July 27, 1965 T. H. CORBIN ETAL 3,197,068

APPARATUS FOR MONITORING THE DISPENSING OF LIQUID

Filed April 27, 1964 3 Sheets-Sheet 1

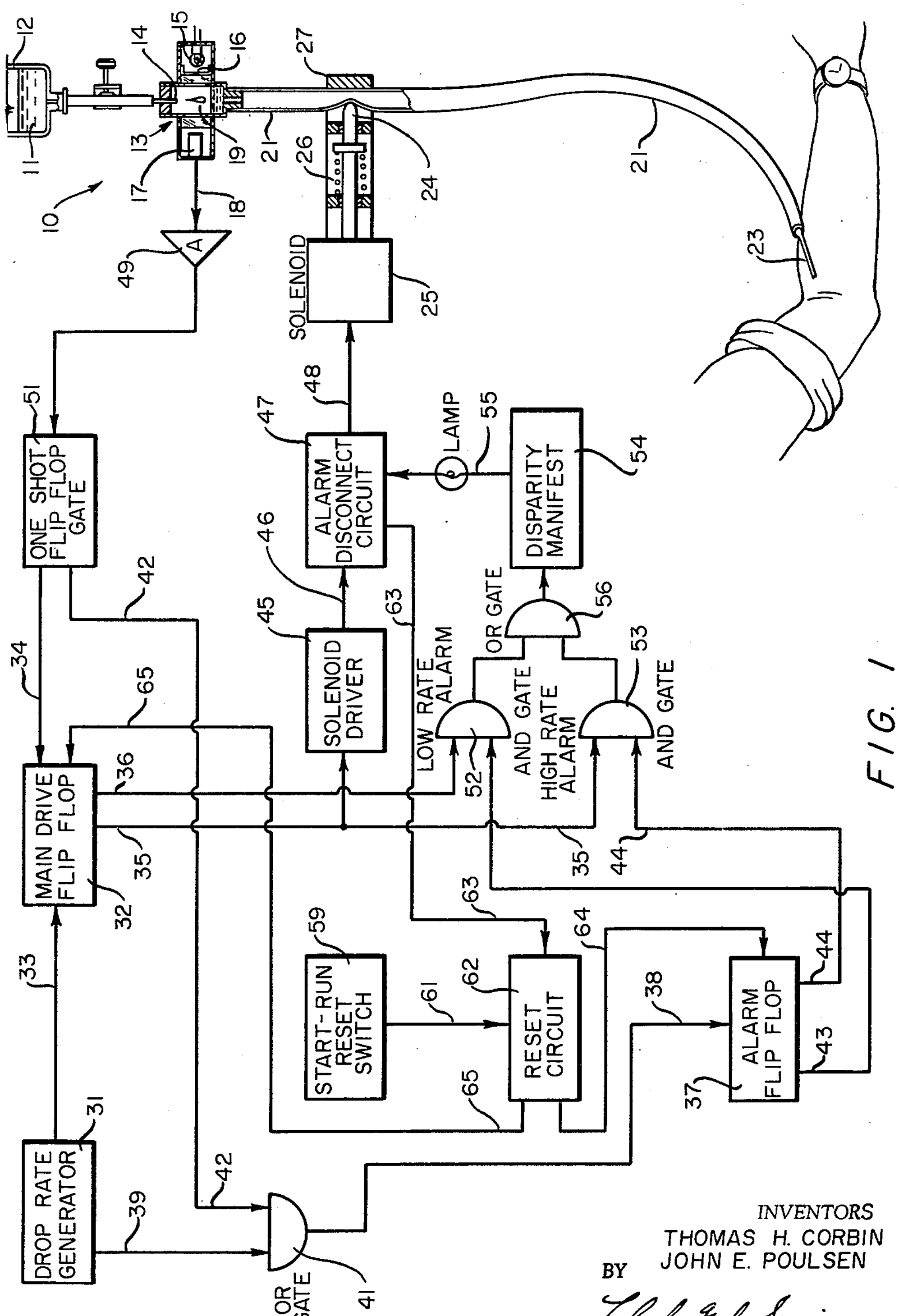

FIG. 1

INVENTORS
THOMAS H. CORBIN
JOHN E. POULSEN

BY Flehr and Swain
ATTORNEYS

APPARATUS FOR MONITORING THE DISPENSING OF LIQUID

Filed April 27, 1964 3 Sheets-Sheet 2

