

[54] **ANESTHETIC VAPORIZER**

[75] Inventor: **Ulrich Sielaff**, McFarland, Wis.

[73] Assignee: **Airco, Inc.**, New York, N.Y.

[22] Filed: **July 16, 1973**

[21] Appl. No.: **379,506**

[52] U.S. Cl. **239/136**

[51] Int. Cl. **B05b 1/24, B44d 3/42**

[58] Field of Search **239/135, 136, 137, 138**

[56] **References Cited**

UNITED STATES PATENTS

2,886,689	5/1959	Garth.....	239/138
3,559,886	10/1968	Howard	239/136

Primary Examiner—Lloyd L. King

Attorney, Agent, or Firm—Roger M. Rathbun;

Edmund W. Bopp; H. Hume Mathews

[57] **ABSTRACT**

An anesthetic vaporizer is disclosed having a linear flow system which insures precise predictability of the desired anesthetic composition. The total flow into the vaporizer is divided into two main gas streams, the first gas stream proceeds through precise linear flow

restrictors and is then subdivided into two gas substreams by a concentration valve. One of the substreams is directed by the concentration valve through a vaporizing chamber where it becomes saturated with anesthetic and then to the vaporizer outlet. The other substream is channeled past the concentration valve directly to the vaporizer outlet where it is reunited with the one substream. By adjusting the concentration valve, the ratio of the substreams may be changed, thus affecting the eventual concentration of the anesthetic composition from the vaporizer outlet. The second main gas stream proceeds through a thermal compensation valve and is subdivided into two substreams, one of which is directed through fixed linear flow restrictors to the vaporizer outlet, and the other substream is directed through a variable thermal bypass also having linear flow restrictors. The flow through the variable thermal bypass to the vaporizer outlet is varied in accordance with the sensed temperature in the anesthetic vaporizing chamber.

A feature of the vaporizer is the use of unique precise linear flow restrictors in every path of flow through the vaporizer so that a predictable anesthetic concentration is obtained and overall linear response is achieved despite variables occurring during operation of the vaporizer.

