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(54) **THIN AND FOLDABLE FLUID PUMP CARRIED UNDER USER'S CLOTHES**

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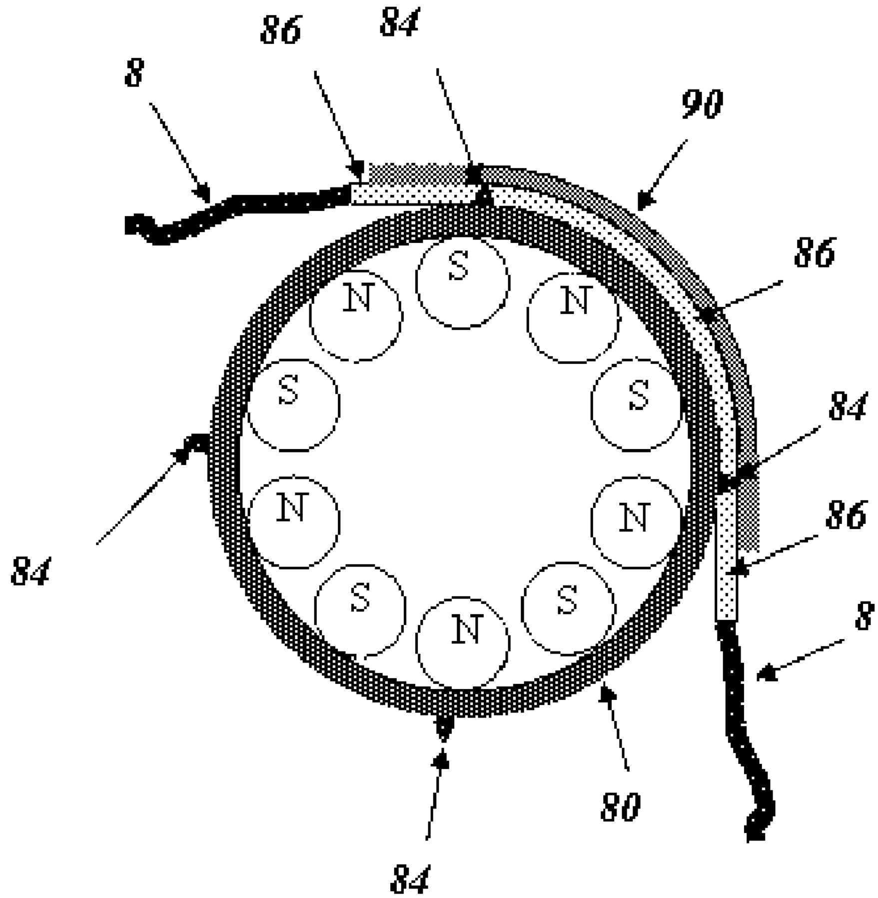
(57) **ABSTRACT**

This invention presents three kinds of conceptual models of fluid pump with similar innovation, to design thin and small compartments and laterally link all compartments with flexible means so that the whole fluid pump is thin and flexible. The first one uses the concept of spiral peristaltic pump. The rollers on the thin and round rotator of the thin spiral type of peristaltic pump roll over a section of elastic tube to press out the fluid in the tube. The rotator may be driven by a thin motor, electromagnetic driver, or spring. The second one uses the concept of linear peristaltic pump. The thin motors or electromagnetic drivers press different places of a section of elastic tube or its variation in special sequence to press out the fluid in the tube. The third one uses the concept of distributed processor. It comprises a number of thin and small pumping units where each one uses the elastic force, compressed air, linear motor, or the electromagnetic device to press out limited amount of fluid in the container. The number of pumping units is appropriate so that the user carries enough fluid to be convenient. For all models, the pump is laterally integrated by linking thin and small compartments with flexible means. The pump is as thin as the compartments and is flexible as the compartments are small and are linked with flexible cables, tubes, and other linking means. So, the user will feel comfortable to carry the pump under their clothes or to attach it to the skin.



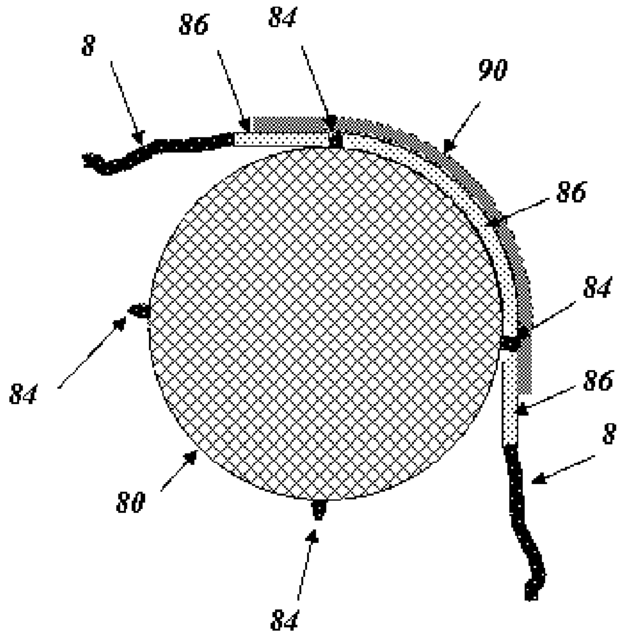

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Fig. 1

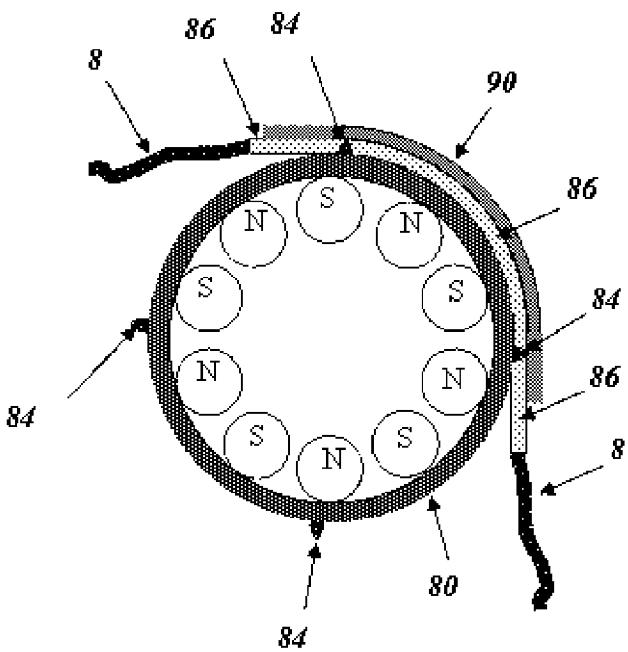
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Fig. 2

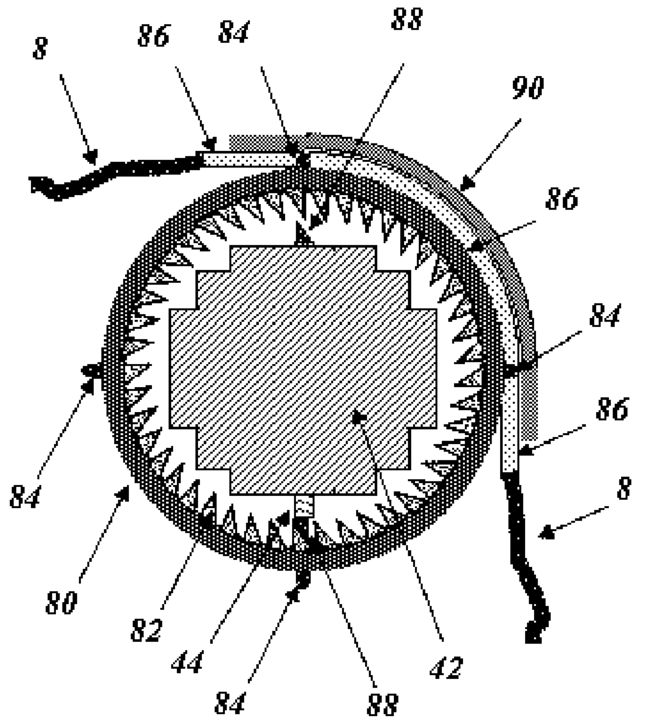
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Fig. 3A

