United States Patent [19]

Hahn

[11] **3,884,228**

[45] **May 20, 1975**

[54] **INTRAVENOUS FEEDING SYSTEM**

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[73] Assignee: **The Lynkeus Corporation,** East Hampton, N.Y.

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[52] **U.S. Cl.** .. **128/214 F;** 128/214 E; 128/DIG. 12; 222/59; 222/96; 222/103; 340/239 R

[51] **Int. Cl.** **A61m 05/14**

[58] **Field of Search** ..... 222/59, 95, 96, 103, 214; 340/239 R; 351/51; 128/214 R, 214 E, 214 F, 214.2, DIG. 12, DIG. 13

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Primary Examiner—Dalton L. Truluck

Attorney, Agent, or Firm—Cameron, Kerkam, Sutton, Stowell & Stowell

[57] **ABSTRACT**

A closed intravenous infusion system comprises a completely filled, collapsible bottle of accordion type construction, motor driven means for mechanically compressing the bottle and forcing the intravenous fluid out of the bottle into an administration set, and means for controlling operation of the motor driven means so as to provide a desired feeding rate and to stop the feed when the bottle has been emptied to the desired degree, or in the event of a fluid blockage or other malfunction of the system. The top flange of the bottle is provided with a diaphragm aperture through which drugs may be injected into the intravenous solution, while the lower end or neck of the bottle also contains a diaphragm through which the administration set may be inserted. The bottom flange is also provided with another diaphragm subject to the fluid pressure in the bottle which is operative to stop the feed if the pressure becomes excessive as a result of fluid blockage downstream. The neck of the bottle is made of a special material which passes infrared energy, which is not passed by liquid, and is associated with an infrared source and detector which detect the failure of drops of fluid to appear in the drop chamber during operation of the system and thereupon produce an alarm.

12 Claims, 12 Drawing Figures

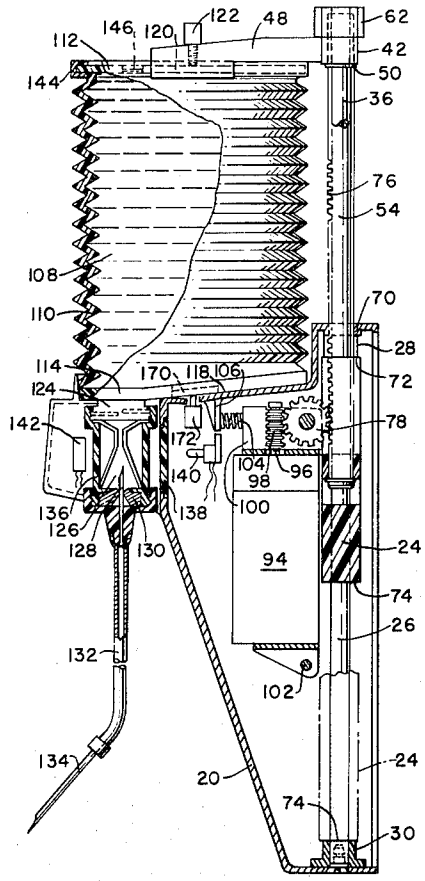

FIG. 1.

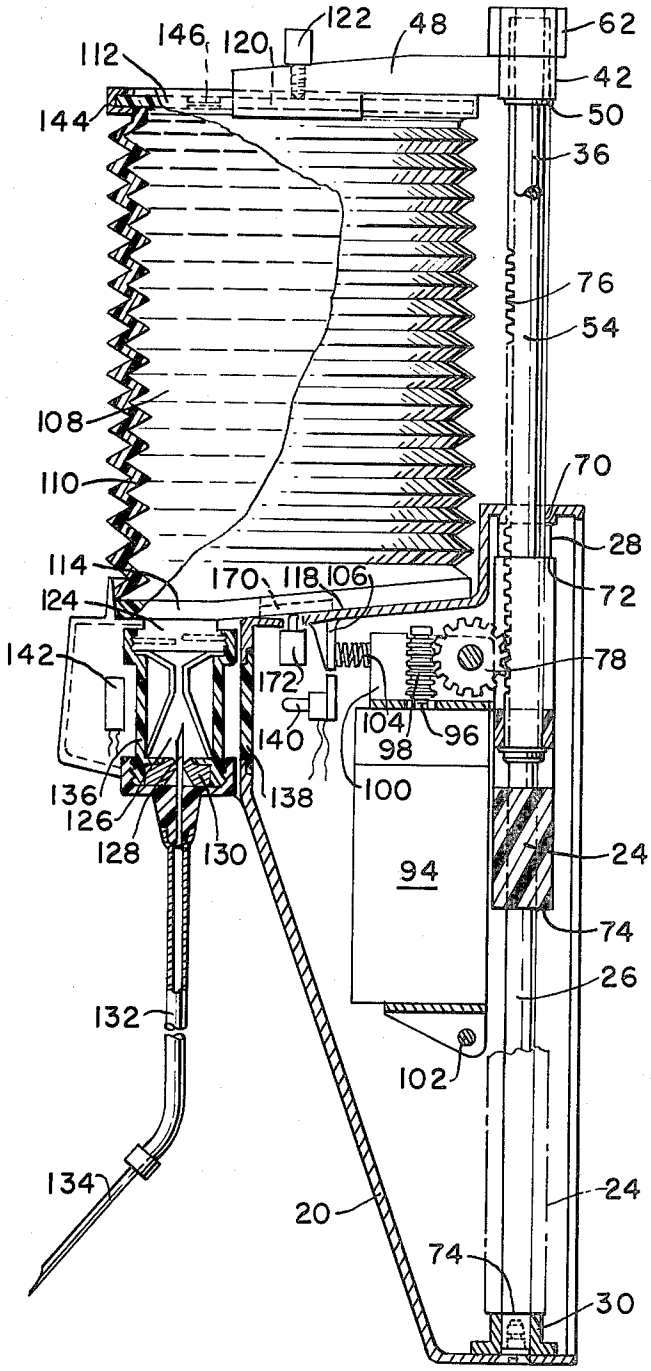
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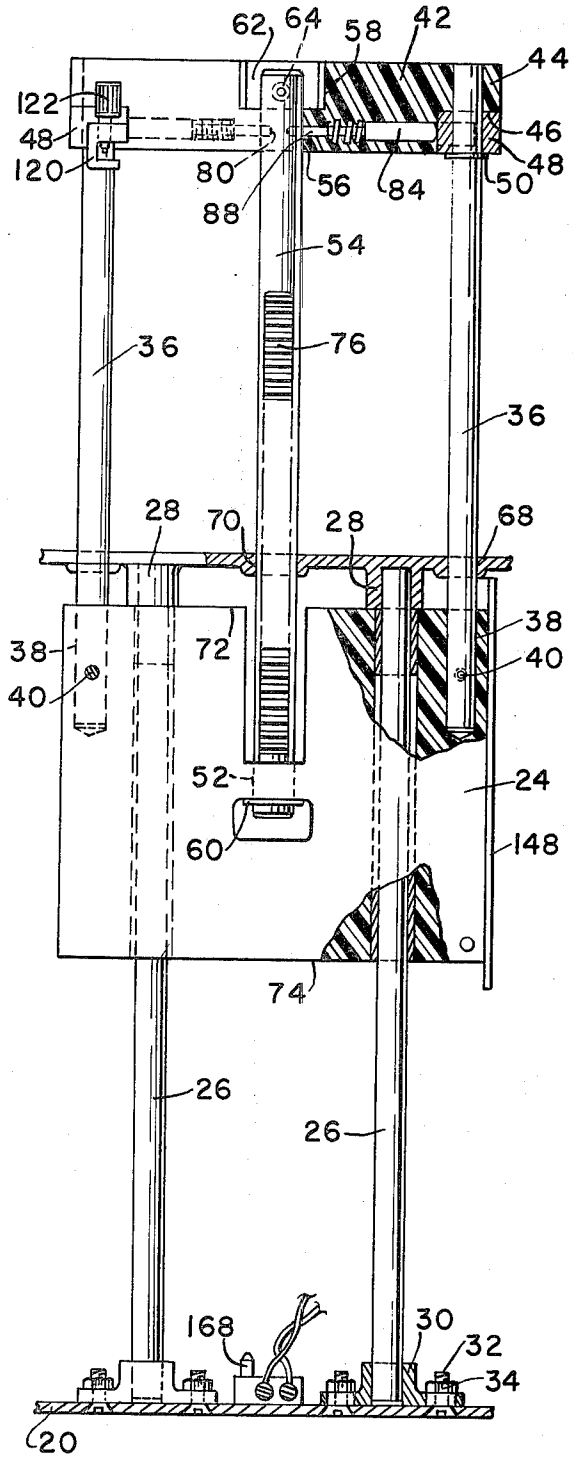
FIG. 2.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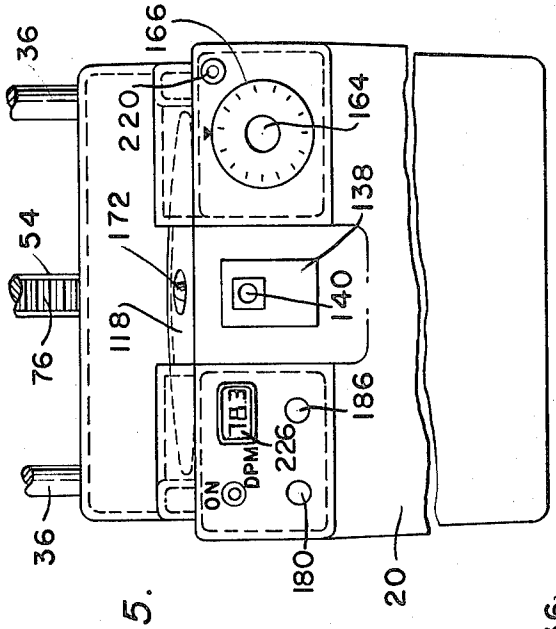