8 Claims, 9 Drawing Figures

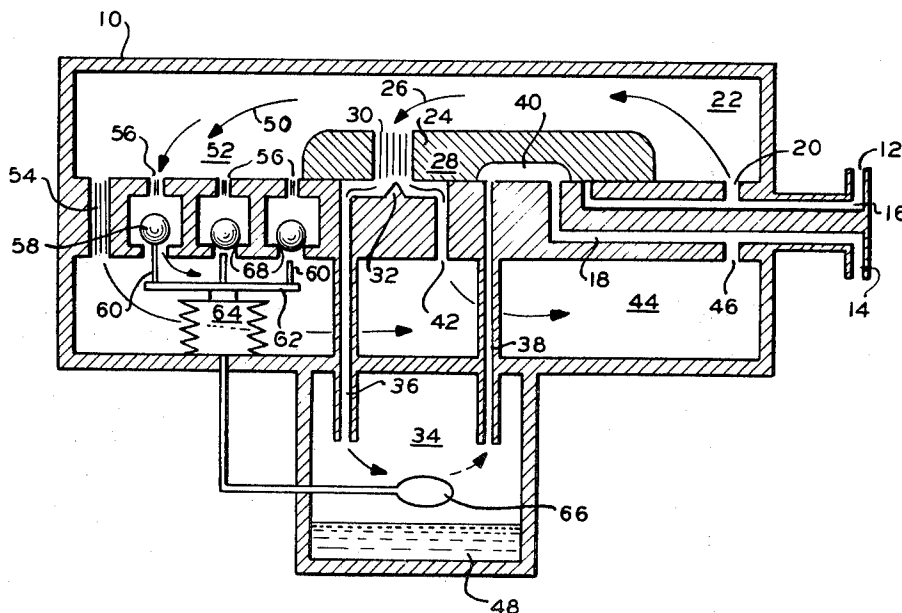


FIG. 1

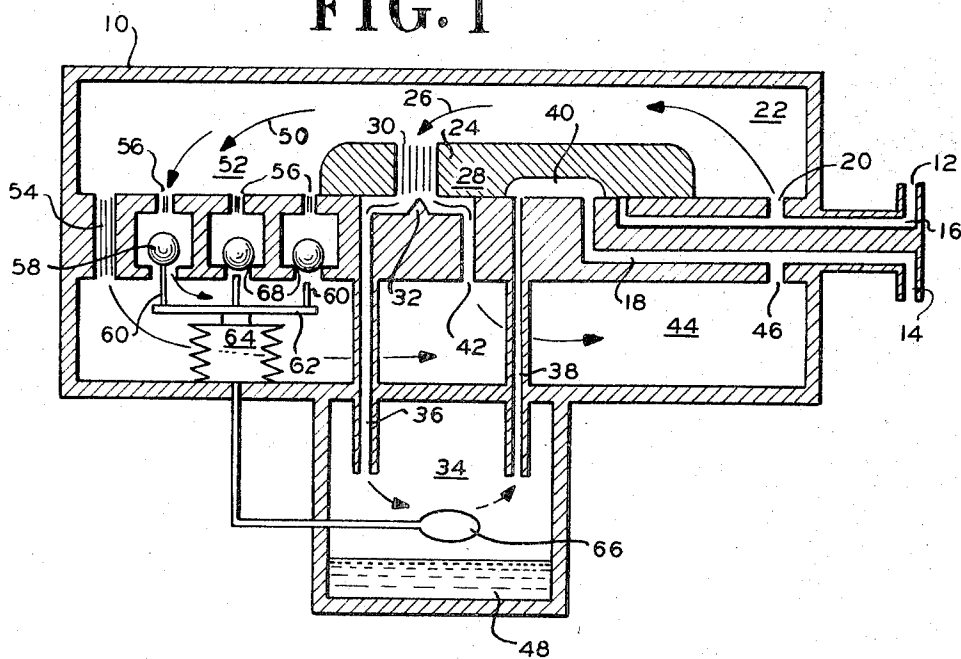


FIG. 3

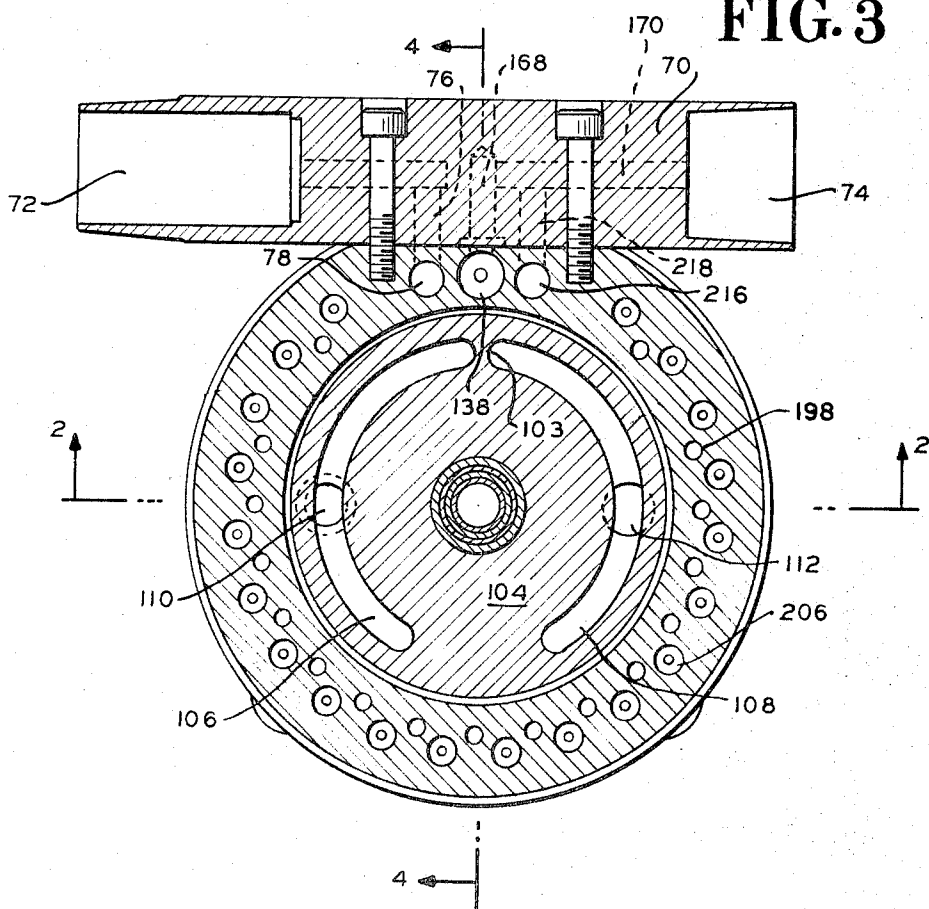


FIG. 4

