

- [54] **APPARATUS FOR MONITORING THE DISPENSING OF LIQUID**
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3,464,438 9/1969 Maurer 137/487.5

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[57] **ABSTRACT**

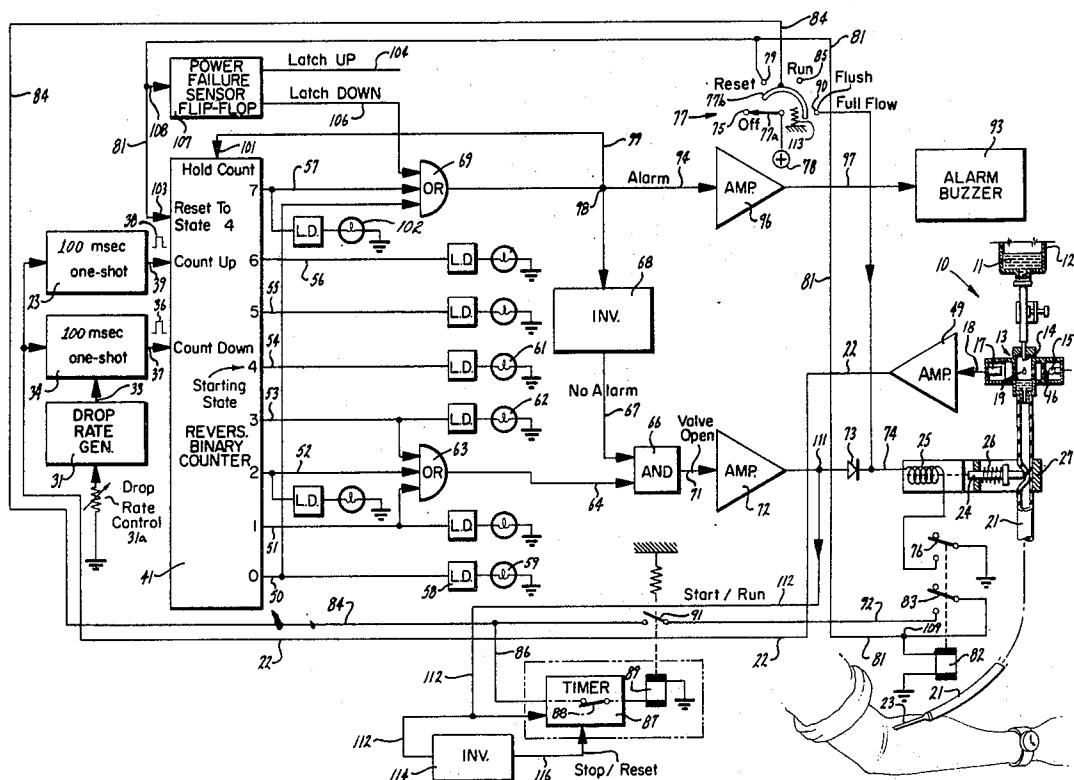
The system delivers a series of drops of liquid and is controlled to release each drop in response to a drop rate generator set at a selected drop rate desired to be delivered. Each drop actually delivered is detected. By comparing pulses derived respectively from the drop rate generator and from the actual drops delivered, any disparity between the rates will be detected. The disparity detecting means includes means which measures and is tolerant to a limited degree of measured disparity between the two rates. When the disparity between the two rates exceeds a predetermined degree, an alarm condition is established which can include conditioning the delivery means to positively arrest further delivery of drops. The delivery means operates in a manner to automatically compensate for excess drops or reduced drops fed during transient variations in the actual feeding or delivery of drops.

