United States Patent

Doniguian

[15] **3,680,557**

[45] **Aug. 1, 1972**

[54] **CONTROLLED ATMOSPHERE INCUBATOR SYSTEM WITH OXYGEN PROBE**

[72] Inventor: **Thaddeus M. Doniguian,** Laguna Beach, Calif.

[73] Assignee: **I.M.I., Division of Becton, Dickinson and Company,** Newport Beach, Calif.

[22] Filed: **May 6, 1970**

[21] Appl. No.: **35,026**

[52] **U.S. Cl.** ....**128/185,** 128/191 A

[51] **Int. Cl.** **A61m 16/02**

[58] **Field of Search** ..128/185, 203, 194, 1 B, 191 A, 128/191, 66, 140 R, 142, 142.2, 142.3, 142.4, 142.5, 142.6, 142.7, 1 R, 192, 193, 395, 145 R

[56] **References Cited**

UNITED STATES PATENTS

3,552,391	1/1971	Deaton	128/194
3,252,458	5/1966	Krasberg	128/147
3,380,369	4/1968	Allander	128/1 B
2,232,156	2/1941	Abeles	128/395
2,389,293	11/1945	Blosser	128/185 X

Primary Examiner—Richard A. Gaudet
Assistant Examiner—J. B. Mitchell
Attorney—White, Haefliger and Bachand

[57] **ABSTRACT**

An oxygen stream is supplied to an incubation hood for diffusion therein at a rate such that a concentrated oxygen layer forms in the hood lower interior at a zone about a patient's head; displacement gas such as air is admitted into the hood upper interior to diffuse into the concentrated oxygen layer for reducing the oxygen concentration at the zone about the patient's head, and to effect exhausting from the hood of downwardly displaced gas containing breath expelled carbon dioxide; and the oxygen supply is controlled in response to sensing of the oxygen concentration in the hood to maintain within a predetermined range the oxygen concentration at that zone.

7 Claims, 5 Drawing Figures

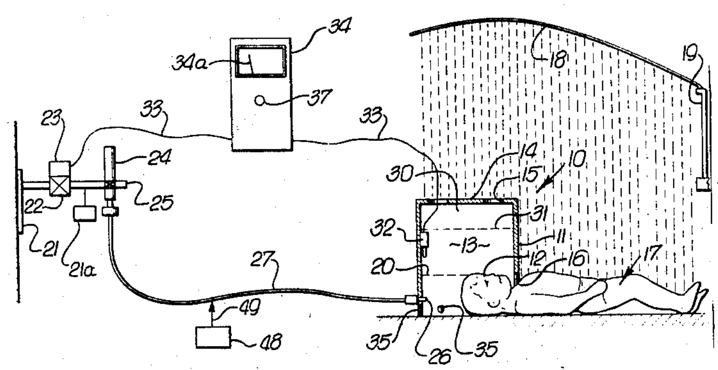


FIG. 1.

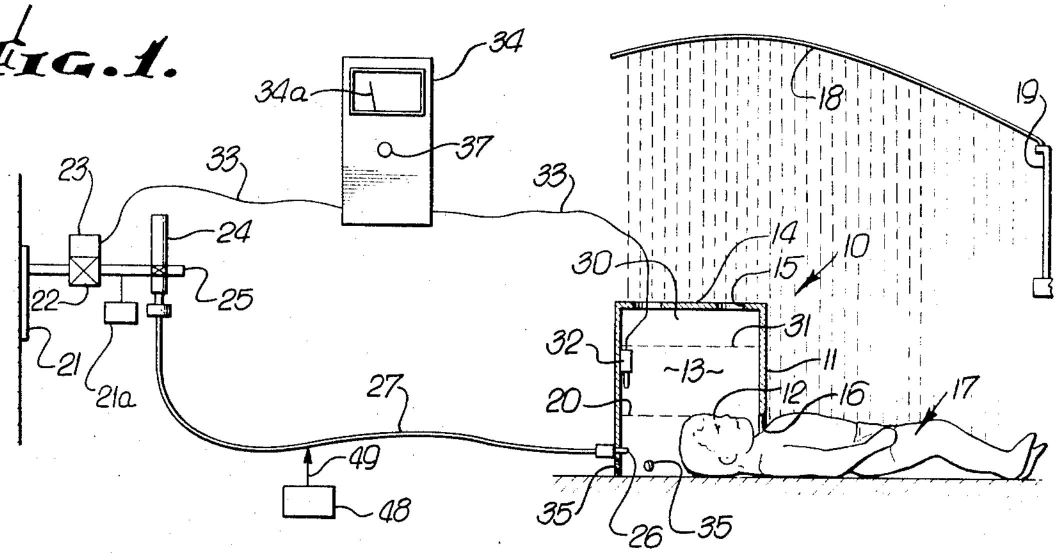


FIG. 2.

