

[54] **BREATH ANALYZER**

3,701,601 10/1972 Plumpe, Jr. et al. 356/180 X

[75] Inventors: **Lawrence Allan Block**, Point Pleasant; **Robert N. De Wilde**, Ocean Township; **Gavino A. Spampinato**, Bricktown, all of N.J.

Primary Examiner—Robert M. Reese
Attorney, Agent, or Firm—Patrick J. Walsh

[73] Assignee: **Bangor Punta Operations, Inc.**, Greenwich, Conn.

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[51] Int. Cl. **G01n 21/24**, G01n 33/18

[58] Field of Search 23/232 R, 254 R, 255 R; 128/2 C; 356/180, 184, 204, 205, 206

[56] **References Cited**

UNITED STATES PATENTS

3,476,516 11/1969 Curry 23/254 R

[57] **ABSTRACT**

Human breath tester for quantitatively measuring alcoholic content as an indication of the state of intoxication, if any, of any person, typically an automobile driver. The unit is fully transistorized and is programmed to sequence through a purge and blank cycle prior to an actual test to assure a reliable reading. A digital display and printer provide duplicate output readings and a novel sample chamber construction insures accurately metered samples of deep lung breath.

29 Claims, 15 Drawing Figures

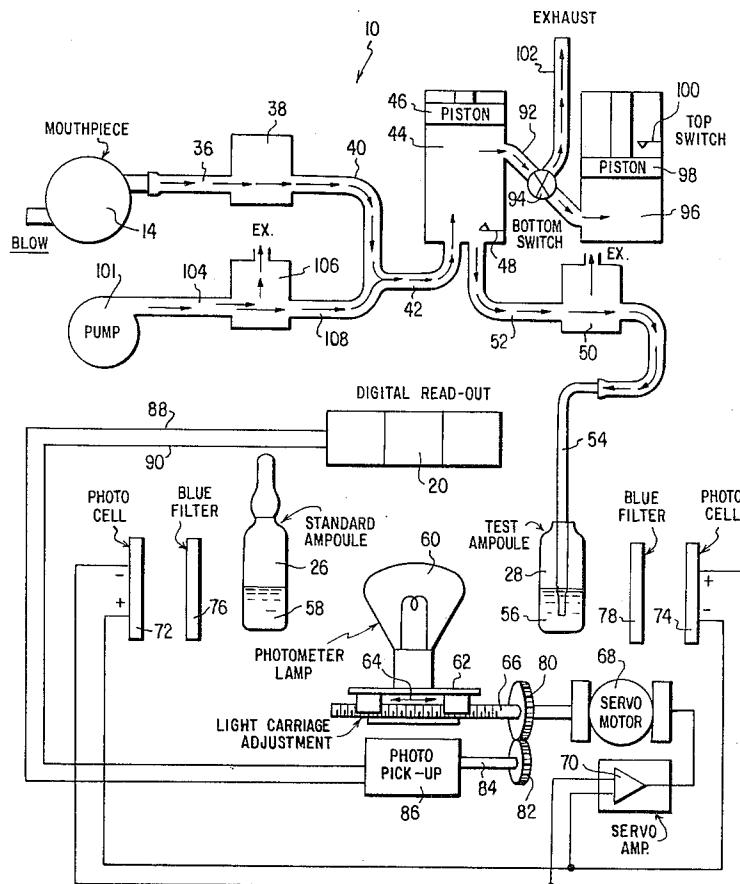


FIG. 1

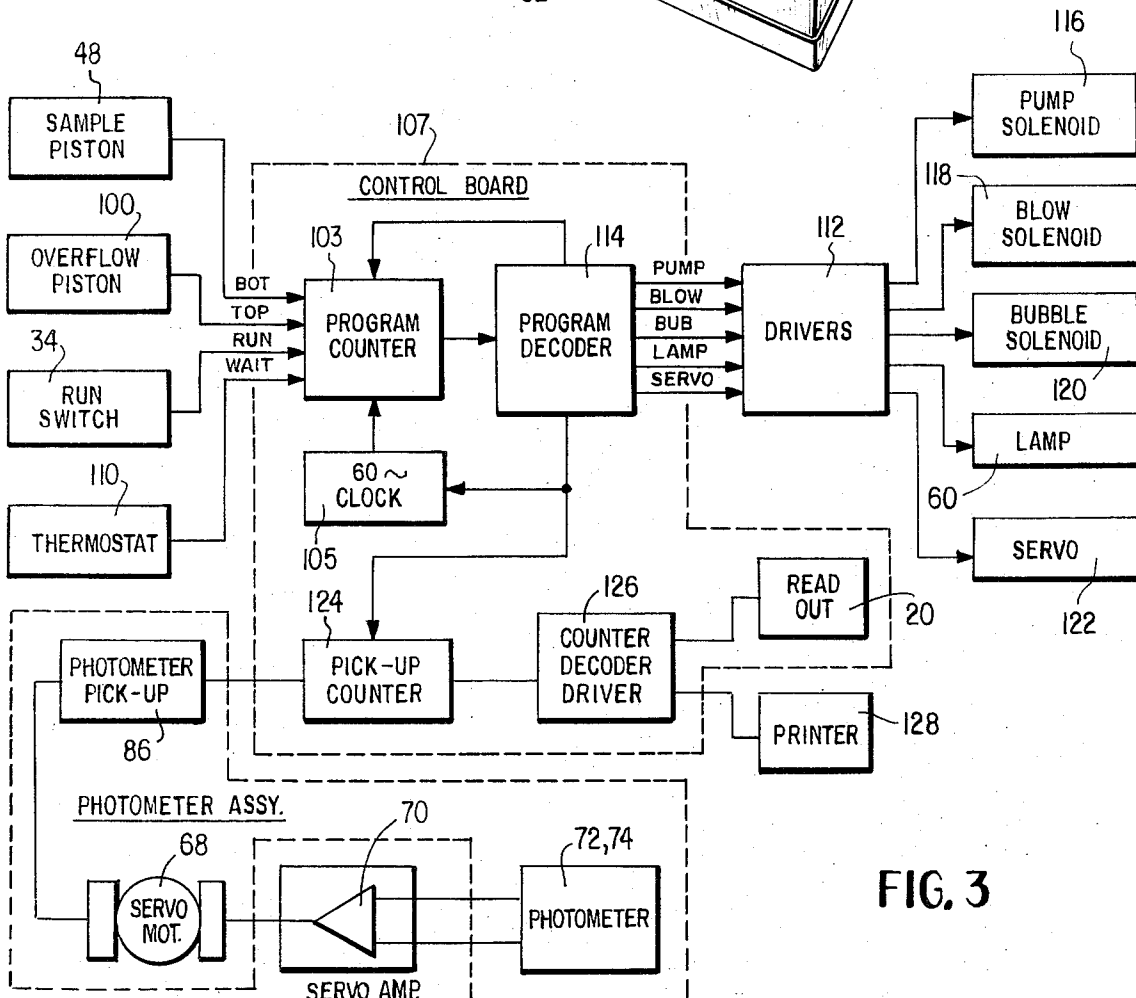
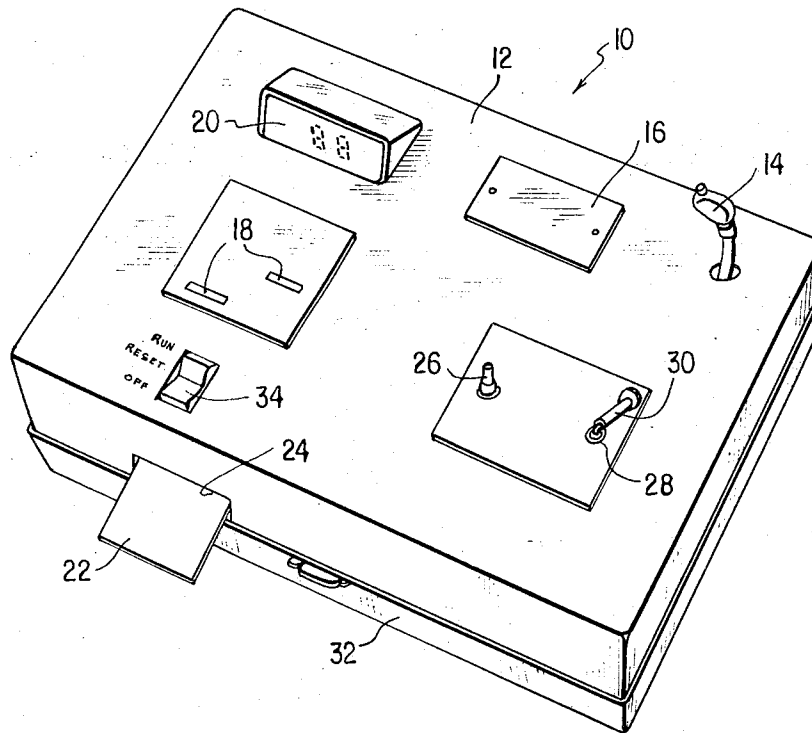
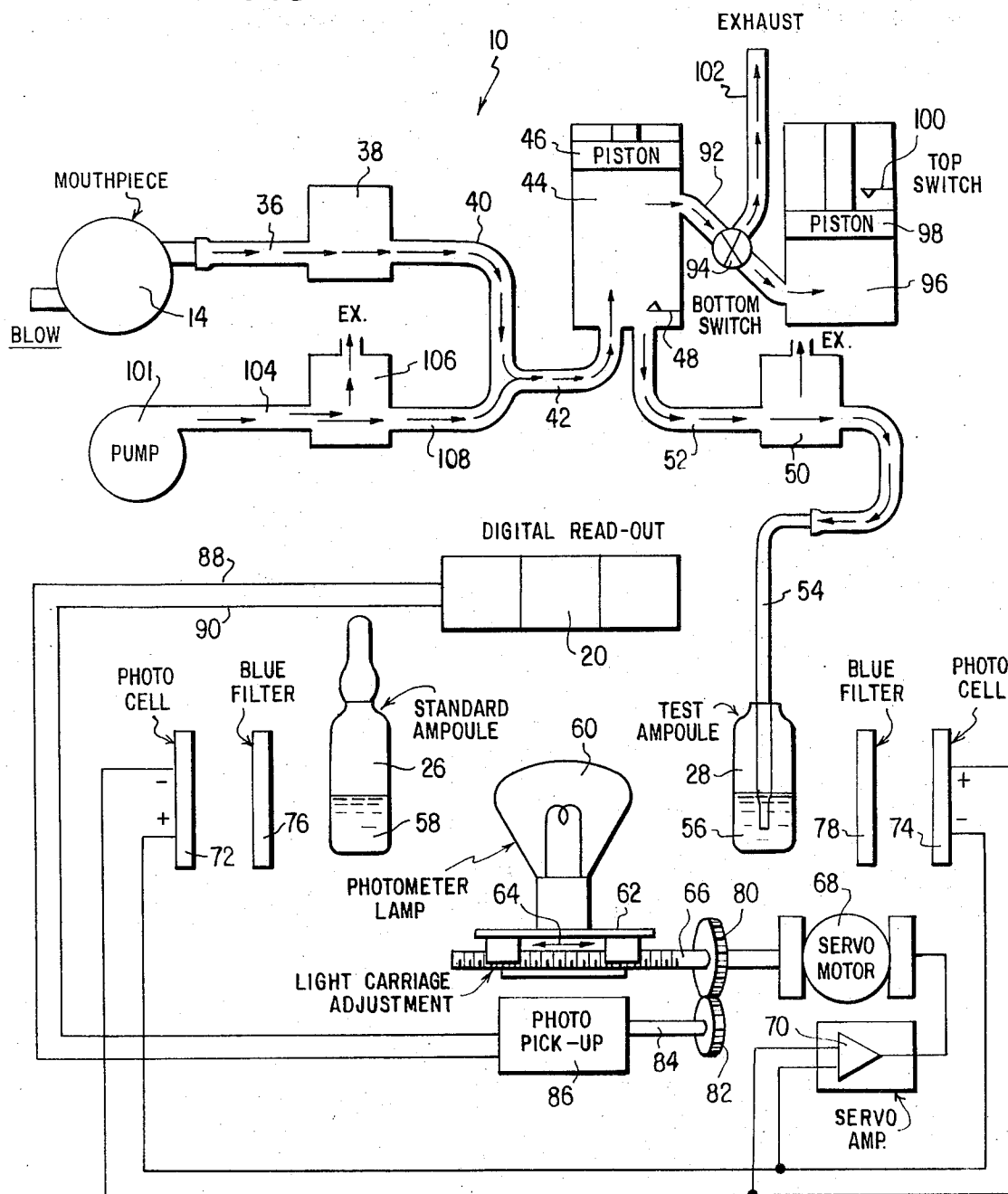


