

[54] PUMP ACTUATOR INCLUDING
ROTATABLE CAMS

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[51] Int. Cl. F16h 25/08

[58] Field of Search 74/53, 568 T, 568 M;
128/124 F, 124 E

[56] References Cited
UNITED STATES PATENTS

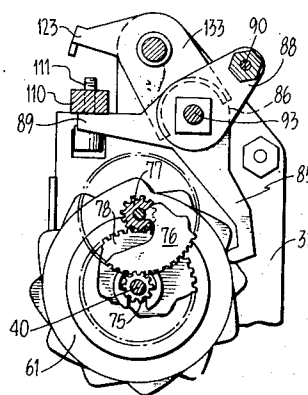
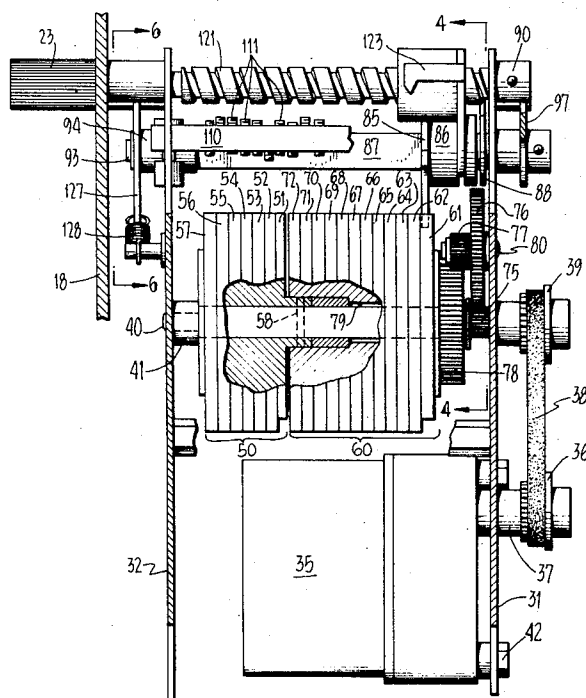
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[57] ABSTRACT

The intravenous feeding pump actuator of the present invention comprises a plurality of cam assemblies (preferably two) rotating on a common shaft, one pinned, or otherwise affixed to the shaft and the other assembly mounted on a quill shaft encompassing the common shaft; the cams being provided with a variable number of cam lobes, the height of the lobe preferably being the same on each cam, but the cams having a varying number of lobes (preferably running from "1" to "19"); a follower positionable along said cam assembly so as to be operated by the rotation of a selected one of said cams; means for adjustably limiting the backstroke of the cam follower; means for operating an intravenous feeding pump, or similar device, from the rocking of the cam follower; and a drive means including an electric motor and a gear reducer for driving the drive shaft at one speed (preferably 10 r.p.m.) and a gear assembly for driving the quill shaft and its cam assembly at a much lesser speed (preferably one-half of one revolution per minute) or a speed reduction of one to 20.

