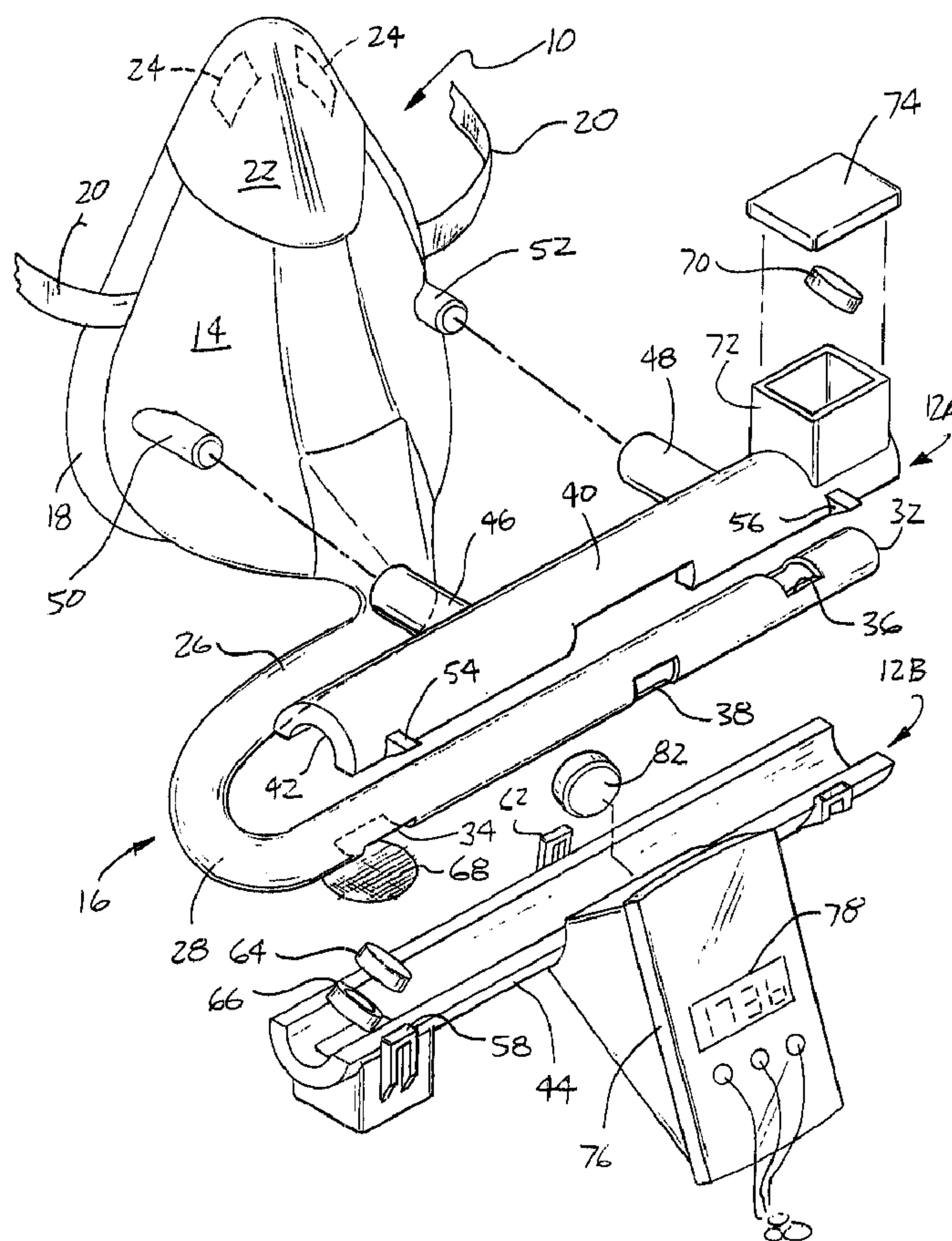




(86) Date de dépôt PCT/PCT Filing Date: 1999/02/05
(87) Date publication PCT/PCT Publication Date: 1999/08/12
(45) Date de délivrance/Issue Date: 2011/08/23
(85) Entrée phase nationale/National Entry: 2000/08/02
(86) N° demande PCT/PCT Application No.: US 1999/002448
(87) N° publication PCT/PCT Publication No.: 1999/039637
(30) Priorités/Priorities: 1998/02/05 (US60/073,812);
1998/10/20 (US60/104,983)

(51) Cl.Int./Int.Cl. *A61B 5/08* (2006.01),
A61B 5/083 (2006.01), *A61B 5/087* (2006.01)
(72) Inventeur/Inventor:
MAULT, JAMES R., US
(73) Propriétaire/Owner:
MAULT, JAMES R., US
(74) Agent: RIDOUT & MAYBEE LLP

(54) Titre : CALORIMETRE METABOLIQUE METTANT EN APPLICATION UNE ANALYSE DE GAZ RESPIRATOIRE
(54) Title: METABOLIC CALORIMETER EMPLOYING RESPIRATORY GAS ANALYSIS



(57) Abrégé/Abstract:

An indirect calorimeter for measuring the metabolic activity and related respiratory parameters of a subject includes a facial mask (14) operative to be supported in contact with the subject so as to pass the inhalations and exhalations as the patient breathes.



