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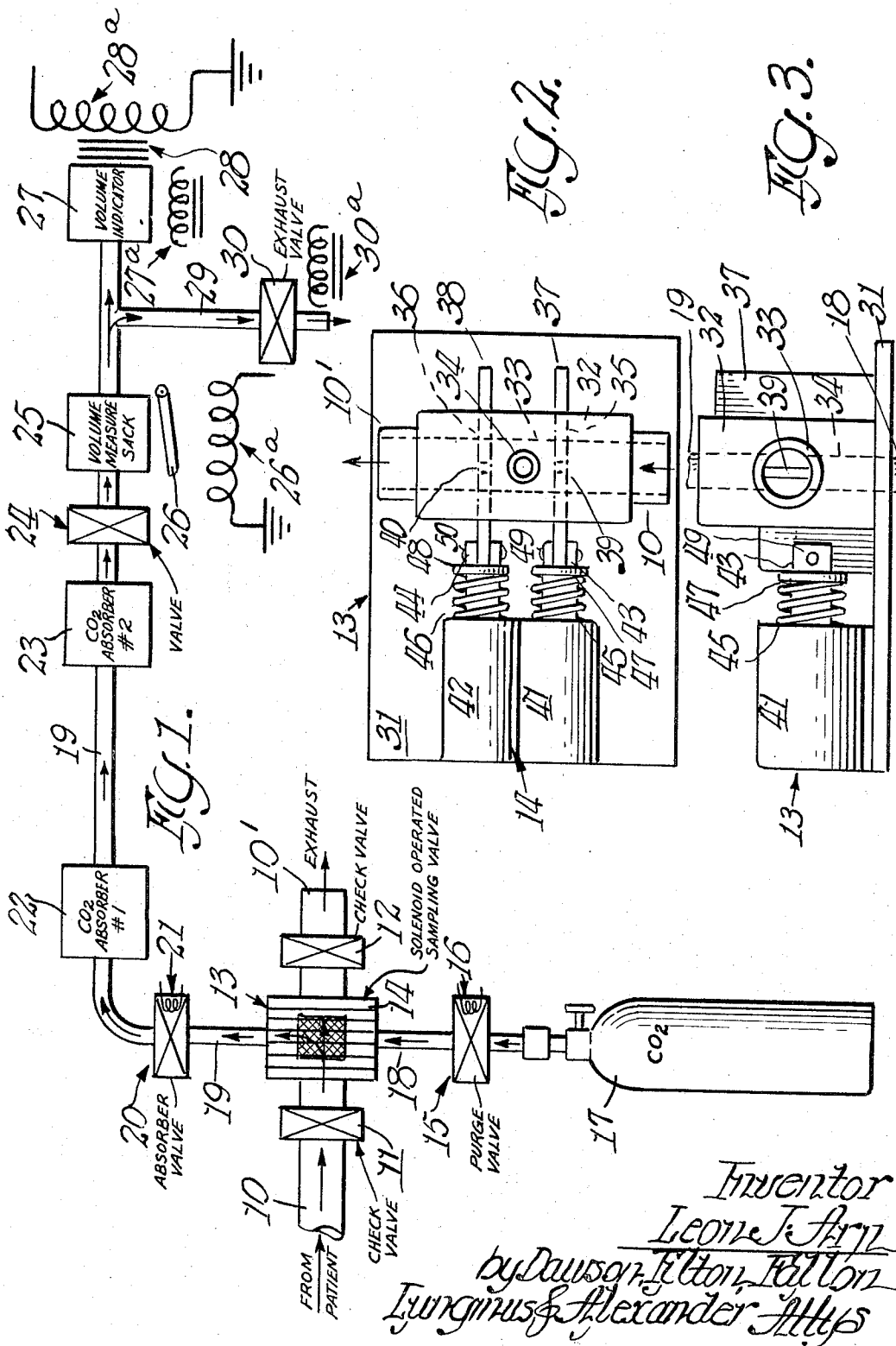
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OXYGEN UTILIZATION ANALYZER