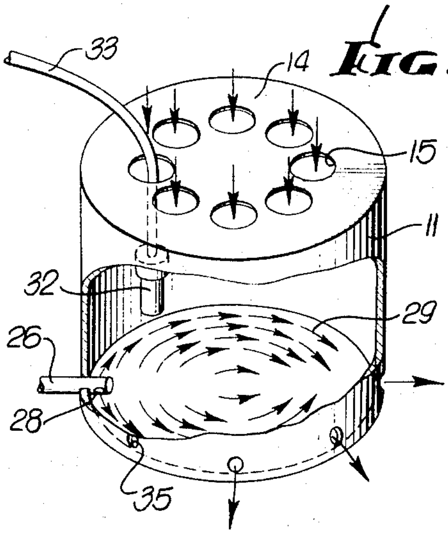


FIG. 4.

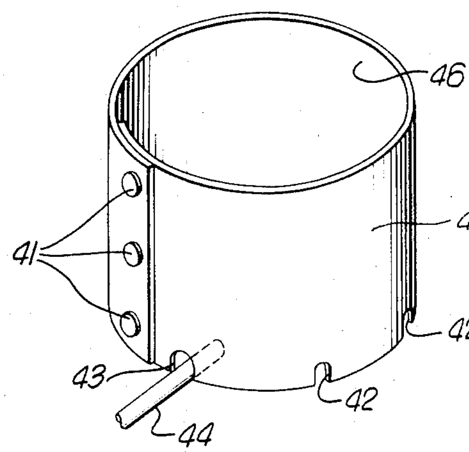


FIG. 3.

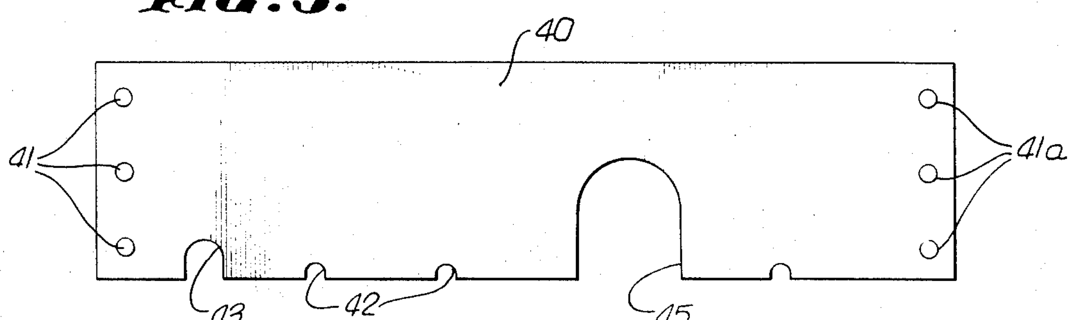
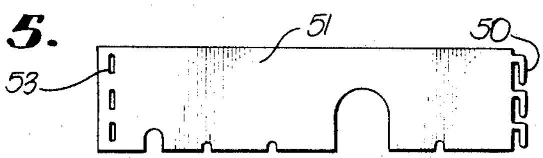


FIG. 5.



INVENTOR.
THADDEUS M. DONIGUIAN
BY
White, Haefliger & Bachand
ATTORNEYS.

CONTROLLED ATMOSPHERE INCUBATOR SYSTEM WITH OXYGEN PROBE

BACKGROUND OF THE INVENTION

This invention relates generally to the control of atmosphere in an enclosure, and more particularly concerns apparatus and method for achieving this objective through taking advantage of the densities and diffusion properties of various gasses such as air, oxygen, nitrogen, and carbon dioxide present in the atmosphere to be controlled.