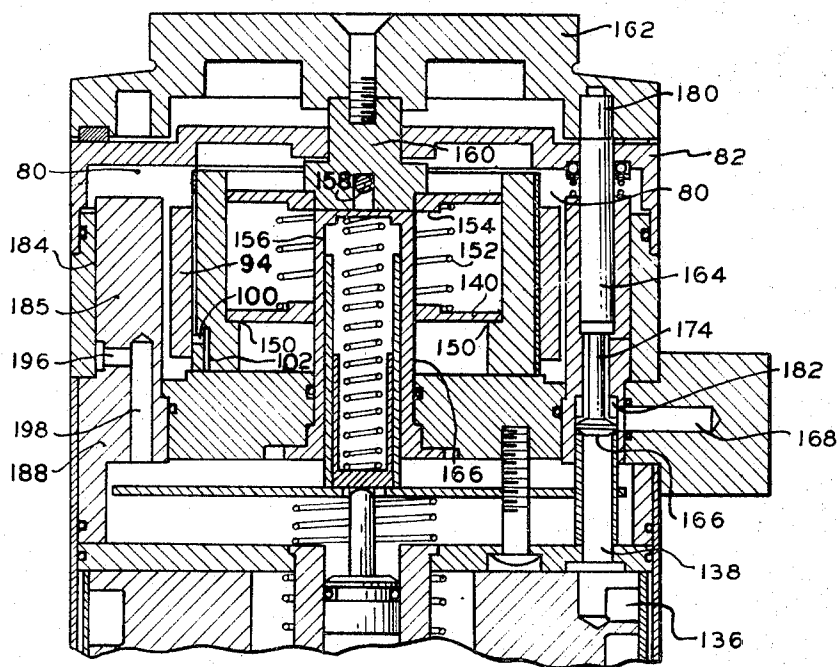
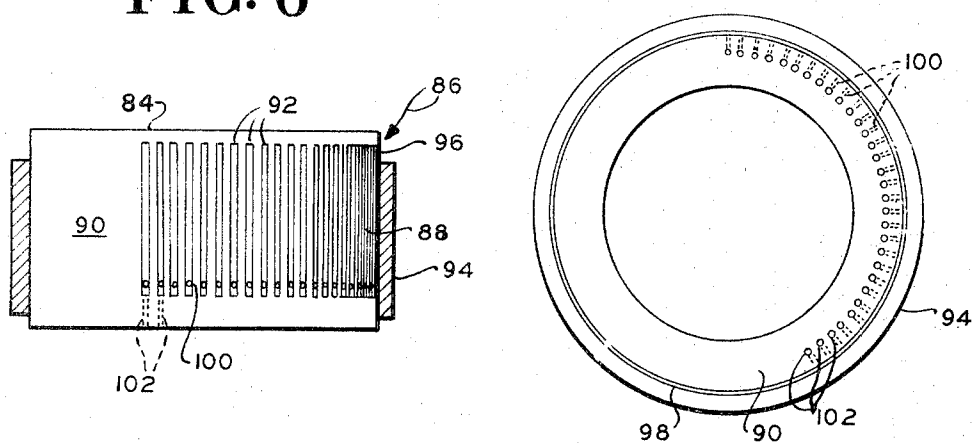
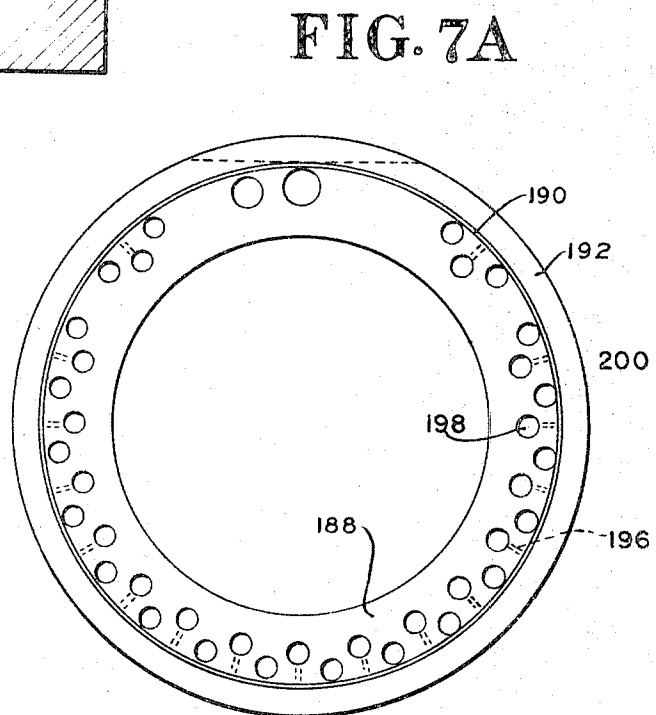
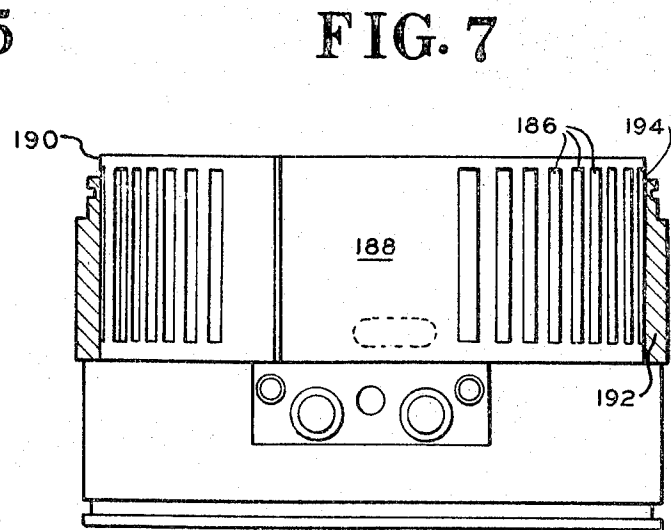
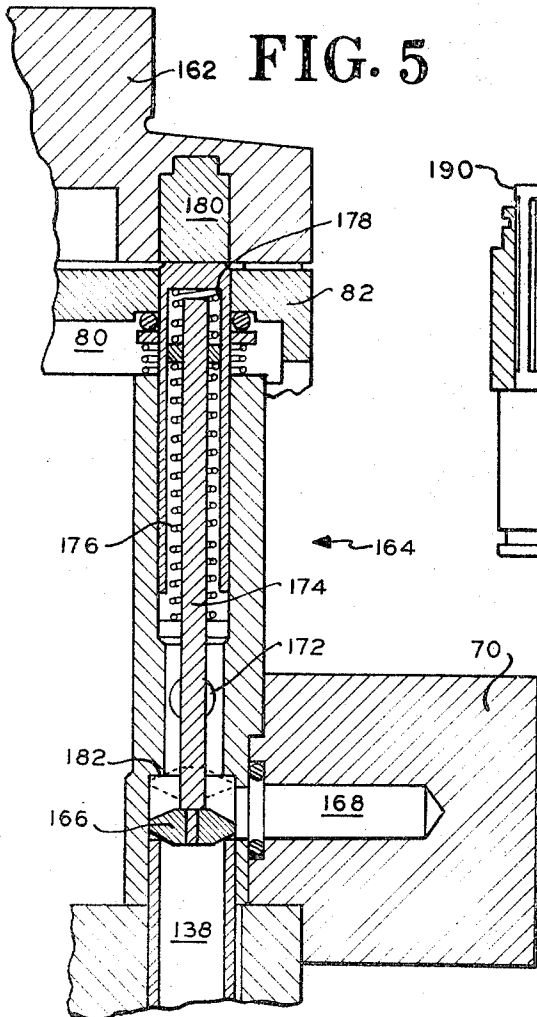


