

[11] 3,622,795

3,435,239	3/1969	Stalberg	250/218
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[73] Assignee **Coulter Electronics, Inc.**
Hialeah, Fla.

[54] **COLORIMETRIC FLUID TEST APPARATUS
HAVING PLURAL FLUID SEQUENTIAL CONTROL**
28 Claims, 10 Drawing Figs.

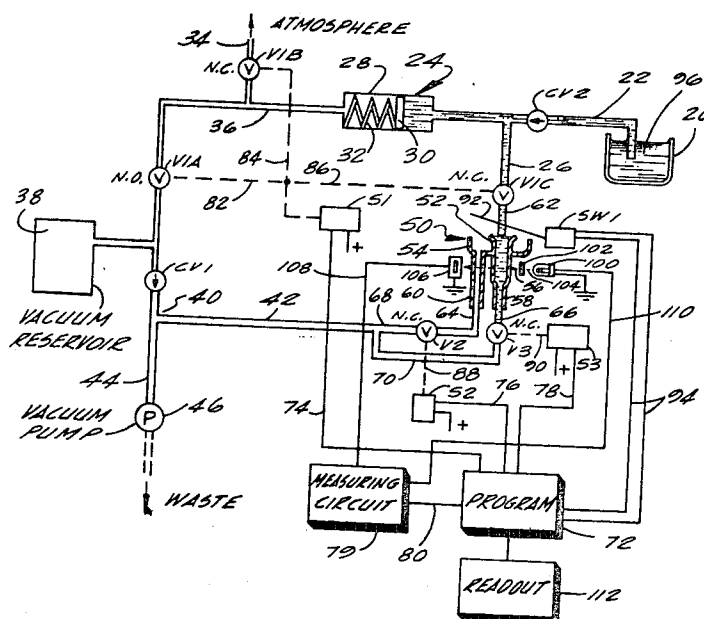
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137/624.13, 250/43.5 D, 356/39, 356/40, 356/42

[51] Int. Cl. **G01n 21/26,**
E03b, G01n 33/16

[50] Field of Search 137/624.11,
624.12, 624.13; 250/218, 43.5; 356/246, 39, 40,
41, 42; 200/61.7

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A novel cuvette construction provides concentric fluid-receiving mouths leading to inner and outer receptacles, the inner being the receptacle for the sample fluid, the outer being an overflow basin. The receptacles lead to respective independent drains, the inner being provided with a light transmitting section at which the fluid is traversed by a beam of radiant energy.



