EUROPEAN PATENT SPECIFICATION

METHOD AND APPARATUS FOR GAS REGENERATION IN AN ANESTHESIA BREATHING CIRCUIT

METHODE UND VORRICHTUNG ZUR ATEMGASREGENERATION IN EINEM NARKOSEGERÄT

PROCEDE ET APPAREIL DE REGENERATION DU GAZ DANS UN CIRCUIT ANESTHESIANT

Designated Contracting States:
AT BE CH DE DK ES FR GB GR IE IT LI LU NL PT SE

Priority: 19.10.1993 US 139233

Date of publication of application: 07.08.1996 Bulletin 1996/32

Proprietor: Abbott Laboratories
Abbott Park, Illinois 60064-3500 (US)

Inventor: GRABENKORT, Eichard, W.
Barrington, IL 60010 (US)

Representative: Modiano, Guido, Dr.-Ing. et al
Modiano, Josif, Pisanty & Staub, Baaderstrasse 3
80469 München (DE)

References cited:
EP-A- 0 518 085
US-A- 4 046 529

EP-A- 0 530 731
US-A- 4 350 662

Note: Within nine months from the publication of the mention of the grant of the European patent, any person may give notice to the European Patent Office of opposition to the European patent granted. Notice of opposition shall be filed in a written reasoned statement. It shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).
Description

TECHNICAL FIELD

[0001] The present invention relates to an apparatus for use in the delivery of an inhalation anesthetic to a patient while employing a closed loop or rebreather gas recirculation system. The invention is particularly suitable for controlling the temperature within a scrubber employing a scrubbing substance such as soda lime which reacts exothermically with carbon dioxide in the patient's expired breath passing through the scrubber.

BACKGROUND OF THE INVENTION AND TECHNICAL PROBLEMSPOSED BY THE PRIOR ART

[0002] US-A-4 350 662 describes a carbon dioxide scrubber device for an underwater breathing apparatus, wherein the breathing gas is recirculated through a canister containing a carbon dioxide adsorbent. A heat exchanger is provided within the canister at the central portion thereof to increase the service life of the adsorbent. Further, the walls of the canister may also be heated.

[0003] Inhalation anesthetics are volatile substances with relatively low boiling points and high vapor pressures. Such anesthetics are typically dispensed in liquid form to an apparatus, such as a vaporizer on an anesthesia machine, which mixes the anesthetic with oxygen and nitrous oxide. The mixture is supplied by the machine in gaseous form to the patient for inhalation.

[0004] During a typical inhalation anesthetic procedure, only a small amount of the active agent or anesthetic is taken up by the patient. For example, when a patient inhales, some amount of the anesthetic enters the lungs, but upon exhalation, up to about 99% of the inhaled anesthetic is exhaled.

[0005] In some anesthesia machines, the exhaled breath is exhausted and cannot be recirculated to the patient. However, improved types of machines have been designed to recirculate the exhausted anesthetic in order to reduce waste and expense. Such machines permit the exhaled breath to be purged of carbon dioxide (CO₂), blended with an appropriate amount of fresh anesthetic and gas, and recirculated to the patient.

[0006] Anesthesia machines which recirculate the anesthetic along with the patient's exhaled breath typically employ a soda lime scrubber to remove carbon dioxide. Soda lime typically contains from about 3 percent to about 5 percent sodium hydroxide/potassium hydroxide and approximately 20 percent water, which, in the presence of carbon dioxide, react to form carbonate species. This effectively removes most of the carbon dioxide from the gas stream. Heat is produced in this process. The observed heat generation in the soda lime scrubber is thought to be due to the exothermic, carbonate-forming chemical reactions as well as to the exothermic dissolution of the soda lime constituents. The heat produced by the exothermic reactions increases the reaction rates. In this specification it shall be understood that the term "exothermic reaction" includes a chemical reaction as well as a physical reaction (e.g., dissolution) of the type that produces or generates heat.

[0007] While such scrubbing systems generally function satisfactorily, there are potential problems that may arise when using certain, newer anesthetics. For example, a new anesthetic which may in the future be approved for use in the U.S.A. is a fluoromethyl 2,2,2-trifluoro-1-(trifluoromethyl) ethyl ether sold under the trademark SEVOFLURANE™ and licensed by Abbott Laboratories, Inc., One Abbott Park Road, Abbott Park, Illinois 60064-3500 U.S.A.

[0008] When SEVOFLURANE™ anesthetic in the patient's exhaled breath passes through a soda lime or similar type carbon dioxide scrubber, the anesthetic is exposed to the heat generated by the above-discussed exothermic reactions or other heat generating processes. Further, if the system is exposed to abnormal, higher temperature operating or ambient conditions, there could be additional heat transfer to the anesthetic.

[0009] Regardless of the source or sources of the heat, the anesthetic might then suffer degradation from exposure to heat in the presence of soda lime, and a degradation by-product could be produced. Even at normal operating conditions in the scrubber of an anesthesia machine, the concentration of such an anesthetic and the gas flow rates are such that some degradation of the anesthetic occurs as a result of the heat produced by the above-described carbon dioxide scrubbing process. In order to eliminate or minimize the potential for such degradation of the anesthetic, and in order to operate with a greater safety margin, it would be desirable to provide an improved apparatus for controlling system temperatures.

[0010] The present invention provides an apparatus as defined on claims 1 and 6 having the above-discussed benefits.

SUMMARY OF THE INVENTION

[0011] The present invention as defined in the appended claims can be employed with an anesthesia machine that employs a system for mixing an inhalation agent, such as an anesthetic, with a gas mixture to be breathed by the patient. The machine recirculates the patient's exhaled breath through a scrubbing substance to remove a selected constituent (CO₂) from the exhaled breath which is subsequently rebreathed by the patient.

