United States Patent

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[54] **GAS ADMINISTRATION APPARATUS**
6 Claims, 4 Drawing Figs.

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[51] Int. Cl. A61m 17/00
[50] Field of Search 128/188, 204, 1, 202, 203, 189, 190, 223, 145.6, 145.8, 145, 142; 119/16, 158, 159, 160,

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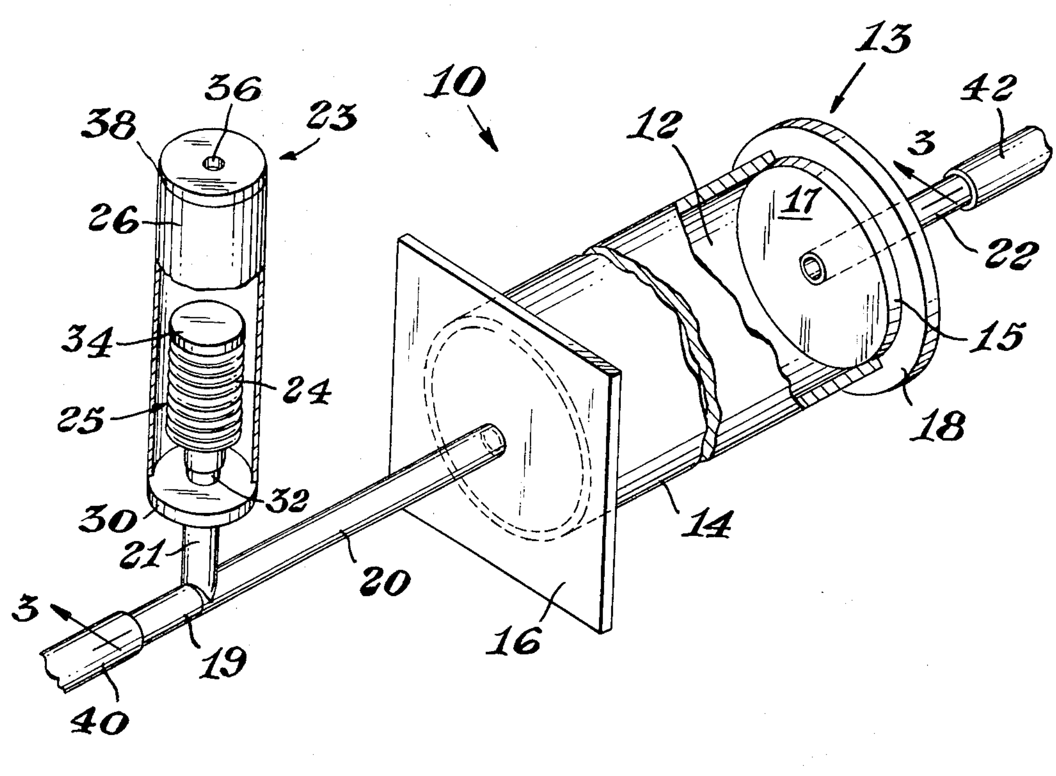
ABSTRACT: The invention provides an apparatus for administration of gases to animals for purposes such as anesthesia, the administration apparatus comprising a first constant-volume subchamber and a second variable-volume subchamber, the volume of the second subchamber varying in response to changes in the constant-volume subchamber pressure, with means for varying the volume of the second subchamber in response to gas pressure changes in the first subchamber and means for placing an animal in respiratory communication with the first subchamber. The device is adapted to be connected to a closed system intermittent gas source device of a conventional type. The chamber is adapted for administration of gases to animals independently of their tidal volume or respiration rate.



