

SPRING DRIVEN FLUID DELIVERY APPARATUS

Technical Field

The present invention relates to a fluid delivery apparatus. In particular, it relates to fluid
5 delivery apparatus for infusion and injection of fluid medical substance.

Background

The use of ambulatory mechanically driven infusion devices have gain wide acceptance
due to its ease of use , safe and effective means of drug delivery in both hospital and non-
10 hospital based settings. The salient benefits are derived from the absence of programming
or infusion settings, unlike electronic pumps which can lead to serious adverse events
arising from human errors.

The general principle of such mechanical pumps is based on a force or pressure action on
a body of fluid within and enclosed receptacle such that the fluid is pushed out through a
15 flow restriction. For any given pressure acting on the fluid, the flow rate achieved is
determined by the internal diameter of the lumen of the restrictor based on Bernoulli's
and/or Hagen principle.

Albeit the safety element imbued in mechanical pumps there are limitations that relates to
flow accuracy and costs, particularly when the pump is intended for single use only. The
20 flow accuracy which is typically designed to meet prevalent international standards of +/-
15% limits the device to its use with drugs that have more tolerant therapy ranges. There
are also other issues pertaining to storage and operational use, for example if the device is
constructed with elastomeric membranes as reservoir the pressure generated would be
affected by the length and conditions of storage.

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Summary of Invention

In this invention, a reusable spring driven apparatus that enables the infusion of
medication at an accurate and uniform flow rate is disclosed.

The disclosed invention employs the use of a constant force tape spring to produce a significantly uniform force that acts on a body of fluid within a generally tubular container. In one embodiment the container consists of a rigid cylindrical shape that is open on one end such that a piston like contraption is axially movable within the container. The other end of the container has a nozzle that lends itself to fluid communication with the outlet of a tube along which a flow restriction is offered, either by its internal diameter or a purposely designed capillary in its path. When the piston like contraption, which would include a fluid sealing feature is pushed towards the nozzle end of the container, the contents inside the container would be discharged via the tubing.

The mechanism that drives the plunger consists of a constant force “Negator” spring. There were prior art in the basic principles of using such a spring for the described purpose, but the novelty of this invention rests in moving the coiled section of the spring away from the free end of the spring to create the required linear displacement that generates the force in pushing the fluid. In all prior art, the displacement of the free end of the spring is used to generate the force when the spring recoils to its natural state.

In USPTO 398,503 (Sealfon) a “Negator” spring is used to create a somewhat constant force to push the plunger of a syringe. In this prior art, the method to produce an extension and thereby storing potential energy involves uncoiling the spring by rotating a knob causing the free end of the tape spring to move away from the stationary uncoiled spring and then attaching the fluid container. It employs a complicated assembly of gears and pulleys to distend the free end of the spring and a cam-catch contraption to release it so that when returning to its initial state a force acts on the plunger of filled syringe to expel its fluid contents. Other than the superfluous number of components that increases the risks of failures, there are many steps involved in attaching the syringe, for example a knob needs to be wound so that the free end of the spring could accommodate the desired distended length of the syringe with its extended plunger. It is to be noted that variable fill volume will result in different extension of the plunger which makes this process less easy to operate. In this invention disclosed the syringe could be filled with any volume up to the maximum that is specified for the syringe, the different extended lengths of the plunger will automatically cause an appropriate uncoiling of the spring when the device is set up for use. This novelty provides less limitations as the volume of medication need no longer be restricted to the specified volume of the syringe. In this disclosed invention, winding

the mandrel in which the spring is installed automatically displaces the coiled section of the spring away from its free end. The displacement is equivalent to the length the piston needs to travel in order to push the fluid out from its reservoir and is therefore independent of the actual length of the piston. As long as the piston lengths exceed the axial length of the fluid reservoir, there will be a residual or pre-stressed force acting on the fluid container when all the fluid is dispensed.

In addition to the practical benefits described above, the technological advantage to be derived from this novelty is that moving a coiled section of the spring is relatively easier to achieve and control, for example an axle mechanism that moves along a track guide could be part of the coiled portion of the spring.