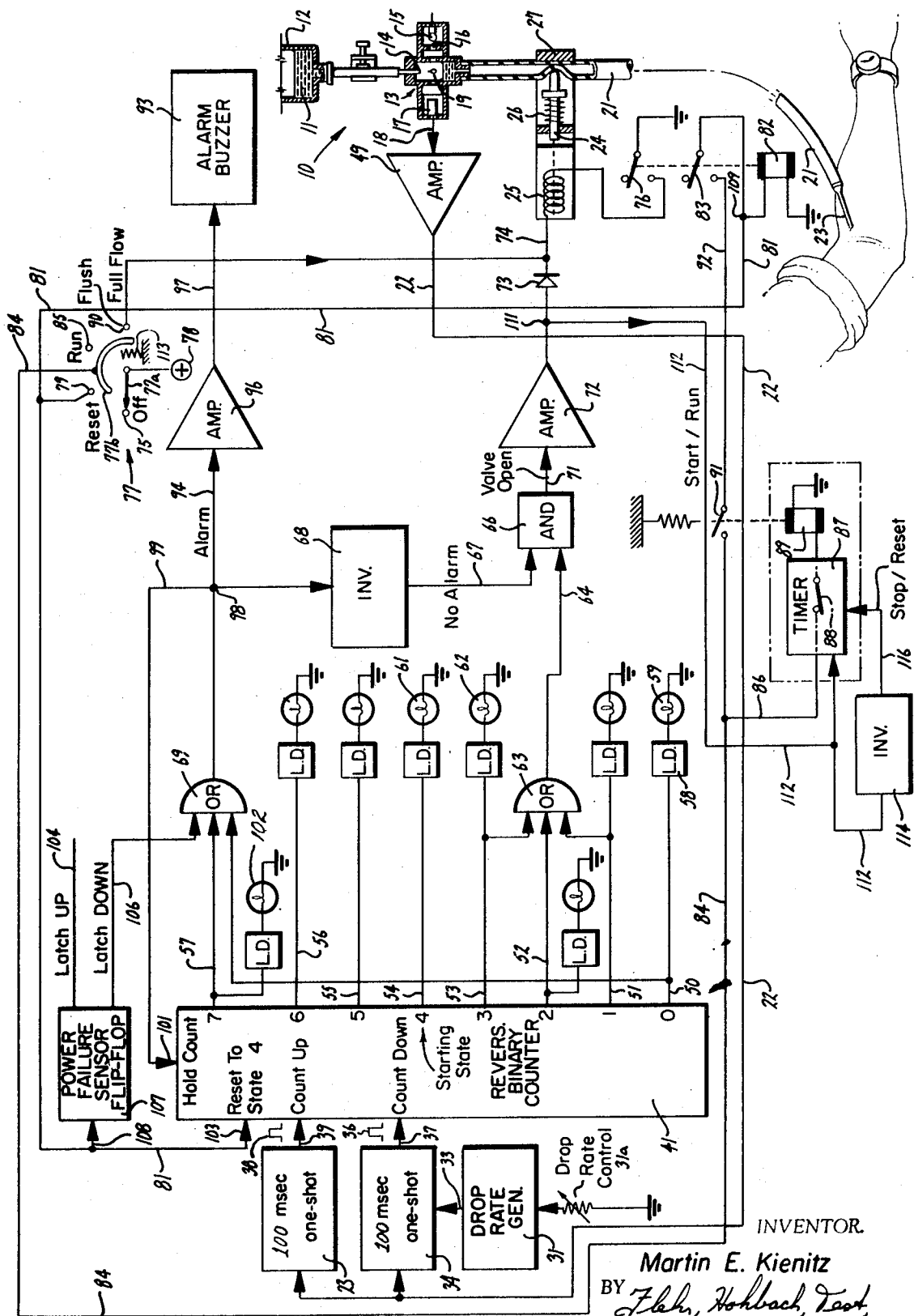
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6 Claims, 1 Drawing Figure





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APPARATUS FOR MONITORING THE DISPENSING OF LIQUID

BACKGROUND OF THE INVENTION

This invention relates to apparatus for controlled feeding and monitoring of drops of liquid or other material delivered in discrete increments. The apparatus is particularly useful in maintaining a close watch over intravenous feeding of drops of liquid material to humans.

Heretofore, systems of the above type have been provided wherein a drop rate generator provides an output pulse train serving to establish the selected drop rate desired to be established by the feeding means. In addition, each drop that is actually delivered is sensed or detected and a pulse train generated in response thereto whereby the two pulse rates can be compared. Upon detecting any disparity between the two, an alarm or other indication of the existence of change in the drop feeding rate may be indicated.

The foregoing style of system is particularly desirable where a very close watch over intravenous feeding is demanded. However, under other circumstances, such a system may prove to be somewhat too sensitive to slight changes in the rate of drop feeding to the patient and can provide what might be felt to be premature alarm signals.

Thus, heretofore, any temporary increase or decrease in the resistance to flow of fluid in the liquid line which is delivering the fluid will cause the foregoing type of system to activate an alarm condition.

It has been observed that a patient may change position, for example, by bending his arm and affect portions of the drop delivery tubing, or may, by his movements, cause the opening in the intravenous feeding needle to press against the wall of the vein so as to momentarily impede the flow of fluid through the delivery tube. Heretofore, such conditions could generate a disparity in what is otherwise a normal feeding situation.

Additional conditions may also exist of the above type or otherwise which can cause momentary, though unsustained, changes in the feeding rate of a type which will generate an alarm condition for the above general type of system.

