(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
22 March 2007 (22.03.2007)

PCT

(10) International Publication Number
WO 2007/033271 A1

(51) International Patent Classification:
A61M 16/00 (2006.01) *A61M 16/22* (2006.01)

(21) International Application Number:
PCT/US2006/035719

(22) International Filing Date:
13 September 2006 (13.09.2006)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/716,674 13 September 2005 (13.09.2005) US

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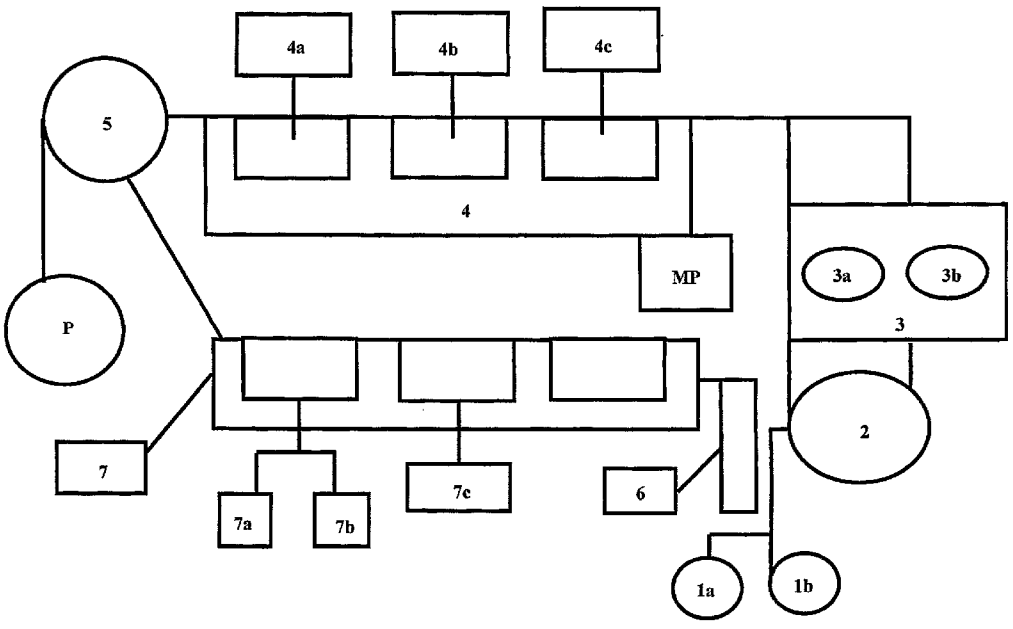
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: SELF-CONTAINED CLOSED LOOP VENTILATOR



(57) Abstract: The present invention is directed to a closed-loop, self-contained portable ventilator (1) that is utilized in far-forward and hospital environments. A primary purpose of the present invention is to protect the medical personnel treating a patient (P) from an exposure to dangerous substances that the patient (P) may have been exposed to.

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SELF-CONTAINED CLOSED LOOP VENTILATOR

PRIORITY INFORMATION

[0001] This application claims priority from provisional application serial number 60/716,674, filed September 13, 2005.

BACKGROUND OF THE INVENTION

[0002] Immediate medical care can save the lives of countless accident victims and military personnel. In the emergency medical services arena, there has long been an emphasis on the golden hour during which a patient must receive definitive medical attention. However, definitive medical attention is often limited, because of the lack of necessary equipment. While state of the art medical equipment can be found in medical facilities, such is not the case in emergency situations or military applications. This is particularly true in the area of ventilators.

[0003] There is a need for portable ventilators that overcome the disadvantages of the existing stationary ventilators and portable ventilators that protect the medical personnel treating a patient from an exposure to dangerous substances that the patient may have been exposed to. This is particularly true in military applications and mass-casualty environments where biological, chemical or nuclear exposure is suspected.

[0004] As is the case with most portable ventilators, these devices provide breathing circuits including valve systems and an oxygen source. However, these devices lack the means by which they can be quickly facilitated in emergency situations where there are no stationary sources of power. These and other drawbacks are overcome by the present invention as will be discussed, below.

SUMMARY OF THE INVENTION

[0005] It is an objective of the present invention to provide a lightweight, self-contained closed loop portable ventilator for patient resuscitation utilizing battery powered compressor(s).

[0006] It is also an objective of the present invention to provide a lightweight, self-contained closed loop portable ventilator that utilizes feedback sensors to control air delivery.

