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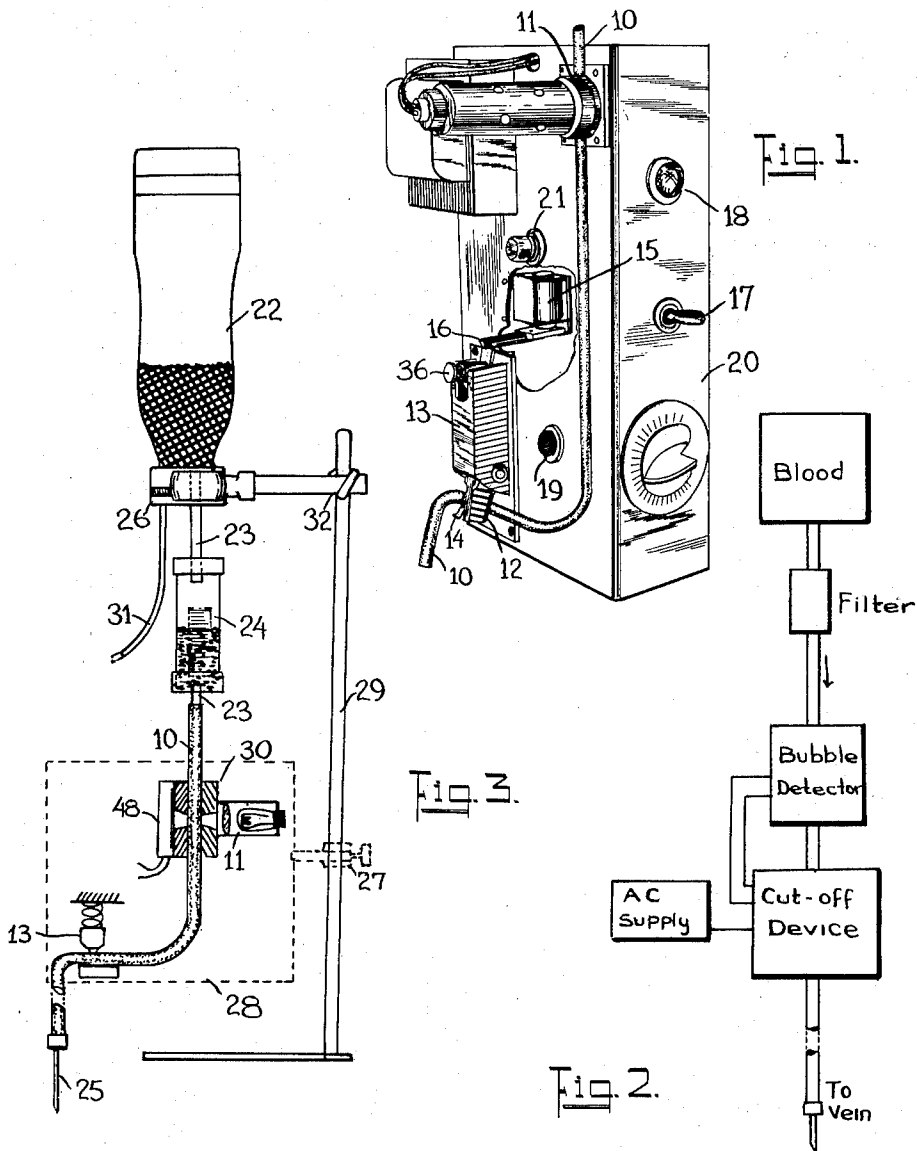
S. B. MAUCHEL