[0012] In one aspect of the invention, an enclosure is provided for containing the scrubbing substance. The enclosure includes a flow path-defining structure, at least a portion of which is a thermally conductive material. The structure defines a first flow path for the exhaled breath through the scrubbing substance between influential and effluent openings. The structure also defines a separate, second flow path for coolant fluid adjacent the
first flow path between inlet and outlet openings. The coolant fluid can flow along the second flow path to remove heat from the interior of the enclosure.

[0013] A coolant fluid is passed into the coolant inlet opening, along the second flow path, and out of the coolant outlet opening to maintain the temperature in the enclosure below a selected value to minimize the buildup of heat in the enclosure, which heat can degrade the anesthetic.

[0014] In a preferred embodiment the second flow path is formed of a plurality of cooling conduits being arranged closer together in a central region of the enclosure than in the peripheral region of the enclosure.

[0015] In another preferred embodiment, the scrubbing substance is contained in conduits arranged in an array in an enclosure. The coolant fluid is air which is moved through the array of conduits by convection or by a forced air handling unit in a radial direction of the enclosure. The forced air handling unit recirculates the air through the conduits and cools the air exterior of the conduit.

[0016] Numerous other advantages and features of the present invention will become readily apparent from the following detailed description of the invention, from the claims, and from the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] In the accompanying drawings that form part of the specification, and in which like numerals are employed to designate like parts throughout the same.

FIG. 1 is a simplified, schematic diagram illustrating a first embodiment of the apparatus of the proposed invention as employed with an anesthesia machine; FIG. 2 is a schematic diagram similar to FIG. 1, but on a larger scale and showing internal fluid flow paths; FIG. 3 is a simplified, perspective view of the chamber of the present invention and related system components shown with portions cut away to illustrate interior details; FIG. 4 is a simplified, perspective view of the components in FIG. 3, but FIG. 4 shows the end caps and shell removed; FIG. 5 is a view similar to FIG. 4, but FIG. 5 shows the coolant baffle plates removed; FIG. 6 is a perspective view of a coolant baffle plate; FIG. 7 is a perspective view of a gas baffle plate; FIG. 8 is a simplified, diagrammatic, axial cross-sectional view of a second embodiment of the apparatus of the present invention with sectioning lines on some of the components omitted for ease of illustration; FIG. 9 is a cross-sectional view taken generally along the plane 9-9 in FIG. 8; FIG. 10 is a simplified, diagrammatic, axial cross-sectional view of a third embodiment of the apparatus of the present invention with sectioning lines on some of the components omitted for ease of illustration; FIG. 11 is a cross-sectional view taken generally along the plane 11-11 in FIG. 10; FIG. 12 is a cross-sectional view taken generally along the plane 12-12 in FIG. 10; and FIG. 13 is a cross-sectional view taken generally along the plane 13-13 in FIG. 10.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0018] While this invention is susceptible of embodiment in many different forms, this specification and the accompanying drawings disclose only some specific forms as examples of the invention. The invention is not intended to be limited to the embodiments so described, however. The scope of the invention is pointed out in the appended claims.

[0019] For ease of description, the system components of this invention are described in one operating position, and terms such as upper, lower, horizontal, etc., are used with reference to this position. It will be understood, however, that the components of this invention may be manufactured, stored, transported, and sold in an orientation other than the position described.

[0020] Figures illustrating the components of the invention show some mechanical elements that are known and that will be recognized by one skilled in the art. The detailed descriptions of such elements are not necessary to an understanding of the invention, and accordingly, are herein presented only to the degree necessary to facilitate an understanding of the novel features of the present invention.

[0021] FIG. 1 illustrates an anesthesia machine 10 for mixing an anesthetic or other inhalation agent with oxygen and nitrous oxide providing the gas mixture to a patient through a patient mask 12. The anesthetic and gas mixture to be breathed by the patient is directed through a first conduit 14 to a scrubber 16 which functions to remove carbon dioxide from the mixture.

[0022] The scrubber 16 employs a scrubbing substance 15, such as soda lime in the form of calcium oxide and sodium hydroxide or calcium oxide and potassium hydroxide. The reaction of carbon dioxide with soda lime produces carbonate species thereby removing the carbon dioxide from the gas. The purged gas exits the scrubber 16 through a line 18 to the patient mask 12. The breath exhaled by the patient is carried by a conduit 20 back to the anesthesia machine 10 where it is blended with fresh anesthetic and gas and recirculated.

[0023] Any suitable conventional or special design may be employed for the systems within the anesthesia machine that produce the anesthetic gas mixture, for the conduit systems that direct the flow of gases to the anesthesia machine, scrubber, and patient, and for the systems that control the gas (patient breath) flow to and
from the patient mask. The detailed design and operation of such an anesthesia machine systems form no part of the present invention.

[0024] According to the present invention, a novel scrubber system is provided to obtain a greater margin of safety with certain anesthetics, such as SEVOFLURANE™, which can be chemically degraded when exposed to heat generated inside the scrubber, such as heat generated by the exothermic reactions of the scrubbing substance with carbon dioxide and water vapor in the patient’s breath. In particular, as illustrated in FIGS. 1 and 2, the scrubber 16 has a novel design that retains the soda lime scrubbing substance (e.g., usually granules) around a plurality of cooling tubes 68. The tubes 68 are hollow, and the upper ends (inlet ends) of the tubes 68 are connected to a plenum 32. The lower ends (outlet ends) of the tubes 68 are connected to a lower plenum 34. The upper plenum 32 is supplied with a cooling fluid through an inlet conduit 36, and the coolant fluid is discharged from the scrubber lower plenum 34 through a discharge conduit 38.

[0025] Preferably, the coolant fluid is air which is recirculated through the scrubber 16, optionally by a forced air cooling unit 40. This can include an axial fan. It is also contemplated that cooling can be effected with natural convection in which case means such as forced air cooling unit are not required. The forced air cooling unit 40 cools the recirculating air that exits from the scrubber 16 and then returns the cooled air to the scrubber 16. The means for providing the coolant fluid to the scrubber 16, such as the forced air cooling unit 40, may be of any conventional or special design. The detailed design and operation of such a coolant fluid handling means forms no part of the present invention.