[0007] It is also an objective of the present invention to provide a lightweight, self-contained closed loop portable ventilator that maintains a constant oxygen level.

[0008] It is also an objective of the present invention to provide a lightweight, self-contained closed loop portable ventilator that provides anesthesia and further provides sensors to monitor anesthesia delivery.

[0009] It is also an objective of the present invention to provide a lightweight, self-contained closed loop portable ventilator that provides a carbon dioxide scrubber.

[0010] It is also an objective of the present invention to provide a lightweight, self-contained closed loop portable ventilator that monitors the overall operation of the system and also utilizes fail-safe mechanisms and alarms.

[0011] It is also an objective of the present invention to provide a lightweight, self-contained closed loop portable ventilator that is lightweight and self-contained.

[0012] These and other objectives are described below.

DESCRIPTION OF THE FIGURES

[0013] **Figure 1** is a schematic of the portable, closed loop ventilator system.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0014] The present invention is directed to a closed-loop, self-contained portable ventilator that is utilized in far-forward and hospital environments. A primary purpose of the present invention is to protect the medical personnel treating a patient from an exposure to dangerous substances that the patient may have been exposed to.

[0015] The closed loop system is an automated operation based on the ventilator system behavior and not based on user input. In this manner, the ventilator of the present system can optimize use of tanked air (oxygen or medical grade air mixtures). The closed loop airway system operates at a higher pressure than ambient, thereby reducing operational stresses on the compressors/pumps utilized in the ventilator.

[0016] As per the present invention, the self-contained ventilator is a device that is capable of operating external gas supplies while not requiring any other items to operate. While external power could be used, internal battery and/or pneumatic power would be sufficient for a duration of operation.

[0017] Additionally, the ventilator of the present invention features a "no vent" mechanism where the ventilator does not vent patient exhaled air to the environment. This embodiment of the present invention is particularly beneficial when the ventilator is utilized in environments where biological, chemical or nuclear exposure is suspected, thereby protecting caregivers from secondary exposure.

[0018] In another embodiment of the present invention, the exhaled air from the patient is not only analyzed after being exhaled (used to measure the effectiveness of ventilator) but is also recirculated and redelivered to the patient after removing substances harmful to the patient (at least CO_2). The present invention may utilize a NBC filter and additional sources of oxygen and anesthesia from a tanked or other gas source (i.e. an oxygen concentrator system) may be utilized when the recirculated/redelivered fluid is deficient of the necessary components.

[0019] In yet another embodiment, the ventilator of the present invention operates to keep small amounts of positive pressure in the patient's lungs on the exhalation phase, rather then returning to ambient pressure. Medical studies suggest that this feature provides beneficial ventilatory effects on the patient.

[0020] As shown in **figure 1**, the present invention utilizes a microprocessor/microcontroller system **MP** that operates the overall delivery and operation of the ventilator. The device, as shown in **figure 1**, includes an oxygen source **1a** and anesthesia source **1b**. Oxygen and/or anesthesia are delivered separately into mixing chamber **2** and mixed in a desired proportion based on patient **P** needs. Patient need is determined by keeping the fluid (gas) pressure within an acceptable limit (typically 1 psig, however higher for COPD patients), the per-breath volume within an acceptable range (typically 800 ml for an otherwise healthy adult, more for larger people, less for children and infants, etc.), and acceptable rate (typically 12 beats per minute, BPM), and acceptable maximum CO_2 concentration (typically 0.5%). It is understood to one of ordinary skill that the CO_2 maximum concentration can be expressed as a partial pressure of CO_2 and the O_2 concentration is above a minimum threshold (typically, 20%). The desired oxygen concentration may be higher if the patient exhibits symptoms of shock. The goal of increased oxygen concentration is to establish that a patient's oxygen saturation, as measured by a pulse oximeter or equivalent, or by blood gas measurements, is above a threshold (typically 98%, ideally 100%); thus the inclusion of a pulse oximeter sensor to the system for the purpose of CONTROL of oxygen delivery is desirable.