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MONITOR APPARATUS FOR BLOOD TRANSFUSIONS

Filed June 6, 1955

2 Sheets-Sheet 1



INVENTOR
S. B. MAUCHEL
by *W. J. Meredith*
Patent Attorney

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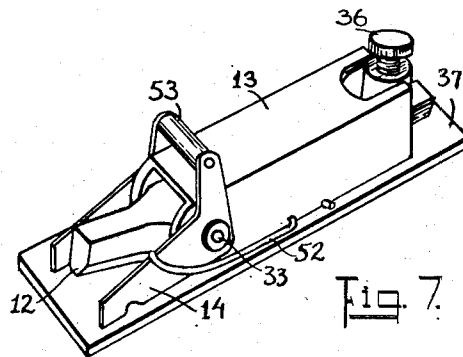
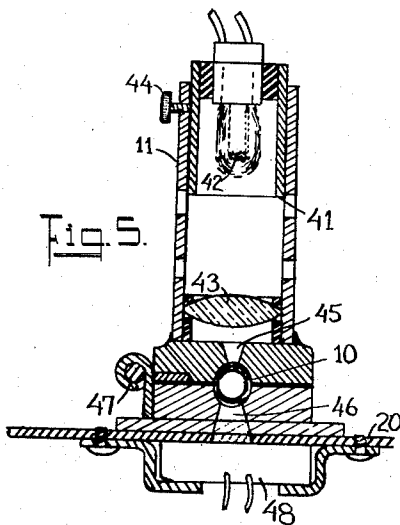
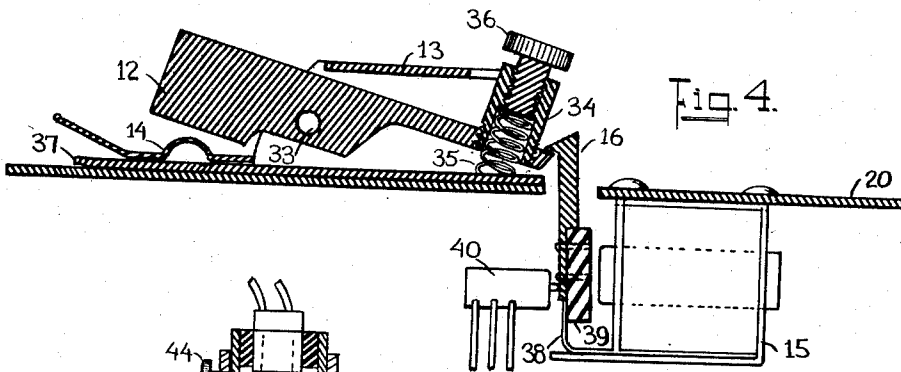
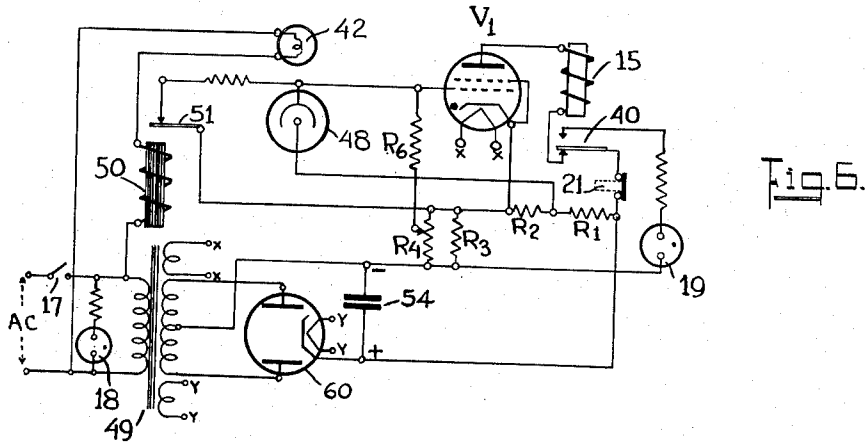
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INVENTOR
S.B. MAUCHEL
by *W.R. Maudslayi*
Patent Attorney

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MONITOR APPARATUS FOR BLOOD TRANSFUSIONS

Sydney Bertram Mauchel, Saskatoon, Saskatchewan, Canada, assignor of one-half to James B. McFadyen, Monrovia, Calif.