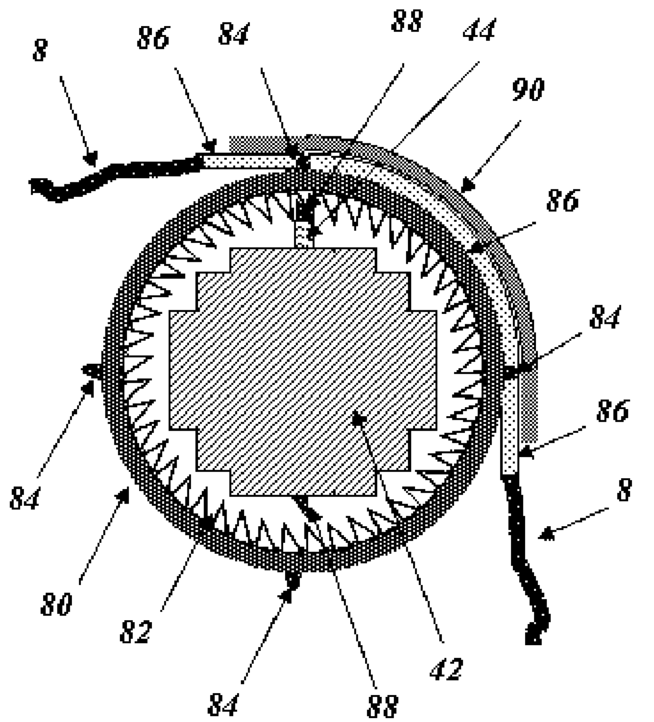
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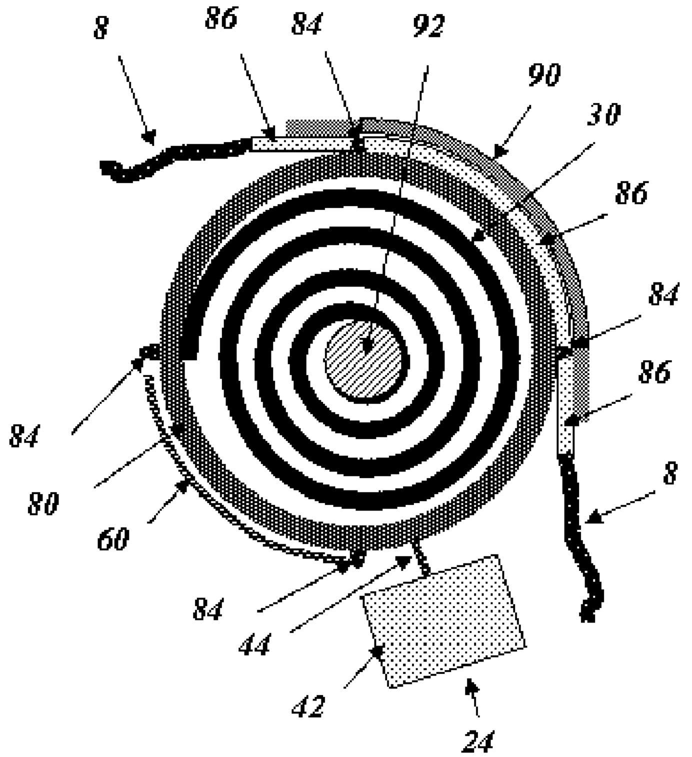
Fig. 3B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92
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84
86
8
84
80
60
84
44
42
24

Fig. 4

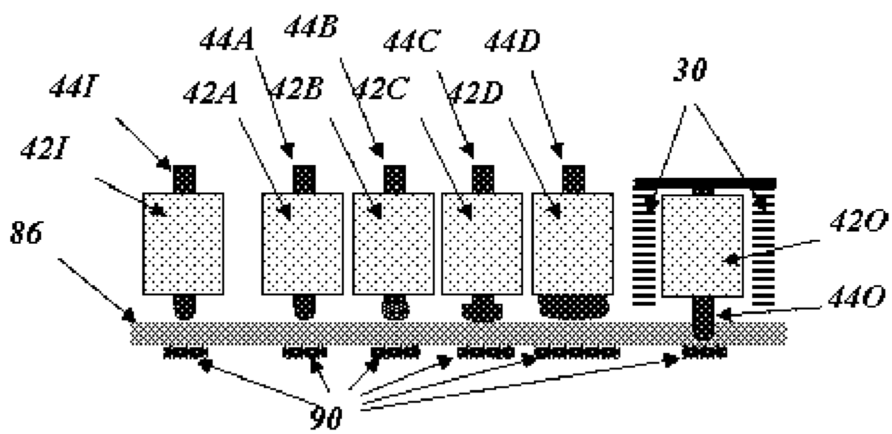
44A
44B
44C
44D
44I
42A
42B
42C
42D
30
42I
86
42O
44O
90

