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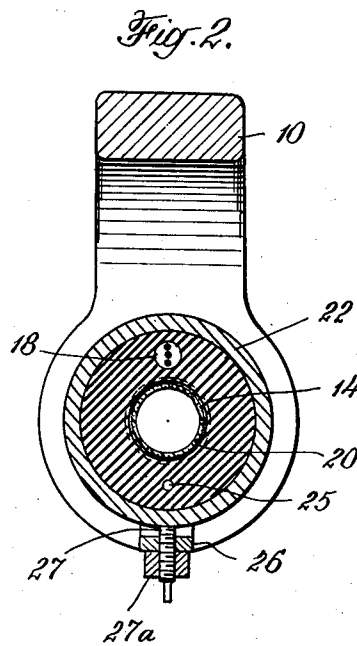
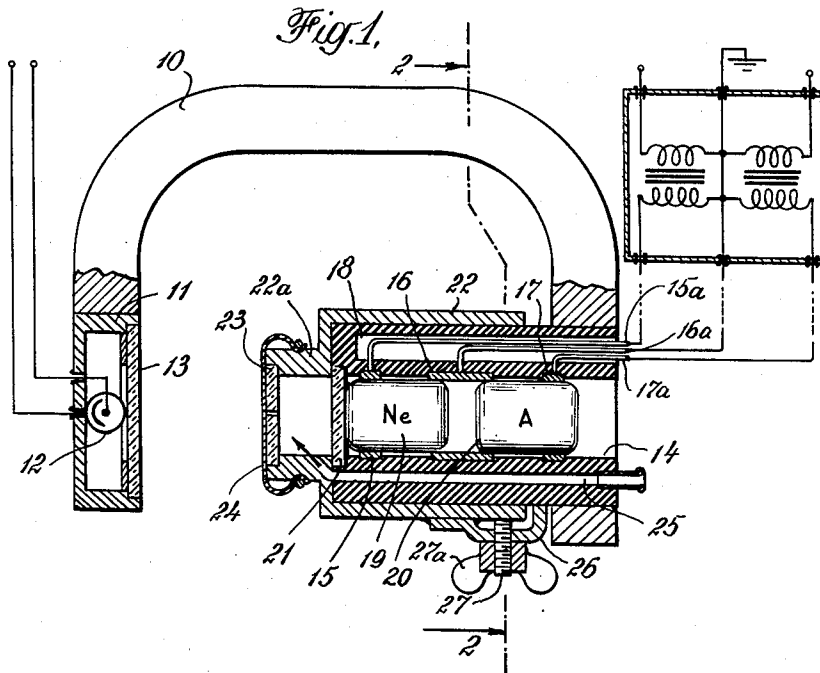
M. D. LISTON

