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(54) BLOOD LEAK DETECTOR

(71) We, TAKEDA YAKUHIN KOGYO KABUSHIKI KAISHA also known as TAKEDA CHEMICAL INDUSTRIES LTD. a Japanese corporation organised and existing under the laws of Japan, of 27, Doshomachi 2-chome, Highashi-ki, Osaka, Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to a blood leak detector. More particularly, it relates to a blood leak detector for detecting leakage of a trace of blood or blood pigment and as such is suited for coupling with artificial kidneys.

U.S. Patent Nos. 3,647,299 and 3,847,483, and Japanese Patent Disclosure No. 49-15493 disclose oximeters taking advantage of the principle that blood absorbs light. Blood leak detectors also employ the same principle. However, while oximeters measure blood in the blood vessels of a portion of the human body, for example, the ear, blood leak detectors serve to detect promptly small traces of blood in a measurement cell should leakage occur. Hence, blood leak detectors differ essentially from oximeters.

Japanese Patent Disclosure No. 48-46193 discloses a blood leak detector coupled with an artificial kidney. This prior art blood leak detector has two photo detecting elements, each provided with a filter of a separate colour characteristic, and since each signal from the respective photo detecting element is DC amplified by a separate circuit system, this prior detector is prone to suffer from such factors as difference in the circuit characteristics, leakage of light from the outside, level drift due to temperature fluctuation, and other factors, As a result, such a prior art blood detecting system is neither sufficiently stable nor highly sensitive.

Blood leak detectors must be capable of detecting blood at a very low concentration, diluted with a great quantity of dialysis solution, because blood is naturally precious to a patient undergoing medical treatment utilizing artificial kidneys and even a small trace of blood such as 5 ml cannot be overlooked. More particularly, since many dialysers in actual use today require about 200 l of dialysis solution and if 5 ml of blood leakage due to, for instance, the existence of a defective junction at the dialysis membranes is to be detected, blood leak detectors should be able to detect blood of a concentration as small as 0.0025% or below. Furthermore, blood leak detectors must of course operate stably for many hours, Another shortcoming to be noted of prior art blood leak detectors is that bubbles in the dialysis solution are often erroneously taken for a blood leak.

The present invention therefore seeks to provide a sensitive blood leak detector than can not only permit prompt detection of very small traces of blood of a concentration as low as 0.001% but also can operate stably over a long period of time, and which can distinguish blood from bubbles often appearing in the cell.

According to the present invention there is provided a blood leak detector which comprises: a cell having an inlet, an outlet and a passage therebetween for solution under test; light-emitting means for irradiating the cell, comprising a first light-emitting element essentially emitting at wavelengths at which blood pigment absorbs light and a second light-emitting element essentially emitting at longer wavelengths than the first light-emitting element; photo detecting means for receiving light from the elements transmitted through the cell; means for driving alternately the first light-emitting element and the second light-emitting element and means for discriminating between output signals of the photo detecting means to discriminate between a first state wherein the amount of transmitted light from the first light-emitting element is in equilibrium with that from the second light-emitting element, a second state wherein the amount of transmitted light from the first light-emitting element is less than that from the second light-emitting element, and a third state wherein the amount of the transmitted light from the second light-emitting element is less than that from the first light-emitting element.

The invention also provides a blood leak detector which comprise a transparent measurement cell through which dialysis solution under test can flow; composite light-emitting diodes for irradiating the measurement cell and having a first light-emitting diode which emits in the range of 520—600 nm and a second light-emitting diode which emits in the range of 600—750 nm; a photo detecting element to receive the light from from the light-emitting diodes transmitted through the measurement cell; means for driving the first and second light-emitting diodes alternately by means of a reference square wave signal; means for balancing the output signal of the photo detecting element due to the first light-emitting diode and the output signal of the photo detecting element due to the second ligh-emitting diode in the normal state in which no blood leak exists; and means for detecting deflection from the normal state whether resulting from change of the output signal of the photo detecting element due to the first light-emitting diode or from change of the output signal of the photo detecting element due to the second light-emitting diode.

Such leak detectors can be provided with an alarm device which gives an auditorily distinguishable warning which varies with the degree of the blood leak thus permitting immediate sensing of the extent of danger; there is thus no danger of overlooking a blood leak, which in some cases might be fatal to a patient, even if an operator does not keep his eye upon the meter panel.

Blood leak detectors in accordance with this invention can be used with a dialysis system for artificial kidneys and are particularly suited for home use. They can function so that blood supply to the dialyzer is cut off to prevent further leakage of blood when blood leak should happen, even if an operator is not at the bedside.

The present invention will now be described further by way of example with reference to the accompanying drawings, in which:

Fig. 1 is a vertical section of an optical portion of a blood leak detector embodying the invention as coupled to a schematic block diagram of electric circuits thereof;

Fig. 2 is a detailed block diagram of an electric circuit of a preferred embodiment of this invention;

Fig. 3 is a circuit diagram corresponding to Fig. 2;

Fig. 4 is a circuit diagram of an alternative emission driving circuit for use in the circuit of Fig. 2;

Fig. 5 A to J is a time chart illustrating examples of function performed by the optical portion of Fig. 1 and the circuit diagram of Fig. 3, the letters from A to J (except G and I) referring to the positions where signals are observed;

Fig. 6 is a perspective view illustrating the exterior of a blood leak detector of this invention;

Fig. 7 is a circuit diagram of an alarm device of a preferred embodiment of this invention;

Fig. 8 L, M and N are waveform charts illustrating examples of function of the circuit of Fig. 7, the letters L, M and N referring to different waveforms of audio alarm signals given according to the degree of blood leak;

Fig. 9 is a schematic side view of another optical portion of this invention when light flux of a wide cross-section is employed;

Figs. 10 and 11 are schematic side view of improved measurement cells of this invention;

Fig. 12 is a schematic representation of an application of a blood leak detector of this invention as coupled to an artificial kidney.