5 Claims, 8 Drawing Figures



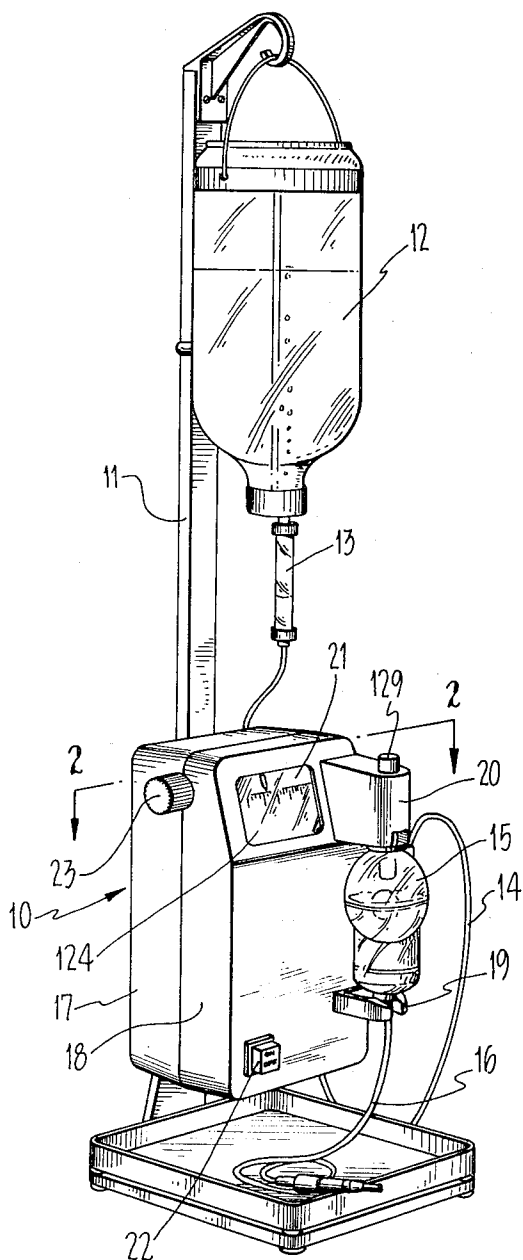


Fig. 1

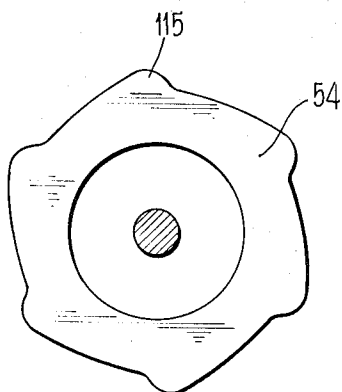


