FLUID ADMINISTERING SYSTEM

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ABSTRACT OF THE DISCLOSURE

This invention relates to fluid administration systems for dispensing fluids at a controlled rate. More particularly, this invention is directed to a system having a syringe with a plunger, the plunger being driven by a pulse generator and motor combination. In addition, this invention is directed to a system driven in a like manner but utilizing rollers to dispense fluid.

This invention relates to apparatus for infusing fluids and more particularly relates to a small, lightweight portable apparatus for administering fluids and other medicants to a subject at a controlled rate.

Present-day medical practice often requires the administration of medicants in the form of fluid solutions to a patient or subject over a relatively extended period of time but at a slow and precise rate. For example, such fluids as glucose, plasma, saline and the like, with or without other medicants, are often administered to patients over periods of a few hours. At the present time, fluids of this type are generally administered by gravity feed, wherein fluid is provided from a bottle through a tube to a patient and the flow rate is controlled by a needle valve placed about the tube. In such cases, the subject is rendered immobile for prolonged periods of time in order to ensure that the needle, which is inserted into the vein or artery of the subject, will not be withdrawn. Although the foregoing method is quite adequate for immobile patients, such a system is not adaptable for administering fluids to ambulatory subjects.

In view of the foregoing, applicants have provided a small, lightweight and portable infusion device which may be attached to a limb on the torso of an ambulatory patient and which may be used for administering fluids to the patient at a controlled rate. The portable infusion apparatus of this invention permits a subject to move about in a normal manner and not be restricted for prolonged periods of time, as was previously required. The apparatus of this invention also finds utility in research on test animals, wherein fluids must be administered over prolonged periods of time. This apparatus has further utility in the dispensing of fluids at a controlled rate, as in chemical analysis procedures.

This invention also includes means for providing a pulsating fluid stream from a source of fluid. It is believed that larger doses of highly toxic medication may be given to a patient if administered in a pulsating fluid stream rather than in a constant fluid stream. It is also believed that high-peak dosages of medication, provided at predetermined time intervals, are more effective than smaller dosages administered continuously. The body appears to be able to tolerate larger toxic doses by pulsating administration of medication, since the body tissues are thereby allowed time to recover between peak dosages.

As referred to herein, a pulsating fluid stream may be defined as a fluid stream which usually flows continuously but which, during periodic intervals, is forced to flow at higher pressures. Thus a greater volume of medicant may be administered to a patient each time the fluid is forced into the patient under increased pressure than would be possible if the medicant was administered in a continuous fluid stream during the same time interval.

It should be understood that the fluid stream may not flow into the patient between intervals of increased pressure, but that this type of fluid stream is also considered a pulsating fluid stream, for the purposes of this invention.

Applicants have accomplished the above by the provision of means for forcing fluid from a fluid source at predetermined time intervals. This has been accomplished preferably by the provision of a motor driven by pulses of current provided for predetermined time intervals.

In view of the foregoing, it is an object of this invention to provide a new and improved fluid administration apparatus.

Another object of this invention is to provide a new and improved small, lightweight, portable apparatus for administration of physiological solutions to a patient at a controlled rate.

Another object of this invention is to provide a new and improved device which may be affixed to a limb or about the torso of a patient and which may be carried by the patient without interfering with the locomotion of the patient or the test animal.

A further object of this invention is to provide a new and improved portable infusion device, whereby the quantity to be injected may be accurately set with great precision.

Still other objects and advantages of this invention will in part be obvious and will in part appear hereinafter.

The invention accordingly comprises the apparatus possessing the features, properties and relation of elements which will be exemplified in the apparatus hereinafter described and the scope of the invention will be indicated in the claims.

For a fuller understanding of the nature and objects of the invention reference should be had to the following detailed description, taken in connection with the accompanying drawings in which:

FIG. 1 is a top view of the preferred form of the invention;
FIG. 2 is a sectional view taken along line 2—2 of FIG. 1;
FIG. 3 is a sectional view taken along line 3—3 of FIG. 2;
FIG. 4 is a schematic diagram of the circuitry for use in conjunction with FIGS. 1—3;
FIG. 5 is a diagram illustrating continuous and pulsating fluid flow;
FIG. 6 is a top view of an alternate embodiment according to this invention;
FIG. 7 is a sectional view taken along line 6—6 of FIG. 6;
FIG. 8 is a schematic diagram of a circuit for use with the device of FIGS. 6 and 7; and
FIG. 9 is a diagrammatic view of another alternate embodiment according to the invention.

