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[33] **Netherlands**
[31] **6904268**

[54] **MOTOR-DRIVEN FLUID-METERING DEVICE, IN PARTICULAR INFUSION PUMP FOR THE OPERATION OF ONE OR MORE HYPODERMIC SYRINGES**
10 Claims, 5 Drawing Figs.

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[51] Int. Cl. **G01f 11/02**
[50] Field of Search ..... 128/218 R, 218 A; 192/150; 254/143, 148, 173; 222/333

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Assistant Examiner—Thomas E. Kocovsky
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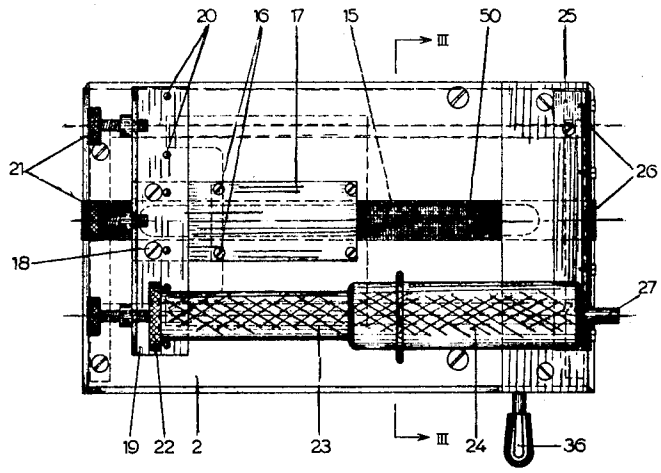
ABSTRACT: An infusion pump for the operation of one or more hypodermic syringes for medical injection purposes in which a slide member operatively connected to the syringes for discharging the latter is mounted in the frame of the device for movement between two end positions and is driven by an electric driving motor through a clutch and a speed reduction transmission which comprises a chain or rope drive having two wheels mounted adjacent both ends of the frame and two further wheels mounted on the slide member, and a chain or rope having its two ends secured to the two ends of the frame and passing from one frame end successively about one slide member mounted wheel, the frame-mounted wheel at this frame end, the opposite frame-mounted wheel at the other frame end, and the other slide member mounted wheel towards said latter frame end, one of the two frame mounted wheels being coupled to the clutch.