Fig. 2

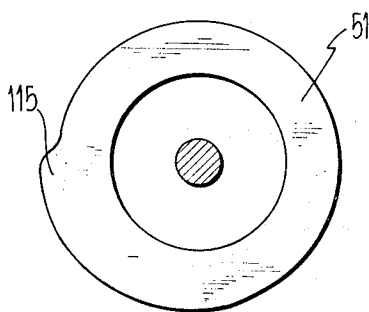
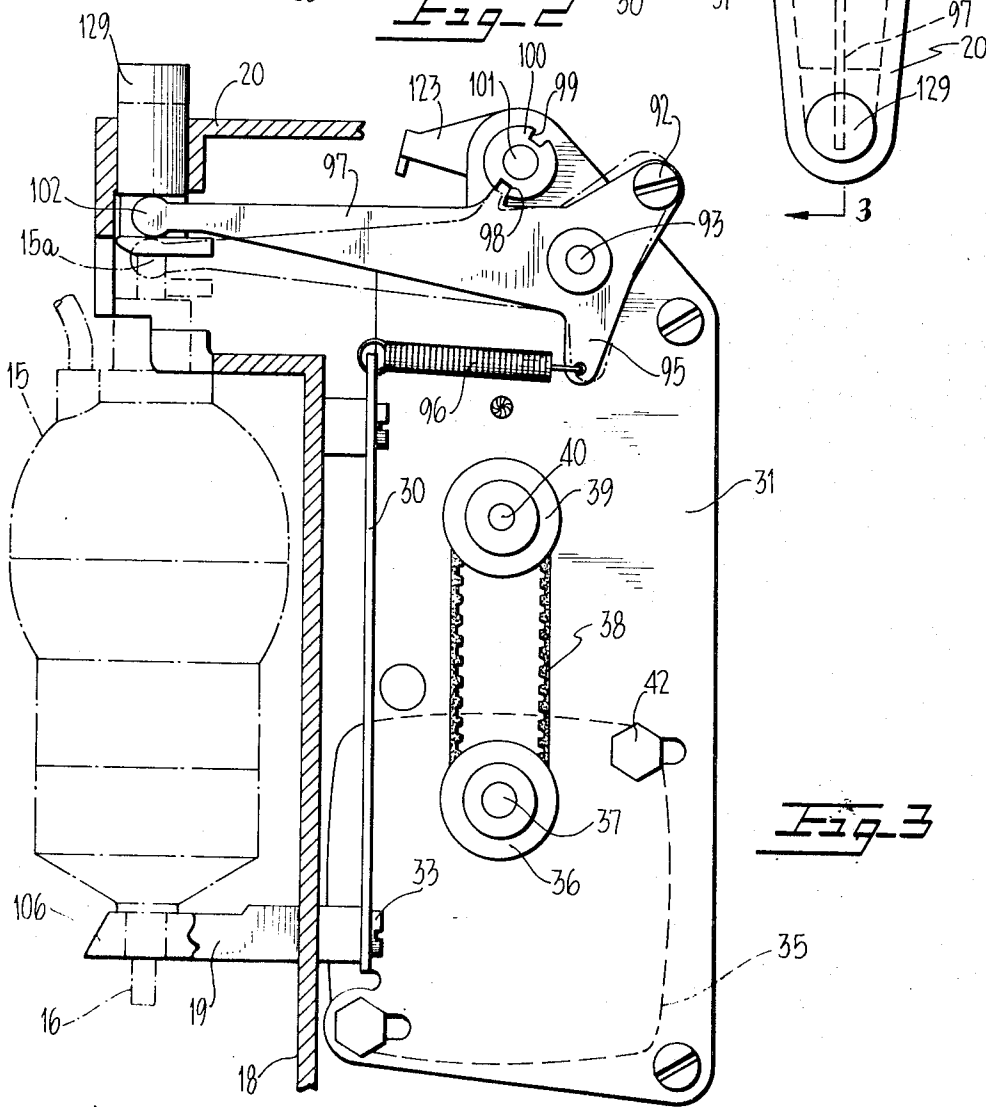
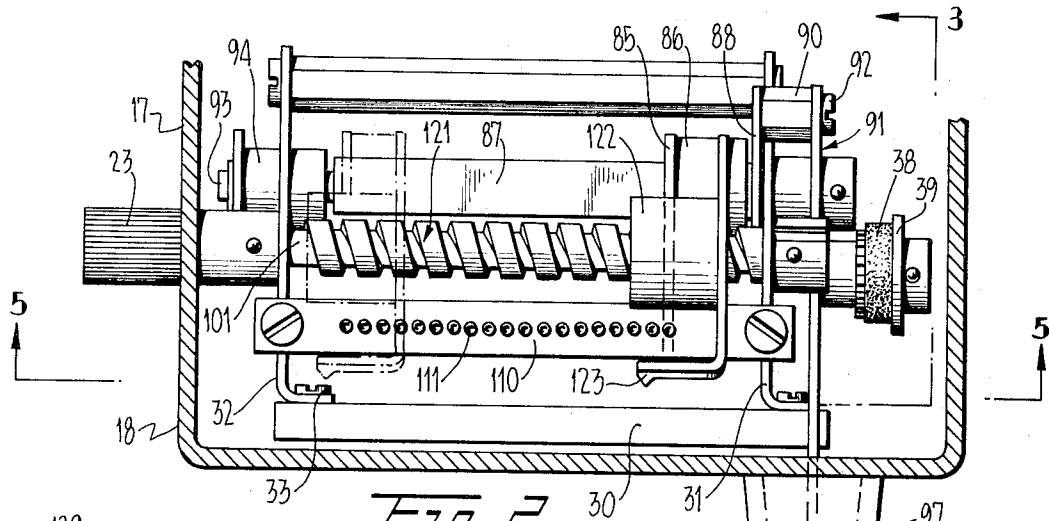