Requirements for incubation apparatus, especially for infants, include accurate control of oxygen concentration at the patient's head; provision for ease of access to the head during incubation, as for feeding; temperature control and administration of medication; light-weight, lost-cost disposable hood construction; and high visibility. In the past, available incubation equipment has not, to my knowledge, satisfied the above as well as other requirements, particularly in the unusually advantageous manner afforded by the present invention.

SUMMARY OF THE INVENTION

It is a major object of the invention to provide an incubation system and method characterized as satisfying the above needs and requirements, affording unusually advantageous results. Basically, the method involves the steps of supplying oxygen in a gaseous stream into an incubation hood for diffusion therein at a rate characterized in that a concentrated oxygen layer forms in the hood lower interior and at a zone about a patient's head; admitting displacement gas (as for example air) into the hood upper interior to diffuse into the concentrated oxygen layer at the top thereof for reducing the oxygen concentration at the zone, and exhausting to the exterior of the hood the downwardly displaced gas in the layer containing breath expelled carbon dioxide; and sensing the oxygen concentration of the gas in the layer and controlling the oxygen supply to maintain within a predetermined range the oxygen concentration at the head zone. As will appear, the oxygen supply is typically carried out to diffuse the supply stream in a laminar flow path circulating about the lower interior of the hood, thereby to produce the layer as described facilitating accurate oxygen concentration control at the head zone.

In its apparatus aspects, the equipment comprises the hood having upright wall means for receiving a patient's head in a hood lower interior zone; means to supply oxygen in a gaseous stream into the hood for diffusion therein to form the layer, the hood upper and lower interiors each having such communication with the exterior that displacement gas may enter the hood upper interior to diffuse into the top of the layer for reducing the oxygen concentration at the head zone, and also for downwardly displacing gas in the layer containing breath-expelled carbon dioxide; and control means to sense the oxygen concentration of gas in the layer and to control the oxygen supply thereby to maintain the oxygen concentration at the patient's head within a predetermined range. As will be seen, the control means typically includes an oxygen concentration sensor mounted to project in the hood at the level of the layer to which oxygen is supplied by diffusion under laminar flow conditions so as not to disturb the concentration measurement and maintenance. Also, the control means may typically include a valve controlling the oxygen supplying gas stream and an operator responsive to the sensor output to control valve operation to increase and decrease the stream flow in response to decrease and increase respectively in the oxygen concentration at the zone.

Additional objects and advantages of the invention include the provision of a laminar flow diffuser at the hood, the latter typically consisting of plastic sheet material; the provision of a flexible hood sheet with fastener joined end portions for disposability; the provision of through openings proximate the top and bottom of the hood to enable displacement gas and exhaust gas flow as described; and the provision of a heater disposed to radiate heat downwardly through the open top of the hood.

These and other objects and advantages of the invention, as well as the details of an illustrative embodiment, will be more fully understood from the following description and drawings, wherein;

DRAWING DESCRIPTION

FIG. **1** is an elevation, taken in section, showing a system incorporating the invention;

FIG. **2** is a perspective showing of an enclosure or hood as used in FIG. **1**;

FIGS. **3** and **5** are elevations illustrating modified hoods, prior to assembly thereof; and

FIG. **4** is a perspective showing of the FIG. **3** hood after assembly.

DETAILED DESCRIPTION

In the drawings, a hood is indicated at **10** as having upright generally curvilinear wall means **11** forming an enclosure for receiving an infant's head **12** in a lower interior zone **13**. The hood may advantageously comprise transparent plastic material which is transparent for use of viewing the infant's head. The hood is also shown as having a transparent top **14** integral with the generally annular wall **11**, and containing one or more openings **15**. A side opening **16** in wall **11** is large enough to loosely receive the infant's neck when the hood is placed downwardly as shown, the torso **17** projecting at the exterior. Thus, aperture means is provided to allow the patient's head to extend into the hood lower interior. A radiant heater **18** is shown projecting above the hood and supported on a pedestal **19**, radiant heat passing downwardly through the openings **15** for warming the infant's head and body.