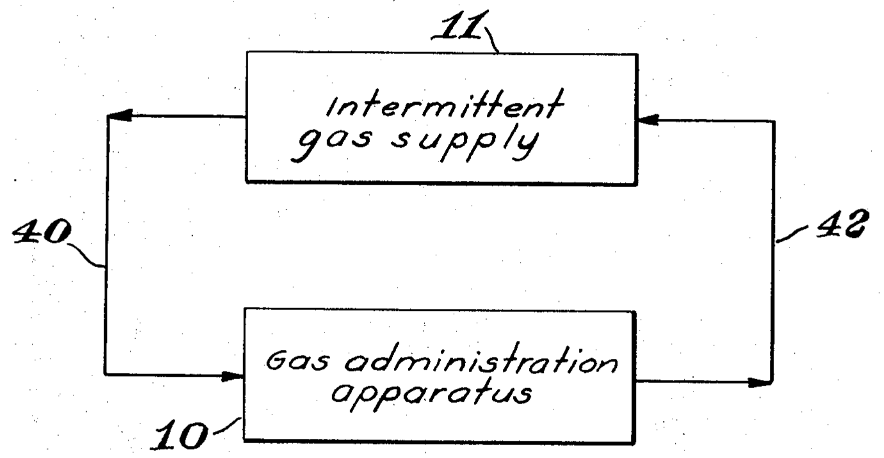


Fig. 1

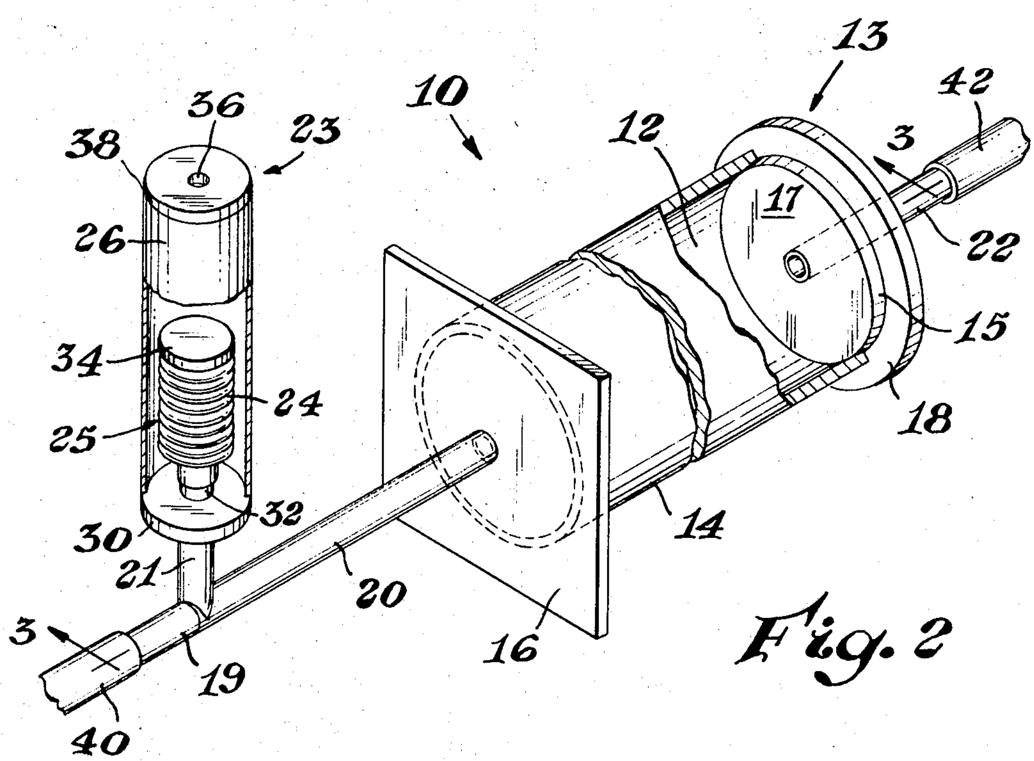


Fig. 2

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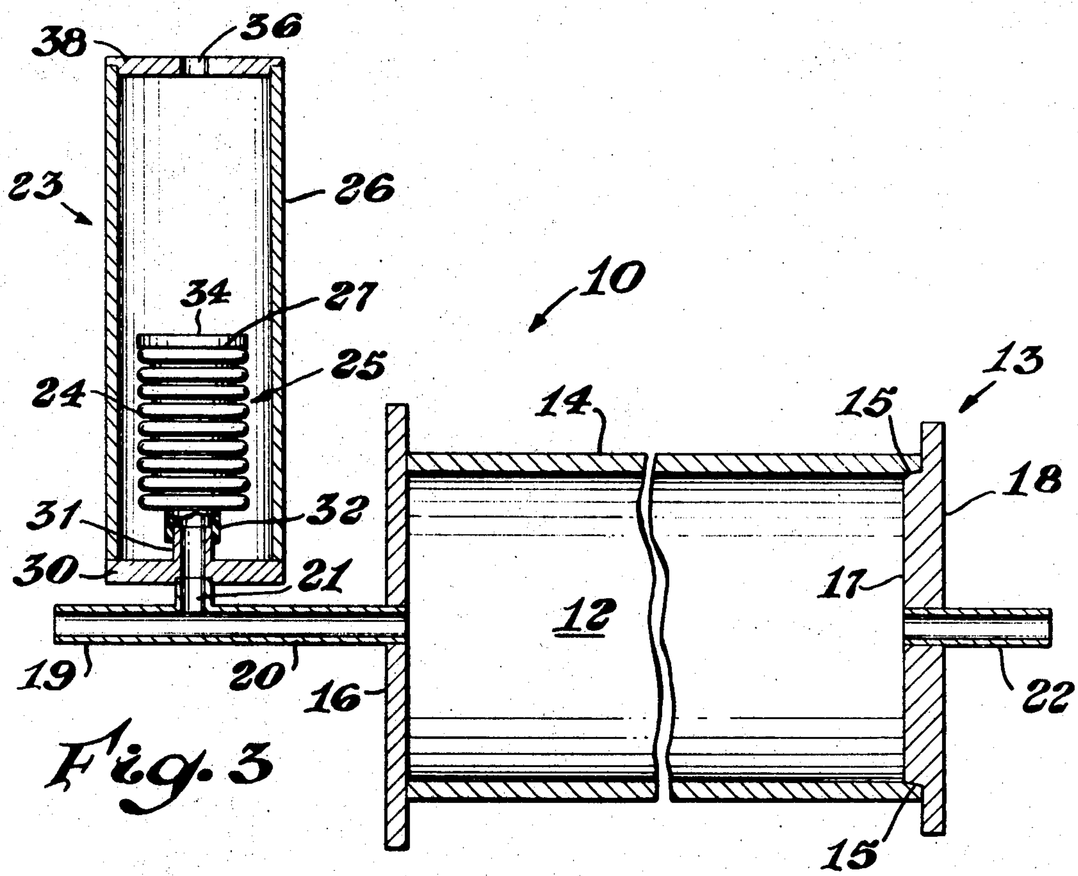