Fig. 5A

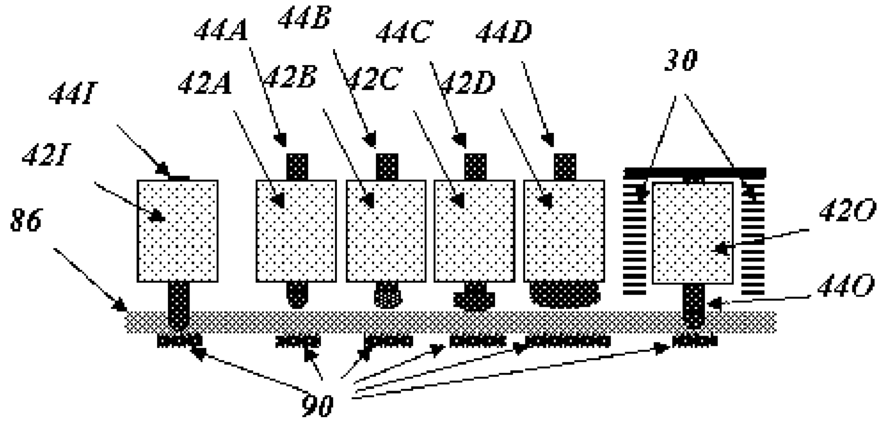

Fig. 5B

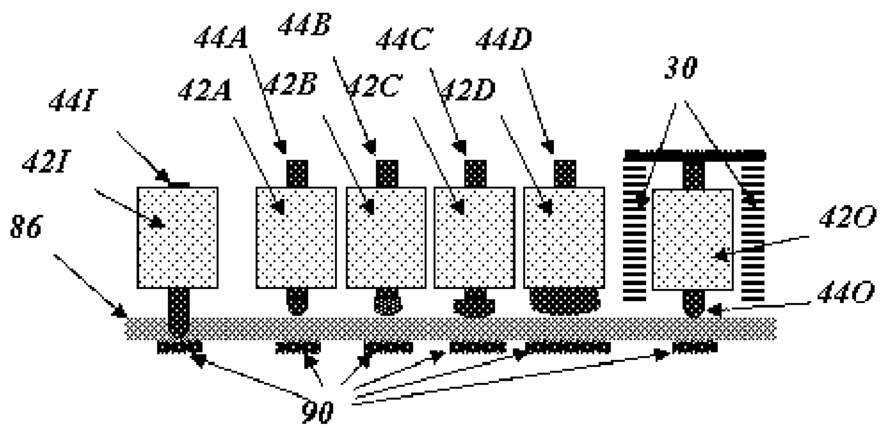

Fig. 5C

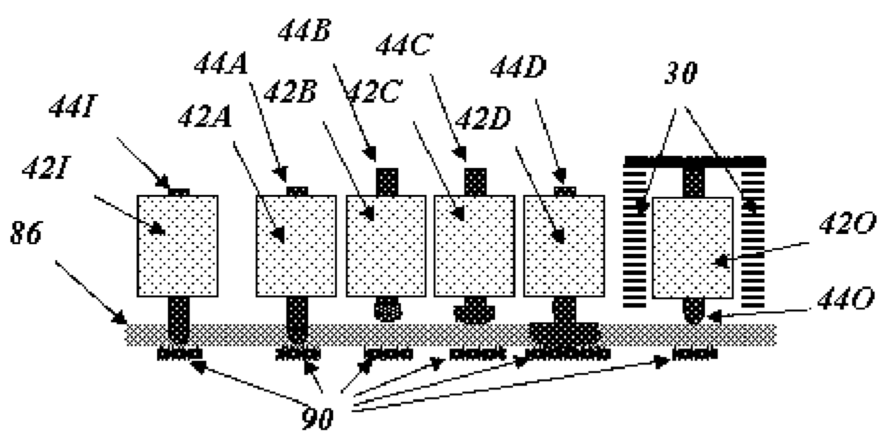

Fig. 5D

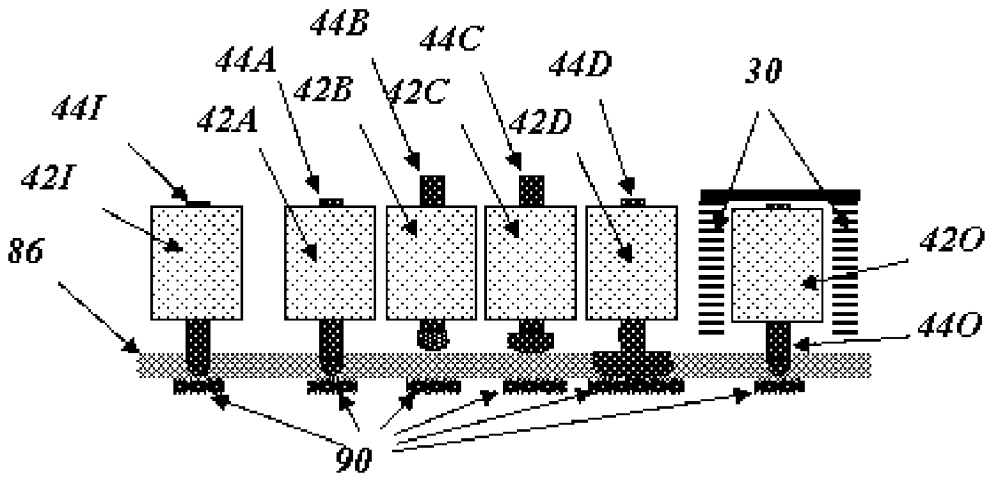

Fig. 5E

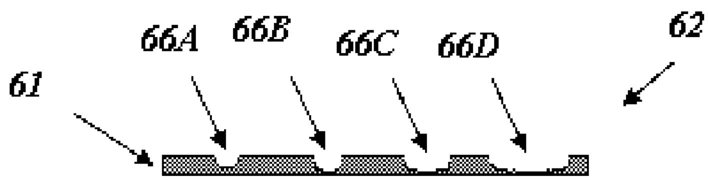

Fig. 5F

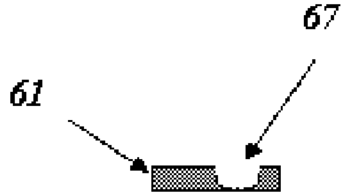

Fig. 5G

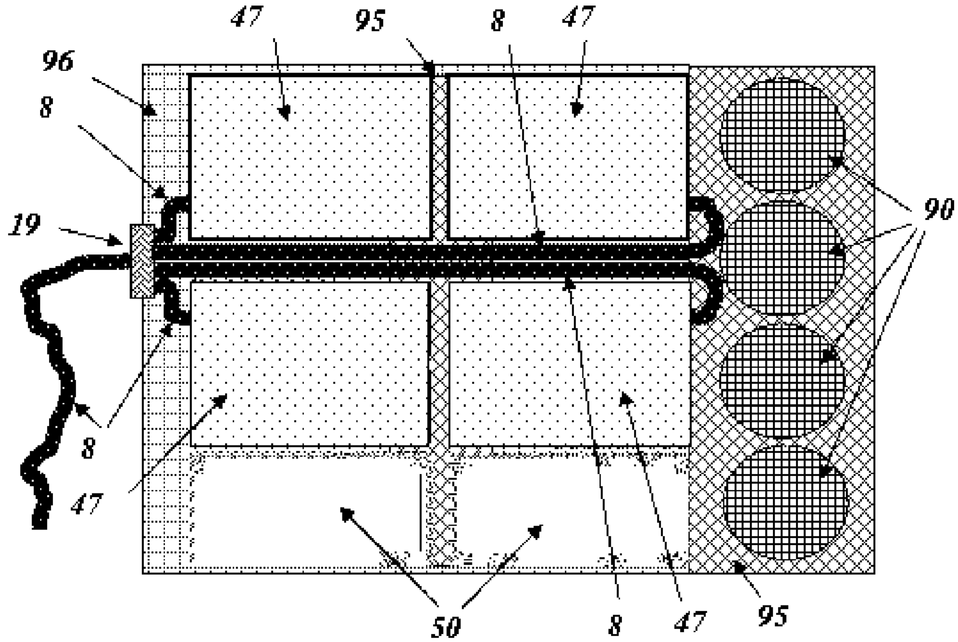

Fig. 6

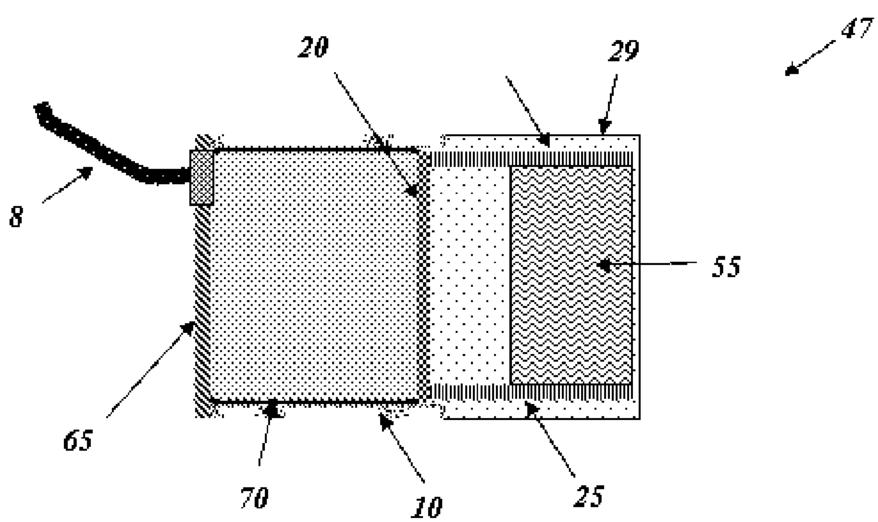

Fig. 7

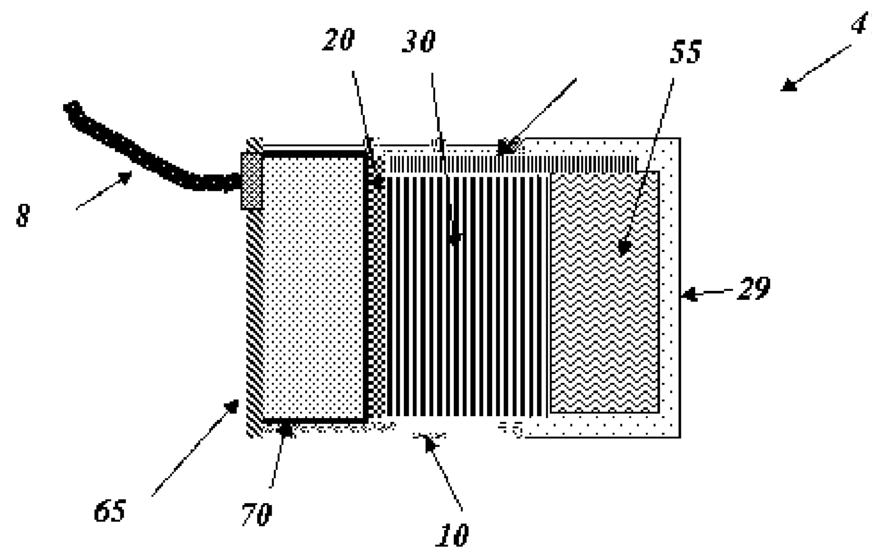

Fig. 8

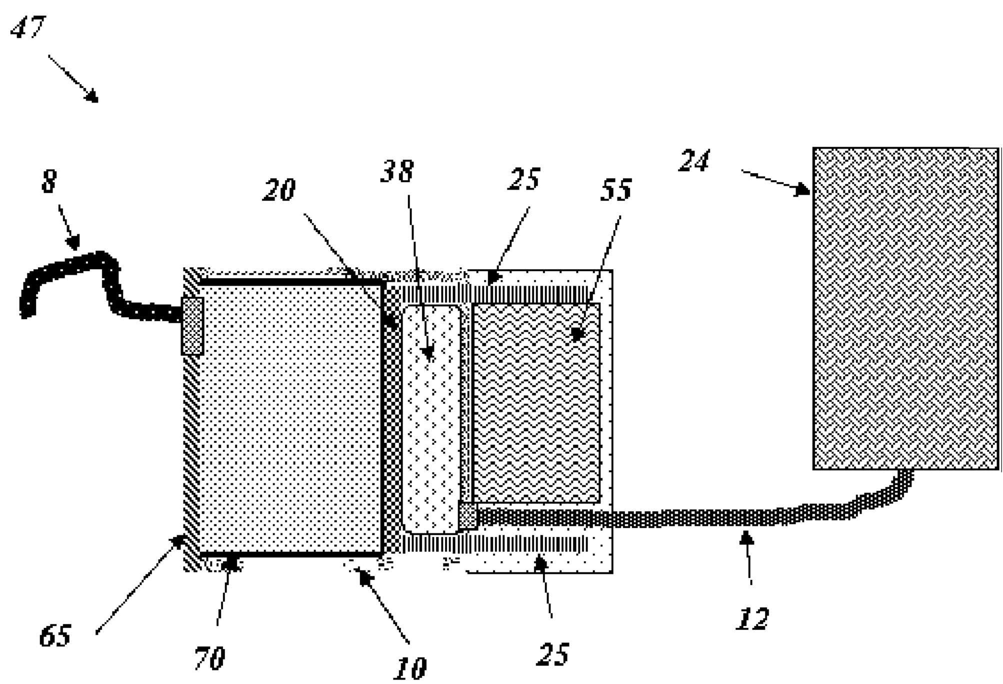

Fig. 9

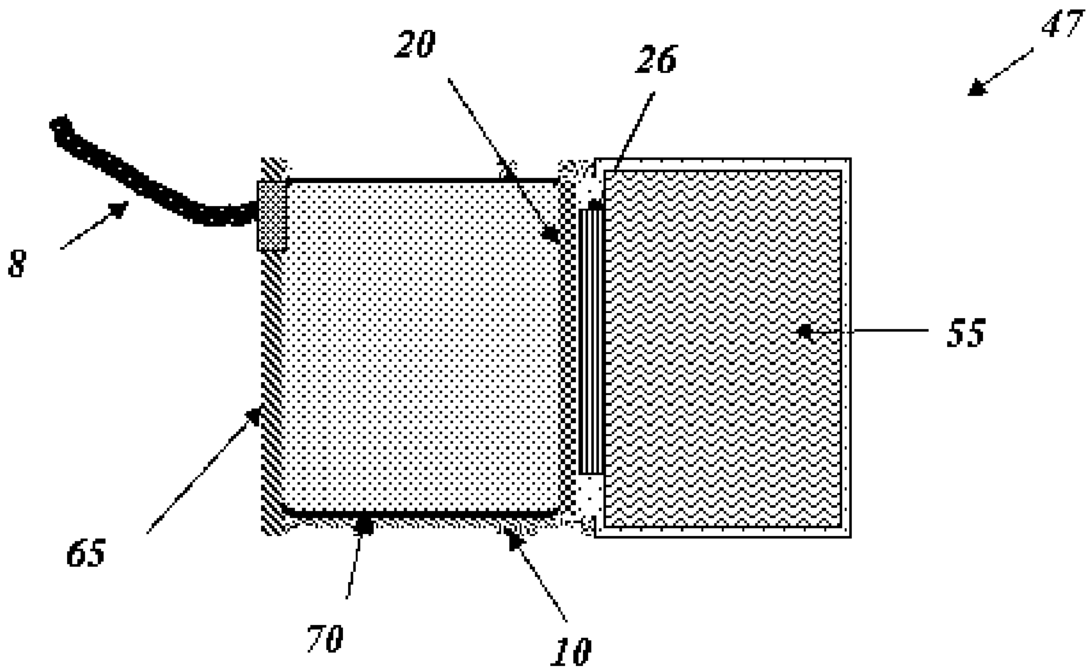

Fig. 10

THIN AND FOLDABLE FLUID PUMP CARRIED UNDER USER'S CLOTHES

FIELD OF INVENTION

[0001] The present invention relates to the thin and foldable fluid pump to be used in the apparatus that is carried under the user's clothes or is attached to the user's skin.

Previous Arts		
U.S. Pat. No.	Inventor	Date
6854620	Ramey	Feb. 15, 2005
6699234	Yeh	Mar. 02, 2004
6659980	Moberg, et al.	Dec. 09, 2003
6656148	Das, et al.	Dec. 02, 2003
5961487	Davis	Oct. 05, 1999
US patent application	Applicant	Date
20050159708	Sidler	Jul. 21, 2005
20050177111	Ozeri	Aug. 11, 2005
20050051580	Ramey	Mar. 10, 2005
20050020980	Inove	Jan. 27, 2005
20040133166	Moberg	Jul. 08, 2004
20050020978	Vollenweider	Jan. 27, 2005

References
http://www.debiotech.com/debiotech.htm

BACKGROUND AND PRIOR ART

[0002] Some patients, like type I diabetics, need medication continuously. The medication infusion pumps, or called insulin pumps, are ideal for them to reduce the number of injections. However, all the medication infusion systems in the market, like those made by Medtronic MiniMed, Disetronic, Deltec, Dana, and Animas, are about a cellular phone's size that are too thick. The systems developed recently, like those presented in the U.S. Pat. No. 6,854,620 by Ramey, U.S. Pat. No. 6,659,980 by Moberg, et al., U.S. Pat. No. 5,961,487 by Davis, and U.S. Pat. No. 6,656,148 by Das, et al., and in the US patent applications 20050177111 by Ozeri, 20050159708 by Sidler, 20050051580 by Ramey, 20050020980 by Inove et al., 20050020978 by Vollenweider, 20040133166, 20040085215, and 20030073954 by Moberg, and 20030233069 by Gillespie have the same problem. They are inconvenient to be carried and are difficult to be hidden in the summer. The users feel that they are connected to an external device and hate to be frequently asked, "What's that?"