Referring now to FIGS. 1—3, there is disclosed at 10 a fluid administration apparatus according to the invention. The apparatus 10 includes a base plate 11 preferably having a strap (not shown) for securing the apparatus 10 to a limb of the patient or subject. The plate 11 may be formed with a contour similar to that of a limb of the patient and a foam rubber pad may be placed on the underside of the plate so that it may be easily secured to the patient. If desired, means such as hinges may be coupled to the plate 11 so as to permit the apparatus to be attached to a stand or animal cage. A syringe 13 is mounted on the plate 11 and has a tube 14 descending therefrom which is attached to a needle 15. The needle 15 may then be inserted in the vein or artery of the patient.
in the normal manner. The syringe 13 is provided with a plunger 17 which is movable toward and away from the opening closest the embou 14. On top of the plunger 17 there is mounted a platen 18 which threadedly engages a threaded shaft 19. The shaft 19 has an unthreaded portion thereof extending outside the plate 11 and connected to a knob 20. The other end of shaft 19 is provided with an unthreaded portion which is supported for rotation, as shown in this preferred embodiment, in a U-shaped member 22 affixed to the plate 11.

Positioned about the unthreaded portion of shaft 19 and secured thereto is a portion of the clutch mechanism 23 having an inner channel 24 in a mating raised surface. The surface 25 engages a mating clutch mechanism 26 mounted on a driveshaft 27 of a motor 28. The motor 28 is secured to the U-shaped member 22. The mating portions 25 and 26 are forced together by the provision of a spring 29 and are separated by a slidable member 30 extending outwardly from the plate 11 and positioned in guide channel 24, such that the surfaces 25 and 26 may be separated by pushing the member 30 toward the right (FIG. 2). Thus the motor will rotate shaft 19 and cause the platen 18 to force the plunger 17 downwardly. To reset the apparatus of FIGS. 1–3, the member 30 is pushed to the right (FIG. 2), such that the shaft 19 may be freely rotated by the knob 20 to return the platen 18 to its initial starting position. The member 30 is preferably guided in a slot 31 in the U-shaped member 22.

As shown in FIG. 1, there is also provided a control 35 for adjusting the flow rate of the fluid being expelled from the syringe 13. A ganged control switch, shown at 36a and 36b, is further provided for setting the speed of operation of the motor 28.

Referring now to FIG. 4, there is shown the preferred circuitry for use in conjunction with the apparatus of FIGS. 1–3. In this figure the motor is shown at 28, the ganged switch at 36a and 36b and the control at 35. The motor 28 is preferably a permanent magnet field type motor and may be provided only with an armature current to drive it. The circuit as shown in FIG. 4 may provide either a pulsating drive current or a continuous current, through motor 28. As shown, the motor is a DC (direct current) motor and the pulses to drive the motor are preferably uni-polar. With the ganged switch 36a and 36b as used in this circuit, in combination with the control 35, it is now possible solely using electronic controls (no gears), to vary the flow rate from 0.6 cc. to 10 cc. per hour with a 0.1 cc. volume syringe. More particularly, the circuit shown in this figure comprises a battery 45 coupled through switch 46 for providing power to the circuit. The switch 46 is preferably supported from the U-shaped member 22 (FIG. 1), such that as the platen 18 engages it, it will be opened to prevent the motor from being operated.

As also shown in FIG. 4, the limit switch is normally closed, opening only upon contact with the platen 18. The limit switch is used to prevent the motor from continuing to operate when the platen has reached the extent of its travel. The circuit as shown in this figure comprises transistors 50 and 51 which are connected together as the multi-vibrator circuit. These transistors have emitters 50a and 51a, bases 50b and 51b and collectors 50c and 51c, respectively. Emitters 50a and 51a are coupled to each other. The collector 50c is coupled through a capacitor 53 to the base 51a. The base 50b is coupled through a capacitor 54 and through a resistor 55 to the collector 51c. Coupled between capacitor 54 and resistor 55 is a capacitor 56 which is itself coupled to the emitter 51a at its other end. Resistor 55 and capacitor 56 operate as a filter network. The base 50b is also coupled to a biasing resistor 58.

