tube upon rotation of the drive means; said cassette means comprising a pair of cassette half-members each describing an approximately **180°** arc and pivotably mounted at one end in a manner such that, when brought together, they extend through an approximately **360°** arc about the fluid-pumping drive assembly, said pumping means comprises grooved rollers, with the channel being the groove and the restraining wall thereof an internal peripheral wall of the cassette means.

8. A medical cassette pump according to claim **1** in which the cassette means is formed with at least one opening therethrough in communication with the channel for passage of the fluidcarrying tube to the channel.

9. A medical cassette pump according to claim **1** in which the cassette means is pivotably mounted on a shaft and having bias means for biasing the cassette means in the first position, holding the fluid-carrying tube in engagement with the pumping means.

10. A medical cassette pump according to claim 1 comprising a switch operatively coupled to the drive means and means engaging the switch.

11. A medical cassette pump according to claim 4 in which there is one pumping means in continuous engagement with one portion of the fluid-carrying tube.

12. A medical cassette pump according to claim 1 in which the channel defines a loop extending over an arc that is less than 360°.

13. A medical cassette pump according to claim 12 in which there are at least two pumping means, of which at least one is always in engagement with a portion of the loop.

14. A medical cassette pump according to claim 1 in which the pumping means is a roller mounted for free rotation on a shaft attached for rotation about the principal axis.

15. A medical cassette pump comprising drive means; a fluid-pumping assembly operatively coupled to said drive means for rotation thereby about a principal axis, said fluid-pumping assembly including at least two planetary rollers freely rotatably mounted in spaced relation to said principal axis to each other; a fluid-carrying tube; and displaceable cassette means for releasably engaging said fluid-carrying tube against at least one of said planetary rollers for the displacement of said fluid therealong, said cassette means including a pair of cassette half-members hingedly joined at one end thereof for relative pivotal displacement toward and away from said principal axis, said cassette half-members being formed so as to define a central opening for receiving said fluid-pumping assembly when said cassette half-members are joined together, at least a portion of the inner periphery of said cassette half-members defining said central opening being formed with a channel facing said principal axis for receiving a portion of said fluid-carrying tube and for crimping said tube substantially closed against at least one of said planetary rollers when said cassette half-members are joined.

16. A medical cassette pump according to claim 15 wherein said channel has an inner wall, said planetary rollers being dimensioned to extend into said channel with said fluidcarrying tube crimped between said channel inner wall and at least two of said rollers when said cassette half-members are joined.

17. A medical cassette pump according to claim 15 wherein said channel is formed with an inner wall, and dimensioned to permit said portion of said fluid-carrying tube received therein to extend laterally therefrom while permitting said planetary rollers to engage said fluid-carrying tube in a substantially closed position against said channel inner wall when said cassette half-members are joined.

18. A medical cassette pump according to claim 15 wherein each of said pair of cassette half-members is formed with a bore therethrough in a region spaced from the hinge thereof and providing communication to said channel, each of said bores being dimensioned to permit the threading of said fluid-carrying tube therethrough with a portion thereof in said channel.

19.. A medical cassette pump according to claim 15 including frame means, and spring latch means mounted on said frame means and positioned to engage each of said cassette half-members for releasably retaining said cassette half-members joined together.

20. A medical cassette pump according to claim 15 including a frame, and latch means mounted on said frame member and releasably engaging said cassette means for retaining said cassette means mounted on said frame while permitting the removal therefrom independent of said fluid-pumping assembly.

21. A medical cassette pump according to claim 15 including at least two fluid-carrying tubes, each of said cassette half-members including at least one channel for receiving each of said fluid-carrying tubes for engaging said fluid-carrying tubes against at least two of said planetary rollers.

22. A medical cassette pump according to claim 21 wherein said fluid-pumping assembly includes two sets of said planetary rollers substantially aligned in two planes spaced along said principal axis and positioned so that one of said sets of planetary rollers engages each of said fluid-carrying tubes.