It has also been observed that the typical momentary change in fluid rate can generally be expected to be followed by an equivalent period of fluid delivery at a quickened pace.

Where the disparity in feeding rates between the selected drop rate generator and the delivery rate for the actual drops being fed to the patient represents a sustained continuous condition, rather than merely momentary, then, it is believed, feeding of fluid should be discontinued until the situation can be adjusted.

OBJECTS

It is an object of the present invention to provide an improved system of the above type.

It is another object of the invention to provide a system of the above general type wherein momentary changes in fluid feeding rates can be tolerated and recognized while a sustained change in the rate of feeding a liquid serves to generate an alarm condition.

It is another object of the present invention to provide a system of the above type wherein a momentary change in the rate of either of the two pulse rate generators accommodates a natural corrective action in the system.

The foregoing and other objects of the invention will become more readily apparent from the detailed description of a preferred embodiment described below when considered in conjunction with the drawings.

SUMMARY OF THE INVENTION

In general, the system described herein includes means for delivering a series of drops of liquid and means defining a selected drop rate for controlling delivery of the drops in response to the drop rate generated. In addition, means for sensing each drop of liquid delivered defines the actual drop rate. Comparison of the two drop rates is made by means serv-

ing to detect a sustained disparity between the two rates by measuring and being tolerant to a limited degree of measured disparity between the two rates while serving to register varying degrees of disparity between the two rates. When the disparity between the two rates exceeds a predetermined degree, an alarm condition is established, such as by arresting further delivery of drops, or sounding an alarm, or both.

BRIEF DESCRIPTION OF THE DRAWING

The single figure of the drawing schematically shows a drop monitoring system according to the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Means for delivering a series of drops of liquid includes the feeding means 10 which feeds discrete drops of liquid 11 from a container 12 into the arm of a patient receiving intravenous feeding. Feeding means 10, as schematically shown, includes a suitable drop forming outlet 14 disposed to deliver drops 19 of liquid 11 from container 12 to a splash chamber 13.

Means for sensing each drop 19 actually delivered includes an attachable drop sensor assembly having a light source 15 to direct a beam of light through an aperture 16, and splash chamber 13, to be sensed by a suitable photo-responsive device 17. Device 17 serves to generate a signal on line 18 whenever the beam is interrupted by the presence of a drop, as at 19. Drops 19 travel along a resilient tube 21 for delivery into the arm of a patient, usually as by means of a hypodermic needle 23.

It is evident that the foregoing arrangement constitutes flow control means providing delivery of the drops. Drop delivery is responsive to a selected drop rate as defined by a drop rate generator 31. In delivering drops, the flow control means is arranged to be operable between active and inactive states to respectively deliver or arrest the liquid.

Means controlling delivery of drops through tube 21 include the valve member 24, operable in one condition to pass a drop of liquid and operable in another condition to arrest delivery of liquid drops through tube 21. A solenoid 25 is arranged whereby when it is energized, member 24 will be withdrawn against the urging of spring 26. Tube 21 is constructed of a resilient material whereby upon withdrawal of member 24, the passage within tube 21 will open to permit a drop to be formed in splash chamber 13.

Notwithstanding the fact that the tube constrictor member 24 is disposed downstream of splash chamber 13, activation of the tube constrictor member 24 exerts a controlling influence on the actual drop rate, i.e., the actual delivery rate of drops passing into splash chamber 13.

Thus, the system from the hypodermic needle 23 back to the reservoir 12 is a closed one and back pressure at the needle 23, caused by temporary stoppage, reflects back to the reservoir and prevents further delivery of fluid. This is true, notwithstanding the fact that the drop chamber or splash chamber 13 will normally not be full of fluid. As a consequence, it is immaterial where the pinch clamp is placed along the delivery tube 21. The usual practice, however, is to place the clamp below splash chamber 13.

De-energizing solenoid 25 permits spring 26 to cause member 24 to pinch tube 21 between the free end of member 24 and a fixed portion 27 of the solenoid assembly.

From the foregoing, it will be evident that the actual drop rate of liquid being dispensed is sensed by photo-responsive device 17. Device 17, therefore, functions as an impulse generator which provides an impulse corresponding to each drop which is actually dispensed to the patient.

These impulses appear on the output line 18 from device 17 and are amplified by a suitable amplifier 49 for transmission along line 22 to a suitable pulse forming and shaping circuit of a type providing a substantially uniform and constant output pulse on the order of 100 millisecond duration, as shown in the drawing merely as box 23. Such a circuit may be of the so-called "one-shot" style, as popularly referred to.