[0021] Anesthesia is determined by the amount of exhaled anesthesia measured in the patient's exhaled air. Alternatively, oxygen from source **1a** and/or anesthesia from source **1b** can be individually delivered into mixing chamber **2**, as determined by patient **P** needs. Electronic, mechanical or pneumatic valves are used to control the (on/off) status of delivered fluid (gas) and/or the amount of gas (flow rate) that will be delivered. Gas may be

introduced by means of regulated flow (a valve opened a proportional amount based on need) or by pulsed flow (the valve opens then closes at regular or irregular intervals) necessary to achieve the overall required gas concentrations. The microprocessor **MP** determines the amount of gas to add to the system based upon mathematical functions used to determine how much of that gas remains in the recirculation loop following delivery to the patient and how much of the tanked source must be added to achieve the desired system concentration.

[0022] The mixed or single gas is then transferred from the mixing chamber **2** into one of a plurality of compressors **3**. A preferred embodiment of the present invention utilizes two compressors, **3a** and **3b**. Once compressed, the fluid leaves the compressors **3** and is monitored through a plurality of sensors **4** to determine concentrations of various components.

[0023] In a preferred embodiment, an anesthesia sensor **4a**, a carbon dioxide sensor **4b** and an oxygen sensor **4c** monitor their respective components of the fluid. The sensors **4a**, **4b** and **4c** may be optical or chemical sensors. Specialized sensors are smaller and generally less expensive to implement.

[0024] However, the present invention can also utilize a spectrum analyzer (not shown) as a substitute for sensors **4a**, **4b** and **4c** to ascertain the concentrations of each of these gasses (and others to be determined – such as chemical exposures) with a single device, as opposed to specialized sensors. The spectrum analyzer requires processing time to compare the acquired spectrum against a database of known species absorbencies to determine which species and what the relative concentrations are.

[0025] In addition, by comparing pre- and post-patient sensor values for O_2 and CO_2, FIC equations can be used to measure the effectiveness of respiration and the work of breathing.

[0026] The monitored fluid than flows through a flutter valve **5** and out to the patient if sensors **4** indicate that the fluid is in compliance with preset patient requirements. If the fluid

does not provide sufficient oxygen, the fluid is diverted to a carbon dioxide scrubber **6**, utilized to enrich the oxygen content of the fluid. Additional sensors **7** monitor fluid characteristics. In a preferred embodiment, sensors **7** include a second anesthesia sensor **7a**, a second carbon dioxide sensor **7b** and a second oxygen sensor **7c**. The sensors may be chemical or optical sensors discussed above. The sensors **7a**, **7b** and **7c** may be replaced by a spectrum analyzer (not shown) as also discussed above.

[0027] Once the fluid meets the necessary requirements, it is then passed through the mixing chamber **2**, the compressors **3**, the first sensors **4** and through the flutter valve **5** to the patient. If the fluid does not meet the necessary requirements, it is again diverted through scrubber **6** and second sensors **7** until the necessary requirements are met.

[0028] Because the ventilator of the present invention is closed loop, unless pressure is increased, a volume of air equivalent to that added from the O_2 source **1a** and anesthesia source **1b**, minus that removed by the CO_2 scrubber **6**, needs to be removed from the closed loop system. Nominally, this can be accomplished by an additional microprocessor controlled or pressure relief valve (not shown) or a pump (not shown) pulling air from the system. In order to prevent care worker exposure, exhaled air/discharged air, when an NBC exposure is suspected, must be captured in an air reservoir (not shown). This reservoir can be either an expanding container and/or a pressure vessel of some sort. If a pressure vessel is used, a pump or compressor will be required to remove air from the close loop system and move it to the pressure vessel, as a valve will be insufficient.

[0029] It is understood by one of ordinary skill that the present invention may include pressure sensors (not shown) to detect blockages and prevent over inflating the patient. Flow sensors (not shown) may be used to verify that sufficient air is delivered to the patient. Similarly, the CO_2 sensors **4b** and **7b** may be used to verify that dangerous levels of CO_2 were not delivered to the patient. O_2 sensors **4c** and **7c** may be used to ensure that minimum

sustainable levels of oxygen are delivered to the patient. Additionally, sensors **4b**, **4c**, **7b** and **7c** can be utilized to detect whether patient exhaled air has increased concentrations of CO_2 to indicate whether there is a failure in the patient circuit setup, or patient expiration. Finally, a spectrum analyzer as discussed above can utilize alarms (not shown) that could be set to go off if dangerous chemical species were detected. Finally, it is understood by one of ordinary skill that the present invention encompasses embodiments, that are not discussed but within the overall teaching as discussed above.