[0003] Micro-Electromechanical Systems (MEMS) is a rapidly growing field that is impacting the micro pumps used in the insulin pumps. However, this kind of pumps is too expensive to be disposable mainly because the coils are difficult to be built in the wafer and integrating the diaphragm and the valves into the micro pump are expensive. The company Debiotech developed the micro pump chip with piezoelectric actuator four years, ago. The products are still not available in the market. The systems developed recently, like those presented in the U.S. Pat. No. 6,827,559 by Peter, et al., have the same problem, too expensive to be disposable. For all these systems, the medication passes through the micro pumps. The medication may have very little residual staying in the devices for a long time if the devices are not disposable. The users will be skeptical to use them. Another research initiated in the California Institute of Technology developed the micro pump that boils a tiny bubble to drive the medication. However, the medication passes through the micro pump and is heated at the same time. This is a big concern and the users may hesitate to use the systems. The system is also too expensive to be disposable.

[0004] In contrast to all the above approaches, my invention "Light, Thin, and Flexible Medication Infusion Apparatuses Attachable to User's Skin" with U.S. Pat. No. 6,699,234 presented conceptual models of thin and flexible infusion systems. The pump, the controller, the batteries, and the reservoir are thin and small and are laterally linked with flexible materials. So, the users can carry the pumps under their clothes or attach the pumps to their skin. Since the system is so close to the user's body and is flexible, the users will feel much more convenient and comfortable than using the conventional ones. Each pump may be expensive, but, the medication only passes through cheap and disposable tubes. Since the users will use the pumps for a long time, using these kinds of pumps will be much more economic than using the MEMS micro pumps. However, the infusion systems need thin and foldable pumps to drive the medication.

[0005] The peristaltic pump has been widely used for medical purposes. There are mainly two kinds of such pump. The one that round rotator with rollers rotates and presses out the fluid from a section of tube is also caller roller pump. The other one is linear where the fluid is sequentially forced out from the input end to the output end of a section of pipe. Base on these concepts, the present invention presents the conceptual models of the fluid pump that are thin and foldable. It is ideal to be used in the medication infusion systems stated above. Since the hard compartments are small, the users will feel to be flexible.