There is also provided another impulse generator which serves to define the desired or selected drop rate for liquid to be fed to a particular patient. Thus, a drop rate generator 31 is provided in the form of a suitable pulse generator which provides a series of output pulses corresponding to the selected drop rate desired to be established. Various saw-tooth generators or the like can be utilized for this purpose and provide a useful pulse train.

The frequency of the output pulses on the output line 33 from drop rate generator 31 can vary over a wide range, for example, from 5 to 150 drops per minute or the like. On the drawing, there is shown a variable resistance 31a which can provide a suitable variable control to establish output pulses within the above range.

Drop rate generator 31 can readily be provided by other conventional means, such as by certain relaxation oscillators or the like. See U.S. Pat. No. 3,252,623. The output train of pulses from generator 31 appears on output line 33 and the pulses are fed to a suitable pulse forming and shaping circuit 34 of a type for providing a single output pulse of predetermined duration, such as the types of the circuit referred to with respect to box 23. Conventionally, a one-shot multivibrator can be employed for this purpose having an output pulse on the order of 100 millisecond duration, for example.

To this point, it will be readily evident that means have been provided for sensing the actual delivery of every drop 19 delivered to the patient by means of the feeding means 10. In sensing each drop 19, a pulse is fed via line 22 and ultimately is shaped and formed to provide the pulse 38 of uniform duration appearing on lead 39. It is also evident that means have also been provided in the form of drop rate generator 31 for developing a train of pulses 36 indicative of the selected rate at which drops should be fed to the patient, pulses 36 appearing via 37.

Means have been provided which serve to detect any sustained disparity between the two rates of pulse generation. A "sustained disparity" may be considered to exist whenever, in addition to the usual pulse 36 or 38 which is normally interposed between successive ones of the other of the two pulses 38, 36 there is further included an additional interposed pulse 36, 38. In short, in normal operation, one of the two pulses 36, 38 will be expected to be interposed between each successive pair of the other of the two pulses. However, the disparity between the two rates of pulses is not herein considered to be "sustained" until a plurality of at least two or more pulses have become interposed between each successive pair of the other of the two pulses 36, 38.

The means for detecting a "sustained disparity" between the two rates includes means which measures and is tolerant to a limited degree of measured disparity between the rate of occurrence of pulses 36 and 38 and which also serves to register varying degrees of disparity between the two rates. In response to a predetermined degree of disparity which may usually be considered to indicate that a sustained condition of imbalance between the two rates has occurred, calling for emergency measures, the apparatus serves to establish an alarm condition wherein the liquid feeding means 10 is inactivated in a manner to arrest further delivery of drops.

Having the foregoing general functions in mind, there is further shown in the drawing a reversible electronic counter 41 of any suitable type having an input to be coupled to lead 39 and another input to be coupled to lead 37 whereby the occurrence of a pulse 38 on lead 39 serves to cause the counter to register a single count in an increasing "direction" (i.e., to increase the registered sum held by the counter in an amount equal to a single first order digit). A pulse on lead 37, however, serves to cause counter 41 to register a count of a single first order digit in an opposite "direction" (i.e., to subtract from the sum registered in counter 41).

To simplify the foregoing detailed description, it may be better understood that a pulse 38 on lead 39 serves to cause counter 41 to be counted "up," i.e., increase the registered sum, while a pulse 36 on lead 37 serves to count the counter 41 "down," i.e., decrease the registered sum.

Counter 41 includes eight output leads numbered 50-57 respectively. Each output lead 50-57 is associated with one of the Arabic numerals 0-7 respectively and indicates when a predetermined bi-stable voltage state on that particular lead represents a count of from 0-7 as the case may be.

Counter 41 may be provided by any suitable conventional reversible electronic counting means and, as shown herein, may be comprised of three cascaded and cyclically arranged flip-flop circuits interconnected one to the next, as is known. Each of leads 50-57 registers one or the other of a pair of binary states and, in the arrangement shown, all of leads 50-57 will be in a common one of the two states with the exception of a single one of the leads which will be in the other of its two binary states. The single existence of this other state will, therefore indicate the sum of the count registered in counter 41. As is known, the two stable states may be indicated by the relative voltage level appearing on the leads 50-57.

The condition of output leads 50-57 is switched from one to the next either upwardly or downwardly depending upon the sequence of receipt of pulses 36, 38 from leads 37, 39 in conventional fashion. Thus, there is provided a counting means for registering, via lead 39, in an increasing amount each drop actually delivered while the counter 41 registers in a negative direction or counts "down" one count for each pulse 36 received from drop generator 31.