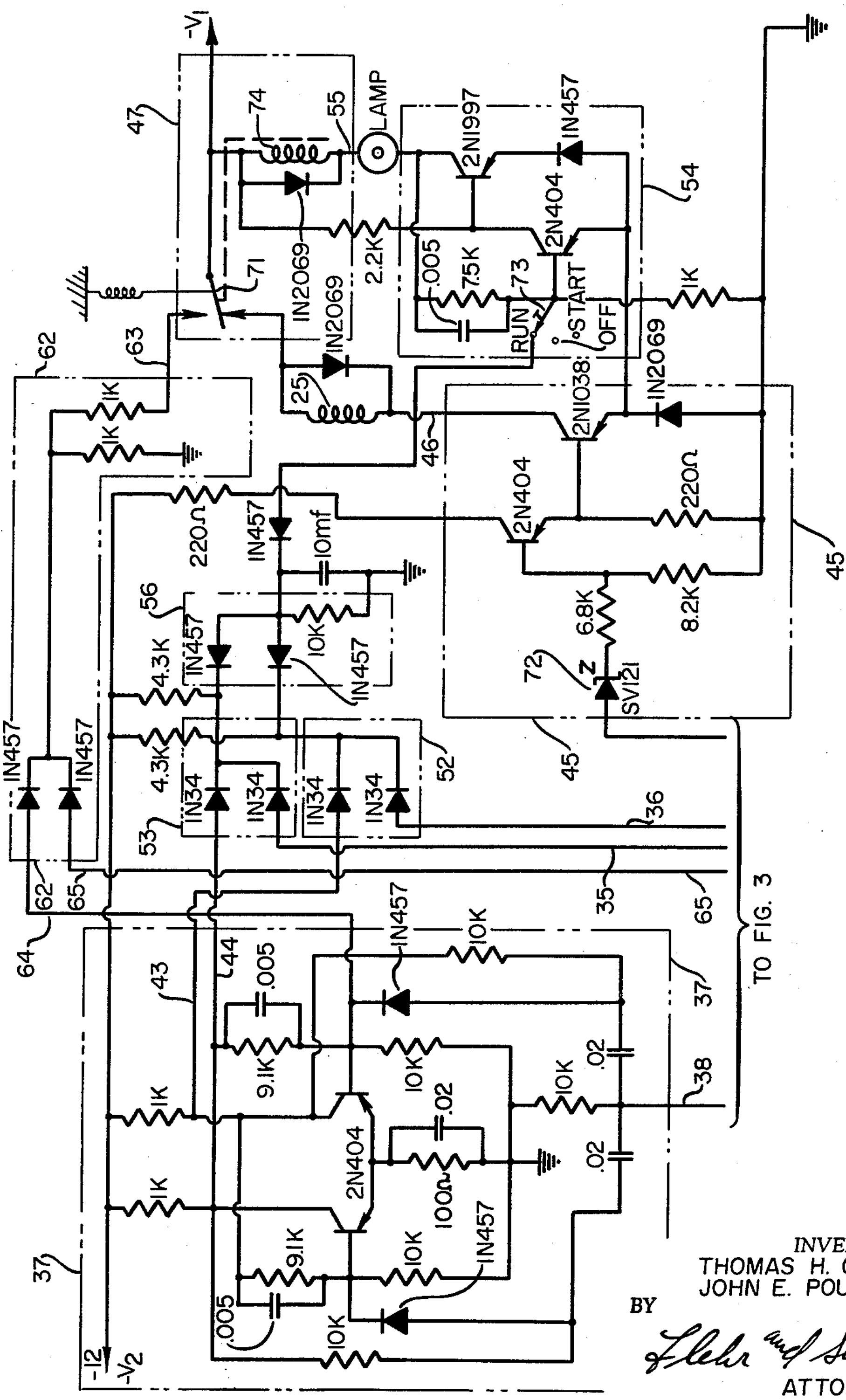

FIG. 2

INVENTORS
THOMAS H. CORBIN
JOHN E. POULSEN
BY
Lehr and Swain
ATTORNEYS

APPARATUS FOR MONITORING THE DISPENSING OF LIQUID

Filed April 27, 1964 3 Sheets-Sheet 3

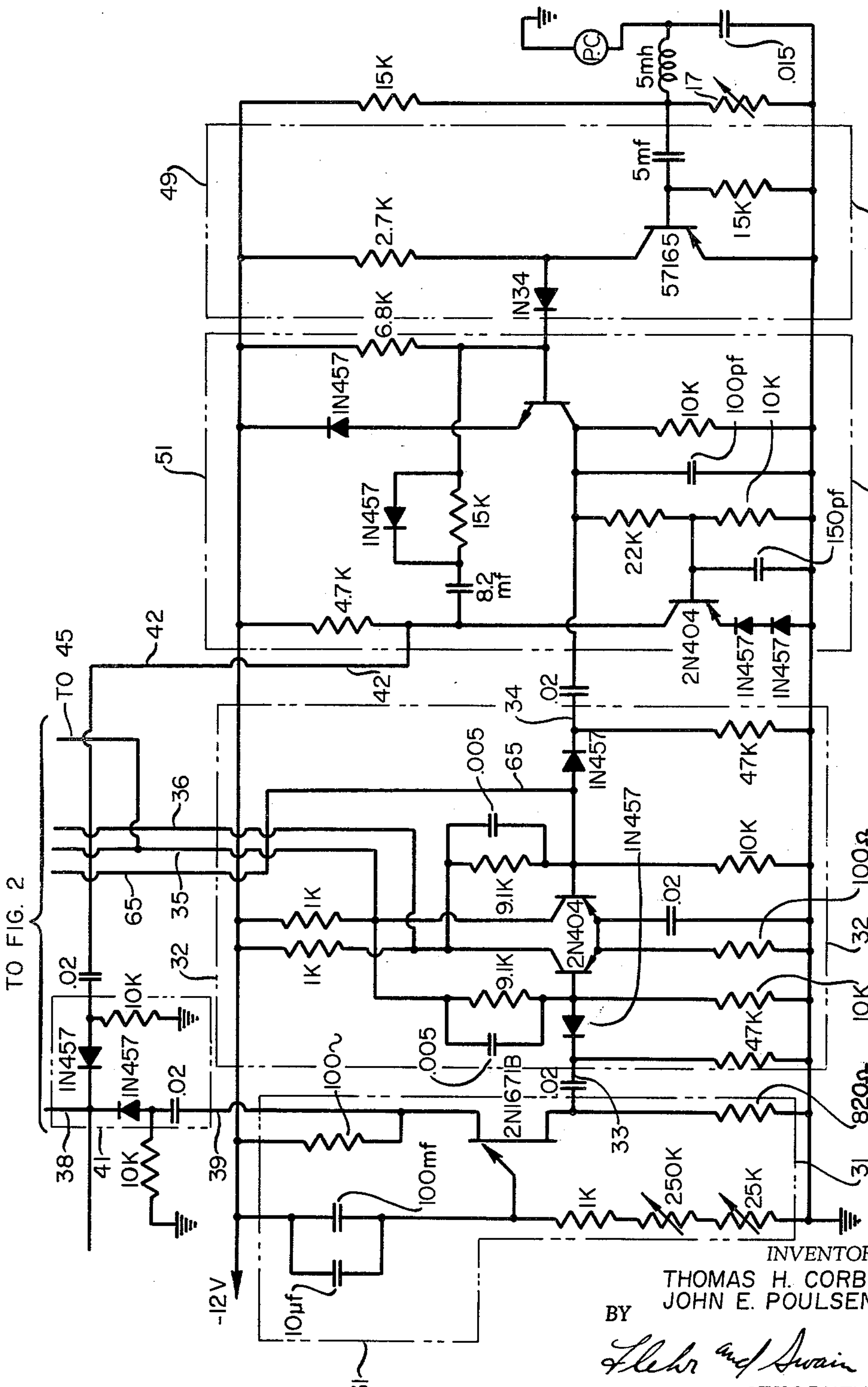

FIG. 3

INVENTORS
THOMAS H. CORBIN
JOHN E. POULSEN
BY
Flehr and Swain
ATTORNEYS

United States Patent Office

3,197,068
Patented July 27, 1965

3,197,068
APPARATUS FOR MONITORING THE DISPENSING OF LIQUID

Thomas H. Corbin, Palo Alto, and John E. Poulsen, Santa Clara, Calif., assignors, by mesne assignments, to Corbin-Farnsworth, Inc., Palo Alto, Calif., a corporation of Delaware