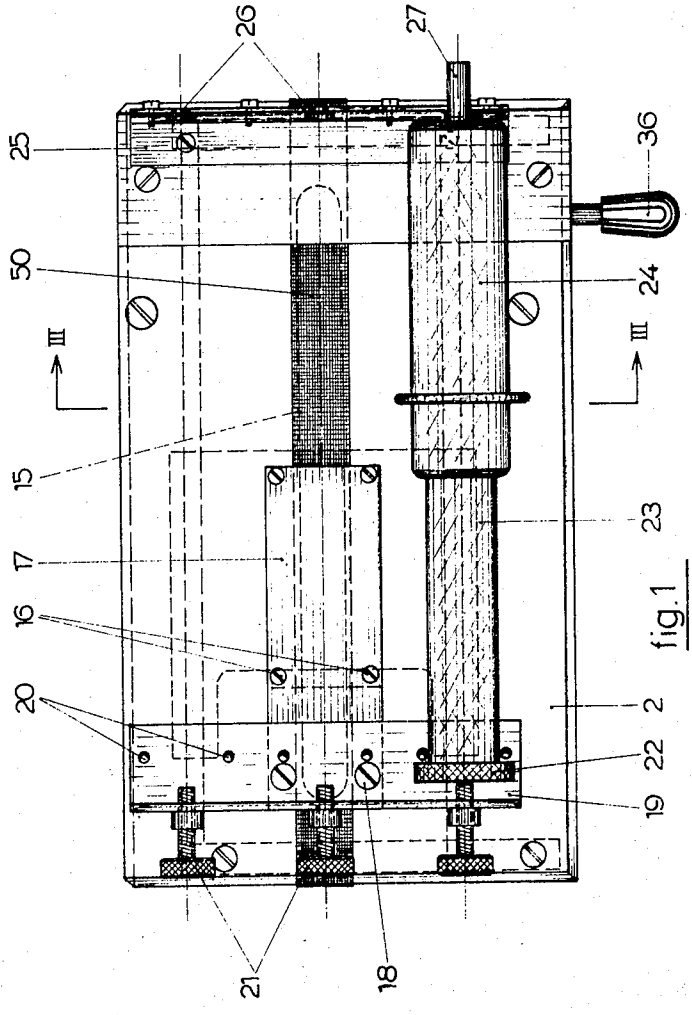


fig. 1

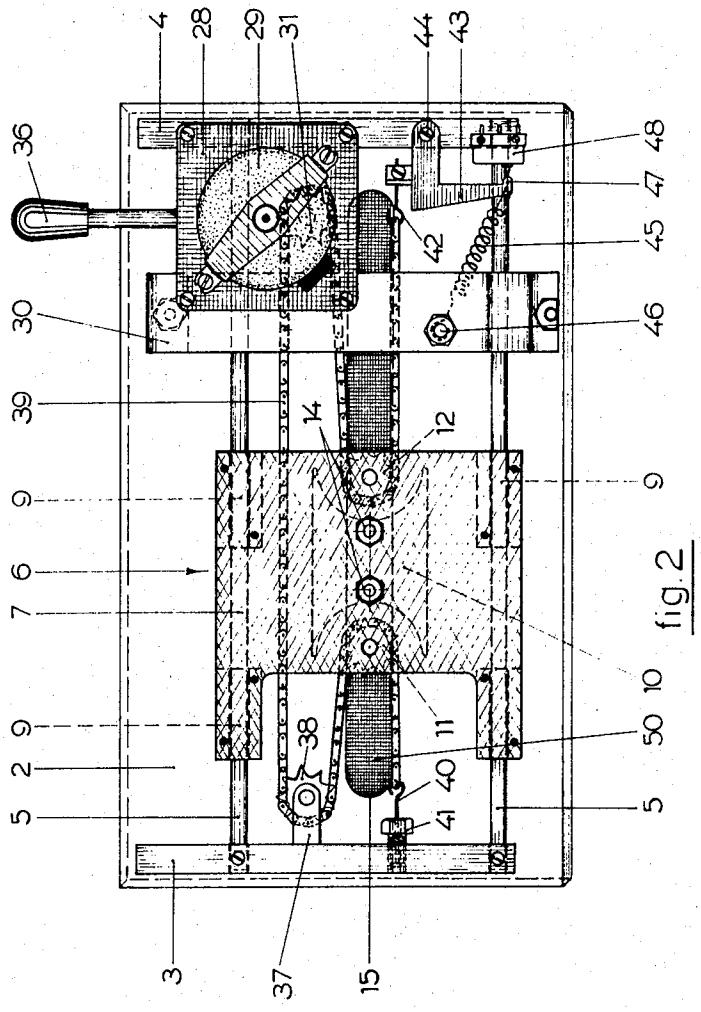

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fig. 2

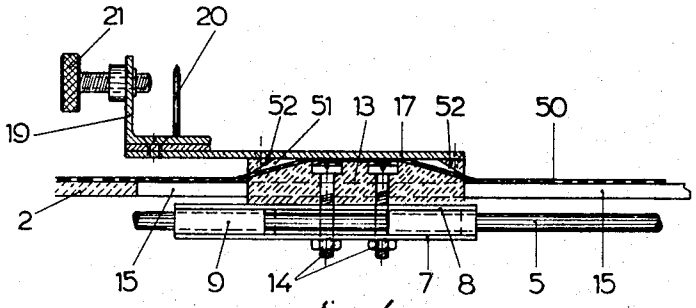
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fig. 4

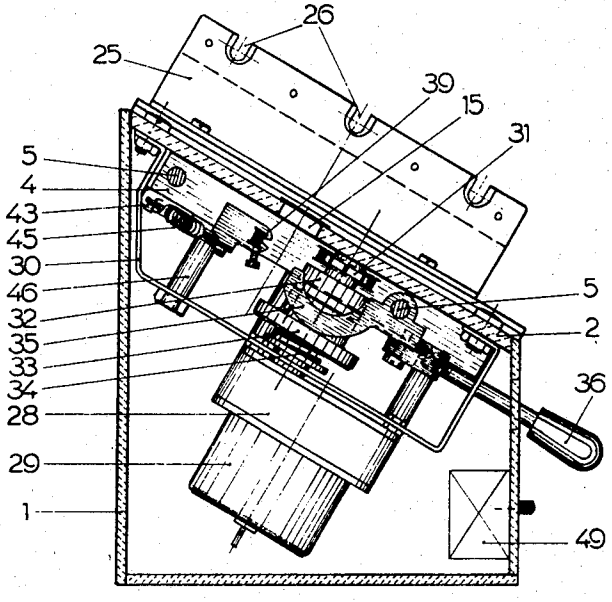
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fig. 3