As shown in FIG. 4, the ganged switch 36a and 36b each comprises five contacts, 1–5, and also includes wiper arms 60 and 61, respectively. The 1 position in each switch represents an "off" condition, such that no current is provided to the motor 28. The 2, 3 and 4 positions of switch 36a connect the emitter 50a through a clipping diode 63 to the base 50b. The switch 36b is connected to the 2, 3 and 4 positions and resistors 65–67, which are coupled to the base 51b. The wiper arm 61 is connected to any of the contacts 2–4 while, at the same time, the arm 60 is connected to corresponding ones of the contacts 2–4, such that the resistors 65–67 which control the frequency rate of the multi-vibrator will be coupled to the base 51b.

Position 5 of the switch 36a is connected to the base 50b while, at the same time, contact 5 of switch 36b is connected through resistor 65 to the base 51b. When the arms 60 and 61 are in position 5 of their respective switches, the multi-vibrator circuit will operate to provide continuous DC to the motor 28.

The current to drive the motor 28 is provided from the collector 51c through the control switch 35, which comprises a pot, shown at 69. A local resistor 70b is provided to set the minimum speed of the motor 28. The collector 51c is coupled through the pot, 69, to an emitter follower transistor 71 which comprises an emitter 71a, a base 71b and a collector 71c. The base 71b is connected to the wiper arm of pot. 69, the emitter 71a is directly coupled to the armature 73 of the motor 28 and the collector 71c is coupled back to the emitter 51a of transistor 51.

Across the motor 28 there is provided a back E.M.F. shorting transistor 75 having an emitter 75a, a base 75b and a collector 75c. The transistor 75 has its emitter 75a coupled to one end of the armature 73 and its collector 75c coupled to the other side of the armature. The base 75b is in turn coupled through a load resistor 76 to the collector 50c of the transistor 50.

The operation of the circuit of FIG. 4 is as follows. When the wiper arms 60 and 61 are in the 1 contact position, the circuit of the device will be rendered non-conductive and no current will be provided to the motor 28. By the movement of the arms 60 and 61 to position 5, the transistor 50 will be rendered non-conductive so that transistor 51 will be rendered conductive by means of a current provided through resistor 55 to the base 51b. This then causes a voltage signal to be applied to the base 71b to cause a current flow through the armature 73 to cause the motor 28 to operate. The motor 28 will be driven continuously by the current provided through transistor 71. In this manner, the platen 18 (FIG. 1) will be driven to force a continuous stream of fluid from the syringe 13.

In order to operate the circuit of FIG. 1 as a multi-vibrator, the wiper arms 60 and 61 are positioned at any one of contacts 2–4, respectively. Assuming that the arms 60 and 61 are on contact 2 of the switch 36a and 36b, respectively, the transistor 50 will turn on due to the current provided through resistor 58 which was previously shunted to ground when arm 60 was on contact 5. This then causes a negative step in voltage to occur at the collector 50c, equal in magnitude to the battery voltage, less the emitter collector drop of transistor 50. This step is coupled by capacitor 53 to the base 51b and renders transistor 51 non-conductive. The voltage applied to the base 71b collapses, as does the current flowing through the motor and the motor coasts to a stop.

The negative step applied to the base of transistor 51 causes its base 51a to become negative with respect to its emitter 51a. However, current flowing through resistor 67 slowly charges capacitor 54, so that this negative voltage diminishes, passes through zero, and then goes positive, causing transistor 51 to conduct once again. At this point capacitor 54 ceases charging and maintains a stable voltage. The conduction of transistor 51 causes the motor to accelerate rapidly to its predetermined speed. The speed of the motor may be adjusted by varying the potentiometer 69. The conduction of transistor 51 causes
a negative step to appear at its collector 51c. This step is applied to the base 50b through capacitor 54 by way of a filter circuit comprising resistors 55 and capacitor 56 and causes transistor 50 to cut off in the same manner. This current now charges capacitor 54, diminishes the negative voltage applied to the base 50b, and then causes the base voltage to go to a positive potential, thus rendering transistor 50 conductive once again. This causes the motor 28 to stop. Thereafter, a repetition of the cycle described above will occur.