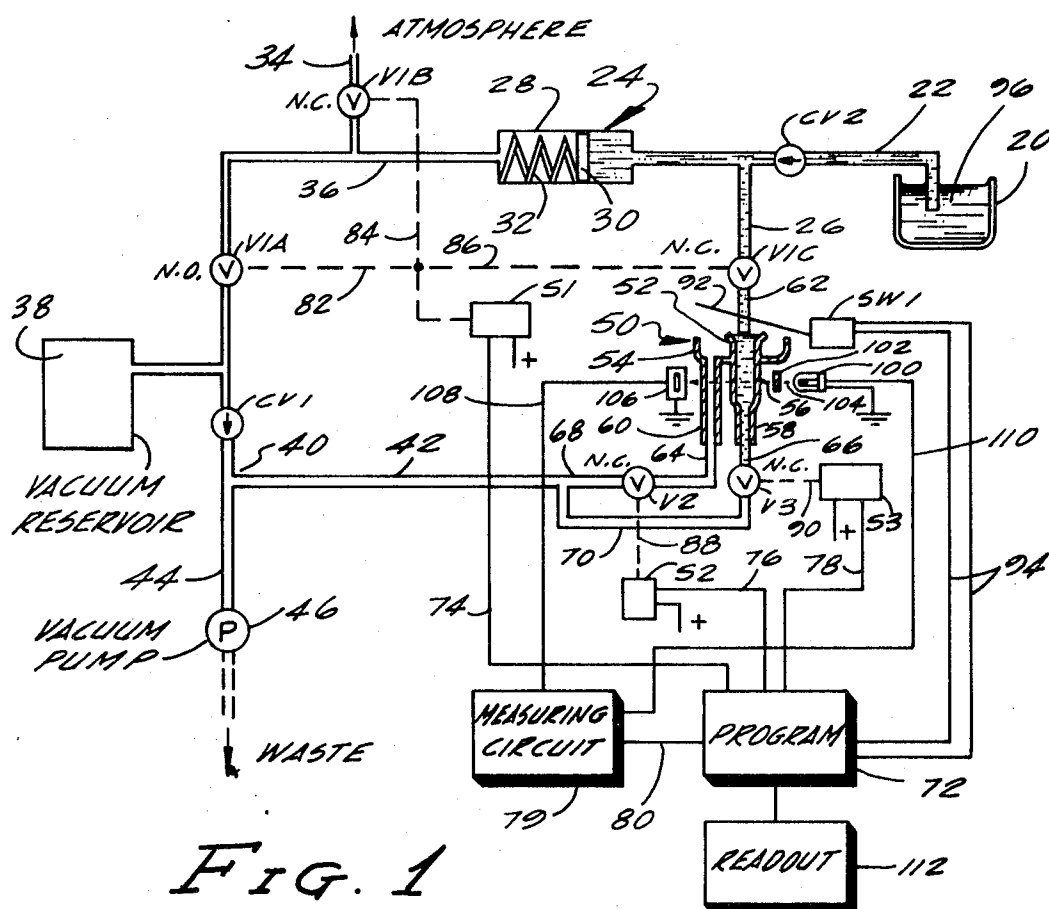


FIG. 1

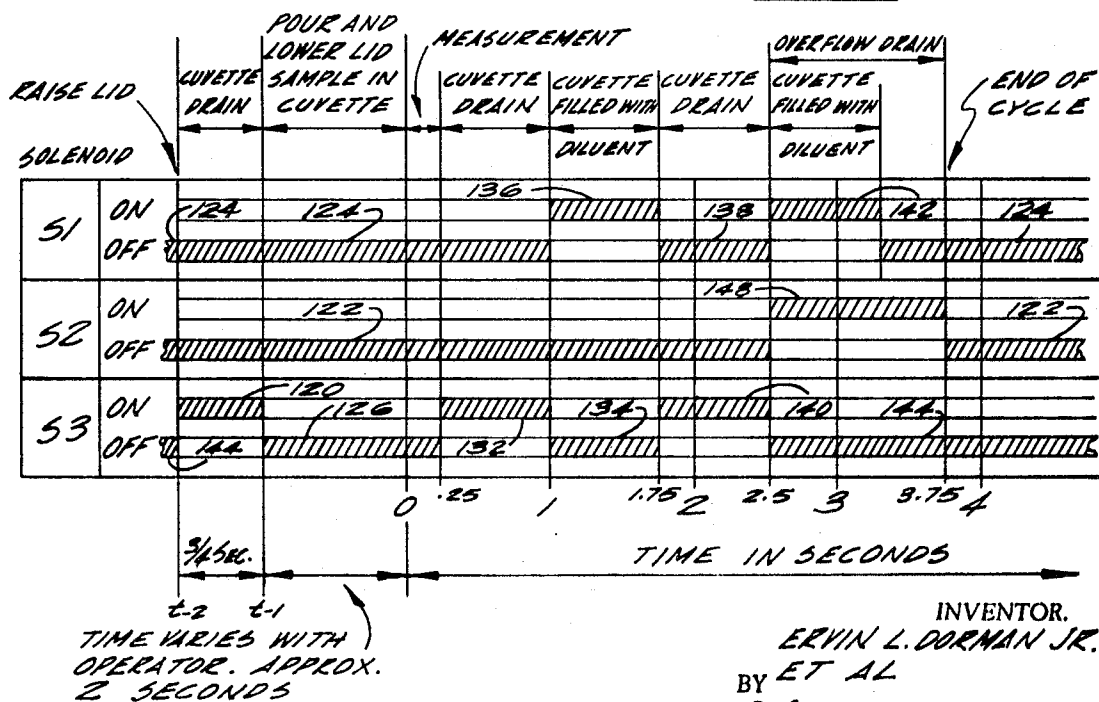


FIG. 2

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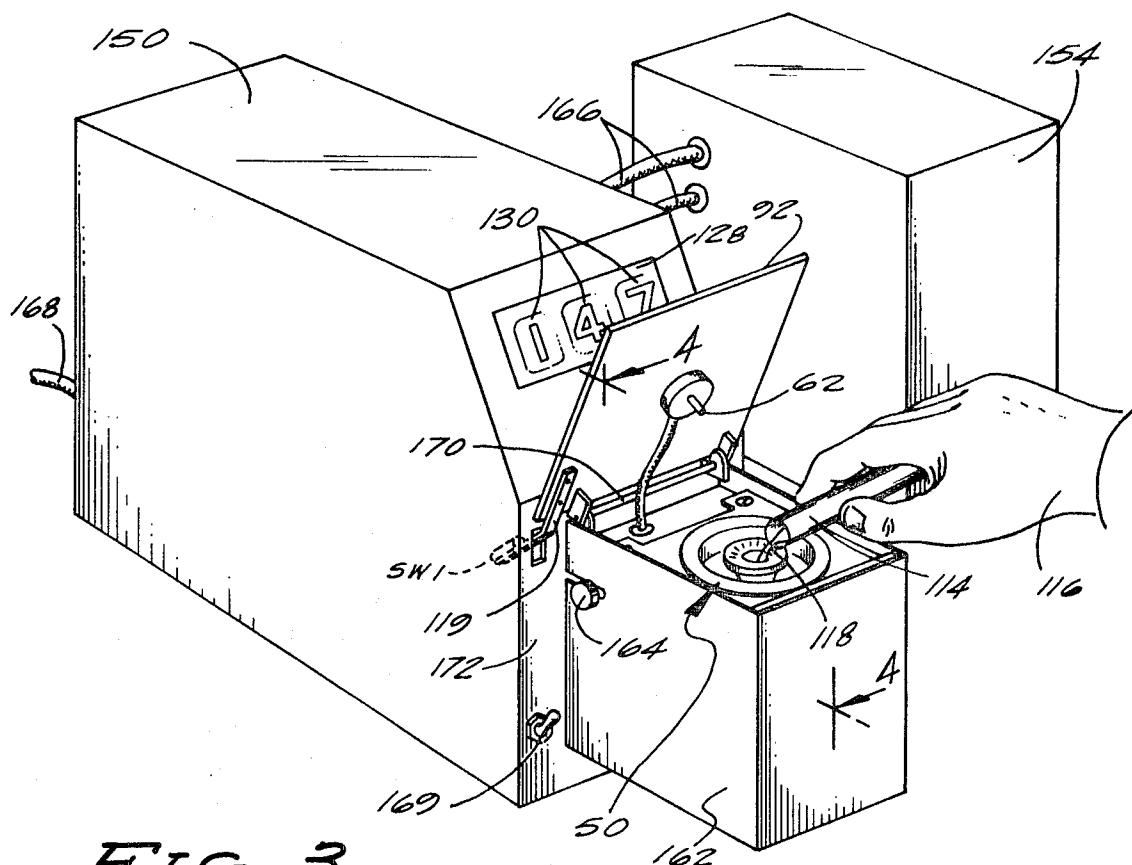


FIG. 3

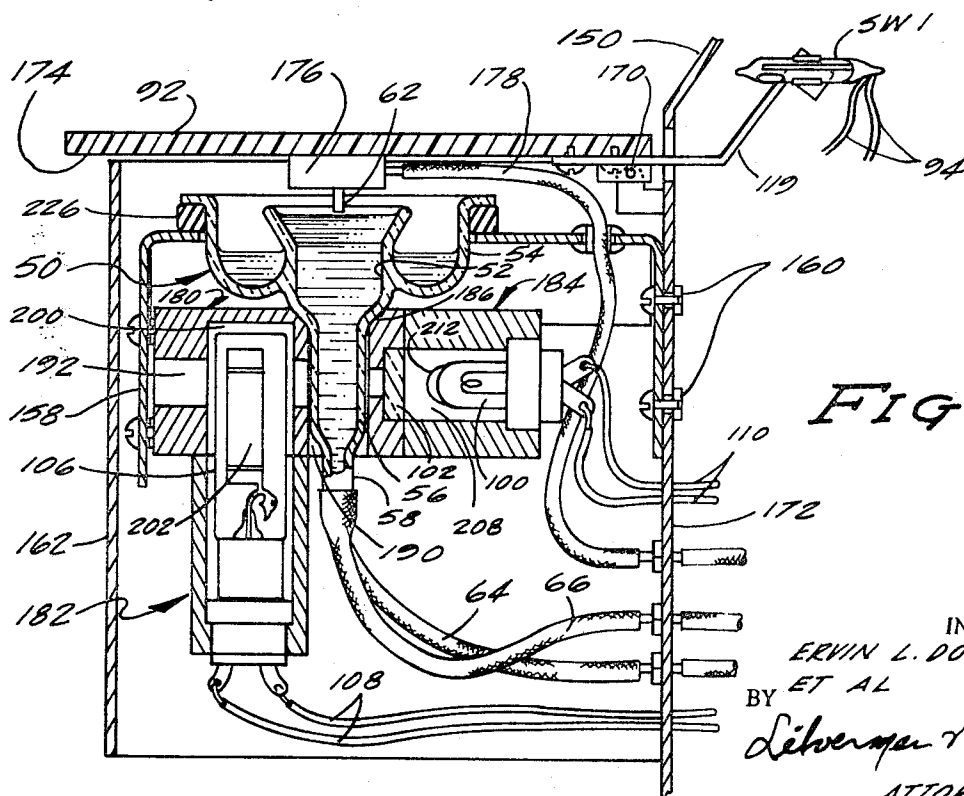
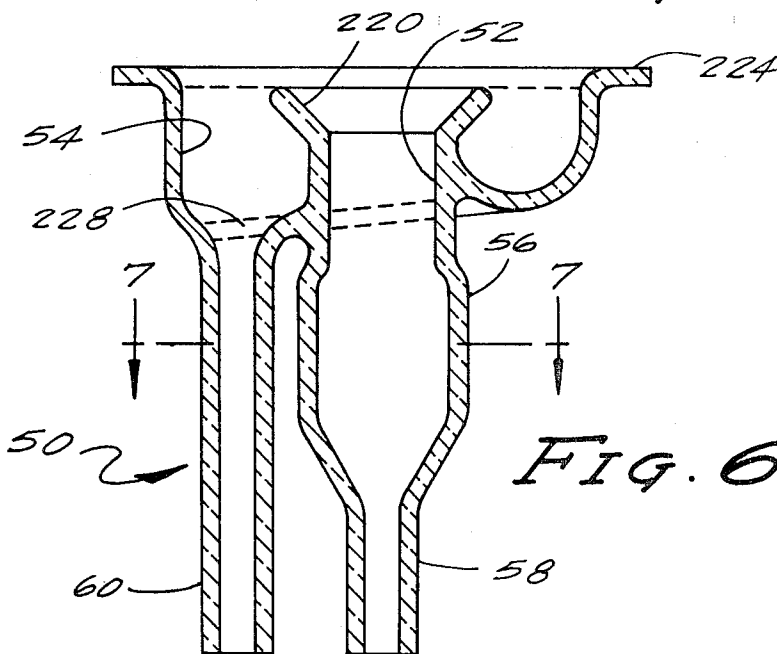
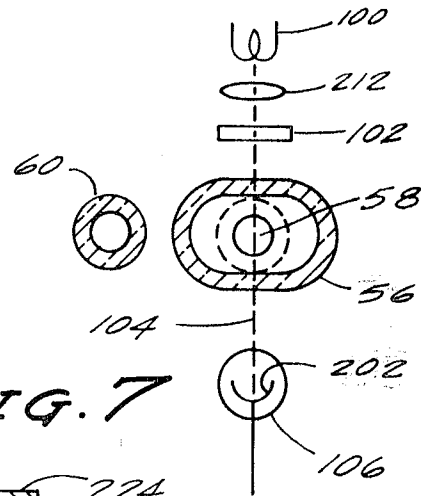
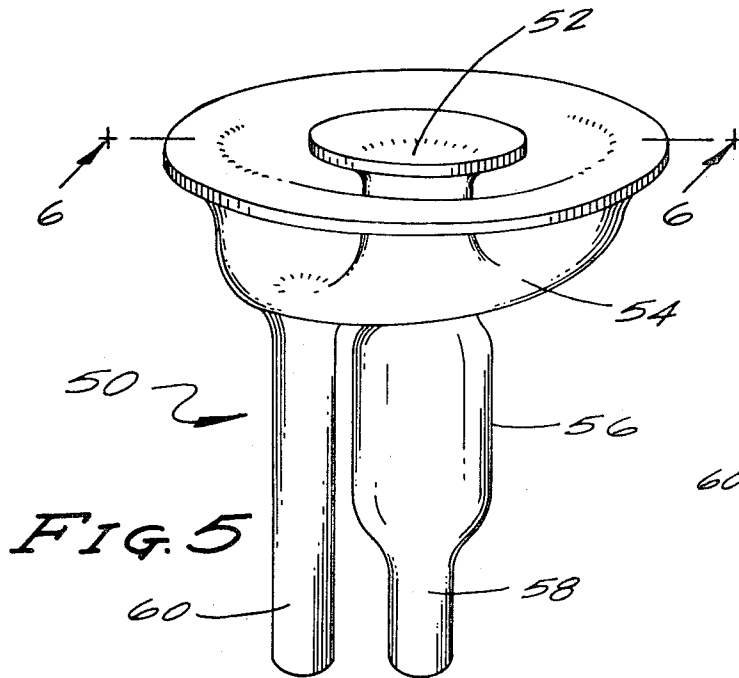
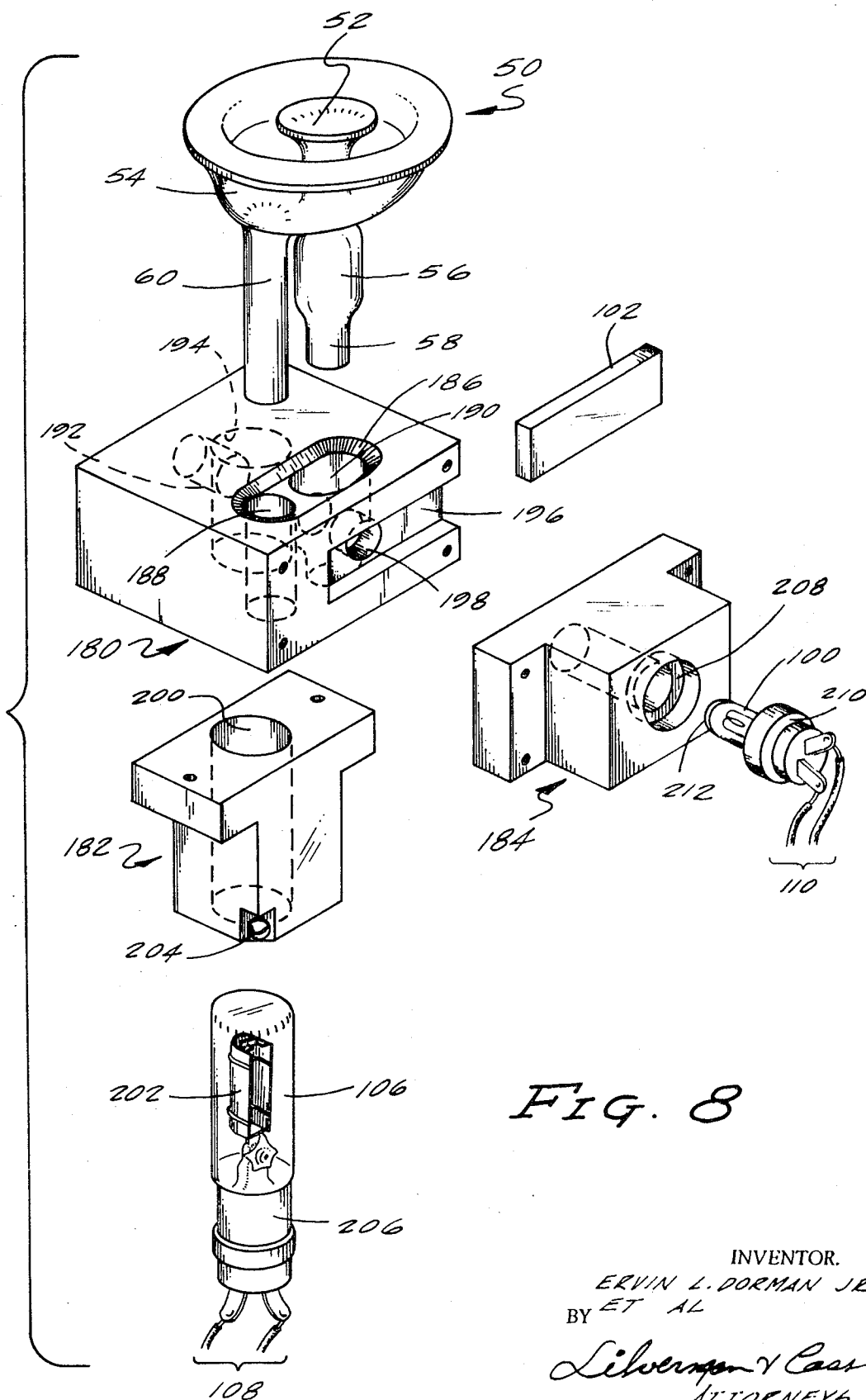