FIG. 3

FIG. 2



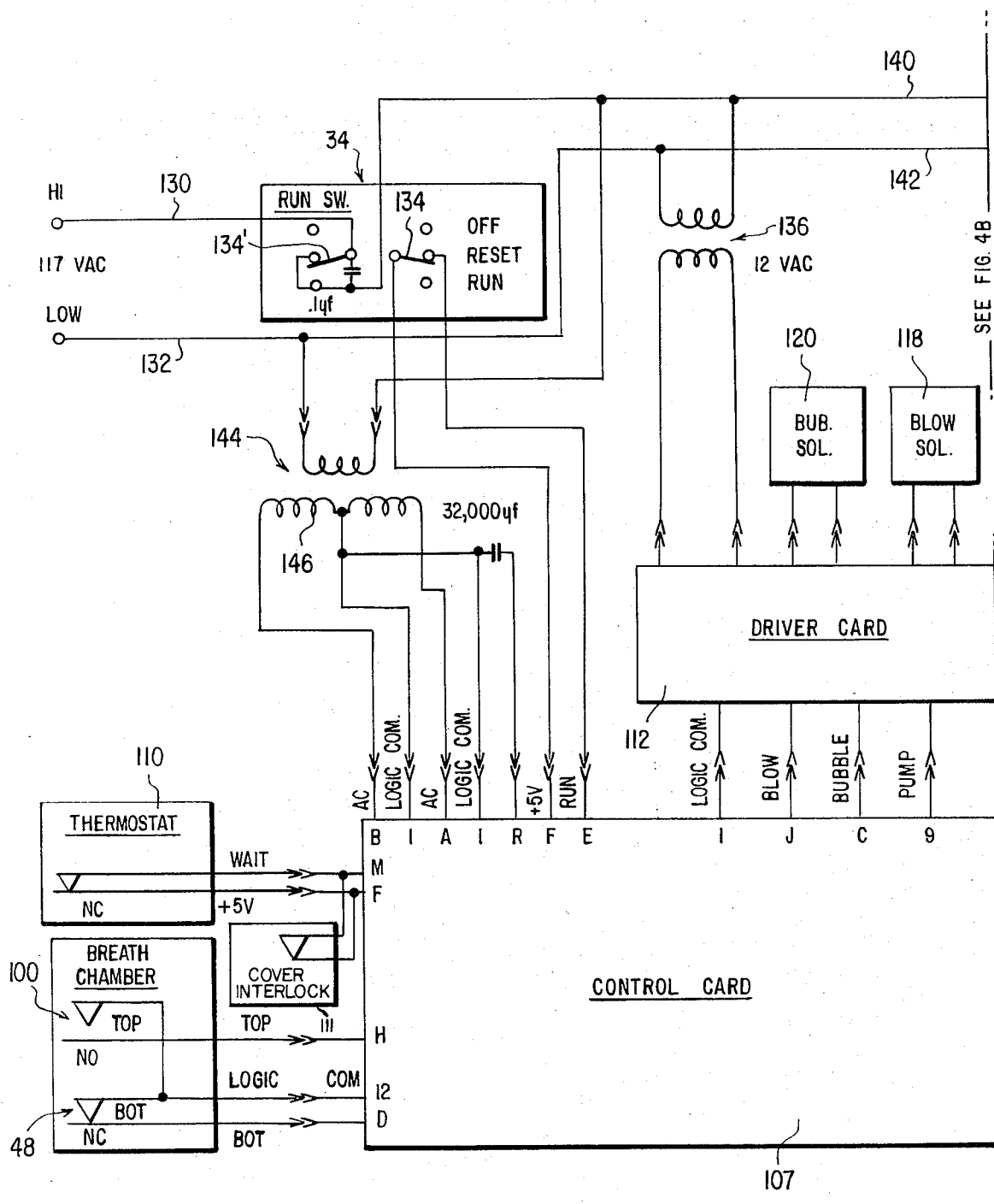


FIG. 4A

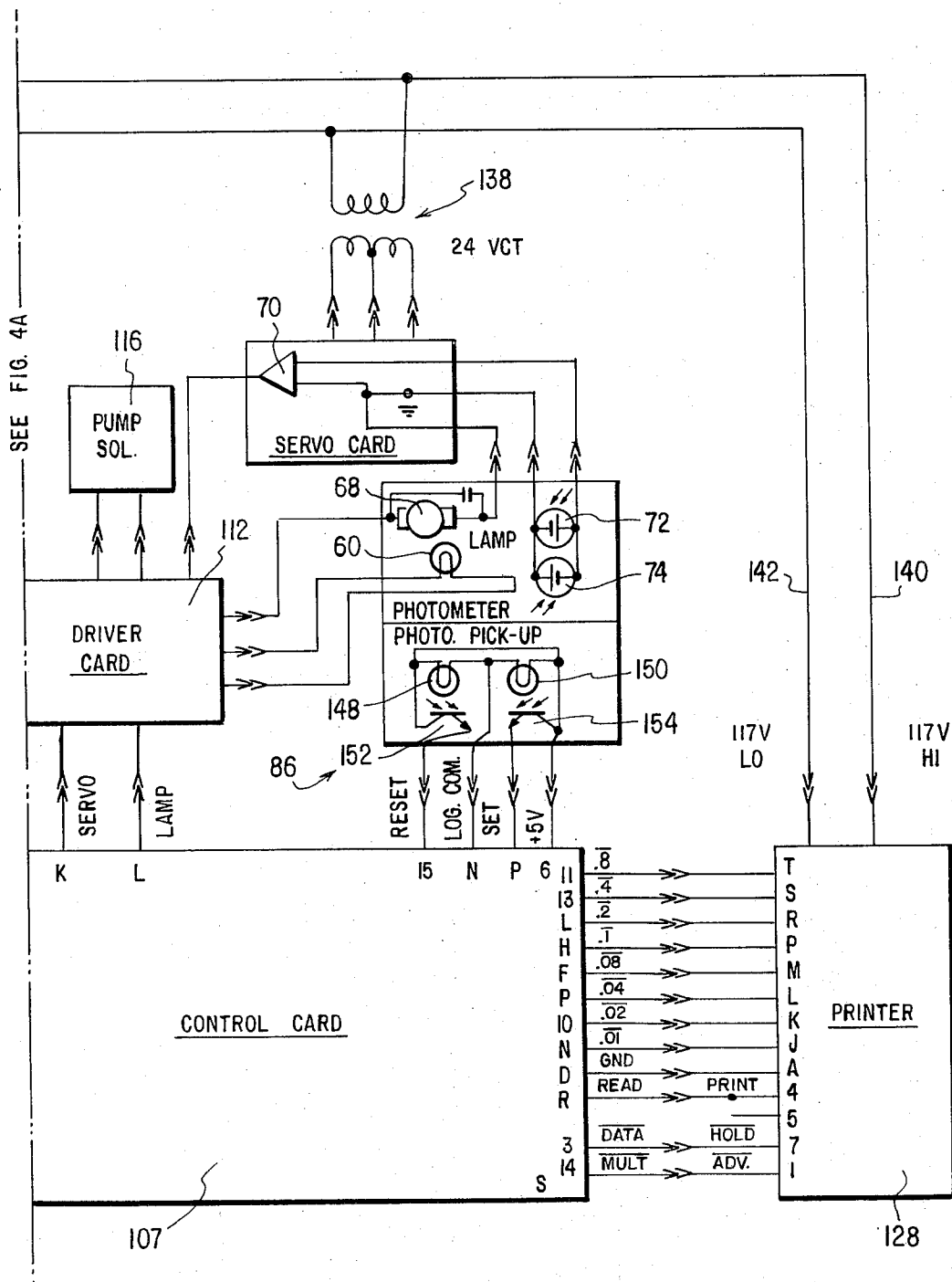
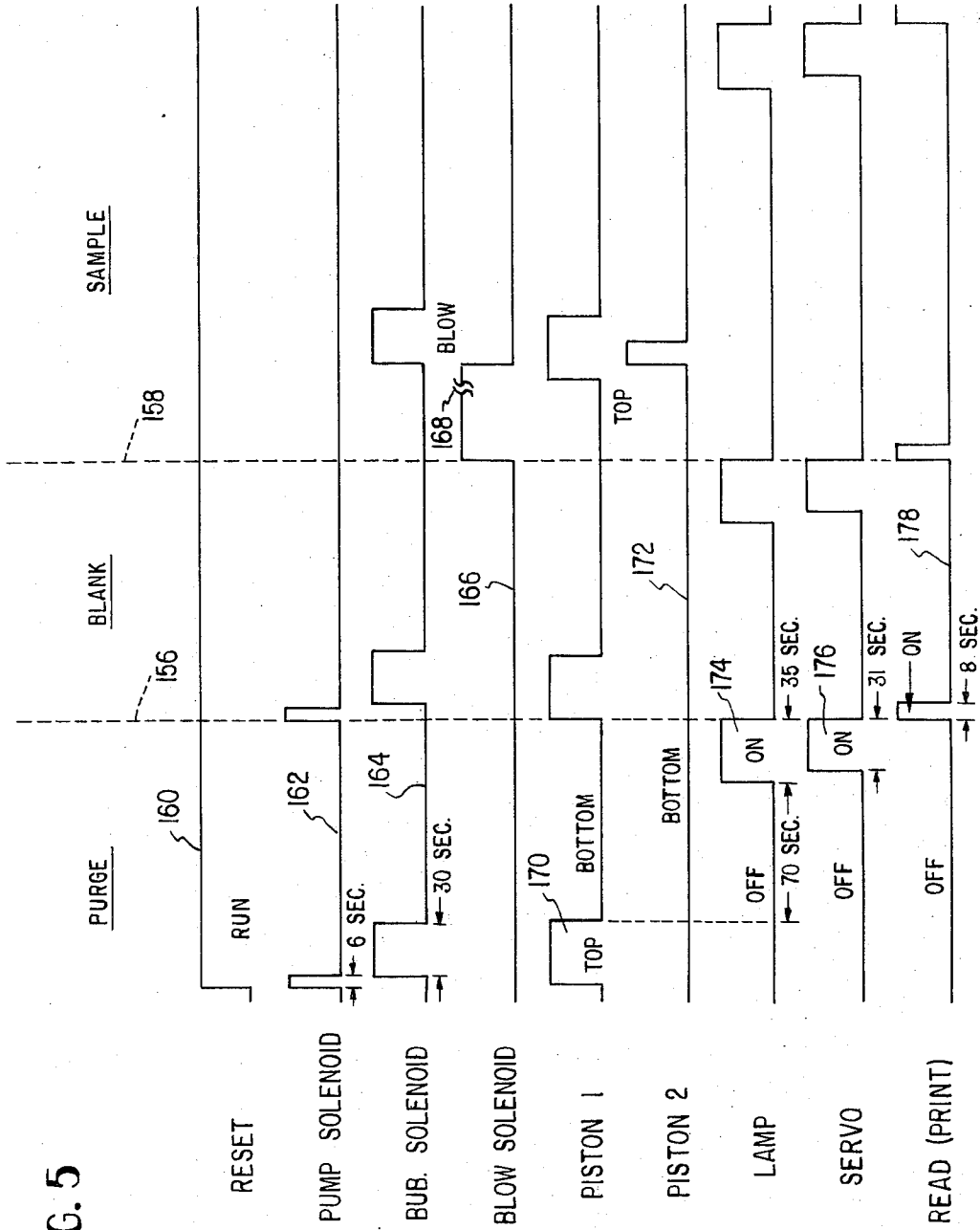


