Infusion pump apparatus for delivering intravenous fluid from a syringe to a patient so that volume may be accurately controlled between a small delivery rate and a large delivery rate is disclosed. The pump is adaptable to adjust the amplitude of the syringe stroke in order to accurately meter the volume of fluid delivered to a patient within a given time period. The pump may be employed in an oxygen atmosphere without creating a potentially dangerous condition likely to result in an explosion. An an optional feature a pressure sensitive arrangement which stops the pump in the event the resistance to flow of fluid becomes greater than that required for normal operation is also disclosed.

5 Claims, 7 Drawing Figures
The present invention relates to an infusion pump system and more particularly to a pump having a synchronous motor adaptable to move a piston of a surgical syringe to deliver to a patient predetermined accurately measured volumetric amounts of intravenous fluid.

The use of surgical syringes for injecting intravenous fluid into the veins of a patient has long been known. It is common practice to employ a syringe comprising a cylinder and a piston reciprocatingly disposed therein to cause fluid to move from a source of supply to a patient who requires a constant and measured amount of the fluid for purposes of life sustaining nourishment or other aspects of medicinal treatment.

Various means may be utilized to operate the piston of a syringe. The most elementary means for causing movement of a piston would be pressing by hand against a rod portion of the piston extending exteriorly of the cylinder, thereby forcing the head of the piston to move rectilinearly and pump fluid from the supply source to the patient. Modern technology has developed more advanced and sophisticated means for delivering fluid from a source of supply by means of a syringe. In this connection, electromechanical devices have been created that automatically move a piston or plunger of a syringe to cause fluid to be pumped to a patient who requires the administering of intravenous fluid to obtain nutrients for sustaining life.

Illustrative of devices that may be used to pump intravenous fluid is a so called syringe pump that comprises a pump assembly adaptable to be either permanently affixed to a syringe or detachably connected thereto. A detachable syringe pump assembly is shown by Rosenberg in U.S. Pat. No. 3,447,479. However Rosenberg discloses a pump driven by the combined efforts of a synchronous timing motor and an induction drive motor.

There are inherent problems to be overcome combining operating characteristics of such drive motors. Among the problems encountered by induction motors are the continual making and breaking of electrical contact with resultant arcing between contacts, the disadvantages of which are self-evident when one is required to operate a motor in an atmosphere wherein free oxygen is present. Moreover, induction type motors are affected by variances in voltage and thus it is difficult if not impossible to deliver with exactitude a constant and closely controlled volume of intravenous fluid wherein the power services may be irregular, thus, the supply of energy to the pump may vary greatly with resultant highly diverse amounts of fluid pumped into a patient’s veins.

**BRIEF SUMMARY OF THE INVENTION**

In accordance with a major feature of the present invention infusion pump apparatus is provided for rectilinear pumping and delivery of fluid, e.g., I.V. solution to a patient, at an average rate which can be selected within a range of rates. The apparatus includes a novel rate selecting mechanism which includes means for defining an arcuate movement path and means for pivotally reciprocating the arcuate means. A driving linkage is coupled to reciprocate the pump and also coupled to be moved by the arcuate means while reciprocating along a range of positions on the arcuate path thereon.

A range of defining member is coupled to the driving linkage for movement therewith and has a fixed pivot whose position is selectively variable. At any fixed pivot point the member limits the range of movement of the driving member along the arcuate path and thus fixes the stroke and average output of the pump.

In accordance with another feature of the invention means are provided for sensing the pressure in fluid output and for stopping the pump or signaling a warning for sensed pressures over a preselected high value.

This latter feature has the advantage of preventing damage to the patient should the I.V. capillary be inserted wrongly, e.g. into a muscle tissue.

These and other features and advantages of the invention will become apparent from the ensuing description, reference being had to the accompanying drawings, in which like members are used to identify like elements in the several views.