FIG. 5.

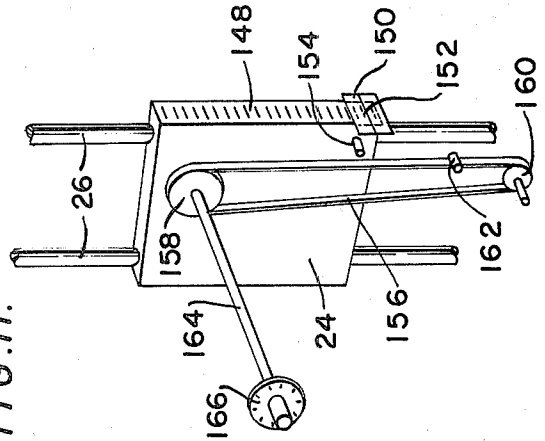


FIG. 11.

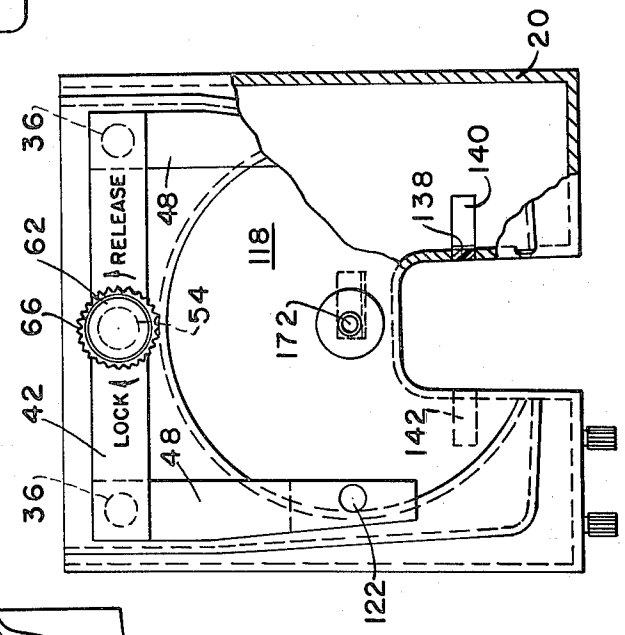


FIG. 4.