Means is provided to supply oxygen in a gaseous stream into the hood and characterized in that a concentrated oxygen layer forms in the hood lower interior. That layer may for example extend below the level indicated by broken line **20**, and the oxygen supply means may include the source **21** of about 100 percent oxygen; a valve **22** controlled by actuator **23**; a flow meter **24**; a manually controlled valve **25**; a diffuser nozzle **26** and a flexible line **27** connecting the outlet of valve **25** with nozzle **26**. The diffuser **26** is shown to have porting **28** located to direct the oxygen stream flow in paths indicated by arrows **29** circulating generally transversely (for example generally tangentially relative to the hood wall) under laminar flow conditions in the hood lower interior, so as to produce the layer referred to. In this regard, turbulent flow conditions are to be avoided since a condition of instability will then result leading to loss of accurate control of the oxygen concentration at the patient's head zone.

Regarding the desired stabilized condition of the oxygen rich layer, it will be noted that displacement gas, as for example air, enters the hood upper interior **30** as via top opening or openings **15**, to diffuse into the oxygen layer at the top of the latter indicated between levels **20** and **31**, for reducing somewhat the oxygen concentration at the top of zone **13**. Thus, the upper surface of the approximately 100 percent oxygen will begin diffusing upwardly into the oxygen-nitrogen mixture above level **20**, and the nitrogen in the air in zone **30** will diffuse downwardly into zone **13** above level **20**. An intermediate layer thus forms in zone **13** and consisting of mixed oxygen and nitrogen varying in concentration between 21 and 100 percent oxygen between levels **31** and **20**.

Also provided is control means to sense the oxygen concentration of gas in the layer between levels **20** and **31** and to control the oxygen supply to the space below level **20** thereby to maintain the desired oxygen concentration in the zone **13**, and particularly at the level of the patient's nose, i.e., within a predetermined range. As illustrated, such means may typically include the oxygen sensor **32**, as for example of the type described in U.S. Pat. No. 2,913,386 to Clark; and the electrical connection between the sensor output and the valve operator **23**. That connection may include a lead **33** and an oxygen controller **34**, the operation being such that oxygen flow from source **21** is increased and decreased in response to decrease and increase respectively in the oxygen concentration at the level of the sensor between levels **20** and **31**. Controller **34** may include a comparator having one input from the sensor and another input from a potentiometer controlled by a manually settable control **37**. An error signal from the comparator and of sufficient magnitude operates the operator **23**. Oxygen concentration is displayed at ***34a***.

The system operation is described as follows. Initially the hood **10** will have an even distribution of air (approximately 21 percent oxygen and 79 percent nitrogen) throughout its interior as air will freely circulate through the appropriately sized holes **15** in the top **14** and exhaust parts **35** at the bottom of the wall **11**. The oxygen sensor will sense the presence of 21 percent oxygen and transmit this information to the controlled **34** where the information is compared with the oxygen concentration desired according to an adjustable setting **37** on the controller. If the oxygen concentration sensed by the oxygen sensor is less than the desired setting on the controller, the latter will activate the operator **23** causing oxygen to flow from the oxygen source **21** through the flow indicator **24**, the flow valve **25**, the connecting hose **27**, the diffuser nozzle **26** and into the enclosure. The flow valve **25** is adjusted manually such that oxygen enters the **25** is to insure laminar movement of gasses therein. The diffuser nozzle causes oxygen entering the enclosure to diffuse in a generally circular path and form a layer of virtually 100 percent oxygen at the bottom of the enclosure. The upper surface of the 100 percent oxygen will begin diffusing up into the oxygen/nitrogen air mixture just above and the nitrogen will begin diffusing down into the upper layers of the 100 percent oxygen blanket, thus forming the above described intermediate layer of mixed oxygen and nitrogen varying in concentration between 21 to 100 percent oxygen.

If we assume that the desired oxygen setting at **37** on the oxygen monitor **34** is 40 percent, then 100 percent oxygen will continue to enter the bottom of the enclosure through the diffuser nozzle until the 40 percent oxygen/nitrogen mixture point within the diffusion layer above the 100 percent oxygen layer reaches the elevation of the oxygen sensor, at which time the operator will turn off valve **22** and oxygen will cease to enter the lower interior of the enclosure.