FIG. 4B

FIG. 5



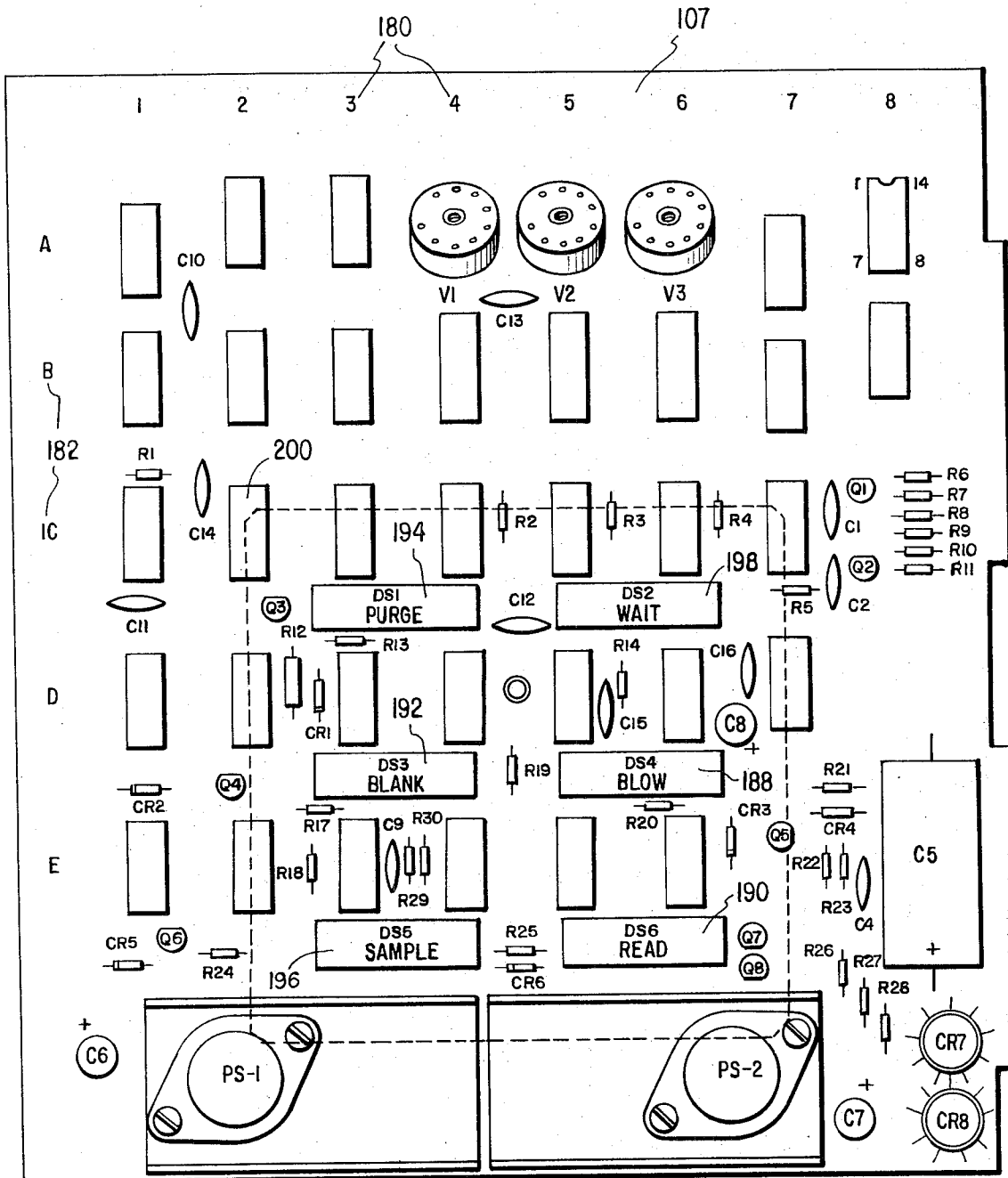


FIG. 6

FIG. 7

A	B	C	D
E	F	G	H

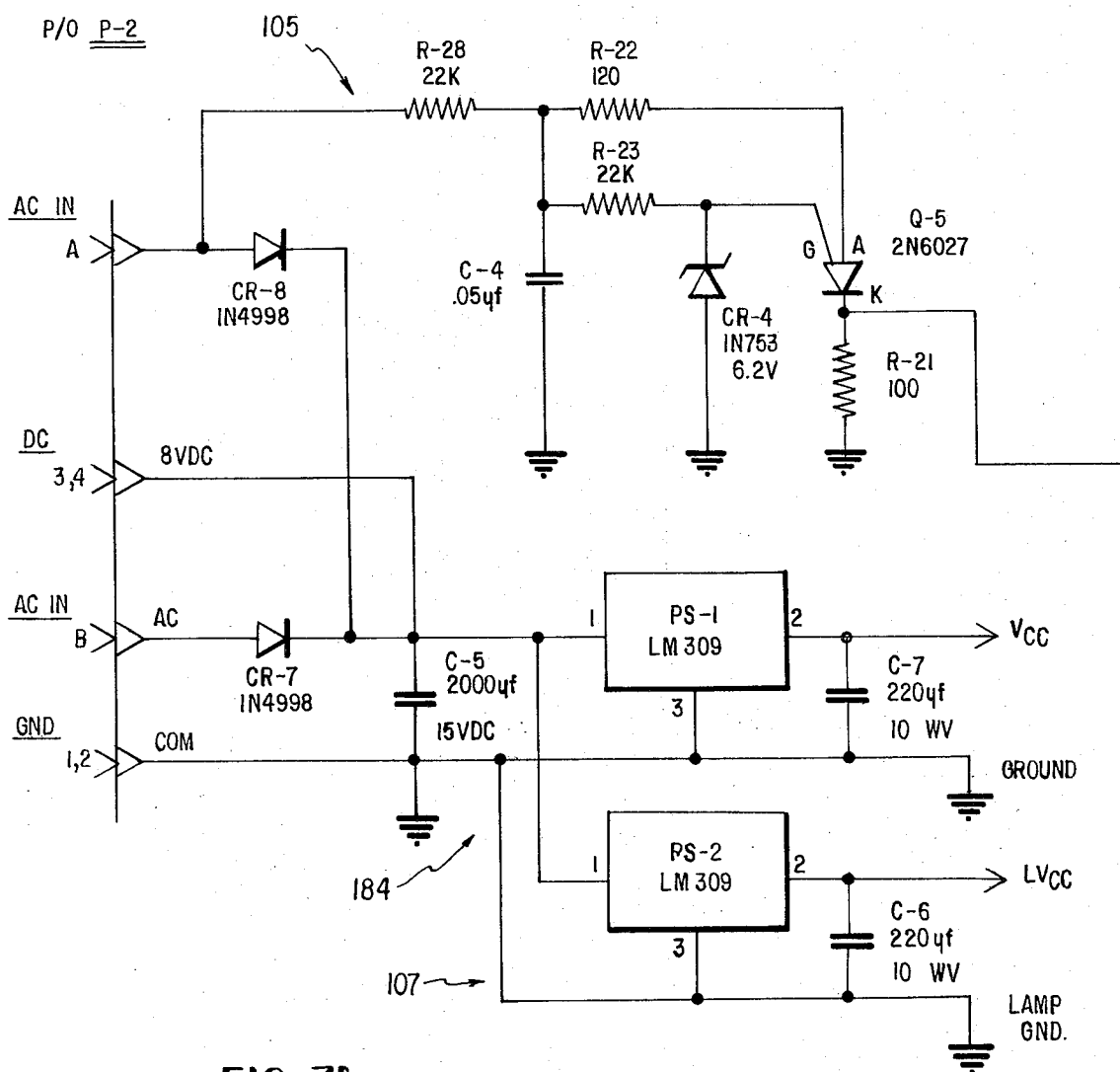


FIG. 7A

FIG. 7B

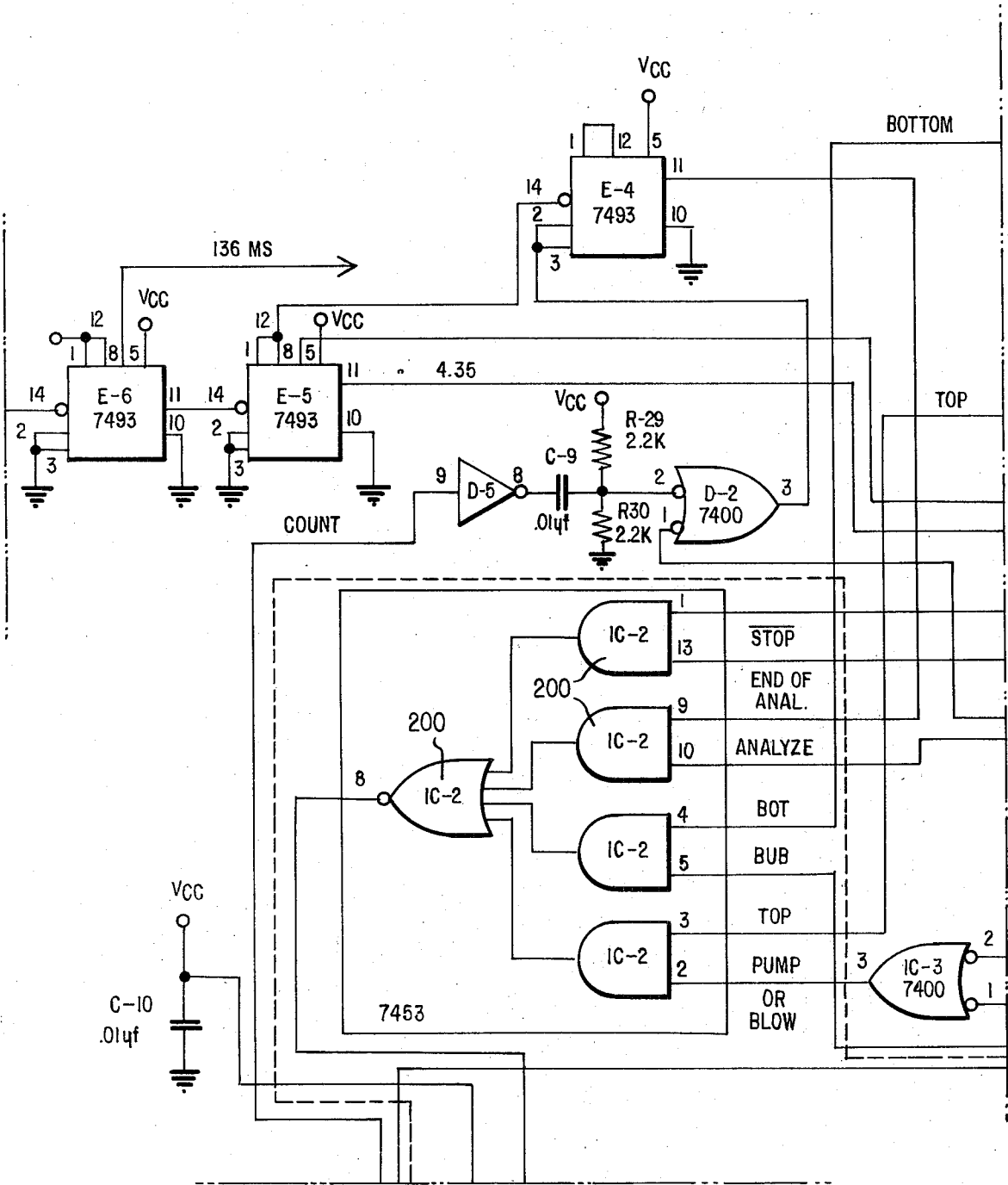


FIG. 7C

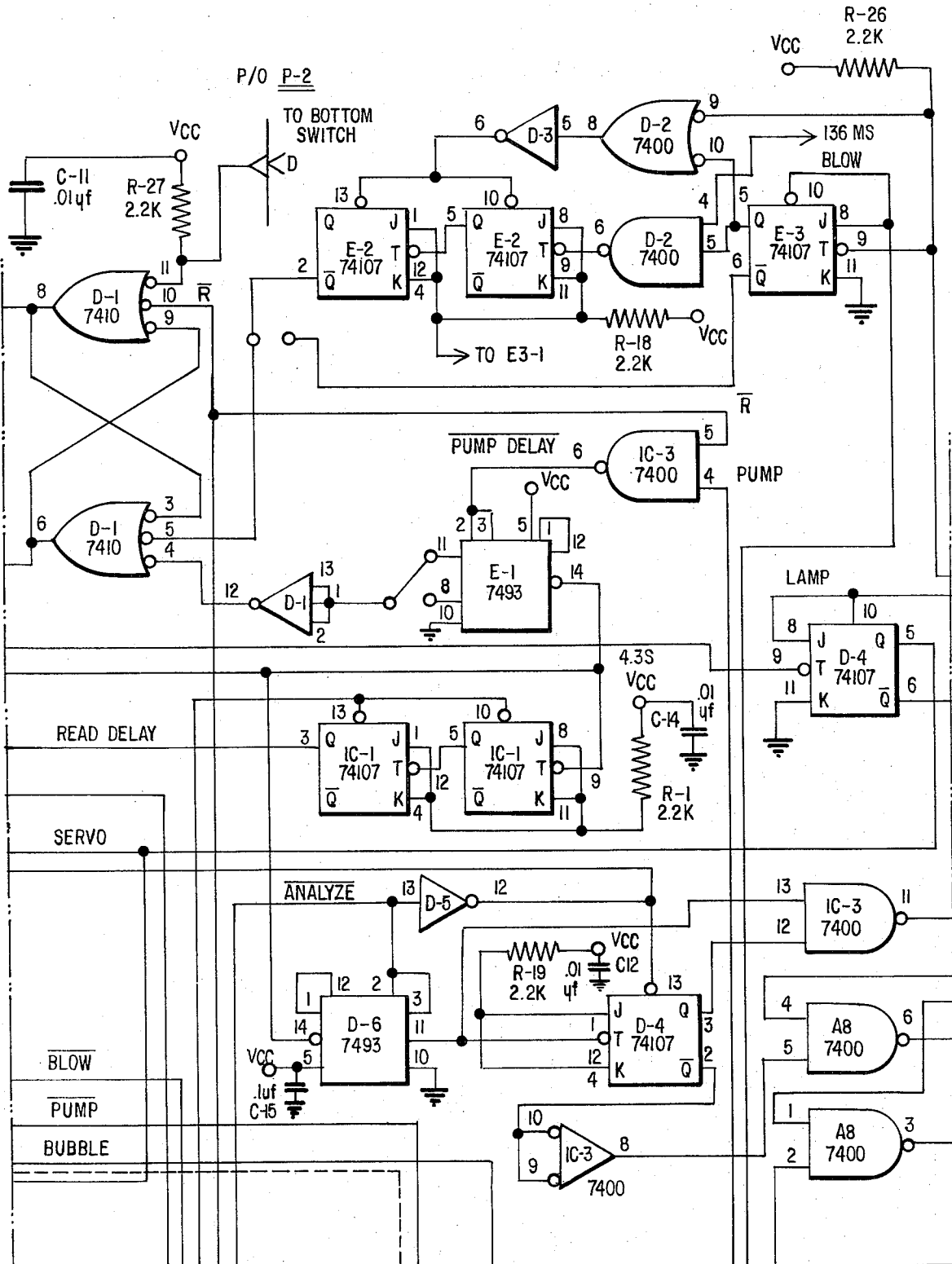