Filed Apr. 27, 1964, Ser. No. 362,832
13 Claims. (Cl. 222—59)

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 closewatch over intravenous feeding of drops of liquid material to humans.

In feeding liquids intravenously to patients it is particularly important in certain circumstances to guard against feeding the patient at a faster rate than intended. In certain instances it is believed that more harm can be done the patient by feeding too rapidly than might be done, for example in an emergency, when all feeding might be terminated.

It is a general object of the present invention to provide an improved scheme for monitoring the feeding of discrete increments of material.

It is another object of the invention to provide a system for insuring against a too rapid feeding of liquid as compared to the selected rate of feeding sought.

It is still another object of the invention to provide a drop feeding system which initiates and accurately controls the number of drops per minute of intravenous liquid delivered to a patient, and which turns itself off if the drop rate delivered to the patient is different from the drop rate desired.

It is yet another object to provide a system of the kind described whereby intravenous feeding of liquid is promptly terminated in case of various emergencies, such as power failure, etc., so as to be relatively "fail safe".

These and other objects of the invention will be more readily apparent from the following detailed description of a preferred embodiment when considered with the accompanying drawing in which,

FIGURE 1 is a schematic and block diagram of a material feeding and monitoring system according to the invention; and

FIGURES 2 and 3, considered together, provide a schematic circuit diagram of an operating embodiment according to the invention, including values and specifications of circuit components thereof.

In general, the apparatus to be described in detail below includes means serving to feed material by discrete increments thereof for delivery, and means serving to define a selected intended rate of incremental delivery. Means are also provided which serve to sense each increment of material to be delivered and thereby to define the actual delivery rate. Any disparity between the selected and actual rate of delivery is detected and develops a signal which controls the feeding means to arrest further delivery of increments of material thereby manifesting existence of such disparity. Where it is not desired to arrest delivery of the liquid upon occurrence of a disparity, an alarm signals the disparity to an attendant.

In the context of intravenous feeding there is generally provided a valve means controlling delivery of the liquid. There is also provided means defining a selected drop rate and means serving to sense each delivered drop so as to define the actual drop rate. Finally, means are provided which serve to detect disparity between the actual and selected rates and inactivate the valve means in response thereto in order to arrest further delivery of fluid.

In achieving the foregoing general arrangement, the approach herein has been to employ valve means operable in one condition to pass a drop of the liquid which is to be delivered, and operable in another condition to arrest delivery of the liquid. A first pulse generator is arranged which serves to provide a series of pulses at a selected rate corresponding to the rate of delivery of drops of liquid intended to be achieved. A second pulse generator is arranged to sense each drop of liquid which is delivered. The second pulse generator serves to generate a pulse in response to sensing each drop.

A pair of bi-stable switch means such as conventional flip-flop devices are each coupled to respond to the pulses generated by both the first and second pulse generators. Each bi-stable switch means is, therefore, alternately driven between its two stable states by alternately receiving a pulse respectively from the first and the second pulse generators thereby maintaining an in-phase relationship. However, if this alternating application of pulses to both switching means is interrupted to cause successive application of pulses from either of the pulse generators to the two switching means this change is detected. Means are provided which serve to sense a change in the predetermined phase relationship of the bi-stable devices and to condition the valve so as to terminate delivery of liquid. The existence of a change in the phase relationship of the operation of the two switching means is thereby registered.

Referring in detail to the schematic diagram shown in FIGURE 1 there is provided feeding means **10** serving to feed a series of 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 from container **12** to a splash chamber **13**. An attachable drop sensor assembly includes a light source **15** which directs a beam of light through an aperture **16**, and splash chamber **13**, to be sensed by a 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 tube **21** for delivery into the arm of a patient.

