

[54] **AIR EMBOLI DETECTOR**

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[56] **References Cited**

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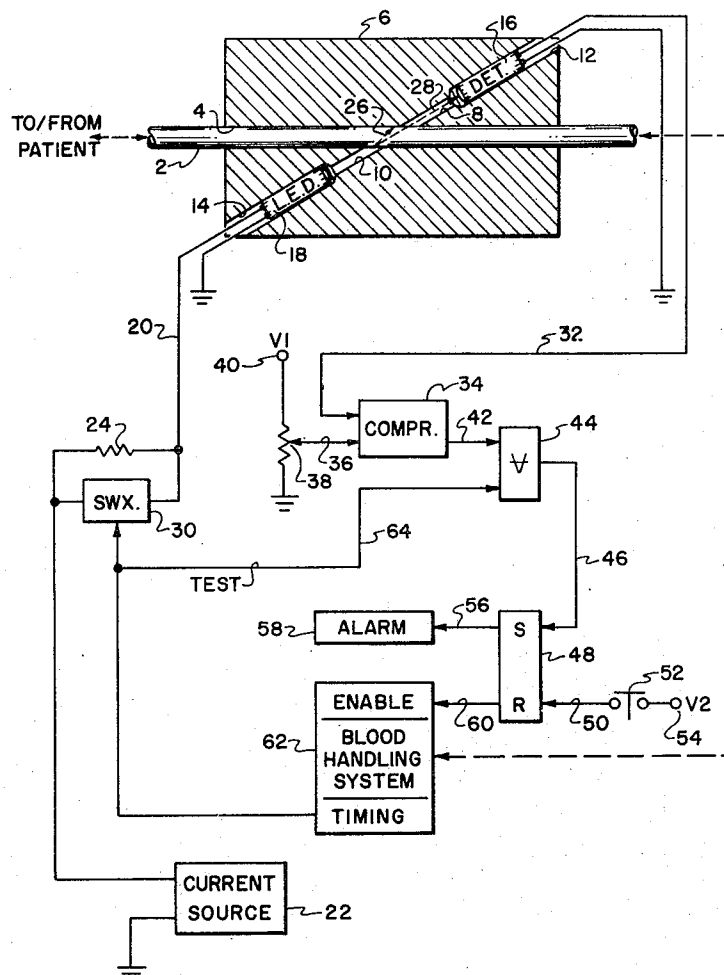
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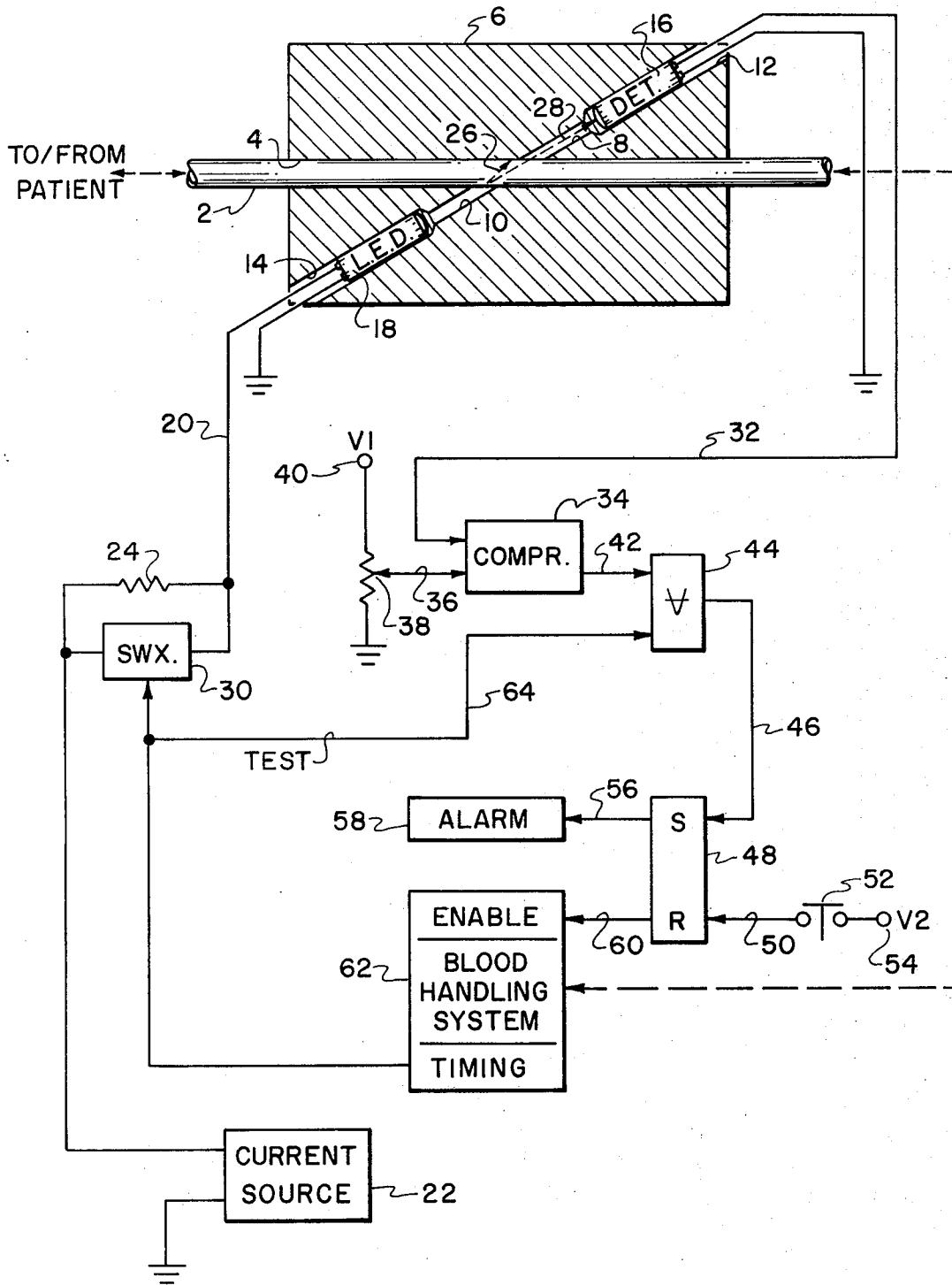
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ABSTRACT