Referring to Fig. 1, a measurement cell 1 of cylindrical or square-pillar tubular form made of transparent material such as "Pyrex" (a registered trademark of Corning Glass Works) has in inlet 2 at one end through which dialysis solution to be tested is introduced into the cell and an outlet 3 at the other end through which the dialysis solution, having been tested, exits therefrom. The central main part of the cell 1 constitutes a photometric portion 20, the details of which will be described below. At the central part of the cell 1 is mounted a holder 4 made of opaque materials such as metals and rubber. Both ends of the holder 4 are sealed with O-ring packings 5, 6. A part of the holder 4 is bored to receive a pair of composite type light-emitting diodes 7 coupled with a condensing lens, and also to receive a photo diode 8 to measure the light emitted by the diodes 7 and transmitted through the cell. A thermistor 9 is mounted in the neighbourhood of the light-emitting diodes 7. This construction is incorporated in a shielded box 10. The lead wires of the light-emitting diodes 7 and the thermistor 9 are connected to a cable 11 which extends through the box 10. The photo diode 8 is similarly shielded in a box 12, its lead wire extending therethrough via a cable 13. The composite type light-emitting diodes 7 comprise a first light-emitting diode D_1 and a second light-emitting diode D_2, each being independently electrically operated and with different wavelength characteristics. The first light-emitting diode D_1 emits radiation mainly at wavelengths of 520—600 nm i.e. within the absorption range of blood pigment, while the second one D_2 emits mainly at 600—750 nm, that is, at longer wavelengths than the first. The photo diode 8 is capable of detecting the radiation from both the light-emitting diodes D_1 and D_2, and has dimensions smaller than that dimension of the cell which extends perpendicular to the light path and to the longitudinal axis of the cell 1, preferably smaller than one fifth thereof. Experiments have shown that when the first and second light-emitting diodes D_1 and D_2 emit radiation with peaks at 555 and 695 nm, respectively, and a measurement cell having a diameter of 8 mm is used, a photo detective area smaller than 2×2 mm² permits blood to be distinguished easily from bubbles. However, an area larger than 8×8 mm² makes discrimination therebetween difficult.

Light-emission driving means 14 alternately energizes the first and the second light-emitting diodes D_1, D_2. These diodes are adjusted to emit with the same light intensity when no blood is present in the cell. This driving means 14 also supplies a reference signal such as a square wave signal to a photo detector output signal detecting means 15.

The detecting means 15 detects blood leaks independently of the existence of bubbles by analyzing the information in the output signal waveform of the photo diode 8. When both the intensities of the light emitted by the two diodes and transmitted through the cell 1 are well balanced or in an equilibrium, the detecting means 15 does not give any detecting signal to an output device which will be later described. If a blood leak has occurred to cause imbalance between the intensities, the detecting means 15 gives an output signal deflected in a positive direction in proportion to the extent of the leak. A signal in a negative direction is given in the case when bubbles are present in the cell, as explained hereinafter in more detail.

The output means 16 indicates the detecting signal of the photo detector output signal detecting means 15 on an indicator or like device, and works an alarm device when the amount of blood leak exceeds a predetermined level.

The above construction thus permits blood to be distinguished from bubbles for the following reasons: the amount of light at longer wavelengths incident upon the photo diode 8 is relatively reduced when fine particles such as bubbles pass through the cell since the bubbles appreciably scatter the light at longer wavelengths. On the contrary, a smaller amount of light at shorter wavelengths enters the photo diode 8 when blood is present in the cell since the blood absorbs mainly at shorter wavelengths. As a consequence, there is a 180 degrees phase shift between the output signals in the two cases, which can be detected by phase detection.

The details of the electric circuit means represented in Fig. 1 as a block diagram, that is, the light emission driving means 14, the photo detection output signal detecting means or transmitted signal detecting means 15 and the output means 16, will now be explained with reference to Figs. 2, 3 and 4.

The light-emission driving means 14 comprises a square wave oscillator 21, a light-emission driving circuit 22, a balance adjusting circuit 23, a temperature compensation circuit 24, and a sensitivity checking circuit 25. The square wave oscillator 21 has a circuit configuration comprising an integrated circuit element IC_1, external resistances R_1, R_2, and a condenser C_1 (Fig.3). It provides a reference square signal, as illustrated in Fig. 5(A), which energizes alternately the two light-emitting diodes D_1, D_2, and also provides the reference square signal to the photo detection output signal detecting means 15 to detect the output signals. A suitable frequency usually employed for the square wave ranges from 100 Hz to 100 KHz. The actual value adopted depends on the values of the resistances R_1, R_2 and the condenser C_1. In this present preferred embodiment 700 Hz is adopted with a 1:1 duty ratio which can be varied by the values of the resistances R_1, R_2. In the case where there is any difference between the brightness of the two light-emitting diodes D_1, D_2, a large current can be supplied to the diode with the less brightness in a shorter time, and in turn a small current in a longer time to the other diode with greater brightness, then the brightness increases, keeping the balance therebetween, and consequently the sensitivity increases.

A light-emission driving portion 22 which comprises transistors Tr_1, Tr_5, Tr_6, resistances R_{12} to R_{14}, R_{29}, R_{30}, variable resistances VR_4, VR_5, and zener diodes Z_1, Z_2, is a circuit for alternate energizing of the two light-emitting diodes D_1, D_2 at a constant current. When a square wave oscillator output voltage (A) is set at a high level (H level), a driving current is fed to the first light-emitting diode D_1 through the resistance R_{13} and the transistor Tr_5. On the other hand, a square wave oscillator output voltage at a low level (L level) causes the transistor Tr_1 to conduct, and the second light-emitting diode D_2 is fed with driving current via the reistances R_{14}, R_{30}, the variable resistance VR_3, and the transistor Tr_6 connected to the collector circuit of the transistor Tr_1. Wave-forms of the driving currents at the first and the second light-emitting diodes D_1 and D_2 are represented in Figs. 5(B) and (C) respectively.

The balance adjusting portion 23 comprising the above mentioned variable resistance VR_3 adjusts the brightness of the second diode D_2 to keep the balance between the brightness of both the diodes so that the meter of the output device 16 reads zero when no blood leak is detected. The temperature compensating portion 24, which comprises a heat sensitive element 9 such as a thermistor arranged in proximity to the light-emitting diodes 7, and a variable resistance VR_6, functions to vary the base voltage of the transistor Tr_6 automatically with temperature.

The sensitivity checking circuit 25 is for checking overall sensitivity of the optical and electric circuit system. During checking a series circuit comprising a push button switch S_4 and a variable resistance VR_7 is connected in parallel with the first light-emitting diode D_1, and temporarily causes the amount of light to vary in proportion to a predetermined level of blood leak. This sensitivity checking function permits not only checking of both the optical and electric systems in a simple operation even if they vary with time, but also adjustment of the sensitivity of the systems to the initial one by a variable resistance VR_8 of a phase detecting circuit 27 explained later, as occasion arises.