**BRIEF DESCRIPTION OF THE DRAWINGS**

**FIG. 1** is a perspective view of a portable stand adaptable to support a source of supply of intravenous fluid, infusion pump apparatus including a syringe pump and a motor drive assembly therefor.

**FIG. 2** is a perspective view of the syringe pump and drive assembly showing more specific details of its exterior construction.

**FIG. 3** is a vertical front sectional view through the pump and drive assembly with the front portion of the housing broken away so that the working parts of the drive assembly may be seen more clearly. The component parts of the assembly are shown in two positions, the solid lines showing the syringe piston fully extended, the dotted lines showing the syringe piston fully retracted, and defining a maximum amplitude of syringe stroke.

**FIG. 4** is a vertical front sectional view of the pump and drive assembly similar to **FIG. 3** but showing the component parts operative between a position of complete piston extension and complete piston retraction, but defining an intermediate amplitude of syringe stroke.

**FIG. 5** is a vertical side sectional view through the drive assembly, taken along line 5—5 of **FIG. 3**, a front portion of the housing broken away to show more clearly the working parts thereof. The drive assembly is shown secured to a portion of a vertical column of the stand.

**FIG. 6** is a schematic diagram of a control circuit for use with the subject pump system.

**FIG. 7** is a schematic diagram of a control circuit similar to that shown in **FIG. 6** employing a pressure sensitive device for use with the subject pump system.

**DESCRIPTION OF THE PREFERRED EMBODIMENT**

Referring to **FIG. 1**, an infusion pump apparatus **10** is shown mounted by a clamping arrangement on a vertical rod member **12** of a portable stand **14** adaptable to support an intravenous fluid storage bottle **16** from a hook member **18** disposed at an upper end of the rod member **12**.

As seen more clearly in **FIG. 2** pump apparatus **10** comprises a housing **20** having a front face member **22**, side members **24**, top **26** and bottom **28** members and a back plate **30**. Front face member **22** may be removably secured to housing **20** as by machine screws **32**.
Access to the interior of the housing is accomplished by unthreading the screws and removing face member 22 from the housing.

Face member 22 has imprinted thereon a scale 34 of incremental numbers corresponding to a desired parameter of operation for pumping of fluid by the apparatus. As illustrated, the scale 34 shows a range of numbers from 10 to 300 and refers to milliliters of fluid pumped per hour. Adjusting knob 36 is keyed in a known manner to an exterior portion of a shaft 38 (Fig. 5) hereinafter described in detail disposed within the housing. Rotation of the knob 36 serves to set the pump at a predetermined rate of delivery of fluid for infusion into the veins of a patient and the volume of fluid flow is indicated by a finger 39 formed integrally with and extending outwardly from knob 36. Adjusting knob 36 must include a friction loaded shaft provision or other means (such as a lock knob) to insure that it will maintain itself in any desired selected position to have the apparatus pump the required flow of fluid. The friction shaft or other provisions are needed to overcome a small tendency of the hereinafter described variable rate mechanism to shift the setting.

A knurled member 42 is located exteriorly of the face 22 and is keyed to a portion of a shaft 44 (Fig. 5) extensive exteriorly of the housing. The knurled member 44 is effective when rotated to move a magnetic switch 46 assembly (Figs. 3 and 4) between off and on positions to activate the pump apparatus. Although the switch is preferably of the type shown, the present invention, at least in its broader aspects, contemplates the use of alternative switches such as the conventional toggle switch.

An operation or “on” light 150 is disposed in face member 22 and serves to indicate that the apparatus has power connected to and is turned “on”.

A bracket 50 (Figs. 2-4) is secured to side 24 of the housing and has formed therein a groove 52 to receive a rectangular flange 54 formed on a cylindrical body 56 of a syringe 58. Extending outwardly from the body 56 of syringe 58 is a rod member 60 having a circular flange 54 formed thereon adapted to be securably and pivotally received by a yoke 64 cut from an exterior end of a lever member 66 (hereinafter described in detail). The rod member has an inner end formed to provide a piston (not shown) head or plunger adaptable to move reciprocally within the body 56 of the syringe 58.