So long as the rates remain the same, the counts 36, 38 will provide signals alternately received which mutually offset the count carried in the counting means 41.

In order to indicate to the human senses the current state of the count of counter 41, each output lead 50-57 has been provided with a conventional lamp driver circuit 58 directly connected to a lamp 59 whereby when the state of lead 50 (or any of leads 51-57 associated with a given lamp driver circuit and lamp as shown) is conditioned to provide that binary state representing the count registered in counter 41, the lamp 59 (or the others as the case may be) will be illuminated.

Counter 41 is of conventional construction as indicated above and is arranged in suitable fashion whereby its initial or "normal" state represents a count of "four" whereby the lamp 61 will be illuminated.

Means are provided whereby drop rate generator 31 serves to dispense a drop of liquid to the patient. Thus, as a pulse appears at the output line 33 and is shaped and formed into pulse 36 on lead 37, counter 41 will be counted "down" one count whereby lead 53 will carry the binary state indicating the presence of a "three" count registered therein and lamp 62 will be illuminated. The output state or condition on lead 53 constitutes a signal which is fed through an OR gate 63 of conventional construction to provide one of the two inputs via line 64 to AND gate 66.

The other input to AND gate 66 via line 67 is supplied from inverter 68 (via OR gate 69) which operates in response to the bi-stable condition of lead 57. Inverter 68, as is known, reverses the binary state indicated on lead 57 whereby the opposite state will exist on line 67 comparable to that appearing on line 64.

AND gate 66 responds to the coincident occurrence of the two similar input signals whereby an output signal is supplied on line 71. This signal is then amplified by suitable amplifier means 72 and directed through diode 73 poled to pass the signal and feed it onto line 74 for operating solenoid 25.

Solenoid 25 will be operated only if the switch armature 76 has been previously conditioned to a closed state.

Means for closing switch armature 76 at an earlier time have been provided as now to be described.

A main control switch 77 employs a switch armature 77a which serves to couple power supply 78 to each of four contact points 75, 79, 85, 90, respectively labeled herein as "off," "reset," "run," and "flush." In addition, an elongated arcuate conductive contact strip 77b is connected to a line 84 to energize timer 87 via lines 84, 86 and to form the source of power for a holding circuit by energizing solenoid 89 promptly upon movement of armature 77a from its "off" position 75.

Thus, upon commencing operation, armature 77a will be rotated clockwise as shown whereby a connection is made between power supply 78 and the "reset" contact 79. As soon as power is thus connected, a circuit is completed via line 81 to ground to operate coil 82.

Coil 82 closes both switch armatures 76 and 83, the latter forming a holding circuit.

Thus, contact closure 91, closed by energizing solenoid 89, serves to energize line 92 whereby the prior movement of armature 77a to contact the "reset" contact point 79 of switch 77 supplies power in the holding circuit to be available to hold coil 82 energized (and armatures 76, 83 closed) as soon as the "reset" contact 79 is struck.

To briefly summarize the foregoing, upon movement of switch armature 77a to the "reset" contact point 79, armature 83 forms a holding circuit whereby armature 76 will be maintained closed to complete the circuit for solenoid 25. The latter, when energized in response to a count appearing on counter 41 on any of leads 51, 52 or 53 serves to withdraw member 24 to dispense a drop 19.

In normal operations, drop rate generator 31 will develop a pulse 36 for counting the counter 41 "down" from a "four" count to a "three" count on lead 53 thereby causing a drop 19 to be dispensed. Photo-responsive device 17, as above described, serves to generate a pulse 38 on lead 39 indicating the actual delivery of drop 19 into the splash chamber 13 whereby pulse 38 serves to count the counter 41 "up," i.e., to increase the sum which is registered in counter 41 and thereby indicate a registered count of "four."

So long as the feeding of drops of liquid via tube 21 proceeds at the same rate as the rate established by drop rate generator 31, the counting means 41 will respond to alternate receipt of signals from the rate generator 31 and feeding means 10 respectively. These signals serve to register first and second mutually off-setting counts in the counting means 41. The mutually off-setting count will oscillate between state No. 4 and state No. 3 wherein upon each conditioning of lead 53 for indicating state No. 3, a drop 19 will be delivered by a momentary energizing of solenoid 25.

On the other hand, should a momentary interruption in either of the two pulse rates occur, for example if a patient should move his arm in a manner which might cause the delivery of drops to be momentarily arrested, counting means 41 as shown will receive at least a plurality of two additional counts in succession from generator 31 before providing an alarm condition. The alarm condition preferably may involve fully arresting further delivery of drops to the patient as well as the sounding of a buzzer of activating any other suitable alarm recognizable by the human senses.