The photo detector output signal detecting means 15 comprises an AC amplifier 26, a phase detecting circuit 27, and a phase detection driving circuit 28, as shown in Fig. 3. The light tranmitted through the measurement cell 1 enters the photo diode 8 and is converted into an electric signal, which is in turn supplied to an AC amplifier 26 as an input thereof via a condenser C_4. The waveform of the photo detecting output voltage after transmission through the condenser C_4 is shown in Fig. 5(D). No blood leak gives no square waveform in the photo detecting voltage as is illustrated in the mode (I) in Fig. 5. When a blood leak has occurred, however, the blood pigment absorbs at the shorter wavelengths emitted by the first light-emitting diode D_1 to produce a square waveform on the photo detecting voltage as shown in the mode (II) in Fig. 5. Now this type of unbalance or disproportion is herein called deflection in the positive direction. On the other hand, when bubbles block the light path, the light at longer wavelengths emitted by the second light-emitting diode D_2 is more distinctively prevented from transmission through the cell, than light at shorter wavelengths, thus producing a square wave as illustrated in the mode (III) in Fig. 5, 180° out of phase with the square wave produced by light absorption by blood pigment. This type of unbalance is called herein deflection in the negative direction. The AC amplifier 26 is a circuit device for high-gain amplification of the AC component, comprising an integrated circuit IC_2 which functions as an operational amplifier. The degree of amplification after choking the DC component with the condenser C_4 is chosen by a switch S_3. This AC amplifier 26 is preferably wide-band so as to follow closely up the high-speed modulated photo signals. An AC amplifier of a band width from DC to 500 KHz is used for this purpose. The waveform after amplification of the AC component is shown in Fig. 5(E); the signal being then supplied to the phase detecting portion 27 via the condenser C_5.

The phase detecting portion 27 comprises a low-frequency transformer T_1 with a turns ratio of 1:1:1, switching transistors Tr_2, Tr_3 and other components. The transistors Tr_2 and Tr_3 are caused to conduct alternately by an output voltage (F) from the square wave amplifier 28 which comprises an operational amplifier IC_3 to amplify an output signal (A) of the square wave oscillator 21. Consequently when an input signal (E) is supplied to the primary winding of the transformer T_1, a phase detecting output (H) of the input signal (E) corresponding to the square wave signal (F) appears at the middle point of the transformer T_1.

The output means 16 comprises a level meter 29, a blood leak detecting level set portion or level setting portion 30, and an alarm portion 31. The level meter 29 is a microammeter connected to an output terminal of the transformer T_1 through the variable resistance VR_8. A smoothing condenser C_7 is also connected to the output terminal of the transformer T_1. Figs. 5(G) and (H) show the waveforms of the phase detector output before and after smoothing, respectively, Thus, the indicator 29 remains at zero reading in the mode (I) and it swings in the positive and negative directions corresponding to mode (II) and (III), respectively.

The level setting portion 30 in Fig. 3 is a potential comparison circuit and uses an operational amplifier IC_4 to compare a reference input voltage set by a resistance R_3 and a variable resistance VR_1 with the voltage (H) from the phase detecting portion 27. An output terminal voltage (J) of IC_4 comes to H level when the voltage (H) exceeds the reference input voltage. Therefore the IC_4 output terminal voltage (J) is at L level in the mode (I) and (III), but at H level only in the mode (II) when the blod pigment is detected.

The alarm portion 31 in Fig. 3 comprises a relaxation oscillation circuit or an astable multivibrator utilizing an operational amplifier IC_5, a switching transistor Tr_4 and an alarm buzzer 32, giving a warning when the voltage (J) come to H level. The waveform of the output signal of the buzzer is illustrated in Fig. 5(K). The audio level of the warning is adjusted by a variable resistance VR_2. The power line from +V has a switch S_2, which is opened to render the alarm portion 31 inoperative when alarming is not necessary.

Fig. 4 shows a circuit diagram of a light-emission driving circuit 42 driven by a driving system with constant voltage. The circuit 42 can replace the light-emission circuit 22 driven by a driving system with constant current as shown in Fig. 3. The replacement gives much better stabilized luminous brightness of the diodes D_1, D_2 which results in higher sensitivity. When a Motorola (Trade Mark) MC-7805 CP is chosen as constant voltage integrated circuit devices 43 and 44, for example, they have constant voltage input terminals 45 and 46, respectively at about 10 volts, and constant voltage output terminals 47 and 48, respectively, at 5 volts. The output terminal voltages are kept constant regardless of fluctuation in the input voltage and ambient temperature. Input voltages of the constant voltage integrated circuit devices 43 and 44 are supplied from the power line (+V) via switching transistors Tr_9 and TR_{12}, respectively, A square wave signal (A) is applied to transistors Tr_8 and a series of Tr_{10} and Tr_{11}, respectively to reverse the phase correspondingly. These transistors control a base current of the switching transistor Tr_9 or Tr_{12}. The other circuits except that above described are the same as those shown in Fig. 3, wherein each element is designated by like reference character.

Fig. 6 shows a perspective view of the exterior of the device of this invention as an example; the housing 33 has the electric circuit devices therein already described herein with reference to Figs. 2 and 3, and is connected through lead wires 11 and 13 to the photometric portion 20 which was described with reference to Fig. 1. The housing is also provided with a power switch 35, and an alarm switch 36 for controlling the switch S_2 of the alarm portion 31, the indicator 29, a knob 37 serving as a control of the variable resistance VR_8 for zero adjustment of the indicator 29, a knob 38 serving as a control of the variable resistance VR_1 used for setting alarm level, and a push button 39 to control the switch S_4 for directing the sensitivity.

Table 1 shows the experimental results when 3 litres of sample liquids admixed with a predetermined amount of blood, bubbles. China ink and red ink, respectively, are tested by a detector according to this invention.