FIG. 6A

FIG. 6





ANESTHETIC VAPORIZER

BACKGROUND OF THE INVENTION

This invention relates generally to anesthetic apparatus, and more specifically relates to anesthetic vaporizing apparatus of the type which is provided with a vaporizing chamber and a bypass channel connected in parallel therewith.

Numerous varieties of anesthetic vaporizing apparatus are known which are so constructed that gas flow through the apparatus is divided with a first portion proceeding through the vaporizing chamber thereof, and a second portion proceeding through a bypass channel connected in parallel with the vaporizing chamber. Operation of devices of this type rely upon producing saturation of the gas passing through the vaporizing chamber; it is then only necessary to properly proportion the amount of gas passing through the vaporizing chamber to the total amount of gas through the vaporizer to be able to predict the concentration of vapor in the resulting mixture. While in principle, therefore, it would seem that achievement of a desired concentration of vapor in the mixture provided by such apparatus should be readily achieved, it is nevertheless found in practice that the concentration of vapor is maintained at a desired level only with the greatest difficulty. Problems with apparatus of the foregoing type arise for several basic reasons. Since, for example, such operation requires that the partial pressure of the vapor be equal to the vapor pressure of liquid from which it is derived at the temperature of the saturated mixture, it follows that the fraction of the total gas flow which must be saturated to produce a given concentration in the resulting total mixture must vary with the temperature of the saturated mixture. Furthermore, it is found in practice that the flow required to be delivered from the vaporizing apparatus varies over a reasonably broad range in accordance with the requirements of a patient and of the particular application in which the apparatus is being utilized. While the simple scheme outlined above of dividing the total flow into substreams passing through and about the vaporizing chamber may be effective for a relatively fixed rate of flow, apparatus in the past have not generally maintained such concentrations over a varying range of flow conditions.

Prior art vaporizing devices have attempted a solution of the problems by maintaining a laminar flow of gas through the vaporizer so that the proportion of the two flow streams through the vaporizer remain constant, despite changes in the total vaporizer flow. Such devices have been extremely difficult to manufacture, inasmuch as laminar flow restrictors often introduce an excess of resistance into the flow path, or are very difficult to be produced, having predictable properties. It is necessary, after manufacture, to individually calibrate such vaporizers by actual test of flows through each vaporizer. Such individual calibration is expensive and is an undesirable manufacturing procedure.

In accordance with the foregoing, it may be regarded as an object of the present invention to provide vaporizing apparatus which ensures an output maintaining a fixed preset concentration level of vapor over widely varying flow conditions, and over widely varying room temperatures, by the use of novel linear flow restrictors which insure laminar flow throughout and yet provide

extreme precision without introducing any significant resistance to the flow paths.

SUMMARY OF THE INVENTION

Now, in accordance with the present invention, the foregoing difficulties of prior art anesthetic vaporizers have been overcome and a vaporizer is described having a linear flow system which insures laminar flow throughout the vaporizer by including linear flow restrictors having accurate predictability of flow there-through.

In the vaporizer of the present invention, the total flow into the vaporizer is divided into two main gas streams. The first main gas stream passes through the linear flow restrictors and is then divided into two substreams by a concentration valve. By adjusting the concentration valve, the ratio of the two substreams may be varied, however, the total flow remains unchanged. One of the substreams from the concentration valve is directed straight to the vaporizer outlet while the other substream passes through the vaporizing chamber where it becomes saturated by the liquid anesthetic before proceeding to and reuniting with the one substream at the vaporizer outlet.

The second main gas stream passes through a thermal compensation valve and thereafter is directed to the vaporizer outlet after being mixed, near the outlet, with the first gas stream. In the thermal compensation valve, there are fixed linear flow restrictors through which one substream of the second main gas stream passes and a series of "on-off" linear flow restrictors where the other substream gas flow proceeds. The "on-off" linear flow restrictors vary the flow of the other substream in accordance with the sensed temperature in the anesthetic vaporizing chamber.

In each flow stream the linear flow restrictors are constructed in a similar manner and comprise a plurality of parallel minute channels formed coaxially in the peripheral surface of a cylindrical metallic core. The outside area of the channels are confined by a ring which, in manufacture, is heat shrunk around the core peripheral surface. An inlet and outlet to each channel is provided to introduce and remove the gas flowing therethrough.

The formation of the linear flow restrictors thus is relatively easy to effect, yet each channel, or series thereof, is extremely accurate and reproducible with existing manufacturing techniques.