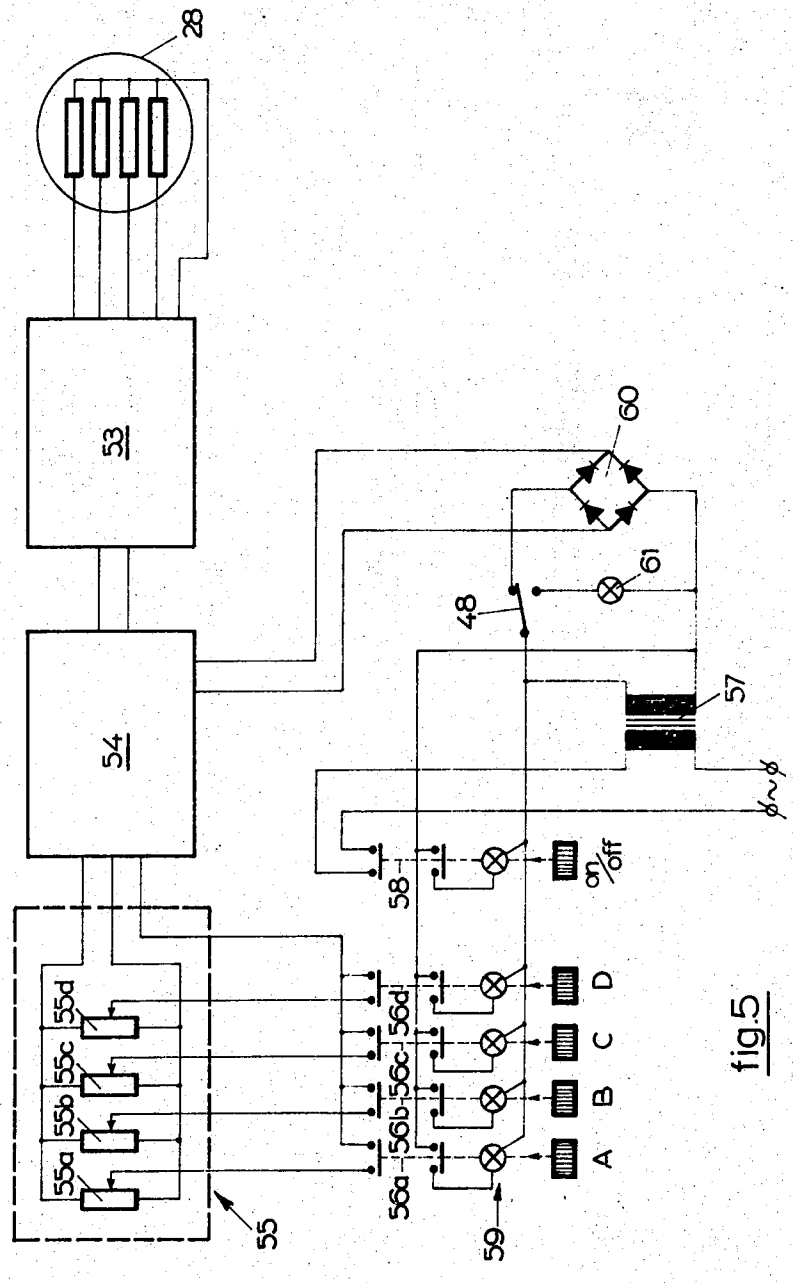
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fig.5

MOTOR-DRIVEN FLUID-METERING DEVICE, IN PARTICULAR INFUSION PUMP FOR THE OPERATION OF ONE OR MORE HYPODERMIC SYRINGES

BACKGROUND OF THE INVENTION

The invention relates to a motor-driven fluid-metering device, and more in particular to an infusion pump for the operation of one or more hypodermic syringes for effecting the medical injection of precise amounts of fluids over predetermined periods of time. Generally such devices comprise a frame with means for mounting one or more syringes and an actuating slide member adapted to be operatively connected to these syringes for discharging the fluid therefrom which slide member is mounted for reciprocating movement in the frame and is driven by an electric driving motor through clutch means for the disconnection of the motor and through a speed reduction transmission means allowing the driving motor to move the actuating slide member at creep rate.