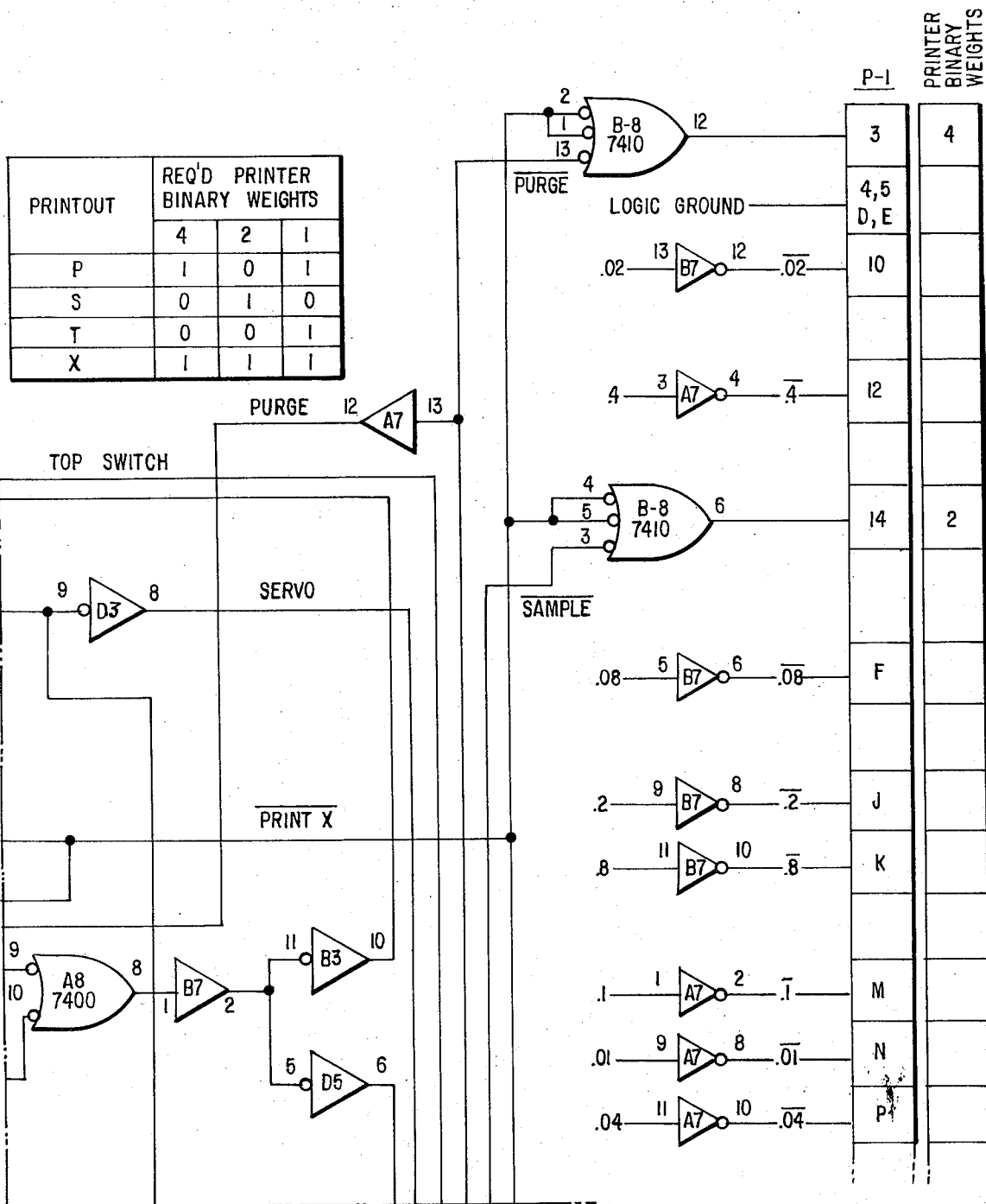


FIG. 7D



SHEET 11 OF 14 FIG. 7E

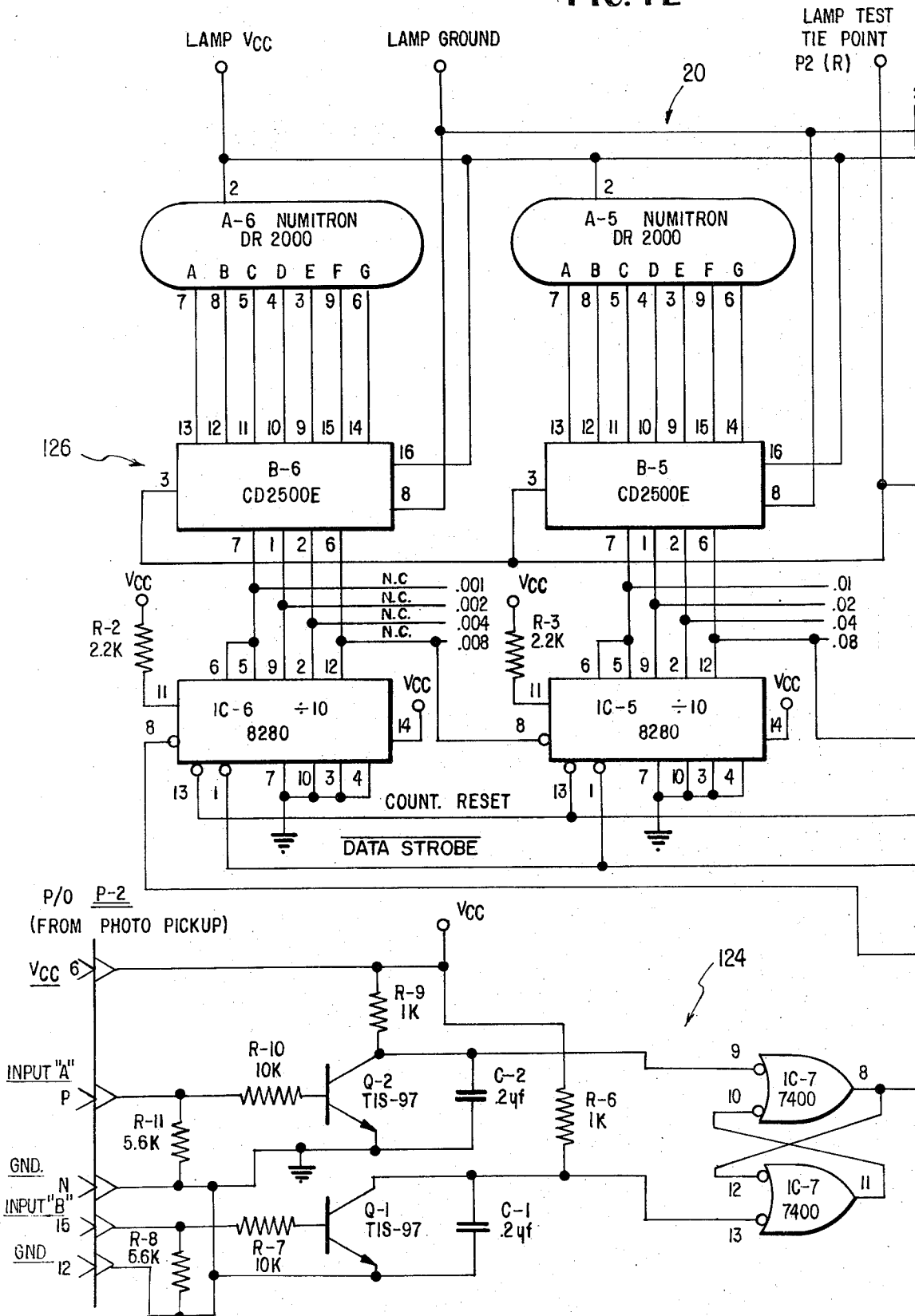


FIG. 7F

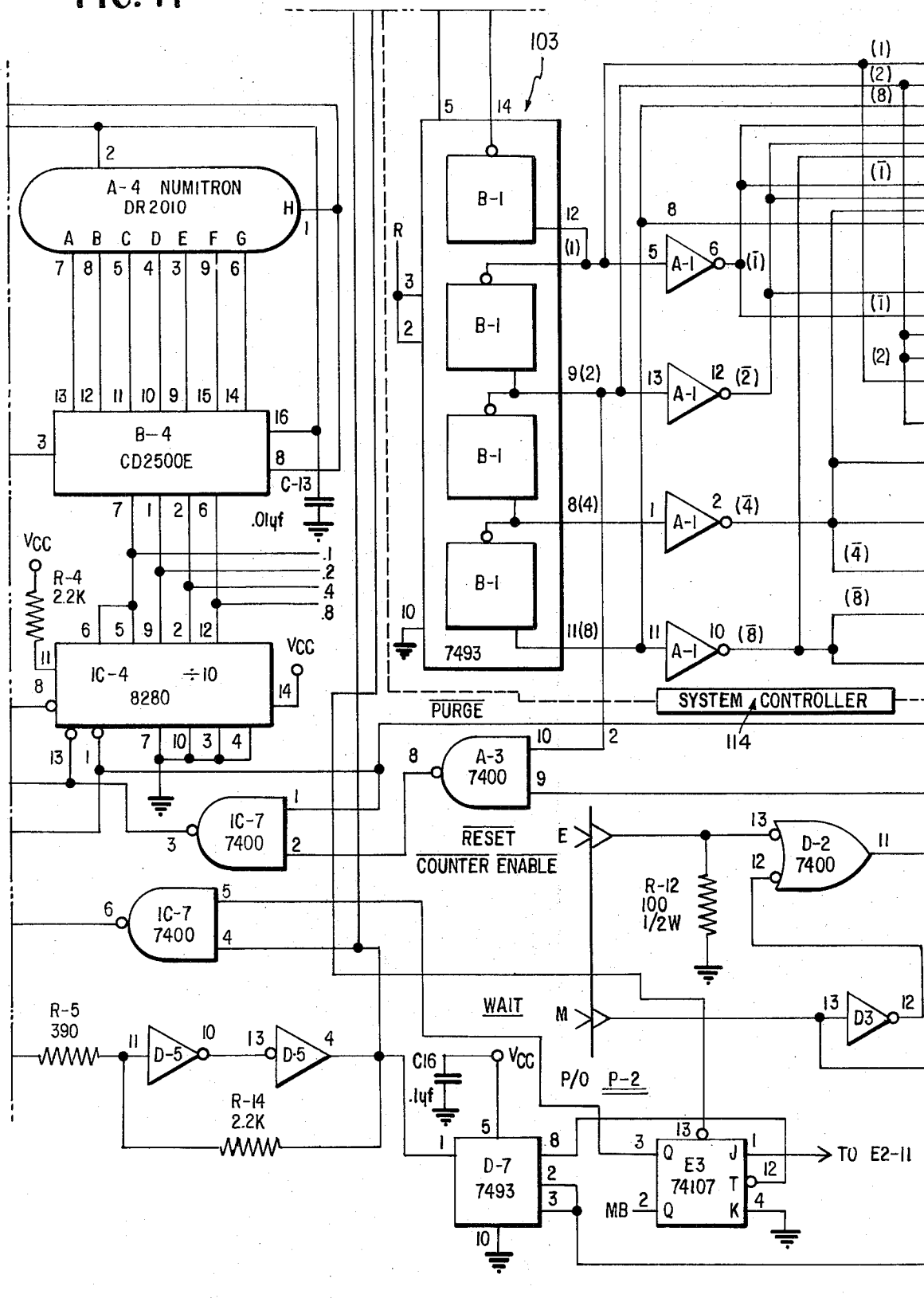
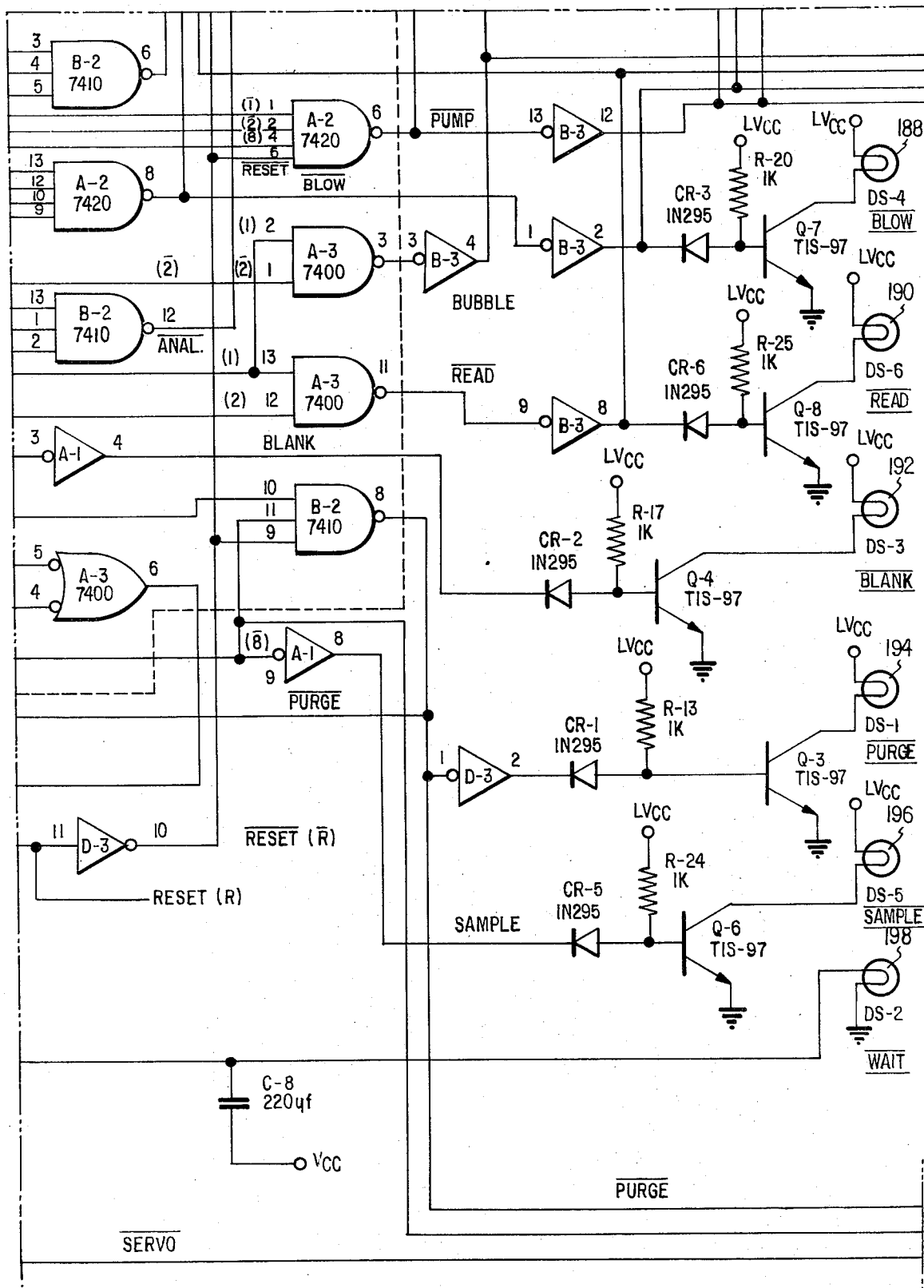