Fig. 3

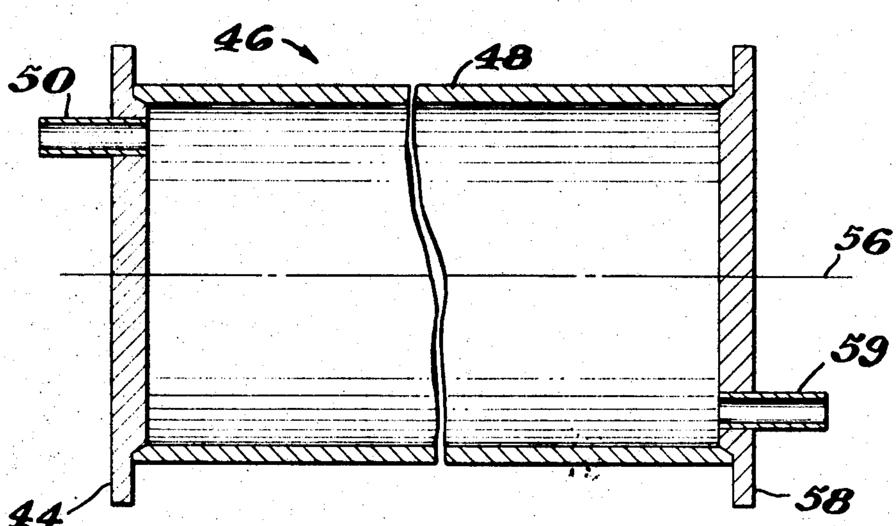

Fig. 4

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GAS ADMINISTRATION APPARATUS

BACKGROUND OF THE INVENTION

Description of the Prior Art

The intermittent gas supply systems employed as components in the present invention are old and well known. The typical intermittent gas supply system is a conventional closed circle anesthetic machine such as those described in U.S. Pat. Nos. 3,183,906 or 3,200,818, wherein the rebreathing bag is alternately expanded and compressed to drive gases down the inhalation tube. Conventional respirators or automatic breathing units such as the respirator sold under the name BIRD MARK II or ventilation valves are typically used for compression and expansion of the rebreathing bag, although it is also known to manually compress and release the rebreathing bag.

The gas administration devices of the prior art have proved to be valuable in the administration of gases to animals, particularly for anesthesia. However, the prior art devices have been limited in use to animals of particular size and tidal volume. It has heretofore been difficult to administer anesthetic gases to small animals such as mice, rats, guinea pigs, cats, dogs and the like with conventional closed circle gas supply devices. As a result, the closed circle intermittent gas supply systems have not been adaptable for use with several different animal species of widely varying size and tidal volume. Thus, there is a need for a single device which can be used to administer a continuous supply of gas to animals of different sizes and tidal volumes.

SUMMARY OF THE INVENTION

The present invention is concerned with apparatus for administering gases to animals and is particularly directed to apparatus for administering gases to small animals independently of their size or tidal volume.

The device is adapted to be coupled to an intermittent gas supply system of conventional type and includes a constant-volume subchamber in communication with a variable-volume subchamber. The device further includes means for placing an animal in respiratory communication with the constant-volume subchamber. The variable-volume subchamber is urged to expand and contract by actuator means as the intermittent gas supply system operates. The dimensions of the two subchambers are such that the expansion and contraction of the variable-volume subchamber furnishes a continuous supply of fresh gas to the constant-volume subchamber and to the animal.

It is an object of the invention to provide a gas administration apparatus for the administration of gases to animals which is adapted to be employed in conjunction with a conventional intermittent gas supply system. It is a further object of this invention to provide an anesthetic apparatus which can be employed for the administration of anesthetic gases to small animals independently of their size, tidal volume or respiration rate while employing an intermittent gas supply system as an anesthetic source. Another object is to provide an apparatus for anesthetizing violent or unruly animals. It is a further object of this invention to provide apparatus for the administration of uniform amounts of anesthetic gases to small animals. A still further object is to provide a device for administering anesthetic gases to animals which are too small to be anesthetized on conventional closed circle anesthetic machines. Another object of the invention is to provide an apparatus for the administration of anesthetic gases to small animals wherein the animals are observable at all times during the administration of the anesthetic.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and advantages of the invention will be apparent on consideration of the following description and claims and of the drawings wherein:

FIG. 1 is a schematic diagram of a gas administration apparatus of the invention in combination with an intermittent gas supply system;