23. A medical cassette pump according to claim 15 wherein the end of said cassette half-member spaced from said hinge connection therebetween is formed with a facing slot providing communication to said channel and dimensioned to receive said fluid-carrying tube as said cassette half-members are brought together, and to retain said fluid-carrying tube when said cassette half-members are joined.

24. A medical cassette pump according to claim 23 including tab means formed with a pair of apertures therethrough dimensioned to have said fluid-carrying tube threaded therethrough to define a loop, said loop being dimensioned to extend about said planetary rollers for receipt in said cassette half-member channels and said cassette half-member slots.

25. A medical cassette pump according to claim 15 including tab means formed with at least a pair of apertures dimensioned to have said fluid-carrying tube threaded therethrough to define a loop in said fluid-carrying tube dimensioned to extend about said planetary rollers, said pump including enabling switch means coupled to said drive means and adapted to enable the operation of said drive means when closed, said tab means including a finger dimensioned to engage said enabling switch means to close same when said loop of said fluid-carrying tube is properly positioned about said planetary rollers.

26. A medical cassette pump according to claim 15 wherein said displaceable cassette means includes a channel for receiving said fluid-carrying tube threaded therein, said displaceable cassette means and said fluid-carrying tube being disposable as a unit.

27. A cassette for a medical cassette pump having a drive means; a fluid-pumping assembly operatively coupled to the drive means for rotation thereby about a principal axis, and a pumping means rotatable about the principal axis comprising, in combination, cassette means for attachment to the pump in a manner to be movable between a first position towards and a second position away from the pumping means; means defining at least one wall of a channel for reception of a fluid-carrying tube, the wall restraining the tube from movement away from the pumping means, and retaining the tube in a path corresponding to the rotational path of the pumping means in close proximity to the pumping means in a manner such that the tube is collapsed by the pumping means against the wall; the cassette means in the first position retaining the fluid-carrying tube in the channel and in a position to be collapsed by the pumping means and in the second position releasing the tube from such engagement to permit insertion of the tube in the channel or removal of the tube from the

channel so that the pumping means in said first position of the cassette means is always in engagement with the tube at some portion of its length, and moves the collapsed portion along the tube for pumping of fluid through the tube upon rotation of the drive means; said cassette means comprising a pair of cassette half-members each describing an approximately **180°** arc and pivotably mounted at one end in a manner such that, when brought together, they extend through an approximately **360°** arc about the fluid-pumping drive assembly and having an inside wall defining one wall of the channel; bias means for biasing the cassette means in the first position, holding the fluidcarrying tube in engagement with the pumping means.

28. A cassette according to claim **27** in which the cassette means comprises a plurality of cassette members each describing a segment of the arc of an approximately circular shape.

29. A cassette according to claim **27** in which the cassette half-members have an inside wall which describes a circular channel about the fluid-pumping assembly.

30. A cassette according to claim **27** in which the cassette means comprises at least one opening therethrough communicating with the channel, for reception of the fluid-carrying tube, so that it can enter the channel.

31. A cassette according to claim **27** in which the channel defines a loop described by the tube in traversing the inside wall of the cassette.

32. A cassette according to claim **31** in which the channel extends over an arc within the range from 180° to 360°.

33. A cassette for a medical cassette pump having a fluid-pumping assembly operatively coupled to a drive means for rotation thereby about a principal axis, said fluid-pumping assembly including at least two planetary rollers freely rotatably mounted in spaced relation to said principal axis and to each other, and for supporting a fluid-carrying tube for the selective engagement of said tube against at least one of said rollers, comprising a pair of cassette half-members hingedly joined at one end for relative pivotal displacement, said cassette half-members being formed so that when joined together, a central opening is formed therein, at least a portion of the inner periphery of said central opening being formed with an axially facing channel for receiving a portion of said tube for crimping against said rollers each of said cassette half-members being formed with an opening therethrough spaced from said hinged connection and providing communication to said channel for said tube.

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