[0006] The first model is to install thin and small driving means in the rotator so that the whole pump is thin and small. The second model comprises a number of stages linked by flexible means so that each hard compartment is thin and small and the whole pump is thin and foldable. The user will feel like flexible. The fluid is drawn into the tube by the elasticity force of the tube and is pressed out of the tube by force applied to the tube. There can be more than one stage between the input and the output stages to improve the efficiency of the pump. For these two models, the pump may either pump the fluid directly or pump the air into a sealed fluid reservoir to force out the fluid indirectly. For the former, the fluid container may be flexible and the empty detection relies on detecting that the elastic tube cannot return to its original shape. For the latter, the empty detection relies on detecting that the elastic tube is over pumped. The user will appreciate the latter more because there are fewer parts to be disposed. Sidler presented to use the linear peristaltic pump for dosage control in the US patent application 2005019708. However, there are few fundamental differences. In Sidler's application, the pump is a one-piece hard compartment and the driving force to make the fluid flow into the pump is the pre-installed force in the fluid reservoir. Consequently, the empty detection relies on detecting the position of the plunger. The third model is to divide the pump into thin and small pieces and to laterally link them with flexible means so that the whole pump is thin and flexible.

OBJECTS AND ADVANTAGES

[0007] My present invention presents conceptual models of thin and flexible fluid pump, using thin motors, electromagnetic drivers, or elastic devices. They are ideal to be used in the medication infusion systems. The users of the apparatuses using such pumps will feel convenient and comfortable to carry the apparatuses under their clothes or to attach the apparatuses to their skin.

DRAWING FIGURES

[0008] FIG. **1**: The conceptual model of a thin fluid pump comprising a round rotator to press out the fluid in an elastic tube.

[0009] FIG. **2**: The conceptual structure of the thin pump driven by rotary or rotary step motor.

[0010] FIGS. **3**A and **3**B: The conceptual model of a thin pump driven by a linear motor or an electromagnetic driver.

[0011] FIG. **4**: The structure of a conceptual model of thin pump that the round rotator is driven by the spiral spring.

[0012] FIGS. **5**A to **5**E: The conceptual model of a thin pump that the elastic tube is pressed at different places in specific sequence to press out the fluid.

[0013] FIG. **5**F: The quantifier to press out precise amount of fluid.

[0014] FIG. **5**G: The device to eliminate the erroneous fluid made by input and output stages.

[0015] FIG. **6**: The conceptual model of a thin pump comprising a number of pumping units.

[0016] FIG. **7**: The conceptual model of a thin pumping unit driven by an elastic fluid bag.

[0017] FIG. **8**: The conceptual model of a thin pumping unit driven by a spring.

[0018] FIG. **9**: The conceptual model of a thin pumping unit driven by compressed air.

[0019] FIG. **10**: The conceptual model of a thin pumping unit driven by a thin linear motor or electromagnetic driver.

SUMMARY

[0020] This invention presents three conceptual models of fluid pump with similar innovation, to design thin and small compartments and laterally link all compartments with flexible means so that the whole fluid pump is thin and flexible. The first one uses the concept of spiral peristaltic pump. The rollers on the thin and round rotator of the thin spiral type of peristaltic pump roll over a section of elastic tube to press out the fluid in the tube. The rotator may be driven by a thin motor, electromagnetic driver, or spring. The second one uses the concept of linear peristaltic pump. The thin motors or electromagnetic drivers press different places of a section of elastic tube or its variation in special sequence to press out the fluid in the tube. Each motor or driver and the associated parts can be made to be a thin and small compartment. The third one uses the concept of distributed processor. It comprises a number of thin and small pumping units where each one uses the elastic force, compressed air, linear motor, or the electromagnetic device to press out limited amount of fluid in the container. Each pumping unit is designed to be a thin and small compartment. The number of pumping units is appropriate so that the user carries enough fluid to be convenient. For all models, the pump is laterally integrated by linking thin and small compartments with flexible means. The pump is as thin as the compartments and is flexible as the compartments are small and are linked with flexible cables, tubes, and other linking means. So, the user will feel comfortable to carry the pump under their clothes or to attach it to the skin.

DETAILED DESCRIPTION

[0021] Three conceptual models of thin and foldable fluid pump are presented. Two of them are peristaltic type pumps that use the thin motors, the electromagnetic drivers, or the spring type of elastic devices to press out the fluid in the tube. The pump may draw in the fluid, like the medication, directed from the reservoir and press the fluid out of the pump. It also may pump the fluid, like the air, into a sealed fluid reservoir to press out the fluid. The first model is to use round driving device whose rollers press the fluid out of an elastic tube in one direction. The second model is that the elastic portions of a tube is pressed at different points with special sequence to press out the fluid. The third conceptual model of thin fluid pump is composed of a number of pump units. Each pump unit uses the thin motor, the electromagnetic driver, or the elastic device to press out the fluid in a thin fluid reservoir. The innovation relies on making them thin and foldable. Since the apparatus is to be carried under the user's clothes, a remote controller is used. To keep the figures neat, the controller, the batteries, and the cables may not be shown in the corresponding figures.

[0022] FIG. **1** shows the first conceptual model of the pump. The round rotator **80** has a number of rollers **84** on its outer edge and can rotate. The pumping tube **86** is elastic. A roller **84** shuts off the pumping tube **86** when it rolls on the pumping tube **86**. There is at least one roller **84** to shut off the pumping tube **86** at any time. The tube support **90** is a hard device to help the rollers **84** to shut off the pumping tube **86** and is optional. A driving means drives the rotator **80** to rotate. The fluid in the pumping tube **86** is pressed along with the movement of the rollers **84**. Hence, the fluid is drawn from the input end and is pressed out from the output end of the pumping tube **86** through the fluid tubes **8**. Note that, when a roller **84** leaves the pumping tube **86**, the pumping tube **86** will return to its original shape. That will draw back the fluid that has been pressed out. So, the controller needs to know when a roller **84** leaves the pumping tube **86** and controls the rotator **80** to rotate to overcome this effect.

[0023] FIG. **2** shows the conceptual structure of the driving means that the round rotator **80** is the thin and round actuator **80** of a thin rotary or rotary step motor. The stators are not shown in the figure. When the rotator, or the actuator, **80** is driven to rotate, the rollers **84** press out the fluid from the pumping tube **86**. For a step motor, the actuator **80** rotates fixed distance for each step or pulse. The controller counts the number of steps that the rotator **80** rotates and translates it to be the distance that the rollers **84** move. The cross section area of the pumping tube **86** times the distance that the rollers **84** move is the volume of the fluid pressed out. When enough fluid is pressed out, the controller stops the electrical current applied to the motor. For a rotary motor, the mechanism to detect the distance that the actuator moves is simple. Contacting points are installed on the actuator and the stators or the substrate. Detecting which contacting point on the actuator contacts which contacting point on the stators, the controller will know how long the actuator moves.

[0024] FIGS. 3A and 3B show the conceptual model of another driving means where the round rotator **80** is driven by a linear motor or a linear electromagnetic driver **42**. The round rotator **80** has a ring of rotating gears **82** on its inner side. Inside the round rotator **80** and the ring of rotating gears **82**, there is a linear motor or linear electromagnetic driver **42** that drives its actuator **44** to move up and down. Each of the two ends of the actuator **44** has a pushing gear **88**. As shown in FIG. 3A, the tip portion of the tilting face of the lower pushing gear **88** encounters the tip portion of the tilting face of the rotating gear **82** right below the actuator **44** when the actuator **44** moves down. Hence, the round rotator **80** is pushed to rotate clockwise when the actuator **44** continues to move down. As shown in FIG. 3B, the tip portion of the tilting face of the upper pushing gear **88** encounters the tip portion of the tilting face of the rotating gear **82** right above the actuator **44** when the actuator **44** moves up. Hence, the round rotator **80** is pushed to rotate clockwise when the actuator **44** continues to move up. The smallest movement of the rollers is one pushing by the actuator **44**. That is a step. The controller is easy to control the volume of the fluid to be pumped.