FIG. 2 is an isometric view of a gas administration apparatus of the invention and a fragmentary isometric view of the input and exhaust lines of an intermittent gas supply system;

FIG. 3 is a cross-sectional view of the gas administration apparatus of FIG. 2 taken along line 3—3 of FIG. 2; and

FIG. 4 is a side elevational view of the constant-volume subchamber of a modified apparatus of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring more particularly to FIGS. 1—3, the gas administration apparatus **10** comprises a constant-volume subchamber **12** having access means **13** for providing respiratory communication between an animal and the interior of the constant-volume subchamber; a variable-volume subchamber **25** in communication therewith and defined by a movable wall **24** and having a maximum and minimum volume; actuator means **23** for urging the variable-volume subchamber between a minimum and maximum volume state in motion corresponding to changes in gas pressure within the apparatus; and first and second coupling means **19, 22** for communicably coupling the chamber housing **10** to input and exhaust lines **40, 42** of an intermittent gas supply system **11**.

The apparatus **10** can be coupled to the input and exhaust lines **40, 42** of the intermittent gas supply system **11** so that the constant-volume subchamber **12** and the variable-volume subchamber **25** are in series relation or in parallel relation with respect to the gas flow in the system. The preferred embodiment is one in which the two subchambers are assembled so that the variable-volume subchamber and the constant-volume subchamber are in spaced relation to each other in the direction of gas flow.

The constant-volume subchamber **12** is defined by a sidewall **14** and first and second end walls **16, 18**. The constant-volume subchamber **12** can have any configuration; however, the cylindrical configuration of FIG. **2** is preferred. In the preferred embodiment, the constant-volume subchamber is of animal-receiving dimensions, that is, it is sufficiently large to comfortably receive and enclose an animal. It is generally at least large enough to enclose a small rodent such as a mouse. The constant-volume subchamber is desirably large enough to comfortably receive a small dog or monkey and a constant-volume subchamber of such dimensions can then be employed for smaller animals without modification. The first end wall **16** can be secured to sidewall **14** to provide a gastight seal by any appropriate means such as adhesive or the like. Second end wall **18** is preferably detachable from sidewall **14**. End wall **18** has a shoulder **17** of reduced diameter which is adapted to fit within subchamber **12** against sidewall **14**. Shoulder **17** has a slightly beveled edge **15** which is adapted to fit tightly against sidewall **14** to provide a gastight, friction fit thereto. The end wall **18** preferably overlaps sidewall **14** to permit manual grasping of a portion of end wall **18** and detaching of end wall **18** from sidewall **14**, thus providing ready access to the constant-volume chamber **12**. The shoulder **17** of end wall **18** and the sidewall **14** are preferably of such dimensions as to permit the introduction of an animal into the constant-volume subchamber **12** when end wall **18** is detached.

While, in the preferred embodiment, the access means **13** thus comprises end wall **18** with its shoulder **17** and beveled edge **15**, other access means can be employed and are within the scope of the invention. For example, a resilient plug of rubber or synthetic plastic material can be employed in lieu of the end wall shoulder; a resilient gasket can be employed in lieu of the beveled edge to provide a tight fit; or any portion of the rigid wall of the constant-volume subchamber can be detachably secured in place by clamps, screw threads or the like; or the access means can comprise a tube inserted into subchamber **12** through one of the walls, and a mask and endotracheal tube communicably coupled thereto.

Sidewall 14 and end walls 16, 18 can be constructed from any suitable material which is resistant to the gases to be employed. The walls can be metal, such as aluminum, brass or steel, or opaque plastic or the like. Such construction is generally undesirable when an animal is to be placed within subchamber 12 because of the need for the operator to observe the animal. It has also been found that animals are generally more calm and easy to handle when they are placed in a transparent chamber from which the environment is visible. Thus, it is greatly preferred that at least a substantial portion of the walls be transparent. Suitable materials for construction of the end walls 16, 18 and the sidewall 14 of subchamber 12 include glass and transparent plastic materials such as anesthetic-resistant plastic including methyl methacrylate or acrylic polymers and including those sold under the name Plexiglas.

End wall 16 can be a part of sidewall 14, secured thereto by adhesive or the like or when both of walls 16 and 14 are plastic, by solvent seal, heat seal or the like. End wall 16 can also be removable in a manner similar to that of end wall 18 so that the detachable access means includes either or both of the end walls. It is preferred to provide at least one of sidewall 14 and end walls 16, 18 with a flat edge to afford stability when subchamber 12 is placed on a flat surface. However, subchamber 12 may be supported by other means such as brackets or the like. The exact configuration of the tubular wall and the end walls is not critical. In the preferred embodiment, the configuration of the walls can vary, provided that subchamber 12 is adapted to contain an animal.