Fig. 3



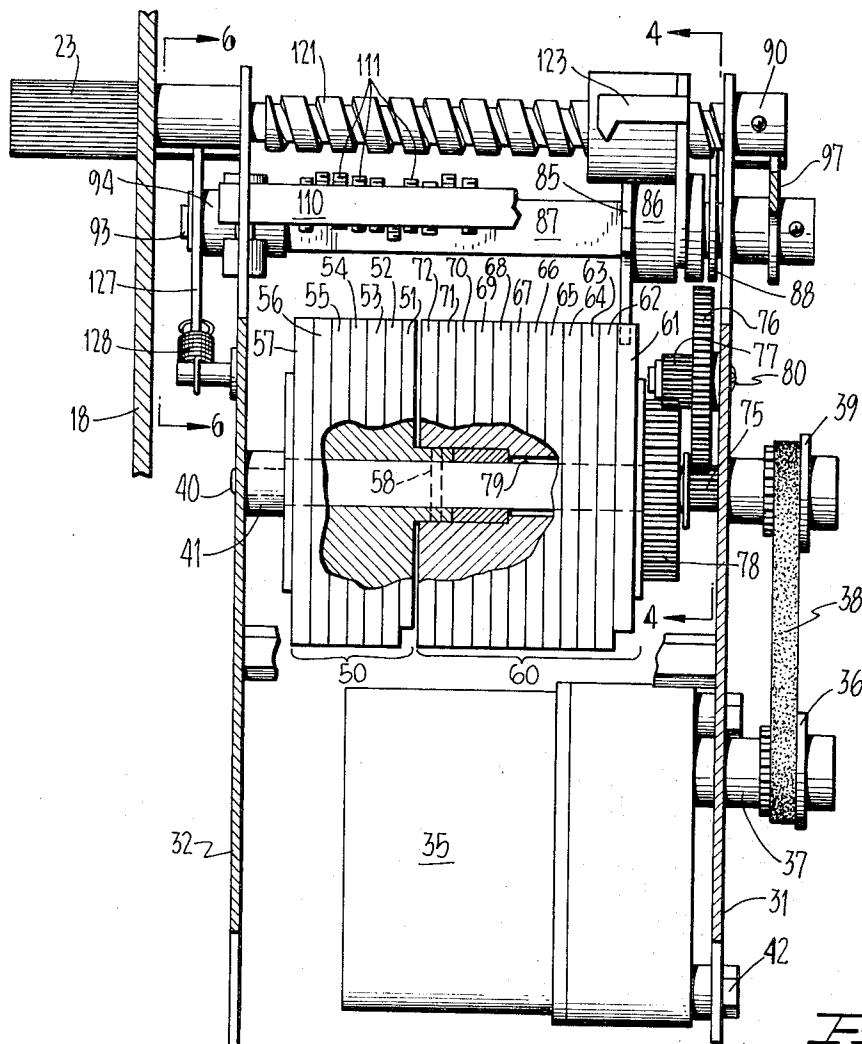


Fig. 4

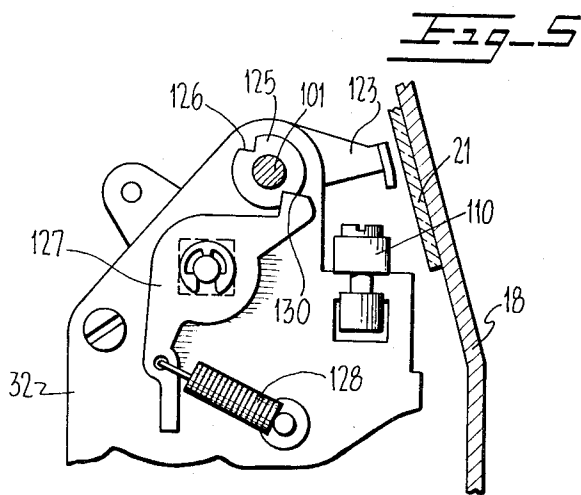


Fig. 5

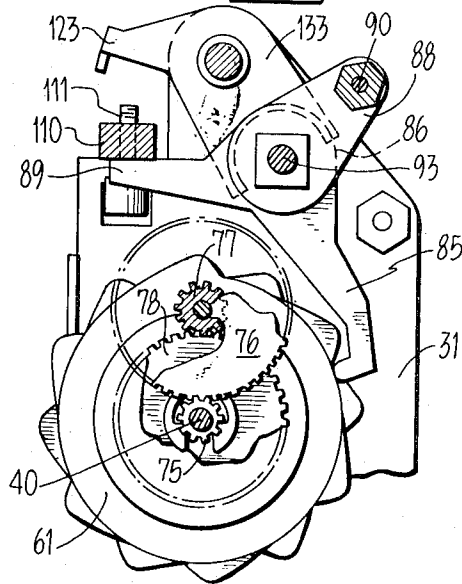


Fig. 6

PUMP ACTUATOR INCLUDING ROTATABLE CAMS

BACKGROUND OF THE INVENTION

For many years, intravenous feeding of blood transfusions, or various feeding solutions, has been by gravity only. Such procedure involves frequent checking by a competent person to see that the apparatus was actually feeding the material at the desired rate as due to the small amount introduced per minute, there was frequent clogging of the delivery tube, or needle, which is used to deliver the material into the vein of a patient. More recently, several efforts have been made to provide an accurate pump which would positively deliver the feeding solution to the patient. This necessitated a pump system of extreme accuracy, as well as one which would be completely sterile at all times. This applicant has recently filed an application for a patent for an intravenous feeding pump, Ser. No. 329,425, filed Feb. 5, 1973, in which the operation of a piston would deliver a measured quantity of fluid from the pump to the patient. The present invention relates to an actuating or driving device for such a pump whereby the number of strokes in a given unit of time and the length of the stroke (which is equivalent of saying "the amount of fluid per stroke") is variable over a wide range.

Such a driver or actuator must be positive in its operation and must be readily adjustable to provide a wide range of delivery. In the preferred form of the present device, the driver is readily adjustable to deliver from 5,000 milliliters per hour to 1,500,000 milliliters per hour, which is equivalent to $83\frac{1}{3}$ to 2,500 milliliters per minute. This is accomplished, in the preferred form of the invention, by using 19 cams, 12 of which are driven at the rate of one-half of one r.p.m. and seven of which are driven at the rate of 10 r.p.m. The cams are provided with a varying number of lobes (preferably one, two, four, six, eight, 10, and 12), all having an equal rise, or height. By limiting the backstroke of the cam follower, these 20 cams can provide a very great variation in the amount of feeding solution delivered to the patient, as will be seen from the detailed description later in the specification. It is recognized that cam-driven actuators are not new and that a variety of cams have been used to vary the speed of operation of an actuator. Still it is believed that the combination of various elements to be hereinafter described is unique.

It is an object of this invention, therefore, to provide a driver, or actuator, for an intravenous delivery pump which is extremely accurate in its operation and which can be easily adjusted to provide for a very wide range of delivery volumes to a patient.

It is another object of the invention to provide a pump actuator which can be readily adjusted, even while in use, with only the delay of a few seconds in its operation.

It is another object of the present invention to provide a pump driver that is particularly adapted to operate the intravenous feeding pump covered by the application Ser. No. 329,425, filed Feb. 5, 1973 by this applicant.