Generally, infusion pumps of this type comprise a lead screw member mounted for rotation in the frame of the device and driven by the electric motor at a low speed which lead screw carries a travelling nut secured to the slide member. The travelling nut may consist of two nut halves adapted to be moved away from each other and from the lead screw for disengaging the slide member from the latter. This disengagement of the travelling nut from the lead screw allows the slide member at the end of its forward stroke to be returned quickly, for instance by hand, to its starting position. This screw drive arrangement has, however, the disadvantage that the manufacture and assembly of the lead screw and the two screw halves require a great precision and thus increase the manufacturing costs. When the disengaged travelling nut halves are again to be coupled to the lead screw it may occur that the two nut halves on being moved against the lead screw do not immediately engage in the threads of the screw but only do so after the screw has made a half turn. This means that in that case in the period required by the driven lead screw to make this half turn the infusion pump does not discharge fluid as required which should, of course, be avoided.

SUMMARY OF THE INVENTION

The invention has for its main object to provide a motor-driven fluid-metering device, and more in particular an infusion pump, of the kind described having a speed reduction transmission means for driving the actuating slide member of the device which is of simple and cheap and yet reliable construction.

Another object of the invention is to provide such a device in which the actuating slide member remains at all times coupled with the drive transmission means therefor and nevertheless this slide member at the end of its operating stroke can be quickly returned to its starting position.

In the device according to the invention the or rope member having a driving motor drives, through disengageable clutch means, a nonslipping chain or rope drive means which is operatively connected to the slide member for driving the latter at creep rate from a first to a second end position thereof and including a first and a second wheel each rotatably mounted in the frame of the device adjacent said first and said second slide member end position, respectively, one of said two wheels being connected to the clutch means, a third and a fourth wheel each rotatably mounted on the slide member, and a chain or rope member having a first and a second end each secured to said frame adjacent said first and said second slide member end position, respectively, said chain or rope member from its first fixed end passing successively about said third slide member mounted wheel, said first frame mounted wheel, said second frame mounted wheel and said fourth slide member mounted wheel to terminate at its second fixed end.

The rotational movement of the driven frame mounted wheel is thus converted to a linear movement of the slide member by the rope or chain engaging the wheels mounted on this member. By disengaging the clutch means the slide

member may be quickly moved by hand in the one or the other direction in which the slide member remains, however, fully coupled to the rope or chain drive. For this clutch means preferably a friction clutch is used. When the infusion pump is put in operation there is thus no starting period in which the slide member remains stationary.

According to a preferred embodiment of the invention, suitable spring means are connected to one end of the rope or chain for tensioning the latter and an actuating arm is coupled to this latter rope or chain end cooperating with switch means adapted to be actuated by this arm when the latter is displaced as a result of an excessive tensioning force exerted on the chain or rope. This switch means on its actuation may energize a suitable signal means or disconnect the electric drive motor. In normal operating conditions the spring means maintain the chain or rope properly stretched whereas when the movement of the slide member is blocked, for instance by clogging of a syringe mounted in the device, the increased tension occurring thereby in the chain or rope causes said end thereof to be displaced against the action of the spring means whereby the arm operates the safety switch. In this way a simple overload protection is obtained.

The electric driving motor for operating the infusion pump may consist of a self-starting synchronous alternating current motor driving one of the frame mounted wheels through a variable speed reduction gearbox allowing to select from a number of predetermined speeds having a ratio of for instance 3:10:30:100 etc. This has the disadvantage, however, that when injecting an infusion fluid it is not possible to use exactly the injection rate required by the circumstances and that, therefore, this injection rate must be adapted to the available speeds of the variable-speed drive. This means that one is forced either to adapt the concentration of the infusion fluid to the nearest available speed or to operate the infusion pump for a first period of time at a speed which is too high and to compensate for this by operating the device for a second period at a lower speed. Both these methods have their disadvantages since they require additional manipulations and supervision and increase the chances of errors.