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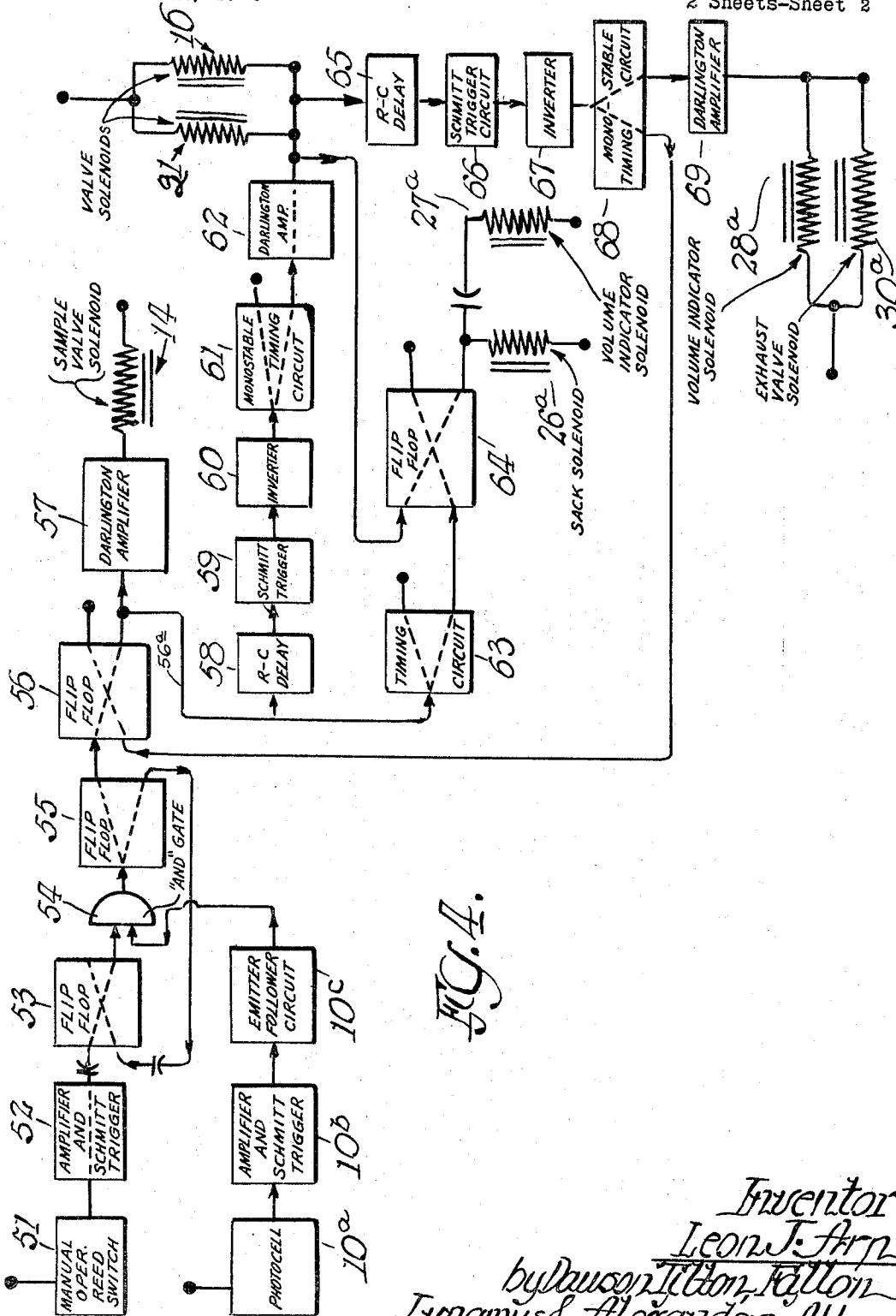


FIG. 2.