[0026] The coolant fluid is directed through the scrubber 16 at a flow rate sufficient to maintain the temperature of the scrubbing substance, and of the exhaled air passing through the scrubbing substance, below a temperature at which the exothermic reaction would occur. The temperature is maintained low enough to limit the buildup of heat in the scrubber even if an abnormally high concentration of anesthetic and carbon dioxide are present in the exhaled air and even if the system is operated at abnormally low flow rates. This insures that conditions cannot exist for supporting an exothermic reaction that might release an amount of heat sufficient to create significant amounts of a degradation by-product.

[0027] FIGS. 3-7 illustrate one form of certain components of the present invention apparatus. The scrubber 16 is illustrated in FIG. 3 as incorporated in a heat exchanger system in accordance with the present invention. The scrubber 16 includes a shell, such as a generally cylindrical tube 50, which surrounds a charge of the scrubbing substance, such as soda lime granules (not illustrated in FIG. 3).

[0028] The upper end of the shell 50 is closed with an upper end cap 52, and the lower end of the shell 50 is closed with a lower end cap 54. The upper end cap 52 defines a central opening 56 for receiving or otherwise being connected to an end of the coolant fluid inlet conduit 36 (FIG. 2), and the lower end cap 54 defines an opening 58 for receiving or otherwise being connected to an end of the coolant fluid outlet conduit 38 (FIG. 2).

[0029] As shown in FIGS. 3 and 4, an upper coolant baffle plate 62 is disposed inwardly of the upper end cap 52, and a lower coolant baffle plate 64 is disposed inwardly of the lower end cap 54. Each baffle plate 62 and 64 defines a plurality of bores 66 (FIG. 6). The cooling tubes 68 are disposed between the coolant baffle plates 62 and 64. An upper end of each tube 68 is sealingly engaged around its inlet opening at one of the bores 66 in the upper coolant baffle plate 62. Similarly, the lower end of each coolant tube 68 is sealingly engaged with the lower coolant baffle plate 64 and communicates through a bore 66.

[0030] The space between the upper end cap 52 and the upper coolant baffle plate 62 defines the upper plenum 32 (FIGS. 2 and 3). Similarly, the space between the lower end cap 54 and the lower coolant baffle plate 64 defines the lower plenum 34 (FIGS. 2 and 3). The coolant fluid is fed into the upper plenum 32 via the conduit 36 through the inlet opening 56. The coolant fluid flows from the upper plenum 32 through the tubes 68 to the lower plenum 34. The coolant fluid leaves the lower plenum 34 through the outlet conduit 38 at the outlet opening 58.

[0031] Inwardly of the upper coolant baffle plate 62 is an upper gas baffle plate 72. Similarly, inwardly of the lower coolant baffle plate 64 is a lower gas baffle plate 74. As can be seen in FIG. 7, each gas baffle plate defines a plurality of bores 76 for accommodating the passage of the coolant tubes 68. Appropriate means are provided for sealing the periphery of each coolant tube 68 to the gas baffle plates 72 and 74 at the penetration regions. This can include various sealant compounds, resilient inserts, etc. (not visible in the figures).

[0032] Each gas baffle plate 72 and 74 also defines a plurality of bores 78 for accommodating the flow of the exhaled breath through the scrubber 16. The space between the upper coolant baffle plate 62 and the upper gas baffle plate 72 defines a plenum 82 for receiving the exhaled breath. To this end, the shell 50 defines an influent opening 84 communicating with the plenum 82. The influent opening 84 is connected to the inlet conduit 14 (FIGS. 1 and 2).

[0033] At the other end of the scrubber 16, the space between the lower coolant baffle plate 64 and the lower gas baffle plate 74 defines a lower plenum 86. The shell 50 defines an effluent opening 88 communicating with the plenum 86. The effluent opening 88 is connected to the outlet conduit 18 (FIGS. 1 and 2). The above-described components which contain the scrubbing substance and which define the flow passages for the exhaled breath and coolant fluid may be characterized as an enclosure.

[0034] The exhaled breath flows from the inlet plenum 82 through the bores 78 in the upper gas baffle plate 72
and into a chamber defined by the upper gas baffle plate 72, the shell 50, and the lower gas baffle plate 74. The chamber between the two gas baffle plates 72 and 74 is filled with the scrubbing substance, such as soda lime granules. The soda lime granules generally fill the space within the shell 50 around the coolant tubes 68.

[0035] The interstitial spaces between the granules provide a porosity that accommodates flow of the exhaled breath from the upper plenum 82, through the scrubbing substance, and into the lower plenum 86. As the exhaled breath passes through the scrubbing substance, the carbon dioxide is removed. If the scrubbing substance is a soda lime mixture, the carbon dioxide is removed by the well-known chemical reaction that forms a carbonate.

[0036] Further, as the carbon dioxide removal reaction occurs, the scrubbing substance and the exhaled breath flowing through the scrubbing substance, are cooled and maintained at a temperature below a desired maximum temperature by the coolant fluid flowing through the coolant tubes 68.

[0037] Preferably, the gas baffle plate bores 78 are arranged to evenly distribute the exhaled breath through the scrubbing substance so as to eliminate or minimize "hot spots" within the enclosure. Further, as can be seen in FIG. 5, the coolant tubes 68 are spaced or clustered more closely together in the center region of the chamber where heat build-up would be greater.

[0038] In view of the heat transfer occurring within the enclosure of the scrubber 16, the conduits 68 and surrounding enclosure components may be characterized as a flow path-defining structure, at least a portion of which is a thermally conductive material. This flow path-defining structure defines a first flow path for the exhaled breath gases and defines a separate, second flow path for the coolant fluid adjacent the first flow path.