It is a further object of the invention to obviate this difficulty and to provide the infusion pump of the present type with an infinitely variable speed drive.

To that effect, according to a preferred embodiment of the invention the electric driving motor of the device is a step motor which is fed through an electronic switch means by an electronic oscillator means of variable frequency. Variable speed step motor drives of this type are as such well-known in the art and offer in the present case the great advantage that by a suitable design of the variable oscillator means an infinite speed variation of the motor shaft through a wide speed range can be obtained. The frequency of the oscillator means may be controlled by means of a potentiometer circuit in a known manner.

According to a preferred arrangement, this potentiometer circuit controlling the output frequency of the oscillator means may comprise a plurality of separately adjustable potentiometers connected in parallel and each covering a predetermined frequency range, and switch means for selectively connecting said potentiometers in said potentiometer circuit. This arrangement has the advantage that by the preadjustment of the several potentiometers the operator may preselect a number of speeds within the total speed range of the step motor which practice has shown to be frequently required. When putting the infusion pump in operation the operator thus need only to actuate the switch means concerned, for instance by pressing a push button, providing the required speed. Apart from this, however, in special cases he has always the possibility to further adapt the speed of the infusion pump by changing the adjustment of the potentiometer concerned.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will more readily understood and the further objects and advantages thereof will be more apparent when read in conjunction with the accompanying drawings in which:

FIG. 1 is an elevation of the removable cover plate of the housing of an infusion pump according to an embodiment of the invention, which cover plate is provided with means for mounting three syringes thereon;

FIG. 2 is a bottom view of the cover plate of FIG. 1 and shows the pump drive mounted on the lower side of this cover plate;

FIG. 3 is a cross-sectional view of the device taken on the line III—III of FIG. 1;

FIG. 4 shows in detail and on an enlarged scale a longitudinal section through the slot in the housing cover plate and illustrates the ribbon covering this slot; and

FIG. 5 shows a circuit diagram.

PREFERRED EMBODIMENT OF THE INVENTION

Referring to the FIGS 1–4 of the drawings, there is shown an infusion pump adapted to receive and operate three hypodermic syringes. The device has a housing 1 of rectangular horizontal cross section and having a cover plate 2 removably mounted in an inclined position on the upstanding sidewalls of the housing as shown in FIG. 3, which cover plate on its lower side carries the drive means for the infusion pump. At its lower side the cover plate 2 carries adjacent each of its ends a transverse mounting bar 3, 4, respectively, of square cross-sectional shape. Two spaced parallel guide rods 5 extend in the longitudinal direction of the cover plate 2 at a small distance from the lower face thereof and are fixedly secured with their respective ends in suitable holes of the mounting bars 3 and 4. A slide member, generally indicated by 6 in FIG. 2, is slidably mounted on the guide rods 5 and comprises two spaced parallel plates 7 and 8 which enclose four nylon blocks 9 arranged between the plates adjacent the four corners thereof which block each have a longitudinal bore thus forming guide sleeves fittingly receiving the guide rods 5 for guiding the slide 6 in its longitudinal movement. A spacer member 10 of nylon is centrally arranged between the two slide plates 7 and 8 (FIG. 2). Two sprocket wheels 11 and 12 are rotatably mounted between the slide plates on both sides of the spacer member 10, the axes of these sprocket wheels lying in the longitudinal plane of symmetry of the slide.