As the motor 28 coasts to a stop, it acts as a generator. This voltage has considerable ripple on it which tends to couple through transistor 71 to potentiometer 69 onto the base 50b, in such a way as to tend to cut off transistor 51 and restart the motor 28. The filter, comprising resistor 55 and capacitor 56, removes the ripple so that restarting does not occur except in normal fashion. The resistor 70 provides two functions, it compensates for the base to emitter drop of transistor 71 and determines the minimum speed of the motor, whereas the pot 69 adjusts the speed from this minimum as determined by the magnitude of resistor 70. In operation, the transistor 75 is responsive to the voltage at collector 50c, such that when the motor 28 is stopped, the transistor 75 is turned on and will act as a low resistance shunt and prevent current flow, by shorting the back E.M.F. generated by the motor 28. By selecting different valued resistors, such as 66 and 65, different frequency signals may be provided from the multi-vibrator circuit of FIG. 4 and thereby cause the motor to operate at different repetition rates. During the time the motor is being operated by response to current pulses, the pulsating fluid stream is provided from the needle 15 of FIG. 1, since the platen 18 will be driven for an interval of time, and then not driven for a corresponding interval of time, depending upon the pulse rate of the pulses provided by the multi-vibrator circuit.

Referring now to FIG. 5, there is shown a diagram illustrating the fluid flow from the needle 15 of FIG. 1. The uppermost diagram of FIG. 5 represents the output volume when the platen is continuously driven by the motor 28. As may be seen with time, the rate of volume remains constant. The lower diagram of FIG. 5 represents the use of pulses to drive the motor 28. In this condition the motor 28 causes the fluid to be expelled and forced into the patient, as shown. During the interval the platen is being driven, a burst of fluid will be expelled and during the interval the platen is not being driven the volume of fluid being expelled will tend toward zero or a much lower value.

Referring now to FIGS. 6 and 7, there is shown an alternate embodiment of the invention disclosed in FIGS. 1–3. As shown in FIG. 6, there is provided a plate 80 on which is mounted a syringe 81 having a plunger 82. A platen 85 is provided for forcing the plunger 82 in order to expel fluid from the syringe. The platen 85 is provided with a threaded bushing 86 which engages a threaded shaft 87. The shaft 87 has on two ends thereof unthreaded portions 88 and 89 supported by members 90 and 91, respectively. A knob 92 manually rotates shaft 87. Slightly mounted on shaft 87, on the unthreaded portion thereof, are two gears 94 and 95. These gears are slidable on the unthreaded portion shown at 96 but are rotatable with the shaft 87. Key-shaped member 97 engages a notch formed in the gears 94 and 95, respectively, to cause the gears to rotate with the shaft 87.

Positioned between gears 94 and 95 is a member 98 which is rotatable therewith and has a slot 99 formed therein. Positioned within the slot 99 is a lever 100 having a U-shaped portion 100a which engages the slot 99. The lever 100 is supported to the left or right (FIGS. 6 and 7) by the provision of a pivotal lever 101 pivoted at point 102 and pivotally connected at 103 to the lever 100. By pivoting lever 100, the gears 94 and 95 are moved to the left or right of FIG. 6 and held in place by a ball and detent shown in the drawing.

In order to drive the shaft 87, there is provided a motor 107 having a driveshaft 108 with a portion thereof supported in a support member 109. The motor itself is supported from the support member 109 as previously mentioned. Mounted on driveshaft 108 are two gears 110 and 111, which mesh with gears 94 and 95, respectively. In particular, gear 94 is positioned to mesh with gear 110 and gear 95 is positioned to mesh with gear 111. The meshing of these gears is accomplished by moving lever 101 to a position such that the gear is meshed with respective ones of the other gears. By positioning gears 94 and 95 such that they do not mesh with gears 110 and 111, the knob 92 may be manually rotated to return the platen 85 to the right (FIG. 6). This must be accomplished after the platen has forced plunger 82 completely into the syringe 81. Positioning on support 109 is a limit switch 112 which stops the motor upon engagement with the platen 85. Also shown in FIG. 6 is a speed control for setting potentiometer 113.

FIG. 6 further discloses a contact 114 which acts in conjunction with pivotal member 110 to form a switch for initiating and controlling the circuitry for use in conjunction with FIG. 6 and 7, such that it will operate in either a pulse or continuous manner in order to drive the motor in either a pulse or continuous mode of operation.

Lever 101 is of a metallic electrical contacting material, as is the contact 114. These are referred to in FIG. 8 as switch 115. It should be noted that another type of switch arrangement could be used, if desired.