Means are provided to control delivery of drops through tube **21**. Thus, a valve member **24**, operable in one condition to pass a drop of the liquid and operable in another condition to arrest delivery of drops through tube **21** is provided. A solenoid **25** is arranged whereby when it is energized member **24** will be withdrawn against the urging of spring **26**. De-energizing solenoid **25** serves to permit spring **26** to cause member **24** to pinch tube **21**. Tube **21** is pinched 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 photocell **17**. Photocell **17**, therefore, serves to function as an impulse generator which provides an impulse corresponding to each drop to be dispensed.

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 to be established. The frequency of these pulses can vary over a wide range, for example, from 5 to 150 drops per minute or the like and such a pulse generator can readily be provided by conventional means, such as by certain relaxation oscillators or the like.

In order to monitor and detect disparity between the actual drop rate and the desired drop rate there is provided a bi-stable switch means such as the "main drive" flip-flop **32**. Flip-flop **32** is of conventional known design. Thus, it will be understood that flip-flop **32** includes a first input to be applied along line **33** to "set" the flip-flop and a second input to be applied on line **34** to "reset" the flip-flop. As is known, a flip-flop has two stable states and these are indicated by the relative voltage level appearing on the two output channels **35**, **36**.

A second bi-stable switch means such as the alarm flip-flop **37** is arranged similarly to the "main drive" flip-flop **32** except that there is provided only a single input **38**. Input **38** is arranged to receive the output pulses from drop rate generator **31** via line **39** and the OR gate **41** of conventional construction, which is arranged to pass a signal on either of two inputs **39**, **42**. Alarm flip-flop **37** having but a single input is a "complementary" flip-flop of conventional construction whereby each succeeding pulse received on input **38** serves to switch the state thereof from one stable condition to the other. The condition of flip-flop **37** is indicated by the voltage level or other suitable signal on each of two output channels **43**, **44**.

Means are provided whereby the drop rate generator **31**, serves to dispense a drop of liquid to the patient. Thus, as a pulse appears at the output line **33** from drop rate generator **31**, flip-flop **32** "sets" output channel **35** in its relatively high level potential. Channel **35**, when "high," operates a solenoid driver circuit **45** which feeds a pulse on line **46** to energize solenoid **25** subject to control of an alarm disconnect relay circuit **47**. When solenoid **25** is energized, member **24** is withdrawn permitting a drop to be dispensed.

Th formation of a drop as sensed by photocell **17** provides a signal which is filtered and amplified by a conventional amplifier unit **49**. This sensing signal serves to "reset" flip-flop **32** by developing a long pulse on input **34**.

The signal from the photo-responsive device **17** is gated via a 150 millisecond monostable one-shot multivibrator **51** in order to prevent noise or extra signals from reaching flip-flop **32** and alarm flip-flop **37** for an elongated period, for example, on the order of 150 milliseconds after the drop occurs, thereby preventing false alarms. Multivibrator **51** can be of any suitable known construction whereby two operating states can be established. One state is a stable state while the other is unstable and after being established will revert, after a predetermined period, to the stable state. The output of multivibrator **51** appears simultaneously on lead **34** and on lead **42**.

From the foregoing it will be readily apparent that a predetermined phase relationship is established between the bi-stable state of flip-flop **32** and the bi-stable state of alarm flip-flop **37**.

In operation, as drop rate generator **31** provides an input pulse simultaneously to both flip-flops **32** and **37**, one stable state of each will be established. At the same time a drop will be dispensed. Thereafter, formation of each drop will cause a pulse to be generated whereby flip-flop **32** and flip-flop **37** change from their preceding state to their other stable state. So long as the pulse repetition frequency of drop rate generator **31** remains matched with the actual drop formation rate, flip-flop **32** will remain in its predetermined phase relation with respect to flip-flop **37**.

However, means are provided to sense a change in the phase relationship and to cause the valve means to terminate the feeding of liquid.

Accordingly, a first and second AND gate have been provided, each being coupled to both flip-flops **32**, **37**. Flip-flop **32** and flip-flop **37** are each arranged whereby they can operate in-phase with each other. Thus, the high output from flip-flop **32** switches between lines **35** and **36** whereby it appears on line **35** at a time when line **43** is high and neither AND gate receives coincident application of the high states. On the other hand when line **36** is high from the "reset" pulse to flip-flop **32**, line **44** will also be high.