2,640,389

OXIMETER

Filed Oct. 31, 1950

2 Sheets-Sheet 1



INVENTOR
Max D. Liston
BY
Perrine Edwards Morton - Parsons
ATTORNEYS

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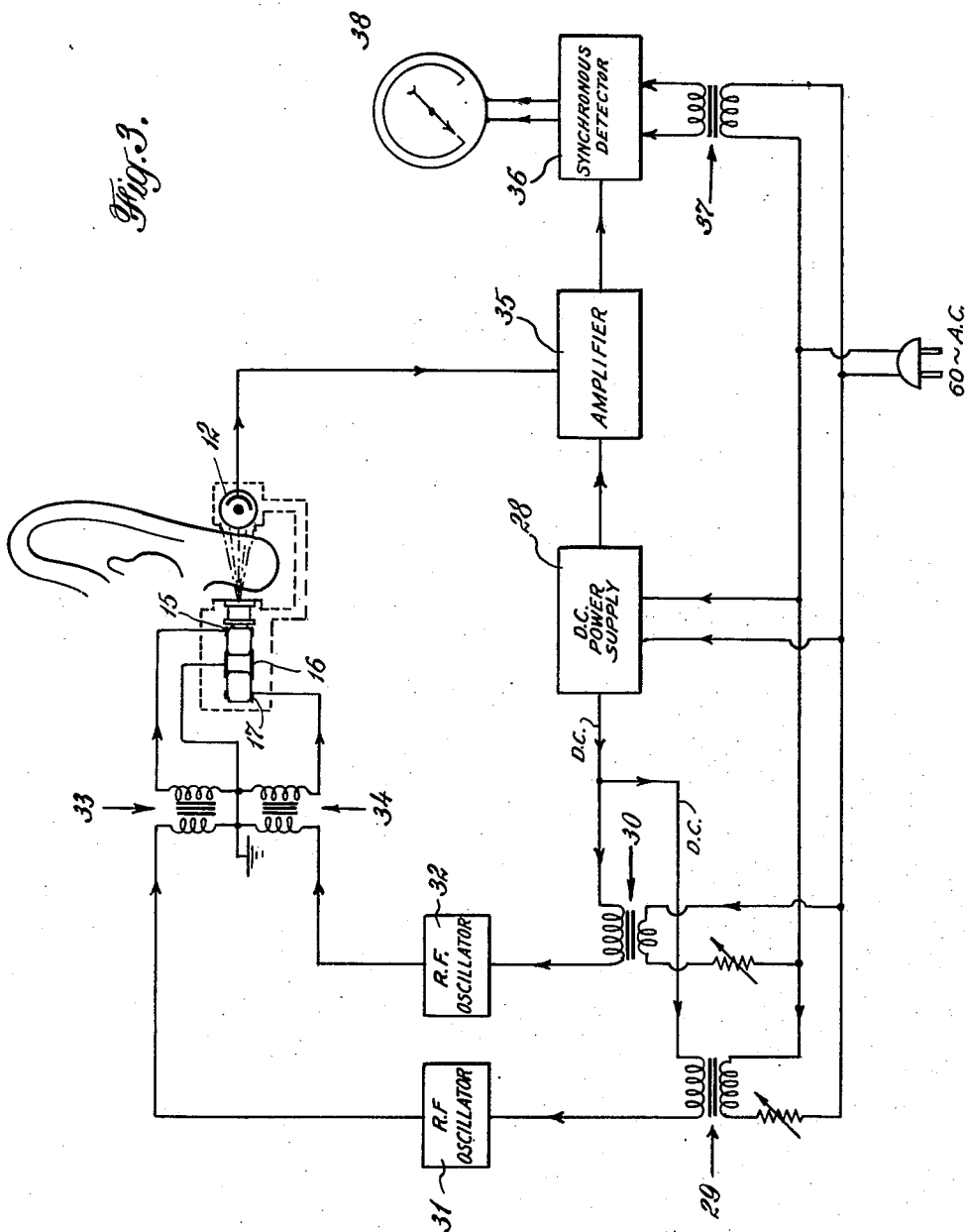
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OXIMETER

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2 Sheets-Sheet 2



INVENTOR
Max A. Luston
BY
Rueie Edwards Morton & Barrows
ATTORNEYS

UNITED STATES PATENT OFFICE

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OXIMETER

Max D. Liston, Darien, Conn., assignor to The Perkin-Elmer Corporation, Glenbrook, Conn., a corporation of New York

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9 Claims. (Cl. 88—14)

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This invention relates to colorimeters and is concerned more particularly with a novel colorimeter suitable for general analytic purposes and especially adapted for indicating and measuring changes in the color of a specimen. In one form, the new instrument may be employed as an oximeter for determining the amount of oxygen in the blood, and such an instrument is of great value in surgery, where modern anaesthetics may have bad effects, if the oxygen tension of the patient is too low, and also in the study of various kinds of heart disease and respiratory ailments frequently found in persons afflicted with poliomyelitis. The advantages of the invention are all realized in such an oximeter and that embodiment of the invention will, accordingly, be illustrated and described in detail for purposes of explanation.

It is well known that the color of the hemoglobin of the blood changes from red toward blue with a decrease in the oxygen content and a number of photo-electric methods for measuring the oxygen saturation of the blood, together with instruments for practising such methods, have heretofore been proposed and put into use to some extent. These instruments depend for their operation upon the fact that, in the red region of the spectrum, reduced hemoglobin and oxyhemoglobin absorb different amounts of light, so that changes in absorption of red light by the specimen indicate changes in the oxygen content of the specimen.

Typical oximeters have been constructed heretofore for examination of the ear and they include an ear piece of C-form, between the ends of which a part of the ear, such as the lobe, is received. One end of the ear piece contains an incandescent lamp serving as a source of light, and the other end of the ear piece contains a pair of photocells lying side by side behind respective filters of different characteristics and facing the source. The responses of the photocells are then used for measuring the oxygen content of the blood in the ear.

Such prior oximeters suffer from the disadvantage that every ear piece has its own characteristic sensitivity and must be calibrated empirically. Calibration involves drawing and analyzing a large number of blood samples, so that it is extremely laborious and costly, since each analysis may consume as much as three hours of the time of a skilled technician. Another disadvantage arises from the fact that the color of the light emitted by the lamp is likely to vary over a period of use and, whenever replacement of the lamp is required, the ear piece must be re-cal-

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ibrated. Similar difficulties ensue from a lack of uniformity in the photocells and filters used. Another serious disadvantage of the prior instruments is that the light falling upon the two photocells does not pass through the same part of the ear and thus an error in measurement may be introduced because of differences in the blood distribution in front of the two photocells. Finally, differences in results are obtained because of differences in the thickness and density of the ears to be examined.