Accordingly, it is to be observed that the output state on leads 51 and 52, when representing a registered count in counter 41 in the amount of "one" or "two" respectively, provides a stable signal on line 64 whereby solenoid 25 will be energized to deliver liquid drops to the patient. Thus, in the event that the alternate receipt of pulses from drop rate generator 31 and feeding means 10 becomes interrupted in a manner whereby drops are only momentarily discontinued, drop rate generator 31 will continue to provide pulses 36 which cause counter 41 to continue to count "down" and provide an output signal on lead 52 and then on 51.

In the event, however, that the disparity in the rate of actual delivery of drops 19 and the desired rate of drop generation (as defined by generator 31) is "sustained" to the point where generator 31 counts "down" to register a count by the output state which appears on lead 50 (representing a registered count of zero in counter 41) the signal on lead 50 serves to establish an alarm condition which functions to activate an alarm 93 via a circuit traced from output lead 50, OR gate 69, lead 94 and amplifier 96, to activate a buzzer or other suitable audible or visual alarm 93 via line 97.

When counter 41 reaches a count of "zero" (as registered by the output state on lead 50) the signal on lead 50 further serves to positively preclude further activation of solenoid 25

and hence serves to block the further delivery of additional drops 19 of liquid 11.

Accordingly, the signal on lead 50 is fed via OR gate 69 and lead 94 to a junction 98 made with line 99 whereby the output state from the "zero" count is directed to inverter circuit 68. Circuit 68 is of conventional design whereby the input signal is inverted to provide an opposite signal of substantially the same magnitude. For example, in a typical instance, if the input signal represents a relatively low voltage state or condition appearing on the input line 99, the output from inverter 68 may appear as an equal and opposite relatively high voltage state on output line 67.

Normally, when the count registered in counter 41 lies between "1" and "6," the inverter 68, as above described, provides an output state on line 67 comparable to the signal appearing on line 64 whereby the conjoint receipt of two like signals by AND gate 66 serves to pass a signal via line 74 to activate solenoid 25.

However, in the present instance, where a "sustained" disparity in the rates between drop rate generator 31 and feeding means 10 exists, the signal on line 67 will have been reversed and this reversal will prevent AND gate 66 from passing signals appearing on leads 51, 52, 53 to reach solenoid 25.

From the above, it will be readily evident that when counter 41 registers a "zero" count, and the lamp 59 has been lighted by lamp driver circuit 58, an operator or attendant can readily determine that the drop feeding has been too slow relative to the rate of generating signals from drop rate generator 31.

In order to hold the count at "zero" for the attendant to be able to observe the state of counter 41 and adjust the system before resetting the system to recommence operation, the output state on the "zero" output lead 50 acts via OR gate 69, lead 94, junction 98, and line 99 to provide an input 101 to counter 41 which conditions counter 41 to hold the count at "zero." In this manner, the attendant will be able to observe the state of counter 41 and determine that, by the lamp 59 being lighted, the liquid flow rate in the feeding means 10 has been slower than the selected rate in drop rate generator 31.

The holding input 101 in known fashion can also serve to permit the use of conventional reversible cyclic style counters whereby after the counter has reached a "zero" count, it is prevented from next moving to a "7" as is conventional in a number of known types of cyclic counters.

With the above explanation in mind relative to a condition wherein the drop feeding has progressed too slowly due to a temporary blockage created by movement of the patient's arm or otherwise, it is readily evident that as soon as the condition has been corrected, as for example, when the patient may have readjusted his arm, any "backed up" liquid (which otherwise would have been fed) is then, in many instances, readily delivered as drops and the pace for feeding drops 19 quickens momentarily whereby, in the event that a "zero" count was not reached, extra pulses 38 will be generated to cause counter 41 to count "up" until the normal phase relationship between the alternate generation of pulses 36, 38 is again resumed.

For example, in the event that counter 41 has counted "down" to a count of "1" to provide a drop delivery signal on lead 51, no drops will have been delivered due to a momentary conditioning of tubing 21, or hypodermic needle 23, or otherwise. Such a momentary blockage of the flow of drops can be expected to usually be followed by a momentary increase in the rate of formation of drops 19 whereby extra drops are quickly formed and delivered each of which is sensed by photo device 17 to provide a pulse 38, and correspondingly cause counter 41 to count "up" one count for each pulse to the point where the count in counter 41 reaches a count of "4" indicated by the electrical state on lead 54 whereby the system resumes the alternate conditioning of leads 54 and 53 to place the drop rate generator 31 in phase with the feeding means 10.