Another novelty in this disclosed invention is the use of appropriately designed coupling that functions as elements in creating a pre-stress force in the spring. The constant force in the spring type described in this invention requires an initial displacement of the free end from the coiled section, it is determined by the outer diameter dimension of the coiled section. The force displacement profile before this pre-stressing is attained is typically not constant. The aforesaid coupling enables the use of the somewhat constant range of the force profile in driving the piston. The flow rate resulting from this will be somewhat flat, unlike typical spring characteristics that exhibits declining force as the stored energy is released. The result of achieving a flat force profile throughout the displaced distance enables the fluid container to be filled with varying volume of fluid without affecting the intended flow rate of fluid delivery.

A further novelty in this disclosed invention is the use of telescopic sleeves to cause the extension of the spring. There were prior arts that describe the use of tubular elements of either solid construction or sleeve-like with screw threads on its surface that will cause springs to be compressed when the elements are moved towards or overlap with each other. In the disclosed invention one tubular element houses the spring mechanism while the sleeves that are movably affixed around it will cause the spring to uncoil when the sleeves are rotated by means of the screw threads in a direction that results in more surface overlap between the sleeve and housing. The uncoiling of the coiled section of the tape is due to the action of piston and coupling on the axle of the coil when the housing and said sleeve overlaps incrementally. The combined effect is to displace the coiled section of the

spring away from its free end which is affixed to the housing, causing an extension of the spring and storing potential energy. The method of extending the tape spring or constant force spring can also be achieved by directly pushing the sleeve element to cause more overlapping of the sleeve and housing, although the force required in this method is
5 appreciably higher when compared to a rotational movement of the sleeve relative to the housing.

The disclosed invention includes a system and device setup for an infusion of medicinal fluids in which a fluid container within which a rigid piston is axially movable such that fluid is discharged through the nozzle of the container when the piston is pushed or
10 displaced in a direction towards the nozzle. The movement of the piston is caused by the force generated by the spring which is extended or uncoiled when the container is affixed to the apparatus by rotational movement executable by manual or machine assisted means. The container and its piston could also be affixed to the apparatus by direct axial force to cause an extension of the spring. When the tubing with its flow restriction that determines
15 flow rate is unclamped, a fluid pathway within the abovementioned tubing which is in fluid communication with the container allows fluid to flow at a somewhat constant rate through-out the duration of fluid flow.

Brief Description of the Drawings

20 Fig 1 is a cross sectional perspective view of one embodiment of the disclosed invention.

Fig 1A is another cross sectional perspective view of one embodiment of the disclosed invention.

Fig 2 is a cross sectional perspective view of the disclosed invention with a filled fluid container attached.

25 Fig 2A is a cross sectional perspective view of the disclosed invention with a fluid container attached and its fluid contents expelled.

Fig 3 is a cross section view of spring housing

Fig 3A is a perspective view of the spring housing

Fig 4 is a diagram showing an array of pumps with network connectivity;

Fig 5 is a chart showing a flow profile;

Fig 6 is a diagram showing mobile connectivity of a pump.

Detailed Description

5 Examples of embodiments will be shown to provide an understanding of the principles of the design features, its function, manufacture, use of the device and methods disclosed. The embodiments shown are intended to be exemplary and non-limiting, and the scope of this invention is defined by the claims herein. The features described in the embodiment
10 may be combined with variants or modifications of other embodiments to achieve the goals of a device with the features and novelties described. Such variants or modifications are intended to be within the scope of this invention.

By way of a non-limiting example, Fig 1 illustrates the construction of the disclosed device. The force required to push fluid out of the container is derived from at least one set
15 of constant force spring 215. The displacement of the axle of the spring 216 is constrained by guide channels 203 and 204 that could be made from specifically formed parts that are installed within the inner walls of the tubular hollow tubular shaped housing 101 or these could be integrated channels of the hollow housing itself. The channels ensure that the direction of the displacement of the axis of the springs takes place in a generally same
20 plane as the axis of the piston movement within the fluid container 400. The choice of the number of springs or its dimensions i.e. width, outer diameter, thickness and spring material determines the force that is desired.