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OXYGEN UTILIZATION ANALYZER

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This invention relates to an oxygen utilization analyzer, and, more particularly, to a device for measuring the amount of carbon dioxide in the exhaled breath.

The invention has use in every operation which requires the presence of an anesthetist. The extent of oxygen utilization is of significant importance to the surgeon, and accuracy in this measurement, along with speed of determination, are prerequisites. These are met by the instant invention, and the provision of a device achieving these ends constitutes an important object of the invention.

In particular, the invention finds utilization in measuring the carbon dioxide in the exhaled breath of infants when it is desired to augment the breathing pattern, particularly in the case of prematurely born infants. As such, the instant invention is advantageously utilized in conjunction with the apparatus for measuring breath volume which is the subject of the co-owned, copending application of Leon J. Arp and Ronald J. Griffith, Serial No. 337,778, filed January 15, 1964.

Other objects, advantages and usages of the invention can be seen in the details of operation and construction set down in the following specification.

The invention is explained in conjunction with the accompanying drawing, in which—

FIG. 1 is a schematic elevational view of a carbon dioxide analyzer embodying teachings of the invention;

FIG. 2 is a top plan view of the sampling valve portion of FIG. 1;

FIG. 3 is a side elevational view of the sampling valve of FIG. 2; and

FIG. 4 is a schematic or diagrammatic view of the electrical circuitry employed in conjunction with the invention.

Referring now to the drawing, and in particular FIG. 1, the numeral 10 designates a conduit which is adapted to receive the exhalation of a patient whose oxygen utilization is to be determined. The conduit 10 thus is adapted to be coupled to the mouth or nose, as the case may be, of a patient for the purpose of collecting and delivering an exhaled breath.

The numerals 11 and 12 designate check valves installed in the conduit 10, the valve 12 being in the portion of the conduit 10 designated 10' and which constitutes the exhaust portion of the conduit, being "downstream" from the sampling valves generally designated 13.

The sampling valve 13 is provided to collect a discrete and predetermined volume of the exhaled breath of the patient (not shown), and operatively associated with the sampling valve 13 is a solenoid operator 14. The details of construction of the sampling valve 13 and its solenoid 14 will be described hereinafter in conjunction with FIGS. 2 and 3.

The numeral 15 designates a purge valve also equipped with a suitable solenoid operator 16. The purge valve 15 is installed in a conduit 18 which is also coupled to a tank source of carbon dioxide designated 17. Thus, upon operation of the valve 15, carbon dioxide from the tank 17 flows through the conduit 18 to purge the sampling valve 13 of the sample collected from a given breath passing along the conduit 10.

The numeral 19 designates piping leading away from the sampling valve for conducting the carbon dioxide-diluted breath sample, and installed in the piping 19 is a

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first absorber valve 20. The absorber valve 20 is operated by a solenoid operator designated 21.

Proceeding along the conduit or piping 19, the first carbon dioxide absorber is designated 22, while the second stage absorber is designated 23, both of which are installed in the path of fluid flowing in the piping 19. Downstream of the second stage absorber 23 is a second absorber valve 24, also operated by the solenoid 21, which has previously been mentioned in connection with the first absorber valve 20.

The numeral 25 designates a collection sack of collapsible nature which is interconnected in the piping 19 and which is utilized to collect the carbon dioxide-stripped sample resulting from purging of the sampling valve 13. Associated with the flexible, collapsible collection sack 25 is a pivotally mounted platen 26, the details of which can be found in the above-mentioned Arp and Griffith application. Associated with the platen 26 is a solenoid operator 26a, which is also described in detail in the above-mentioned copending application. Reference may be had to the above-mentioned application for details of construction and operation not set down here.

The numeral 27 designates generally an indicator of the volume of fluid collected in the collection sack 25, and associated with the indicator 27 is a solenoid 27a for unlocking the indicator upon the initiation of collapse of the collection sack 25. Again, the details of construction and operation of this portion of the apparatus may be found in the above-mentioned copending application.