(57) **Abrégé(suite)/Abstract(continued):**

Both the inhaled and exhaled gasses pass through a tube (16) which incorporates an ultrasonic pulse transit time flow meter (64, 70) adapted to generate electrical signals as a function of the instantaneous flow volume. A fluorescence quench oxygen sensor (82) is supported in the flow tube (16) and generates electrical signals as a function of the instantaneous oxygen content of the respiratory gasses. A computation unit (76) receives output signals from the flow sensor (64, 70) and the oxygen sensor (82) to calculate oxygen consumption, and related parameters.

PCTWORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁶ : A61B 5/08	A1	(11) International Publication Number: WO 99/39637 (43) International Publication Date: 12 August 1999 (12.08.99)
---	-----------	---

(21) International Application Number: PCT/US99/02448

(22) International Filing Date: 5 February 1999 (05.02.99)

(30) Priority Data:

60/073,812

5 February 1998 (05.02.98)

US

60/104,983

20 October 1998 (20.10.98)

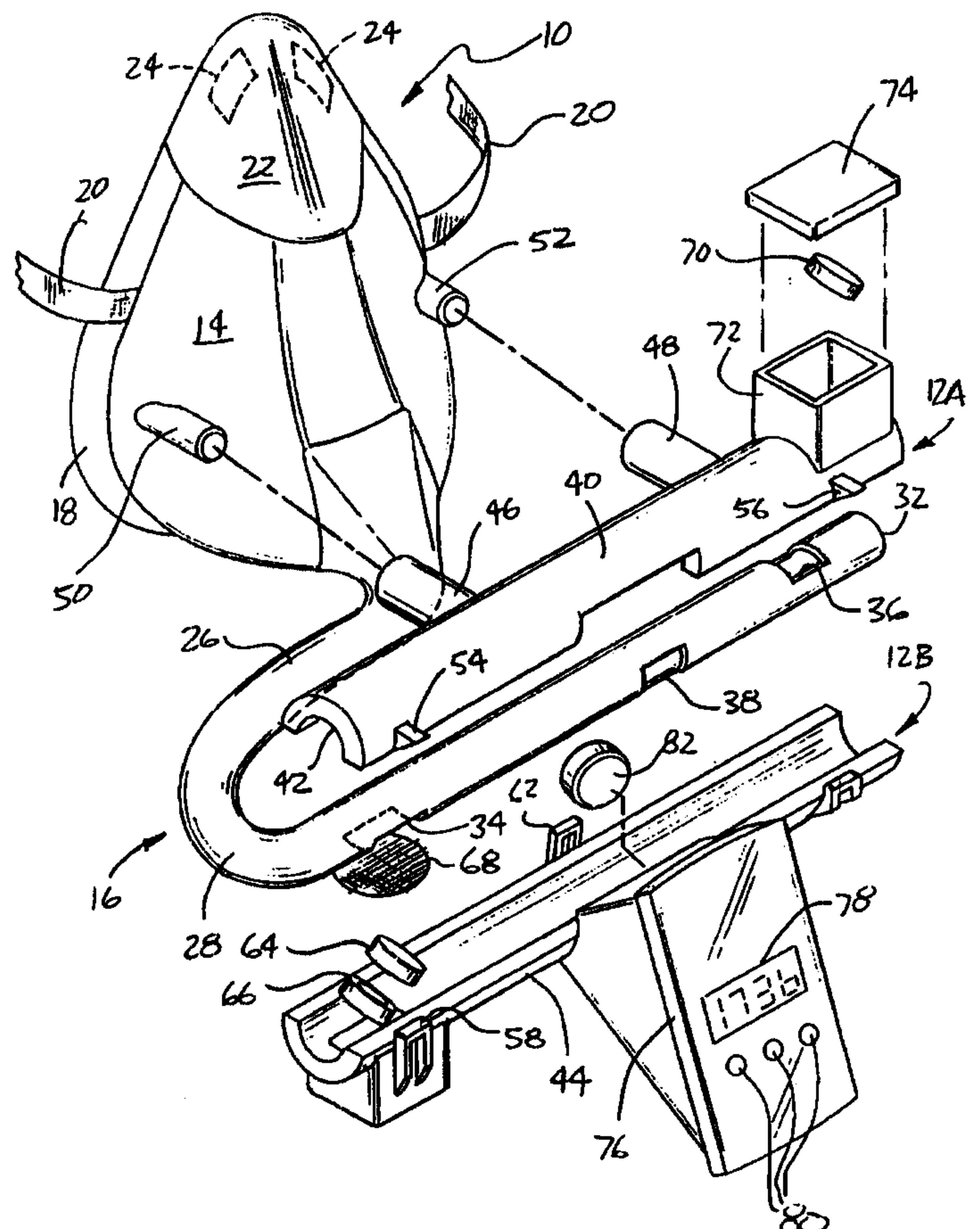
US

(71)(72) Applicant and Inventor: MAULT, James, R. [US/US];
1580 Blakcomb Court, Evergreen, CO 80439 (US).(74) Agents: KRASS, Allen, M. et al.; Gifford, Krass, Groh,
Sprinkle, Anderson & Citkowski, P.C., Suite 400, 280
N. Old Woodward Avenue, Birmingham, MI 48009-5394
(US).(81) Designated States: CA, JP, US, European patent (AT, BE, CH,
CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL,
PT, SE).**Published***With international search report.**Before the expiration of the time limit for amending the
claims and to be republished in the event of the receipt of
amendments.*