TABLE 1

Additive	Amount added (ml)	Meter Reading (microampere)
blood	0.5	+10
blood	0.05	+1
China ink	0.5	0
Bubbles	—	ca.—1
Red ink	0.5	0

As clearly seen, the meter reads about 10 microamperes in the positive direction when the sample contains as low as about 0.015% blood, but is deflected in the negative direction by bubbles. However the meter scarcely varies when China ink or red ink is contained in the liquid. Thus obstacles have the least influence upon the blood leak measurement. Furthermore it has been found that the meter hardly drifts in measurement for 48 hours under the experimental conditions. This enables one to assure the detecting limit of blood to lower than 0.001%. When constant current or voltage circuit portions are not directly connected to the light-emitting portion, and the stability of the system depends merely on the stability of power lines then the meter drift reaches as much as 10 microamperes in measurements over several hours, so that it is impossible to detect a low concentration of blood.

Fig. 7 illustrates a circuit diagram of an alarm device embodying this invention, which gives a warning which varies its tone or the like output depending on the degree of blood leak detected. Reference voltages e_1, e_2 and e_3 of comparators OP_1, OP_2 and OP_3, respectively, where each comparator comprises an operational amplifier, are set at separate levels by variable resistances VR_{11}, VR_{12} and VR_{13}, respectively. A phase detector voltage e is commonly given to each comparator, each output terminal thereof being connected to relays RL_1, RL_2 and RL_3, respectively, each relay having at least a pair of 'a' contacts, a_{11} and a_{12}, a_{21} and a_{22}, a_{31} and a_{32}, respectively. A free running multiple oscillator or an astable multivibrator 71 comprising an operational amplifier OP_4 generates a square wave f_1 with different frequency, such as, for example, 1.5 KHz, 1 KHz and 500 Hz, dependently on which of the resistances R_{31}, R_{33} and R_{35} is connected between the terminals 72 and 73. Similarly a free running multiple oscillator 74 including an operational amplifier OP_5 produces a long period square wave F_2 alternating between H and L level at intervals of 0.5, 1 or 2 seconds dependently upon which of the resistances R_{32}, R_{34} or R_{36} is connected between the terminals 75 and 76. A NAND gate circuit 77 draws $f_1.f_2$, the logical product of f_1 and f_2, causing the alarm device 78 to be driven by a transistor Tr_7. This alarm device 78 operates in such a manner that when an input voltage e is low, the comparator OP_3 works and causes the alarm device to give an undertone warning of 500 Hz at intervals of two seconds as shown in Fig. 8(L). On the other hand, a moderate input voltage above e_2 works the comparator OP_2 to give a medium-toned warning of 1 KHz every one second as shown in Fig. 8(M) and similarly a high input voltage above e_3 in turn works the comparator OP_1 to give rise to a shrill alarm of 1.5 KHz at intervals of half a second as shown in Fig. 8(N). Accordingly this embodiment of the blood leak detector provided by the invention readily permits an operator to sense the extent of the blood leak without keeping his attention on the meter panel.

The above described alarm device 78 utilizes a combination of an oscillation frequency varying system and an intermission period varying sound system, but it should be understood that either system can be sufficiently employed independently. Furthermore, such a system in which for instance, two types of sound having different frequencies are alternately given with variation in the switching period thereof can be provided. It should be also understood that according to this invention the composite type light-emitting diodes 7 of the light-emitting portion can be formed by a plurality of monochromatic diodes, each emitting at a separate wavelength. Alternatively filters having the necessary wavelength characteristics can be put in front of a light-emitting element such as an incandescent bulb radiating in a broad range of wavelengths. In addition, instead of light-emitting diodes, other light-emitting elements such as lasers can be employed. Furthermore the phase detecting driving portion can be omitted by the use of light-emitting diodes of both polarity as a light source and replacing the square wave generator with a positive-negative pulse generator. In the meantime, in addition to photo diodes previously described herein, various photo detecting elements such as photo transistors, photo tubes, or CdS cells can be used, of course. Such photo detecting elements however preferably have a response time of the order below 10^{-2} second, preferably below 10^{-3} second so as to recapitulate a reference square wave with high fidelity. It is desirable that whatever the photo detecting elements, they have limited or comparatively small photo detective areas so that the influence of scattered light is reduced. Such limitation or reduction of the photo detective areas can be achieved either by designing the elements themselves or by means such as irises.

When a light source as shown in Fig. 9 of relatively large size 91 and a parallel light beam 92 of a large cross-section are used, together with a photo detector 93 with a wide photo detective area, bubbles can still be distinguised to some extent if a Soller slit 94 is inserted parallel to the light path between the measurement cell 1 and the photo sensitive detecting portion 93 as is shown in Fig. 9. The surfaces of the slit are black coloured and have spacing preferably less than 2 mm.

Further according to this invention, measurement cells of improved configuration are provided, embodiments thereof being represented in Figs. 10 and 11. As hereinbefore described, flowing bubbles can be accurately distinguished by the detectors of this invention. However, when bubbles stick to the wall of the cell and block the light path, the amount of the light transmitted is decreased to lower the sensitivity of the detector. The improved measurement cell of this invention has a certain cross-section at its dialysis solution entering portion 101, 111 usually determined by pressure and flowing amount of the solution, but has a cross-section of about 1/2 to 1/3 of this value at the portion 102, 112 through which light emitted by the diodes passes. In other words the measurement tube is narrowed to form a tapered portion 103, 113 at the upstream side of the light path traverse the tube.

For example, let the entering portion 101 or 111 and the narrower portion 102 or 112 be 1.2 cm and 0.7 cm, respectively, in inside diameter, and the flow rate be 500 ml per minute, then the dialysis solution flows at a rate of 7.35 cm a second at the wider, entering portion, and at a rate of 21.3 cm a second at the narrower portion. Thus bubbles which flow into the cell are prevented from sticking to the wall of the narrower portion 102 or 112.

A schematic illustration of a blood leak detector of this invention is shown in Fig. 12 as incorporated into an artificial kidney.