Brief Description of the Drawings

The invention is diagrammatically illustrated by way of example in the drawings appended hereto in which:

FIG. 1 is a schematic depiction in cross-section of an anesthetic vaporizer made in accordance with the present invention;

FIG. 2 is a longitudinal cross-sectional view of a preferred embodiment of a vaporizer made in accordance with the invention; the view is taken along the line 2—2 in FIG. 3;

FIG. 3 is a transverse cross-sectional view taken along the line 3—3 of FIG. 2;

FIG. 4 is a partial longitudinal cross-section taken along the line 4—4 of FIG. 3;

FIG. 5 is an enlarged partial sectional view of a valve used in the present invention;

FIGS. 6 and 6A are respectively elevational and bottom plan views of the concentration valve used with the invention; and

FIGS. 7 and 7A are respectively elevational and bottom plan views of the thermal compensation valve used with the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In FIG. 1, there is shown a simplified schematic view of the anesthetic vaporizer in accordance with this invention. Because the actual vaporizer construction is relatively complex, the overall operation will be first explained by reference to FIG. 1. The anesthetic vaporizer 10, shown schematically in FIG. 1, includes a gas inlet 12 and a gas outlet 14, each communicating, respectively, with inlet and outlet passageways 16 and 18. A further inlet passage 20 admits gas entering inlet 12 into an inlet chamber 22 where the main gas flow is essentially divided into first and second main gas flows, which, for convenience, will be explained separately.

The first main gas flow enters a concentration valve, shown generally as 24 in the direction depicted by arrow 26. The concentration valve 24 has a slide member 28 in which is provided a linear flow restrictor 30 through which all of the first main gas stream flows. The flow restrictor 30 includes a plurality of minute, capillary-like flow passages which produce laminar flow in the gas stream and insure a linear relationship between the flow and the pressure drop across the flow restrictor 30. The actual construction of flow restrictor 30 will be later explained.

In the position shown in FIG. 1, the first main gas stream flows through linear flow restrictor 30 and is divided into two substreams by divider 32. One such substream enters vaporizing chamber 34 through vaporizing chamber inlet 36 where it becomes saturated with anesthetic vapor and proceeds through vaporizing chamber outlet 38 where it is channeled by a recess 40 in slide member 28 to outlet passageway 18 and through the vaporizer outlet 14. The other substream created by divider 32 proceeds through a passage 42 into an outlet chamber 44 where it collects and mixes with further gas streams, as will be later explained, and eventually reunites with the saturated gas stream in outlet passageway 18 via passage 46. Thus it may be seen that by changing the lateral position of slide member 28 the relative proportions of the substreams created by divider 32 may be varied and since one substream becomes saturated by the anesthetic 48 in vaporizing chamber 34, the concentration of anesthetic in the combined stream which eventually leaves the vaporizer outlet 14 may be controlled. As a further feature of the slide member 28, when it is in the far right position, not shown, the recess 40 serves to channel incoming gas in inlet passageway 16 directly into outlet passageway 18 and the vaporizer chamber outlet 38 is closed. Thus, the recess 40 serves as an on-off valve to shut off the flow from the vaporizing chamber 34 while allowing a direct channel for gas entering inlet 12 to pass to outlet 14. The vaporizing chamber 34 is then shut off, yet remaining open passages offer little flow resistance and the vaporizer need not be physically removed from the patient circuit. It also can be seen that although the on-off type valve is shown integral with the concentration valve 24, it may be separate therefrom.

Turning now to the second main stream from inlet chamber 22, the second main gas stream proceeds generally in the direction indicated by the arrow 50 and is divided into two substreams by thermal compensator valve, shown generally at 52. One of such substreams passes through a fixed linear flow restrictor 54 which is, as previously explained, a plurality of capillary-like passages. This substream then flows directly into the outlet chamber 44 and to the vaporizer outlet 14 by way of passage 46 and outlet passageway 18. The other substream enters a variable flow thermal bypass by entering linear restrictors 56 where the flow then passes a plurality of separate valves 58. Each valve 58 has a valve stem 60 of varying length and a common actuator 62. The valve actuator 62 moves the valves individually in accordance with the expansion or contraction of a thermal motor, shown diagrammatically as a bellows 64, acting in response to a sensor 66 located within the vaporizing chamber 34. As the temperature within vaporizing chamber 34 goes up, the thermal motor, or bellows 64 expands and lifts more of the individual valves 58 from their seats 68, thereby allowing more gas to flow through the variable thermal bypass to outlet chamber 44 and thus to the vaporizer outlet 14 via passage 46 and outlet passageway 18.

In the operation of the schematic, as shown, the incoming gas stream is divided into first and second main gas streams. The first main gas stream enters concentration valve 24 where it passes through linear flow restrictor 30 and is divided into two substreams, one of which passes directly to the vaporizer outlet 14, and the other substream passes through vaporizing chamber 34 before being reunited with the one substream to the outlet 14. The concentration valve 24 can be adjusted to vary the concentration of the anesthetic in the combined flow stream leaving outlet 14. The second main gas stream flows through a thermal compensator valve 52, where it is divided into substreams, one of which passes through fixed linear flow restrictors 54, and the other substream passes through "on-off" flow restrictors where the flow is varied in accordance with temperature changes in the vaporizing chamber. Since this second main stream eventually combines with the first main stream, its flow also determines the eventual anesthetic concentration to the patient. The fixed linear flow restrictors 54 are designed to allow sufficient gas flow therethrough for the lowest design temperature at which operation of the vaporizing chamber 34 can be expected. As the temperature increases in vaporizing chamber 34, the substream from the first main gas stream picks up additional anesthetic since the saturation pressure increases with the temperature of the anesthetic. The increased amount of anesthetic picked up is, therefore, compensated by the movement of thermal motor 64 which senses the increase in temperature and expands to open a corresponding number of additional valves 58, increasing the total gas flow through the thermal compensator valve 52. Thus, changes in temperature of the anesthetic 48 are compensated for and the final anesthetic concentration remains constant. Also, because all flows through the vaporizer are essentially laminar, by means of the linear flow restrictors, a change in overall flow does not affect the relative proportions of flow in any of the flow paths.