What is claimed is:

1. A self-contained, closed-loop ventilator comprising:

a mixing chamber constructed so as to receive oxygen from an oxygen source, said mixing chamber further constructed so as to receive anesthesia from an anesthesia source;

a microcontroller system constructed so as to determine quantity of said anesthesia to be delivered to said mixing chamber based upon a patient's exhaled air, said microcontroller system further constructed so as to determine quantity of said oxygen to be delivered to said mixing chamber based upon said patient's needs;

a plurality of compressors constructed so as to receive a mixed quantity of oxygen, anesthesia and carbon dioxide obtained from said patient's exhaled air, said compressors further constructed so as to compress said mixed quantity of oxygen, anesthesia and carbon dioxide into a mixed gas;

a plurality of first sensors connected to said plurality of compressors and constructed so as to monitor quantity of anesthesia, carbon dioxide and oxygen in said mixed quantity;

a flutter valve constructed so as to deliver said mixed gas to said patient;

a carbon dioxide scrubber connected to said flutter valve and constructed so as to receive said mixed quantity if said quantity of carbon dioxide in said mixed quantity is high, said carbon dioxide scrubber further constructed so as to scrub said mixed quantity and enrich said oxygen in said mixed quantity so as to form an enriched oxygen mixed quantity;

said mixing chamber further constructed so as to receive said enriched oxygen mixed quantity, said plurality of compressors constructed to receive said enriched oxygen mixed quantity from said mixing chamber, said compressors further constructed so as to compress said enriched oxygen mixed quantity and form an enriched oxygen mixed gas, and said flutter valve further constructed so as to deliver said enriched oxygen mixed gas to said patient; and

said ventilator constructed so as to prevent said patient exhaled air from contaminating ambient surroundings.

2. The closed-loop ventilator as recited in claim 1, wherein said plurality of compressors comprise two compressors.

3. The closed-loop ventilator as recited in claim 2, further comprising a plurality of second sensors connected to said flutter valve and said scrubber, constructed so as to monitor said enriched oxygen mixed gas.

4. The closed-loop ventilator as recited in claim 3, wherein said plurality of first sensors comprise a first anesthesia sensor, a first carbon dioxide sensor, and a first oxygen sensor; and

said plurality of second sensors comprise a second anesthesia sensor, a second carbon dioxide sensor and a second oxygen sensor;

wherein said first and second carbon dioxide sensors are constructed so as to verify said mixed gas and said enriched mixed gas do not comprise dangerous levels of carbon dioxide, and said first and second oxygen sensors are constructed so and to ensure that minimum sustainable levels of oxygen are delivered to said patient.

5. The closed-loop ventilator as recited in claim 4, wherein said first and second plurality of sensors are constructed so as to detect increased concentrations of carbon dioxide in said patient's exhaled air so as to indicate failure in patient circuit set up and patient expiration.

6. The closed-loop ventilator as recited in claim 3, wherein said first and second sensors are selected from a group comprising spectrum analyzers, optical sensors and chemical sensors.

7. The closed-loop ventilator as recited in claim 6, wherein said first and second spectrum analyzers are further constructed so as to detect increased concentrations of carbon dioxide in said patient's exhaled air so as to indicate failure in patient circuit set up and patient expiration.

8. The closed-loop ventilator as recited in claim 7, wherein said first and second spectrum analyzers comprise alarms constructed so as to indicate the presence of contaminants.