The upper end of syringe 58 is operatively connected as is well known in the art to a valve arrangement 68 (Figs. 2 and 1) that permits flow of fluid therethrough only to the patient and prevents back flow of solution into the bottle 16 when rod member moves upwardly to cause pressure to be exerted in valve arrangement 68. This is preferably a pair of one-way valves permitting fluid flow from a 1 V bottle 16 to syringe 58 and from syringe 58 to the patient-connected line.

Referencing now to Figs. 3, 4, and 5, it can be seen that lever 66 extends interiorly into housing 20 and has an inner end 70 pivotally connected to a mounting plate 72 (Fig. 5) secured substantially intermediate and in parallel relationship with face member 22 and back plate 30 as by sleeves 74 and bolts 76.

A substantially inverted U-shaped arcuate means or member 78 has two legs 78A and 78B and a curving middle portion 80 and formed to provide an arcuate configuration wherein are formed on opposite sides a pair of arcuate grooves 82. The first leg 78A has its end 84 pivotally connected at 86 to the mounting plate 72.

A first link driving member 90 has a first end 92 pivotally secured substantially intermediate the ends of lever 66 and has a second end 94 secured as by pins 96 received in the arcuate grooves 82 of member 78. It should be noted that the second end 94 of link 90 may be assumed positions along an arcuate path defined by the grooves 82 formed in the middle portion member 78.

A synchronous electrical motor 98 (Fig. 5) is secured to a back side of mounting plate 72 and is adaptable to rotate a drive shaft 100 that extends through a mounting plate aperture 102 having a diameter somewhat larger than the diameter of the drive shaft. The drive shaft 100 is keyed or otherwise affixed to an eccentric member 104. The member 104 has an outboard end that pivotally receives a pin 106 secured in one end of a pivot link 108. Pivot link 108 has secured in its other end a pin 110 pivotally received by the aperture formed in the second leg 78B of U-shaped member 78.

A range defining member 112 has one end 114 pivotally secured to link member 90 and extends to connect its other end in pivotal engagement at 112P with one end of a rod member 116. The other end of rod member 116 is secured to shaft 38 and rotates coincidentally therewith. As hereinafter described shaft 38 is connected to and controlled by adjusting knob 36.

Note that the control knob selects or fixes the position of pivot 112P and this in turn controls through a range of positions that pivot 96 can travel on arcuate path 82 (considering the relative movement between arcuate means 78 and the pivot 96). This, however, in accordance with a major feature of the present invention determines the vertical stroke distance of driving linkage 90 and thus, (through arm 66) of the pump stroke the syringe 58. The rate of reciprocating of the syringe plunger is determined by the rotation of the motor 98 which is preferably fixed so that the position of pivot 112P by fixing the stroke determines the average pumping rate.

The pump unit as described has been constructed and tested. Empirical data has established that a near linear relationship can be made to exist between the setting of knob 36 and the flow rate and that the average rate of pumping can be precisely controlled over a satisfactory range.

In order to control the rotation of shaft 38 between minimum and maximum limit positions, as indicated on scale 34, calibration means 118 is provided comprising a block 120, a first adjustment screws 122 threadably receivable therethrough for establishing a minimum adjustment position and a second adjustment screw 124 threadably receivable by the block for establishing a maximum adjustment position of the shaft 38. It should be noted that either screw when threaded inwardly or outwardly of the block will, upon rotation of shaft 38, establish a contact point with either edge of rod member 116 and thereby prevent further rotation of shaft 38. Thus, it is possible to adjust the rotation of shaft 38 between minimum and maximum positions so that opposite correspondence is maintained with scale 34 when knob 36 is turned to rotate shaft 38 and thereby select a desired rate of fluid infusion.