[0025] FIG. 4 shows the structure of another conceptual model of the driving means that the round rotator **80** is driven by the thin spiral spring **30**. The outer end of the spiral spring **30** is connected to the round rotator **80** and the inner end is connected to the fastener **92**. The fastener **92** can fasten the spring **30** in one direction only. So, the fastened spring **30** drives the round rotator **80** to rotate accordingly. The mechanism to detect the distance that the round rotator **80** moves is similar with that explained above. Contacting points are installed on the round rotator **80** and the substrate. Detecting which contacting point on the round rotator **80** contacts which contacting point on the substrate, the controller will know how long the round rotator **80** rotates. That is translated to be the volume of the fluid delivered. The unit controller **24** is a linear motor or linear electromagnetic driver **42** that can drive its actuator **44**. The actuator **44** is driven to stick into the round rotator **80** to stop the round rotator **80** normally. When the round rotator **80** needs to rotate, the actuator **44** is pulled to let the round rotator **80** rotate. When enough fluid is delivered, the actuator **44** is controlled to stick into the round rotator **80** to stop the round rotator **80** again.

[0026] FIGS. 5A to 5E show the conceptual model of a thin pump that the elastic tube is pressed at different places in specific sequence to press out the fluid. There are three or more stages: an input stage, one or more dosage stages, and an output stage. Each stage has a linear motor or a linear electromagnetic driver that can drive its actuator back and forth. In the example shown in the figures, there are four dosage stages. The input stage **42**I, the dosage stages **42**A, **42**B, **42**C, and **42**D, and the output stage **42**O can drive the input actuator **44**I, the dosage actuators **44**A, **44**B, **44**C, and **44**D, and the output actuator **44**O, respectively. FIG. 5A shows the state that the pump is not pumping where the output stage shuts off the pumping tube **86** normally. The left end of the elastic pumping tube **86** is connected to the fluid source and the right end is connected to the destination. The input actuator **44**I and the dosage actuators **44**A, **44**B, **44**C, and **44**D do not press the pumping tube **86**. The output actuator **44**O is connected to the spring **30** to press and to shut off the pumping tube **86**. When the pump begins to pump the fluid, the input actuator **44**I is driven to press and to shut off the pumping tube **86** as FIG. 5B shows. Then, the output actuator **44**O is driven to leave and to open the pumping tube **86** as FIG. 5C shows. Then, the dosage actuators **44**A, **44**B, **44**C, and **44**D are selectively driven to press the pumping tube **86**. In this example, the dosage actuators **44**A and **44**D are selected as FIG. 5D shows. Then, the output stage **42**O is deactivated. The spring **30** will drive the output actuator **44**O to press and to shut off the pumping tube **86** as FIG. 5E shows. Then, the input and all dosage stages **42**I, **42**A, **42**B, **42**C, and **42**D are deactivated. The pumping tube **86** is elastic and, hence, will push all the input actuator **44**I and the dosage actuators **44**A, **44**B, **44**C, and **44**D back as FIG. 5A shows. Or, the input actuator **44**I and the dosage actuators **44**A, **44**B, **44**C, and **44**D are driven by the stages to leave and to open the pumping tube **86**. The elasticity of the pumping tube **86** will draw the fluid from the fluid source into the pumping tube **86**. This cycle presses out some fluid in the pumping tube **86**. Each of the dosage actuators **44**A, **44**B, **44**C, and **44**D may press out different volume of fluid. Preferably, the volume pressed out by the dosage actuators **44**A, **44**B, **44**C, and **44**D is 1, 2, 4, and 8 units, respectively. So, the volume pressed out in one cycle can be any units from 1 to 15. In the example shown in FIG. 5D, 9 units of fluid are pressed out.

[0027] The volume of the fluid pressed out by a dosage actuator needs to be precise. The quantifier **62** shown in FIG. 5F solves the problem. It is a piece of hard tube **67** whose outer diameter is the same as the inner diameter of the pumping tube **86** and is installed inside of the pumping tube **86**. It has one dosage concavity associated with each dosage actuator. The volume of each dosage concavity is the volume of the fluid to be pressed out by the associated actuator. The tip of each dosage actuator matches the contour of the associated dosage concavity. So, when a dosage actuator is driven to press the pumping tube **86**, the dosage actuator fits into the associated dosage concavity. Hence, exact amount of the fluid is pressed out. In the example, there are four dosage concavities **66**A, **66**B, **66**C, and **66**D associated with the dosage actuators **44**A, **44**B, **44**C, and **44**D, respectively. The material of the pumping tube is chosen to be that, when there is not any pressure on it, it always returns to the original shape. So, when a dosage actuator releases the quantifier, exact amount of the fluid is drawn in. An alternative is that each dosage concavity of the quantifier is covered and laminated with an elastic membrane. Then, the fluid tubes are connected to the two ends of the quantifier. It works the same way.

[0028] When the output stage releases the elastic pumping tube **86**, the fluid in the output tube is drawn back to the output stage. The same amount of the fluid will be pressed out when the output stage shuts off the pumping tube **86**. However, since the tube is elastic, these two amounts may have very small difference. The solution is similar with the above and is shown in FIG. 5G. The hard tube **67** has a concavity **67** and is installed in the pumping tube **86**. The tip of the output actuator **44**O matches the contour of the concavity **67**. When the output stage shuts off the pumping tube **86**, the actuator **44**O presses the pumping tube **86** fits in the concavity **67** so that the pumping tube **86** is shut off. Since the contour of the concavity **67** and the tip of the output actuator **44**O are hard and permanent, the amount of the fluid drawn in and pressed out the output stage will be the same. The input stage has similar problem and the solution is the same.

[**0029**] Any number of stages may be installed to be a hard compartment. The quantifiers of different hard compartments are linked with flexible tubes, flexible cables, and other flexible linking means. For the best flexibility, each stage is installed to be a hard compartment and all stages are linked with flexible tubes, flexible cables, and other flexible linking means. So, the resulting fluid pump is flexible.

[**0030**] Alternatively, the input stage may shuts off the pumping tube when the pump is not in operation. For either model, the springs **30** of the input or the output stage may be eliminated. Then, current needs to be applied to the input or the output stage to shut off the elastic pumping tube **86**. Or, the input or the output stage is latched after the elastic pumping tube **86** is shut off.

[**0031**] For the above two models, the fluid pump either draws the fluid directly from the reservoir and presses out the drawn fluid or pumps the air into the sealed fluid reservoir to press out the fluid indirectly. For the former, the empty detection is to detect that the pump is unable to draw the fluid. In the other words, this is to detect that the pumping tube cannot return to the original shape. An easy way to do so is to add a section of empty detection tube having a portion that is significantly more flexible than the pumping tube between the reservoir and the pump. So, when the reservoir is empty and the pumping tube returns to the original shape, the elastic portion of the empty detection tube will be concave. That can drive a switch. The controller will know that the reservoir is empty when the switch changes state. For the latter, the empty detection is to detect that the air is over pumped into the reservoir. The solution is similar with the above. The empty detection tube has a portion that is significantly more flexible than the pumping tube. So, when the reservoir is empty and the pump pumps the air into the reservoir, the elastic portion of the empty detection tube will be convex. That can drive a switch, too. The controller will know that the reservoir is empty when the switch changes status.

[**0032**] FIG. **6** shows another conceptual model of the fluid pump that comprises a number of pumping units **47**. A pumping unit **47** further comprises a unit controller **55**, a pumping means, and a fluid bag **70** to hold the fluid. Since the fluid pump is carried under the user's clothes, the pumping unit **47** must be small. However, it may be too small to carry enough fluid in the fluid bag **70** because the pumping means also takes space but the total fluid in all fluid bags **70** is enough. The system controller **50** controls that the pumping units **47** take turns to deliver the fluid. The unit controller **55** controls the pumping means to press out the fluid in the fluid bag **70**. The output fluid tubes **8** of the pumping units **47** are connected to an adapter **79**. The output fluid tube **8** of the adapter **79** is connected to the destination. Alternatively, the fluid bags **70** are linked in cascade where every two consecutive fluid bags **70** are linked with a flexible fluid tube **8**. All hard compartments, the pumping units **47**, the system controller **50**, and the batteries with holders **90**, are linked with flexible fluid tubes **8**, cables **95**, and pad type linking means **96** so that the system is thin and foldable.