A blood vessel of the human body 121 is

connected to a dialyzer 122 of an artificial kidney through a switching valve means 123. The valve means 123 comprises a moving member 128 which can take a first state and a second state alternatively, the first state being a normal state where no blood leak exists and the second state being the state where a blood leak has occurrred, a fixed member 133 surrounding the member 128, and a switching member to switch the moving member 128 from one state to the other. The fixed member 133 is provided with a first tube 124 for removing blood from the blood vessel, a second tube 127 for returning the blood after dialysis to the blood vessel, a third tube 125 connected to a blood inlet of the dialyzer and a fourth tube 126 connected to a blood outlet of the dialyzer. The moving member 128 has at least two flow paths: A first flow path 129 and a second flow path 130. Thus in the normal state where blood is dialyzed without leakage, the first flow path 129 interconnects the second tube 127 with the fourth tube 126 while the second flow path 130 interconnects the first tube 124 with the third tube 125. In the second state however, which is produced by the blood leak signal, the first flow path 129 or the second path 130 interconnects the first tube 124 with the second tube 127. A rotary valve means as shown in the drawing permits switchover operation of the first state to the second by turning the moving member 90 degrees. This switch-over operation can be achieved as well by a sliding switchover valve separately provided with first and second paths used in the first state, and a short path used in the second state. As previously described herein the dialyzer 122 has a blood leak detector according to the invention comprising an optical portion 20 detecting blood leaks in the measurement cell and the blood leak detecting device 131 which gives an output signal if a leak is detected to cause the moving member 128 to switch over from the first state to the second state. Accordingly if a blood leak should occur for one reason or another, the moving member 128 is automatically switched over so that the first tube 124 connected to the human body and the second tube 127 are interconnected or shorted out to prevent the blood from further leaking into the dialysis solution.

WHAT WE CLAIM IS :—

1. A blood leak detector which comprises: a cell having an inlet, an outlet and a passage therebetween for solution under test; light-emitting means for irradiating the cell, comprising a first light-emitting element essentially emitting at wavelengths at which blood pigment absorbs light and a second light-emitting element essentially emitting at longer wavelengths than the first light-emitting element; photo detecting means for receiving light from the elements transmitted through the cell; means for driving alternately the first light-emitting element and the second light-emitting element and means for discriminating between output signals of the photo detecting means to discriminate between a first state wherein the amount of transmitted light from the first light-emitting element is in equilibrium with that from the second light-emitting element, a second state wherein the amount of transmitted light from the first light-emitting element is less than that from the second light-emitting element, and a third state wherein the amount of the transmitted light from the second light-emitting element is less than that from the first light-emitting element.

2. Blood leak detector according to claim 1 which has AC amplifying means to amplify an AC component of a photo detecting signal of the photo detecting means, and phase discriminating means which is supplied with an emission switching signal as a reference input signal and with an output signal of the AC amplifying means as an input signal to be detected.

3. Blood leak detector according to claim 1 or 2 wherein the means for alternately driving the first and second light-emitting elements comprises sealed constant voltage integrated circuit means having a constant output terminal and a power input terminal voltage; switching means having an input control line and a 2-terminal switching circuit which cycles on and off by the input control line; circuit means to connect one terminal of the switching circuit to a power line; circuit means to apply a square wave signal to the input control line of the switching means; circuit means to connect the other terminal of the switching circuit to the constant voltage integrated circuit means; and circuit means to connect the first or second light-emitting element to the constant voltage integrated circuit means.

4. Blood leak detector which comprise a transparent measurement cell through which dialysis solution under test can flow; composite light-emitting diodes for irradiating the measurement cell and having a first light-emitting diode which emits in the range of 520—600 nm and a second light emitting diode which emits in the range of 600 to 750 nm; a photo detecting element to receive the light from the light-emitting diodes transmitted through the measurement cell; means for driving the first and second light-emitting diodes alternately by means of a reference square wave signal; means for balancing the output signal of the photo detecting element due to the first light-emitting diode and the output

signal of the photo detecting element due to the second light-emitting diode in the normal state in which no blood leak exists; and means for detecting deflection from the normal state whether resulting from change of the output signal of the photo detecting element due to the first light-emitting diode or from change of the output signal of the photo detecting element due to the second light-emitting diode.

5. Blood leak detector according to claim 4 which includes a sensitivity checking circuit operable by means of a push-button switch to cause a temporary deflection from the said normal state in proportion to a predetermined level of blood leak.

6. Blood leak detector according to claim 4 or 5 which includes first and second driving circuits for energising alternately the first and second light-emitting diodes, and a thermally sensitive element connected to one of the driving circuits and positioned in proximity to its associated diode so as to compensate automatically for change in temperature.

7. Blood leak detector according to claim 1 or 2 wherein the photo detecting area of the photo detecting means has dimensions smaller than that dimension of the adjacent portion of the cell which extends perpendicular to the light path and to the longitudinal axis of the cell.

8. Blood leak detector according to any of claims 1 to 4 wherein the portion of the cell through which the light from the light-emitting means passes is of reduced cross-section compared to an adjacent length of the cell.

9. Blood leak detector according to any of claims 1 to 8 which includes alarm means to give an auditorily distinguishable warning which varies with the strength of a blood leak output signal.

10. Artificial kidney dialysis apparatus which includes a blood leak detector according to any of claims 1 to 9.

11. Apparatus according to claim 10 including a first tube to remove blood from a blood vessel, a second tube to return blood into the blood vessel after dialysis, a third tube connected to a blood inlet of the dialyzer, a fourth tube connected to a blood outlet of the dialyzer, flow path means capable of being switched over between a first state in which the first tube it interconnects the first tube to the third and the second tube to the fourth, and a second state in which the first tube it interconnects the first tube to the second, and means to switch over the flow path means from the first to the second state on a blood leak output signal of the blood leak detector.

12. A blood leak detector substantially as hereinbefore described with reference to the accompanying drawings.

13. Artificial kidney dialysis apparatus according to claim 11 and substantially as hereinbefore described with reference to Fig. 12 of the accompanying drawings.