(54) Title: METABOLIC CALORIMETER EMPLOYING RESPIRATORY GAS ANALYSIS

(57) Abstract

An indirect calorimeter for measuring the metabolic activity and related respiratory parameters of a subject includes a facial mask (14) operative to be supported in contact with the subject so as to pass the inhalations and exhalations as the patient breathes. Both the inhaled and exhaled gasses pass through a tube (16) which incorporates an ultrasonic pulse transit time flow meter (64, 70) adapted to generate electrical signals as a function of the instantaneous flow volume. A fluorescence quench oxygen sensor (82) is supported in the flow tube (16) and generates electrical signals as a function of the instantaneous oxygen content of the respiratory gasses. A computation unit (76) receives output signals from the flow sensor (64, 70) and the oxygen sensor (82) to calculate oxygen consumption, and related parameters.



**METABOLIC CALORIMETER EMPLOYING
RESPIRATORY GAS ANALYSIS**

Field of the Invention

5 This invention relates to a respiratory instrument for measuring metabolism and related respiratory parameters by indirect calorimetry.

Background of the Invention

 United States Patent Nos. 5,038,792; 5,178,155; 5,179,958; and 5,836,300 all to the same inventor as the present application disclose systems for measuring metabolism and related respiratory parameters through indirect calorimetry. These instruments employ bidirectional flow meters which pass both the inhalations and the exhalations of a user breathing through the instrument and integrate the resulting instantaneous flow signals to determine total full flow volumes. The concentration of carbon dioxide generated by the user is determined by either passing the exhaled volume through a carbon dioxide scrubber before it passed through the flow meter so that the differences between the inhaled and exhaled volumes is essentially a measurement of the carbon dioxide contributed by the lungs or by the measurement of the instantaneous carbon dioxide content of the exhaled volume with a capnometer and integrating that signal with the exhaled flow volume. The oxygen consumption can then be calculated.

 The scrubber used with certain of these systems was relatively bulky and required replenishment after extended usage. The capnometers used with the instruments to measure carbon dioxide concentration had to be highly precise and accordingly expensive because any error in measurement of the carbon dioxide

content of the exhalation produces a substantially higher error in the resulting determination of the oxygen contents of the exhalation.

Summary of the Invention

The present invention overcomes these disadvantages of prior art indirect
5 calorimeters by providing a respiratory calorimeter in which both the inhaled and
exhaled flow volumes pass through a flow meter which provides an output
representative of the instantaneous flow rate and the inhalations and exhalations
also pass over an oxygen sensor in contact with the flow pathway which provides
an output as a function of the instantaneous oxygen concentration in the flowing
10 gas. These two signals are provided to a computer which integrates them to derive
signals representative of the inhaled and exhaled oxygen volume. From these
measurements the oxygen consumption, carbon dioxide production, respiratory
quotient, caloric expenditure and related respiratory parameters are calculated and
displayed.

15 The preferred embodiment of the invention utilizes an ultrasonic transit
time flow meter and a fluorescence quench oxygen sensor. Both of these sensors
operate upon the respiratory gasses as they pass through a flow tube with a
substantially continuous, uninterrupted internal diameter so that the flow is
substantially laminar. Previous indirect calorimeters, including those disclosed
20 in the above-described U.S. patents, have employed flow measurement techniques
that require protrusions in the flow path such as pressure differential transducers,
hot wire transducers or the like. Great difficulties are encountered in maintaining
a largely laminar flow in transducers of this type, resulting in inaccuracies in the

flow measurement. The present invention preferably employs a volume flow meter which transmits ultrasonic pulses through the flow stream in a direction either parallel to the flow path or at least having a component parallel to the flow path. The transit time of the pulses is a function of the flow rate of the gas and
5 because the interior diameter of the flow tube wall is substantially uninterrupted, laminar flow conditions are maintained providing a high uniformity of measurement.