A light emitting diode and a photodetector are disposed on opposite ends of an optical path oriented at an angle with respect to a substantially transparent blood conduit, such as clear plastic tubing. Liquid, such as blood or saline, whether opaque or clear, flowing in the tubing refracts the light emitted by the diode out of the straight optical path so that only an insignificant portion thereof reaches the detector, but gas, such as air emboli, due to lower indexes of refraction than liquids, hardly refracts the light, so that a significant portion reaches the optical detector. An output of the optical detector in excess of a settable threshold causes an alarm and a disablement of the blood handling system. The optical system is tested with liquid in the tubing by over-driving the light emitting diode so that, despite defraction, sufficient light should reach the detector to cause it to provide an output equivalent to the output it would normally have when detecting gas in the tubing with the light emitting diode driven in a normal manner.

7 Claims, 1 Drawing Figure





AIR EMBOLI DETECTOR

BACKGROUND

1. Field of Invention

This invention relates to an improved air emboli detector employing optical defraction.

2. Prior Art

Recent advances in technology include an automated blood analysis system which is disclosed and claimed in a commonly owned copending U.S. Pat. application of Justin S. Clark and Lloyd George Veasy, Ser. No. 319,561, Filed on Dec. 29, 1972, and entitled AUTOMATED BLOOD ANALYSIS SYSTEM. In such a system, the health and safety of a patient is paramount. Such systems employ sources of fluids, such as irrigation fluids and pumping fluids (which may comprise saline solutions), and include pumps, valves and conduits (such as tubing). As a result, it is possible, at times, that small amounts of air may enter the system and form bubbles in any of the system fluids, which may be transferred to blood moving in the system, or may directly form as air emboli within the blood. Depending on the particular function being performed, it is not uncommon for such systems to frequently return a certain portion of blood to the patient, or to infuse other solutions into the patient. As is known, air emboli can be extremely dangerous in a patient, particularly when the patient is very sick, and more particularly in the case of premature or sick newborn infants.

It is therefore desirable to provide automatically operated means for detecting the presence of air emboli in blood, or air bubbles in other solutions in a blood handling system. However, such a system must distinguish between gases and liquids as such, and therefore clear fluids (such as saline) must cause a response which is similar to the response caused by opaque fluids (such as blood), and must cause a response which is different from the response caused by clear gases (such as air). In addition, it is necessary that the patient be well protected, and that the blood or other fluids be isolated from any electrical means utilized in such a system.

BRIEF SUMMARY AND OBJECTS OF INVENTION

The object of the present invention is to provide an improved air emboli detector.