Variable-volume subchamber 25 is defined by a movable wall or bellows 24 which is enclosed on all sides with the exception of a mouth 32. The bellows 24 has an end portion 27 opposite mouth 32. The variable-volume subchamber 25 is communicably coupled to constant-volume subchamber 12 through connection tubes 20, bellows connecting tube 21 and a connecting plate 30. One end of the tube 20 extends through end wall 16 and another end thereof is communicably coupled with tube 21 at one end thereof. The connecting plate 30 is communicably coupled to another end of tube 21. The dimensions of tubes 20, 21 are not critical. For example, tube 20 can be any convenient length or tubes 20, 21 can comprise a relatively short extension of sidewall 14. However, it is preferred that they be of a size adapted to prevent an animal from entering the variable-volume subchamber 25 and interfering with the the motion thereof.

Connecting plate 30 has a raised portion 31 adapted to fit tightly within the mouth 32 of the movable wall or bellows 24 to provide a gastight friction fit. The variable-volume subchamber 25 can also be communicably coupled to the constant-volume subchamber 12 by adhesive or by heat sealing the mouth 32 of the movable wall or bellows 24 to the raised portion 31 of connecting plate 30, or by other suitable means to provide a gastight connection.

The movable wall 24 can be of various configurations provided that it is adapted to move between a maximum and minimum volume in response to the changes in the differential between the external atmospheric pressure and the internal pressure of the chamber which will be employed in the use of the apparatus. The particular maximum and minimum volumes are dependent upon and correspond to the pressure differentials. Generally, such pressure differentials are on the order of from about 1 to about 30 millimeters of mercury, it being desirable to administer gases for veterinary anesthesia, toxicology studies, respiration studies or the like at pressures at or near atmospheric pressure. For the movable wall, it is preferable to employ a rubber bellows bag such as a conventional concertina-type bellows having a narrow cylindrical shape and with a more-or-less circular end portion 27 disposed at one axial end thereof and a mouth 32 at the other axial end thereof. Such concertina-type bellows are well known and are adapted for reciprocating expansion and contraction in a direction predominantly along the axis thereof.

It is generally preferred that the axis of the movable wall or bellows 24 be oriented vertically to minimize friction of the wall 24 against the nonmoving components of the actuator means 23. The movable wall 24 is preferably in either an upright position with the end portion 27 above the mouth 32, or in an inverted position with the end portion 27 below the mouth 32. The device also gives good results when operated with the movable wall in orientations other than vertical.

Actuator means 23 comprises an expansion tube 26 which is of such volume and configuration as to enclose subchamber 25 and permit free expansion and contraction of flexible walled bellows 24 between a maximum and minimum volume. Expansion tube 26 rests on the connecting plate 30 at its lower end and has a cap 38 at its upper end. Expansion tube 26 can be attached to connecting plate 30 and to cap 38 by any suitable means such as friction fit, adhesive, heat sealing or the like. Expansion tube 26, cap 38 and connecting plate 30 are preferably constructed of transparent material such as glass or gas-resistant plastic. The cap 38 is provided with an orifice 36 to permit free flow of air between the interior of expansion tube 26 and the atmosphere so that the external pressure on bellows 24 is equal to atmospheric pressure at all times. Actuator means 23 further comprises a weight 34 which is disposed in expansion tube 26 against the end portion 27 of the bellows 24. The movable wall or bellows 24 can also be selected to have an end portion 27 of sufficient weight so that the end portion comprises the weight 34 and a separate element is not required. The force of gravity on weight 34 serves to urge the end portion 27 of the movable wall or bellows 24 downward. When the device is in the upright position shown in FIGS. 2 and 3, the downward motion of the end portion 27 compresses the bellows in response to low gas pressure in the apparatus and thus urges the variable-volume subchamber to a minimum volume. The expansion tube guides the bellows and weight in an axial direction as the bellows expands and contracts in response to gas pressure changes in the apparatus.

The bellows 24, weight 34 and the dimensions of expansion tube 26 are selected to provide for expansion and contraction of the variable-volume subchamber 25 between a maximum and a minimum volume in response to the pressure changes created by the operation of the intermittent gas supply system 11. The variable-volume subchamber 25 should be to expand or contract in response to pressure differentials between the atmosphere and the inside of subchamber 25 on the order of about 1 to about 30, and preferably from about 2 to about 12 millimeters of mercury. When the apparatus is employed with the variable-volume subchamber 25 upstream, the actuator means is adapted to compress the variable-volume subchamber to a minimum volume when the intermittent gas supply system is in the low pressure phase of operation and the gas pressure in the apparatus is low. When the variable-volume subchamber 25 is downstream, the actuator means is adapted to compress the variable-volume subchamber to a minimum volume in response to the high gas pressures occurring when the intermittent gas supply system is in the high pressure supply phase of operation and to permit expansion thereof during the low pressure phase of operation.

The variable-volume subchamber can comprise a variety of other systems such as a piston and cylinder or a hydraulic water leg. The actuator means can also be coupled to the intermittent gas supply system by mechanical linkages or the like. Actuator means, other than the gravity-operated means of FIGS. 2 and 3, such as springs, manually or mechanically-operated plungers and the like can be employed to urge the variable-volume subchamber toward a minimum volume. However, the pressure and gravity-operated actuator means of the invention are simple and economical to construct and to operate and are much to be preferred.