FIG. 7c SHEET 13 OF 14



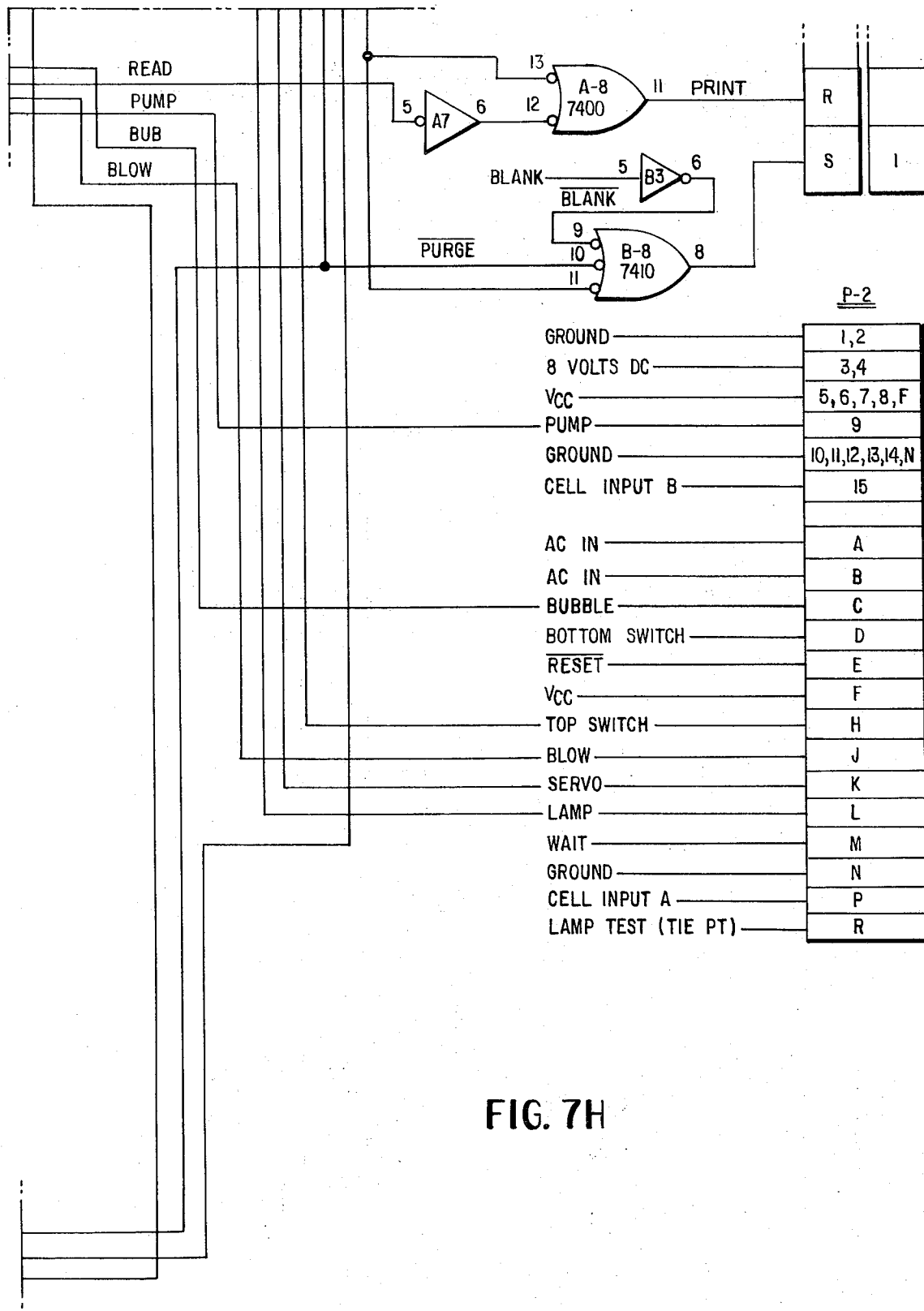


FIG. 7H

BREATH ANALYZER

This invention relates to a device for testing human breath and more particularly to a full programmed instrument for quantitatively measuring the alcoholic content of the aveolar or deep lung breath of a human being as an indication of the amount of alcohol in the blood. The tester of this invention is particularly adapted for use in indicating the state of intoxication, if any, of the operator of an automotive vehicle.

The role of the intoxicated automobile driver in traffic crashes has become a matter of international concern. Within the United States the Federal administration as well as most state and local law enforcement agencies have assigned a high priority to the relationship between alcohol and the traffic safety problem.

One aspect of the drinking driver problem involves a determination of the driver's level of intoxication. The field of chemical testing for intoxication has shown a solid and continual progress. This progress has been in part the result of many highly qualified representatives of the enforcement, scientific and judicial disciplines devoting their talents and time to provide the exhaustive and methodical guidance to the field that has brought about success. Their contributive influences are perhaps most readily evidenced in the increasingly stringent performance standards being recommended for quantitative breath alcohol instrumentation.

In U.S. Pat. No. 2,824,789 issued Feb. 25, 1958 there is disclosed an instrument for testing the alcoholic content of the human breath based upon the change in the transmission of light by a chemical solution through which the breath has been passed. In the device of that patent a light source is movably positioned between a pair of ampoules containing a solution of potassium dichromate in sulfuric acid. In accordance with the amount of alcohol or the like in a charge of gas passing through the solution it becomes more transparent. By moving the light source in such a direction as to equalize the amount of light passing through a test ampoule and a reference ampoule filled with the same solution, the position of the light source is indicative of the alcoholic content in the charge of human breath which has been passed through the test ampoule. This is an indication of the alcoholic content in the human blood stream and consequently an indication of the state of intoxication of the person whose breath has been sampled. A somewhat similar cam operated device is disclosed in U.S. Pat. No. 3,552,930.

The present invention is directed to a quantitative breath alcohol measuring instrument of the same general type but of improved construction and in particular to an instrument in which the test sequence is almost completely electronically controlled. Computerized operational programming in the device of this invention in combination with solid-state electronic circuitry results in a virtually "fail-safe" operational reliability. The instrument is under the control of a self-contained program counter which acts as the instrument "brain." After the unit has undergone complete purging an indicator lights and the human breath sample is introduced. The program counter then electronically monitors each subsequent phase of the test. The unit is insensitive to line voltage variation or temperature insuring an accurate test result under all operating conditions.

In the present invention the person whose breath is to be sampled blows into a mouthpiece connected to

the instrument. After a certain portion of the breath has been wasted or exhausted to atmosphere the remaining portion or so-called deep lung portion is captured in a sample chamber. When the chamber is filled, a switch is closed and the breath sample in the chamber flows through or bubbles through the solution in the test ampoule. Any change in the transmission of light through the test ampoule with reference to a second standard ampoule of the same solution is sensed by a servo system which produces a digital or pulse output indicative of the change in the light transmission. These output pulses are used to activate both a digital light display and a printer so that a permanent record of the test reading is created.

However, before the test cycle described above, the instrument is programmed to go through two preceding cycles hereafter referred to as a purge cycle and a blank cycle. During the purge cycle air is pumped through the sample chamber to make sure that no residue from previous samples remain. After the system has been completely purged a first run or "blank" run is made with a sample of captured air to insure that all readings are correct and all portions of the system are operating properly. Only after the purge and blank cycles have been completed is an actual test made.

Thus, there are three major divisions to the program cycle. The first division hereinafter referred to as purge is that in which air is pumped through the breath chamber to drive out traces of alcohol and moisture from any previous test. The second division or cycle is the blank cycle in which a reading is taken to assure that the breath chamber is not contaminated. The third or last cycle is that in which an actual breath sample is tested.

Each of these three major divisions or cycles is further subdivided into four minor divisions or steps. In the first step called pump, in the purge or blank cycle (or blow step in the sample cycle) the breath chamber is pushed up by the pump (or by the person blowing into the mouthpiece). In the second step called bubble the piston is allowed to drop, bubbling the contents of the breath chamber through the test ampoule. In the third subcycle or third step called analyze the change in light transmission through the ampoule is detected and in the fourth step called read, the results of the tests are displayed on the read out lights and printed on a suitable ticket to form a permanent record.

It is, therefore, one object of the present invention to provide an improved method and apparatus for quantitatively measuring the amount of alcohol or similar material in a gas sample.

Another object of the present invention is to provide an improved quantitative breath alcohol instrument.

Another object of the present invention is to provide an improved breath tester having increased reliability of operation to insure a more accurate result.

Another object of the present invention is to provide a breath testing instrument in which the instrument is purged by air after each test sample.

Another object of the present invention is to provide an improved method and apparatus for testing breath samples in which each test involves three cycles, namely, a purge cycle in which the system is purged by air, a blank cycle in which a reading is taken against an air sample and finally a third or test cycle in which an actual breath sample is tested.

Another object of the present invention is to provide a fully transistorized quantitative breath alcohol instrument of simplified, improved construction and one that is readily portable.

Another object of the present invention is to provide an alcoholic content breath tester including both an optical or visual readout and a printed or permanent record readout.

Another object of the present invention is to provide a breath tester in which the result of the test is displayed in digital form.

Another object of the present invention is to provide a human breath tester in which the sequence of events undergone during a test are programmed by a control circuit in the tester.

These and further objects and advantages of the invention will be more apparent on reference to the following specification, claims and appended drawings wherein:

FIG. 1 is a perspective view of a quantitative breath alcohol instrument constructed in accordance with the present invention.

FIG. 2 is a simplified operational diagram of the tester of FIG. 1.

FIG. 3 is a simplified block diagram for the tester of FIG. 1.

FIGS. 4A and 4B taken together show an overall wiring diagram with parts in block form for the tester of FIG. 1.

FIG. 5 is a timing diagram for the tester showing the purge, blank and sample cycles.

FIG. 6 is a view of the component side of the control board for the tester of FIG. 1 and

FIGS. 7A through 7F taken together constitute a detailed circuit diagram of the logic for the tester of FIG. 1.

Referring to the drawings, FIG. 1 shows the breath tester of the present invention generally indicated at 10 as comprising a housing 12 from which projects a tube and associated mouthpiece 14, into which the person whose breath is to be sampled blows. Also mounted on housing 12 is a nameplate 16 and a plurality of indicator lights 18. A reading from a test sample is adapted to be displayed by a visual indicator 20 preferably comprising a three digit display in which each digit is formed by a seven bar segment array of lights. At the same time as a reading is shown on indicator 20 a permanent record of the test results is printed on a card 22 adapted to be inserted into a slot 24 in housing 12. FIG. 1 also shows a reference or standard ampoule 26 received in a suitable receptacle in the tester and also shows a test ampoule 28 into the top of which projects the end of a bubble tube 30. Tester 10 is shown as received in the lower half of a case 32 by means of which it may be carried from place to place and is adapted to be plugged into a conventional 60 Hz 117 volt a.c. electrical outlet. Electrical energy supplied to the tester 10 is under the control of a three position switch 34 adapted to be manually moved between off, reset and run positions.