An elongated mounting block 13 is secured by means of bolts 14 on the upper slide plate 8 in a position extending in the direction of said longitudinal plane of symmetry (FIG. 4). The heads of the bolts are received countersunk in recesses in the upper side of the mounting block 13 and the bolts 14 extend through the two slide plates 7 and 8 and the spacer member 10 therebetween, carrying nuts at their lower ends. The mounting block 13 projects upward through a longitudinal slot 15 in the cover plate 2 and has in cross section a T-shaped configuration whereby the upper part of the mounting block above the cover plate 2 extends at both sides transversely of the slot 15. By means of four screws 16 an upper support plate 17 is secured on the mounting block 13 which support plate extends at a small distance above the housing cover plate 2 and supports a first syringe mounting member 19 in the shape of an angle bar extending transversely of the elongated support plate and secured thereto by screws 19. The horizontal leg of the mounting member 19 is provided with three pairs of upstanding pins 20 and the vertical leg of the mounting member is provided with threaded holes receiving three clamping screws 21 having knurled heads and each arranged midway between one of the pairs of pins 20. As shown in FIG. 1, each pair of pins 20 may receive the piston 23 of a conventional hypodermic syringe directly to the rear of the customary enlarged end 22 of the piston whereby this enlarged piston end can be clamped between these pins and the associated clamping screw 21. At its opposite end the syringe 24 is supported by a second angle bar mounting member 25 secured to the housing cover plate 2. The vertical leg of this mounting member 25 has three slots 26 in its upper edge, each arranged opposite one of the clamping screws 21 and adapted to accommodate the tubular nozzle 27 of the syringe to which an outlet tubing (not shown) may be attached in a known manner carrying a hypodermic needle its outer end to be inserted in the body of the patient. The syringe is thus held between the relevant clamping screw 21 and the vertical leg of the second mounting member 25 and as a consequence a movement of the slide 6 and therefore of the mounting member 19 to the right, as seen in FIG. 1, causes the syringe to discharge its fluid content through the outlet nozzle 27. If desired, two or three syringes may be arranged in the mounting members 19 and 25 for simultaneous operation.

Against the lower side of the housing cover plate 2 an electric driving motor 29 and a reduction gearcase 28, together forming a unit, have been mounted, the gearcase 28 being secured by screws against the mounting bar 4 and a bracket member 30 carried by the cover plate 2. The outgoing shaft of the gearcase drives a sprocket wheel 31 through a friction clutch comprising a first clutch part 32 connected to this sprocket wheel 31, a second flanged clutch part 33 slidably mounted on the outgoing gearcase shaft, and a compression spring 34 tending to keep the two clutch parts engaged. Friction clutches of this type are well known in the art. A curved lever arm 35 cooperates with the flange of the clutch part 33 which lever arm is mounted for rotation on the guide rod 5 and is connected to an actuating arm 36 extending outwardly through a slot in the front wall of the housing 1. By means of this actuating arm 36 the lever arm 32 may thus be moved to disengage the friction clutch part 33 from the clutch part 32 against the action of the spring 34.

The sprocket wheel 31 is situated adjacent one end of the device, that is adjacent the end of the forward stroke of the slide 6. Opposite this driven sprocket wheel 31 a further sprocket wheel 38 is mounted for free rotation in a bracket 37 secured to the mounting bar 3, the sprocket wheel 38 thus being situated adjacent the second end position of the slide 6 corresponding to the starting position of its operating stroke.

A chain 39 has its one end connected to a hook 40 secured to a threaded bolt 41 which is received in a threaded bore of the mounting bar 3, the hook 40 being arranged substantially in the plane of and spaced from the sprocket wheel 38. As shown in FIG. 2, the hook 40 and the sprocket wheels 38 and 31 lie on opposite sides of the slot 15. From the hook 40 the chain 39 successively passes around the sprocket wheel 11 on the slide 6, back to the sprocket wheel 38, around this wheel 38 to the driven sprocket wheel 31 at the opposite end of the device, around this wheel 31 to the other sprocket wheel 12 on the slide 6 and around this latter wheel 12 towards the mounting bar 4 where the other end of the chain is connected to a second hook 42. This hook 42 is secured to an angle-shaped lever arm 43 pivotally secured at 44 to the mounting bar 4. A tension spring 45 is connected between the free end of the angle-shaped lever arm 43 and a bolt 46 secured to the bracket 30. The spring 45 thus keeps the chain 39 under tension and eliminates undesirable play in the chain. The lever arm 43 has at its free end a projection 47 adapted to cooperate with the actuating button of a microswitch 48 (FIG. 2) mounted on the bar opposite this projection 47. The microswitch 48 on its actuating deenergizes the electric motor 29 and preferably also energizes an acoustical or optical signaling means (not shown). Such means and the circuits therefor are as such well-known in the art and are, therefore, not shown and described in further detail.