[**0033**] FIG. **7** shows a conceptual model of pumping unit **47** that uses elastic fluid bag to press out the fluid in the bag. The unit case **10** is small and thin enough to be comfortably carried under the user's clothes or attached to the user's skin. Inside the unit case **10**, there is a piston **20**, a movement transferor **25**, and an elastic fluid bag **70**. The movement transferor **25** can be any combination of movement transferors, chains, strings, rods, or any kind of similar material as long as it can transfer the movement between the piston **20** and the unit controller **55**. The fluid bag **70** connects to the piston **20** and the case front **65**. When it is filled with fluid, the tension of the fluid bag **70** is strong enough to press out the fluid. It also pulls the piston **20** toward the case front **65**. The tension also keeps the fluid bag **70** straight so that the variation of the cross section area of the fluid bag **70** is negligible. The inner cross section area of the fluid bag **70** times the distance that the piston **20** moves is the amount of fluid that is pressed out. The piston **20** can be a little bit smaller than the inner cross section of the unit case **10** so that the friction between the unit case **10** and the piston **20** is minimized. The movement transferor **25** connects to the piston **20**. So, when the fluid bag **70** pulls the piston **20**, the movement transferor **25** transfers the movement of the piston **20** to the unit controller **55** that determines the movement of the piston **20**. The unit controller **55** can hold the movement transferor **25** so that the fluid stops flowing out of the fluid bag **70** and can also release the movement transferor **25** so that the fluid bag **70** pulls the piston **20** to press out the fluid. When the fluid pressed out is enough, the unit controller **55** holds the movement transferor **25** to stop the fluid flowing out.

[**0034**] FIG. **8** shows a conceptual model of the pumping unit **47** using an elastic device **30**, like the spring, to press out the fluid in the fluid bag **70**. The tightened or straightened elastic device **30** either drives the piston **20** directly or drives the movement transferors **25** to drive the piston **20** indirectly to press out the fluid. The rest is similar with that shown in FIG. **7**.

[**0035**] FIG. **9** shows a conceptual model of the pumping unit **47** using the compressed-air bag **38** to press out the fluid in the fluid bag **70**. The compressed-air bag **38** is connected to the air pump **24** via the air pipe **72**. Then, the air pump **24** pumps the air into the compressed-air bags **38**. When enough air is pumped into the compressed-air bag **38**, the air pump **24** and the air pipe **12** are detached. The compressed air in the compressed-air bags **38** will press out the fluid if the unit controller **55** releases the movement transferors **25**. The rest is similar with the above. Alternatively, the air pump **24** may pump the air into air reservoirs originally and the air reservoirs are linked to the air bags **38**. The figure is not shown.

[**0036**] FIG. **10** shows a conceptual model of the pumping unit **47** that the unit controller **55** comprises a thin linear step motor whose actuator **44** either drives the piston **20** directly or drives the movement transferors **25** to drive the piston **20** indirectly to press out the fluid. Each step that the actuator **44** advances will press out fixed amount of the fluid. The rest is similar with that shown in FIG. **7**.

CONCLUSION

[0037] Accordingly, the readers can see that each of the three models of the fluid pump is composed of small and thin compartments that are laterally linked with flexible means. Hence, each pump is as thin as the compartments and is foldable. The present invention also showed that all such compartments can be thin. Therefore, the fluid pump is thin. The apparatuses using such fluid pump are thin, too. Since each hard compartment is small, the user will feel like flexible. They are ideal to be carried under the user's clothes or be attached to the user's skin. The user will feel much more comfortable to use them.

[0038] Although the description above contains many specifications, these should not be constructed as limiting the scope of the invention but as merely providing illustrations of some of the presently preferred embodiments of this invention. Thus the scope of the invention should be determined by the appended claims and their legal equivalents, rather than by the examples given.

1. A thin fluid pump to deliver the fluid from the fluid reservoir to the destination, comprising:

a round rotator having any number of rollers on its outside edge,

a rotating driving means installed inside of said round rotator to drive said round rotator to rotate,

a section of elastic pumping tube installed along part of the outer edge of said round rotator and said rollers,

an amount controlling means,

a controller,

flexible fluid tubes and adapters,

any number of thin batteries,

flexible cables to laterally link said controller, said rotating driving means, and said batteries, and

flexible linking means to laterally link said controller, said rotator, and said batteries where there is at least one roller that presses and shuts off said pumping tube at any time;

the input end of said pumping tube is connected to said fluid reservoir and the output end is connected to said destination said fluid tubes and adapters when said fluid pump delivers said fluid directly from said fluid reservoir to said destination; and the input end of said pumping tube is open and the output end is connected to said fluid reservoir and said fluid reservoir is connected to said fluid destination with said fluid tubes and adapters when said fluid pump pumps the air into said fluid reservoir to deliver said fluid indirectly from said fluid reservoir to said destination

so that said controller controls said rotating driving means to drive said round rotator to rotate in the direction from the input end to the output end of said pumping tube; said rollers that press and shut off said pumping tube press said fluid inside said pumping tube to move along said pumping tube from the input end to the output end when said rotator rotates; either said fluid is delivered from said fluid reservoir to said destination or the air is pumped into said fluid reservoir to press out said fluid from said fluid reservoir to said destination; said amount controlling means detects the amount of said fluid that is delivered; said controller controls said rotating driving means to stop said round rotator when enough fluid is delivered; and said fluid pump is as thin as said controller, said round rotator, and said rotating driving means and is foldable.

2. The closure of claim 1 wherein said rotating driving means is a thin and flat rotary step motor and said round rotator is the actuator of said rotary step motor;

and said amount controlling means is that said controller counts the steps that said actuator rotates and translates said number to be the amount of said fluid pressed out.

3. The closure of claim 1 wherein said rotating driving means further comprises a ring of driving gears fixed to the inner side of said round rotator and a thin driver having an actuator installed inside of said ring of driving gears; and said amount controlling means is that said controller counts the number of times that said actuator presses said driving gears and translates it to be the amount of said fluid pressed out

where said round rotator rotates when said actuator presses said driving gears

so that said controller controls said driver to drive said actuator to press said driving gears that drives said ring of driving gears to rotate in the direction from the input end to the output end of said pumping tube; hence, said round rotator and said rollers rotate accordingly to deliver said fluid; and said controller stops said driver when enough fluid has been pressed out.

4. The closure of claim 1 wherein said rotating driving means further comprises an spiral elastic device, a fastener, and a unit controller and said amount controlling means further comprises a set of stator contacts and a set of actuator contacts

where said spiral elastic device is installed inside of said round rotator; the outer end of said spiral elastic device is fixed to said round rotator; the inner end of said spiral elastic device is fixed to said fastener; said unit controller can release said round rotator to let it rotate and can hold it to stop it; said stator contacts are installed to be stationary; said actuator contacts are installed to rotate with said round rotator; and the angular distance that said rotator rotates between two consecutive pairs of stator contact and actuator contact are connected is constant

so that said spiral elastic device is fastened by said fastener before said fluid pump is used; said unit controller releases said round rotator to let it rotate when delivering starts; said spiral elastic device drives said round rotator and said rollers to rotate in the direction from the input end to the output end of said pumping tube; said controller or said unit controller determines the amount of said fluid delivered by counting how many times that one stator contact and one actuator contact are connected; and said unit controller holds said round rotator to stop delivering said fluid when said fluid delivered is enough.

5. The closure of claim 1 wherein said fluid pump further comprises an empty detector, comprising:

a switch, and

a section of empty detecting tube having an elastic portion

where the input end of said empty detecting tube is connected to the output end of said pumping tube and the output end of said empty detecting tube is connected to said fluid reservoir if said fluid pump is to pump the air into said fluid reservoir to press out said fluid from said fluid reservoir to said destination; the input end of said empty detecting tube is connected to said fluid reservoir and the output end of said empty detecting tube is connected to the input end of said pumping tube if said fluid pump is to draw said fluid from said fluid reservoir and to pump the drawn fluid to said destination; said elastic portion is significantly easier than said pumping tube to be deformed by the pressure in said empty detecting tube and in said pumping tube; and said elastic portion is linked to said switch

so that, when said fluid reservoir is empty, said elastic portion is deformed that changes the state of said switch and, hence, said controller acknowledges that said fluid reservoir is empty.