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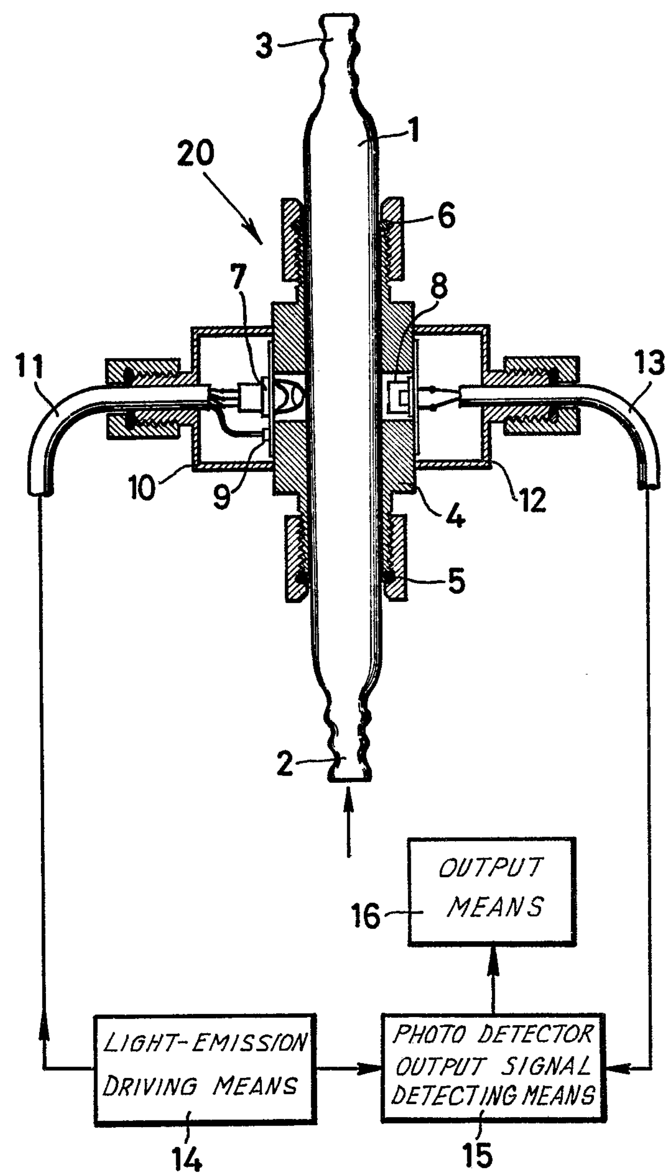
3
1
20
6
7
8
11
13
10
9
4
12
5
2
OUTPUT MEANS
16
LIGHT-EMISSION DRIVING MEANS
PHOTO DETECTOR OUTPUT SIGNAL DETECTING MEANS
14
15

FIG. 1

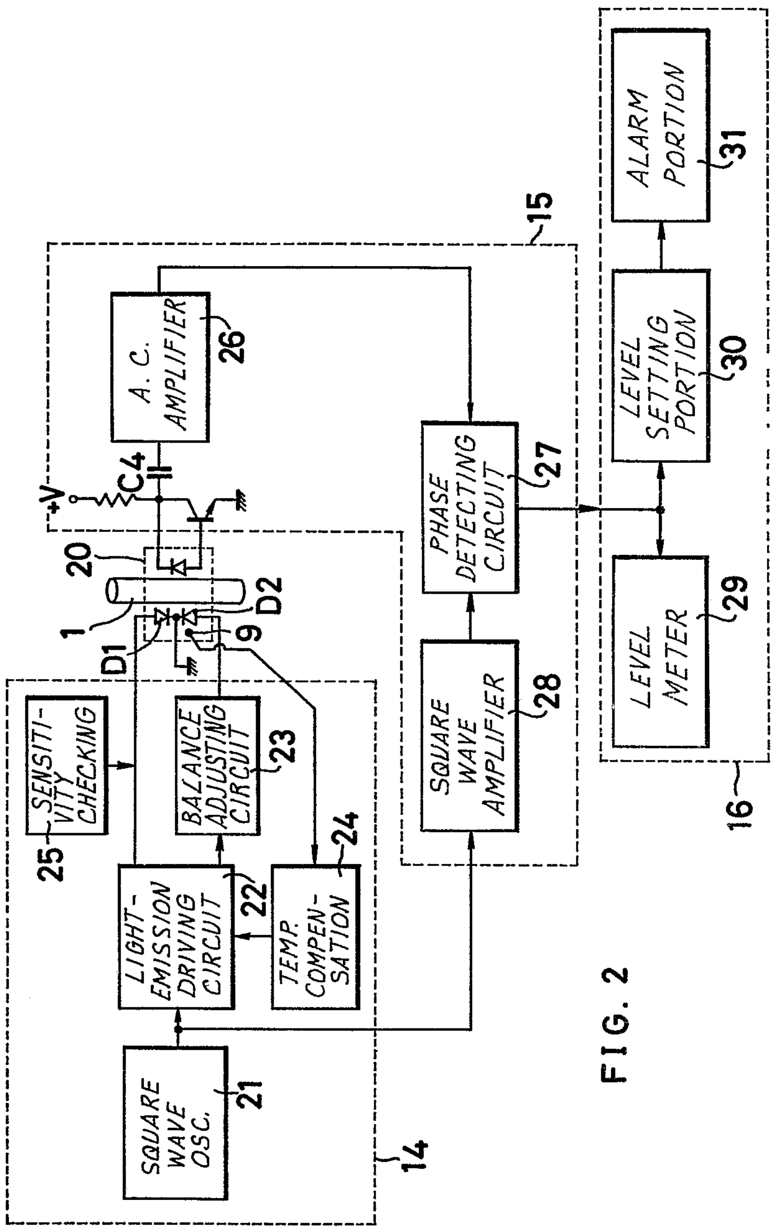
SQUARE WAVE OSC.
21
LIGHT-EMISSION DRIVING CIRCUIT
22
TEMP COMPEN-SATION
24
BALANCE ADJUSTING CIRCUIT
23
SENSITI-VITY CHECKING
25
14
D1
1
9
D2
20
+V
C4
A. C. AMPLIFIER
26
PHASE DETECTING CIRCUIT
27
SQUARE WAVE AMPLIFIER
28
15
LEVEL METER
29
LEVEL SETTING PORTION
30
ALARM PORTION
31
16