FIG. 2 is a simplified operational diagram of the tester 10 of FIG. 1. In FIG. 2 the mouthpiece 14 communicates with a tube 36 in which is located a solenoid valve 38 adapted to be opened by what will hereinafter be referred to as the "blow" solenoid. The breath sample after passing through valve 38 goes through a tube 40 and an entrance tube 42 to the interior of a sample

chamber or breath chamber indicated at 44. Movable through breath chamber 44 is a piston 46. In its lowermost position within chamber 44 piston 46 is adapted to engage and actuate a bottom switch 48 for a purpose more fully set forth below.

When the person whose breath is to be sampled blows into the mouthpiece 14 the breath passes through solenoid valve 38 into chamber 44 driving piston 46 upwardly to its uppermost position as illustrated.

The breath continues to overflow "through tube" 92 into cylinder 96 moving piston 98 upward until top switch 100 is made. When breath flow stops, contact breaks at top switch 100. Valve 38 is closed and a second solenoid valve 50 is opened by what is hereinafter referred to as the "Bubble" solenoid. Valve 50 communicates with an exit tube 52 from sample chamber 44 and permits the breath sample to flow from chamber 44 by way of exit tube 52 and valve 50 to a bubbler tube 54, the lower end of which is received in the test ampoule 28. This ampoule is partially filled with a liquid as indicated at 56 in FIG. 2 so that the breath sample exiting from the lower end of bubbler tube 54 passes in the form of bubbles through the solution 56. After the breath sample has been bubbled through solution 56 and after a waiting period 90 ± 30 seconds for chemical reaction is completed, the yellow color of the solution changes to a lighter shade of yellow, thereby permitting increased light transmission through the solution. The increased light transmission through solution 56 is compared with the light transmission through an identical reference solution 58 in the standard ampoule 26. For this purpose, a lamp 60 is mounted on a carriage 62 positioned between the standard ampoule 26 and the test ampoule 28 and is movable back and forth between the ampoules as indicated by the arrows 64 with the rotation of a screw 66 thread engaging carriage 62. Screw 66 is rotated by a servomotor 68 under the control of a servo-amplifier 70. Servo-amplifier 70 has its input connected to the output of a pair of photocells 72 and 74 with photocell 72 positioned to intercept light from lamp 60 passing through the solution 58 in ampoule 26 and photocell 74 positioned to intercept light transmitted from the lamp through the solution 56 in test ampoule 28. In order to render the photocells sensitive primarily to blue light (440 millimicrons), the blue filters 76 and 78 are positioned between the respective ampoules and their corresponding photocells. Screw 66 is connected by driver wheel 80 and driver wheel 82 to an output shaft 84 whose angular position is indicative of the displacement of lamp 60. The amount of rotation of output shaft 84 is sensed by a photoelectric pickup 86 and the output of the pickup is supplied over leads 88 and 90 to the three-digit optical display 20.

The interior of breath chamber 44 is connected by a tube 92 and valve 94 to the interior of a second chamber or waste chamber 96. Movable through chamber 96 is a second piston 98 and in its uppermost position this piston is adapted to engage and actuate a top switch 100. In the preferred embodiment, valve 94 is a proportioning valve such that approximately one-eighth of the overflow from chamber 44 passes into chamber 96 and the other seven-eighths of the gas charge overflow from chamber 44 is exhausted to atmosphere through exhaust tube 102. The object of the second chamber and proportioning valve is to ensure a sample of more than 400 ml. being expired by the sub-

ject being tested. This ensures a sample of alveolar or deep lung breath to be analyzed.

An alternative method (not shown) for measuring 400 ml. is to use a second chamber 96 with a volume of 400 ml. All exhaust from the first chamber 44 would pass into chamber 96 and be further exhausted from there.

A second alternative method (not shown) for measuring 400 ml. is measure the time during which exhaust is flowing from the first chamber 44. A given flow rate for a given period of time is equal to a given volume.

Breath chamber 44 is adapted to be purged by air from a pump 101 connected to a second inlet tube 104. This air passes through a solenoid valve 106 actuated by what is hereinafter referred to as a "pump" solenoid, through a tube 108 and common tube 42 to the interior of chamber 44. The pump not only supplies air during the purging cycle but also supplies air to sample chamber 44 during the blank cycle when a measurement is taken against a charge of pure air as more fully described below at pages 22 and seq.

FIG. 3 is a simplified block diagram for the tester 10 of FIG. 1 in which like parts bear like reference numerals. The piston switches 48 and 100 along with run switch 34 actuate a program counter 103 under the control of a system clock 105 which by way of example only may be driven at the line frequency of 60 Hz. Program counter 103 and clock 105 form part of a control board indicated by the dash line 107. Program counter 103 also receives an input from a heat responsive bimetallic thermostat 110 which prevents operation of the device until the proper operating temperature has been reached. An alternative device to the thermostat is an electronic thermistor circuit capable of determining the proper operating temperature. Also mounted on the control board, connected to program counter 103 and supplying outputs to a plurality of drivers 112 is a program decoder 114. Drivers 112 actuate a pump solenoid 116 which actuate the pump valve 106 of FIG. 2, a blow solenoid 118 which actuates a "blow" valve 38 of FIG. 2 and a bubble solenoid 120 which actuates "bubble" valve 50 of FIG. 2. Also actuated by drivers 112 is the lamp 60 and the windings 122 of servo-motor 68. Photometer pickup 86 is connected to a pickup counter 124. The pickup counter 124 counts the pulses from the photometer pickup 86 indicative of the position of lamp 60 and supplies the count through a counter decoder driver 126 to the digital display 20 and to a printer 128.

FIGS. 4A and 4B taken together show an overall wiring diagram for the tester 10. Again, like parts bear like reference numerals in FIGS. 4A and 4B. A pair of power supply leads 130 and 132 connected to a conventional a.c. outlet are adapted to supply 117 volt 60 Hz a.c. electrical energy to the unit through the three position switch 34 having the ganged movable contacts 134 and 134' movable in unison between the uppermost or off position, the intermediate reset position and the lowermost run position in FIG. 4A. 12 volt electrical energy is fed from the supply line through a step-down transformer 136 to the driver card 112 and 24 volt electrical energy is supplied to the servo-amplifier 70 by way of a stepdown transformer 138. Full line voltage is applied by way of leads 140 and 142 to the printer 128. Electrical energy is supplied to control card 107 through a transformer 144 having a center

tapped secondary 146. Also connected to control card 107 is the thermostat 110, the breath chamber bottom switch 48, the top switch 100 and cover interlock switch 111. An additional feature illustrated in FIG. 4B is the photo-pickup 86 which is shown as comprising a pair of lamps 148 and 150 adapted to transmit radiant light energy to a pair of photosensors in the form of phototransistors 152 and 154. The light sources 148 and 150 and sensors 152 and 154 straddle a disc which is provided with a concentric circle of small holes (not shown). This disc is part of the photopickup 86. As light is periodically passed through the holes with rotation of the disc each hole allows the light source to reach its corresponding phototransistor, thus creating pulses to the counter 124 of FIG. 3. In the preferred embodiment when the servo-motor drives the lead screw 66 (FIG. 2) and driver wheel 80 and in turn the driver calibration wheel 82 on shaft 84, it rotates the above described disc of the photopickup 86.

FIG. 5 is a timing diagram for the tester 10 of FIG. 1. The timing diagram of FIG. 5 is divided by the vertically dashed lines 156 and 158 into three cycles or three time periods labeled purge, blank and sample, respectively. Waveform 160 in FIG. 5 illustrates the run position of switch 34 during all three cycles. Waveform 162 illustrates the energization time of the pump solenoid 116, waveform 164 illustrates the operation of the bubble solenoid 120 and waveform 166 indicates the time of operation of the blow solenoid 118. Waveform 166 is broken away at 168 to indicate the variable nature of the time for the blow cycle which depends on how fast the sample chamber is filled by the person blowing into the mouthpiece. The operation of the piston bottom switch 48 is illustrated by the waveform 170 in FIG. 5 and the operation of the top switch 100 by the waveform 172. Energization of lamp 60 is illustrated by waveform 174, actuation of the servomotor by waveform 176 and the printer is actuated during the blank sample cycle as indicated by the waveform 178.

Following is a step-by-step description of a typical operating procedure for the tester 10 of FIG. 1. The person whose breath is to be sampled should be kept under strict observation for a minimum of 15 minutes during which time nothing should be ingested by mouth and no smoking permitted.

STEP 1

Unlock the instrument cover latch and remove the top cover. Attach the power cord in the receptacle in the back of the instrument and insert the plug into any 110 volt a.c. power outlet.

STEP 2

Advance the function switch 34 located in the lower lefthand corner of the top panel from the off position to the reset position.

STEP 3

Upon concluding step 2, the operator of the tester will notice the "wait" program indicator is illuminated. This indicator is only illuminated when the instrument is not maintained at the required operational temperature of 50°C. with tolerance of $\pm 3^\circ$. When this indicator is illuminated the instrument does not allow the program counter to initiate any test activity. When the temperature is within the tolerance, the "wait" indicator goes out and the operator may continue with the test procedure.

STEP 4

Gauge both the reference and test ampoules and insert them into the tester. This includes opening the test ampoule and the connection of the bubbler tube 54 into the specimen delivery outlet of the test ampoule. This step may be completed along with following step 5 while the operator is waiting for the instrument to attain operating temperature.

STEP 5

Insert the result ticket into the printer by way of the small slot 24 in the left-hand side of the front panel. The printed format end of the ticket is inserted first, pushing the ticket into the printer until the printer mechanism "grabs" the ticket and does not permit further insertion.

STEP 6

As soon as the wait indicator goes out, advance the function switch 34 from the reset position to the run position. At this time the tester becomes virtually self-contained and operates to the conclusion of the test sequence. The operator of the instrument for the most part simply monitors the program functions but provides some external guidance of a nature which is not an integral increment of the operational loop of the instrument.

STEP 7

Step 6 will cause the "purge" program indicator to illuminate and at the same time creates a .88 reading on the display 20. This display confirms that all elements of the Numitron tubes used for the display are functioning. The various operations of the instrument's purge phase are sequentially executed. The conclusion of the purge is indicated by the sound of the printer 128 operating almost immediately and by the illumination of the "read" program indicator. At this stage the display tubes still read .88 as its lamp test, the results ticket 22 has printed on it the same .88 reading in the purge location on the ticket confirming that the tube displays mechanisms are interlocked, and the purge and read program indicators will be illuminated. In approximately five seconds the program counter 103 of FIG. 3 commands a reset of all displays and the activation of the next phase.

STEP 8

The program counter proceeds to command the instrument to perform a blank test on ambient air. During this phase the "blank" indicator is illuminated. Again at the conclusion of this phase, the printer can be heard printing the results of the analysis in the blank location on the results ticket 22, and the illumination of both the blank and read program indicators for a duration of approximately five seconds before the program counter advances to the next phase. The operator must monitor the performance of the instrument at this stage. After the instrument has completed a blank analysis on ambient air, the operator must inspect the analysis result printed on the ticket to confirm that the blank analysis result does not exceed 0.01 percent. A reading of 0.01 percent is considered an excessive blank and the operator should not proceed to the next step but rather return to step 5 and proceed again.

STEP 9

When the blank analysis has been successfully completed, the operator instructs the person whose breath is to be sampled to follow the illuminated instructions displayed by the program indicator, namely, "sample" and "blow." This person simply blows into the instrument through the mouthpiece 14 located in the upper

right-hand corner of the top panel in FIG. 1 until the blow program indicator light goes out.

STEP 10

The program counter 103 continues to command the instrument through the remainder of the test of the breath sample. At the conclusion of the test the printer can be heard operating and the illumination of the read program indicator light is added to the sample indicator. This concludes the test and in this phase both the read and sample indicator lights remain on.

STEP 11

After removing and disposing of the test ampoule, bubbler tube 4 and the results ticket 22, the instrument should be secured for storage or if subsequent testing is desired the function switch 34 is returned to the reset position.

ALTERNATE TEST SEQUENCE

For a demonstration of the instrument's ability to properly analyze a reference standard of a predetermined simulated breath alcohol concentration, a single change in the sequence is required. Steps 1 through 8 remain the same but step 9 is modified as follows.

STEP 9A

When the blank test has been successfully completed, the operator attaches the breath delivery tube attached to mouthpiece 14 to a suitable simulator and blows the vapor of the simulator into the instrument until the blow program indicator light goes out. After this, all subsequent steps remain the same as given above.

The tester 10 is a completely computerized and transistorized device utilizing transistor-transistor logic to control the operating functions of the instrument. Program counter 103 of FIG. 3 is the "brain" of the instrument and this circuit performs the twelve basic functions or steps in proper chronology. The program counter is affected basically by four outside signals which are generated by the function switch 34, the temperature interlock, the piston switches 48 and 100 of FIG. 2 and the program clock 105 of FIG. 3. The function switch 34 both initiates the warmup and activation of the program cycle. The instrument is warmed up by a conventional heater (not shown) and the temperature is sensed by the thermostat 110 of FIG. 3. This thermostat or temperature interlock prevents any program activity when the instrument is not within the temperature tolerances. The piston switches provide signals indicating the full and empty positions and the program clock provides electronic timing as required by the program.