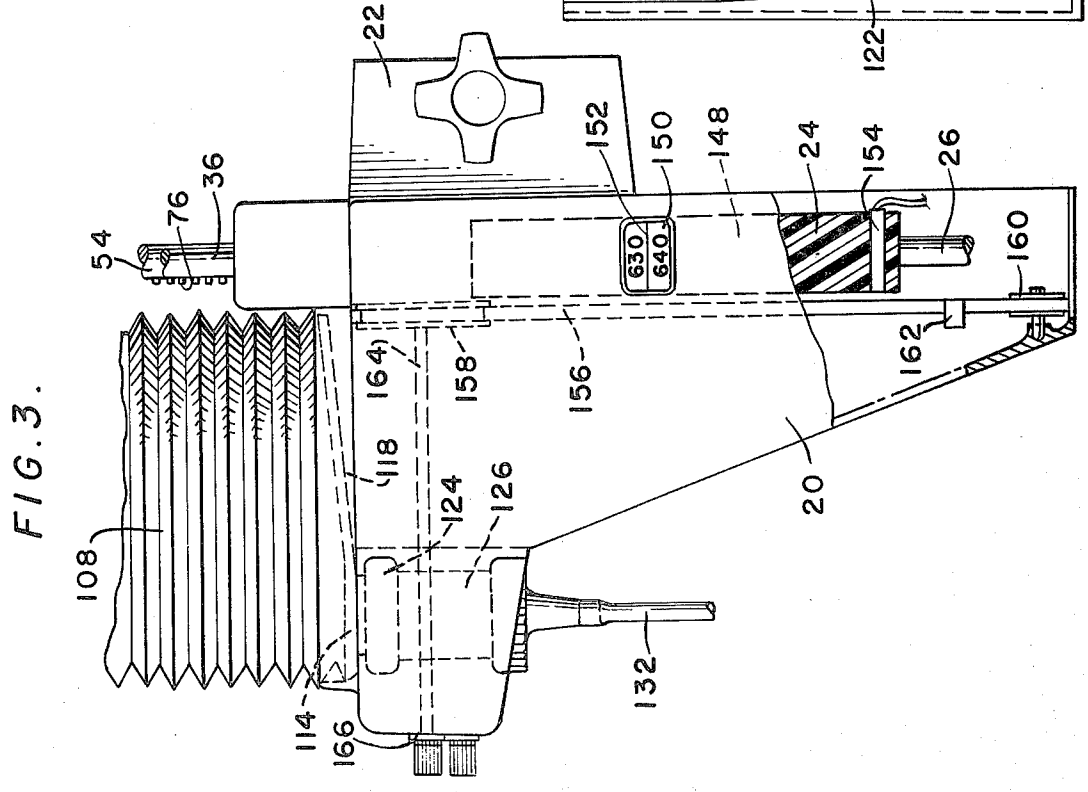


FIG. 3.

FIG. 6.

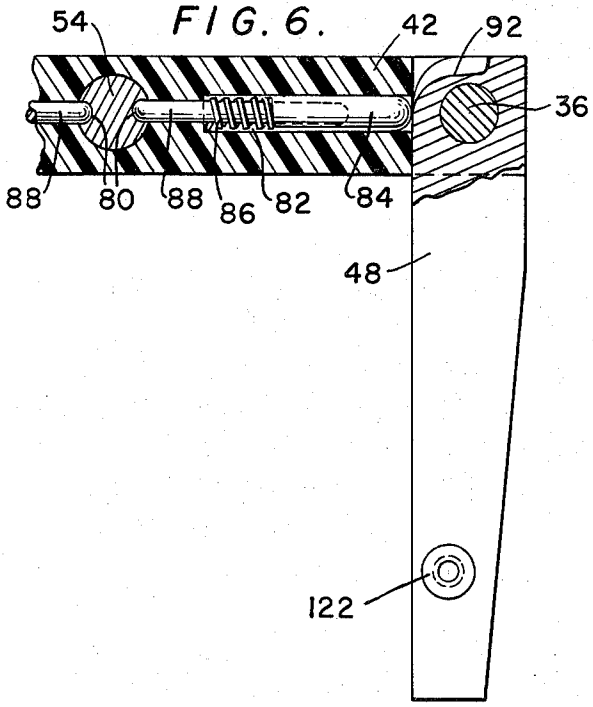


FIG. 7.

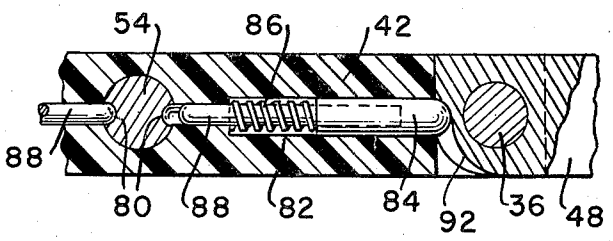


FIG. 8.

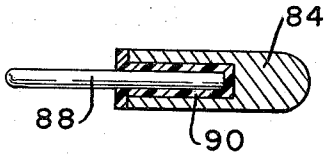


FIG. 9.

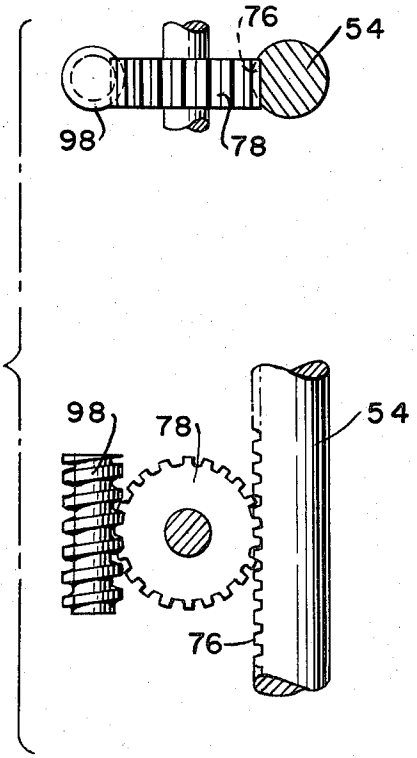


FIG. 10.