In operation the above described infusion pump functions as follows. If the slide 6 is not in its left hand end position or starting position, as seen in FIGS. 1 and 2, first the clutch 32, 33 is disengaged by means of the actuating arm 36 and the mounting member 19 is moved by hand to its position shown in FIG. 1. Next, one or more syringes 24 filled with injection fluid are arranged between the syringe mounting members 19

and 25 in the manner as above described and the electric motor 29 is switched on by means of a switch such as 49 shown in FIG. 3. The motor drives the sprocket wheel 31 through the reduction gearcase 28 at slow speed in the counterclockwise direction as seen in FIG. 2 which speed is further reduced by the above-described chain drive pulling the slide 7 at creep rate through its operating stroke from its left-hand end position to its right-hand end position. The injection fluids are thus slowly discharged from the syringes 24. If the forward movement of the slide 6 is blocked, for instance at the end of the operating stroke or because one of the syringes or the tubing connected thereto gets clogged, the tension in the chain part between the driven sprocket wheel 31 and the hook 42 increases whereby the lever arm 43 is turned against the action of the spring 45 and with its projection 47 actuates the microswitch 48. Thereby the motor 28 is disconnected and an optical or acoustical signal is started.

The slot 15 in the cover plate 2 is covered by a ribbon 50 (FIGS. 1 and 4) which is secured at both ends by suitable means flat against the upper surface of this cover plate. The ribbon 50 passes through a groove 51 in the upper face of the mounting block 13 which groove is covered by the support plate 17. The bottom of the groove has at both ends downward inclined end portions terminating adjacent the upper face of the cover plate 2 and the support plate 17 carries two guide blocks 52 of triangular cross section projecting downward into these recessed groove ends. The ribbon 50 passing through the groove 51 across the countersunk heads of the bolts 14 is thus held by these blocks 52 against the inclined groove bottom ends as the ribbon enters and leaves the mounting block. In this way the slot 15 is covered by the ribbon 50 immediately in front and to the rear of the mounting block 13 also when during sliding movement of the slide 6 the ribbon moves through the groove 51.

The electric motor 28 may be a self-starting synchronous motor, Preferably, however, the motor 28 is a variable-speed step motor which, as shown in the diagram of FIG. 5 is fed and controlled by an electronic oscillator 54 through an electronic switch means 53. The speed of the motor 28 depends on the supply frequency of the oscillator 54 which can be varied within a wide range by means of a potentiometer circuit 55. This arrangement with potentiometer-controlled electronic oscillator and electronic switch means are as such well known to those skilled in the art and the elements 53 and 54 need, therefore, not be shown and described in detail.

The potentiometer circuit 55 controlling the supply frequency of the oscillator 54 is especially adapted to its present function of controlling the operating speed of an infusion pump. The circuit 55 comprises four potentiometers 55*a*, 55*b*, 55*c* and 55*d* connected in parallel and each separately adjustable by means of a suitable regulating knob or by means of a regulating screw to be adjusted by a screw driver (not shown). The four potentiometers are so dimensioned that each covers a predetermined different part of the total frequency range of the oscillator 54. The potentiometers have pushbutton switches 56*a*, 56*b*, 56*c* and 56*d*, respectively, with pushbuttons A, B, C and D associated therewith for connecting a selected potentiometer in the circuit of the oscillator 54 in the manner as shown. In this way, by the actuation of one of the pushbuttons A–D it is possible to select immediately the desired speed of the step motor 28 as predetermined by the selected adjustment of the potentiometer concerned. The pushbutton mechanism of the pushbuttons A–D may be carried out in a known manner in such a way that only one pushbutton at a time can occupy its operating position and that when a pushbutton is actuated a previously actuated pushbutton is automatically returned to its rest position.

The arrangement is supplied with current through a transformer 57 to be connected to the network and having a primary winding connected in series with a main pushbutton switch 58. Each of the pushbutton switches 56 and 58 has one of a row of signal lamps 59 associated therewith which through extra contacts of the respective pushbutton switches are connected in parallel across the secondary winding of the transformer 57 and which are thus energized in the closed position of the associated pushbutton switch. The transformer 57 feeds the oscillator 54 through a rectifier circuit 60. The circuit of the secondary transformer winding further comprises the above-discussed microswitch 48 which serves as a safety and limit switch and which on its actuation by the lever arm (FIG. 2) interrupts the supply circuit of the rectifier 60 and closes the circuit of a warning signal lamp 61.