In this embodiment, the constraints in the volume space of the hollow housing dictates the use of a single spring. In order that the force desired is realised. In other embodiments, the
25 spring set could simply be a single spring or multiple spring arranged in other configurations. By way of example, multiple springs could be arranged within a common axis or with their axes along the lateral direction in which they are displaced when the device is in use.

Further referring to Fig 1, A “Negator” spring 215 and its housing 210 is installed within the volume space 102 of a tubular mandrel 101. The spring housing 210 encapsulates the spring axle 216 in such a manner that the axle is free to rotate when the spring 215 is uncoiled. The free end of the spring 217 protrudes out of the spring housing and renders itself mountable onto a fixed position within the tubular mandrel. When a force is applied onto the spring housing 210 in a lateral direction relative to the spring axle 216 and its free end 217, the spring will be forced to uncoil resulting in a displacement away from its free end. This force is produced by the action of winding the tubular mandrel 101 in a direction that moves it into an outer hollow concentric sleeve to which the fluid container 401 is attached. The restrictor tubing 415 that is affixed to the container 400 could be dimensioned accordingly to produce the intended flow rate. A standard connector available in for medical infusion 414 could be used to connect the tube to the container 400.

Fig 1A shows another perspective view of the embodiment shown in Fig 1. The hollow mandrel housing 101 is shown in its fully withdrawn position relative to the telescopic sleeve 301 of the apparatus. The spring mechanism resides within a spring housing 210 which is movable long the tracks 203 and 204 (omitted but visible in Fig 1). When the constant force “Negator” spring 215 is un-stretched, the spring housing 210 is located generally at the opened end of the hollow housing 101. The fluid container, in this embodiment is a syringe, could be affixed to the telescopic sleeve 301 by means of a guide 302 that approximately resembles the shaped of a syringe flange. Upon twisting the syringe, the guide has groove-like features 303 that holds the syringe somewhat securely in place. Other forms and means of affixing the fluid container of other designs do not exclude the claims of this disclosed invention. In this embodiment, the spring housing has an integrated piston seat 211 which is somewhat movable in a radial direction. The purpose is to reduce torsional forces acting on the piston 402 when the mandrel housing is rotated into the telescopic sleeve. The absence of such features obviously do not limit the scope of the disclosed invention

The telescopic sleeve 301 has grooves on its inner wall such that screw threads 105 of appropriate dimension and pitch on the outer surface of the mandrel hollow housing 201

will allow it to be displaced into the telescopic sleeve by a rotating action. The screw threads 105 could be a single loop or multiple loops around the outer circumference of the mandrel hollow housing.

Referring to Fig 2 a fluid container is attached to the apparatus. The piston 402 of the container 400 is in contact with the coupling 211 of the spring assembly housing 210. The hollow mandrel housing 101 is wound into the telescopic sleeve 301. The coiled section 215 of the “Negator” spring assembly is forced to be displaced away from its free end 217 and its housing 210 is now located at the closed end 111 of the hollow housing 101. The fluid inside the container is prevented from being expelled by a blockage in its fluid path 415. This could be easily achieved by having a standard tube clamp (not shown). The displacement of the spring housing 210 from its initial position at the open end of the hollow mandrel to its position at the close end results in the uncoiling of spring 215. This consequently exerts a somewhat constant force on the piston 402 of the fluid container.

Further referring to Fig 2, the hollow mandrel 101 has screw threads 102 on its outer surface that engages the grooves 302 on the inner wall of the outer telescopic sleeve 301 such that rotating the mandrel radially about its own axis will cause a change in the overlapped surface area between itself and the telescopic sleeve. The telescopic sleeve 102 has features on one end that allows the flange of the fluid container 401 to be securely attached. These features depicted in the drawings are intended for illustrative purposes and are non-limiting and that the disclosed invention includes any other means of securing the fluid container to achieve the intended purpose of delivery fluid delivery from the container.

Referring to Fig 2A, the fluid in the fluid container is expelled. The spring housing 210 has now returned to its initial position at the open end of the hollow mandrel 101.