FIG. 4

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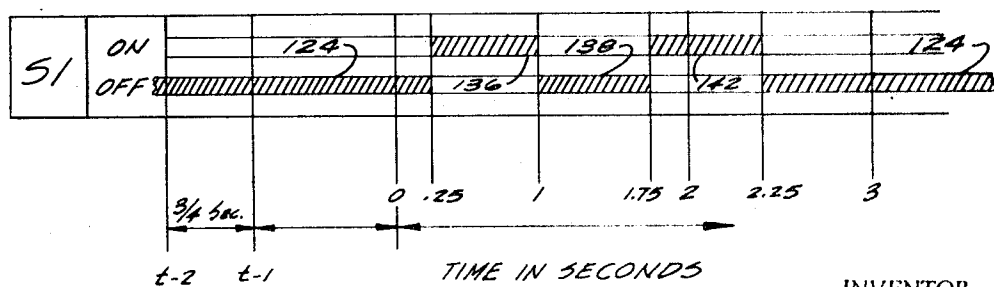
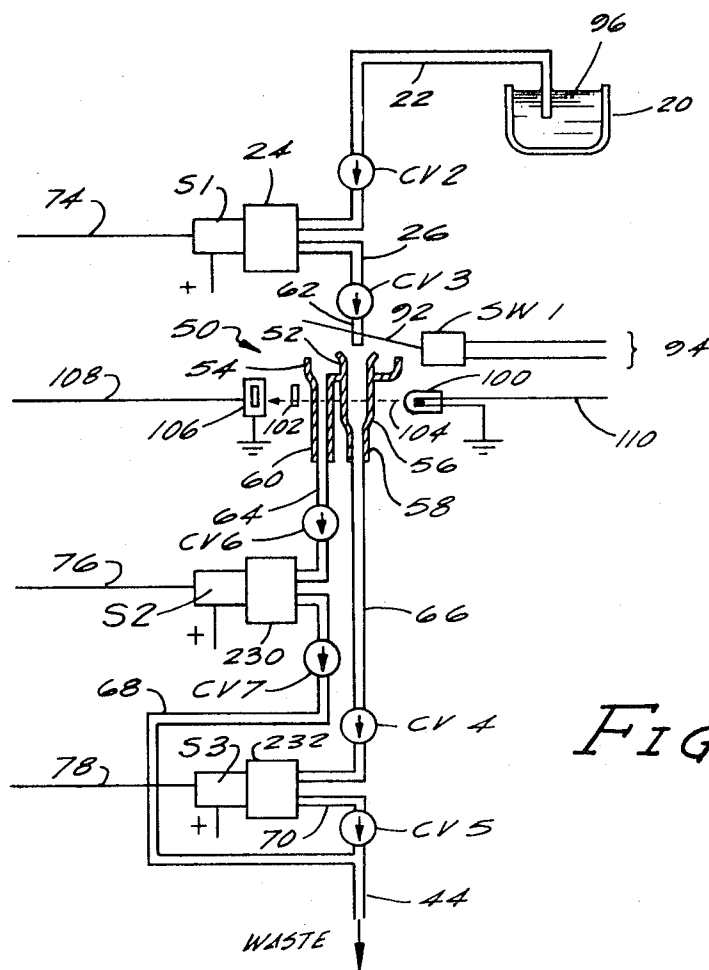


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COLORIMETRIC FLUID TEST APPARATUS HAVING PLURAL FLUID SEQUENTIAL CONTROL

REFERENCE TO RELATED APPLICATIONS

In the specification and claims herein reference is made to a measuring circuit which gives a signal output representing the colorimetric comparison between a sample liquid and a reference liquid. The particular purpose for which the apparatus was intended is to measure the hemoglobin content of a blood sample, although this is not intended to be limiting of the invention. The electronic circuit receives a signal from the optical portion of the device which represents the light absorbance of a reference liquid, remembers this signal, then receives a second signal which represents the light absorbance of the sample, then compares the two signals and provides an output signal that is proportional to the absorbance of the sample, related in terms of the number of grams of hemoglobin per 100 cubic centimeters of blood.