Referring now to FIG. 8, there is shown a schematic diagram of a circuit for use in conjunction with FIGS. 6 and 7. This circuit is substantially equivalent to the circuit described in connection with FIG. 4, hence only one portion of the changes therein will be given for purposes of explanation. In this figure, the motor is shown at 107, the speed controlling device is shown at 113 and comprises a potentiometer, the limit switch is shown at 112 and is normally closed. When the switch 112 is opened by the platen engaging it, the circuit will be opened to stop the motor. The switch comprising the lever 101 and the contact 114 is shown at 115. The battery is shown at 120 and the on-off switch at 121. The circuit comprises first and second transistors 125 and 126 which, together, act as a multi-vibrator circuit. An additional transistor 127 is provided which acts as an emitter follower and is connected to provide current to the armature of motor 107. Still another transistor 128 is provided which acts to shunt the back E.M.F. of the motor in order to reduce the coating when the motor is pulse-operated. When the switch 115 is closed, the transistor 125 will be cut off and transistor 126 will act as a normal amplifier and provide current on a continuous basis to the motor 107 through potentiometer 113 and the emitter follower transistor 127. By moving lever 101 to the left and away (see FIG. 6) from contact 114, the switch 115 is opened to permit the circuitry of FIG. 8 to operate as a multi-vibrator. The multi-vibrator operation of transistors 125 and 126 is the same described in conjunction with FIG. 4. The remainder of the circuit also functions likewise, to alternately turn on and cut off transistor 126 to provide current pulses to drive motor 107.

Referring now to FIG. 9, a further alternate embodiment of the invention is shown. In this figure there is disclosed a housing 150 for supporting a fluid reservoir or source of fluid supply 151. A flexible tube 152 coupled to reservoir 151 is provided and has attached thereto a needle 153 for injecting the fluid into a patient. The tubing 152 could be of a rubber or plastic material and is positioned between a track segment 155 and a rotor 156 having a plurality of rollers 157 which are radially coupled thereto. Upon rotation of rotor 156, the rollers 157 cause fluid to be forced downwardly from the tube 152 to the needle 153. The track 155 is provided with slots 160 in which are mounted bolts 161. In this manner the track
155 may be adjusted closer to or further from the rollers 157. The rotor 156 is mounted on shaft 162 having a worm gear 163 positioned thereon. The gear 163 is driven by a worm 164 which in turn is driven by a motor 165. The motor 165 is controlled by circuit 166 which may be of the type disclosed in either FIG. 4 or 8. By the use of the control circuitry 166, the rotor 156 may be caused to operate in a pulse manner to provide pulsating fluid through needle 153 to a patient.

It will be evident from the foregoing, that the mechanisms described herein may be easily designed to cover a wide range of desirable speeds and flow rates. It will also be observed that other modifications may be made in this device without departing from the spirit and scope of the invention. Furthermore, instead of a needle, as shown, the tubing itself may be implanted in the patient.

It is also to be understood that the following claims are intended to cover all the generic and specific features of the invention disclosed and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

What is claimed is:

1. A system for providing fluid at a controlled rate, comprising a motor having an armature winding, a pulse generator for providing current pulses to said motor, a first transistor having base, emitter and collector terminals, the collector terminal connected to one side of the armature winding and the emitter terminal connected to the other side of the armature winding, and means coupling the base terminal of said transistor to said pulse generator to short the back E.M.F. generated by the motor to prevent coasting of the motor.

2. A system according to claim 1, in which the pulse generator is a multi-vibrator circuit, comprising second and third transistors, and in which the collector terminal of the second transistor is coupled to the base of the first transistor.

3. A system according to claim 2, including a resistor-capacitor filter coupled in said multi-vibrator circuit for preventing any ripple voltage from said motor causing the multi-vibrator circuit to falsely restart.

4. A system for use with a container having a piston for forcing fluid through an orifice in the container, comprising a motor having an armature winding, said motor having means coupled thereto for forcing the piston to expel fluid from the container, a pulse generator circuit for providing current pulses to said motor, and first means responsive to a signal from said pulse generator to selectively short circuit said armature winding to prevent coasting of the motor.

5. A system according to claim 4, wherein said pulse generator comprises a multi-vibrator circuit having first and second transistors, one of said transistors providing current pulses to drive said motor and the other transistor providing a signal to control the operation of said first means.

6. A system according to claim 5, wherein said means for shorting the armature winding comprises a third transistor having its emitter and collector terminals connected across said armature winding and its base coupled to the second transistor.

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