The preferred embodiment of the invention directly measures the oxygen concentration in the inhaled and exhaled gasses passing through the flow tube by
10 a technique which does not introduce any protuberances into the flow area and which may be positioned to measure the oxygen content in the same area in which flow is measured. Thus, unlike previous systems which require some linear separation between the point of flow measurement and the point of gas analysis, and accordingly would result in inaccuracies were the two to be integrated, the
15 present system does not create any phase lag between the oxygen measurement and the flow measurement which would otherwise result in inaccuracies and the need for signal processing to correct for the displacement of the measurements. The preferred embodiment of the invention employs a fluorescence quench technique for oxygen measurement which utilizes a fluoresceable chemical
20 disposed on the interior diameter of the flow wall in the area of ultrasonic pulse transmission. This fluorescent coating may be formed on the tube wall directly or supported on the end of a fiberoptic probe terminating in alignment with the interior diameter of the tube. This coating is subjected to exciting radiation from

the exterior of the tube and the resulting fluorescence may be measured from the exterior. The fluorescence is quenched by oxygen passing over the coating and the percentage of oxygen in the flow tube can be instantaneously measured by the intensity of the fluorescence.

5 The flow tube is preferably formed as a disposable insert which may be inserted into a permanent, reusable structure which includes the ultrasonic transmitter and receiver and the fluorescence oxygen sensor. The fluorescent coating may be covered on the tube side with a microbial filter formed as part of the disposable insert. This filter prevents the fluorescent coating from being
10 bacterially contaminated. The disposable insert is utilized to avoid the spread of disease from user to user in situations in which the indirect calorimeter is used by a succession of persons. The insert is preferably produced of an inexpensive material such as plastic.

 In the preferred embodiment, the disposable insert is supported by a
15 disposable breathing mask that covers the nose and the mouth of the user, allowing normal breathing over the measurement time. Most prior art devices have employed mouthpieces; however, it has been determined that in certain applications the mouthpiece can induce a mild form of hyperventilation which increases the user's energy consumption and results in erroneous metabolic
20 readings. In one embodiment of the present invention, the metabolic measurement components are integrated with and are contained within the mask with no requirement for external connections. When the mask is attached to the user's head by straps, adhesive, or the like, it allows a full range of user movement

during the measurement. Thus, it can be used during normal exercise to allow determination of the effect of that activity on respiratory parameters and may also be used to measure resting energy expenditure. The increased user comfort resulting from the elimination of connections between the mask and associated apparatus allows measurements to be made over longer periods of time and minimizes the labored breathing often associated with conventional respiratory masks which affects accurate measurement of energy expenditure.

The mask also preferably incorporates a nasal spreader on its interior surface which adhesively attaches to the nares of the user's nose and pulls them outwardly to enlarge the nose flow area and minimize the energy expenditure in breathing, which is often increased with conventional masks.

In an alternative form of the invention the computation unit and display and controls are supported in a separate desktop or hand held unit and connected to the sensors within the mask by highly flexible cables or wireless transmission such as infrared or RF.

Brief Description of the Drawings

Other advantages and applications of the present invention will be made apparent by the following detailed description of preferred embodiments of the invention. The description makes reference to the accompany drawings in which:

Figure 1 is a perspective view in exploded form of a first embodiment of the invention;

Figure 2 is a cross-sectional view through the flow tube of Figure 1; and

Figure 3 is a perspective view of a second embodiment employing a desk-top computation and display unit.

Detailed Description of the Invention

Referring to Figures 1 and 2, a preferred embodiment of the invention includes a disposable section, generally indicated at 10, and a nondisposable section shown exploded into parts generally indicated at 12a and 12b. The disposable section 10 is made of low cost materials and is intended to be replaced when the calorimeter is employed by serial users to avoid hygiene problems such as transfer of bacterial infections. The disposable section 10 may be retained by a user for reuse at a later date or may be discarded. If the calorimeter is repeatedly used by a single user, the section 10 may not need to be discarded between uses. The section 10 broadly consists of a mask 14 and a U-shaped breathing tube generally indicated at 16. The mask is adapted to be retained over a user's face so as to cover the user's nose and mouth. The mask 14 has a resilient edge section 18 which engages the user's face in an airtight manner. The mask may be supported against the user's face by the user holding the outer side, but preferably the mask has straps 20 which connect to its edges and pass around the rear of the user's head. Alternatively, the mask could be retained by a pressure sensitive coating formed on the edge seal 18.

The mask proper is preferably formed of a rigid plastic but the section 22 at the top of the mask which is intended to surround the user's nose, is preferably formed of a more resilient material. Pressure sensitive adhesive pads 24 are formed on the interior surfaces of the nose section 22 and allow the user to press

the outer surfaces of the nose section together so as to engage the outer surfaces of the user's nares with the pressure sensitive pads 24. When the pressure on the outer surface of the nose section 22 is released, the sections will spring outwardly and will pull the nares away from the nose so as to enable easy breathing through the nose into the mask.

The U-shaped breathing tube 16 connects to the interior of the mask 14. The tube then extends from the lower forward section of the mask and extends laterally as at 26 to the right of the user in a generally horizontal plane. At the extreme right it forms a 180 degree bight 28 and extends to the left of the user in an elongated measurement section 30. The far end of the tube 16 is opened at 32 so that as the user inhales while wearing the mask 14 air is drawn into the tube 16 through the end 32 and as the user exhales air is expelled through the end 32. The straight section 30 of the tube has three windows or openings, one, 34, formed at its lower side adjacent to the bight 28, the second, 36, formed on its upper side adjacent to the opening 32 and a third, 38, formed on the side of the tube in the middle of the section 30.