[0039] Although not illustrated, the scrubber shell 50 may be provided with a suitable, sealable, door providing access to the enclosure between the gas baffle plates 72 and 74. Such a door can be used to accommodate replacement of the expended scrubbing substance and to accommodate inspection and/or other maintenance.

[0040] FIGS. 8 and 9 illustrate a presently preferred form of the invention employing a forced air (or other gas) heat transfer system. In FIGS. 8 and 9, the scrubber is generally designated by the reference number 116, and the scrubber 116 has a generally cylindrical configuration. The scrubber 116 is an enclosure which includes, among other components, a cylindrical, outer shell 150 and a cylindrical, inner shell 151.

[0041] An annular gas flow space or plenum 153 is defined between the outer shell 150 and inner shell 151. The inner shell 151 defines a plurality of holes 149 to accommodate the flow of coolant fluid from the interior of the scrubber to the annular plenum 153. The upper ends of the outer shell 150 and inner shell 151 are covered by an upper end plate or cap 152A and an attached annular flange 152B (FIG. 9). An inlet pipe or conduit 114 is connected to the center of the upper end cap 152A and defines an influent opening through which the patient's exhaled breath passes into the scrubber 116. The conduit 114 may be connected to, or may be a unitary part of, the main conduit 14 extending from the anesthesia machine as illustrated in FIG. 1.

[0042] At the lower end of the scrubber 116 (as illustrated in FIG. 9), a lower end cap 154 is mounted across the bottom of the outer shell 150. A pipe or conduit 138 is connected to the lower end cap 154 and defines an outlet opening through which gases pass out of the scrubber. The conduit 138 may be connected to, or may be a unitary part of, the coolant fluid return line 38 extending to the forced air cooling unit 40 as illustrated in FIG. 1.

[0043] The lower end of the inner shell 151 is closed with a bottom closure plate 164. A pipe or conduit 118 is connected to the bottom closure plate 164 to define an effluent opening through which scrubbed, exhaled breath gases flow out of the scrubber 116. The conduit 118 may be connected to, or may be a unitary part of, the purged gas line 18 extending to the patient mask 12 (FIG. 1).

[0044] A plurality of conduits 168, preferably in the form of cylindrical pipes or tubes, are mounted within the scrubber 116 to hold the scrubbing substance 115. Each tube 168 is fabricated from a suitable, thermally conductive material, such as steel or other appropriate material. Each conduit has a first, or upper, open end and a second, or lower, open end. In the preferred contemplated embodiment, the nominal diameter of each conduit 168 is about 1 inch.

[0045] The bottom of each conduit 168 is sealingly engaged, and supported, by a floor 174. The lower end of each conduit 115 is received in an aperture or bore 178 defined in the floor 174 so that the interior of each conduit 168 can communicate below the floor 174 with a space or plenum defined between the floor 174 and the closure plate 164. The bottom end of each conduit 168 is covered with a foraminous member or fine screen 165 to retain the scrubbing substance 115 within the conduits 168.

[0046] The upper end of each conduit 168 is sealingly mounted in a retention plate 172. The retention plate 172 defines a plurality of bores or openings 173 for each receiving an upper end of a conduit 168. An orifice plate 162 covers the tops of the conduit 168 over the plate 172. The orifice plate 162 defines at least one hole or orifice 163 associated with each conduit 168. In the preferred embodiment, at least one orifice 163 is aligned on the longitudinal axis of each conduit 168.

[0047] The exhaled breath gases enter the scrubber 116 through the conduit 114 into a space or plenum defined between the upper end cap 152A and the orifice plate 162. The exhaled breath gases flow from the plenum through the orifices 163 into the conduits 168. Preferably, in order to provide a relatively uniform flow pat-
tern through the scrubber 116, the orifices 163 have varying sizes depending upon the radial locations of the orifices relative to the inlet conduit 114. Typically, the orifices which are located radially closer to the inlet conduit 114 would have a smaller diameter than the orifices located radially further from the inlet conduit 114.

[0048] If desired, separate groups or sets of orifices 163 may be provided in the plate 162 so that each group of orifices is associated with, and is located over, one conduit 168. Preferably, the orifices 163 within a group would be arranged and sized as necessary to facilitate the establishment of a relatively uniform flow of the exhaled breath gases into the conduit 168.

[0049] As illustrated in FIG. 9, a conduit 136 is connected to the bottom of the scrubber 116 so as to accommodate the flow of the coolant fluid into the scrubber. The conduit 136 penetrates the lower end cap 154, the lower closure plate 164, and the floor 174. Each of the penetrations is sealed to prevent gas leakage along the exterior of the conduit 136. The conduit 136 defines an inlet opening through which the coolant fluid can flow into the center of the scrubber 116.

[0050] In operation, the expired or exhaled breath gases are directed through the influent conduit 114 into the top of the scrubber 116. The breath gases flow downwardly through the orifice plate 162 and through the scrubbing substance 115 in the conduits 168. As the exhaled breath gases pass through the scrubbing substance 115, the carbon dioxide is removed by the process previously described in detail above.

[0051] Preferably, the orifice plate 162 is designed to evenly distribute the exhaled breath gases through the scrubbing substance so as to eliminate or minimize “hot spots” within the scrubber enclosure. At the bottom of the scrubber, the exhaled breath gases (now without the carbon dioxide) are carried out of the scrubber through the effluent conduit 118.

[0052] The scrubber is cooled and maintained at a temperature below a maximum design temperature by the coolant fluid entering the inlet conduit 136 at the center of the scrubber. In a presently contemplated preferred embodiment, the coolant fluid is air, and the air is supplied at a pressure greater than atmospheric pressure by a forced air cooling unit (e.g., unit 40 in FIG. 1). The coolant air flows upwardly into the center of the scrubber 116 and radially outwardly past the conduits 168 whereby heat is transferred from the scrubbing substance 115 through the conduits 168 to the coolant fluid. The coolant fluid flows to the periphery of the scrubber, through the inner shell holes 149, and into the annular plenum 153. The coolant fluid is then carried away from the scrubber through the outlet conduit 138.