First coupling means 19 comprises a tube communicably coupled to the apparatus 10 via the connecting tube 20 so that tubes 19, 20 and 21 form a T-shaped junction. Second coupling means 22 comprises a tube having one end extending through second end wall 18 and the shoulder 17 thereof to communicate with the interior of constant-volume subchamber 12. The coupling means can be attached to other portions of the apparatus, provided that they are attached to other portions of the apparatus, provided that they are attached so as to provide for gas flow through the constant-volume subchamber **12**. Tubes **19**, **20**, **21** and **22** can be constructed of metal such as steel, brass, aluminum or the like or they can be glass or a plastic material which is resistant to the gas to be administered.

Coupling means **19**, **22** are coupled to the input line **40** and the exhaust line **42**, respectively, of a closed system intermittent gas supply system **11**, with the apparatus in the upright position, in the preferred embodiment. Coupling means **19**, **22** are preferably coupled to the exhaust and input lines, respectively when the apparatus is employed in the inverted position.

The term "intermittent gas supply system" is intended to refer to any of the well known devices which alternately supply gas to an input line during one phase of a cyclic operation and which have a second phase during which substantially no gas is supplied by the device and in which gas flow is unidirectional from the supply system to a point of use. In the preferred embodiment, the gas supply system is of the closed system type. Such systems typically comprise means for maintaining a predetermined gas pressure in the system by introduction of oxygen or air, means for removing waste gases such as carbon dioxide and water, means for introducing gases to be administered into the system, means typically including a rebreathing bag for intermittently increasing the gas pressure in the system to a point above the predetermined system gas pressure, means to provide for unidirectional flow of gas through an input line to a point of use when the system gas pressure is elevated and exhaust line means for returning gas from a point of use. The systems generally operate in a cycle having a high pressure phase and a low pressure phase. Typically, a predetermined pressure on the order of about -2 to $+2$ millimeters of mercury is employed during the low pressure phase and of about 4 to about 10 millimeters of mercury during the high pressure phase, with the pressure change occurring at rates from about 4 to about 20, to about 30 cycles per minute.

The expansion and contraction of the variable-volume subchamber supplies fresh gas to the constant-volume subchamber during the exhaust or low pressure phase of the intermittent gas supply system. The fresh gas is supplied by compression of the variable-volume subchamber when said subchamber is upstream. When the device is oriented with the constant-volume subchamber upstream, the expansion of the variable-volume subchamber during the low pressure phase creates a partial vacuum which removes breathed gases from the constant-volume subchamber. The partial vacuum also draws fresh gas into the constant-volume subchamber from the intermittent gas supply system and the inhalation tube. Since no fresh gas is supplied to the apparatus by the gas supply system during the low pressure phase of the intermittent gas supply system, the variable-volume subchamber **25** must fulfill certain criteria in order to furnish a continual fresh supply of gas to the animal. In general, the expansion volume (difference between the maximum and minimum volume of the variable-volume subchamber) must be at least equal to the volume of gas breathed by the animal during the exhaust or low pressure phase of the intermittent gas supply. Thus, the ratio of the expansion volume of the variable-volume subchamber **25** to the volume of the constant-volume subchamber **12** is important in the use of the chamber. The ratio should be sufficient so that the expansion volume is at least equivalent to the volume of air breathed by the animal when the intermittent gas supply is in the low pressure exhaust phase of its cycle. The ratio of the expansion volume of subchamber **25** to the constant volume of subchamber **12** should be at least about 1:40. The exact ration, however, is not critical so long as sufficient fresh gas is supplied to the constant-volume subchamber. The ratio can vary depending upon factors such as the tidal volume and respiration rate of the animal, the size of the animal, the volume of the constant-volume subchamber, the concentration of oxygen, anesthetic, etc. and the rate of operation of the intermittent gas supply source. The ratios of from about 1:40 to 1:4 (expansion volume: constant volume) have been found to be useful in a variety of applications. The ratio can be greater such as from 1:40 to 1:4, to 1:2, or to 1:1,if desired. However, the larger ratios such as from 1:2 to 1:1 result in greatly increased flow of gas when the larger variable-volume subchamber contracts. The ratios of from about 1:40 to 1:4 provide a relatively steady, even flow of gas and such ratios are preferred.