The nondisposable portion of the calorimeter consists of the interlocking upper section 12a and lower section 12b. The upper section 12a is formed about a semi-cylindrical section of tube 40. The inner diameter 42 of the tube section 40 matches the outer diameter of the disposable tube section 30 and the section 40 is slightly shorter than the straight line tube section 30. Similarly, the nondisposable section 12b is formed of a semi-cylindrical tube half 44 having an

inner diameter matching the outer diameter of the tube section 30 and having a slightly shorter length.

The tube section 40 is formed with two rearward facing tubular supports 46 and 48, spaced along its length. These supports removably engage bosses 50 and 52 which are formed integrally with the face mask 14 and project forwardly from its upper sides. The lower tube section 44 is then locked to the upper tube section 40 so as to surround the breathing tube section 30. Cam sections 54 and 56 formed at the forward end of the tube section 40 engage latches 58 and 60 formed on the lower tube half and a similar cam (not shown) projecting from the rear of the tube 40 engages a latch 62 formed at the rear of the lower tube section 44 adjacent its free edge.

An ultrasonic transceiver 64 which is housed in a ring 66 formed in the lower tube section 44 projects into the window 34 of the tube section 30. An anti-microbial filter 68 covers the surface of the transducer 64. Similarly, an ultrasonic transducer 70 supported within a section 72 formed on the upper tube 40, and protected by a cover 74, projects into the window 36 adjacent the outlet and inlet end of the tube 30. An anti-microbial filter (not shown) may protect the surface of the transducer. The lower tubing section 44 is integrally formed with a housing 76 which contains the microprocessor which receives the signals from the transducers and sensors and controls their operation, and computes the oxygen consumption and other respiratory factors measured by the device. The unit 76 includes a display 78 and control switches 80. In certain embodiments of the invention a digital keypad may be included on the unit 76.

The computation unit determines oxygen consumption by solving the equation $VO_2 = V_I \times (F_I O_2) - V_E \times (F_E O_2)$ where VO_2 is the consumed oxygen, V_I is the inhaled volume, V_E is the exhaled volume, $F_I O_2$ is the fraction of oxygen in the inhalation, and $F_E O_2$ is the fraction of volume in the exhalation. The system integrates the instantaneous flow volumes with the instantaneous oxygen levels over an entire breathing cycle, which is typically three to ten minutes. The system calculates carbon dioxide production in accordance with the following equation:

$$V_{CO_2} = [V_E - (V_E \cdot F_E O_2)] - [V_I - (V_I \cdot F_I O_2)]$$

Other respiratory parameters such as RQ, REE, etc. may be calculated in the manner disclosed in my previous issued patents.

An oxygen concentration sensor 82 is supported within the housing 76 so that when the tube sections 40 and 44 are joined, the surface of the oxygen sensor, preferably covered with an anti-microbial filter 83, is disposed within the window 38 so that its outer surface is substantially flush with the internal diameter of the tube section 30. In alternate embodiments of the invention the fluorescent chemical, which is formed on the end of the oxygen concentration sensor 82 in the preferred embodiment, could be coated directly on the interior diameter of the tube section 30 and the fluorescence stimulating radiation and sensing of the resulting fluorescence intensity could be performed through a suitable window in the wall of the tube 30.

In use, a subject dons the mask 14 and attaches the straps so that the subject's nose is disposed within the section 22 of the mask, the subject's mouth is covered, and the area surrounding the mouth and nose are sealed by contact of the section 18 with the subject's face. The subject then pinches the outer surface
5 of the section 22 of the mask so that the adhesive pads 24 are brought into pressured contact with the two sides of the subject's nose. The resilient section 22 is released so that the nares are separated, allowing free breathing within the mask.

Either prior to donning the mask or subsequently, the nondisposable
10 sections 12a and 12b are attached so as to surround the tube 30 and the connecting sections 46 and 48 are attached to the bosses 50 and 52 on the front surface of the mask 14.

The user may then breathe in a normal manner so that the inhalations and exhalations are passed through the tube 16 and connect to the atmosphere at the
15 tube end 32. After the subject has breathed through the mask for a minute or two to stabilize the breathing, one of the buttons 80 is depressed to start the measuring cycle. In alternative embodiments of the invention, rather than manually depressing the button 80 to start the measuring cycle, the computation unit 76 could sense the flow of gasses through the tube 30 and automatically initiate the
20 measurement cycle when the breathing reached a normal level.

The ultrasonic transducers 64 and 70 face each other and transmit and receive ultrasonic pulses along a path 90 illustrated in Figure 2 or some alternative path which is either parallel to or has a substantial component in the direction of

the flow. The gas flow acts to advance or retard the flow of the pulses so that the full transmit time of the pulses is a function of the flow rate. The system preferably employs an ultrasonic flow meter manufactured by NDD Medizintechnik AG, of Zurich, Switzerland, and disclosed in U.S. Patents No. 3,738,169; 4,425,805; 5,419,326; and 5,645,071.