The numeral 28 designates a reset mechanism associated with the indicator 27, and the reset mechanism is actuated by a solenoid 28a.

The numerals 29 and 30 refer respectively to an exhaust pipe and exhaust valve operatively connected to the piping 19 between the collection sack 25 and the indicator 27. The exhaust valve 30 is equipped with a solenoid actuator 30a.

The general scheme of operation involves collecting a portion of a given exhaled breath in the sampling valve 13—the sample volume being of the order of one cubic centimeter. When this is done, the purge valve 15 is opened to flush the sampling valve and conduct the carbon dioxide-diluted sample through the two-stage absorber consisting of the absorbers 22 and 23. The carbon dioxide portion of the sample, including the purged carbon dioxide, is absorbed in passing through the absorbers 22 and 23, and the remaining volume of the original sample passes to the collection sack 25. Actuation of the platen 26 collapses the sack 25, causing the sample to flow into the indicator 27, which may take the form of the piston-equipped syringe shown in the above-mentioned copending application. The indicator 27 is provided with suitable reporting or indicating means to tell the operator the volume of the carbon dioxide-analyzed sample. Thereafter, the indicator is reset by operation of the solenoid 28a of the indicator mechanism 28 and simultaneously therewith the exhaust valve 30 is opened to free the system of the now-analyzed sample. The electrical operations and elements are diagrammatically illustrated in FIGURE 4 and described hereinafter.

The valve 13 is seen in greater detail in FIGS. 2 and 3, wherein the numeral 31 designates a base, which may be a portion of a larger platform accommodating the other elements hereinbefore described. Mounted on the base 31 is a valve body 32 which, in the illustration given, is seen to be of block-like form with a passage 33 for conducting the exhaled breath of a patient whose breath is to be analyzed. As seen in FIG. 2, the passage 33 is coupled to the conduits 10 and 10' previously described in connection with FIG. 1.

A second passage 34 is provided in the body 32, the

second passage 34 being arranged at right angles to the first-mentioned passage 33 and intersecting the same.

The numerals 35 and 36 designate slots in the body extending transversely of the passage 33 for the accommodation of slide valve elements 37 and 38. Each of slide valve elements 37 and 38 is equipped with a centrally disposed aperture 39 and 40, respectively. It will be appreciated that in the normal position, the apertures 39 and 40 are aligned with the passage 33 so as to permit flow of the breath through the valve body 32. Movement of the slide valve element to the left in the illustration given moves the apertures 39 and 40 out of registry, and thus establishes a sample chamber in the central longitudinal portion of the passage 33 and which is also in communication with the carbon dioxide purge passage 34.

For this purpose, the solenoid operator 14, consisting of solenoid coils 41 and 42, is mounted on the base 31, with each of the coils 41 and 42 being equipped with a suitable armature as shown at 43 and 44. The armatures 43 and 44 are biased to the right by virtue of the coil springs 45 and 46 extending between the coils 41 and 42, and the washers 47 and 48, respectively. Each of slide valve elements 37 and 38 is coupled to a respective armature 43 and 44, respectively, by means of a pivot 49 and 50, respectively.

In the operation of the specific embodiment illustrated, the solenoid coils 41 and 42 are actuated to retract the armatures 43 and 44 and thus establish an isolated chamber in the central longitudinal portion of the passage 33. This determines the volume of the breath sample to be analyzed, after which carbon dioxide is introduced through the pipe 18 (see FIG. 3) to purge the sampling chamber with the carbon dioxide-diluted sample issuing from the valve body 32 into the pipe 19 (still referring to FIG. 3).

The electrical system will now be described which regulates the sequence of operations of the carbon dioxide analyzer, and for this purpose reference is now made to FIG. 4. The numeral 51, in the extreme upper left-hand portion of FIG. 4, designates a read switch which is operated by the operator of the carbon dioxide analyzer. Operation of the switch 51 causes a negative pulse to be delivered through the amplifier and Schmitt trigger 52 to the double input flipflop circuit 53. The two-input flipflop 53 then supplies a negative input signal to the "And" gate 54.