The first and second AND gates are designated and shown as a low rate alarm AND gate **52** and as a high rate alarm AND gate **53**. Gate **52** is fed by channels **36**, **43**; gate **53** by channels **35**, **44**. The AND gates **52**, **53** are of a known style whereby coincident application of two relatively high voltage state signals is required to produce an output signal. It is to be noted that while flip-flops **32**, **37** are operatively coupled so as to alternate in-phase between one stable state and the other they are coupled out of phase to AND gates **52**, **53**. Thus, normally only one high voltage state signal will be applied to each of the two AND gates **52**, **53**.

However, whenever both inputs to one or the other of the AND gates **52**, **53** are high, then a disparity manifest circuit **54** receives a signal via OR gate **56** from one or the other of gates **52**, **53** to provide a signal on line **55**. This signal conditions circuit **47** to prevent solenoid **25** from being energized and thereby precludes further delivery of liquid through tube **21**. Circuit **54** is a flip-flop whereby manual open-circuiting of a control electrode thereof serves to reset the circuit as described below.

Thus, the high outputs from gates **52**, **53** are fed to circuit **54** via a conventional OR gate **56** of the type adapted to pass either of two input signals. Assuming that the actual drop rate is low it will be evident that the drop rate generator **31** will provide two successive pulses on outputs **39** and **33** before an "actual" drop impulse is received by either flip-flop **32** or **37**. The output of drop rate generator **31** on line **33** will be ineffective to switch flip-flop **32** inasmuch as the latter switches from one state to the other dependent upon the application of pulses alternately to the inputs **33**, **34** respectively. On the other hand, flip-flop **37** has but a single input **38** and in response to two successive pulses will change its stable state whereby the high state signal on output channels **43**, **44** will switch from one to the other. Thus, the high state signal of one flip-flop is switched whereas on the other, it is not. In this condition coincident existence of two high voltage signals will occur at AND gate **53**.

If the actual drop rate is higher than the desired rate two successive impulses will appear on lines **34**, **42** prior to generation of an impulse on lines **39**, **33**. Successive pulses applied to line **34**, however, will not cause a transfer of the high state from line **35** to line **36** for flip-flop **32**, whereas successive pulses on line **42** will cause such a transfer from line **43** to **44**. Thus, coincident existence of the high state signals will occur at AND gate **52**. Accordingly, in either event circuit **54** is conditioned so as to deactivate the valve means and terminate delivery of liquid.

After arresting the feeding of liquid through tube **21**, as caused by any rate disparity, the system is reset to re-establish a proper in-phase relation between flip-flops **32**, **37** and reset circuit **54**.

Thus, means are provided whereby upon actuation of the alarm disconnect relay circuit **47**, switch means **32** and **37** are both reset to re-establish their predetermined phase relationship. Circuit **47** is provided with an output line **63** operatively coupled to actuate a reset circuit **62**. Circuit **62** includes a pair of output leads **64**, **65** coupled to respectively reset the alarm flip-flop **37** and the main drive flip-flop **32**.

While conventional circuits can be employed in the various boxes referred to above, FIGURES 2 and 3, when taken together provide a preferred operable embodiment of the system when taken with the component values and designations shown on the drawing.

For ease in correlating the system taught in FIGURE 1 to the schematic circuit diagram of FIGURES 2 and 3, phantom lines have been used which somewhat generally enclose the elements thereof in the latter and have been given corresponding reference numerals.

Thus, the amplifier and filter circuit **49** is comprised of an RC coupled transistor fed from the photoresponsive device **17**. The one-shot mono-stable multivibrator **51** includes a pair of transistors of opposite conductivity type whreein the emitter of one includes a pair of diodes poled in a common direction.

Main drive flip-flop **32** includes two transistors wherein the collector of one is fed back to the base electrode of the other. Separate input signals are received to "set" and "reset" the device as in the well-known Eccles-Jordan trigger. Thus, flip-flop **32** is diode coupled to receive, and be "reset" by, pulses or step functions via line **34** defining the actual drop rate. Flip-flop **32** is "set" by pulses or step functions on line **33** which indicate the desired drop rate developed by pulse generator **31**.