These and other objects of the invention will be apparent from the detailed specification which follows when taken in view of the drawings which are a part hereof.

FIG. 1 is a perspective view of the driver of the present invention shown in connection with the preferred form of pump.

FIG. 2 is a cross-sectional plan view taken along a horizontal plane, immediately below the top of the casing, such as indicated by the lines 2—2 of FIG. 1, and showing particularly the means for setting the actuating arm for operation by one of its associated cams.

FIG. 3 is a cross-sectional end view taken along a vertical plane immediately inside of the right side of the casing, such as is indicated by the lines 3—3 of FIG. 2.

FIG. 4 is an end view of the driving mechanism taken along a vertical plane just inside of the frame plates as indicated by the line 4—4 of FIG. 5.

FIG. 5 is a front view of the device, partly in cross-section, showing the cam assemblies, the cam follower and other necessary mechanisms to provide the variable delivery required by a pump actuator of this nature.

FIG. 6 is an end view of the device shown in FIG. 5 taken along a vertical plane at the left of FIG. 5, such as indicated by the line 6—6 of FIG. 5.

FIG. 7 is a side view of a six-lobed cam of the present invention; and

FIG. 8 is a side view of a single lobed cam of the present invention, which are illustrative of the shape of the various cams used in this device.

As best shown in FIG. 1, the pump actuator 10 of the present invention preferably is adapted to be mounted on a suitable stand 11. The stand 11 preferably should also be provided with a suitable holder for a bottle 12 of material to be used for intravenous feeding, which material will flow through a bubble trap 13 and delivery tube 14 to a pump 15, and thence through tube 16 to a needle to be inserted in the arm of a patient. As shown in this figure, the pump actuator 10 is preferably enclosed within a two-part casing having a back section 17 and a front section 18. The front casing 18 is provided with a suitable mounting bracket 19 for supporting the intravenous feeding pump 15 and a second mounting bracket 20 adapted to receive the upper end of the pump 15 and also enclosing the actuating arms of the driver which operates the piston of the pump 15, as will hereinafter be disclosed. The front section 18 will also be provided with a window 21 through which the setting of the pump actuator can be readily viewed, and an electric switch 22 which will be used to control the flow of power to the pump motor, as hereinafter mentioned. A setting knob 23 extends through the left wall of the casing and is used to set the actuator at a desired value, as will be described hereafter.

On the inside of the casing 17, 18 is a mounting frame suitably attached to the casing. In the preferred construction, the frame comprises a front plate 30 (see FIGS. 2 and 3) and side plates 31 and 32. These can be rigidly secured together and mounted on the front casing 18 by any suitable means, such as mounting bolts 33 which are threaded into bosses 34 formed on the inside wall of the front casing plate 18.

The pump actuator will be driven by an electric motor 35 which is mounted on the frame plate 31 by any suitable means, such as mounting bolts 42 (FIGS. 3 and 5). Preferably, the motor is combined with an integral speed reducer so that the output shaft 37 will be driven at a speed of 10 r.p.m. The shaft 37 carries a timing pulley 36 which drives a timing belt 38 that,

in turn, drives timing pulley 39. The timing pulley 39 is mounted on the cam drive shaft 40 which is journaled in suitable bearing bosses 41 formed in, or affixed to, the side frames 31 and 32. It will be understood that in order to have very accurate delivery of material to be pumped to the patient, it is necessary that there be no slippage between the motor driving the apparatus and the operating cams, hence it is very desirable, if not essential, that a timing belt 38 and the timing belt pulleys 36 and 39 be used.

The shaft 40 carries two groups of integral cams (see FIGS. 4 and 5); group 50 which comprises seven integral cams 51 to 57, respectively, which cams have one, two, four, six, eight, 10, and 12 lobes, respectively; and group 60 comprising 12 integral cams 61 to 72, inclusive, which have one, two, four, four, six, eight, 10, 12, 12, 12, 12, and 12 projections, or lobes, respectively. It will be noted that in group 60 there are two adjacent cams with four lobes and five adjacent cams with 12 lobes. It can be mentioned here that a different volume of fluid will be pumped by each of these cams by adjustably limiting the length of the backstroke of the follower, as will be explained more in detail subsequently. For the moment it should be noted that the cams of group 50 will rotate at the speed of shaft 40, namely, 10 revolutions per minute, while the cams of group 60, which are mounted on a quill shaft 79 encompassing the shaft 40, will be driven at a speed of one-half of a revolution per minute through reducing gearing comprised of a pinion 75 pinned or otherwise rigidly secured to shaft 40, which drives a larger gear 76. The gear 76 has an integral pinion 77 which, in turn, meshes with a larger gear 78 which is pinned or otherwise rigidly secured to the quill shaft 79. The combination gear 76, 77 rotates on a stud 80 fastened on the side frame 31. The sizes of the gears are selected to give a 20:1 reduction in the speed of the quill shaft with respect to the drive shaft 40. It will thus be seen that the cams of group 50, which are pinned to the shaft 40 by any suitable means, such as pin 58, will rotate at a speed of 10 r.p.m., or 600 r.p.m. per hour, while the cams of group 60 will rotate at a half a revolution per minute or 30 r.p.h.