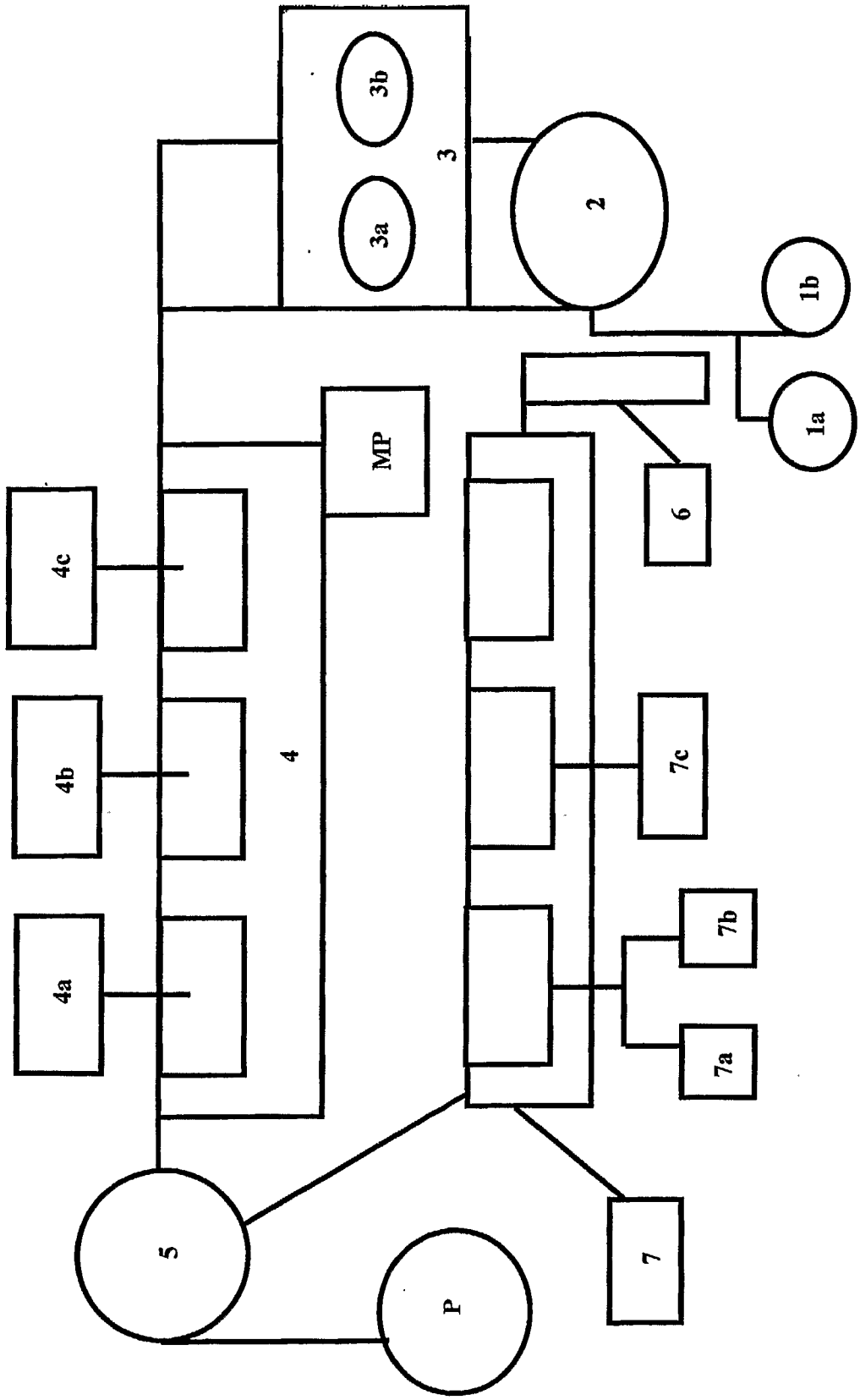

Figure 1

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2006/035719

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61M16/00 A61M16/22

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61M A62B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 6 131 571 A (LAMPOTANG SAMSUN [US] ET AL) 17 October 2000 (2000-10-17) column 7, line 3 - column 23, line 23; figures 1,2	1-8
Y	WO 99/40961 A (ANMEDIC AB [SE]; KVARNHEM TOMMY [SE]; MALIC DANILO [SE]) 19 August 1999 (1999-08-19) page 3, line 12 - page 5, line 18; figure 1	1-8
A	GB 2 338 902 A (ALI FALAH HASAN [GB]) 12 January 2000 (2000-01-12) page 5, line 7 - line 16; figure 1	1

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
16 January 2007	23/01/2007

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INTERNATIONAL SEARCH REPORT

International application No
PCT/US2006/035719

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6 295 985 B1 (KOCK MIKAEL [SE] ET AL) 2 October 2001 (2001-10-02) column 2, line 58 - column 5, line 13; figure 1	1
A	US 6 002 133 A (NELSON SHARI [US] ET AL) 14 December 1999 (1999-12-14) column 1, line 6 - line 36; figures	1,6-8
A	WO 2004/033044 A (LOVELL WILLIAM S [US]) 22 April 2004 (2004-04-22) paragraph [0075] - paragraph [0081]; figures 1,21,22	1,2

INTERNATIONAL SEARCH REPORT

Information on patent family members

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