Pulse generator **31** includes the unijunction transistor wherein the control electrode is coupled to a junction between a series of three resistors and a relatively large capacitance formed by a pair of parallel condensers which serve to establish the pulse rate when the resistors are varied.

OR gate **41** includes a conventional arrangement of the two diodes shown wherein a signal on either line **39** or **42** will be fed out on line **38** from the junction between the diodes. The alarm flip-flop **37** is a conventional "complementary" flip-flop wherein a single input receives a succession of signals. Each signal received serves to switch the device from one stable state to the other. Thus, since signals are passed to flip-flop **37** via OR gate **41** from either the desired or actual pulse rate generator circuits without ability to distinguish one from the other, its state can be compared with the state of flip-flop **32** by means of AND gates **52, 53.**

AND gates **52, 53** each include a pair of diodes arranged as is well known.

Circuit **54** provides a flip-flop circuit employing a pair of transistors. The output from circuit **54**, when disparity in the phase relation between flip-flops **32** and **37** has been sensed, serves to de-energize a normally energized relay coil **74** in circuit **47**. When the coil **74** is de-energized an armature **71** is spring-transferred to open-circuit the solenoid coil **25** of the valve operating solenoid. At the same time, (−) V1 is applied to lead **63** so as to cause reset circuit **62** to "reset" both flip-flops **32, 37.**

Circuit **62** includes the two diodes poled in a normally non-conducting direction. Transfer of armature **71**, however, serves to bias them into conduction to apply a reset function to the base (control) electrodes of one side of each flip-flop **32, 37.** Thus, an initial predetermined "reset" phase relation is established.

Circuit **45** is Zener diode coupled by diode **72** to flip-flop **32** and includes a conventional two stage transistor amplifier circuit with the collector of the second stage directly coupled to solenoid coil **25**.

A manually operated switch **73**, when positioned to the "off" position serves to de-energize the holding coil **74**. Another position of switch **73** serves to permit pulse generator **31** to start dispensing drops while the system becomes adjusted, before implementing the drop arresting control portion of the circuit.

A circuit with the component values and voltages shown was constructed and operated.

Thus, there is provided an improved system for the controlled feeding and monitoring of drops of liquid. Drops are fed by gravity at an accurate rate established by an impulse generator whereby an intended selected rate can be established. If the rate sought varies from the selected rate, the system manifests this disparity by a visual signal and shuts itself off. The system is relatively fail safe, since if power fails, the intravenous feeding tube will be immediately pinched closed.

We claim:

1. In apparatus for delivering a series of drops of liquid, means defining a selected drop rate, means controlling delivery of the drops responsive to the first named means, means serving to sense each drop to be delivered and define the actual drop rate, and means serving to detect disparity between said rates and condition said means controlling delivery of the drops to arrest further delivery of drops.

2. In apparatus for delivering a series of drops of liquid, valve means operable in one condition to pass a drop of the liquid to be delivered and operable in another condition to arrest the delivery of a drop of the liquid, first pulse generator means serving to provide a series of first pulses at a selected rate, second pulse generator means sensing each drop of fluid to be delivered and serving to generate a second pulse in response thereto, first and second bi-stable switch means each operatively coupled to receive and respond to receipt of said first and second pulses to change the state of both said switch means and maintain the states of same in a predetermined phase relationship, and means serving to indicate a change in said relationship.

3. Apparatus according to claim **2** wherein the last named means is operatively responsive to a change in said relationship and coupled to condition said valve to the last named condition thereof.

4. In apparatus for delivering a series of drops of liquid, valve means operable in one condition to pass a drop of the liquid to be delivered and operable in another condition to arrest the delivery of a drop of the liquid, first pulse generator means serving to provide a series of first pulses at a selected rate, second pulse generator means sensing each drop of fluid to be delivered and serving to generate a second pulse in response thereto, first and second bi-stable switch means each operatively coupled to receive and respond to receipt of said first and second pulses to change the state of both said switch means and maintain the states of same in a predetermined phase relationship, said first bi-stable switch means including a pair of input connections respectively coupled to receive said first and second pulses, said second bi-stable switch means having a single input connection operatively coupled to receive both said first and second pulses, and means serving to sense a change in said relationship and condition said valve to the last named condition thereof.