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5 Claims. (Cl. 128—214)

This invention concerns a system for automatic monitoring of flow of fluid administered from a container via a delivery tube into the circulatory system of a subject, and in particular relates to apparatus for and method of carrying out an intravenous transfusion incorporating means for guarding against introducing air or gas bubbles into a vein of the recipient.

It is essential in carrying out a transfusion of any fluid into the arterial system of a subject that gas or air be prevented from entering, since even very small amounts of air in the blood vessels may give rise to a gas embolism which would be fatal. Whenever a body fluid such as whole blood is to be administered from a source as a blood bottle, a certain amount of froth is almost inevitably developed at the interface between air occupying the space above the blood and the blood volume, so that as the contents flow into the delivery tube there is an ever present possibility that some of the small bubbles may become entrained with the blood and carried into the subject's arterial system.

In certain circumstances sterile air is applied under pressure to give a positive pressure in the flask in addition to the usual gravity head provided to urge the flow, and the entry of such air bubbling through part of the blood volume tends to entrain small bubbles in the fluid.

It may be stated generally that the concept of filtering and trapping undesirable gas occlusions or other matter at some point along the flow path of a fluid in a transfusion is one that is old in the art. Many of the devices realized heretofore have relied on the separation of the bubbles entrained by providing a trap chamber, wherein the velocity of flow is arranged to be slow and a gravity separation clears at least the larger bubbles. Devices of this sort have included baffles and similar features for deflecting bubbles to assist them to rise to the surface of the trap volume. Notwithstanding the efficacy of such apparatus there is inevitably a longer set-up time, more items to be cleaned and sterilized, and waste of some fluid in the trap. Furthermore attention must always be given to such additional equipment otherwise a gas occlusion could conceivably arise if the trap drains below a certain level.

Inasmuch as transfusion apparatus of known type and widely in use comprises a length of delivery tube associated with which are a filter and the connectors whereby it may be attached to a blood bottle at one end and to a blood needle at the other, the use of a trap has obvious disadvantages. According to this invention, the flow in such delivery tube is monitored externally thereof and without requiring any connections, by an automatic guard whereby even very minute bubbles may be detected and the flow arrested, such method representing a decided simplification and improvement in reliability over gravity type traps.

It is therefore an object of the invention to provide a means for monitoring the flow continuously and automatically by a sensing device including a photoelectric cell and a source of light so arranged as to detect any

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change in opacity of the fluid passing through a test portion of the delivery tube between the light source and the photoelectric device.

The invention also provides a flow arresting device which is positive and simple in its operation and which may be tripped from a latched position in response to the detection of a predetermined reduction of opacity of the fluid, signifying the presence of an occluded or entrained volume of gas, to arrest the flow by clamping the tube downstream of the detection point.

It is also an object of the invention to provide apparatus for arresting the flow and holding such arrested condition until such time as an attendant has cleared the gas bubbles to a safe condition and then taken deliberate steps to restore the flow by re-latching the arresting device.

Still another object of the invention is the provision of a novel and simple analyzer into which a portion of the length of delivery tube of a transfusion apparatus may be placed or from which it may be removed with a minimum of handling.

A further object of the present invention is the provision of a control whereby the sensitivity of the analyzer may be adjusted.

Yet another object is the realization of a simple safety device whereby failure of the lamp in the analyzer or failure of the A. C. power supply arrests the flow of the fluid.

Referring to the drawings, Fig. 1 is a perspective view of the external appearance of the monitor, with arresting, indicating, and control elements together with a length of delivery tube in use;

Fig. 2 is a schematic block diagram of the disposition of units in their functional inter-relationship;

Fig. 3 is a generalized layout diagram of the monitor in use;

Fig. 4 is an elevation view in cross-section showing the flow-arresting clamp in latched position, and the tripping relay;

Fig. 5 shows a cross-section in elevation of the analyzer assembly comprising a housing, lamp, lens, and photoelectric tube;

Fig. 6 is an electrical schematic diagram of the circuit of the analyzer and the fail-safe lamp circuit; and

Fig. 7 is a perspective view of the flow-arresting unit fitted with a dual-finger retainer for the delivery tube.