The pushbutton switches 56 and 58 may be mounted in a common switch box at 49 (FIG. 3) arranged in the front wall of the housing 1. A counting mechanism (not shown) may be coupled to the shaft of the motor 28 for accurately indicating how far the slide 6 has progressed from its starting position as a measure of the quantities of injection fluid discharged by the syringes.

Although the invention has been shown and described with references to a preferred embodiment thereof, it will be obvious to those skilled in the art that various modifications may be resorted to within the scope of the following claims. For instance, although a chain drive is preferred, also a rope drive could be employed in which case the chain 39 is replaced by a V-belt or string and the sprocket wheels 11, 12, 31 and 38 by proper pulleys.

What is claimed is:

1. A motor-driven fluid-metering device, in particular an infusion pump for the operation of at least one hypodermic syringe, comprising a frame, means for mounting a fluid container, such as an syringe, having an outlet opening on said frame, an actuating slide member adapted to be operatively connected to said container and movable in relation thereto for discharging said fluid, said slide member being mounted for reciprocating movement in said frame between a first and second end position, an electric driving motor, a disengageable clutch means, and a speed reduction transmission means comprising a nonslipping chain or rope drive means coupled to said driving motor through said clutch means and operatively connected to said slide member for driving the latter at creep rate from one of said end positions to the other, said drive means including a first and a second wheel each rotatably mounted in said frame adjacent said first and said second slide member end position, respectively, one of said two wheels being connected to said clutch means to be driven by said motor, a third and a fourth wheel each rotatably mounted on said slide member, and a chain or rope member having a first and a second end each secured to said frame adjacent said first and said second slide member end position, respectively, said chain or rope member from its first fixed end passing successively around said third slide member mounted wheel, said first frame mounted wheel, said second frame mounted wheel and said fourth slide member mounted wheel towards its second fixed end.

2. The device of claim 1 in which said clutch means is a disengageable friction clutch.

3. The device of claim 1 further comprising a reduction gear arranged between said electric motor and said clutch means.

4. The device of claim 1 further comprising two spaced guide rods mounted in parallel in said frame and in which said slide member comprises two spaced parallel plates and a plurality of guide blocks secured between said plates and each having a bore receiving the one or the other of said two guide rods, said slide-mounted wheels being arranged between said two plates.

5. The device of claim 1 further comprising a housing enclosing said driving motor, said chain or rope drive and said slide member and having an upper wall provided with a longitudinally extending slot, said slide member being mounted below said upper housing wall for reciprocating movement in the longitudinal direction of said slot, a mounting member secured to said slide member and projecting upward therefrom through said slot, a first syringe mounting means secured to said mounting block above said housing upper wall, a secondary stationary syringe mounting means secured to

said housing upper wall, said two mounting means being adapted to accommodate at least one syringe, and a ribbon extending over and covering said slot and secured with its two ends to said housing upper wall, said mounting member having a channel extending in the longitudinal direction of said slot and accommodating said ribbon, said channel having downward inclined end portions opening closely adjacent the upper surface of said housing upper wall.

6. The device of claim 1 further comprising a spring means connected to one end of said chain or rope for tensioning the latter, an actuating arm coupled to said latter chain or rope end, and a microswitch mounted on said frame and adapted to be operated by said arm when the latter is displaced as a result of an excessive tensioning force exerted on said chain or rope.

7. The device of claim 6 in which said switch means on its actuation energizes a signal means.

8. The device of claim 6 in which said switch means on its actuation disconnects said electric driving motor.

9. The device of claim 1 in which said electric motor for driving said slide member is a step motor, further comprising an electronic oscillator means of variable frequency and an electronic switch means, said oscillator means feeding said step motor through said electronic switch means.

10. The device of claim 9 further comprising a potentiometer circuit for controlling the output frequency of said oscillator means, said potentiometer circuit including a plurality of separately adjustable potentiometers connected in parallel and each covering a different predetermined frequency range, and a plurality of switch members each associated with one of said potentiometers for selectively connecting said potentiometers in said potentiometer circuit.

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