5. An apparatus for delivering a series of drops of liquid, valve means operable in one condition to pass a drop of liquid to be delivered and operable in another condition to arrest the delivery of a drop of the liquid, first pulse generator means serving to provide a series of first pulses at a selected rate, second pulse generator means sensing each drop of liquid to be delivered and serving to generate a second pulse in response thereto, first and second bi-stable switch means each operatively coupled to respond to receipt of said first and second pulses to change the state of both, said first and second pulse generator means being operatively coupled to direct their respective pulses to switch both said first and second switch means from one state thereof to the other in a predetermined phase relationship and means serving to sense a change in said relationship and condition said valve to the last named condition thereof.

6. In apparatus for delivering a series of drops of liquid, first pulse generator means serving to provide a series of first pulses at a selected rate, second pulse generator means sensing each drop of liquid to be delivered and serving to generate a second pulse in response thereto, first and second bi-stable switch means each operatively coupled to respond to receipt of said first and second pulses to switch the state of both said switch means to maintain the states of each in a predetermined phase relationship, means for sensing said phase relation and for detecting a change therein, and means operatively coupled to register the existence of such a change.

7. Apparatus according to claim **2** wherein said valve means is disposed to normally establish the last named condition and to establish the first named condition only so long as the phase relationship is maintained thereby requiring said phase relationship to exist in order to deliver liquid.

8. Apparatus according to claim 2 further including reset means to initially establish said phase relationship.

9. Apparatus according to claim 2 wherein said second pulse generator means develops a pulse of a predetermined timed duration.

10. In apparatus for delivering a series of drops of liquid, valve means operable in one condition to pass a drop of the liquid to be delivered and operable in another condition to arrest the delivery of a drop of the liquid, first pulse generator means serving to provide a series of first pulses at a selected rate, second pulse generator means sensing each drop of liquid to be delivered and serving to generate a second pulse in response thereto, first and second bi-stable switch means each operatively coupled to respond to receipt of said first and second pulses to change the state of both, each said bi-stable switch means serving to develop a signal representing one of the two states thereof, said signal from said first bi-stable switch means being operatively coupled to condition said valve means to the first named condition, said first and second pulse generator means being operatively coupled to direct their respective pulses to switch both said first and second switch means from one state thereof to the other in a predetermined phase relationship, means serving to sense a change in said relationship and condition said valve to the last named condition, the last named means including disparity manifesting means to be operated in response to a change in said phase relationship and serving to condition said valve to the last named condition thereof, a first and second AND gate, each of said switch means having two output channels coupled respectively to each AND gate to transmit said signal of each switch means alternately to one or the other of the AND gates, each AND gate being operatively connected to operate said disparity manifesting means upon coincident receipt of both said signals.

11. Apparatus according to claim 10 wherein said first pulse generator means is operatively coupled via said first switch means to condition said valve to the first named condition to deliver drops of liquid in response to said series of first pulses.

12. In apparatus for delivering a series of drops of liquid, first pulse generator means serving to provide a series of first pulses at a selected rate, second pulse generator means sensing each drop of liquid to be delivered and serving to generate a second pulse in response thereto, means serving to feed discrete drops of liquid along a path for delivery, first and second bi-stable switch means disposed to be alternately driven between two stable states by alternate receipt of said first and second pulses to maintain an in-phase relationship, each switch means including a pair of output channels to carry a given signal on one or the other dependent upon the state thereof, one of the output channels from said first switch means being coupled to condition the feeding means to feed liquid for delivery, and first and second AND gates, each coupled to both said switch means to normally receive said signal from only one of said switch means, and means to register coincident receipt of said signals at either of said AND gates thereby indicating a change in the phase relation of said first and second switch means.

13. Apparatus according to claim 12 wherein the last named means serves to condition the feeding means to terminate delivery of liquid.

References Cited by the Examiner

UNITED STATES PATENTS

2,672,581	3/54	Gorham	222—55 X
3,042,258	7/62	Mayes	222—76 X

RAPHAEL M. LUPO, *Primary Examiner.*

HADD S. LANE, *Examiner.*