In operation, the detachable access means **13** is removed by manually grasping end wall **18** and pulling end wall **18** away from sidewall **14**. An animal such as a rodent, cat, dog, monkey or the like is then placed within the constant-volume subchamber **12** and the access means **13** is replaced using sufficient force to form a tight friction fit between sidewall **14** and the beveled edge **15** of the shoulder **17** of end wall **18**. The device is maintained upright and coupling means **19** is communicably coupled to the input line **40**, and coupling means **22** is communicably coupled to the exhaust line **42** of the intermittent gas supply system **11**. Sufficient oxygen, air or gas or the like is introduced into the intermittent gas supply system by conventional means to elevate the gas pressure in the gas supply system to operating level. When the intermittent gas supply system is a conventional anesthetic machine, such as the Heidbrink Model 960 or the like, sufficient gas is introduced to substantially fill the rebreathing bag. The intermittent gas supply system **11** is then activated. In the supply phase of the gas supply cycle, the gases including the administered gas, oxygen, air and the like are moved through the input line and into the apparatus **10**, thus elevating the gas pressure within the apparatus **10** to a maximum operating level and inflating the variable-volume subchamber **25** to a maximum volume. When the intermittent gas supply enters the low pressure phase of operation, no additional gas is supplied to the chamber. The force of gravity acting on the weight **34** of actuator means **23** urges variable-volume subchamber **25** to a minimum volume state, thus moving gases from variable-volume subchamber **25** through tubes **21** and **20** and into constant-volume subchamber **12**. During this phase of operation, the pressure of gases moving into subchamber **12** from variable-volume subchamber **25** drives the gas exhaled by the animal from subchamber **12** through coupling means **22** and into the exhaust line **42** of the intermittent gas supply system **11**. The intermittent gas supply system then repeats the gas supply phase of the cyclical operation, thus repeating the movement of gas throughout the system and repeating the expansion and contraction of variable-volume subchamber **25**. The apparatus functions in substantially the same way regardless of the tidal volume or respiration rate of the animal.

The apparatus can also be employed with the coupling means **19** communicably coupled to the exhaust line **42** and coupling means **22** similarly coupled to the input line **40** of the intermittent gas supply system **11**. The apparatus is then employed in the same way as described above. Gravity-operated actuator means can be employed by inverting the apparatus and selecting a weight adapted to urge the variable-volume subchamber downward to a maximum volume during the low pressure phase. Selection of small diameter tubes **20**, **21** can also be employed to create a venturi effect which urges the variable-volume subchamber upward to a minimum volume by the motion of gas past the bellows mouth during the high pressure supply phase. Mechanical or manually-operated actuator means can also be employed to provide movement of the variable-volume subchamber in coordination with changes in gas pressure within the apparatus. Regardless of the exact actuator means employed, when the variable-volume subchamber is downstream, the variable-volume subchamber should expand when the gas pressure is low and contract when the gas pressure is high.

The constant-volume subchamber **46** of FIG. **4** can be employed in the apparatus of the invention. Subchamber **46** has a cylindrical sidewall **48** with a longitudinal axis **56**. Subchamber **46** has an input end plate **44** at one end and an exhaust end plate 58 at the other. End plates 44 and 58 are constructed substantially as described above with respect to end wall 18 of the embodiment of FIGS. 2 and 3. End plates 44 and 58 are circular and adapted to be rotated in relation to cylindrical sidewall 48 while maintaining a gastight seal. Connecting tube 50 extends into constant-volume subchamber 46 through end wall 44 at a point between the axis 56 of subchamber 46 and the sidewall 48. Coupling means 59 similarly extends into subchamber 46 through end plate 58 at a point between axis 56 and cylindrical sidewall 48. The constant-volume subchamber 46 of FIG. 4 is adapted to provide flow of gas through the subchamber in a vertical direction as well as from input end of the chamber at end plate 44 to the exhaust end of the chamber at end plate 58. Such vertical flow can be desirable in a downward direction when a heavier-than-air gas is administered, or in an upward direction when a lighter-than-air gas is employed. The end plates 44, 58 can be rotated to dispose either the connecting tube 50 or the coupling means 59 above or below the subchamber axis 56.

In operation, the input end plate 44 is rotated to dispose the connecting tube 50 in a desired relation to the subchamber axis 56. Connecting tube 50 is then coupled to a variable-volume subchamber having actuator means and to the input line of an intermittent gas supply system as described above with respect to FIGS. 2 and 3. Exhaust end plate 58 is removed; an animal is placed within subchamber 46; and the exhaust end plate is replaced and rotated to dispose coupling means 59 in the desired relation with respect to the subchamber axis 56. Coupling means 59 is then connected to the exhaust line of the intermittent gas supply system and the system is activated.

One chamber constructed in accordance with the invention had a constant-volume subchamber of clear plastic (Plexiglas) 20 inches in length and having an inside diameter of 7.75 inches. The end walls were of 0.125 inch thick plastic (Plexiglas), one end wall being square and attached to plastic (Plexiglas) cylindrical sidewall by solvent seal. The second end wall was a circular plate with a diameter of 9.5 inches, extending about 0.75 inch beyond the cylindrical sidewall when in place. This same end wall had a shoulder about 7.75 inches in diameter raised about 0.19 inch from the remainder of the wall and having a bevel of approximately 3°—8°. The shoulder could be inserted into the cylinder to form a gastight friction fit, and when so inserted, was manually removable. The connecting tubes and the tubular coupling means were constructed from copper tubing having an inside diameter of 0.75 inch and the bellows connecting tube was copper tubing having an inside diameter of 1.125 inches. A rubber concertina-type bellows about 2.25 inches long and 2.125 inches in diameter, having a mouth about 1.625 inches in diameter, was then fitted securely to the raised portion of a flanged connecting plate which was fitted to the bellows connecting tube. A plastic cylinder 9.5 inches in height and having an inside diameter of about 2.19 inches with a plastic cap having a hole therethrough was secured to the flanged plate by friction fit. A metal weight of about 66 grams was placed inside the cylinder on the upper end of the rubber bellows. The weight and bellows were selected to compress the bellows to a height of about 2.125 inches when the pressure inside the chamber was approximately 3 millimeters of mercury. The coupling means adjacent the variable-volume subchamber was connected to the input line of a Heidbrink Model 960 veterinary anesthesia machine and the coupling means on the end plate of the constant-volume subchamber was attached to the exhaust line of the same machine. The machine was equippped with a BIRD MARK II automatic ventilating respirator. In operation, the rebreathing bag on the Heidbrink machine was filled to about two-thirds volume with oxygen and the flow meter set for the size of animal selected. The apparatus as described above was employed to induce surgical anesthesia in several species of animals including mice, guinea pigs, hamsters, rabbits, monkeys, dogs, cats and aves. The apparatus performed as described herein.