In the event that drops are formed and fed to the patient too quickly relative to the selected rate of formation (as

represented by pulses 36 from rate generator 31), it will be readily evident that the registered count carried in counter 41 as indicated by the state on output leads 54, 55 and 56 will fail to provide any signals for energizing solenoid 25 and thus tubing 21 will remain pinched by member 24 so as to slow the formation and feeding of drops 19.

Thus, it is clear that the present system contemplates an arrangement of means operating the dispensing means in response to a control signal so as to momentarily vary the rate of actual dispensing of increments of liquid in a manner tending to restore the normal predetermined relationship desired to be established between the drop rate generator and the actual dispensing of drops as sensed by photo-responsive device 17.

Accordingly, it is apparent that the feeding means 10 in conjunction with the balance of the system operates in a manner whereby sufficient additional or fewer increments of liquid such as the drops of liquid being sensed will be dispensed in order to re-establish the normal alternating relationship so as to compensate for any transient variation in the flow of the increments of fluid being dispensed.

In this manner, even though the actual rate of dispensing drops of liquid may be subject to transient variations in the dispensing rate intended to be delivered, the system is characterized by means which serve to cause an automatic restoration of the number of drops which should have been fed to the patient, provided, of course, that a "zero" or "7" count is not reached during the period of such transient variation in the dispensing rate.

Any "sustained" disparity between the rate of formation of drops 19 and the desired rate will cause counter 41 ultimately to count "up" to "seven" whereby the output state on lead 57 provides a signal which, not only serves to illuminate the associated lamp coupled to lead 57, but also, via OR gate 69, serves to activate alarm buzzer 93 and via inverter 68 acts to de-energize solenoid 25 as well as to provide a signal on line 99 which is fed to the holding input 101.

With lamp 102 lighted and held in its lighted condition by the holding input 101, it will be readily evident to an attendant that the alarm condition was caused by the fact that drops were formed too rapidly relative to the selected rate desired to be established by rate generator 31.

An attendant will normally be expected to make certain adjustments in the feeding means 10 so as to adjust the rate of drop feeding whereby it corresponds closely to the selected rate desired and then he will reset the system. To reset the system, it is only necessary to move control switch armature 77a to the "reset" contact 79 which thereby connects power supply 78 to line 81. Counter 41 is provided with an input 103 in known manner which serves to reset the counter 41 to a starting count of "4."

Means are provided whereby in the event of a power failure, alarm 93 will be activated. Thus, a power failure sensor in the form of a flip-flop circuit 107 of conventional design having a pair of bi-stable output states represented by the leads 104, 106 is provided and is reset at the above time by connecting power supply 78 via lines 81, 108. The flip-flop circuit 107 may be of any suitable conventional type having an input connection or lead 108 which, when subjected to the voltage of the power supply, serves to establish the bi-stable state represented by a "high" voltage state on lead 104.

In normal operation, power supply 78 can be expected to be sensed by input lead 108 from a circuit traced from armature 77a contacting the arcuate strip 77b and then via line 84, contact closure point 91 (then in its closed position as held closed by the energization of solenoid 89) line 92, armature 83, and coil 82 to ground. The junction point 109 will therefore be at a positive potential sensed on line 81 so as to condition the power failure sensor flip-flop circuit 107 to its normal state.

However, when power fails for any reason, then the change in voltage on line 81 (and at input connection 108) serves to establish the bi-stable state on lead 106 which provides a signal via OR gate 69, amplifier 96 and line 97 so that buzzer alarm 93 is activated.

Means are provided to interrupt the power supply voltage on line 81 and thereby activate the alarm condition in the event that solenoid 25 remains energized for too long a period.

Thus, each signal appearing on leads 51, 52, 53 (as described above for delivering a drop 19 of liquid 11 to the patient) is also transmitted from any of these three leads via junction 111 and line 112 to start the timing cycle of timer 87.

Timer 87 is of a conventional type of known construction employing a pair of input connections whereby a steady state condition applied to one of the input connections serves to initiate the timing cycle and the application of a similar pulse to the other input connection serves to terminate the timing cycle and reset the timer to an initial starting condition. The function of the timing circuitry involved in timer 87 is to control the operation of switch 88 whereby it is normally closed for purposes of permitting solenoid 89 to be energized from lead 86 but in the event that feeding of drops continues for too long a period for any given drop, timer 87 serves to interrupt the operation of the system by opening the power to de-energize solenoid 25 delivering drops.