Still referring to FIG. 4 but below the subcircuit just described, the numeral 10a designates a photocell associated with the conduit 10 and connected to an amplifier and Schmitt trigger 10b to produce a negative pulse each time the patient begins inspiration. These pulses are routed by the emitter follower 10c to the "And" gate 54, but are ineffective until the read switch 51 has been depressed, since the gate 54 produces an output pulse only when there is coincidence of input pulses from 53 and 10c.

Upon the first coincidence of the output from the two-input flipflop 53 and the emitter follower 10c, the "And" gate 54 supplies a negative pulse to the single input flipflop 55. The single input flipflop 55 supplies a negative pulse which is delivered through a capacitor coupling to one of the inputs of the two-input flipflop 56. This in turn supplies a negative signal to the Darlington circuit 57, causing the sample valve solenoid 14 to be energized.

Upon energization of the sample valve solenoid 14, and referring to FIGURE 1, the expiration path from the input conduit 10 is routed through the sample valve which is equipped with the pair of one-way check valves 11 and 12—one upstream from the sample valve 13, and one downstream. The check valves 11 and 12 prevent the infant or other patient from rebreathing exhaled air as well as preventing the dilution of the exhaled air trapped in the sample-collecting chamber portion of the passage 33.

The two-input flipflop 56 also supplies a negative signal via line 56a to an RC delay circuit 58 and a Schmitt trigger 59 through an inverter 60 to a monostable timing circuit 61. The RC delay 58 is designed to supply sufficient delay to the negative output signal from the two-input flipflop 56 to the monostable time circuit 61 to allow the sample valve 13 to close, thus trapping the sample for analysis.

The sample valve 13 closes following the second inhalation by the infant or other patient after the read switch 51 has been depressed.

The output of the two-input flipflop 53 is still present at one input of the "And" gate 54. However, the second time the patient inhales after the initial depression of the read switch 51 causes the vane-actuated photocell 10a to deliver a negative pulse through the amplifier and Schmitt trigger 10b and the emitter follower 10c to the "And" gate 54. Upon the second coincidence of the two-input signals to the "And" gate 54, the single input flipflop 55 changes its condition, thus delivering a negative pulse to the second input of the two-input flipflop 53. This change removes one of the signals at the "And" gate 54, thus preventing the passage of any additional pulses generated by the vane-operated photocell 10a.

By this time the sample valve 13 has trapped the exhaled breath and the RC delay 58 has allowed the Schmitt trigger 59 to deliver a negative pulse through the coupling capacitor to the inverter 60. The inverter 60 delivers a positive pulse to the monostable timing circuit 61, turning it on so that a negative signal is delivered to the Darlington circuit 62. In FIG. 1, this energizes the purge valve solenoid 16 and the solenoid 21 associated with the valves 20 and 24 on each side of the absorbers 22 and 23. The monostable timing circuit 61 shuts itself off after a predetermined time, closing the purge valve 15 and the valves 20 and 24 on each side of the absorbers 22 and 23. At this time the sample originally trapped in the sample chamber, i.e., the portion of passage 33 between the sides 37 and 38, has been purged out of the chamber with pure carbon dioxide gas and into the two-stage carbon dioxide absorbers 22 and 23, where water and all carbon dioxide is removed. The remainder of the sample is held in the collection chamber sack 25.

When the purge valve 15 and the valves 20 and 24 on each side of the absorbers 22 and 23 are deenergized, the Darlington circuit 62 delivers a negative signal through a coupling capacitor to the two-input flipflop 64, energizing the indicator unlocking solenoid 27a and the platen actuation solenoid 26a. The sample trapped in the collection chamber 25 is then forced into the syringe indicator 27, where the measurement of the sample is made. The Darlington circuit 62 also delivers a negative signal to an RC delay 65 which controls the length of time the reading is displayed on the analyzer indicator 27—the negative signal being delivered to a Schmitt trigger 66 coupled by a capacitor to an inverter 67. The inverter 67 supplies a positive pulse through a coupling capacitor to the monostable timing circuit 68. The timing circuit 68, after being triggered by the positive pulse from the inverter 67, supplies a negative signal to the Darlington circuit 69.