FIG. 2

1560422 COMPLETE SPECIFICATION

7 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 3

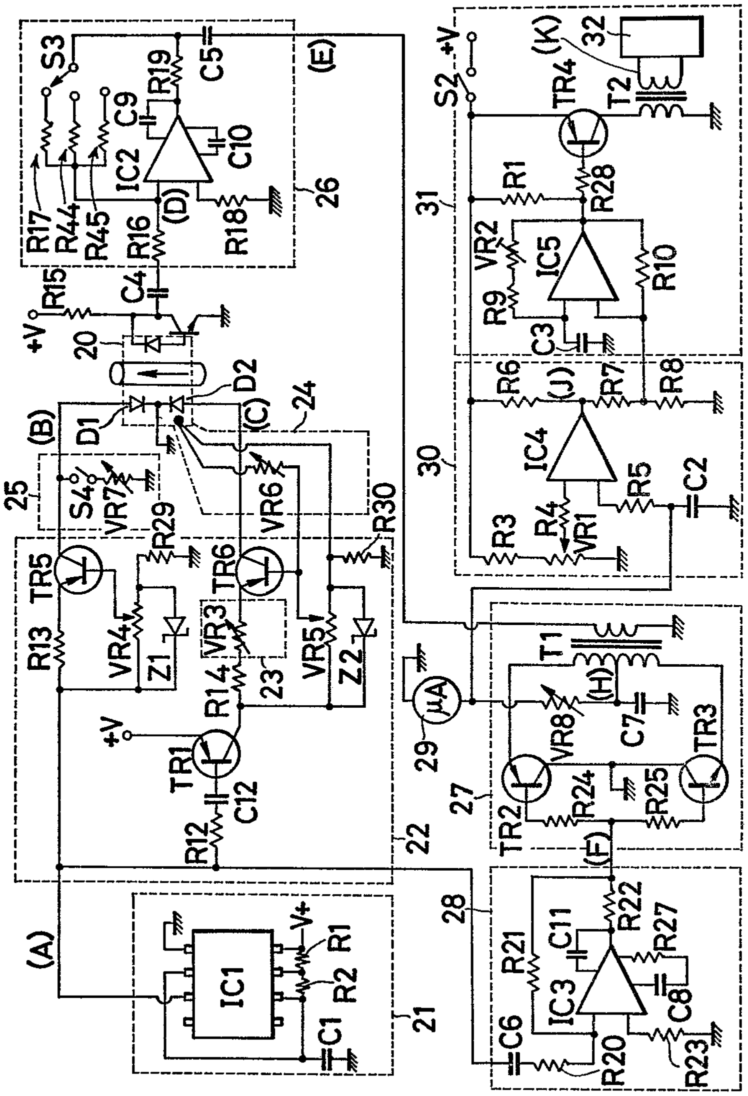

FIG. 3

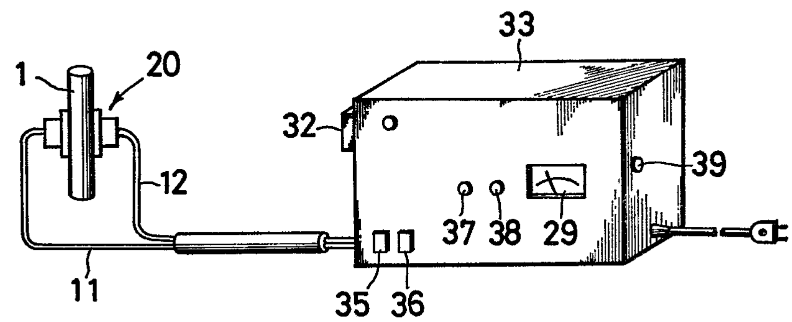
33
1
20
32
12
39
37
38
29
11
35
36

FIG. 6

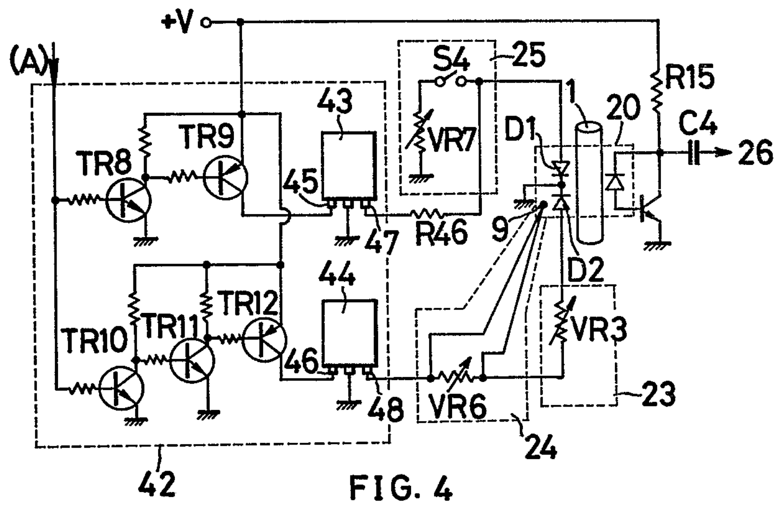
+V
(A)
S4
25
R15
43
1
20
C4
TR9
D1
VR7
26
TR8
45
47
R46
9
D2
44
TR12
TR11
TR10
VR3
46
48
VR6
23
24
42