[0053] In view of the heat transfer occurring within the scrubber 116, the conduits 168 and surrounding components of the enclosure may be characterized as a flow path-defining structure, at least a portion of which is a thermally conductive material. This flow path-defining structure defines a first flow path for the exhaled breath gases and defines a separate, second flow path for the coolant fluid adjacent the first flow path.

[0054] A third embodiment of the present invention, employing a convection heat transfer system, is illustrated in FIGS. 10–13. In FIG. 10, the scrubber is designated generally by the reference numeral 216. The scrubber 216 is adapted to be mounted between an upper gasket 218A and a lower gasket 218B in a conventional clamshell type housing employed in commercially available anesthesia machines to retain scrubbers. The housing has an upper portion 219A and a lower portion 219B.

[0055] The scrubber 216 includes an enclosure having an outer shell 250 defining an open upper end engaged with the upper gasket 218A and an open lower end engaged with the lower gasket 218B. The shell 250 is sealingly engaged adjacent the upper end with an end plate or upper plate 272 and adjacent the lower end with a lower plate 274.

[0056] An upper space or plenum is defined between the upper clamshell housing portion 219A and the upper plate 272 for receiving exhaled breath gases entering through an opening 214 in the upper housing portion 219A. At the bottom of the scrubber, a space or plenum is defined between the lower plate 274 and the lower housing portion 219B. Exhaled breath gases, without the carbon dioxide, flow out of the lower plenum through an opening 221 defined in the lower housing portion 219B.

[0057] A plurality of conduits 268 are mounted between the upper plate 272 and lower plate 274, and the conduits 268 contain a scrubbing substance 215. The conduits each have a first or upper, open end and have a second, or lower, open end. The upper plate 272 defines openings 273 into which the upper ends of the conduits 268 extend. Similarly, the lower plate 274 defines openings 278 into which the bottom ends of the conduits 268 extend. The upper ends of the conduits 268 are thus in communication with the upper plenum defined between the upper plate 272 and upper housing portion 219A, and the lower ends of the conduits 268 are in communication with the plenum defined between the lower plate 274 and the lower housing portion 219B.

[0058] The scrubbing substance 215 is retained within the conduits 268 by a foraminous member, orifice plate, or screen 265. The upper end of each conduit 268 is open, and the exhaled breath gases can pass down through the scrubbing substance 215 in the conduits, and then out through the orifice plate or screen 265 at the bottom of the conduits.

[0059] The orifice plate 265 accommodates the discharge of the exhaled breath gases from the scrubbing substance 115. The flow through the conduits 268 can be regulated as a relatively uniform flow pattern through the scrubber 216 by providing orifices in the plate 265 with varying sizes depending upon the radial locations of the orifices relative to the inlet opening 214. Typically, the orifices which are located radially closer to the opening 214 would have a smaller diameter than the orifices.
located radially further from the inlet opening 214.

[0060] If desired, separate groups or sets of orifices may be provided in the plate 265 so that each group of orifices is associated with, and is located below, one conduit 268. Preferably, the orifices within a group would be arranged and sized as necessary to facilitate the establishment of a relatively uniform flow of the exhaled breath gases through the conduit 268.

[0061] Spaced upwardly from the lower plate 274 is a baffle plate 264. The baffle plate 264 has openings 265 for accommodating the conduits 268, and the baffle plate 264 is sealed to the conduits 268 at the openings 265 to prevent gas leakage.

[0062] An annular opening or channel 266 is defined between the lower plate 274 and baffle plate 264 to accommodate the flow of coolant fluid, such as ambient air, into the scrubber 216. The coolant fluid flows past the conduits 268 and upwardly along the conduits 268. The baffle plate 264 defines a central supply passage, hole, or opening 265 to accommodate the flow of coolant fluid into the center of the scrubber.

[0063] The conduits 268 are arranged to define a central space into which much of the coolant fluid flows. The heat from the scrubbing substance 215 is transferred through the conduits 268 to the coolant fluid, and the heated coolant fluid rises under the influence of the chimney effect in the scrubber 216. The coolant fluid is prevented from rising above the tops of the conduits 268 by the sealed upper plate 272. The heated coolant fluid flows radially outwardly past the conduits 268 to the annular space between the outer shell 250 and conduits 268. The upper portion of the outer shell 250 defines an annular opening 277 through which the heated, coolant fluid exits.

[0064] In view of the heat transfer occurring within the enclosure of the scrubber 216, the conduits 268 and surrounding enclosure components may be characterized as a flow path-defining structure, at least a portion of which is a thermally conductive material. This flow path-defining structure defines a first flow path for the exhaled breath gases and defines a separate, second flow path for the coolant fluid adjacent the first flow path.

[0065] The conduits (268, 168, or 68) may be of any suitable material which can transfer sufficient heat to the coolant fluid to maintain the temperature within the scrubbing substance (215, 115, or 15) below a desired maximum value. In contemplated designs for the embodiments illustrated in FIGS. 8-13, each tube is fabricated from steel and has a nominal diameter of about 1 inch.

[0066] With any of the above-described embodiments, when the scrubbing substance is exhausted, or when it is otherwise desired to replace the scrubbing substance, the apparatus can be opened so that the original scrubbing substance (or what remains) can be removed. The apparatus is refilled with a new charge of the scrubbing substance, and the apparatus is then returned to the closed, operating condition.

[0067] With the novel apparatus and process of the present invention, the temperature of the interior of the scrubber enclosure can be controlled and maintained below the point where the heat buildup becomes a problem. The system of the present invention is readily adapted for use with a variety of anesthesia machines which employ scrubbing substances. The apparatus is relatively easy to operate and maintain, and the apparatus is very effective in maintaining desired temperatures within the scrubbing substance so as to provide an even greater safety margin when using anesthetics that might degrade at elevated temperatures.