It can be seen that rotation of knurled knob 42 causes a magnetic arm 126 affixed thereto to rotate therewith throughout an angle of substantially 90° as defined by
limit pin 128 protruding from the mounting plate and an exterior side of an enclosed magnetic switch 130 secured as by screws to the mounting plate 72. The pump assembly is inoperative when magnetic arm 126 is engaged with pin 128 and becomes operative when magnetic arm 126 is rotated by knob 42 into contact with magnetic switch 130. Magnetic switch 130 is wired in a known manner to an insulated terminal assembly 132 (FIGS. 6 and 7) secured to the mounting plate 72.

Referring now to FIG. 6, the Unit 10 is designed to be connected to the commonly available AC power mains (60 Hz, 120 v) via a conventional three prong plug 134 which includes a separate ground male prong for connection to ground. Of course, other power sources and double insulation may be employed without departing from the invention. However, the added ground wiring system is commonly used in hospitals in the U.S. and provides additional protection against electrical shock and leakage currents which could be very dangerous in this environment of use.

The plug 134 has three conductors 134A, 134C and 134G leading to the unit 10. Conductors 134A and 134C are for the convention AC power and conductor 134G is connected to the ground prong of plug 134.

The ground wire 134G is connected to a terminal 146 of a terminal block 132. The terminal 146 is securely electrically and physically connected to the housing of the unit 10 to ground that housing.

The AC power line 134A is connected through a terminal 133 on block 132 to one side of the switch 130. As best shown in FIG. 6, the switch 130 comprised an insulated sealed envelope housing 130H and a pair of switch blades normally mechanically biased apart switch blades 130B which are made of magnetic material. When the magnet 126 is moved to the horizontal position the magnetic flux causes the blades to move together and complete the connection through the switch 130.

The other side of switch 130 is connected via a line 136, terminal 138 and line 140 to the motor 98 of the pump assembly. The other side of the motor connects by a wire 142 with a post 144 of the terminal assembly 122 which part is, in turn, connected to the power input line 134C of the power cord.

The indicator light 150 is connected between wires 140 and 142, and is lighted to signal when the motor is running and is off when the motor is shut down.

In FIG. 7 a second preferred embodiment of the invention is illustrated employing, in accordance with a feature of the present invention, means 152 for sensing pressure in the I.V. line to the patient and for automatically shutting off the pump unit 10 in response to a sensed pressure over a selected level.

This means 152, in this embodiment, includes a closed housing 152H having a diaphragm 152D which is in pressure communication (via a noncompressive, non-conductive fluid in zone 152A and a flexible diaphragm 152F) with the I.V. line to the patient. When the pressure in the IV chamber 152C rises above a threshold level, it moves diaphragm 152D to break the contact of a switch 168 and disconnect the connection between lines 162 and 164.

A two prong plug 160 is adaptable to be received by receptacle 154 and includes the two wires 162; 164 leading from the pressure sensitive switch 168. A relay switch arrangement 172 is disposed along the wire 158 of the device and includes an indicator light 174 for warning of an overpressure. It should be noted that in the event pressure sensor 152 "reads" an overpressure consi dered inimical to the operation of the system, switch 168 will open, causing the light 174 to light and, more importantly the interruption of current flow through switch 172 to shut down motor 98 even though magnetic switch 130 remains in a closed position.

In the operation of the present invention, a supply of intravenous fluid is attached to a stand and from the supply conduit means is connected through the pump apparatus 10 to a vein of a patient as is well known. The pump apparatus is set to a desired flow of fluid by rotating adjusting knob 36 to the selected point as indicated on scale 34. Knob 42 is rotated from the off to on position and the motor will begin operation to cause the syringe piston to reciprocate in cylinder 56, alternately drawing fluid into one-way arrangement means 68 on a retraction stroke and forcing fluid out of this means 68 into a vein of a patient on an extension stroke.

The fluid flow setting as accomplished by rotating knob 36 is translated into a desired volume of fluid flow by varying amplitude of the syntinge piston between positions of full retraction and extension. Rotation of knob 36 causes rod 116 to turn between the switches 122, 124 of the calibration means 118 to have indicator arm 39 point to a desired number on scale 34.