FIG. 4

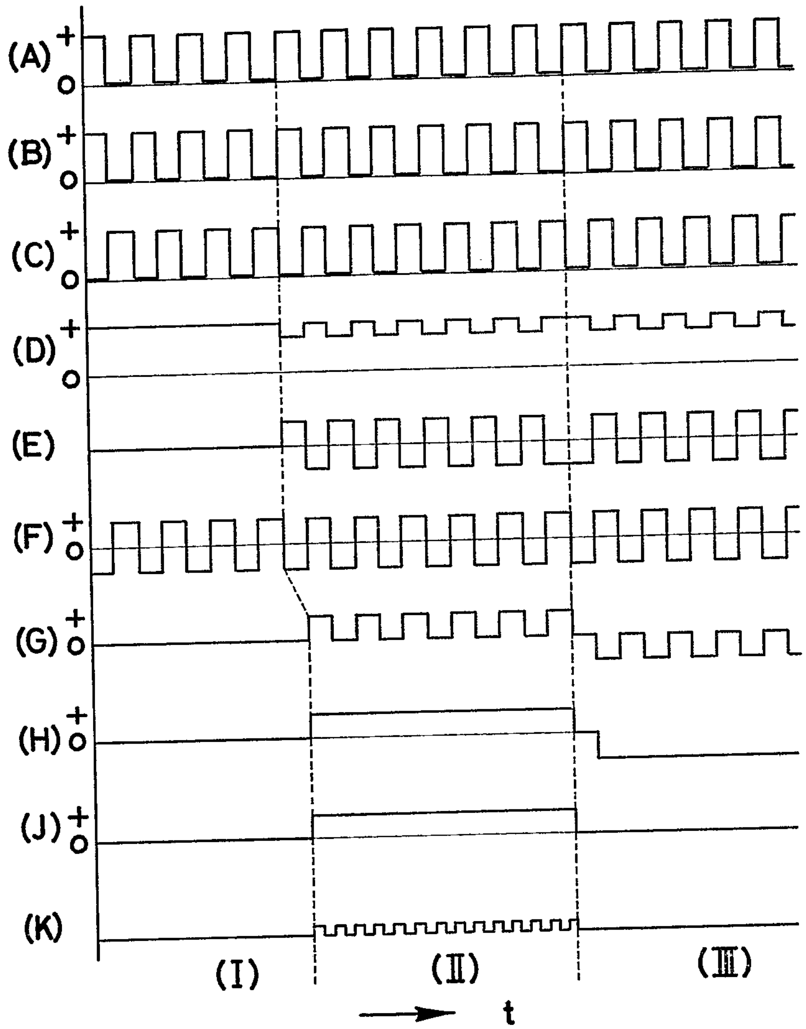

FIG. 5

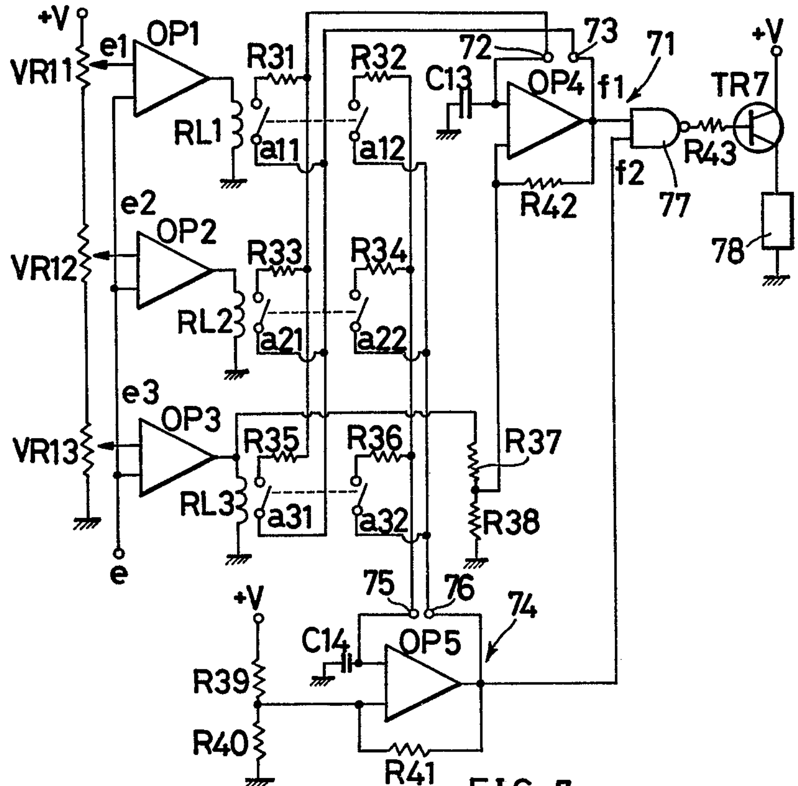
+V
e1
OP1
VR11
R31
R32
C13
72
73
71
OP4
f1
+V
TR7
RL1
a11
a12
R43
f2
77
R42
e2
OP2
VR12
R33
R34
78
RL2
a21
a22
e3
OP3
VR13
R35
R36
R37
RL3
a31
a32
R38
e
75
76
74
+V
C14
OP5
R39
R40
R41

FIG. 7

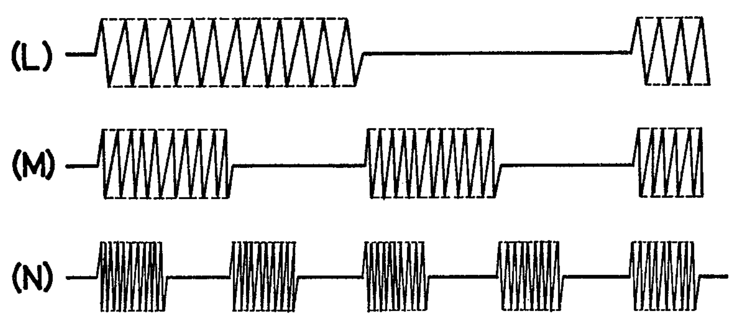
(L)
(M)
(N)

FIG. 8

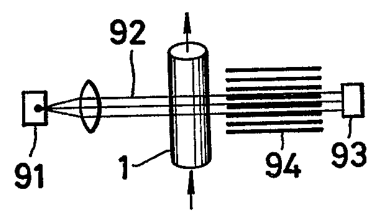

FIG. 9

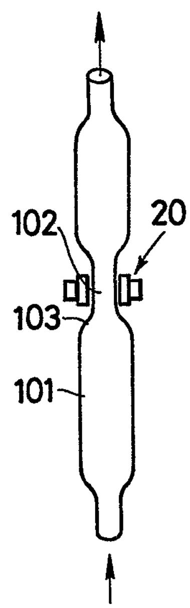

FIG.10

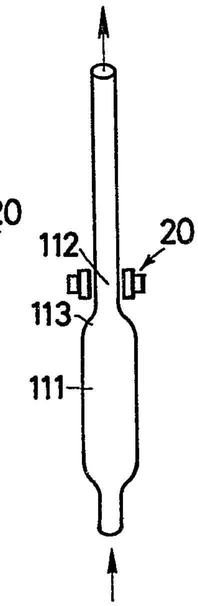

FIG.11

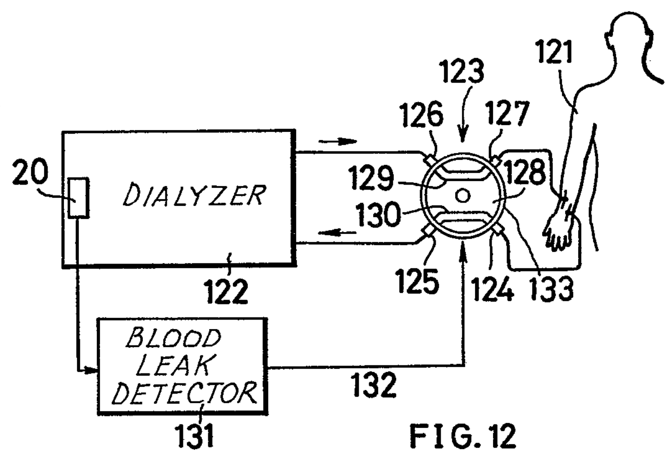

FIG.12