According to the present invention, light is transmitted at an angle through a substantially clear fluid conduit to an optical detector, the presence of liquid in the conduit defracting the light from reaching the detector, the presence of gas in the conduit causing the light to pass substantially straight through the conduit to the detector. In accordance further with the present invention, the output of an optical detector in such a system is compared with a threshold, and an excess of optical detector output comprises an alarm condition; the alarm condition may be signaled, and may in addition be utilized to disable the related blood handling system. In still further accord with the present invention, an optical air emboli detector which senses the presence of gas by a lack of defraction of light passing through a conduit from a light emitter to an optical detector is tested with liquid in the conduit by over-driving the light emitter sufficiently for reflected light to generate a significant output from the optical detector.

The present invention provides optical isolation of blood and other fluids being tested for air emboli and bubbles from electric circuitry related therewith. The invention treats liquids as being proper, whether they are clear or opaque, and treats gases as being different than liquids. The invention is simple to implement, and is readily configured utilizing technology and components which are readily available in the market. The invention permits checking of a gas detector without necessitating the presence of gas in the conduit to be monitored.

Other objects, features and advantages of the present invention will become more apparent in light of the following detailed description of a preferred embodiment thereof, as illustrated in the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

The sole FIGURE herein comprises a simplified schematic block diagram of one embodiment of an air emboli detector according to the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENT

Referring to the drawing, a fluid conduit such as a tube 2 (which might comprise clear plastic tubing) of a relatively small bore (on the order of 35 mils) is disposed within a bore 4 of a block 6. A second bore passes through the bore 4 so as to form a pair of optical paths 8, 10 on either side of and at an angle with respect to the bore 4. Each of the bores 8, 10 is bored out to a larger diameter at either end thereof so as to form receptacles 12, 14 for an optical detector 16 and a light emitting diode 18. The light emitting diode (LED) 18 may emit infrared light, or electromagnetic radiation at any suitable wave length, and the detector 16 may comprise any incoherent optical detector operative over a wave length including that of the diode 18. As an example, the light emitting diode may be that sold under the trade designation Monsanto ME4; similarly, the detector may be that sold under the trade designation Fairchild 2175.

The light emitting diode 18 is driven by current supplied on a line 20 from a suitable source of current 22 through a resistor 24. In normal operation, the current may be on the order of 100 milliamperes. In such a case, the intensity of electromagnetic radiation emitted by the diode 18 is such that when there is liquid (which has a higher index of refraction) within the tube 2, the light is defracted as indicated by the arrow 26 so that an appreciably reduced amount of it reaches the optical detector 16. Thus, the detector 16 will have substantially reduced output when there is blood, saline, or other liquid within the tubing 2. on the other hand, with normal excitation of the LED 18, should there be a bubble of gas, which is of a size on the same order of magnitude as the diameter of the bore of the tubing 2, present between the optical paths 8, 10, it will not appreciably defract the light beam so that it will pass directly into the optical path 8 and to the detector 16 as indicated by the dashed arrow 28.

The resistor 24, however, is shunted by a selectively operable switch 30 which may comprise a field effect transistor and which, when operated, shorts out the resistor 24 so that the current source 22 will supply significantly greater current on the line 20 to the diode 18; for instance, currents on the order of 200 milliamperes may typically be provided when the switch 30 is oper-

ated. Under such a condition, even though there be liquid in the tubing 2, the intensity of light emitted by the diode 18 is sufficiently great that through deflection, a significant amount of light will activate the detector 16 so as to supply an output therefrom which is on the same order of magnitude as the output resulting from sensing of an air bubble with normal excitation.