Apparatus which provide the circuitry and structure for accomplishing this kind of measurement are disclosed and claimed in the following application:

Ervin L. Dorman, Jr. and Walter R. Hogg application, Ser. No. 713,958 filed Mar. 18, 1968, U.S. Pat. No. 3,566,133 and entitled A HEMOGLOBINOMETER.

Although it is intended that the apparatus of the invention herein use the circuitry of the copending application mentioned above, any other circuitry may be used which is capable of measuring the absorbance of a sample of liquid as related to the absorbance of a reference liquid.

The instant application, as well as the copending application, are owned by a common assignee. The applicant Ervin L. Dorman, Jr., named in said copending application is the same applicant named with others herein.

FIELD OF THE INVENTION

The invention relates generally to measurement of absorbance of light in a liquid, and more particularly relates to the absorbance of light of a particular wavelength in a specific liquid in order to ascertain the colorimetric factor which caused the absorbance. The most important example, as considered by the principal purpose for the invention, is the ascertaining of the hemoglobin content of a sample of blood. This index is well known in medicine, and furnishes important information for diagnosis and cure of disease. Through the use of the information relating to hemoglobin, other indices of the blood may be obtained which provide additional important data.

Sufficient discussion of the nature of hemoglobin are contained in the copending applications to justify curtailing detailed discussion herein. Suffice it to say that a blood sample is diluted, treated to release the protein pigment of the red cells, and this latter mixed with a suitable reagent to provide the necessary sample liquid. Light of a particular wavelength is passed through the liquid and its absorbance represents the change in color caused by the presence of the pigment. This absorbance is compared with the absorbance of the same beam of light passing through a reference, which ideally is of the identical color as the diluent. The difference is the absorbance due only to the pigment, and this is related to the hemoglobin content of the original blood sample.

The invention contemplates a fully automatic device in which the operator performs only one simple act and causes the entire process of measurement to take place. This act consists of pouring a liquid sample into the cuvette of the apparatus from a vessel. Actually, the act is made up of several simple motions which may be described as follows: first, the technician brings his hand holding the liquid sample close to the device; next, with the same hand he lifts the lid covering the cuvette and holding the lid in open position, he pours the sample liquid into the center receptacle of the cuvette; finally, he removes his hand carrying the vessel away from the device and permits the lid to drop down to its original closed position. The hemoglobin index immediately appears as a readout from the device and the apparatus is ready for the next sample.

In the structure described above the lid carries a switch which is actuated to one condition when the lid is opened and is actuated to another condition when the lid is closed. These conditions activate the programming device and cause the functions of the apparatus to be performed. A simple mercury switch or any other can be used, being normally open when the lid is closed and closed when the lid is open—or vice versa, if desired.

The invention contemplates that the act of bringing the technician's hand adjacent the apparatus can be used in several alternate schemes to perform the same functions. For example, it could interrupt a light beam, or change the capacitance of a tank circuit, or actuate a heat-sensitive switch of the type used in modern elevators. Removal of the hand would restore the controlled switching circuit to its original condition. This, of course, would eliminate the need for a lid or cover member over the cuvette, but as will be seen, this lid provides advantages which justify its use as being preferred.

Any colorimetric measurement may be made by the device, and not necessarily a determination of hemoglobin. This should be kept in mind during a reading of the specification and a consideration of the claims.

DESCRIPTION OF THE PRIOR ART

The literature on methods and apparatus for measuring hemoglobin is quite extensive. The most common methods used in laboratories today are batch methods, although some flow-through apparatuses are available albeit they are expensive. Spectrophotometers are in general use, using split beams to compensate for changes in the system during the measurement of samples. These provide the monochromatic light required by international standards, or the light can be provided by filters. The invention herein contemplates a simple system not requiring expensive apparatus, and it is substantially compact.

Some of the prior art contemplates chemical methods, but the method utilized by the invention is colorimetric and has been described as comparing the color of the acid hematin of a diluted blood sample with a standard and calculating the hemoglobin content of the original blood sample from the result of colorimetric evaluation. This descriptive statement will be noted in a discussion in U.S. Pat. No. 3,374,063, which itself is concerned with a chemical method.

SUMMARY OF THE INVENTION

The invention contemplates a compact apparatus in one or at most two housings, light in weight and easily transported. The technician has nothing to do, after the hemoglobin sample has been prepared, but to pour it into the apparatus. The hemoglobin index appears almost immediately as a readout. The next sample requires nothing more than the same act.

In order to accomplish the above, the apparatus of the invention provides for a sequence of events that make the same reliable, fast and accurate.

The apparatus has a cuvette which is connected with a liquid system operated by suitable valves, these valves are actuated as a result of the proximity of the technician's hand with the sample vessel held therein. In the preferred embodiment, the cuvette mouth is covered by a hinged lid, and the technician lifts the lid using the knuckles of the same hand that holds the sample vessel. This closes an electric switch in a programming circuit. After the liquid is poured into the cuvette, the hand is taken away, the lid lowered, and the same switch is opened. The programming circuit operates the measuring device to provide the desired information, and this is used to drive some kind of readout device, such as digital display electronic counter tubes.

When the lid has been lowered, the photoresponsive circuit is programmed to provide a signal representing the absorbance of a beam of specific wavelength of radiant energy which has passed through the center receptacle of the cuvette carrying the sample, and since the measuring circuit has been

remembering a signal from a reference liquid which previously had been in the receptacle, it can make the comparison and computation. As soon as this is done, by a system of valves and the use of a liquid dispenser, the cuvette is emptied of the measured sample, rinsed with diluent, emptied, filled with diluent, and a measurement is made of absorbance of the diluent and is electrically stored in the measuring circuit, waiting for the next sample measurement.

The actual function performed when the lid is lifted is to close a circuit which starts the programming cycle. The first thing that happens is to empty the reference, comprising a quantity of diluent standing in the center receptacle of the cuvette. The liquid line leading from the center receptacle is then quickly closed so that the next sample may be poured in and will not drain out.

The programming means also programs the draining of liquid from an overflow receptacle, which is coaxially arranged as an annular basin around the principal receptacle.

The cuvette construction, and the arrangement for mounting the cuvette and its associated apparatus are believed also novel.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram of a system constructed in accordance with the invention, same being primarily a flow diagram, but also including some electrical circuitry and blocks representing the measuring circuit, programming means and readout device, these three elements being capable of assuming many different forms.

FIG. 2 is a bar chart illustrating the operation of the apparatus on the basis of time sequence energization of the several solenoids illustrated in the diagram of FIG. 1.

FIG. 3 is a perspective view illustrating the apparatus of the invention in use.

FIG. 4 is a fragmentary median sectional view taken generally on a vertical plane at the line 4—4 of FIG. 3 and in the indicated direction, showing the optical system of the apparatus located at the front thereof.

FIG. 5 is a perspective view of the cuvette of the apparatus dissociated from the remainder of the apparatus.

FIG. 6 is a median sectional view through the cuvette generally along a vertical plane at 6—6 of FIG. 5 and in the indicated direction.

FIG. 7 is a sectional view taken through the cuvette generally along the line 7—7 of FIG. 6 and in the indicated direction.

FIG. 8 is an exploded perspective view of the components making up the mounting means for the optical system of the apparatus.

FIG. 9 is a partial schematic diagram of the system, illustrating an alternate embodiment of the fluid flow control elements.

FIG. 10 is a bar chart showing the sequencing of that portion of the embodiment of FIG. 9 which differs from the timing sequence in FIG. 2.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The invention will best be understood preliminarily by considering the flow diagram of FIG. 1 in conjunction with the timing sequence chart of FIG. 2. The several symbols used in the chart of FIG. 1 are for the most part conventional, although the system is believed novel. Likewise, some of the components illustrated are believed novel, these including the flow-through cuvette and the measuring circuit, the latter being disclosed and claimed in said copending application Ser. No. 713,958. Other measuring circuits can be used.