In Fig. 1 there is shown a complete assembled guard device in a form as it would be used in a location such as an emergency ward, hospital operating room, or laboratory. A section of the clear plastic delivery tube 10 is shown in position, leading from a supply of blood or other body fluid (not shown) to be administered intravenously. The tube passes through an analyzer housing 11 into which it is inserted by tipping the housing sideways about a hinge (shown in Fig. 5) and laying the tube into a groove. The further portion of the tube is passed under the jaw or pinch 12 of a clamp unit designated generally as 13 and is restrained by a spring finger 14 on the downstream side of the jaw. Alternatively, a dual-finger retainer 14 may be employed, as shown in Fig. 7, normally biased against plate 37 by spring 52, and actuated by handle 53. A tripping relay 15 is shown in its relationship with the latch 16 of the clamp. A supply control switch 17 is provided at the side of chassis 20, while a pilot lamp 18 of distinctive colour is also mounted on the side to provide visible indication of the energization of the apparatus. A warning lamp 19 is mounted on the face of the chassis for the purpose of indicating visually the tripping of the latching relay. A reset button 21 is provided, whose function will be made evident as the description proceeds.

In Figs. 2 and 3, a body fluid supply, here indicated as

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whole blood in blood bottle 22 of standard design, is administered by intravenous injection through a delivery tube 10 comprising the usual connectors 23 which may be glass or plastic, a filter 24, and a needle 25. It is to be understood that such assembly represents a standard kit packaged as sterile transfusion equipment already assembled, requiring only to be attached to the blood bottle through the cap 26. The monitor of Fig. 1 is located along the delivery tube, preferably as near as possible to filter element 24, and held in position as shown by the dashed outline 28 by clamp 27 supported on upright of stand 29. This monitor includes photocell 48 and housing 11 containing the light source incorporating filament 42. The stand will also be used to support clamp 32 by which the blood bottle is held. The delivery tube is passed through the analyzer unit 30 and under the jaw of pinch 12, the remainder of the tube, ordinarily some feet in length, being disposed in any manner convenient for the type of transfusion to be effected. A pressure tube 31 through which sterile air or a suitable gas under pressure may be applied to assist discharge of the contents is led into the bottle through the cap 26.

Referring to Fig. 4, the arrangement of elements forming the flow arresting unit will be described in detail. A pinch 12 extending beyond a housing 13 forms one end of a lever arm which pivots about axis 33, the other end of the lever arm carrying a spring retaining tube 34 into which is threaded an adjusting device 36. Spring 35 is adjustably compressed by turning thumbscrew 36 to produce a biasing force tending to close the jaw or pinch 12 against the base plate 37 of the housing. A latch device 16 normally holds the lever in the cocked position, the spring 38 and relay 15 tending to hold the latch engaged. When the winding of relay 15 supported on chassis 20 is energized by the application of voltage the armature member 39 is attracted to the core and thereby moves the latch 16 out of engagement with the lever arm, which pinches the tube 10. The delivery tube is held in position under the jaw by being gripped under the bow or spring fingers 14.

A switch 40 which is preferably a single pole double throw micro-switch is arranged to be opened when the relay operates and to transfer a circuit from one contact to the other.

The analyzer unit, shown in cross section in Fig. 5, comprises a ventilated lamp housing 11 and a tube 41 slidably positionable therein, for the purpose of adjusting the distance between the lamp filament 42 and lens 43. A set screw 44 may be employed to retain the tube in desired position. The analyzer includes a light gate, arranged in the form of collimating discs having apertures 45, 46, and opposed semi-cylindrical grooves diametrically of the discs, to provide a cylindrical space for receiving tube 10. A hinge joint 47 is provided between the discs to permit the housing 11 to be swung into an open position, thereby enabling the tube 10 to be laid into the groove. A suitable spring device is incorporated in any manner to tend normally to hold the light gate in closed position. The lower collimating disc is secured to the chassis 20, in registry with an aperture therein. A photoelectric detector device 48 which may preferably be a phototube is mounted on the under side of the chassis 20 in light receiving relation with the collimating apertures of the light gate.