The output of the photodetector is applied by a line 32 to a compare circuit 34, the other input to which comprises a line 36 from a suitable source of a threshold or other reference potential, such as a potentiometer 38 attached to a suitable source of voltage (V1) 40. The wiper of the potentiometer 38, together with choice of the magnitude of voltage at the source 40, can be adjusted to provide a voltage on the line 36 equivalent to an output of the detector 16 which represents the amount of light received at the detector 16 expected in response to an air emboli within the liquid in the tubing 2. The compare circuit 34 may comprise any suitable circuit such as, for example, that shown in U.S. Pat. No. 2,851,638 wherein there is a voltage source (22) and a potentiometer (21) equivalent to the source 40 and potentiometer 38 herein. In such a case, the compare circuit 34 provides an output signal on a line 42 which passes through an EXCLUSIVE OR circuit 44, the output of which on the line 46 will register an alarm condition in a suitable device such as a bistable device 48. The bistable device 48 may comprise any suitable circuit such as, for example, that shown in U.S. Pat. No. 3,588,545. The EXCLUSIVE OR circuit 44 may comprise any suitable circuit such as that shown, for instance, in U.S. Pat. No. 3,384,759. The bistable device 48 is set by a signal on the line 46, and may be reset by a signal on a line 50 in response to any suitable means, such as a manually operable push button or other momentary contact switch 52 connected to a suitable voltage source (V2) 54. When set, the bistable device 48 provides a signal on a line 56 which may actuate a suitable alarm signaling device 58; when reset, the bistable device 48 provides a condition on a line 60 which may provide an enabling input to the blood handling system 62 with which the air emboli detector of the present invention is associated. The blood handling system 62 may include timing means for providing a test signal on a line 64, which is utilized to actuate the switch 30 thereby to over-drive the LED 18 for testing of the air emboli detector as described hereinbefore, and for also applying the test signal on the line 64 to a second input of the EXCLUSIVE OR circuit 44. Thus, when the diode 18 is overdriven as a result of operation of the switch 30 during a test of the air emboli detector, the optical detector 16 is supposed to provide a suitable output signal, so that the compare circuit 34 will provide an output on the line 42. If it does, then there is currently two inputs to the EXCLUSIVE OR circuit 44 so there will be no output therefrom on the line 46 and the alarm condition registering bistable 48 will not be operated. On the other hand, if there is an insufficient output from the optical detector 16, then there will be no output from the comparator 34, no signal on the line 42, so that the EXCLUSIVE OR circuit 44 will provide a signal on the line 46 to register an alarm condition in the bistable device 48. When the test signal is no longer present, the driving current on the line 20 to the diode 18 is again reduced, and, the test signal on the line 64 no longer being present at one input of the EXCLUSIVE OR circuit 44, then the operation of the compare

circuit 34 as a result of a large output from the optical detector 16 will pass through the EXCLUSIVE OR circuit so as to register an alarm condition in the bistable 48. Thus, no gas need be introduced into the system for test purposes.

The blood handling system 62 may comprise the Automated Blood Analysis System of the aforementioned copending application, or other systems. In the aforementioned copending application, the air emboli detector of the present invention is briefly disclosed in an embodiment differing somewhat from that herein, and in which the timing of the blood handling system is effected by a drum contact timer. However, it should be apparent that any sort of timing, or manual operation of a switch to cause testing of the air emboli detector may be utilized if desired.

Similarly, although the invention has been shown and described with respect to an illustrated embodiment thereof, it should be understood by those skilled in the art that the foregoing and various other changes and omissions in the form and detail thereof may be made therein without departing from the spirit and the scope of the invention.

Having thus described a typical embodiment of my invention, that which I claim as new and desire to secure by Letters Patent is:

1. A system for detecting gas bubbles in a liquid comprising:

an opaque block having first and second bores there-through intersecting each other at an angle;
a substantially translucent conduit for conducting a flow of liquid in which the presence of gas bubbles is to be detected, said conduit disposed in a first one of said bores;

a light emitter and an optical detector disposed at opposite ends of a substantially straight optical path within said second bore, said optical detector providing an output signal, the magnitude of which is a function of the intensity of light delivered thereto along said optical path, such that the presence of fluid in said conduit at the intersection therewith of said light path refracts light from said optical path, whereby said optical detector has an insignificant output;

means for exciting said light emitter;

a source of a reference signal; and

means for comparing the output signal of said optical detector with the reference signal of said source and for providing an alarm signal in response to the signal output of said optical detector being of a greater magnitude than said reference signal.

2. A system according to claim 1 and further comprising means responsive to said alarm signal for registering an alarm condition.

3. A system according to claim 2 further comprising: alarm signaling means responsive to said alarm registering means for signaling an alarm condition.

4. A system according to claim 2 wherein said alarm registering means comprises means settable in either of two states, said means when set in a first one of said states generating an enable signal indicative of the lack of an alarm condition, said means when set in the other of said states generating a signal indicating a registered alarm condition, said means being set in said second state by said alarm signal, and further comprising:
selectively operable means for setting said bistable means into said first state.

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5. A system according to claim 4 wherein said selectively operable means comprises a manually operable switch.

6. A system according to claim 1 wherein said means for exciting said light emitter comprises means for providing normal excitation to said light emitter, and selectively operable means for providing excitation to said light emitter which is significantly greater than normal, whereby said light emitter emits light of a given intensity normally, and emits light of intensity significantly greater than normal in response to the operation of said selectively operable means.

7. A system according to claim 6 including test means

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presenting a test manifestation which by its presence controls the testing of said system, said test manifestation connected to said selectively operable means for operating the same, thereby to increase the intensity of light emitted by said light emitter, and wherein said test means includes means responsive to said test manifestation in the absence of a signal from said compare circuit to generate said alarm signal and responsive to the presence of an output from said compare circuit in the absence of test manifestation to generate said alarm signal.

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