Referring to the flow diagram, the fluids which are utilized for achieving the operation of the apparatus comprise gas and liquid, the gas in this case being air, and the liquid being diluent and the blood sample. A reservoir of diluent is shown at 20, this diluent being that which has been used previously to dilute the blood sample. This same diluent is used to rinse the

cuvette and likewise serves as a blank or standard for use in comparing with the colorimetric response of the blood sample. Most diluents will have some color, and it is best that the so-called blank take this color into account. The liquid conduit 22 is connected to the reservoir 20 and extends through a check valve CV2 to a liquid dispenser pump 24, with a lateral connecting line 26 branching down between the valve CV2 and the pump 24.

The pump 24 includes a cylinder 28 which has a free piston 30 therein, there being helical spring 32 on the left side of the piston 30 whose function is to dispense the fluid when permitted to do so. The left-hand end of the cylinder 28 is connected to the atmosphere by way of the air conduit 34 in which the normally closed valve V1B is located. The air conduit 34 is a branch of the principal air line 36 which connects directly with the left-hand end of the cylinder 28. The air line 36 has a normally open valve V1A in the path of airflow, followed by a vacuum reservoir 38 which may be in series, if desired, and a check valve CV1. At the bottom of the air line 36, connection is made at 40 with the liquid flow line 42 that brings fluids from the cuvette 50, and the combined liquid and air line 44 connects with a vacuum pump 46 by means of which air and liquid are constantly being sucked out of the lines if the valves and connections are suitably arranged therefor.

The flow-through cuvette 50 has inner and outer receptacle parts 52 and 54, respectively, the principal receptacle being the inner one. The exact construction will be described in detail in connection with FIGS. 5, 6 and 7 hereinafter. The inner or central receptacle 52 is substantially longer than the outer one, the latter serving as the overflow receptacle. The word "cuvette" will be used principally to refer to the entire structure comprising both receptacles. The central receptacle has a central light-transmitting section at 56 through which a beam of radiant energy is to be projected, as described below, for the purposes described in said copending applications. Also, there is a drain formed at 58 at the bottom end of the receptacle 52. The outer or overflow receptacle 54 is relatively shallow and has a drain 60 formed at the bottom end thereof, neither the receptacle nor its drain being located to interfere with clear passage of the radiant energy beam through the light-transmitting section 56 of the central receptacle.

When permitted to do so, liquid dispensed through the line 26 will pass through the valve V1C and will enter the upwardly opening mouth of the central receptacle 52 of the cuvette 50 by way of the nozzle 62. Also, as described later, the operator may pour a sample into the central receptacle by way of its mouth. Overflow from either of these operations will enter the annular mouth of the overflow receptacle 54 and pass to the bottom thereof at the drain 60. In both cases, the liquid will flow down into the respective conduits 64 and 66, being blocked normally by the normally closed valves V2 and V3. If permitted to pass through these valves, the liquid will enter the liquid flow line 42 by way of the respective branches 68 and 70. It should be kept in mind that the valves V2 and V3 need not operate simultaneously.

The block 72 represents a programming device, which in a practical example is preferably an electronic logic circuit providing necessary signals to accomplish the desired sequence of events operating the system. It could alternatively be a timed rotating member with suitable contacts to be made and broken in desired sequence, as used in some well-known types of apparatus. The precise structure is not material to the invention. The programming device operates three solenoids S1, S2 and S3 through the connections 74, 76 and 78, respectively. It also energizes the measuring circuit 79 at the proper time with respect to the sequence of events, the connection 80 being indicative of this control. The lines or connections respectively may be electrical leads or a plurality thereof, the diagram being symbolic and not intended to constitute an actual electrical circuit.

The solenoids in the diagram FIG. 1 are connected to the several valves by dashed lines, these signifying mechanical driving connections. Thus, the solenoid S1 is connected to the valves V1A, V1B and V1C by the respective dashed lines 82, 84 and 86 because all three of these valves are mechanically operated simultaneously when the solenoid S1 is energized. The condition of the respective valves is indicated alongside the valves in FIG. 1, so that V1A is normally open, V1B is normally closed and V1C is normally closed. When the solenoid S1 is energized, the valves operate to the conditions closed, open and open, respectively. When the solenoid is deenergized, these valves return to their normal condition.

Solenoid S2 is connected to the outer receptacle drain valve V2 which is normally closed by the mechanical driving connection 88. The solenoid S3 is connected to the central receptacle drain valve V3 by the mechanical driving connection 90.

The programming means 72 is initially started by the closing of a switch SW1 that is connected to the lid 92 of the apparatus, as will be described. Switch SW1 has an electrical connection 94 with the programming means 72.

Starting with the condition that the lid 92 is down, covering the mouths of the receptacles of the cuvette 50, at this time, the condition of the respective valves is as indicated alongside the valves in FIG. 1. The receptacle 52 is filled with liquid comprising the same diluent which was used to make the blood sample to be measured, this liquid being that shown at 96 in the reservoir 20. None of the solenoids has been energized. This condition is represented on the bar chart as the period of time before t_{7E} and the period of time after 3.75 seconds, this latter being the end of the cycle. The entire apparatus has been energized, of course, and the vacuum pump 46 is operating, pulling a vacuum in the lines 42 and 36. This has pulled the piston 30 to the left against the bias of the spring 32, which is now contracted and has potential energy stored in it. When the piston moves to the left, diluent 96 is drawn through the check valve CV2 into the cylinder 28 on the right-hand side of the piston 30. It therefore fills the line 22 throughout its extent and likewise the chamber in the cylinder to the right of the piston 30. The line 26 will always be filled. At this time, the center receptacle 52 is filled with a charge of liquid consisting of the diluent 96. It has been deposited there as a part of the previous cycle. The optical system is "looking" at this liquid, which is the reference fluid. The blood samples, which are to be tested for hemoglobin content in the apparatus, have been diluted using this identical fluid, so that whatever the response of the optical system due only to the cast of the diluent, this color will be compensated by reason of using the diluent as a reference. Obviously, this is not essential, since the apparatus may be calibrated using any other kind of liquid, clear or colored.

The optical system will be described in detail below, but for the moment, there is a light source 100 which projects a beam of light 104 through a suitable color filter 102 in order to achieve the desired wavelength of light required for a hemoglobin determination. The wavelength according to the international standard of today is 540 nanometers, and this may be achieved by color filters. The formula which is accepted as the definition of hemoglobin in grams per centimeter as given in said copending application Ser. No. 713,958, is based upon absorbance in the sample while traversing 1 centimeter of length, and the length of the path of the beam 104 through the liquid blood sample in the light-transmitting section 56 is considered in the measurement and computation of the index. There is a photoresponsive device 106 which has the beam 104 projected thereon after it has passed through the section 56. Although the diagram of FIG. 1 appears to have the drain 60 in the path of the beam 104, the drain is actually displaced from the beam by a substantial angular distance and does not interfere therewith.

The circuits for the optical system are connected to the measuring circuit 79, such as shown in FIG. 1. The photoresponsive device 106 is connected by the channel 108 to the measuring circuit 79 so that the response produced therein

may be used to make the necessary computations and achieve the desired information. The light source 100 is energized by the connection 110 from any suitable electrical energy source, and is shown in FIG. 1 connected to the measuring circuit 79 although this is not essential, since the light source 100 may be energized at all times. Some form of good regulation is preferred for the electrical energizing of the light source. As will be seen, the measuring circuit 79, programming means 72 and the readout device 112 are all conveniently housed in a single cabinet or housing.

With the beam 104 passing through the reference liquid and impinging upon the active element of the photoresponsive device 106, the resulting output of the device is a signal which establishes a condition in the measuring circuit of the type described in said copending application. The apparatus is now ready for the next signal.

Looking now at FIG. 2, the next period of time commences at t_{7E2} with the raising of the lid 92 by the technician. As seen in FIG. 3, this is easily done by the technician grasping the test tube or other vessel 114 in his hand 116, raising the lid 92 with his knuckles or fingers, and holding the lid while he pours the sample 118 into the cuvette 50. This could be as easily done with the left hand as the right. As soon as the lid is raised, a mercury switch SW1 connected to the lid 92 by the bracket 119 closes and the programming device 72 energizes the solenoid S3. The bar 120 extending from time t_{7E2} to t_{7E1} represents the energization of the solenoid S3 for a period of three-fourths of a second, which, of course, is substantially less than the time that it takes for the technician to lift the lid fully and bring the mouth of the vessel 114 into position for pouring. During this period of time, the conditions of the other two solenoids S2 and S1 do not change, and the bars 122 and 124 are still shown in the "OFF" level in the bar chart FIG. 2.