Associated with the two groups of cams 50 and 60 is a cam follower arm 85 (FIGS. 3 and 4) which is rigidly secured on a spool 86 that is slidably mounted on a square shaft 87. The square shaft 87 preferably is milled to provide bearing extensions 93 which are journaled in suitable bosses 94 mounted on the frame plates 31 and 32. It will thus be seen that rotation of the cam clusters 50 and 60 will rock the cam follower arm 85 at a rate depending upon its position with respect to the respective cams in the clusters, and this, in turn, will rock the spool 86 and square shaft 87, 93. The follower 85 is formed as a rocker with a forwardly extending arm 89 which is utilized to limit the backstroke of the cam follower assembly, and hence the length of the pumping stroke of the pump with which this driver is associated, as will be explained shortly.

Adjacent the frame plate 31 is an arm 88 which is also rigidly mounted on the square shaft 87, 93. As is shown in FIGS. 2 and 4, the arm 88 extends rearwardly from the square shaft 87 and terminates beyond the side wall 31. To the right of the wall 31 is a pump operating arm 91, likewise pinned to the shaft 87, 93, and also connected at its rear end to the arm 88 by means of a spacer spool 90 and a bolt 92 which holds the two

arms rigidly together. It will be seen by reference to FIG. 3 that the arm 91 has a lower projection, or arm, 95 which provides a seat for a tension spring 96 tensioned between the arm 95 and the front frame plate 30. The arm 91 also has a long forwardly extending arm 97 provided with an enlarged circular tip 102 which is adapted to overlie the piston 15a of the pump 15. It can also be seen in FIG. 3 that the lower bracket 19 on the front casing 18 is slotted at its forward or outer end, as at 106, and is adapted to embrace the lower end of the pump 15. It is also noticed in this figure that the upper projection 20 of the front casing is hollow to enclose the arm 97 and the upper part of the pump 15 so that the pump is held firmly in position. The rocking of the arm 97 will depress the outer end of piston 15a of the pump 15 (counter-clockwise in this figure), thereby operating the pump as disclosed in said previously mentioned application. The arm 97 also carries a locking projection 98 adapted to engage one or the other of diametrically opposed slots 99 in a locking washer 100 that is pinned or otherwise rigidly secured on adjusting shaft 101. The rocking of the arm 97 will cause the locking projection 98 to disengage its associated notch. However, the pump driving assembly is locked in position when the device is at rest.

The locking engagement is desirable, so that when the pump actuator is at rest, the setting of the cam follower arm 85 cannot be changed until the projection 98 is removed from the locking notch 99 to rock the cam follower 85 away from contact with any of the cams. It is also necessary to lock shaft 101 in an adjusted position while the pump actuator is in operation, and this is accomplished by means now described.

At the other end of the shaft 101, as is shown in FIG. 6, the shaft 101 carries a detent washer 125 rigidly secured thereto, which is provided with a pair of diametrically opposed V-notches 126. It will be obvious that the notches 99 in washer 100 and notches 126 in washer 125 should be aligned so that they will be effective in parallel. At the left end of the shaft 101 is a detent arm 127 spring-biased into engagement with the detent washer 125 by any suitable means, such as tension spring 128. Since the notches 126 are V-shaped, the shaft 101 can be rotated by the knob 23 manually whenever the detent at the right end of the shaft is released, as by depression of a button 129 (FIG. 3). However, since the engagement of the nose 130 (FIG. 6) of the arm 127 with a notch 126 comes from the force of spring 128, and since the notches 126 are V-shaped, the shaft 101 can be manually rotated by manipulation of knob 23 if the pushbutton 129 has been depressed to rock the straight sided locking projection 98 (FIG. 3) out of the straight sided notches 99 at the right end of the shaft. However, the force of the spring 128 is sufficient to hold the shaft 101 in a set position except when considerable force is applied to rotate knob 23. However, it should be noted that when the pump is operating, the lock 98 is never entirely removed from its associated notch 99, so that the pump cannot be adjusted during operation. By this means the pump actuator can be adjusted only when it is at rest, but after once adjusted, it is held by one or the other or both of the detents mentioned so that it will not change its adjustment during operation.