It is also possible to employ the chamber of the invention with other access means such as by communicably coupling a face mask or endotracheal tube with the interior of the constant-volume subchamber. In this case, the animal can be outside the constant-volume subchamber when the gas is administered and the constant-volume subchamber need not be of animal-receiving dimensions.

Various modifications of the chamber can be made by those skilled in the art without departing from the scope of the invention. For example, the variable-volume subchamber can be coupled to the constant-volume subchamber through the sidewall so that the two subchambers will be parallel with respect to gas flow through the chamber.

I claim:

1. An apparatus for administration of gases to animals independently of their tidal volume or respiration rate, the apparatus comprising:
- a constant-volume subchamber of animal receiving dimensions;
- a variable-volume subchamber communicably coupled thereto;
- an intermittent gas supply system communicably coupled to the constant-volume subchamber and adapted for cyclic operation between a high pressure phase and a low pressure phase;
- means for placing an animal within the constant-volume subchamber to provide respiratory communication between the animal and the constant-volume subchamber, said means comprising a removable wall of the constant-volume subchamber;
- actuator means in operative engagement with the variable-volume subchamber for urging said subchamber between a minimum and maximum volume in response to the high and low pressure phases of the intermittent gas supply system; and
- the expansion volume of the variable-volume subchamber being at least as great as the volume of gas breathed by an animal during the low pressure phase of the intermittent gas supply system.

2. The apparatus of Claim 1 wherein the ratio of the expansion volume of the variable-volume subchamber to the volume of the constant-volume subchamber is at least about 1 to 40.

3. The apparatus of claim 1 wherein the variable-volume subchamber is disposed upstream of the constant-volume subchamber with respect to the gas flow therethrough and the actuator means is adapted to permit expansion of the variable-volume subchamber to a maximum volume when the gas pressure in the apparatus is at a predetermined high pressure.

4. A gas administration apparatus comprising:
- a constant-volume subchamber having first and second ends;
- access means on said subchamber for providing respiratory communication between an animal and the constant-volume subchamber;
- connecting means for providing communication between the variable-volume subchamber and the first end of the constant-volume subchamber;
- actuator means in operative engagement with the variable-volume subchamber for urging said subchamber between maximum and minimum volumes in response to changes in gas pressure in the apparatus, the expansion volume of the variable-volume subchamber being at least about one-fortieth the volume of the constant-volume subchamber;
- first coupling means in the connecting means;
- second coupling means in the second end of the constant-volume subchamber; and
- an intermittent gas supply system having an input line and an exhaust line the input line being coupled to the first coupling means and the exhaust line being coupled to the second coupling means to provide gas flow through the constant-volume subchamber. the connecting means and the second coupling means being movable with respect to each other to provide a plurality of gas flow paths through the constant-volume subchamber.

5. The apparatus of claim 4 wherein the variable-volume subchamber and actuator means comprise a bellows adapted to expand in response to an increase in gas pressure and a weight disposed against the bellows and adapted to compress the bellows in response to a decrease in gas pressure.

6. An apparatus for administration of gases to animals adapted for use with an intermittent gas supply system, the apparatus comprising;

a constant-volume subchamber of animal receiving dimensions, said constant-volume subchamber having a removable wall to permit introduction of an animal into said subchamber;

means comprising the removable wall of the constant-volume subchamber for providing respiratory communication between an animal and said subchamber;

a variable-volume subchamber in communication with the constant-volume subchamber;

actuator means in operative engagement with the variable-volume subchamber for urging said subchamber between a minimum and a maximum volume in response to changes in gas pressure in the apparatus, the expansion volume of the variable-volume subchamber being at least one-fortieth the volume of the constant-volume subchamber; and

first and second coupling means for communicably coupling the apparatus to the intermittent gas supply system to provide gas flow through the constant-volume subchamber.

PO-1050
(5/69)

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,557,785 Dated 26 January 1971

Inventor(s) William D. McQueen

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In column 8, Claim 4, between lines 55 and 56 insert -- a variable- volume subchamber; --.

Signed and sealed this 11th day of May 1971.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

WILLIAM E. SCHUYLER,
Commissioner of Pater