The Darlington circuit 69 energizes the exhaust valve solenoid 38 associated with the valve 30, and the solenoid 28a associated with the reset mechanism 28 which empties the measuring syringe indicator 27.

After a preset time, the monostable timing circuit 68 returns to its original state, thus deenergizing the Darlington circuit 69 and the solenoids 28a and 30a. The timing circuit 68 also supplies a negative signal to a second input of the two-input flipflop 56. The output of flip-flop 56 for all practical purposes goes to ground, thus a positive pulse is supplied to a uni-junction timing circuit 63 which, after a preset delay, supplies a negative output signal through a coupling capacitor to the second input of the two-input flip-flop 64, deenergizing

the platen and indicator unlocking solenoids 26a and 27a.

The sampling, measuring, displaying and resetting sequences are now complete and the analyzer apparatus is ready to make another measurement as soon as the operator depresses the read switch 51.

While in the foregoing specification a detailed description of an embodiment of the invention has been set down for the purpose of illustration, many variations in the details herein given may be made by those skilled in the art without departing from the spirit and scope of the invention.

I claim:

1. In apparatus for the volumetric determination of exhaled carbon dioxide, means including a valve for isolating a predetermined quantity of exhaled breath, means including a source of carbon dioxide coupled to said valve for purging the first-mentioned means and delivering the carbon dioxide-diluted quantity to a carbon dioxide absorber, a carbon dioxide absorber coupled to said valve, and means operatively associated with said absorber for reporting the unabsorbed portion of said quantity.

2. The structure of claim 1 in which said valve includes a valve body having first and second intersecting fluid flow passages extending therethrough, said first passage being equipped with apertured slides flanking the intersection thereof with said second passage, and means coupled to said slides for moving the apertures thereof out of registry with said first passage to confine a discrete quantity of fluid in said first passage for purging removal by fluid flowing through said second passage.

3. The structure of claim 1 in which electromechanical means are operatively associated with said valve, carbon dioxide absorber and reporting means for sequentially purging said carbon dioxide-diluted quantity from said valve, measuring the unabsorbed portion of said quantity, and removing the last-mentioned quantity from said apparatus.

4. The structure of claim 3 in which said reporting means includes a collapsible chamber for receiving said last-mentioned quantity from said carbon dioxide absorber and a reporting chamber coupled to said collapsible chamber, said electromechanical means being opera-

tive to collapse said collapsible chamber before removing said last-mentioned quantity from said apparatus, and maintaining said collapsible chamber in collapsed condition until after said last-mentioned quantity has been removed from said apparatus.

5. The structure of claim 1 in which electromechanical means are operatively associated with said valve for orienting said valve in quantity non-isolating condition, and manually-operable means electrically connected to said electromechanical means for coaction therewith in orienting said valve to quantity-isolating condition.

6. A breath analysis system, comprising a valve having a body equipped with first and second intersecting fluid flow passages extending therethrough, said first passage being equipped with apertured slides flanking the intersection thereof with said second passage, means coupled to said slides for moving the apertures thereof out of registry with said first passage to confine a discrete quantity of fluid in said first passage for purging removal by fluid flow through said second passage, and means for sequentially delivering fluid to said passages.

7. A breath analysis system, comprising a valve adapted to isolate a discrete and predetermined quantity from a flowing stream of multi-component fluid, means coupled to said valve for purging said quantity of fluid from said valve and selectively absorbing a component therefrom, means operatively associated with said purging and absorbing means for indicating the quantity of unabsorbed components, and electromechanical means operatively associated with said valve for orienting the same to receive a single breath from a patient and reject all subsequent breaths until after the said quantity of unabsorbed components has been indicated for a predetermined time.

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