The oxygen concentration center 82 is preferably of the fluorescent quench type as disclosed in U.S. Patents No. 3,725,658; 5,517,313 and 5,632,958. The preferred embodiment may employ a sensor manufactured by Sensors for Medicine and Science, Inc. of Germantown, Maryland. The computation unit includes a source (not shown) for directing exciting radiation to the fluorescent coating on the end of the oxygen sensor 82 from exterior of the tube 30 and sensing the resulting fluorescence intensity which is diminished as a function of the concentration of oxygen and gas flowing over its surface to produce a direct measurement of oxygen concentration. The exciting radiation and fluorescent signal may be carried to the sensor by an optical fiber (not shown). In practice, after a user's breathing has stabilized and a test cycle is initiated either automatically or through manual depressions of one of the buttons 80, the flow rate and oxygen levels through the tube 30 are monitored by the sensors and provided to the computation unit. At the end of the cycle, which is preferably automatically timed, the measured quantity such as oxygen consumption will be shown on the display 78.

Figure 3 illustrates an alternative embodiment of the invention in which the computation and display unit, 76, instead of being incorporated integrally with

the nondisposable section which is secured to the master in use, is formed in a separate desktop unit 94. The unit incorporates a display 96, control switches 98, and a keyboard 100. It is connected to the section 12a by a flexible electrical cable 102. This arrangement lowers the weight of the unit which must be supported on the mask 14 during testing and allows more convenient user control of the unit and observation of the display. The computation and control unit 76 of the first embodiment is replaced in the embodiment by a box 104 which includes a connector for the cable 102 and also supports the oxygen sensor 82 in the same manner as the embodiment illustrated in Figure 1. Otherwise, the system of Figure 3 is identical to the system of Figure 1 and similar numerals are used for similar sections.

We Claim:

1. A respiratory gas analyzer comprising:

a respiratory connector operative to be supported in contact with the subject so as to pass inhaled and exhaled gases as the subject breathes;

a disposable flow tube connected at one end to the respiratory connector and at the other end to a source and sink for respiratory gases so as to receive and pass inhaled and exhaled gases, the disposable flow tube having a substantially uninterrupted interior wall surface to maintain laminar flow conditions during the passage of the inhaled and exhaled gases;

a cylindrical housing coupled to the respiratory connector and enclosing the disposable flow tube and configured to facilitate removal and replacement of the disposable flow tube after use;

a pair of ultrasonic transducers disposed on opposite ends of the flow tube and configured to transmit and receive ultrasonic pulses along a path defined by the flow tube, wherein the gas flow through the flow tube acts to advance or retard the flow of the ultrasonic pulses;

an ultrasonic flow meter operatively connected to said flow tube and adapted to measure the transmit time of the ultrasonic pulses as a function of flow rate to generate electrical signals as a function of the instantaneous volume of inhaled and exhaled gases passing through the flow tube;

a fluorescence quench oxygen sensor supported on the flow tube so as to generate electrical signals as a function of the instantaneous fraction of oxygen in the inhaled and exhaled gases as they pass through the flow tube; and

a computation unit for receiving said electrical output signals from the flow sensor and the oxygen sensor and operative to integrate the electrical signals which are functions of the instantaneous volume of gases passing through the flow tube with the electrical signals which are functions of the instantaneous fraction of oxygen in the gasses passing through the flow tube as the subject breathes over a period of time, the computation unit being operative to compute the oxygen consumption of the subject over the period of time by calculating the integral of the

instantaneous flow volumes during inhalation, multiplied by the instantaneous oxygen content measurements at the time of such instantaneous flow volumes, and subtracting from that integral the integral of the instantaneous flow volume during exhalation multiplied by the instantaneous oxygen content measurements at the time of such instantaneous flow volumes.

2. The respiratory gas analyzer of claim 1, wherein said respiratory connector comprises a mask having a free edge which can form a seal about a portion of a subject's face.
3. The respiratory gas analyzer of claim 2, wherein said flow tube forms a flow pathway for communicating said respiratory gases and said flow meter and said oxygen sensor are disposed within said pathway.
4. The respiratory gas analyzer of claim 3, wherein said flow meter is a bidirectional flow meter, said oxygen sensor is an ultrasonic oxygen sensor, and said bidirectional flow meter and said ultrasonic oxygen sensor are supported by an insert, said insert adapted to matingly engage at least a portion of said mask.
5. The respiratory gas analyzer of claim 1, wherein said computation unit comprises a digital processor, visual display, and a power source.
6. The respiratory gas analyzer of claim 4, further comprising at least two nares spreaders adapted to resiliently engage the nares to enlarge opening of the nares.
7. The respiratory gas analyzer of claim 6, wherein said nares spreaders comprise outwardly biased adhesive regions which engage the user's nares and resiliently spring outwardly to enlarge the opening of the nares.
8. The respiratory gas analyzer of claim 1, further comprising a mechanism for transferring output from said sensors to said computation unit.
9. The respiratory gas analyzer of claim 8, wherein said mechanism comprises a conductive line.