Referring now to FIGS. 2 through 7 herein, an anesthetic vaporizer is shown which incorporates the various features set forth in the simplified schematic appa-

ratus of FIG. 1 in further detail. As the following specification is read, it will be obvious that the description of the preferred embodiment parallels the foregoing description of the schematic shown in FIG. 1.

In FIGS. 2-5, in particular, there is shown an anesthetic vaporizer having a manifold 70, FIG. 3, in which there is a gas inlet 72 and a gas outlet 74. The gas entering inlet 72 proceeds through an inlet passageway 76 and, at bore 78, passes upwardly to inlet chamber 80 seen in FIGS. 2 and 4 which is formed beneath the top cover 82.

As the gas flow passes through inlet chamber 80, it is divided into first and second main gas streams which, for convenience, again will be explained separately.

The first main gas flow enters a moveable concentration valve, shown generally as 84 in FIG. 6 in the direction depicted by arrows 86, where the flow enters linear restrictors 88.

In FIGS. 6 and 6A, the construction of valve 84 containing the linear restrictors 88 is shown comprising a cylindrical core 90 having a plurality of capillary-like passages 92 formed, coaxially, along the outer periphery of cylindrical core 90. A ring 94 surrounds the passages 92 and seals them except for a minor part of the passages 92 extending above ring 94, shown at 96. In the preferred embodiment, a metal shim 98 is wrapped about the periphery of core 90 and the passages themselves are formed in the metal shim 98.

The ring 94 is heat shrunk around the metal shim 98, thereby sealing the passages 92 except for entrance openings 96. The slots, once formed, receive a flow of gas and its passage therethrough becomes laminar so that the relationship between pressure drop and flow through passages 92 is linear. The passages are extremely thin and long to achieve this linear relationship. When a metallic shim is used, the shim may be stainless steel stock having a thickness of 0.005 ± 0.0001 inch.

Application of the well-known Hagen-Poiseville laminar formula flow equation shows corresponding flow variations of ± 5 percent. By fabricating all of the shims required for one vaporizer from one small area in a given sheet of metal stock, the thickness variations over that area will typically be less than ± 0.0001 inch. In order to further minimize slot thickness variation due to machining burrs, the preferred mode of forming the slots is by etching techniques, rather than mechanical forming techniques.

In contrast with other means of achieving laminar flow, such as passage of gas through sintered metal, fine wire mesh and the like, the final parameters of the present restrictors are predictable and do not vary extensively from one application to another, and the eventual vaporizer has predictable properties.

At or near the bottom of passages 92, the flow of gas proceeds radially inwardly through tiny openings 100 where the flow then is directed downwardly through drilled holes 102 and emerge at the bottom of the core 90. As shown in FIG. 6A, each hole 102 emerges individually corresponding to each passage 92.

Returning to FIGS. 2 and 3, the flow path of the first main stream can be seen entering the concentration valve 84 at arrows 86 where it proceeds downwardly through the capillary-like passages 92 of the linear flow restrictor 88, then entering radial openings 100 and leaves the movable valve 84 through drilled holes 102 where the first main flow stream is divided into two

substreams by divider 103 in baseplate 104. The base plate 104 is a cylindrical body which is fixed in its position in the vaporizer. As shown in FIG. 3 at the upper surface of baseplate 104 there is formed two crescent shaped cavities 106 and 108, each of which individually communicates with flow outlets 110 and 112, FIG. 2. The region between crescents 106 and 108 comprises a divider 103. The bottom of the valve 84 rests upon the upper surface of baseplate 104 such that the drilled holes 102 communicate into the crescent shaped cavities 106 and 108. As the moveable core is rotated, the number of drilled holes 102 which communicate with each of cavities 106 and 108 may be varied, thus the relative proportion of flow through divider outlets 110 and 112 can be selectively varied by rotating moveable valve 84.

In this manner, the first main flow stream is selectively divided into one substream passing through divider outlet 110 downwardly through vaporizing chamber inlet 114 to the vaporizing chamber 116 while the other substream flows through divider outlet 112 directly into outlet chamber 118 without passing through the vaporizing chamber 116, on FIG. 2. The one substream becomes saturated by the liquid anesthetic within the vaporizing chamber 116 in a generally known manner. The one substream passes from vaporizing chamber inlet 114 into an outer spiral passage 120 formed in the exterior of flow guide 122 where it spirals downwardly in close association with outer tubular fabric wick 124, saturated with liquid anesthetic contained within outer casing 126.