6. A thin and foldable fluid pump to deliver the fluid from the fluid reservoir to the destination, comprising:

a controller,

an input stage and an output stage, each further comprising: a driving means and a valve means having an elastic portion where said driving means can press said elastic portion to shut off said valve means that disallows said fluid or the air to flow through said valve means and can release said elastic portion to open said valve means that allows said fluid or the air to flow through said valve means under the control of said controller,

any number of dosage stages, each further comprising: a driving means and a quantifier having an elastic portion and a housing under said elastic portion where said driving means can press said elastic portion to press out said fluid or the air in said housing and can release said elastic portion to let said elastic portion returns to the original shape that draws said fluid or the air into said housing under the control of said controller,

flexible and/or hard tubes and adapters to connect the input ends of all said quantifiers to the output end of said valve means of said input stage and to connect the output ends of all said quantifiers to the input end of said valve means of said output stage, and either to connect the input end of said valve means of said input stage to said fluid reservoir and to connect the output end of said valve means of said output stage to said destination when said fluid pump delivers said fluid directly from said fluid reservoir to said destination or to connect the output end of said valve means of said output stage to said fluid reservoir while the input end of said valve means of said input stage is open when said fluid pump pumps the air into said fluid reservoir to press out said fluid from said fluid reservoir to said destination,

any number of thin batteries,

flexible and/or hard cables or the similar to laterally link said controller, all said driving means, and all said batteries, and

flexible linking means to laterally link said controller, said input stage, all said dosage stages, said output stage, and all said batteries

where either said input stage shuts off its associated valve means or said output stage shuts off its associated valve means when said fluid is not being delivered

so that each hard compartment of said fluid pump is small and all hard compartments are linked by flexible tubes, flexible cables, and flexible linking means; said fluid or the air is drawn into and pressed out of said dosage stages with the following five-step cycling sequence under the control of said controller: 1) said input stage shuts off its associated valve means; 2) said output stage opens its associated valve means; 3) selected said dosage stages press their associated elastic portions, respectively, to press out said fluid or the air in their associated housings, respectively; 4) said output stage shuts off its associated valve means; and 5) said input stage opens its associated valve means and said dosage stages release their associated elastic portions, respectively, to draw said fluid or the air into their associated housings, respectively; said fluid is delivered from said fluid reservoir to said fluid destination; said controller determines how much said fluid is delivered; said cycling sequence repeats until enough said fluid is delivered; and said fluid pump is as thin as said controller, said input stage, said output stage, said dosage stages, and said batteries and is foldable.

7. The closure of claim 6 wherein said valve means is a section of elastic tube.

8. The closure of claim 6 wherein any number of said valve means and any number of said quantifiers are built in a compartment that comprises a section of elastic tube and a section of hard tube that has one concavity for each said valve means and each said quantifier

where said hard tube is installed inside of said elastic tube and all said concavities are covered with said elastic tube; and said elastic portion is the portion of said elastic tube covering each said concavity

so that, for each said valve means, said elastic tube touches the contour of the associated concavity to shut off said elastic tube and said hard tube when the associated driving means presses said elastic tube; for each said quantifier, said elastic tube touches the contour of the associated concavity to press out the fluid or the air in the associated housing when the associated driving means presses said elastic tube; and said elastic tube returns to its original shape when the associated driving means releases said elastic tube.

9. The closure of claim 6 wherein any number of said valve means and any number of said quantifiers are built in a compartment that comprises a section of hard tube that has one concavity for each said valve means and each said quantifier and said elastic portion is an elastic membrane laminated to cover each said concavity

so that, for each said valve means, the associated elastic membrane touches the contour of the associated concavity to shut off said hard tube when the associated driving means presses the associated elastic membrane; for each said quantifier, the associated elastic membrane touches the contour of the associated concavity to press out the fluid or the air in the associated housing when the associated driving means presses the associated elastic membrane; and each said elastic membrane returns to its original shape when the associated driving means releases said elastic membrane.

10. The closure of claim 6 wherein any number of said valve means and any number of said quantifiers are built in a compartment that has one cavity for each said valve means and each said quantifier and a tunnel to link all said cavities and the two ends on a surface of the body of said compartment and said elastic portion is an elastic membrane laminated to cover each said concavity and said tunnel

so that, for each said valve means, the associated elastic membrane touches the contour of the associated cavity to shut off said tunnel when the associated driving means presses the associated elastic membrane; for each said quantifier, the associated elastic membrane touches the contour of the associated cavity to press out the fluid or the air in the associated housing when the associated driving means presses the associated elastic membrane; and each said elastic membrane returns to its original shape when the associated driving means releases said elastic membrane.

11. The closure of claim 10 wherein a cover layer is further installed on the top of said elastic membrane where there is a hole on said cover layer for each said cavity so that the associated driving means can press said elastic membrane.

12. The closure of claim 6 wherein said driving means that shuts off the associated valve means when said fluid is not being delivered has an actuator that is connected to an elastic device so that said elastic device drives said actuator to press the associated elastic portion to shut off the associated valve means when said fluid is not being delivered and said controller activates said driving means to drive said actuator to release the associated elastic portion to open the associated valve means in said cycling sequence to deliver said fluid.

13. The closure of claim 6 wherein said driving means that does not press the associated elastic portion when said fluid is not being delivered has an actuator that is connected to an elastic device so that said elastic device drives said actuator to release the associated elastic portion and said controller activates said driving means to drive said actuator to press the associated elastic portion in said cycling sequence to deliver said fluid.

14. The closure of claim 6 wherein said controller applies the electrical current with different polarities to said driving means to press and to release the associated elastic portion.

15. The closure of claim 6 wherein said driving means that does not press the associated elastic portion when said fluid is not being delivered is applied with the electrical current to press the associated elastic portion by said controller and is pushed back by the associated elastic portion when the electrical current is stopped.

16. The closure of claim 6 wherein said fluid pump further comprises an empty detector, comprising:

a switch, and

a section of empty detecting tube having an elastic portion

where the input end of said empty detecting tube is connected to the output end of said valve means of said output stage and the output end of said empty detecting tube is connected to said fluid reservoir if said fluid pump is to pump the air into said fluid reservoir to press out said fluid from said fluid reservoir to said destination; the input end of said empty detecting tube is connected to said fluid reservoir and the output end of said empty detecting tube is connected to the input end of said valve means of said input stage if said fluid pump is to draw said fluid from said fluid reservoir and to pump said drawn fluid to said destination; said elastic portion of said empty detecting tube is significantly easier than said elastic portions of said valve means and said elastic portion of said quantifiers to be deformed by the pressure in said empty detecting tube; and said elastic portion is linked to said switch

so that, when said fluid reservoir is empty, said elastic portion of said empty detecting tube is deformed that changes the state of said switch and, hence, said controller acknowledges that said fluid reservoir is empty.

17. A thin and foldable fluid pump to pump the fluid pre-stored in said fluid pump to the destination; comprising:

a system controller;

any number of thin pumping units, each further comprising: a housing, a flexible fluid holder holding said fluid, a piston, a unit controller, and a driving means where one end of said fluid holder is fixed to said piston and the other end is fixed to said housing and said driving means drives said piston to press out said fluid in said fluid holder;

any number of thin batteries;

flexible fluid tubes and adapters to laterally link said fluid holders to said destination;

flexible cables to laterally link said system controller, said unit controllers, said driving means, and said batteries; and

flexible linking means to laterally link said pumping units, said system controller, and said batteries;

so that said system controller determines which pumping unit to deliver said fluid; each said unit controller controls the associated driving means to drive said piston to press out said fluid; said fluid pump is as thin as said pumping units, said system controller, and said batteries and is foldable.

18. The closure of claim 17 wherein said driving means of said pumping unit is that said fluid holder is elastic and has tension when said fluid holder holds fluid so that said fluid holder pulls said piston and presses out said fluid when said unit controller releases said piston and said piston stops pressing said fluid when said unit controller holds said piston.

19. The closure of claim 17 wherein said driving means of said pumping unit comprises elastic devices so that said elastic devices press said piston to press out said fluid when said unit controller releases said piston; and said piston stops pressing said fluid when said unit controller holds said piston.

20. The closure of claim 17 wherein said driving means of said pumping unit comprises air bags that are pumped with air or are linked to the air reservoirs that are pumped with air before said pumping unit is used so that the compressed air in said air bags presses said piston to press out said fluid when said unit controller releases said piston; and said piston stops pressing said fluid when said unit controller holds said piston.

21. The closure of claim 17 wherein said driving means of said pumping unit comprises thin driver whose actuator drives said piston to press out the fluid.

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