10. The respiratory gas analyzer of claim 1, wherein said computation unit further calculates the subject's carbon dioxide production over said period of time in accordance with the following equation:

$V_{CO_2} = [V_E - (V_E F_{EO_2})] - [V_I - (V_I F_{IO_2})]$, wherein V_I is the inhaled volume of gas, V_E is the exhaled volume of gas, F_{IO_2} is the fraction of oxygen in the inhalation, F_{EO_2} is the fraction of volume in the exhalation, and V_{CO_2} is the volume of carbon dioxide production.

11. A respiratory gas analyzer comprising:

a permanent, reusable section having sensors adapted to measure gases within a disposable section;

a disposable flow tube adapted to engage said permanent section wherein said disposable flow tube is adapted to communicate respiratory gases between a subject's airway and a source of respiratory gases, the disposable flow tube having a substantially uninterrupted interior wall surface to maintain laminar flow conditions during the passage of the inhaled and exhaled gases;

a gas sensor comprising a pair of ultrasonic transducers disposed on opposite ends of the flow tube and configured to transmit and receive ultrasonic pulses along a path defined by the flow tube, wherein the gas flow through the flow tube acts to advance or retard the flow of the ultrasonic pulses ;

a flow meter disposed on said permanent section and a detector for receiving reflected ultrasonic pulses, the flow meter comprising an ultrasonic flow meter operatively connected to said flow tube and adapted to measure the transmit time of the ultrasonic pulses as a function of flow rate; and

a computer /computation unit operative to receive outputs from said gas sensor and said flow meter and to calculate respiratory parameters.

12. The respiratory gas analyzer of claim 11, wherein said flow meter is a bidirectional flow meter.
13. The respiratory gas analyzer of claim 11, wherein said gas sensor is an oxygen sensor.
14. The respiratory gas analyzer of claim 11, wherein said flow meter includes an emitter of ultrasonic pulses.
15. The respiratory gas analyzer of claim 13, wherein said oxygen sensor is a fluorescence quench oxygen sensor.
16. The respiratory gas analyzer of claim 15, wherein said oxygen sensor includes an emitter for stimulating radiation for a fluorescing coating and a receiver for measuring the intensity of the fluorescing radiation emitted by said coating.
17. The respiratory gas analyzer of claim 11, wherein said disposable flow tube comprises a mask having a free edge which can form a seal about a portion of a subject's face.
18. The respiratory gas analyzer of claim 11, wherein said flow meter and said gas sensor are disposed within said flow path.
19. The respiratory gas analyzer of claim 11, wherein said disposable flow tube is an insert, said insert adapted to matingly engage at least a portion of a mask.
20. The respiratory gas analyzer of claim 11, wherein said computer/computation unit comprises a digital processor, visual display and a power source.
21. The respiratory gas analyzer of claim 17, wherein said mask comprises at least two nares spreaders adapted to resiliently engage the nares to enlarge opening of the nares.
22. The respiratory gas analyzer of claim 21, wherein said nares spreaders comprise outwardly biased adhesive regions which engage the user's nares and resiliently spring outwardly to enlarge the opening of the nares.
23. The respiratory gas analyzer of claim 17, further comprising a mechanism for transferring output from said sensors to said computer/computation unit.

24. The respiratory gas analyzer of claim 23, wherein said mechanism comprises a conductive line.

25. The respiratory gas analyzer of claim 11, wherein said computer/computation unit further calculates the subject's carbon dioxide production over said period of time in accordance with the following equation:

$$V_{CO_2} = [V_E - (V_E F_{EO_2})] - [V_I - (V_I F_{IO_2})]$$
, wherein V_I is the inhaled volume of gas, V_E is the exhaled volume of gas, F_{IO_2} is the fraction of oxygen in the inhalation, F_{EO_2} is the fraction of volume in the exhalation, and V_{CO_2} is the volume of carbon dioxide production.

26. A respiratory gas analyzer comprising:

a respiratory connector configured to interface with the subject so as to pass inhaled and exhaled gases in use;

a disposable flow pathway in fluid communication with the respiratory connector and with a source of respiratory gases and configured to pass inhaled and exhaled gases in use, the disposable flow pathway comprising a disposable flow tube disposed within a cylindrical housing, and having a substantially uninterrupted interior wall surface to maintain laminar flow conditions during the passage of the inhaled and exhaled gases;

an ultrasonic flow meter provided along said flow pathway and adapted to generate electrical signals as a function of the instantaneous volume of inhaled and exhaled gases as said gases are actually passing through the flow pathway, the flow meter receiving signals from a pair of ultrasonic transducers disposed on opposite ends of the flow tube that transmit and receive ultrasonic pulses along a path defined by the flow tube, wherein the gas flow through the flow tube acts to advance or retard the flow of the ultrasonic pulses, the flow meter further comprising a measurement component to measure the transmit time of the ultrasonic pulses as a function of flow rate;

a fluorescence quench oxygen sensor provided along said flow pathway and adapted to generate electrical signals as a function of the instantaneous fraction of oxygen in at

least one of the inhaled and exhaled gases as said gases are actually passing through the flow pathway; and

a computation unit for receiving said electrical signals from the flow meter and the oxygen sensor and adapted to utilize said electrical signals to compute the subject's oxygen consumption over a period of time.