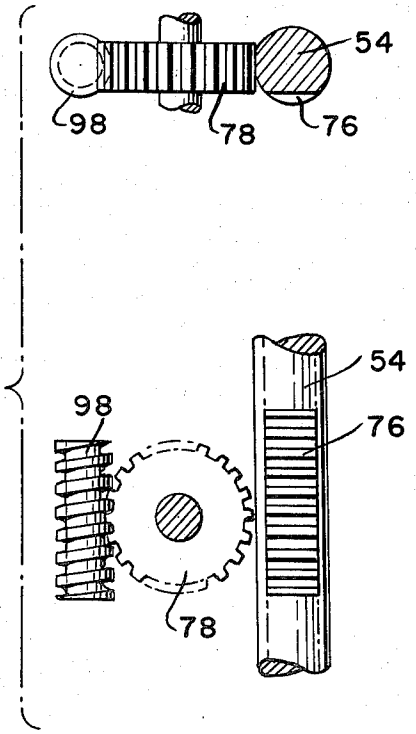
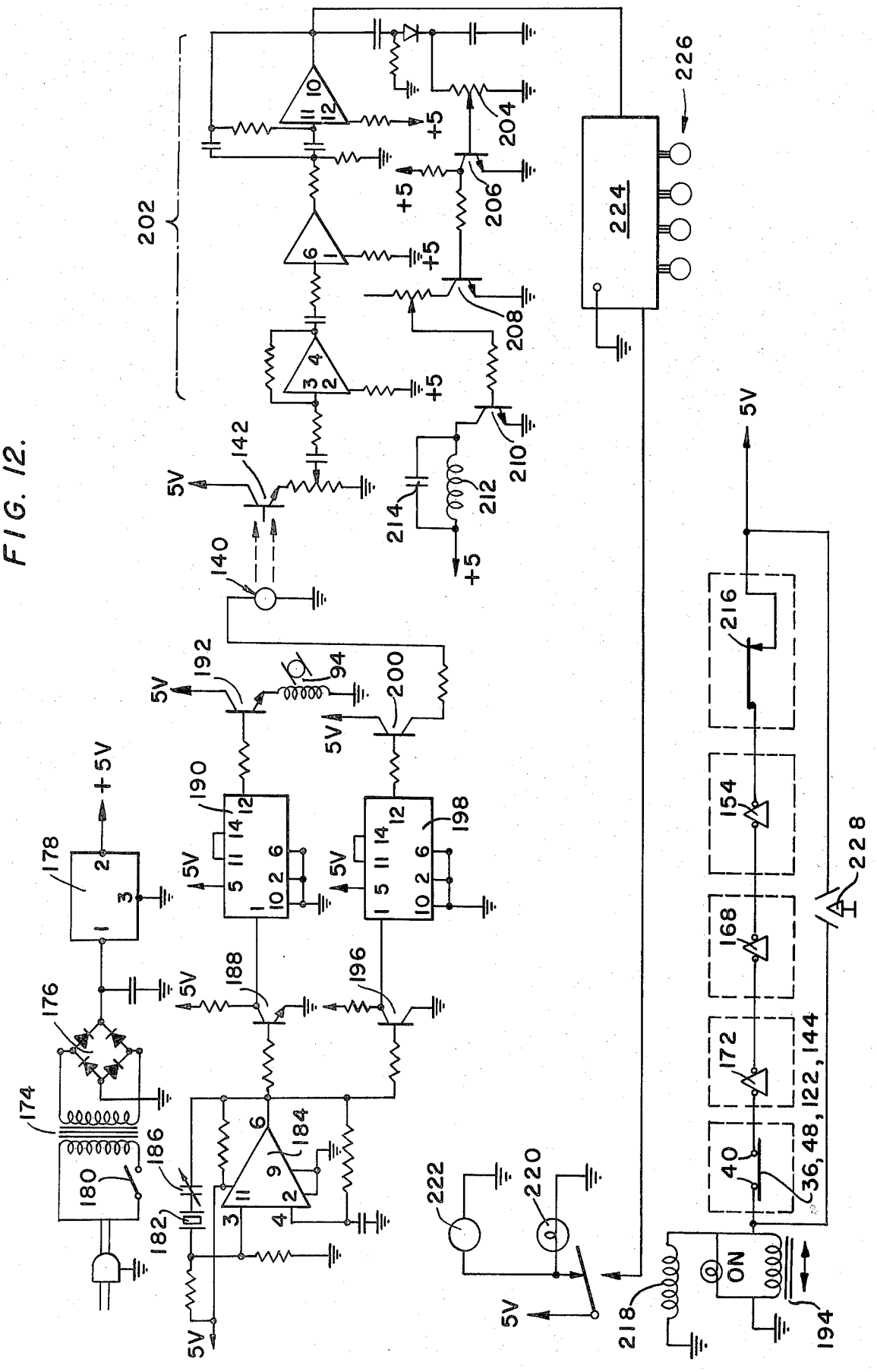


FIG. 12.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INTRAVENOUS FEEDING SYSTEM

This invention relates to systems for the intravenous feeding to patients of fluids such as blood, saline and sugar solutions. and is particularly directed to an improved apparatus for positively forcing the fluid into the administration set at a predetermined rate and automatically stopping the feed when the bottle has been emptied to a predetermined amount, or if the fluid pressure becomes excessive as a result of a fluid blockage downstream, or in the event of some other malfunction of the system. The apparatus also energizes an alarm when the feeding is stopped, or when the disappearance of fluid drops in the drop chamber is detected.

The conventional intravenous feeding system consists of a glass bottle containing the solution, an administration set which usually comprises a drop chamber and a rudimentary valve to control flow, and a catheter which is inserted into the patient. In a majority of cases, these prior systems are gravity fed, although in some instances some sort of pump, usually peristaltic or hypodermic, may be employed. A number of problems arise in use of the traditional intravenous feeding systems, including variations in the desired feed rate as a result of plastic deformation and bottle head pressure changes. Furthermore, such systems usually do not include monitoring features which inform the nursing staff when a bottle is empty, or when a pronounced deviation has taken place from a preset feed rate.

A number of devices have been developed for improving the performance of these prior systems, including that disclosed in the application of Steven Hahn et al., Ser. No. 350,922, filed Apr. 13, 1973. Other existing systems for feeding intravenous fluid from a closed container by compressing the container, including devices for controlling feed rates, and for stopping the feed when the container is empty or when the fluid pressure therein exceeds a predetermined amount, are shown in such patents as Cherkin, U.S. Pat. No. 2,761,445 and Adelberg, U.S. Pat. No. 3,640,277.

The device of the present invention is an improved intravenous feeding system which operates on the force feed principle and comprises a completely filled, collapsible bottle of accordion type construction, motor driven means for mechanically compressing the bottle and forcing the intravenous fluid out of the bottle into an administration set, and means for controlling operation of the motor driven means so as to provide a selected feeding rate, and to stop the feed, and to sound an alarm, when the bottle has been emptied to a predetermined extent, or in the event of a fluid blockage downstream or other malfunction of the system. The top flange of the bottle is provided with a diaphragm aperture through which drugs may be injected into the intravenous solution, and the lower end or neck of the bottle also contains a diaphragm through which the administration set may be inserted. The bottom flange is provided with another diaphragm subject to the fluid pressure in the bottle which is operative to stop the feed if the pressure becomes excessive. The neck of the bottle includes a window made of a material which passes infrared wavelengths, and is associated with an infrared source and detector which detect the absence of fluid drops in the drop chamber and sound an alarm if this condition occurs.

The feed control system includes a housing containing a carriage mounted on two parallel guide rods so as to move freely in a vertical path; a drive rack attached at its lower end to the carriage and to a guide bar at its upper end; two parallel connecting rods similarly attached to both the carriage and the guide bar; two rotatable contact arms attached to and pivotable about the upper ends of the connecting rods and adapted to be detachably connected to the top flange of the bottle; and an electric motor and associated driving means for pulling the drive rack downwardly when the system is in operation, the speed of which motor is accurately controlled dependent upon the setting of a feed rate member forming part of the contrl system. The top flange of the bottle is provided with a conductive metal rim which constitutes part of a series circuit which must be completed through the contact arms and connecting rods before the motor is operative to pull the drive rack downwardly and collapse the bottle.