Rotational movement of rod 116 to a desired position between threadably adjustable screws 122 and 124 forces bar member 112, by virtue of its pinned and articulated relationship with the link 90, to position the link in a desired position along the curvilinear path defined by grooves 82 formed in the member 78. The link 90 having one end positioned in grooves 82 and its other end secured substantially intermediate the ends of lever 66 is effective to move the lever 66 through an acute angle about its end 70 pivotally secured to mounting plate 72.

It can be seen that rotation of eccentric 104 by the motor causes pivot link 108 to urge the free end 88 of member 78 upwardly and downwardly and thereby define angular displacement about the end 84 of member 78 pivotally secured to the mounting plate. Link 90 positioned in grooves 82 of member 78 and connected to lever 66 causes the lever to rotate about its end 70. The lever in turn translates its angular motion to the rod 60 of the piston syringe 58 and by virtue of its pivotal connection therewith, causes the piston to move rectilinearly and reciprocatingly within the cylinder of the syringe. Thus, it can be seen that the cooperative construction of the present invention makes it possible by interrelated structure to combine in a unique arrangement angular motion with rectilinear motion to establish a desired amplitude of stroke for a piston syringe. It should be noted that positioning the end 94 of link 90 at any desired point along the curvilinear path defined by grooves 82 is effective to change the amplitude of the piston stroke and thereby deliver to a patient's vein a highly accurate and closely controlled volume of intravenous fluid.

It is thought that the invention and many of its attendant advantages will be understood from the foregoing description and it will be apparent to those skilled in the art that various changes may be made in the form, construction and arrangement of the component parts without departing from the spirit and scope of the invention or sacrificing all its material advantages, the
form hereinbefore described being merely a preferred embodiment thereof.

I claim:

1. Infusion pump apparatus with an adjustable piston stroke amplitude for reciprocating a piston within a syringe to deliver fluid comprising:
   a housing;
   angulation means pivotally disposed in said housing and operatively connected to said piston to cause said reciprocation of said piston in said syringe;
   arcuate means pivotally disposed in said housing operatively connected to said angulation means;
   said arcuate means adaptable to adjustably determine said piston stroke amplitude by varying the displacement of said angulation means;
   motor means connected to said arcuate means operable to reciprocate said angulation means through said angular displacement; and
   calibration means cooperable with said operative connection between said angulation means and said arcuate means,
   said calibration means comprising (a) means for pre-selecting the fluid flow rate of said infusion pump apparatus by adjusting said displacement of said angulation means, and (b) adjusting means for establishing the minimum and maximum displacement of said angulation means.

2. The infusion pump apparatus of claim 1 wherein said adjusting means comprises a plurality of threadably adjustable screws.

3. The infusion pump apparatus of claim 1 wherein said angulation means comprises lever means having one end pivotally secured within said housing, said arcuate means comprising a substantially U-shaped member having a middle portion shaped to form a portion of an arc and having grooves formed in said middle portion to define a curvilinear path, link means connected between a point substantially intermediate the ends of said lever means and a point adjustably positioned along said curvilinear path of said U-shaped member, said point of position of said link means along the curvilinear path of said U-shaped member being effective to control the angular distance traveled by said lever and thereby control the amplitude of the syringe piston.

4. The infusion pump apparatus of claim 1 wherein said motor means comprises a brushless synchronous electric motor, and magnetic switch means for controlling said motor means between on and off positions, said motor means and said magnetic switch means being adaptable to operate safely in an explosive atmosphere when said switch controls said motor in an operable condition or causes said motor to turn on or off.

5. The infusion pump apparatus of claim 3 wherein said motor means comprises a synchronous motor adaptable to operate safely in an explosive atmosphere, an eccentric member keyed to a shaft rotatable by said motor, and a pivot link having one end pivotally connected to said eccentric member and another end pivotally connected to the point of position between said arcuate means and said link means located on the curvilinear path of said U-shaped member.

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