27. A method for calculating oxygen consumption of a subject, comprising:

providing a disposable flow tube within a cylindrical housing through which the subject may inhale and exhale gas, the disposable flow tube having a substantially uninterrupted interior wall surface to maintain laminar flow conditions during the passage of the inhaled and exhaled gases;

transmitting and receiving ultrasonic pulses along a path defined by the flow tube through a pair of ultrasonic transducers disposed on opposite ends of the flow tube;

measuring the transmit time of the ultrasonic pulses as a function of flow rate to measure the flow volume of inhaled and exhaled gases as they pass through the flow tube;

measuring within the flow tube the oxygen concentration of at least one of said inhaled and exhaled gases as they pass through the flow tube through a fluorescence quench oxygen sensor; and

calculating oxygen consumption using the inhaled flow volume, the exhaled flow volume, and the oxygen concentration.

1/2

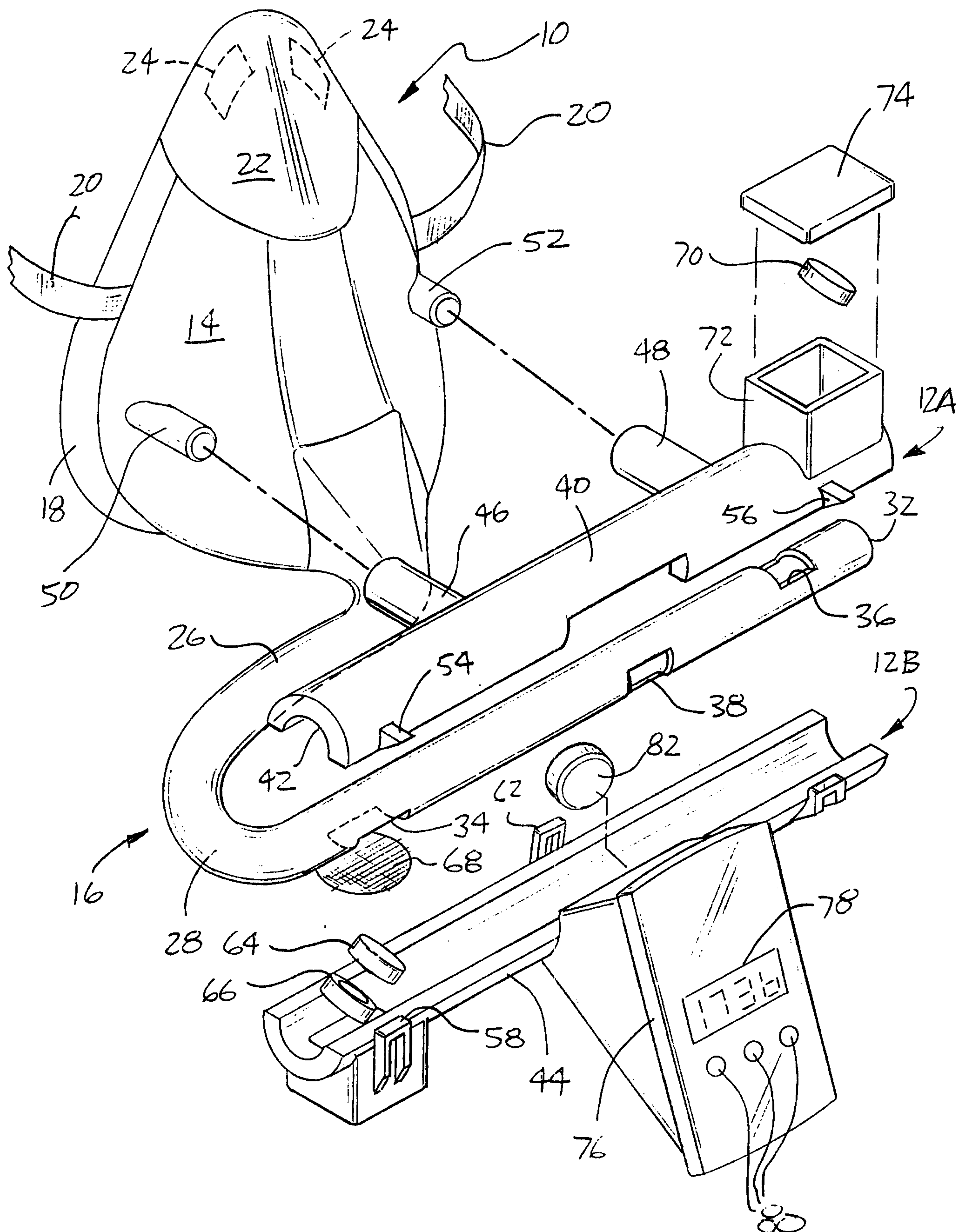


FIG - 1