Referring now to the drawings, wherein like reference characters indicate like parts throughout the several views:

FIG. **1** is a side view, partially in section, of an intravenous feeding system constituting one embodiment of the present invention;

FIG. **2** is a front view, partially in section, of the apparatus of FIG. **1** with the intravenous fluid bottle (hereinafter referred to as the IV bottle) and other parts omitted in the interest of clarity;

FIG. **3** is a partial side view of the housing of the system showing the reserve solution scale and window, and partially broken away to show components of the feed limit control;

FIG. **4** is a top view of the system housing with the IV bottle omitted, showing the guide bar and contact arms, and partially broken away to illustrate the drop detection means.

FIG. **5** is a partial front view of the housing with the IV bottle omitted, showing the system controls;

FIG. **6** is a fragmentary top view, partially in section, of the guide bar and contact arm assembly in closed position;

FIG. **7** is a view similar to FIG. **6** showing the guide bar and contact arm assembly in open position;

FIG. **8** is a detailed view of one of the lock pins carried by the guide bar;

FIGS. **9** and **10** are schematic representations of the drive rack and motor driven worm and driving gear elements in engaged and disengaged positions, respectively;

FIG. **11** is a perspective view of the feed limit control mechanism and the reserve solution scale and window relative to the carriage; and

FIG. **12** is a diagram of the electronic circuitry of the intravenous feeding system illustrated in FIGS. **1–11.**

With reference to FIGS. **1–5,** the intravenous feeding system of the present invention comprises a housing **20** of any suitable material which contains and supports all of the mechanical and electronic components of the system and serves as a base on which an IV bottle is mounted when the system is in operation. As shown in FIG. **3,** housing **20** is provided with a clamping member **22** by which the housing may be detachably connected to an ordinary IV bottle standard or any other support adjacent the bedside of a patient.

Inside the housing **20** a carriage **24,** fabricated of electrically non-conductive plastic, is mounted on a

pair of vertically extending carriage guide rods **26**, the upper ends of which are attached to bosses **28** integrally molded with the top wall of housing **20** and having their bottom ends attached to sockets **30** which are adjustably connected to the bottom wall of the housing by means of screws **32** and nuts **34** to permit alignment of the guide rods. A pair of vertically extending, electrically conductive connecting rods **36** are pressed at their lower ends into recesses **38** in carriage **24** and are fixed thereto by contact screws **40** which also form part of the electronic circuit hereinafter described. Mounted on the upper ends of connecting rods **36** is a horizontal guide bar **42**, also formed of electrically non-conductive plastic, having openings **44** into which the upper ends of connecting rods **36** are pressed, the guide bar thus extending transversely between and rigidly interconnecting the upper ends of the connecting rods. The underside of guide bar **42** is provided at each end with a recess **46** receiving the inner end of a movable contact arm **48** which is mounted on and free to pivot about connecting rod **36** and is held in position on the latter by means of a retaining ring **50**.

Mounted in a sleeve **52** in carriage **24** and extending upwardly in the same vertical plane as connecting rods **36**, equally spaced from the latter, is a drive rack **54**, the upper end of which passes through a sleeve **56** in the central portion of guide bar **42** and into a recess **58** formed in the upper surface of the guide bar. Drive rack **54** is freely rotatable about its longitudinal axis, but it is restrained from longitudinal axial movement relative to carriage **24** and guide bar **42** by a retaining ring **60** beneath sleeve **52** at its lower end and by a knob **62** secured to its upper end by a set screw **64**. As will be seen in FIG. **4**, the knob **62** has a knurled edge **66** of a diameter greater than the width of guide bar **42** so that it may be manually turned and thereby rotate the drive rack **54** about its longitudinal axis for a purpose hereinafter described.

As shown in FIG. **2**, the connecting rods **36** and the drive rack **54** pass freely through openings **68** for the guide rods and opening **70** for the drive rack, these openings being formed in the top wall of housing **20**, so that in the uppermost position of the carriage **24** the top surface **72** thereof abuts against the bottom ends of bosses **28**, while in its lowermost position the bottom surface **74** of the carriage bears against the tops of sockets **30**.

Drive rack **54** is a cylindrical steel rod with gear teeth **76** machined in a plane parallel to the rod axis and tangent to its circumference, and to a depth proportionate to the standard gear pitch selected for mating with the worm gear **78** (FIG. **1**) of the motorized rack driving assembly later to be described. The upper end of drive rack **54** which passes through guide bar **42** beneath the recess **58** is provided with two transverse blind holes **80** (FIG. **2**) extending parallel to the plane of the gear teeth **76**. As shown in detail in FIGS. **6–8**, the lower portion of guide bar **42** between recesses **46** is provided with a pair of horizontally extending stepped recesses **82** in which are mounted lock pin assemblies each consisting of a cam follower portion **84** which is urged outwardly of recess **82** by a spring **86** interposed between the inner end of the cam follower portion and the shoulder of recess **82**, and a pin **88** having a forced fit in cam follower portion **84** and a rounded end adapted to extend into one of the blind holes **80** in the drive rack when the rack is in the position illustrated in FIG. **2**. In order to avoid a short circuit in the safety circuit hereinafter described, a sleeve **90** (FIG. **8**) of insulating material is interposed between the outer end of each pin **88** and the recess in cam follower **84**. The inner or pivoted end of each contact arm **48** is provided with a cam surface **92** against which cam follower **84** is maintained by spring **86**, so that when the drive rack and the contact arm are in the positions illustrated in FIGS. **2** and **6**, respectively, the associated pin **88** is forced into one of the blind holes **80** in the drive rack. The drive rack is then fixed to guide bar **42** against rotation by knob **62** with its gear teeth **76** in messh with worm gear **78**.

Turning now to FIG. **1**, the mechanism for pulling the drive rack **54** downwardly, carrying with it the connecting rods **36**, guide bar **42** and contact arms **48**, comprises a driving motor **94** having a shaft **96** connected to a worm **98** which extends upwardly into engagement with the worm gear **78**, the latter having its horizontal shaft journaled in a bracket **100** on top of the motor casing. The motor **94** is connected to shaft **96** through a solenoid operated clutch (not shown in FIG. **1**), and is pivoted at its lower end on a horizontal shaft **102** carried by the housing **20** so that worm gear **78** may be yieldably urged toward driving engagement with the gear teeth **76** of drive rack **54** by means of a spring **104** interposed between bracket **100** and a stop **106** carried by the housing **20**. With the parts positioned as shown in FIGS. **1** and **2** and the motor clutch engaged, motor **94** causes rotation of worm **98** and worm gear **78**, and rotation of the latter is converted into linear downward movement of drive rack **54**.