[0068] It will be readily apparent from the foregoing detailed description of the invention and from the illustrations thereof that numerous variations and modifications may be effected without departing from the scope of the novel concepts or principles of this invention, as defined in the appended claims.

[0069] Where technical features mentioned in any claim are followed by reference signs, those reference signs have been included just for the sole purpose of increasing intelligibility of the claims and accordingly, such reference signs do not have any limiting effect on the scope of each element identified by way of example by such reference signs.

Claims

1. Apparatus for removing a selected constituent from a patient's exhaled breath, said apparatus comprising:

an enclosure (50, 52, 54) defining a chamber containing a means (16) for removing a selected constituent from exhaled breathing fluids passing through said chamber, said means (16) for removing comprising a scrubbing substance (15);
a means for admitting exhaled breathing fluids into said chamber comprising a first influent opening (14);
a means for admitting a coolant fluid into said chamber comprising a second influent opening (36);
a means for discharging scrubbed exhaled fluids from said chamber comprising a first effluent opening (18);
a means for discharging used coolant fluid from said chamber comprising a second effluent opening (38); and
a means (40, 68) for cooling said chamber of said enclosure (50, 52, 54), said means (40, 68) for cooling comprising a plurality of cooling conduits (68) extending through said chamber defined by said enclosure (50, 52, 54) and through said scrubbing substance (15) contained in said chamber, said plurality of cooling conduits...
Apparatus according to one or more of claims 1-3, wherein said apparatus further comprises:

- a scrubber (116; 216) holding a scrubbing substance (115; 215) which removes a selected constituent from a patient's exhaled breath in a re-breather gas recirculation system employed in the delivery of an inhalation agent to said patient, and
- an enclosure (150; 250) containing said scrubbing substance (115; 215), said enclosure (150; 250) having a flow path-defining structure, at least a portion of which is a thermally conductive material, said structure defining a first flow path for said exhaled breath through said scrubbing substance (115; 215) between influent and effluent openings (114, 118; 214, 221) and defining a separate, second flow path for coolant fluid adjacent said first flow path between inlet and outlet openings (136, 138; 266, 277) whereby a coolant fluid can flow along said second flow path to remove heat from the interior of said enclosure (150; 250),

said enclosure (150; 250) including a plurality of conduits (168; 268) containing said scrubbing substance (115; 215) and that define portions of said first flow path on the interiors of said conduits (168; 268) and that define portions of said second flow path on the exteriors of said conduits (168; 268), said conduits (168; 268) being arranged around an empty central region, whereby said coolant fluid flows past said conduits (168; 268) generally from the center of said enclosure (150; 250) toward the periphery of said enclosure (150; 250), when centrally entered, whereby simultaneous cooling and removing of the constituent is provided.

2. Apparatus according to claim 1, wherein said apparatus further comprises a first inner baffle plate (72) and a second inner baffle plate (74) disposed within said chamber defined by said enclosure (50, 52, 54), said second inner baffle plate (74) being spaced from said first inner baffle plate (72), said first and second inner baffle plates (72, 74) containing therebetween said scrubbing substance (15).

3. Apparatus according to claim 2, wherein said apparatus further comprises a first outer baffle plate (62) and a second outer baffle plate (64) disposed within said chamber defined by said enclosure (50, 52, 54), said first and second outer baffle plates (62, 64) being spaced between said first and second outer baffle plates (62, 64), said first outer baffle plate (62) and said enclosure (50, 52, 54) defining a first plenum chamber (32) fluidly sealed from said first and second inner baffle plates (72, 74), said second outer baffle plate (64) and said enclosure (50, 52, 54) defining a second plenum chamber (34) fluidly sealed from said first and second inner baffle plates (72, 74), said first end portions of each of said plurality of cooling conduits (68) being fluidly connected to said first plenum chamber (32), said second end portions of each of said plurality of cooling conduits (68) being fluidly connected to said second plenum chamber (34).

4. Apparatus according to one or more of claims 1-3, wherein said apparatus further comprises:

- a patient's mask (12);
- a first conduit (20) having a first end portion and a second end portion, said first end portion of said first conduit (20) fluidly connected to said

patient's mask (12), said second end portion of said first conduit (20) fluidly connected to said means for admitting exhaled breathing fluids into said chamber; and

- a second conduit (18) having a first end portion and a second end portion, said first end portion of said second conduit (18) fluidly connected to said means for discharging scrubbed exhaled fluids from said chamber, said second end portion of said second conduit (18) fluidly connected to said patient's mask (12).

5. Apparatus according to one or more of claims 1-4, wherein said means (40, 68) for cooling further comprises a means (40) for circulating and cooling coolant fluid through said means (40, 68) for cooling.

6. Apparatus for removing a selected constituent from a patient's exhaled breath, said apparatus comprising:

- a scrubber (116; 216) holding a scrubbing substance (115; 215) which removes a selected constituent from a patient's exhaled breath in a re-breather gas recirculation system employed in the delivery of an inhalation agent to said patient, and
- an enclosure (150; 250) containing said scrubbing substance (115; 215), said enclosure (150; 250) having a flow path-defining structure, at least a portion of which is a thermally conductive material, said structure defining a first flow path for said exhaled breath through said scrubbing substance (115; 215) between influent and effluent openings (114, 118; 214, 221) and defining a separate, second flow path for coolant fluid adjacent said first flow path between inlet and outlet openings (136, 138; 266, 277) whereby a coolant fluid can flow along said second flow path to remove heat from the interior of said enclosure (150; 250),
Patentansprüche