The present invention is, accordingly, directed to the provision of a novel colorimeter, which measures the differential light absorption of a sample and is not subject to the objections to prior similar instruments. In the new colorimeter, a single photocell is employed and the photocell receives light from two sources passing alternately along the same path through the specimen. The output of the photocell is then passed to an amplifier and a synchronous detector, the output of which passes to a meter showing the difference in transmission of the light from the two sources. An oximeter constructed in accordance with the invention includes a frame or ear piece of C-shape, one end of which has a cavity containing the photocell disposed behind a transparent window. The other end of the ear piece is formed with a cavity containing the light sources and closed by a window facing the window in the other end of the frame. The light sources are gas tubes, preferably electrodeless, and, if such electrodeless tubes are used, they are excited by radio-frequency fields. The end of the ear piece containing the light sources is provided with an adjustable sleeve, which can be moved to place a window at the end of the sleeve in contact with the ear, and the window may be covered by a transparent diaphragm, which can be inflated to squeeze blood out of the ear tissue to be examined to secure a bloodless reading, by air under pressure admitted to the sleeve and passing to the diaphragm through an opening in the sleeve window.

For a better understanding of the invention, reference may be made to the accompanying drawings, in which:

Figure 1 is a view, partly in elevation and partly in section, of a frame or ear piece of an oximeter embodying the invention;

Fig. 2 is a sectional view on the line 2—2 of Fig 1; and

Fig. 3 is a circuit diagram of the oximeter.

The oximeter illustrated in the drawings comprises an ear piece 10 of any suitable metal and of C-shape, and one end 11 of the ear piece has a

cavity, within which is mounted a photocell 12. The inner side of the cavity is closed by a transparent window 13.

The other end of the ear piece carries a chamber 14, generally cylindrical in form and disposed with its axis aligned with photocell 12. The chamber 14 is preferably made of an insulating material, such as a suitable plastic, and ring electrodes 15, 16, 17 are embedded in the wall of the chamber and connected to leads 15a, 16a, and 17a, respectively, which extend through a passage 18 in the wall of the chamber to the exterior thereof. The ring electrodes support a pair of electrode-less gas tubes 19, 20, of which tube 19 is filled with neon and tube 20 contains argon. Each tube has one end mounted in an outer electrode 15 or 17 and electrode 16 serves for both tubes. The inner end of chamber 14 is closed by a transparent window 21 without filtering effect, but, for some purposes, the window may filter out light of undesired wave lengths from the two tubes. Also, a filter may be mounted within chamber 14 to filter the light from the outer source, in this case, argon tube 20. The position of the two tubes in chamber 14 is not critical, although it is preferable to place the source emitting the light, to which the photocell gives the stronger response, in the outer position, that is, farther from window 21.

A cylindrical sleeve 22 is telescoped over chamber 14 and the sleeve has a neck 22a at its inner end and the neck having an inner diameter approximately the same as chamber 14. The end of the neck is closed by a transparent window 23 having a central hole and a thin transparent rubber diaphragm 24 overlies the window 23 and is held in place by having its edge clamped against the outer surface of the neck. A passage 25 is formed in the walls of the neck and the chamber, so that air under pressure may be admitted through the interior of the neck to the under side of the diaphragm to inflate it. The sleeve 22 is adjustable along the outside of chamber 14 and is held in adjusted position by a clamp 26, which is carried by the sleeve and may be forced against the outside of the chamber by a screw 27 provided with a wing nut 27a.

The wiring diagram, Fig. 3, shows that the instrument may be operated by a 60 cycle A. C. source, which supplies energy to a D. C. power supply unit 28 and the primaries of modulation transformers 29, 30, the connections to the primaries being reversed. The unit 28, which comprises an electronic rectifier and a filter, is connected to one terminal of each of the secondaries of transformers 29, 30, and the other terminals of the secondaries are connected to respective radio frequency oscillators 31, 32. The oscillators supply radio frequency energy to the primaries of respective radio frequency step-up transformers 33, 34, the secondaries of which are connected to the ring electrodes 15, 17, while electrode 16 is grounded. The low level signal from photocell 12 passes to an amplifier 35, receiving D. C. power from unit 28. The A. C. output from the amplifier represents the difference in response of the photocell to the light from the two sources falling thereon and the output is passed to a synchronous detector 36, receiving A. C. power from the secondary of a transformer 37, the primary of which is connected to the 60 cycle A. C. line. The output of the synchronous detector passes as a D. C. signal to a meter 38, which may indicate only or both indicate and record.