When lamp filament 42 is at incandescence, light shines on a short length of the tube in the light gate. Normally the phototube receives negligible light when blood fills the delivery tube, but the presence of a small bubble of gas decreases the opacity and therefore increases the amount of light incident on the phototube. The action of the monitor when such condition is detected will now be described in detail with reference to Fig. 6. A. C.

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supply is applied to the primary of a transformer 49 through an "on-off" switch 17, and energizes neon lamp 18, as well as heating lamp filament 42 which is in series with a low voltage A. C. relay 50. The secondary voltage of transformer 49 is rectified by full wave rectifier tube 60 and filtered by condenser 54. While the lamp current is flowing, the moving contact 51 is held open, thereby holding off positive bias from the grid of the gas tube V1. Positive direct voltage is applied to the anode of phototube 48 in series circuit with resistance R6, from a voltage divider network comprising R1, R2 in series with the parallel combination of fixed resistance R3 and variable unit R4. When the phototube detects an increase of incident illumination, the grid bias of V1 is reduced, depending on the setting of control R4, and at a chosen threshold value will cause the gas trigger tube to fire. Relay 15 thereupon has its winding energized and trips the latch 16, causing flow in tube 10 to be shut off rapidly, before the bubble or other disturbing occlusion has appreciably passed out of the light gate. Switch 40 now transfers the D. C. positive supply voltage from the relay 15 to the warning lamp 19.

As the relay core field weakens the armature falls back, operating switch 40 and re-energizing the gas tube, the cycle repeating as long as the bubble or other disturbing occlusion remains in the light gate. The operator thereupon will take steps to clear the bubble. One method which may be resorted to is to apply pressure to the blood tube 10 at a point close to the pinch 12, and to squeeze the contents back through the light gate by sliding a finger along to collapse the tube against the chassis 20 up to the exit side of the housing 11. This will return the bubble into the filter 24 where it may collapse or float out of the active stream or otherwise be rendered harmless. Should it be desirable to flush the tube free of blood or fluid in which gas bubbles may be entrained, the operator has merely to hold the button 36 down while the contents are discharged through the needle into waste.

To reset the monitor after the tube above the pinch has been cleared of any foreign matter other than fluid, the reset button 21 is pressed to ensure that the gas trigger is not in circuit for the purpose of de-ionizing the space discharge whereby the grid circuit is restored to control. The control potentiometer R4 is turned up until the gas tube fires with the photocell dark, then the potentiometer R4 is backed off slightly to a setting at which the tube V1 does not fire with the tube in the light gate filled with blood. The reset button is pressed to restore grid control of V1, and the pinch 12 is latched in cocked position, whereupon transfusion may be allowed to proceed. This control in practice should not require the resetting outlined unless it has been disturbed. If the instrument has been in operation for a long time, it may be advisable to check the setting in the manner described.

In the event that the circuit to lamp filament 42 should inadvertently become open, which would make the monitor unsafe by making the analyzer insensitive, the release of relay 50 closes the moving contact 51 against the stationary contact, and in effect reduces the negative bias on the control grid of V1. By a suitable choice of constants this reduction effects the firing of the tube and arrests the flow. Should the A. C. power supply fail during the use of the monitor, relay 50 rapidly releases, thus closing contacts 51, which will fire V1 due to the charge stored in the main high-voltage filter condenser 54.

Fluids more transparent or less opaque than blood, such as plasma, glucose, and other fluids capable of being administered intravenously may also be monitored by the device. In such case the change in opacity can be rendered more easily detectable when a bubble enters the light gate, by adding a harmless coloring material, or employing a polarizing filter and analyzer on opposite sides of the delivery tube in the light path.

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In one successful installation the following components were employed:

Tube V1-----	Type 2D21 "Thyratron."
P. E. cell 48-----	Type 927 phototube.
Lamps 18, 19-----	Type NE 51 neon.
R1-----	13 kilohms.
R2, R3, R4-----	10 kilohms each.
RG-----	10 megohms.
D. C. rectifier output-----	250 volts.