As soon as the solenoid S3 is energized, it opens the valve V3 and keeps it open for the three-fourths second mentioned above, during which time the vacuum pump 46 sucks the diluent from the receptacle 52 by way of the lines 70, 42 and 44 and discharges the same to waste. When the solenoid S3 once more reverts to its original off condition, the valve V3 closes, as indicated by the bar 126 and remains closed from the time t_{7E1} until one-fourth second after the time "O" on the bar chart. This period of time is indefinite because it represents the time that the technician uses to empty the contents of the vessel 114 into the center receptacle 52 of the cuvette 50 and to permit the lid 92 to lower to its covering position. Experience has shown that this will probably be of the order of 2 or more seconds.

While the sample 118 is being poured into the center receptacle, the conditions of the respective solenoids are the same as during those periods between cycles, except that the receptacle 52 has been emptied of the reference liquid.

When the lid 92 has been lowered sufficiently to open the switch SW1, the timing represented by the bars to the right of 0 in FIG. 2 commences. The programming means 72 responds to the closing of the switch SW1 first, by commanding the measuring circuit 79 to make the measurement needed to obtain the value of the absorbance of the sample which was poured into the receptacle 52. The same light source 100 and photoresponsive element 106 are used to produce the signal. This measurement occurs some time between 0 time and one-fourth second later, preferably toward the end of this period of time. As soon as the measurement is made, the circuit described in the copending application, preferably that of application Ser. No. 713,958, makes the computation and the index appears in the readout device 112 as a number seen by the technician. Note the window 128 of the housing 150 of FIG. 3 in which there are shown the axial ends of three digital display counter tubes 130 which provide the visual display desired. The technician can see this index almost immediately after pouring the sample into the cuvette 50.

At the point in time designated 0.25 second, the programming means again energizes the solenoid S3 and the condition thereof is represented thereafter by the bar 132. Thus,

the sample which was disposed in the receptacle 52 empties to waste in the manner described in connection with the previous energization of the solenoid S3.

At the time designated 1 second, the solenoid S3 is once more deenergized and this is represented by the bar 134. This means, of course, that the valve V3 is closed for three-fourths second after the 1-second point. During the same period, the programming means energizes the solenoid S1 which operates the three valves V1A, V1B and V1C. The valve V1A closes, blocking the vacuum effect from being felt in the line 36. The valve V1B opens to atmosphere, relieving any vacuum remaining in the line 36, and the spring 32 is now permitted to expand from its previously contracted condition. Since the valve V1C is also opened, the spring 32 pushes the piston 30 to the right, emptying the contents of the right-hand end of the cylinder 28 into the line 22 from which it passes by way of the lateral branch 26 through the nozzle 62 into the receptacle 52. The bar representing this action is 136, its length being three-fourths second. The cuvette is filled with diluent for this period of time, the programming device acting to provide the necessary commands. The optical system is also rendered inoperative by the programming device, since the purpose of the introduction of the liquid into the receptacle 52 at this time is for rinsing.

The next period of time extends from 1.75 seconds to 2.5 seconds, also a period of three-fourths second. During this period as seen from the bar chart, the solenoid S1 is deenergized as indicated by the bar 138 and the solenoid S3 is energized as indicated by the bar 140 and the result will be that the liquid in the receptacle 52 will be drained to waste. At 2.5 seconds, the solenoid S3 is deenergized, the solenoid S1 energized and, for the first time, the solenoid S2 is energized.

The bars 142 and 144 provide the same conditions that existed between 1 second and 1.75 seconds, so, the cuvette 50 is once more filled with diluent, but since the solenoid S3 is not energized after the liquid dispenser pump 24 has operated, the charge of liquid remains in the receptacle 52. Note that the condition of solenoid S3 obtains to the end of the cycle and continues as bar 144 until the time $t_{7/8}$ of the next succeeding cycle. The condition of the solenoid S1 reverts to deenergized after three-fourths second as indicated by the bar 124, and this likewise obtains until the start of the next succeeding cycle. The energizing of the solenoid S2 from the time 2.5 seconds to the time 3.75 seconds as indicated by the bar 148 causes the mechanical connection 88 to open the valve V2 and this enables the vacuum pump 46 to suck any overflow liquid from the receptacle 54 out of the drain 60 by way of the lines 64, 68 and 42 to the main line 44 and discharge the same to waste. Thereafter the solenoid S2 is deenergized and reverts to its original condition represented by the bar 122.

The filling and draining of the cuvette 50 as represented by the sequence from 1 second to 2.5 seconds may be programmed to repeat several times if desired, since this is a rinsing function. In this described structure, the rinsing is done only once, after which the receptacle 52 is permitted to retain the diluent. If the rinsing is not needed for some types of colorimetric measurements, the fill and drain cycle may be omitted, and the receptacle 52 is filled with the reference sample immediately after the test sample has been drained.

The structure described above uses very little sample and diluent. The charge provided by the dispenser 24 need only be about 3 cc. The overflow assures that no liquid will contaminate the optical system and likewise assures that the receptacle 52 will be full, or at least have sufficient liquid to fill the measuring section 56. The technician will not hesitate to pour as much liquid as required into the cuvette because he knows that the overflow receptacle 54 will be emptied once each cycle when the solenoid S2 is energized. Its volume could be chosen at about 5 to 7 cc., while the volume of the center receptacle 52 is about $2\frac{1}{2}$ to 3 cc. The maximum vacuum is used for draining the center receptacle 52 by draining the overflow receptacle 54 while valve V3 is closed and not during any period of time that speed of draining receptacle 52 is important.

The reservoir 38 provides a constant vacuum notwithstanding the pulsing of the pump 46, so that the action of the piston 30 will be fast and so that it will stay in "cocked" position during the portion of the cycle that it is compressing the spring 32. In FIG. 3 the apparatus of the invention is illustrated in a design which is convenient. The cabinet 150 will house the entire electrical circuitry, including the programming means 72, the measuring circuit 79 and the readout 112. In the view there has been shown another cabinet or housing 154 which conveniently will carry the vacuum pump 46, an electric motor (not shown) to drive the pump, the vacuum reservoir 38 and various other parts of the apparatus, but these could easily be incorporated into a single cabinet. The separation of the electrical parts from these larger components of the liquid system may make for ease of assembly and servicing. Some of the valves and the pump 24 are easily included in the main cabinet 150.

The optical system and the cuvette mounting means are supported in a chassis of sheet metal such as indicated at 158 that is connected to the front of the cabinet 150 as shown at 160 in FIG. 4. The mounting gives easy access to these structures especially if an outer shroud or sheet metal enclosure 162 is provided to be removed readily. Slots and thumbscrews as at 164 provide for removability of the shroud 162.

The cabinet 150 has cables and connections with the cabinet 154, these including fluid and electrical connection and being indicated at 166. The main electric power cable from the power line is shown at 168. Only one operating control is needed, being the main power switch 169.

The lid 92 is hinged at 170 to the front wall 172 of the cabinet 150 and preferably has an overhang 174 extending forward of the shroud 162 and over its sidewalls so that the technician may easily be enabled to engage his hand under the lid to lift the same when using the apparatus. There is a fitting 176 secured to the underside of the lid aligned with the center of the receptacle 52 so that the nozzle 62 may be supported thereat. The nozzle is part of the flexible pipe 178 that connects through the wall 172 with the valve V1C that is not shown in FIG. 4.

Looking now at FIGS. 4 and 8, the center of the chassis 158 mounts three blocks 180, 182 and 184 which are secured together by any suitable fastening means to form the assembly shown in FIG. 8. The mounting block 180 carries the cuvette 50, and is provided with a shallow recess 186 for seating the fillets or bulges formed in the cuvette at the points where the depending portions are connected, and two vertical passageways 188 and 190 for accommodating the drain 60 and the measuring section 56 of the cuvette 50. When engaged in these passageways, the bowl-like exterior of the receptacle 54 will be spaced slightly above the upper surface of the block 180. A cylindrical passageway passes horizontally through the block, intersecting the vertical passageway 190 and another vertical passageway 194, and opens to the bottom of a groove 196 at 198. The groove 196 accommodates a glass or other filter, and since the groove opens to the side of the assembly, the filter 102 is readily exchanged for any suitable other kind. The passageway 192 is aligned with the light-transmitting section 56 when the structure is assembled so that the beam of light 104 passing coaxially through the passageway 192 will also pass through any liquid in the section 56.