Thus, for each steady state condition indicating a count of 1, 2 or 3 on leads 51, 52, 53, the steady state condition will be sensed at junction 111 and fed via line 112 to the input of timer 87 which commences the timing cycle. As explained above, whenever a pulse 38 on lead 39 serves to count the counter 41 "up" to the condition number 4, the steady state condition on lead 53 will be removed whereby the change in this state is sensed via an inverter circuit 114 which serves to provide a suitable input voltage state to timer 87 via lead 116. This input resets timer 87 whereby the timer is ready to reinitiate its operation upon receipt of a signal via lead 112.

Finally, as part of the procedure for clearing any blockage from tubing 21, the attendant may desire to hold solenoid member 24 withdrawn so that the tubing remains open. Then, it may be possible to flush all materials from tubing 21 using hospital techniques.

Accordingly, switch armature 77a can be moved to contact point 90 labeled "flush" while continuing to make a parallel wiping contact with strip 77b. In this manner, power supply 78 will be coupled directly to line 74 to energize solenoid 25 since armature 76 is then held closed by the circuit traced from power supply 78, switch 77, lines 84, 92, and via solenoid armature contact 91 (then closed by action of solenoid 89), armature 83 and coil 82.

A spring 113 is mounted so as to require the attendant to keep his finger on armature 77a in order to operate the system in the above "flushing" manner. Whenever the attendant removes his finger from armature 77a, spring 113 serves to disconnect point 90 from armature 77a.

I claim:

1. In apparatus for delivering a series of drops of liquid, and having means defining a selected drop delivery rate, delivery means controlling delivery of the drops in response to the first named means to normally deliver one drop at a time, means serving to sense each drop to be delivered and define the actual drop rate, means serving to detect a sustained disparity in the phase relationship between actual drop delivery and selected drop delivery, the last named means including means measuring and tolerant to a limited degree of measured disparity in said phase relationship and serving to register varying degrees of said disparity, said last named means being further responsive to a predetermined degree of disparity serving to condition the delivery means to inhibit or release further delivery of drops, said measuring means including counting means for registering increases and decreases in said disparity as measured from a normal position representing no disparity, said counting means being responsive to alternate receipt from the first named said means and said sensing means respectively of first and second signals to register a first and second mutually off-setting count in the counting means, and means operated by said counting means and responsive to a predetermined difference in the counted number of said first and second signals to provide an alarm signal operably coupled to said delivery means to arrest further delivery of drops.

2. In apparatus for delivering a series of drops of liquid, first means forming a series of signals at a rate corresponding to a selected drop rate, delivery means controlling delivery of the drops in response to said first means, second means serving to sense each drop to be delivered and provide signals corresponding to the actual drop rate, and means serving to normally alternately receive both signals and serving to detect disparity in the phase between receipt of said different signals, the last named means including a counting register responsive to delivery of each drop to change its registered count in a given direction and responsive to said first means to change its registered count in an opposite direction, and responsive to increases or decreased in excess of a predetermined tolerated registered minimum to arrest delivery of drops.

3. In apparatus for delivering each of a series of drops of liquid in response to a first signal from a drop rate generator and having means for developing a second signal in response to actual delivery of each drop, and means to normally maintain an alternating relationship between said first and second signals, the improvement wherein the last named means responds to said signals for detecting a sustained change in the alternating relationship of said signals, the last named means serving to detect a condition including the interposition of an additional one of said signals between successive ones of the other of said signals and to provide a control signal, and means operated by said control signal for indicating existence and degree of said sustained change in the alternating relationship of said signals.

4. In apparatus for delivering each of a series of drops of liquid according to claim 3 wherein the means indicating ex-

istence of said sustained change in relationship includes means for arresting further delivery of drops of liquid in response to detecting existence of said sustained change in relationship as indicated by said control signal.

5. In a system for monitoring the dispensing of discrete increments of liquid in a stream subject to transient variations in the dispensing rate, the improvement comprising means for dispensing said increments, means forming a first signal representing the intended desired rate of dispensing said increments, sensing means serving to form a second signal representing the actual rate of dispensing said increments, means normally maintaining a predetermined phase relationship between said first and second signals and serving to detect a sustained change in said phase relationship to provide a control signal, means operating said dispensing means in response to said control signal to momentarily vary the rate of the actual dispensing of said increments in a manner tending to restore said normal predetermined relationship.

6. In a system for monitoring the dispensing of discrete increments of liquid according to claim 5 wherein said predetermined relationship includes an alternating formation of said first and second signals, and further wherein the last named means restores said normal alternating relationship by operating said means for dispensing said increments in a manner to momentarily dispense additional or fewer increments sufficient to re-establish said normal alternating relationship, thereby compensating for the transient variation in flow of the increments being dispensed.

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