In order to disengage the drive rack **54** from worm gear **78**, contact arms **48** are moved manually outwardly about their pivots on connecting rods **36** to the position indicated in FIG. **7**, at which time the cam follower portions **84** of the lock pin assemblies will be urged by springs **86** outwardly against the receding portions of cam surfaces **92** and the pins **88** will be withdrawn from the blind holes **80** in the drive rack. Drive rack **54** may then be rotated by means of knob **62** through an arc of 90° or more, and thus cause gear teeth **76** to disengage worm gear **78**. The subassembly comprising guide bar **42**, connecting rods **36**, drive rack **54** and contact arms **48** may then be moved vertically by manual force applied to either the guide bar or the contact arms so as to position the subassembly, including carriage **24**, at any point within the limits of its vertical travel range. When the subassembly has been moved upwardly or downwardly to the desired position, drive rack **54** is rotated by knob **62** into the position illustrated in FIGS. **1** and **2**, whereupon the gear teeth **76** are again in engagement with worm gear **78**. Contact arms **48** are then pivoted to the closed position illustrated in FIGS. **1**, **2** and **6** so that the locking pins **88** again enter the blind holes **80** in the drive rack, whereupon the subassembly is held in its set position against the force of gravity.

The apparatus is now ready to receive the IV bottle **108** which, as shown in FIGS. **1** and **3**, is of cylindrical accordion pleated, collapsible construction, made of any suitable plastic material, including biodegradable material, and having a relatively thin side wall **110**, a relatively rigid top flange **112**, and a relatively rigid bottom flange **114** providing a base adapted to rest on and to be supported by a slanting platform **118** forming part of the top wall of housing **20**.

After the subassembly comprising drive rack 54 and the associated elements previously mentioned has been raised to the proper height, and the drive rack has been rotated to the engaged position, the IV bottle 108 is placed on platform 118, contact arms 48 are moved to their closed position, and the outer ends thereof are fixed to the top flange 112 of the bottle by means of channel shaped, flange-embracing clasps 120 and lock screws 122. If the motor clutch is now engaged, worm gear 78 will exert a downward pull on drive rack 54 and, through guide bar 42 and contact arms 48, force the top flange of bottle 108 downwardly so as to compress the bottle and force the IV fluid through the neck 124 thereof into a drop chamber 126 which is threaded onto the neck 124. The lower end of drop chamber 126 is externally threaded to receive the upper end of an administration set having a hollow needle 128 adapted to pierce a diaphragm 130 carried by the lower drop chamber 126. The administration set also includes a length of flexible tubing 132 to the end of which is attached a conventional catheter 134 adapted to be inserted in a vein of the patient to be fed intravenously.

The cylindrical wall 136 of the drop chamber is formed of an optically clear plastic material, such as Plexiglass or Lucite, which passes infrared light, and is positioned adjacent a window 138 of similar material forming part of housing 20 behind which, within the housing, is located a source of infrared light 140. At the side of drop chamber wall 136 opposite the window 138, diametrically opposite the infrared source 140, is an infrared detector 142 which forms part of the electronic circuitry of the system later to be described with reference to FIG. 12. For convenience of illustration, window 138, infrared source 140 and detector 142 are shown in FIGs. 1 and 5 at positions 90° from their actual positions indicated in FIG. 4.

In order to prevent premature engagement of the clutch of rack drive motor 94 when the rack 54 is in mesh with worm gear 78, a safety interlock is provided as an integral part of the system. As previously indicated, the carriage 24 and guide bar 42 are made of an electrically non-conductive plastic material, while connecting rods 36 and contact arms 48 are metallic and electrically conductive. The top flange 112 of IV bottle 108 is provided with a metallic, electrically conductive collar or rim 144 so that, when the metallic lock screws 122 of the flange embracing clasps 120 of contact arms 48 are tightened against the metal collar 144, a conductive path is established starting at contact screw 40 on the left (in FIG. 2) connecting rod 36, through left connecting rod 36, left contact arm 48 and its lock screw 122, through metal collar 144 to right lock screw 122, right contact arm 48, right connecting rod 36 and ending at the latter's contact screw 40. As will later appear from FIG. 12, unless the conductive path thus described is closed, motor 94 cannot drive rack 54. At the same time, the insulating sleeves 90 (FIG. 8) of the lock pin assemblies prevent the establishment of a parallel electrical path to the metal ring 144 via the drive rack 54, the blind holes 80 and the lock pin assemblies. Consequently, no electrical continuity is established unless the IV bottle 108 is in properly clamped position.

The IV bottle 108 is completely filled with intravenous fluid, either by the solution manufacturer or at the hospital, and does not contain any air relief valves. However, the top flange 112 of the bottle is provided with a small neoprene diaphragm 146 through which a physician or nurse may hypodermically inject drugs which are to be administered to the patient in addition to the intravenous solution. In order to indicate the volumetric condition of the IV bottle when the system is in operation, a calibrated scale 148 is adhesively bonded to one side of carriage 24, and a window 150 having an index line 152 is provided in housing 20 through which the scale 148 is visible, as shown in FIGS. 2, 3 and 11. Motion of the carriage 24 and the scale 148 can be observed through the window 150, and the calibration numbers on the scale can be read against the index line 152 to give a quantitative indication of the volumetric condition of, or the amount of reserve solution remaining in, the IV bottle.

Means are also provided for presetting the amount of solution to be dispensed and automatically stopping the downward movement of carriage 24 when the preset amount of solution has been forced out of the IV bottle. As shown best in FIG. 11, carriage 24 is provided with a reed switch 154 which, when closed, produces an electrical signal which declutches motor 94 from rack driving worm 98 and thus stops downward movement of carriage 24. Mounted adjacent the path of movement of carriage 24 is a belt 156, carried by a drive pulley 158 and a spring-loaded idler pulley 160, and fixed to the belt 156 is a magnet 162. Drive pulley 158 is mounted on a shaft 164 which extends horizontally outward of the housing 20 and is provided at its outer end with a feed limit control dial 166 calibrated to indicate the amount of intravenous solution which it is desired to dispense when the system is activated (see FIG. 5). Rotation of dial 166, transferred by shaft 164 to drive pulley 158, causes the belt 156 to move linearly between the pulleys 158 and 160 so as to move the magnet 162 to a predetermined position parallel to the path of reed switch 154 as the latter moves with carriage 24. When the reed switch comes into alignment with magnet 162, the switch is activated to stop downward movement of carriage 24 at the preset point representative of the desired volumn of intravenous solution to be dispensed. In order to signal when the IV bottle is empty, a normally closed limit switch 168 (FIG. 2) is mounted on the bottom wall of housing 20 beneath the carriage 24 and is opened by the latter when it reaches the lower end of its path of movement.