The anesthetic level itself is not shown, nor are conventional drains for removing anesthetic or a filler for introducing anesthetic into the vaporizing chamber 116 as both are conventional in the art. At the lower end of outer spiral passage 120, the substream enters cross-over passage 128 and then proceeds upwardly through inner spiral passage 130 in close association with anesthetic-saturated inner wick 132 where it again passes through a cross-over bore 134 to an upper spiral 136 and eventually flows from vaporizing chamber 116 through vaporizing chamber outlet 138 in FIG. 4. The now saturated substream flows through an on-off valve, is mixed with the other gas stream and proceeds to the vaporizer outlet 74 as will be later explained.

Thus, it may be seen that by rotating the moveable concentration valve 84, the proportions of the first main stream flowing through the vaporizing chamber 116 and bypassing the same can be selectively varied.

The cylindrical core 90 is biased downwardly to effect a seal against the upper surface of baseplate 104, as shown in FIGS. 2 and 4, by a lower spring guide 140 which bears against an inner ledge 150 on core 90. A compression spring 152 is positioned between lower spring guide 140 and upper spring guide 154, both spring guides being centered in position by valve guide 156. The upper spring guide 154 is held in position compressing spring 152 by a drive pin 158, the ends of which, FIG. 2, i.e., rest in slots in the upper edge of cylindrical core 90 and the center of which is positioned in a slot through the lower end of valve stem 160, supported against top cover 82. Concentration control knob 162 is affixed to valve stem 160 and, as will be seen, by rotating control knob 162, the moveable concentration valve 84 will also rotate therewith the

change the desired concentration of the anesthetic vapor from the vaporizer outlet.

As a further feature of the anesthetic concentration valve 84, an on-off valve 164 is provided which is also operable by rotation of control knob 162. This valve is shown particularly in FIGS. 4 and 5 and, in the solid position shown, the valve plug 166 is seated against the vaporizing chamber outlet 138, thereby preventing any anesthetic saturated gas passing from the vaporizing chamber 116 to the vaporizer outlet 74 via passage 168 and outlet passageway 170, see FIG. 3. In this position, therefore, gas may enter the vaporizer inlet 72, pass directly through a cross bore 172 of FIG. 5 which joins inlet passageway 76 and outlet passage 168 so that the gas can directly pass from the vaporizer inlet 72 to the outlet 74 with a minimum of flow resistance. In this position of valve plug 166, there are no drilled holes 102 in cylindrical core 90 which align with the crescent shaped cavity 106 so that there is also no gas flow into the vaporizing chamber.

As the control knob 162 is rotated, the valve stem 174 of on-off valve 164 is raised by result of a spring bias in the upward direction imposed by spring 176, seated at its lower end and acting against cam follower 178 at its upper end. A cam 180 within control knob 162 further recedes into the knob 162 and, as the knob 162 is rotated, cam follower 178 follows the receding cam 180 upwardly, thereby allowing valve plug 166 to lift from vaporizing chamber outlet 138 to eventually seat at upper seat 182 to prevent gas from flowing from cross bore 172 to the outlet passage 168. Thus, all of the gas entering the vaporizer proceeds into the inlet chamber 80 and none is bypassed directly to the outlet 74. At this point of rotation, the position of the linear passages 92 in concentration valve 84 is such that further rotation causes some, then an increasing number of the drilled holes 102, to communicate with crescent shaped cavity 106 to introduce gas into the vaporizing chamber 116. Further rotation of the control knob 162 increases the proportion of gas through vaporizing chamber 116, yet the overall total gas flow of the first gas stream remains constant, i.e., as the substream gas through vaporizing chamber 116 is increased, there is a corresponding decrease in gas flow of the substream bypassing the vaporizing chamber 116.

Turning now to the second main gas stream from inlet chamber 80, FIGS. 2 and 4, the second gas stream proceeds generally in the direction indicated by the arrows 183 into a linear flow restrictor 184 of thermal compensator valve shown generally at 185. Again, the linear flow restrictor 184 is formed by a plurality of capillary-like passages 186 in the same manner as linear flow restrictor 88, and, as shown in FIGS. 7 and 7A, the passages 186 are located around the external periphery of cylindrical core 188. Again, the passages 186 are preferably formed in thin metallic shim 190, held about the perimeter of core 188 by a ring 192, heat shrunk into position while leaving an inlet opening 194 at the top of the passages 186. As the second main stream passes through the restrictor passages 186, it is divided into two substreams, one of which proceeds radially inwardly through outlet openings 196, downwardly through drilled holes 198 and into the outlet chamber 118, see FIG. 2. The other substream proceeds through "on-off" thermal bypass valves via radial openings 200, FIG. 2, and into individual chambers 204, each having a valve 205 shown in the shape of a

ball, separating each chamber 204 from the outlet chamber 118. Each valve ball 205 is actuated by a valve stem 206 of varying length fixed to a common actuator 208. The valve actuator 208 moves the valves 205 individually in accordance with the expansion or contraction of a thermal motor 210 located within vaporizing chamber 116. The thermal motor 210 is of generally conventional construction and may consist of expanding bellows which moves valve actuator 208 upwardly or downwardly in accordance with the sensed temperature of the anesthetic within vaporizing chamber 116. As shown in FIG. 2, the thermal motor 210 includes a stem 212 which moves up or down depending upon, respectively, an increase or decrease of temperature in vaporizing chamber 116.