The block 182 has a vertical cylindrical bore 200 which aligns with the vertical passageway 194 when the block 182 is connected to the bottom of the block 180. A photoresponsive device 106, such as a photomultiplier tube is mounted in the block 182 with its sensitive element 202 facing the opening 198 and aligned therewith. A suitable setscrew 204 holds the base 206 of the tube 106 in place. Over the front of the block 180, there is secured the lamp-mounting block 184, having a central horizontal passageway 208 aligned with the passageway 192. A lamp 100 is mounted to a socket 210 that plugs into the end of the passageway 208 so that the lamp may serve to provide a light source. The lamp 100 is preferably of a type having a lens 212 incorporated in the end thereof to enable collimating of the light.

Light passes through the filter 102 and the liquid in the light-transmitting section 56 and illuminates the element 202 of the tube 106. The purpose is as explained above.

Reference may now be had to FIGS. 5, 6 and 7 for the details of the cuvette 50. The cuvette is preferably formed from glass parts suitable fused together by well-known glass-blowing techniques. The receptacle 52 and the receptacle 54 are concentric with the receptacle 52 having a bell-shaped mouth 220 opening in the center and slightly below the annular flanged rim 224 of the receptacle 54. This rim 224 engages upon the top of a resilient pad 226 (see FIG. 4) which supports the same. The receptacle 45 is in the form of an annular bowl that slopes slightly toward the lateral opening 228 which serves as the entrance to the depending drain 60. The light-transmitting section 56 is somewhat oval at the point where the beam 104 passes through the same and the opposite walls are flat at this point to prevent distortion and refraction of the beam and to enable the distance between them to be easily ascertained.

Modifications of the structure are capable of being made within the scope of the invention. For example, a cuvette could be used without the overflow receptacle 54 and the added drain and electrical and fluid structure for emptying the same. Certain advantages would be lost, but benefits as taught by the invention would be achieved. The method of initiating the operation of the programming means is preferred to be a lid, covering the mouths of the cuvette, but instead there could be some other structure which is actuated when the technician's hand comes into sample-pouring position. The lid is preferred because it prevents contamination of the sample and the reference, and keeps light out of the optical system. Other modifications can be made.

As understood from the above, although the apparatus is specifically intended for use as a hemoglobinometer, it is capable of making colorimetric determinations of fluid other than blood samples. The filter 102 is readily changed to give wavelengths as desired, and modifications readily made in the measuring circuit 79 to provide the desired range of measurements.

One modification, which would increase the compactness of the apparatus and enable all components to be contained in a single, relatively small housing, is shown in FIG. 9. Such modification relates to the fluid controlling elements, and, except as next specifically noted, is the same as that described in connection with FIGS. 1 and 2.

The primary purpose of this modification is to eliminate the bulk of the vacuum reservoir 38, the vacuum pump 46, and the need for solenoid driven valves, while retaining the simple fluid flow pattern and programmed cyclic action of the primary embodiment. Such is accomplished by employing the solenoid S1 to actuate the fluid dispensing pump 24, and by adding similarly operating fluid pumps 230 and 232 actuated respectively by the solenoids S2 and S3.

All of the solenoid driven valves are eliminated as well as the check valve CV1. In lieu thereof there are a check valve CV3 in the line 26 leading to the nozzle 62; check valves CV4 and CV5 leading to and from the fluid pump 232, respectively in the conduit 66 and branch 70; and check valves CV6 and CV7 leading to and from the fluid pump 230, respectively in the conduit 64 and the branch 68.

The timing of the activation of the solenoids S2 and S3 are the same as previously described with respect to FIG. 2, and the fluid controlling thereby is also the same. However, the timing of the solenoid S1 is advanced by three-fourth second, as shown in FIG. 10, specifically with reference to time bars 136' and 142' so as to place the fluid pump 24 in the cocked position in sufficient time for diluent dispensing to commence at the same times as in the primary embodiment, i.e., 1 second and 2.5 seconds of the cycle, as represented by time bars 138' and 146'. Such dispensing is accomplished on the release of the solenoid S1 which drives the piston 30 toward the right end of the cylinder 28 (with reference to FIG. 1).

In the event that the lid 92 and its switch SW1 are replaced by another form of proximity initiating arrangement, some stray light might impinge upon the photoresponsive device 106. In such event, the filter 102 could be located in protective proximity to the device 106 as illustrated. In all other respects, the embodiment of FIG. 9 is intended to be the same as that of FIG. 1, and common reference designations have thus been employed.

It is anticipated that those skilled in the art might find it advantageous to introduce certain technical changes to suit particular environmental, testing and measuring need, while at the same time remaining within the scope of the invention.

What is desired to secure by Letters Patent of the United States is:

1. Colorimetric fluid test apparatus for rapidly and cyclically comparing the absorbance of a reference fluid against a succession of fluid test samples, comprising:

A. means providing a beam of radiant energy impinging on a photoresponsive device,

B. a flow-through cuvette having a radiant energy transmitting section in the path of the beam,

C. a source of an absorbance reference fluid and means directing the flow of said fluid into said cuvette,

D. said cuvette also adapted to have one of a succession of fluid samples poured into said cuvette from a vessel brought into pouring position over said cuvette,

E. means for controlling the flow of the reference fluid into said cuvette and both fluids out of said cuvette,

F. means responsive to signals from said photoresponsive device for comparing against each other the absorbance of the reference and sample fluids,

G. programming means for commanding the operation of said flow-controlling means and said absorbance comparing means to occur in a predetermined, rapidly repeating cycle of entry of the fluids into said cuvette at mutually exclusive periods of time and draining thereof from said cuvette, and

H. structure responsive to the bringing of said vessel into said pouring position over said cuvette for initiating the operation of said programming means.

2. Colorimetric fluid test apparatus comprising:

A. means providing a beam of radiant energy impinging on a photoresponsive device,

B. a flow-through cuvette having a radiant energy transmitting section in the path of the beam,

C. a source of a first fluid and means directing the flow of said fluid into said cuvette,

D. said cuvette also adapted to have a second fluid poured into said cuvette from a vessel brought into pouring position over said cuvette,

E. means for controlling the flow of the first fluid into said cuvette and both fluids out of said cuvette,

F. means responsive to signals from said photoresponsive device for comparing the absorbance of the two fluids,

G. programming means for commanding the operation of said flow controlling means and said absorbance comparing means to occur in a predetermined cycle of entry of the fluids into said cuvette at mutually exclusive periods of time and draining thereof from said cuvette, and

H. structure responsive to the bringing of said vessel into said pouring position over said cuvette for initiating the operation of said programming means, in which said initiating structure comprises a movable closure blocking the admission of said second fluid into said cuvette and is required to be moved to unblocking condition to enable said vessel to be placed in said pouring position and in which said flow-directing means comprise a conduit extending from said source of first fluid and having a discharge end which moves into discharge position only when said closure is in its blocking condition.

3. Apparatus as claimed in claim 2 in which said cuvette has two separate receptacles arranged with upwardly opening concentric mouths comprising an inner receptacle having said

radiant-energy-transmitting section and an outer overflow-receiving receptacle, said flow directing means being arranged to flow said first fluid into said inner receptacle and the second fluid adapted to be poured into said inner receptacle, the said blocking position of said closure being such as to cover both of said mouths.

4. The apparatus as claimed in claim 2 in which said initiating structure also includes a control element operated by movement of said closure.

5. The apparatus as claimed in claim 4 in which said control element comprises an electrical switch having two circuit states and being coupled with said closure member so that movement of the closure member between blocking and unblocking conditions will change the switch between said states, and in which said programming means operation is electrically initiated when said switch is in one of said states.

6. The apparatus as claimed in claim 4 in which said movable closure is a lid hinged at one edge and adapted to be rotated upward about said one edge, and in which said control element is a switch linked to said lid for mechanical movement therewith.

7. The apparatus as claimed in claim 6 in which the switch is electrical and the operation of said programming means is electrically initiated by said switch when said lid is raised.

8. Colorimetric fluid test apparatus comprising:

A. means providing a beam of radiant energy impinging on a photoresponsive device,

B. a flow-through cuvette having a radiant energy transmitting section in the path of the beam,

C. a source of a first fluid and means directing the flow of said fluid into said cuvette,

D. said cuvette also adapted to have a second fluid poured into said cuvette from a vessel brought into pouring position over said cuvette,

E. means for controlling the flow of the first fluid into said cuvette and both fluids out of said cuvette,

F. means responsive to signals from said photoresponsive device for comparing the absorbance of the two fluids,

G. programming means for commanding the operation of said flow-controlling means and said absorbance comparing means to occur in a predetermined cycle of entry of the fluids into said cuvette at mutually exclusive periods of time and draining thereof from said cuvette,

H. structure responsive to the bringing of said vessel into said pouring position over said cuvette for initiating the operation of said programming means, said structure also responsive to said vessel being moved out of pouring position for further operation of said programming means, and

I. said flow-directing means comprising a conduit extending from said source of first fluid and having a discharge end which moves into discharge position only when said structure is being responsive to said vessel being moved out of pouring position.