The program decoder 114 of FIG. 3 monitors the position of the program counter 103. Depending upon the program phase the decoder 114 actuates the components under its control, namely, the pump solenoid 116, blow solenoid 118, bubble solenoid 120, a lamp 60 and the servo-motor. Depending upon the step of the program counter, the program decoder signals the drivers 112 of the various components to accomplish the required function. The servo-motor 68 of FIG. 2 is connected to the lead screw 66 and is supplied with current to drive the light carriage 62 in the appropriate direction to achieve a null. The servo-amplifier 70 is a solid-state printed circuit board which monitors the signals generated by the photocells 72 and 74. It detects the imbalance in cell output and commands motor 68 to drive the light carriage to a null. When the null con-

dition is reached, no power is supplied to the servomotor 68 and the null is maintained.

Program decoder 114 in FIG. 3 also energizes the pickup counter 124 which drives the counter decoder driver and the outputs 20 and 128. This activation occurs during the measurement of a blank or sample sequence and at this time the program decoder 114 enables the pickup counter 124 to actuate the readouts. Counter 124 receives and digests the pulses from the pickup 86 and forwards display information to the counter decoder driver 126 which in turn produces the required signals to present the appropriate results on the display tubes and on the printer ticket.

Referring to FIG. 2, piston 46 in sample chamber 44 is normally located at the bottom of the chamber resting against bottom switch 48. When a charge of gas is applied to the chamber, piston 46 is driven upwardly uncovering outlet 92 and overflow from this chamber passes through proportioning valve 94 into chamber 96 also driving the piston 98 upwardly. In its uppermost position, piston 98 actuates switch 100 indicating a full charge. Solenoid valve 38 then closes and bubbler valve 50 opens. The weight of the pistons cause them to move downwardly with the gas in chamber 96 wasting through valve 94 and exhaust tube 102 to atmosphere while the gas charge in chamber 44 is driven by piston 46 through valve 50 and bubbler tube 54 into test ampoule 28. When piston 46 reaches its bottommost position, switch 48 is activated to indicate that a full charge has been bubbled through the test ampoule. By incorporating the separate waste chamber 96 the person whose breath is being sampled is required to expire a volume of breath in excess of 400 ml before the sample is deemed acceptable. Even though the minimum quantity has been expired the person can continue to blow the advance to the next phase is activated any time after the minimum expiration when the person stops blowing. The volume measurement of the breath sample is approximate 55 to 58 ml at operational temperature. As previously indicated, the reagent in the ampoules is of a standard size and preferably a solution of potassium dichromate in a sulfuric acid solution such that the dichromate of the solution oxidizes the ethyl alcohol in the breath sample. The program indicators generally shown at 18 in FIG. 1 are six in number as more fully described below.

FIG. 6 is a view of the component side of the control card 107 of FIGS. 4A and 4B. This board is mounted on the top left side of the instrument and controls the operating and timing sequence of the unit. The board also provides the digital display of the blood alcohol determined from the breath sample test and drives the

digital printer to provide a permanent record of the reading obtained. The six lamps on the board indicate the operating status of the tester. FIGS. 7A through 7F show a detailed circuit diagram of the logic elements mounted on the board 107. Like parts in FIGS. 7A through 7F bear like reference numerals.

Referring to FIGS. 6 and 7A through 7F, the control board 107 uses nine numbers of the standard 7400 series TTL family in molded plastic packages. The SN7400N, SN7404N, SN7410N, SN7420N, and SN7453N are general purpose logic gates. The CD2500E (or SN7446AN) is a special purpose logic block which decodes a number in binary coded decimal form to the seven lines required to drive a seven segment display tube and the SN7493N, SN74103N and DM8280 (SN74175N) perform counting and storage functions. The designation given a particular package in these drawings is determined by its position on the board with respect to a grid specified in FIG. 6 by numbers 1 through 8 as indicated at 180 across the top of the board and letters A, B, IC, D and E down the side of the board as indicated at 182. Thus, D3 for example is the package in FIG. 6 (and FIGS. 7A through 7F) at the intersection of row D and column 3. Viewing the package from the top the pins are numbered in a clockwise direction from the end marked with a notch or a dot.

The power supply is generally indicated at 184 in FIG. 7A and is nominally a 5.0 volt $\pm$ 5percent. The "zero" (low) logic level is typically 0.2 volt and the "one" (high) is typically 3.5 volt.

As previously indicated, there are three major divisions to the program cycle of the tester, namely, purge in which air is pumped through the breath chamber to drive out traces of alcohol and moisture from any previous test; blank in which a reading is taken to assure that the breath chamber is not contaminated, and sample in which the actual breath sample is tested. Each of these can be subdivided into four minor steps. In the first minor step or subcycle called pump, in the purge or blank cycle (or blow in the sample cycle) the breath chamber piston is pushed up by the pump (or by the person blowing). In the second subcycle called bubble, the piston is allowed to drop, bubbling the contents of the chamber through the test ampoule. In the third subcycle called analyze, the change in the ampoule is detected and in the fourth subcycle called read, the results of the test are displayed on the readout and printed on the ticket.

The program counter 103 with the four flip-flops labelled B-1 in FIG. 7F has a unique set of outputs for each of the twelve steps in the program. This relationship is shown in the following table.

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TABLE

Major Steps	Minor Steps	B1 Logic Levels				Pin No. Logic Symbols
		11 (8)	8 (4)	9 (2)	1,12 (1)	
Purge	Pump	0	0	0	0	
	Bubble	0	0	0	1	
	Analyze	0	0	1	0	
	Read	0	0	1	1	
Blank	Pump	0	1	0	0	
	Bubble	0	1	0	1	
	Analyze	0	1	1	0	
	Read	0	1	1	1	
Sample	Blow	1	0	0	0	
	Bubble	1	0	0	1	
	Analyze	1	0	1	0	
	Read	1	0	1	1	

These outputs are decoded in the decoder 114 FIGS. 7F and 7G which will light lamps, enable the counting circuit, etc. only during the proper steps in the program. The lamps FIG. 7G which are lit comprise the blow lamp 188, read lamp 190, blank lamp 192, purge lamp 194, and sample lamp 196 in conjunction with the wait lamp 198 controlled by the thermostat. The program proceeds from one step to the next under the control of the gates IC-2 labelled 200 FIG. 7B. Each time the output of IC-2 goes from one to zero B1 FIG. 7F is advanced by one count. The output of the IC-2 FIG. 7B gates goes to zero whenever a pair of inputs are both one. One input of a pair is normally made one by one of the outputs of the decoding circuit and the other goes to one when some desired action such as closure of the top (P2-H) or bottom (P2-D) switch FIG. 7H in the breath chamber occurs or after a specified time has elapsed. Timed functions are dependent on the time base generally indicated at 105 FIG. 7A running at the power line frequency and on E5 and E6 FIG. 7B which operate as dividers to provide slower timing signals.

For convenience, various points in the circuit of FIGS. 7A through 7F are assigned names such as PURGE, PURGE, BLOW and SERVO etc. which indicate whether the point is high or low at any given time. For example, when the unit is in the purge mode, the variable PURGE is high and $\overline{\text{PURGE}}$ is low. When the unit is not in the purge mode, PURGE is low and $\overline{\text{PURGE}}$ is high. Similarly, SERVO is high when the servo is off and low when the servo is on.

In the circuit 107 FIG. 7A, 12.6 volt a.c. enters the board on pins A, B, and 1 of P2, is fullwave rectified by CR7 and CR8 and filtered by C5 to yield 8 volt d.c. which is applied to voltage regulators PS1 and PS2 which supply 5.0 volt d.c. to the logic circuitry and lamps. Capacitors C6 and C7 filter the regulator outputs and capacitors C10 (FIG. 7B) C11, C12, C14, C15 (FIG. 7C) and C13, C16 (FIG. 7F) through C16 are distributed on the board to decouple the logic power supply.

One side of the incoming a.c. (pin A or P2) FIG. 7A is applied to the circuit composed of capacitor C4, zener diode CR-4, programmable unijunction transistor Q5, and resistors R21, R22, R23 and R28 which produces narrow 2 volt positive spikes at line frequency (16.7 ms apart) across resistor 21 and at the input (pin 14) of E6. E6 FIG. 7B and E5 FIG. 7B operating as divide by 16 counters divide this line frequency input by factors of 2 up to a total of 256, to produce a series of timing signals with periods ranging up to 4.3 seconds. If the thermostat 110 or cover interlock 111 FIG. 4 is closed, 5 volts is applied to the wait lamp DS2 FIG. 7 and pin 13 of D3 FIG. 7F by way of PIN E of connector P2, FIG. 7F and 7H. D3-12 FIG. 7F and D2-12 are low and D2-11 is high regardless of the position of switch 34 FIG. 1, holding the unit in a reset condition. When the interlock switches open, the +5 volts is removed and the low resistance of the wait lamp pulls D3-13 FIG. 7F down to a low. Pins D3-12 and D2-12 FIG. 7F are then high and D2-11 (reset) is high if the run/reset switch 34 FIG. 1 is in the reset position and low if it is in the run position. Capacitor C8 minimizes the effects of noise or slight chatter of the thermostat contacts.

The unit is in the reset mode when the run/reset switch is in the reset position or when the wait light is activated. Pins D2-11 (reset) FIG. 7F are connected to Pins B1-2 and B1-3 of the program counter 103 and

serves to reset B1 to its proper initial condition with all outputs low. Pin D3-10 ($\overline{\text{RESET}}$) FIG. 7G is connected to Pin D1-10 FIG. 7C to set the top/bottom flip-flop (% of D1) to its proper initial condition (BOT high).

The following is a step-by-step description of a normal operating cycle.

PURGE MODE

Throughout the purge mode, $\overline{\text{PURGE}}$ is zero, enabling the data strobe (Pin 1) on IC4 FIG. 7F IC5 and IC6 FIG. 7E causing the display to read all eights which have been programmed in the counters by pulling the data inputs (Pins 11) of IC4, IC5, IC6 high with resistors R2 and R3, FIG. 7E through R4 FIG. 7F and grounding data inputs (Pins 3, 4 and 10 of IC4, IC5, IC6). This verifies that all display segments are operating.

PUMP — When the run/reset switch 34 is advanced to run, RESET goes low and B1 FIG. 7F is then able to count since pins 2 and 3 are low. $\overline{\text{PUMP}}$ at IC3-1 FIG. 7B is low causing PUMP or BLOW on IC3-3 and IC2-2 to be high. PUMP and RESET on IC3-4 FIG. 7C and IC3-5 are both high, making IC3-6 and E1-2 and E1-3 low, enabling E1 to count the 4.3 second timing signals applied to pin 14 from E5-11. Referring to FIGS. 7B, 7C, and 7D PUMP and PURGE on A8-1 and 2 are both high so A8-3 and 10 are low, making A8-8 and B7-1 high and B7-2, B3-11 and D5-5 low. D5-6 goes high, signalling the driver card to turn on the photometer lamp. B3-10 goes high, pulling D4-8 and 10 high. The high on Pin 10 enables the flip-flop and the high on Pin 8 along with the ground on Pin 11, condition the flip-flop so that the Q output (Pin 5) will go high when the timing signal applied to Pin 9 by E5-8 falls from high to low. When D4-5 goes high D4-6 and D3-9 go low and D3-8 FIG. 7d goes high signalling the driver board to turn on the servo-amplifier. E1 is still counting the 4.3's timing signals. When the eight count is reached (after approximately 32's) E1-11 and D1-1, 2 and 13 go high and D1-12 and 4 go low toggling the top/bottom flip-flop to make TOP (D1-6) and IC2-3 high. Since IC2-2 is already high, the pair of inputs IC2-2 and 3 are both high and IC2-8 drop low, triggering B1 to its next state.

BUBBLE — BUBBLE is now high holding IC2-5 high and signalling the driver card to open the bubble solenoid in the breath chamber. The piston drops in the chamber and activates the bottom switch, pulling D1-11 from the high set by R27 to a low and toggling the top/bottom flip-flop to make BOT (D1-8) and IC2-4 high. Since IC2-5 is already high, IC2-8 goes low stepping B1 again.

ANALYZE — ANALYZE is high, $\overline{\text{ANALYZE}}$ is low so D5-13 and D6-2 and 3 are low and D5-12 and D4-13 are high enabling D6 and D4 to count the 4/3's timing signal placed on D6-14 by E5-11. On the eighth count (about 32's), D6-11 goes high. After another eight counts 64's total) D6-11 goes low again. Resistor R19 holds the J & K inputs of D4 (Pins 1 and 4) high, so that when D6-11 and D4-12 go low D4-3 goes from low to high and D4-2 goes from high to low pulling IC3-9 and 10 low and IC3-8 high. IC3-11 is also high since Pin 13 is now high and Pin 12 is low, so A8-4 and 5 are both high and A8-6 is low. A8-9 is also low which makes A8-8 high, turning on the lamp and servo as described

for PUMP above. With the servo on SERVO is high making D2-1 high. Assuming no signals come through C9, R29 and R30 keep D2-2 at about 2.5 V which is an effective high, so D2-3 and E4-2 and 3 are low enabling E4 to count. E4-11 and IC2-9 go high when E4 has counted eight cycles of the 530MS timing signal applied to Pin 14 by E5-1 and 12. (About 4 sec.) IC2-10 has been high all this time since it is connected to ANALYZE so when IC2-9 goes high, IC-8 goes low, stepping B1 again.