A combination of springs 213 and 214 retains the stem 212 actively engaging the valve actuator throughout its total stroke, as shown. Since the many valve stems 206 are of differing lengths, the relative position of the valve actuator determines, at any time, how many of the valves 205 are open and how many are closed. As the temperature within vaporizing chamber 116 increases, the valve actuator moves upwardly and opens more valves 205 so that additional flow proceeds through the thermal compensator valve 185 to outlet chamber 118. Thus, the total of the second main stream is temperature compensated, as the temperature of anesthetic increases, additional flow passes through the thermal compensator valve 185 to off-set the increased pickup of anesthetic from the vaporizing chamber 116 by the first main gas stream. By this means, the thermal compensator valve 185 includes a fixed linear flow restrictor 184 through which the second main stream passes and then creates two substreams, one of which passes through a series of "on-off" valves which vary flow in accordance with the temperature of the anesthetic vapor. The fixed restrictors are designed to allow sufficient flow through to achieve the desired outlet anesthetic concentration for the lowest design temperature at which the anesthetic will be used. As this temperature increases, therefore, additional flow is automatically allowed through the series of "on-off" valves. Again, all of the second main gas stream passes through the specially designed linear flow restrictors.

The outlet chamber 118 thereby receives all of the flow from the second main gas stream as well as that proportion of gas flow of the first main gas stream that does not pass through the vaporizing chamber. The flow from outlet chamber 118 proceeds upwardly through outlet bore 216, see FIG. 3, through passage 218 and reunites in outlet passageway 170 with the anesthetic-saturated flow of gas from the vaporizing chamber 116, thus the combined flow of gas passes through the vaporizer outlet 74.

While the present invention has been particularly described in terms of a specific embodiment thereof, it will be understood, in view of the present disclosure, that numerous variations may be made without departing from the teachings of the overall invention. Accordingly, the invention is to be broadly construed and limited only by the scope and spirit of the claims now appended hereto.

I claim:

1. An anesthetic vaporizer apparatus, comprising in combination:

a vaporizer housing having a main gas inlet and a main gas-vapor outlet,
 a bypass passageway communicating between said gas inlet and said gas outlet,
 a vaporizing chamber in said housing for containing liquid anesthetic and adapted to saturate gas passing through said vaporizing chamber with anesthetic vapor,
 vaporizing passage means adapted to direct a portion of gas from said main inlet through said vaporizing chamber to said outlet,
 thermal bypass passageway communicating between said gas inlet and said gas outlet and adapted to control the flow of gas through said thermal bypass passageway in accordance with the temperature within said vaporizing chamber,
 linear flow restrictors in each of said vaporizing passage means and thermal bypass passageway,
 said linear flow restrictors comprising a plurality of minute capillary passages adapted to maintain a linear relationship between the gas flow and pressure drop across said flow restrictors.

2. An anesthetic vaporizing apparatus as defined in claim 1 wherein said capillary passages further comprise inner and outer annular rings, an annular thin metallic ring of stock being compressed between said inner and outer rings, said metallic ring having narrow, parallel axially disposed slots, and inlet and outlet means for providing gas flow into one end and from the other end of said slots for providing a continual flow path through said slots.

3. An anesthetic vaporizer apparatus, comprising in combination:
 a vaporizer housing having a main gas inlet and a main gas-vapor outlet,
 a bypass passageway communicating between said gas inlet and said gas outlet,
 a vaporizing chamber in said housing for containing liquid anesthetic and adapted to saturate gas passing through said vaporizing chamber with anesthetic vapor,
 vaporizing passage means adapted to direct a portion of gas from said main inlet through said vaporizing chamber to said outlet,
 thermal bypass passageway communicating between said gas inlet and said gas outlet and adapted to control the flow of gas through said thermal bypass

passageway in accordance with the temperature within said vaporizing chamber,
 linear flow restrictors in each of said bypass passageway, vaporizing passage means and thermal bypass passageway,
 said linear flow restrictors comprising a plurality of minute capillary passages adapted to maintain a linear relationship between the gas flow and pressure drop across said flow restrictors.

4. An anesthetic vaporizing apparatus as defined in claim 3 wherein said capillary passages further comprise inner and outer annular rings, an annular thin metallic ring of stock being compressed between said inner and outer rings, said metallic ring having narrow, parallel axially disposed slots, and inlet and outlet means for providing gas flow into one end and from the other end of said slots for providing a continual flow path through said slots.

5. An anesthetic vaporizer apparatus as defined in claim 3 further including a concentration valve means adapted to selectively vary the proportion of main gas directed through said bypass passageway and said vaporizing passage means.

6. An anesthetic vaporizing apparatus as defined in claim 3 wherein said thermal bypass passageway comprises a plurality of individual passages, each having a valve, each said valve means being individually operated to open or close in accordance with the temperature within said vaporizer chamber.

7. An anesthetic vaporizing apparatus as defined in claim 6 including temperature detecting means in said vaporizing chamber and actuating means connected to said detecting means for individually operating said valves in accordance with the temperature detected within said vaporizing chamber.

8. An anesthetic vaporizing apparatus as defined in claim 7 wherein each said valve comprises a ball normally closing each such individual passage and said actuating means comprises a plurality of valve stems of differing length, each of which is adapted to be raised to lift a corresponding individual ball to open each such individual passage, and a common operating member adapted to move said plurality of valve stems a predetermined distance in response to a change in temperature within said vaporizing chamber.

* * * * *

50

55

60

65