Referring to Fig 3 and 3 A, The details of the spring housing 210 is shown. In this embodiment only one set of spring is used and the use of multiple springs do not diminish the scope of this invention. The use of spring housing enables the coiled portion of the spring 215 to be displaced from free end of the spring 217 instead of conventionally uncoiling the spring involves pulling the free end away from its coiled body.

The spring housing 210 described aforesaid could be affixed with a magnetic sensor that in conjunction with a magnetic linear strip attached on the adjacent track, for example 204

or 203 could display its position or displacement onto a display integrated within the device itself or onto a separate extraneous display. The stubs 221, 222, 223 and 224 (not shown) located at the corners of the spring housing 210 creates a clearance between the housing and the tracks that allows displacement sensors to be installed. The communication between the displacement sensor and the control board of the display can be done by Bluetooth, Wi-Fi or direct cable connections. It is obvious to any person skilled the art of electronic circuitry to extrapolate the data on position and or displacement of the spring capsule relative to the track to obtain valuable information like flow rate at which the fluid is expelled, volume expelled and volume remaining in the syringe. With a built in data base of drug dose limits, commonly known as drug library, the aforesaid data could be used to provide alarms for patient risk situations related to overdose or under dose.

Fig 4 shows an array of the disclosed invention connected to a display unit that is connected to each apparatus via a direct communications and power supply cable.

Operation of the device

As the hollow mandrel 101 is caused to move into the volume space of formed by the walls of the telescopic sleeve 102, which increases the overlapped surface area between the hollow mandrel 101 and the telescopic sleeve 102, the axis 205 of the springs 201 will be propended to move in a direction away from the piston 402 of the fluid container 400. The non-compressible fluid inside the fluid container 400 prevents any appreciable movement of the piston 402 when the conduit 404 that allows fluid communication between the fluid container and the distal end of the conduit is clamped or blocked. The resulting force pushes the axes of the constant force springs in an opposite direction relative to the movement of its hollow mandrel 101. As the springs are uncoiled from its reel in the aforesaid steps, a relatively constant force acts on the coupling 301 which in turns produced a force on the piston 402 in the axial direction of the barrel 403 of fluid container. When the conduit that allows fluid communication between the fluid container and its distal end is unclamped, the force generated by the displacement of the uncoiled spring body from its free end will expel the fluid from its container. The coupling element 225 that is connected to the spring housing is dimensioned to cause the spring 215 to be displaced a distance away from its initial unstressed position within

the hollow mandrel such that the total distance the axis of the springs travelled is longer than the displacement required of the piston 402 to fully discharge the fluid in the container when the conduit 404 is unclamped. In principle, the length of the coupling is sufficient to cause the constant force spring to be uncoiled from its free end so that the

5 force exerted on the piston 402 would have already reached its constant level when fluid start to flow. Typically this deflected length is about 1 to 1 ¹/₂ times the outer diameter of the spring. Without this feature, the force acting on the fluid would initially be lower and gradually increase as the spring 215 recoil resulting in a less than constant flow profile.

A typical flow profile of the disclosed apparatus is shown in Fig 5.

Claims

1. A fluid delivery apparatus comprising:
a housing;
a fluid container coupled to the housing;
5 a spring coupled to the housing and the container in driving fluid out of the container;
whereby the force derived from uncoiling the spring is achieved by displacing its coiled body away from the free end of the spring.
- 10 2. The apparatus of claim 1, wherein contraction of the spring creates a pre stress in the spring such that the apparatus operates in the linear range of the spring stress-strain profile.
3. Use of a constant force spring (negator spring) in driving fluid out of a container
15 whereby the force derived from uncoiling the spring is achieved by displacing its coiled body away from the free end of the spring.
4. Use of a coupling between the container and the spring assembly such that dimensionally the contraction creates a pre stress in the spring such that the device
20 operates in the linear range of the spring stress-strain profile.
5. Use of linear displacement measurement means in a mechanically driven infusion device to allow monitoring of the parameters related to expelling fluid.