9. The apparatus as claimed in claim 8 in which said cycle includes two phases, one phase being initiated when said vessel is brought into said pouring position and the other phase being initiated when said vessel is moved out of said pouring position.

10. The apparatus as claimed in claim 9 in which said initiating structure comprises a movable closure blocking the admission of said second fluid into said cuvette and is required to be moved to unblocking condition to enable said vessel to be placed in pouring position, said closure being constructed such that it will return to blocking condition when said vessel is moved out of pouring position.

11. The apparatus as claimed in claim 10 in which said initiating structure also includes a control element operable between two control conditions by movement of said closure between blocking and unblocking conditions.

12. The apparatus as claimed in claim 11 in which the first phase of said cycle comprises draining first fluid remaining in said cuvette from a previous cycle and accepting and retaining

said second fluid poured into said cuvette, said programming means commanding performance of said first phase when said control element is in one control condition, the second phase of said cycle comprising responding to the absorbance of said second fluid and making said comparison, draining the second fluid from said cuvette and replacing the same with a quantity of first fluid and responding to the absorbance of said first fluid while retaining same in said cuvette, said programming means commanding performance of said second phase when said control element is in said second control condition.

13. The apparatus as claimed in claim 12 in which said second phase further includes a filling of said cuvette with said first fluid and a draining thereof without measurement, for rinse purposes after the draining of said first fluid from said cuvette.

14. Apparatus as claimed in claim 8 which said flow-directing means further comprise a piston-type liquid dispenser connected to said conduit upstream of said discharge end.

15. Apparatus as claimed in claim 12 in which said cuvette has two separate receptacles arranged with upwardly opening concentric mouths comprising an inner receptacle having said radiant-energy-transmitting section and an outer overflow-receiving receptacle, said flow-directing means being arranged to flow said first fluid into said inner receptacle and the second fluid adapted to be poured into said inner receptacle, said lid covering both of said mouths when in blocking condition, said second phase also including draining any fluids from said overflow receptacle.

16. Apparatus as claimed in claim 8 in which said cuvette has two separate receptacles arranged with upwardly opening concentric mouths comprising an inner receptacle having said radiant-energy-transmitting section and an outer overflow-receiving receptacle, said flow directing means being arranged to flow said first fluid into said inner receptacle and the second fluid adapted to be poured into said inner receptacle.

17. Apparatus as claimed in claim 15 in which said flow-directing means comprise a first piston-type liquid dispenser having a discharge end coupled to discharge said first fluid into said inner receptacle.

18. Apparatus as claimed in claim 17 in which the receptacles have independent drain means operated by said flow-controlling means which further comprise a second and a third piston-type liquid dispenser, respectively connected to said independent drain means.

19. Colorimetric fluid test apparatus for rapidly and cyclically comparing the absorbance of a reference fluid against a plurality of different fluid test samples comprising:

A. means providing a beam of radiant energy impinging on a photoresponsive device,

B. a flow-through cuvette with an upwardly opening mouth, having a radiant energy transmitting section in the path of the beam,

C. a source of a first fluid, such fluid to be employed cyclically as the absorbance reference, and means directing the flow of said reference fluid into said cuvette, said flow-directing means including a fluid-conducting path from said source to said cuvette and a first piston-type liquid dispenser within said fluid-conducting path between said cuvette and source,

D. said cuvette also adapted to have a second fluid poured into the mouth of said cuvette from an external vessel, said second fluid constituting a test sample,

E. means for controlling the flow of the reference fluid into said cuvette and both fluids out of said cuvette, said flow-controlling means including automatic means operating the piston of said dispenser to withdraw a measured quantity of reference fluid out of said source on one movement of the piston and to dispense said amount into said cuvette on an opposite dispensing movement of said piston,

F. means responsive to signals from said photoresponsive device for comparing against each other the absorbance of the two fluids, and

G. programming means for commanding the operation of said flow-controlling means and said absorbance comparing means to occur in a predetermined cycle of entry of the fluids into said cuvette at mutually exclusive periods of time and draining thereof from said cuvette and providing rapidly repeating cycles for entry of different of the test samples.

20. The apparatus as claimed in claim 19 in which said piston has spring-biasing means for producing said dispensing movement, said piston operating means comprise a source of vacuum and a vacuum line extending to said dispenser and connected to reduce pressure on one face of the piston, said flow-controlling means include a first valve in said line, and said programming means controls operation of said first valve to relieve the vacuum to permit said spring-biasing means to drive the piston in dispensing movement during said cycle.

21. The apparatus as claimed in claim 20 in which said cuvette has a drain and said source of vacuum has a second line connected to said drain, said flow-controlling means includes a second valve in said second line, and said programming means controls said second valve to enable draining said cuvette of first or second fluid during said cycle.

22. The apparatus as claimed in claim 21 in which a two-state control element is provided for operating said programming means in two phases of said cycle, the normal condition of said apparatus with the control element in one state being with the valves closed, a quantity of first fluid in the dispenser and in the cuvette, the response to the absorbance of said first fluid having been received and stored in said comparing means, the first phase beginning with a change of the state of the control element to its second state and a pouring of said second fluid into said cuvette thereafter, and said first phase consisting of opening the second valve to drain the first fluid from said cuvette and closing the same valve in quick succession to enable the cuvette to retain said second fluid, the second phase beginning with a reversion of the control element back to its first state, and comprising responding to the absorbance of the second fluid and comparing said response with that of the first fluid to obtain the difference, opening the second valve to drain the second fluid from said cuvette, closing said second valve, opening the first valve and dispensing said measured quantity of first fluid into said cuvette and clos-

ing said first valve to draw another quantity of first fluid into said dispenser and responding to and storing the absorbance of said measured quantity in the cuvette.

23. The apparatus as claimed in claim 22 in which the second phase includes opening and closing of said second valve and a subsequent opening and closing of the first valve so that the first quantity of first fluid dispensed into said cuvette comprises a rinse.

24. The apparatus as claimed in claim 19 in which said flow-controlling means comprise at least a second piston-type liquid dispenser connected to said cuvette and coupled to said programming means for purposes of draining said cuvette.

25. The apparatus as claimed in claim 24 in which a two-state control element is provided for initiating operation of said programming means, said cuvette having said measured quantity of first fluid therein while said control element is in one state, the first fluid being drained from said cuvette and the cuvette conditioned to receive the second fluid when the control element is placed in the second state, an absorbance response to said second fluid being received by said comparing means after said control element has been returned to its first state, said cycle including the sequential draining of said second fluid from said cuvette, further dispensing of first fluid into said cuvette, and an absorbance response to said first fluid being received and stored by said comparing means.

26. Apparatus as claimed in claim 25 in which said cuvette has two separate receptacles both arranged with upwardly opening concentric mouths comprising an inner receptacle, having said radiant-energy-transmitting section, and an outer overflow-receiving receptacle, said directing means being arranged to flow said first fluid into said inner receptacle, and the second fluid to be poured into said inner receptacle.

27. Apparatus as claimed in claim 26 in which said second piston-type liquid dispenser has an input connected to said inner receptacle, for draining same and said flow-controlling means further comprise a third piston-type liquid dispenser having an input connected to said outer receptacle, for draining same.

28. Apparatus as claimed in claim 27 in which solenoid drive means is provided for each of said liquid dispensers and check valves are positioned at the input and output of each liquid dispenser.

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Certificate

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Patented November 23, 1971

Ervin L. Dorman, Robert I. Klein, Robert L. Kreiselman, and
Wallace H. Coulter

Application having been made by Ervin L. Dorman, Robert I. Klein, Robert L. Kreiselman and Wallace H. Coulter, the inventors named in the patent above identified, and Coulter Electronics, Inc., Hialeah, Florida, a corporation of Illinois, the assignee, for the issuance of a certificate under the provisions of Title 35, Section 256, of the United States Code, adding the name of Walter R. Hogg as a joint inventor, and a showing and proof of facts satisfying the requirements of the said section having been submitted, it is this 20th day of March 1973, certified that the name of the said Walter R. Hogg is hereby added to the said patent as a joint inventor with the said Ervin L. Dorman, Robert I. Klein, Robert L. Kreiselman and Wallace H. Coulter.

FRED W. SHERLING
Associate Solicitor.