I claim:

1. In a monitor of flow of fluid in a delivery tube, control apparatus responsive to detection of the presence of gas bubbles in the fluid and effective to arrest the flow thereupon, comprising an analyzer adapted to have a portion of the length of the tube passed therethrough, a source of light, a collimating aperture disposed adjacent said length of tube to direct incidence of light upon an exterior wall area thereof, a photocell disposed to receive such light as is transmitted through the fluid from said source, a spring-biased clamp located downstream of the analyzer having a jaw actuatable between a cocked or open position and a tripped or closed position, said clamp being adapted to be held in the open position by a latch, a retaining finger associated with the clamp for positioning the tube in the line of action of the jaw, a solenoid having an armature, a detent carried thereby and cooperating with the latch to restrain closing of the jaw when the solenoid is de-energized, and means responsive to detection by said photocell of an increase in light transmitted through the fluid in the analyzer to energize the solenoid and to trip the said latch.

2. In a body fluid injection system, control apparatus effective in response to the detection of gas bubbles in a delivery tube for said fluid to arrest the flow, comprising a spring-biased clamp whereof a jaw is actuatable between a cocked or open position and a tripped or closed position, a support for a portion of the delivery tube passing through the clamp to position said tube in the line of action of the jaw whereby said tube will be squeezed when the clamp is closed, a latch carried by the clamp, a solenoid having a winding, and an armature co-operating with the latch, said armature being actuatable between a rest position corresponding to the de-energized condition of said winding at which said latch is effective to prevent closing of the jaw of the clamp when cocked, and an alternate position corresponding to the energized condition of said winding in which the latch is released to allow the clamp to squeeze the tube and arrest the flow, an analyzer comprising a source of light and a photocell disposed on opposite sides of a transparent portion of the flow path upstream of the clamp,

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whereby the photocell is subjected to light transmitted through the fluid from the source, and means responsive to detection by said photocell of a decrease in opacity of the fluid in the delivery tube within the analyzer to cause energization of the winding of the solenoid.

3. Apparatus as in claim 2, wherein the means causing the energization of the winding includes a thyratron having the solenoid winding in the anode circuit thereof, and the photocell is in circuit relation with the control grid whereby detection of a predetermined increase of light transmitted through the fluid causes the biasing of the control grid to a potential at which the thyratron fires.

4. In a monitor for detecting decrease in the opacity of fluid in a flow tube, an analyzer comprising a housing, a light source within the housing, a tunnel space through the housing adapted to receive a test length of said flow tube, a collimating aperture in the tunnel wall between the light source and the space occupied by said test length, a photocell disposed in light-receiving relation with a second aperture in the tunnel wall diametrically opposite of the collimating aperture whereby to detect light transmitted through the fluid, a space discharge device having an ionizable filling medium and including at least a control grid and an anode, said control grid being associated with circuit means determining the potential of said grid, said means including the said photocell in circuit with an electrical supply and effective in response to detection of a predetermined increase in light transmitted to condition the potential of said grid to fire the device, an anode load circuit comprising a solenoid winding adapted to be energized upon ionization of the device, a spring-biased clamp normally closed and located downstream of the analyzer along the tube, a length of flow tube disposed within the clamp, a latch carried by the clamp, a detent associated with the latch and effective in a latching position to hold the clamp open and in a release position to permit the clamp to close, and an armature supporting the detent, said armature being actuatable between a de-energized and an energized position by said solenoid to move the detent to latching and release positions respectively.

5. The monitor of claim 4 further including, in the circuit means determining the potential of the grid, a relay arranged to be energized together with the source of light from an electrical supply, a switch actuated by the relay in the energized state to a first condition to render the photocell effective to control the potential of the said grid, and actuated to an alternate condition when the relay is in deenergized state to substitute at said control grid a positive potential tending to fire the space discharge device.

No references cited.