Means are also provided for producing a signal and declutching rack driving motor 94 in the event that an obstruction or blockage to the flow of intravenous fluid occurs downstream of the bottle which increases the fluid pressure within the bottle. To this end, as indicated in FIGs. 1 and 4, the bottom flange 114 of IV bottle 108 is provided with a relatively thin, pressure sensitive diaphragm 170 which overlies and engages the plunger of a normally closed, pressure actuated switch 172 carried by the platform 118 of housing 20. When the fluid pressure in bottle 108 increases above a predetermined amount, switch 172 is opened by downward movement of diaphragm 170. Like reed switch 154 and limit switch 168, switch 172 is located in the energising circuit of a solenoid which controls a clutch between the motor 94 and its rack driving worm 98. When any of switches 154, 168 and 172 opens, power is removed from the clutch operating solenoid, the motor 94 is disconnected from the worm 98 and the downward movement of drive rack 54 stops. The electronic circuitry of the motor 94 and its solenoid oper-

ated clutch will be described in detail hereinafter with reference to FIG. 12.

Referring now to FIG. 12, the electronic circuitry of the intravenous feeding system of the present invention includes a DC power supply having a transformer 174, a bridge rectifier 176 and an integrated circuit 5 volt regulator 176 which furnishes the regulated DC voltage for operating the system. A push-button switch 180 in the primary circuit of transformer 174 constitutes the system on/off switch.

The system also includes a 100 KC crystal oscillator 182 and an associated integrated circuit 184, the frequency of the oscillator being controlled by a feed rate control variable capacitor 186. The output of oscillator 182 is fed to an integrated circuit down divider and buffer amplifier 188, 190, 192 which divides the 100 KC clock frequency (which is variable over a narrow range by the setting of the feed rate control capacitor 186) down to 60 cycles which is again variable in direct proportion to the frequency variation of the basic oscillator 182. The 60 cycle signal produced by down divider 190 is fed to the power amplifier 192 from which it is applied to the 60 cycle synchronous motor 94, the motor which pulls down the drive rack 54 and thereby empties the IV bottle 108 at a rate depending upon the frequency which is applied across the motor. This frequency can be made to vary between 50 and 70 cycles by varying the clock frequency of the 100 KC crystal oscillator 182, thereby causing the motor 94 to speed up or slow down. The motor 94 runs continuously as long as the on/off switch 180 is closed, but is connected to the rack driving worm 98 (FIG. 1) by a solenoid operated clutch 194 (FIG. 12), the functioning of which is hereinafter described.

At the same time that the clock oscillator 182 is running at approximately 100 KC, the output signal of the associated integrated circuit 184 is fed through another series of buffer amplifiers and down dividers 196, 198, 200 which take the variable 100 KC signal and divide it down to 10 KC through the down divider 198, the output of which is fed to the power amplifier 200 which in turn drives the infrared light emitting diode 140. As shown in FIG. 1, the infrared diode 140 is located in housing 20 and shines its narrow 10 KC beam through the window 138 and the drop chamber 126 of the IV bottle 108 onto the phototransistor or infrared detector 142. The detector 142 will thus see a 10 KC signal whenever the path between it and the diode 140 is open. However, when a drop of the intravenous solution interrupts the beam, the 10 KC signal will be removed while the drop is in the path of the beam. Consequently, the higher the drop rate, the shorter will be the period during which the 10 KC signal will appear between drops.

The output of infrared detector 142 is fed to a narrow band-pass amplifier consisting of three stages on an integrated circuit chip 202. The output of band-pass amplifier 202 is fed through a sensitivity control element 204 to a three stage transistor amplifier 206, 208, 210, the last stage 210 terminating in a relay circuit 212 across which a capacitor 214 is placed. As long as a 10 KC signal is received from the infrared transmitter 140 by the detector 142, a signal will appear through the band-pass filter 202 into the amplifier circuitry 206, 208, 210, the relay 212 will be energized and its contacts, shown at 216, will remain closed. As soon as the infrared beam disappears, the amplifier 206, 208, 210 will open the relay 212. However, the relay will not open immediately because the charged capacitor 214 will tend to hold it closed for from 5 to 10 seconds. The circuit will thus detect the absence of a 10 KC signal for periods of time exceeding approximately ten seconds, but will disregard absence of the infrared beam caused by drops passing through the beam which is only a brief phenomenon. Accordingly, when the feed bottle 108 is empty and drops fail to appear in drop chamber 126, or when some other malfunction has taken place causing a disappearance of drops, opening of the contacts 216 will deenergize clutch 194 and thereby stop the movement of drive rack 54, and also deenergize an alarm relay 218, the coil of which is connected in parallel with the winding of clutch 194. When this occurs, an alarm or warning condition exists which is brought to the attention of the nurce by means of a signal light 220 and an audible signal member 222, such as a buzzer.

In addition to feeding the alarm circuit, the band-pass amplifier 202 also feeds to a digital counter system 224 the clock signal which is interrupted by the drop rate. The digital counter 224 counts the number of cycles between each two drops and displays this count on a four digit display 226. For example, assume that the drop chamber of the IV bottle 108 generates a drop every second, which means that the 10 KC signal is present for 1 second, then interrupted by a drop is then present another second, then interrupted by another drop, etc. This means that the input signal to counter 224 occurs at the rate of 10 KC. If drops should occur every half second, this rate would be decreased to 5 KC, while if drops should occur every 2 seconds, the rate would be increased to 20 KC. The integrated circuit of counter 224 receives this information and converts it into an actual drop rate or feed rate display with the drop passing through the beam acting as a reset signal. Consequently, the display 226 will continuously show the feed rate as it actually appears in the drop chamber. The actual feed rate is controlled through the synchronous motor 94 which pulls down the IV bottle 108 at a rate determined by the clock crystal oscillator 182 and its associated feed rate control 186.

As previously mentioned, the rack driving or feeding motor 94 is always running when the on/off switch 180 is closed. However, since the motor 94 is connected to the rack driving worm 98 through the solenoid operated clutch 194, the clutch must be energized before the drive rack 54 can be actuated, even though the motor 94 is running. But before the clutch can be energized, a number of conditions must exist.

First, as previously described, the IV bottle contains a continuity circuit indicated at 40, 36, 48, 122, 144, 40 in FIG. 12. As long as there is no IV bottle in the system, or if the bottle is not properly clamped in position, the continuity circuit is open and the clutch 194 will not be energized, Second, the system also contains the internal pressure sensing switch 172, operated by the diaphragm 170 in the bottom flange of the IV bottle, which switch is normally closed and opens when the diaphragm is moved downwardly as a result of excessive pressure in the bottle due to blockage or some other malfuntion down in the catheter 134. As soon as pressure switch 172 opens, power is removed from the solenoid of clutch 194 and the feeding action stops. Third, the system also contains the normally closed limit switch 168 which, when the carriage 24 reaches the

limit of its downward movement and the IV bottle is fully compressed, opens and again deenergizes the solenoid of clutch **124.** Fourth, the system also includes a partial feed control, comprising the reed switch **154** and magnet **162,** which permits the nurse to feed only a fraction of the contents of the IV bottle. The reed switch is normally closed, but when it passes the magnet **162** in the latter's adjusted position, corresponding to the portion of the bottle which it is desired to dispense, the switch will open and once again cause the feeding action to stop. As previously mentioned, the normally closed contacts **216** of relay **212** also open and deenergize the clutch **194** when drops of the intravenous fluid fail to appear in the drop chamber **126.** A series of safety devices are thus built into the system, all of which embody switches in the energizing circuit of clutch **194** which must be closed before the clutch can be energized so as to couple the feed motor **94** to the rack driving mechanism.