It perhaps should be mentioned at this point that when it is desired to check the accuracy of the pump setting, especially as to volume per stroke, this can be

accomplished by rapidly operating the button 129 a number of times and measuring the output. Pump operation is ordinarily so slow that testing during operation is not practical. It has previously been mentioned that the volume that could be pumped on any stroke was controlled, not only by the height of the cam projection on the respective cams, but also by the amount of the backstroke of the arm 97. The means for so controlling the backstroke is shown particularly in FIGS. 4 and 5. It will be seen in these figures that the square bar 110 is rigidly mounted in the frame plates 31 and 32 above the cam clusters 50 and 60. This bar carries a series of adjusting screws 111, such as Allen head screws, one such adjusting screw being located over each cam. It has been mentioned that the cam follower arm 85 is a rocker having a forwardly extending arm 89. This arm 89 engages the lower face of the square bar 110 or the end of the adjusting screw 111 if it has been moved or set inwardly to stop the arm 89 at a lower position. Thus, if one of the adjusting screws has been moved downwardly, as is shown in FIG. 5, it will stop the arm 89 below the bar 110, and thereby prevent the other arm of this rocker 85 from dropping to the bottom of the notch between the cam lobes 115 (see FIGS. 7 and 8). It will be obvious that the volume to be pumped for a particular interval of time will depend in part upon the number of lobes on the cam which is engaged by the follower arm 85. The number of lobes obviously control the number of strokes per minute. Since it is preferred that all the lobes be of the same height, means should also be provided for adjusting the volume to be pumped per stroke, and this is accomplished by the set screws 111. The cooperation of the number of lobes on the cam and the setting of the set screws can well be illustrated by the following table which shows the preferred assembly of cams and the adjustment of the stroke. In this connection it should be noted that since, in medical circles the volume is normally measured in milliliters per hour, this is used in the following table:

CAM SELECTIONS

Cam No.	Volume/hr. in mm.	No. of Cam Lobes	No. of Strokes/hour	Volume/stroke	RPM
61	5,000	1	30	166.66	1/2
62	10,000	2	60	166.66	1/2
63	20,000	4	120	166.66	1/2
64	25,000	4	120	208.33	1/2
65	30,000	6	180	166.66	1/2
66	40,000	8	240	166.66	1/2
67	50,000	10	300	166.66	1/2
68	60,000	12	360	166.66	1/2
69	70,000	12	360	194.44	1/2
70	75,000	12	360	208.33	1/2
71	80,000	12	360	222.22	1/2
72	90,000	12	360	250.00	1/2
51	100,000	1	600	166.66	10
52	250,000	2	1,200	208.33	10
53	500,000	4	2,400	208.33	10
54	750,000	6	3,600	208.33	10
55	1,000,000	8	4,800	208.33	10
56	1,250,000	10	6,000	208.33	10
57	1,500,000	12	7,300	208.33	10

The shape of the cams is illustrated in FIGS. 7 and 8. FIG. 8 shows a single lobe cam, such as 51 or 61. The single lobe 115 has a slow but steady rise throughout the entire circumference of the cam, rising to the high point 115, followed by a rather abrupt drop. It is obvious that when a single stroke or revolution is desired,

it is preferable to pump a minute quantity over a prolonged period than to pumping the full volume in a matter of a fraction of a second. FIG. 7 shows a six rise cam, such as 54 or 65, in which there are six lobes 115 equally spaced around the circumference of the cam, each of which has a gradual rise to its high point 115 followed by a rather abrupt drop.

It will be noted in the above table that in cam cluster 60, the cams 63 and 64 have four lobes, each of which provides an equal number of strokes per hour but that the volume per stroke is changed from 166% milliliters per stroke to 208%. This adjustment is accomplished by means of the setting of the adjusting screws 111. The same principle applies to cams 68 to 72, inclusive, all of which have 12 lobes, and accordingly, have an equal amount of strokes per hour, but in which the volume per stroke is changed from 166% milliliters per stroke to 250 per stroke, and this again is accomplished by the setting of the set screws 111. It can be noted at this point that it is assumed that in any particular case the doctor will know in advance what volumes he will want to use and these can be preset either at the factory or at the hospital, and the set screws 111 need not be re-adjusted thereafter.