In the use of the oximeter, the ear piece is ap-

plied to the lobe of the patient's ear, and sleeve 22 of the ear piece is adjusted, so that the ear lobe is snugly engaged on opposite sides. Air under pressure is then admitted to inflate the diaphragm and cause it to exert pressure to squeeze the blood out of the tissue. The tubes 19, 20 are so operated that they flicker in alternation and, with the tubes thus operating, a reading is taken. The meter shows the difference in absorption by the tissue of the red light from the neon tube and the infrared light from the argon tube. After the preliminary empty cell reading, the air pressure is released and a second reading, taken after the blood has returned to the part of the lobe being examined, gives an indication of the oxygen content of the blood.

In the instrument, the co-axial mountings for the tubes, the walls of chamber 14, and the transparent windows 21 and 23 cooperate to cause the light from both the red and infrared sources to travel along paths having co-linear portions through the specimen and errors, which might arise from differences in the specimen, if the light from the two sources had different paths through it, as in the former instruments, are, accordingly, eliminated. The tubes are preferably without electrodes, since this avoids variations in the color of the light emitted as a result of the gettering action of electrodes and the use of radio-frequency excitation for such tubes gives higher intensities and longer life.

The simple amplifier reading the difference between the transmitted red and infrared light gives an approximate solution of the theoretical problem and, at present, appears to be satisfactory for most purposes. For a more accurate instrument, a log ratio amplifier may be employed.

The method of obtaining an empty cell reading involving squeezing all the blood out of a portion of the ear lobe eliminates another absorbing element, namely, tissue fluid, from the sample, and, if preferred, zero readings may be obtained by trapping the blood in a portion of the tissue, so that the blood cannot circulate. In a short time, the trapped blood becomes completely reduced because of the use of the oxygen by the tissue and the zero reading is then that of the tissue, the tissue fluid, and the reduced blood. The method involving trapping probably gives more accurate results.

The new oximeter, in the form described, may be employed for determining the oxygen content of the blood in the body of the patient, as, for example, by examining the lobe of the ear, the web between two fingers, etc., or it may be used for determining the oxygen content of a sample of arterial blood drawn from the patient and placed in a sealed cell or cuvette.

I claim:

1. In an oximeter, the combination of a frame having a pair of mountings spaced to receive a part of the body between them, a pair of gas tubes in one mounting, one of the tubes containing neon and the other argon, a window in said mounting, through which light from the tubes passes along the same path toward the second mounting, a detector in the second mounting in position to receive light from the tubes, which has passed through the part of the body, means for exciting the tubes alternately, and measuring means receiving the output of the detector and measuring the difference in the response of the detector to light from the two tubes.

2. An ear piece for use in an oximeter compris-

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ing a frame of C-shape, a chamber in each branch of the frame adjacent the end thereof, windows at the opposed faces of the chambers, a pair of gas tubes producing light of different wave lengths mounted in alignment in one chamber and coaxial with the window of that chamber, and detecting means mounted in the second chamber in position to receive light from the tubes passing through the windows.

3. A colorimeter, which comprises a pair of sources of light of different wave lengths, means for causing light from the sources to travel along paths having co-linear portions, a detector lying at the end of the co-linear portions of the paths in position to receive light from the sources, the detector responding to light from the sources falling thereon, and the co-linear portions of the paths being of sufficient length for insertion therein of a specimen to be examined, and means for operating the sources to cause them to flicker in alternation.

4. A colorimeter as defined in claim 3, in which the sources of light are gas tubes.

5. A colorimeter as defined in claim 3, in which the sources of light are gas tubes and the tubes are operated by radio frequency fields to cause them to flicker in alternation.

6. A colorimeter as defined in claim 3, in which the sources of light are electrode-less gas tubes.

7. An oximeter, which comprises a frame having a pair of mountings spaced to receive a part of the body between them, a pair of sources of light of different wave lengths in the first mount-

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ing, a window in said first mounting through which light from the sources issues to travel along a single path from the window to the second mounting, a detector in the second mounting in position to receive light from the sources along said path, and means for operating the sources to cause them to flicker in alternation.

8. An oximeter as defined in claim 7, in which the sources emit red and infrared light, respectively.

9. An oximeter, as defined in claim 7, in which the sources are gas tubes and the tubes are disposed in a line passing through the window and the detector.

MAX D. LISTON.

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