Alarm relay **218,** in addition to producing a warning signal in the case of a malfunction of the system, also serves another function. In the energized state, this relay feeds the necessary positive DC power to the digital counter system **224** and its associated display **226.** Since the relay **218** is energized only when the feeding system is in operation, the display will appear only under normal operating conditions. If a malfunction occurs, deenergization of relay **218** will also take DC power off the counter and display system so that no display is visible when an alarm condition occurs.

When first putting the IV bottle into the system, it will be necessary to purge the system. For this purpose, a normally open, manually actuated purge switch **228** is connected in parallel with the fault detection circuits and, when closed, permits the nurse to start feeding the intravenous fluid and watch for the drops emanating from the needle of catheter **134.** Once the drop operation has been established, involving only a few seconds, the purge switch **228** can be released, whereupon normal operation of the system will commence.

There is thus provided by the present invention an improved intravenous feeding system which operates on the force feed principle and will automatically feed preset quantities of fluid to a patient at any desired feed rate. The system is adapted to use completely filled, collapsible IV bottles of accordion type construction having transparent drop chambers adapted to be associated with means which detect the absence of fluid drops in the drop chamber and produce an alarm if this condition occurs. The system also includes sophisticated electronic circuitry which accurately controls and indicates the feed rate, and incorporates safety devices which stop the feed and provide an alarm in the event of a malfunction of the system.

Although only one embodiment of the feeding system has been described and illustrated in the accompanying drawings, it will be understood that various changes in the mechanical and electronic elements of the system, which will be obvious to those skilled in the art, may be made without departing from the inventive concept. Reference should therefore be had to the appended claims for a definition of the scope of the invention.

What is claimed is:

1. A closed intravenous feeding system comprising a feed container of collapsible fluid-tight construction adapted to be completely filled with fluid to be intravenously administered to a patient, an administration set detachably connected to said container, means for mechanically compressing said container and thereby forcing fluid out of the container into said administration set, means for controlling the rate of compression of said container and thereby controlling the rate of feed of fluid to the administration set, means for disabling said compression means and stopping compression of said container when the pressure of the fluid therein rises above a predetermined value, means for disabling said compressing means when said container has been emptied to a predetermined extent, means for producing an alarm signal when said compressing means becomes disabled, a drop chamber between said administration set and the lower end of said container, means for detecting the presence of fluid drops in said drop chamber, means for producing an alarm signal when drops fail to appear within said chamber during a predetermined period of time, said container being of accordian construction having upper and lower flanges, and said compressing means including a pair of vertically extending rods offset from said container, means for detachably connecting the upper ends of said rods to the upper flange of said container, and means including an electric motor and a solenoid operated clutch for positively moving said rods downwardly at a predetermined speed.

2. A closed intravenous feeding system as defined in claim **1** wherein said rods and said connecting means are electrically conductive, and the energizing circuit of said clutch includes said rods, said connecting means and an electrical circuit in said upper flange adapted to be closed by said connecting means.

3. A closed intravenous feeding system as defined in claim **1** including a stationary support for the lower flange of said container, a pressure sensing diaphragm in said lower flange, and a normally closed pressure actuated switch carried by said support positioned beneath and in contact with said diaphragm, said switch being operable to open the energizing circuit of said clutch and thereby disable said compressing means when the pressure in said container sensed by said diaphragm exceeds a predetermined amount.

4. A closed intravenous feeding system as defined in claim **1** wherein said connecting means includes a horizontal bar connecting the upper ends of said rods, and wherein said means for moving said rods downwardly includes a vertically extending toothed rack having its upper end connected to said bar, and gearing driven by said motor for engaging said rack.

5. A closed intravenous feeding system as defined in claim **4** wherein said rack is rotatable about its longitudinal axis to move the teeth thereof into and out of engagement with said gearing.

6. A closed intravenous feeding system as defined in claim **1** including means for varying the speed of said motor and thereby varying the rate at which fluid is fed to said administration set.

7. A closed intravenous feeding system as defined in claim **1** including an electric circuit for energizing said solenoid operated clutch, said circuit having a plurality of switches connected in series all of which must be closed in order to energize said clutch, and means for selectively opening one of said switches in the event of a malfunction of the system.

8. a closed intravenous feeding system as defined in claim **1** including an electric circuit for energizing said solenoid operated clutch, said circuit having a plurality

of switches connected in series all of which must be closed in order to energize said clutch, and means for opening one of said switches when the fluid pressure in said container exceeds a predetermined mount.

9. A closed intravenous feeding system as defined in claim **1** including an electric circuit for energizing said solenoid operated clutch, said circuit having a plurality of switches connected in series all of which must be closed in order to energize said clutch, and means for opening one of said switches when said container has been emptied to a predetermined extent.

10. In a closed intravenous feeding system for use with an airtight feed container of collapsible construction adapted to be completely filled with fluid to be intravenously administered to a patient, said container having upper and lower flanges, a flexible wall connecting said flanges and an administration set connected to the lower end thereof, means for mechanically compressing said container and thereby forcing fluid out of the container into said administration set comprising a support for the lower flange of said container, a pair of vertically extending connecting rods offset laterally from said support, a pair of arms pivotally mounted on the upper ends of said connecting rods for movement in a horizontal plane toward and away from the upper flange of said container when the latter is mounted on said support, means carried by said arms for releasably engaging the upper flange of said container, and means for positively moving said rods downwardly including a vertically extending toothed rack connected to said connecting rods, an electric motor and gearing driven by said motor for engaging and driving said rack.

11. In a closed intravenous feeding system, the combination defined in claim **10** including a solenoid operated clutch for drivingly connecting said motor to said gearing, and wherein said connecting rods and said arms are electrically conductive, and the energizing circuit of said clutch includes said rods, said arms and means carried by the upper flange of said container for forming a conductive path between said arms when the latter are in engagement with said flange.

12. In a closed intravenous feeding system, the combination defined in claim **10** wherein said toothed rack is rotatable about its longitudinal axis to move the teeth thereof into and out of engagement with said gearing.

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