1. Ein Gerät zur Entfernung eines ausgewählten Bestandteils aus dem ausgeatmeten Atem eines Patienten, wobei das Gerät folgendes umfaßt:

   ein Gehäuse (50, 52, 54), das eine Kammer definiert, die ein Mittel (16) zur Entfernung eines ausgewählten Bestandteils aus den ausgeatmeten Atemfluids enthält, die durch die Kammer hindurchziehen, wobei das Mittel (16) zur Entfernung eine Waschsubstanz (15) umfaßt;
   ein Mittel zum Einlassen ausgeatmeter Atemfluids in die Kammer, die eine erste Einflußöffnung (14) umfaßt;
   ein Mittel zum Einlassen einer Kühlflüssigkeit in die Kammer, die eine zweite Einflußöffnung (36) umfaßt:
   ein Mittel zum Ablassen von gewaschenen, ausgeatmeten Fluiden aus der Kammer, die eine zweite Einflußöffnung (18) umfaßt;
   ein Mittel zum Ablassen der verwendeten Kühlflüssigkeit in die Kammer, die eine zweite Einflußöffnung (38) umfaßt; und
   ein Mittel zum Ablassen von ausgewählten Fluiden aus der Kammer, die eine erste Einflußöffnung (14) umfaßt;

2. Das Gerät nach Anspruch 1, worin das Gerät weiterhin eine erste innere Aufprallplatte (72) und eine zweite innere Aufprallplatte (74) umfaßt, die innerhalb der Kammer, die vom Gehäuse (50, 52, 54) definiert wird, angeordnet sind, wobei die zweite innere Aufprallplatte (74) von der ersten inneren Aufprallplatte (72) beabstandet ist, wobei die erste und die zweite innere Aufprallplatte (72, 74) dazwischen die Waschsubstanzen (15) enthalten.

3. Das Gerät nach Anspruch 2, worin das Gerät weiterhin eine erste äußere Aufprallplatte (62) und eine zweite äußere Aufprallplatte (64) umfaßt, die innerhalb der Kammer, die vom Gehäuse (50, 52, 54) definiert ist, angeordnet sind, wobei die erste und die zweite innere Aufprallplatte (72, 74) zwischen den ersten Endabschnitten einer jeden der Vielzahl von Kühleitungen (68) definiert ist, wobei die erste äußere Aufprallplatte (62) und das Gehäuse (50, 52, 54) eine erste Plenumkammer (32) definieren, die von der ersten und der zweiten inneren Aufprallplatte (72, 74) strömungs-abgedichtet ist, wobei die erste äußere Aufprallplatte (64) und das Gehäuse (50, 52, 54) eine zweite Plenumkammer (34) definieren, die von der ersten und der zweiten inneren Aufprallplatte (72, 74) strömungs-abgedichtet ist, wobei die ersten Endabschnitte einer jeden der Vielzahl von Kühleitungen (68) mit der ersten Plenumkammer (32) fluid-verbunden werden, wobei die zweiten Endabschnitte einer jeden der Vielzahl von Kühleitungen (68) mit der zweiten Plenumkammer (34) fluid-verbunden werden.

4. Das Gerät nach einem oder mehreren der Ansprüche 1-3, worin das Gerät weiterhin folgendes umfaßt:

   eine Patientenmaske (12);
   eine erste Leitung (20), die einen ersten Endabschnitt und einen zweiten Endabschnitt hat, wobei der erste Endabschnitt der ersten Leitung (20) mit der Patientenmaske (12) strömungsverbunden wird, wobei der zweite Endabschnitt der ersten Leitung (20) mit dem Gehäuse (50, 52, 54) fluid-verbunden ist, wobei die zweite Leitung (18) mit dem Gehäuse (50, 52, 54) fluid-verbunden ist, wobei die zweite Leitung (18) mit der ersten Leitung (20) fluid-verbunden ist, wobei die zweite Leitung (18) mit der Patientenmaske (12) fluid-verbunden ist, wobei die Patientenmaske (12) mit der ersten Leitung (20) strömungsverbunden ist, wobei die Patientenmaske (12) mit der zweiten Leitung (18) strömungsverbunden ist.

5. Das Gerät nach einem oder mehreren der Ansprüche 1-4, worin das Mittel (40, 68) zum Kühlen wei-
Appareil pour l'élimination d'un constituant déterminé des gaz respiratoires exhalés par un patient, le dit appareil comprenant :

une enceinte (50, 52, 54) délimitant une chambre contenant des moyens (16) d'élimination d'un constituant déterminé des gaz respiratoires exhalés traversant ladite chambre, lesdits moyens (16) d'élimination comprenant une substance d'épuration (15) ;
des moyens d'admission des gaz respiratoires exhalés dans ladite chambre comprenant une première ouverture pour affluents (14) ;
des moyens d'admission d'un fluide de refroidissement dans ladite chambre comprenant une seconde ouverture pour affluents (36) ;
des moyens de refoulement des gaz exhalés épurés de ladite chambre comprenant une première ouverture pour effluents (18) ;
des moyens de refoulement du fluide de refroidissement de ladite chambre comprenant une seconde ouverture pour effluents (38) ;
et des moyens (40, 68) de refroidissement de ladite chambre de refroidissement de ladite chambre enceinte (50, 52, 54), lesdits moyens (40, 68) de refroidissement comprenant une pluralité de conduites de refroidissement (68) s'étendant dans ladite chambre délimitée par ladite enceinte (50, 52, 54) et dans ladite substance d'épuration (15) contenue dans ladite chambre, ladite pluralité de conduites (68) recevant et dirigeant un fluide de refroidissement à travers celle-ci, chacune de ladite pluralité de conduites de refroidissement (68) comportant une première partie d'extrémité et une seconde partie d'extrémité, ladite première partie d'extrémité de chacune de ladite pluralité de conduites (68) étant en communication fluidique avec ladite seconde ouverture pour effluents (38) délimitée par ladite enceinte (50, 52, 54), ladite seconde partie d'extrémité de chacune de ladite pluralité de conduites de refroidissement (68) étant en communication fluidique avec ladite seconde ouverture d'affluents (38) délimitée par ladite enceinte (50, 52, 54), ladite pluralité de conduites de refroidissement (68) étant disposée plus rapprochée dans une zone centrale de ladite chambre que dans une zone périphérique de ladite chambre, moyennant quoi le fluide de refroidissement admis dans ladite chambre par ladite seconde ouverture pour affluents (36) circule dans ladite pluralité de conduites de refroidissement (68) et est refoulé par ladite seconde ouverture pour effluents (38), moyennant quoi l'on obtient le refroidissement et l'élimination simultanées du constituant.