The means for setting the cam follower arm 85 is best shown in FIGS. 2, 5 and 6. The hand-adjusting knob 23 is mounted on the left end of shaft 101 (see also FIG. 1), being pinned, or otherwise rigidly secured, thereto. The shaft 101 is suitably journaled in bearings, not shown, in the frame plates 31 and 32. Between the two frame plates, the shaft 101 is formed as a worm gear 121. Fitted on the worm gear 121 is a nut 122 which carries a pointer 123. The pointer 123 is viewable through the window 21 and registers against a scale 124 (see FIG. 1) inside window 21. The pointer 123 has a rearwardly extended bifurcated arm 133 that rides in an annular groove 134 which is formed in the spool 86 that carries the cam follower 85. Hence, rotation of knob 23 not only moves the pointer 123 across the face of scale 124, it also moves the cam follower 85 to the proper cam to provide the desired volume of fluid. It will be recalled that the right end of the shaft 101 carries the locking washer 100 rigidly secured thereto, which washer has a pair of diametrically opposed notches 99 adapted to receive the detent projection 98 on the pump-operating arm 97. When the detent 98 is within one of its registering notches 99, the shaft 101 cannot be turned. However, when the pump is at rest, a button 129 (see FIG. 3) which is mounted in the upper projection 20, can be manually depressed to rock the arm 97 downwardly and remove detent 98 from its registering notch 99. Thus, the setting of the pump can be changed only when the pump is at rest.

It is believed that the operation of the actuating device of this invention will be obvious. Briefly it can be mentioned that the doctor in charge can determine in advance what volume of fluid he desires to pump into the patient. Then, upon depressing the pushbutton 129 and manipulation of the knob 23, the pointer 123 is moved across the scale 124 to the desired position. When the pump is connected to the delivery conduit 14 and the discharge conduit 16 and inserted in the pump, as shown in FIG. 1, the electric switch 22 can be operated to start the pump in operation. According to the setting of the shaft 101 and the pointer 123, the lobes 115 of the cam selected will operate the follower arm 85, the length of its stroke being determined by the

setting of the corresponding set screw 111. The rocking of the follower arm 85 is, of course, transmitted to the square shaft 87 and thence to the arm 86 and from it, through the spacer 90 to arm 97. This arm 97 is gradually depressed to depress the piston 15a of the pump 15 and then is quickly released to permit another stroke of the pump.

It is believed obvious that many modifications can be made in the present invention. For example, I have mentioned the number of lobes on the respective cams, as shown in the table above, and shown settings for the most commonly used volumes. It is obvious, however, that cams with other numbers of lobes could be used, although for economy in manufacturing it is desired to limit the number to a minimum design. It is also believed obvious that the amount of volume per stroke could be adjusted by changing the height of the lobe 115, but again it is preferred to use a uniform height on all cams and to control the length of the stroke by setting the set screws 11 to limit the backstroke of the cam follower as has been described. It is also obvious that the speed reductions can be changed from that shown and described, and the same quantities can be pumped per hour by changing the number of lobes on the respective cams and the length of the stroke per minute. These and other such changes are believed within the scope of the present invention and accordingly an interpretation of the claims should be commensurate with the breadth of the invention.

I claim:

1. An actuator for a detachable piston comprising:
 1. a plurality of axially aligned cam assemblies, the cams of each assembly having a differing number of rises thereon;
 2. means for rotating said cam assemblies at different speeds;
 3. a cam follower movable along an operating shaft parallel to the axis of said cams;
 4. means for causing said follower to follow the contour of the cam to which it is in opposition;
 5. means for moving said cam follower along its operating shaft;
 6. means for adjusting the length of stroke of the follower in each position thereof;
 7. a piston operating member operated by the cam

follower and adapted to operate the pump piston; and

8. detaining means for holding the cam follower in an adjusted axial position.
2. The apparatus of claim 1 comprising also a scale for indicating the position of said follower.
3. The apparatus of claim 1 wherein the cam assemblies are mounted on a common shaft, one of said assemblies being affixed to the shaft and the other of said assemblies being mounted on quill shafts journalled on the common shaft.
4. An actuator for a detachable intravenous feeding pump having a piston extending outside of its casing and resilient means for returning the piston to an inoperative position, said actuator comprising:
 1. a shaft;
 2. a pair of cam assemblies on said shaft, one of said assemblies being affixed to the shaft and the other of said assemblies being mounted on a quill shaft journalled on the shaft, the cams of each assembly having a differing number of lobes on the periphery thereof;
 3. means for rotating said cam assemblies at different speeds;
 4. a cam follower movable along an operating shaft parallel to the shaft;
 5. means for resiliently biasing said cam follower into engagement with said cams;
 6. means for moving said cam follower along its operating shaft;
 7. means for adjusting the length of stroke of the follower in each position thereof;
 8. a piston operating member operated by the cam follower and adapted to operate the pump piston;
 9. locking means for holding the cam follower to an adjusted axial position; and
 10. a pointer and scale for indicating the position of said follower.
5. The apparatus of claim 4 comprising also manual means for operating said piston operating member to an extreme operative position and releasing said locking means.

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