READ — STOP (IC2-13) is high. A7-5 FIG. 7H, which is connected to READ is now high and A7-6 and A8-12 are low, making A8-11 high and causing the printer to print. READ is also connected to IC1-10 and 13 making them high and enabling both flip-flops to count. J and K inputs of both (Pins 1, 4, 8 and 11) are pulled high by R1. When the 4.3's timing signal at the input (Pin 9) falls for the second time, IC1-3 and IC2-1 go high and since IC2-13 is already high, IC-8 goes low and steps B1 again.

BLANK — IN BLANK, PURGE is high letting DATA STROBE (Pins 1) of counters IC4, 5, 6 (FIGS. 7F and 7E) go high so 8's are no longer displayed. IC7-3 holds the counter reset inputs (Pins 13) low in PUMP and BUBBLE disabling the counting circuits.

PUMP — Same operation as in PURGE mode.

BUBBLE — Same operation as in PURGE mode.

ANALYZE — Same operation as in PURGE mode with the following differences:

First, when the servo comes on there may be enough of an imbalance in the servo system to drive the counter wheel enough to send a few counts into the counter inputs (Pins P and 15 of connector P2 FIG. 7E). These count pulses are amplified by Q1 and Q2 and associated components R6-R11, and C1 and C2, conditioned by a set-reset flip-flop (1/2 IC7) and shaped with two inverters (1/3 D5) FIG. 7F and resistors R5 and R14. From this point the counts go to D5-9 FIG. 7B and from D5-8 to C9, R29 and R30 which differentiate them into a 100 nanosecond negative going spike which is applied to D2-2 causing a positive spike on D2-3 and at Pins 2 and 3 of E4, resetting E4 each time a count pulse is received. This means E4-11 no longer goes high after 4 seconds, after the servo comes on. Instead, it goes high when the servo is on and no counts have been received in the preceding 4 seconds.

Referring to FIGS. 7C, 7E and 7F, the incoming counts also go to D7-1. D7-2 and 3 are connected to SERVO and go low when the servo comes on, enabling D7 to count. When D7 has counted two counts, D7-8 goes high, on the fourth count it goes low again, pulling E3-12 low. E3-13 is connected to SERVO and is high enabling the flip-flop. J (Pin 1) is pulled high by R-18 and K (Pin 4) is low, so when E3-12 goes low, E3-3 and IC7-5 go high. The incoming counts also go to IC7-4, and with IC7-5 high, the counts appear (inverted) at IC7-6 and IC6-8, the counter input, and are counted and displayed the the readout tubes.

READ — Same operation as in PURGE mode.

SAMPLE — Same comments as for BLANK.

BLOW — In BLOW the subject blows the piston up to the top of the breath chamber, making the top switch, and pulling E3-9 and D2-9 down from the high set by R26 to a low. E3-8 and 10 are connected to BLOW and are high. The high on E3-10 enables the flip-flop and the high on E3-8 in combination with the low on E3-11,

sets up the flip-flop so that E3-5, and D2-5 and 10 go high when E3-9 goes low. 136 millisecond timing signals are applied to D2-4 and since D2-5 is high, they appear inverted at D2-6 and E2-9, but E2 is not enabled to count at this time. When the subject finishes blowing, the piston drops slightly and the top switch opens, allowing D2-9 to go high. D2-10 (along with E3-5 and D2-5) is still high so D2-8 and D3-5 go low and D3-6 and E2-10 and 13 go high enabling the flip-flops to count the 136MS counts still coming in on E2-9. On the second count, E2-2 goes low, pulling down D1-5 and toggling the top/bottom flip-flop making TOP (D1-6) and IC2-3 high BLOW on IC3-2 is low, making PUMP or BLOW on IC2-2 high. When IC2-3 goes high, IC2-8 goes low and steps B1 again.

BUBBLE — Same operation as in PURGE and BLANK.

ANALYZE — Same operation as in BLANK with one exception. Note that the servo comes on when D6-11 is low and D4-3 is high. If the servo system cannot get to a null within 32 seconds counts are still coming in resetting E4 preventing E4-11 from going high and ending the ANALYZE step. However, after 32 seconds D6-11 will go high again. IC3-12 and 13 are then both high and X (IC3-11) is low, pulling A8-13 FIG. 7H and B8-1, 2, 4, 5, FIG. 7D 11 low and A8-11 and B8-12, 6 and 8 high causing the printer to print an X indicating that the servo did not get to a null in the allotted time. 4.3 seconds timing signals are still applied to D6-14, and D6 and D4 will continue to count until the case where D6-11 is low and D4-3 is high is reached again, at which time the lamp and servo will come on as before. If a null is reached within the 32 seconds this time E4 is no longer reset and E4-11 goes high as discussed in BLANK ANALYZE. If a null is still not reached, the process will repeat again until a null is reached, and B1 is stepped again.

READ — Same operation as in PURGE and BLANK except in this step STOP has gone low, so when IC2-1 goes high, this time IC2-13 is low, preventing IC2 from stepping B1 any further.

The printer prints when A8-11 goes from low to high. Each digit is determined by a 4-bit BCD code from the counters IC4, 5 and 6. The BCD bits from the counters are inverted to operate the printer which responds to negative-true coding. (That is, it will print an 8 when the bit with a weight of 8 is low, and the other bits are high.) The letter printed P, S, T or X is controlled by functions decoded from program counter B1 and the analyze circuit. The weight column on the logic diagram shows the printer weights for the letter column, and the table at the top shows the combinations of highs and lows which these weights must assume to print a particular letter.

All lamps except the WAIT lamp are controlled by functions decoded from program counter B1. When the input to the driver is high, the diode is reverse biased on and a 1K resistor biases the transistor on to light the lamp. When a low input is present, the diode is forward biased and shunts bias current away from the base, turning transistor and lamp off. Note that the diodes used must be low forward voltage germanium units since the drop of the forward biased diode plus the .2 volt or so which constitutes a low must be less than the drop across the forward biased transistor emitter base junction if the lamp is to be fully extinguished.

It is apparent from the above that the present invention provides an improved tester for quantitatively determining the amount of alcohol in the human breath. Important features of the invention include improved sample chamber constructions, an improved sequence of operation and a fully transistorized sequential control circuit, all designed to insure that the reading taken from a person under test will be accurate and reliable. At the same time, the tester is of relatively simplified and inexpensive construction and is preferably provided in a small carrying case or cover for ease of portability. The logic readout is in decimal digital form and three digits are displayed. If desired for enforcement purposes, the last digit may be covered so that only two digits are displayed. The printer is preferably a two digit printer.

While the invention has been described in conjunction with the testign of the human breath, it is apparent that the tester of the present invention may be used to quantitatively measure various gas components in a wide variety of gases. Similarly, while the device has been described as preferably incorporating a second sample chamber or waste chamber, it is apparent that in certain instances a single sample chamber may be employed. A separate waste chamber is preferred since it assures that the sample charge will be representative of the deep lung breath and that a carefully metered breath charge will be obtained. By providing both purge and blank cycles prior to an actual test, the unit of the present invention minimizes the possibility of the test being adversely affected by any residual alcohol from previous tests remaining in the sample chamber. That is, the purge cycle acts to drive out any alcohol and moisture residue and the blank cycle takes a reading based upon a charge of ambient air so that if even after the purge cycle some residual gas or moisture does remain, this will be so indicated by the readout obtained by the blank cycle.

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiment is, therefore, to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are, therefore, intended to be embraced therein.

What is claimed is:

1. A breath tester for quantitatively measuring the alcoholic content of the human breath comprising a sample chamber, an inlet tube for receiving a breath sample, a blow solenoid valve coupling said inlet tube to said sample chamber, an air pump, a pump solenoid valve coupling said pump to said sample chamber, an outlet tube connected to said sample chamber, a bubble solenoid valve coupled to said output tube for supplying gas from said sample chamber to a bubbler tube, means including a photodetector for sensing the amount of alcohol in a charge of gas from said bubble valve, a first switch coupled to said chamber for producing an electrical signal when said sample chamber is empty, a second switch coupled to said sample chamber for producing an electrical signal when said sample chamber is full, a clock for producing timing signals, a solid-state program counter having inputs coupled to said switches and said clock, and a solid-state program

decoder coupling said program counter to said solenoid valves.

2. A tester according to claim 1 including a heat responsive bimetallic thermostat switch coupled to said program counter.

3. A tester according to claim 1 including a case, and a plurality of tester function indicator lights mounted on said case and electrically coupled to said program counter.

4. A tester according to claim 1 wherein said program counter and said program decoder are both formed of transistor-transistor logic circuits.

5. A tester according to claim 1 including an electronic thermistor circuit to control operating temperatures.

6. A tester according to claim 1 including a run switch coupled to said program counter.

7. A tester according to claim 6 wherein said run switch forms part of a three-position switch manually movable between off, reset and run positions.

8. A tester according to claim 1 wherein said photodetector includes a digital pickup, a digital display, and a pickup counter coupling said digital pickup to said display.

9. A tester according to claim 8 wherein said program counter, program decoder, clock and pickup counter are all mounted on a common circuit board.

10. A breath tester for quantitatively measuring the alcoholic content of the breath of a subject comprising a sample chamber for receiving a charge of breath, means defining a first fluid path communicating with said chamber for taking a breath sample exhaled by the subject, a first electrically operated valve in said first fluid path for controlling the flow of breath into said sample chamber, a first electric switch for indicating when said chamber is empty, a second switch for indicating that a minimum volume of breath has been taken from said subject, a test container having test solution therein supported within said tester, means in said tester defining a second fluid path for flow of the breath sample from said sample chamber to said test container, means for moving the breath sample from the sample chamber through the second fluid path into said test solution, a second electrically operated valve in said second fluid path for controlling the flow of breath out of said sample chamber, a reference container having a reference solution therein supported within said tester, means in said tester for comparing the light transmission through said test container with light transmission through said reference container, a digital optical display coupled to said comparison means for displaying the result of the breath test, a solid state program counter for controlling the operating functions of the tester, means for actuating said program counter, said switches connected to said program counter, a solid state program decoder coupled to said counter, said program counter being operatively coupled to said valves, said comparison means and said digital optical display respectively, to control flow of said sample through the second fluid path to the test container, and to actuate said comparison means and said display means for displaying a test result.

11. A tester according to claim 10 wherein said first and second valves comprise solenoid valves.

12. A tester according to claim 10 including a mouthpiece for blowing a breath sample into said sample chamber, and in which said first valve comprises a blow

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valve coupling said mouthpiece to said sample chamber.

13. A tester according to claim 10 including a pump for supplying a charge of air to said sample chamber, said first valve comprising a pump valve coupling said pump to said sample chamber.

14. A tester according to claim 10 including a clock coupled to said program counter whereby the operation of said first and second valves is responsive to the operation of said clock.

15. A breath tester as defined in claim 10 which further includes an overflow chamber in fluid communication with said sample chamber for insuring a minimum volume of breath sample being taken from the subject and the second switch being coupled to said overflow chamber for indicating that a minimum volume of breath has been taken from the subject.

16. A tester as defined in claim 10 which further includes a pump, means defining a third fluid path between said sample chamber and said pump for purging the sample chamber, and a third electrically operated valve in said third fluid path for controlling the flow of air from said pump into said sample chamber.

17. A tester as defined in claim 10 which further includes means for providing a printed record on the breath test.

18. A tester as defined in claim 10 which further includes means to prevent operation if said test container or said reference container is subject to external manipulation.

19. A tester according to claim 10 wherein said optical display comprises a printer.

20. A tester according to claim 19 wherein said tester is provided with a slot for inserting a card into said printer.

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21. A tester according to claim 10 wherein said display comprises an electro-optical display.

22. A tester according to claim 21 wherein said display comprises a plurality of digital display stations each formed by a seven bar segment array of lights.

23. A tester according to claim 10 including overflow means coupled to said sample chamber for measuring a volume of 400 ml.

24. A tester according to claim 23 in which said overflow means comprises a time actuated valve to measure 400 ml at a predetermined flow rate.

25. A tester as defined in claim 10 which further includes means for maintaining said sample chamber at a fixed elevated temperature.

26. A tester as defined in claim 25 which further includes means for preventing operation of said tester if said sample chamber is not at said elevated temperature.

27. A tester according to claim 10 including an overflow chamber coupled to said sample chamber, each chamber having a piston movable in it, said first switch being located adjacent the bottom of said sample chamber for actuation by the sample chamber piston, and said second switch being located adjacent the top of said overflow chamber for actuation by the overflow chamber piston.

28. A tester according to claim 12 including a proportioning valve coupling said sample and overflow chambers, said proportioning valve having an exhaust port for wasting to atmosphere a predetermined portion of gas flowing through said proportioning valve from said sample chamber to said overflow chamber.

29. A tester according to claim 27 in which said overflow chamber has a volume of 400 ml.

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