Revendications

1. Appareil pour l'élimination d'un constituant déterminé des gaz respiratoires exhalés par un patient, le dit appareil comprenant :


2. Appareil selon la revendication 1, caractérisé en ce que ledit appareil comprend en outre une première chicane intérieure (72) et une seconde chicane intérieure (74) disposées à l'intérieur de ladite chambre délimitée par ladite enceinte (50, 52, 54), ladite seconde chicane intérieure (74) étant espacée de ladite première chicane intérieure (72), lesdites premières et seconde chicanes intérieures (72, 74) contenant ladite substance d'épuration (15) entre celles-ci.
3. Appareil selon la revendication 2, caractérisé en ce que l'appareil comprend en outre une première chicane extérieure (62) et une seconde chicane extérieure (64) placées à l'intérieur de ladite chambre délimitée par ladite enceinte (50, 52, 54), lesdites première et seconde chicanes extérieures (72, 74) étant placées entre lesdites première et seconde chicanes extérieures (62, 64), ladite première chicane extérieure (62) et ladite enceinte (50, 52, 54) délimitant une première chambre de répartition d'air (32) scellée de manière fluidique à partir desdites première et seconde chicanes intérieures (72, 74), ladite seconde chicane extérieure (64) et ladite enceinte (50, 52, 54) délimitant une seconde chambre de répartition d'air (34) scellée de manière fluidique à partir desdites première et seconde chicanes intérieures (72, 74), lesdites premières parties d'extrémité de chacune de ladite pluralité de conduites de refroidissement (68) étant raccordées de manière fluidique à ladite première chambre de répartition d'air (32), lesdites secondes parties d'extrémité de chacune de ladite pluralité de conduites de refroidissement (68) étant raccordées de manière fluidique à ladite seconde chambre de répartition d'air (34).

4. Appareil selon une ou plusieurs des revendications 1 à 3, caractérisé en ce que l'appareil comprend en outre :

un masque pour le patient (12) ;

une première conduite (20) comportant une première partie d'extrémité et une seconde partie d'extrémité, ladite première partie d'extrémité de ladite conduite (20) étant raccordée de manière fluidique auxdits moyens d'admission des gaz respiratoires exhalés dans ladite chambre ;

et

une seconde conduite (18) comportant une première partie d'extrémité et une seconde partie d'extrémité, ladite première partie d'extrémité de ladite seconde conduite (18) étant raccordée de manière fluidique auxdits moyens pour le refoulement des gaz exhalés épurés de ladite chambre, ladite seconde partie d'extrémité de ladite seconde conduite (18) étant raccordées de manière fluidique audit masque du patient (12).

5. Appareil selon une ou plusieurs des revendications 1 à 4, dans lequel lesdits moyens (40, 68) de refroidissement comprennent en outre des moyens (40) pour la circulation et le refroidissement du fluide de refroidissement à travers lesdits moyens (40, 68) de refroidissement.

6. Appareil pour l'élimination d'un constituant déterminé des gaz respiratoires exhalés par le patient, l'appareil comprenant :

un épurateur (116 ; 216) renfermant une substance d'épuration (115 ; 215) qui élimine un constituant déterminé des gaz exhalés dans un système de ré-circulation des gaz de ré-inhalation utilisé pour l'apport d'un agent d'inhalation audit patient, et

une enceinte (150 ; 250) contenant ladite substance d'épuration (115 ; 215), ladite enceinte (150 ; 250) ayant une structure de définition de la trajectoire d'écoulement, dont au moins une partie est un matériau à conduction thermique, ladite structure définissant, pour ledit gaz exhalé, une première trajectoire d'écoulement traversant ladite substance d'épuration (115 ; 215) entre les ouvertures pour affluents et effluents (114 ; 118 ; 214 ; 221) et une seconde trajectoire d'écoulement séparée pour le fluide de refroidissement adjacent à ladite première trajectoire d'écoulement, entre les ouvertures d'entrée et de sortie (136, 138 ; 266, 277) moyennant quoi un fluide de refroidissement peut s'écouler le long de ladite seconde trajectoire d'écoulement afin d'éliminer la chaleur émanant de l'intérieur de ladite enceinte (150 ; 250),

ladite enceinte (150 ; 250) comprenant une pluralité de conduites (168 ; 268) contenant ladite substance d'épuration (115 ; 215) et définissant des parties de ladite première trajectoire d'écoulement sur les parties internes desdites conduites (168 ; 268) et définissant des parties de ladite seconde trajectoire d'écoulement sur les parties externes desdites conduites (168 ; 268), lesdites conduites (168 ; 268) étant disposées autour d'une zone centrale vide, moyennant quoi ledit fluide de refroidissement circule, lorsqu'il est admis au centre, après lesdites conduites, généralement à partir du centre de ladite enceinte (150 ; 250) vers la périphérie de ladite enceinte (150 ; 250), moyennant quoi l'on obtient le refroidissement et l'élimination simultanés du constituant.
FIG. 10

EXHALED BREATH GASES

214

COOLANT FLUID

219A

218A

216

273

272

250

250

277

277

250

268

268

215

265

215

265

265

265

264

266

267

267

268

268

250

250

219B

219B

EXHALED BREATH GASES
(CO₂ REMOVED)

221