The 100 percent oxygen (1.43 g/l) being heavier than air (1.29 g/l) will tend to stay at the bottom of the enclosure and will slowly exit out the holes **35** in the bottom of the enclosure as long as all flow into the chamber is circumferentially laminar and no turbulence occurs. As the 100 percent oxygen flows out of the holes **35**, the oxygen concentration at the sensor **32** will decrease until the concentration becomes less than 40 percent at which time the valve **22** will be opened allowing 100 percent oxygen to again enter the enclosure. The entire cycle will continue to be repeated, thus maintaining the concentration of oxygen at the tip of the sensor **32** to about 40 percent or to whatever concentration is set at the controller. Any object (such as the patient's nose) within the enclosure at the same height as the tip of the sensor will experience the oxygen concentration as determined by the controller. Any carbon dioxide (1.98 g/l) generated within the enclosure by, for instance, the patient's breath, will tend to diffuse downward and out through the holes **35** at the bottom of the enclosure, since carbon dioxide is heavier than either 100 percent oxygen or air.

The size of the openings **15** at the top of the enclosure that permit the entrance of air is not particularly critical. The openings act only to insure a laminar situation within the enclosure and if the enclosure is small enough and tall enough, the top may be left open completely.

The size of the openings **35** at the bottom of the enclosure are more important, however, as they determine the rate of exit of the 100 percent oxygen at the bottom of the enclosure. Large holes will result in an unnucessary waste of oxygen and too small a hole will result in an undesired build-up of 100 percent oxygen.

The system described above is essentially an "on-off" system, whereby the electric valve is either "on" or "off." If a suitable proportioning valve and controller are used instead of the "on-off" electric valve and controller, the 100 percent oxygen would enter the enclosure continuously at a rate determined by the controller and achieve essentially the same control except possibly for greater accuracy.

The source of the oxygen as described above is shown as a wall outlet as is common in most hospitals. The source could also be pressure cylinders. Pre-mixed gasses or equipment such as proportioning nebulizers which dilute the source gas as well as humidify it could also be used. The block **48** indicates humidifying or nebulizing equipment connected at **49** with line **27**, so that the patient does not experience dry oxygen. Such equipment may incorporate a heater, so that the oxygen supply is both moist and warm.

If desired, valve **22** and actuator **23** may be placed at the outlet side of manual control valve **25**. Also, a certain amount of total oxygen may be supplied to valve **25** at **21***a*, i.e., so as not to be controlled by valve **22**. The latter is then used to control make-up oxygen supply as is necessary for control as described above. In situations where sterility is important, the enclosure could be designed utilizing inexpensive materials and in such a manner that the entire enclosure would be disposable after each use, thus circumventing the need for sterilization between each use. FIGS. **3** and **4** describe such a design. The enclosure **40** would be fabricated in a flat sheet form (as seen in FIG. **3**) out of inexpensive plastic materials. Inexpensive snap fasteners **41** and **41***a* are incorporated at opposite longitudinal ends of the enclosure such that the enclosure can be assembled easily as seen in FIG. **4**. Holes **42** are provided in the bottom of the enclosure for allowing the controlled gasses to escape. A hole **43** would also be provided for the oxygen line **44**, and a larger hole **45** is formed to receive the infant patient's neck. The enclosure top is entirely open as seen at **46**.

The hood of FIG. **5** is like that of FIG. **3**, excepting that the fasteners comprise hooks **50** at one end of the sheet **51**, and eyes **52** at the opposite end of the sheet to receive the hooks.

Controller **34** may incorporate suitable temperature compensation such as a temperature sensitive resistance (i.e., thermistor) used with the sensor **32** so that the temperature of the resistance is the same as that of the gas adjacent the sensor. Such compensation eliminates the effect of temperature change upon the current flow from the sensor to the controller.

I claim:

1. In incubation apparatus, the combination comprising

a. a hood having upright generally curvilinear wall means with aperture means to allow a patient's head to extend into a hood lower interior zone,

b. means including an oxygen inlet port to disperse oxygen in a gaseous stream into the hood and generally tangentially of said wall means for diffusion therein and characterized in that a concentrated oxygen layer forms in the hood lower interior and at said zone, the hood having upper and lower through opening means the upper opening means located near the hood top to pass atmospheric air entering the hood upper interior to diffuse into said layer at the top thereof, for reducing the oxygen concentration at said zone, and also for downwardly displacing gas in said layer containing breath expelled carbon dioxide for discharge to the hood exterior, the lower opening means located near the bottom of the hood wall to pass to the exterior gas including oxygen displaced in said layer, and

c. control means to sense the oxygen concentration of gas in said layer and to control said oxygen supply thereby to maintain the oxygen concentration at said zone within a predetermined range, said control means including an oxygen sensor effectively located between the levels of the oxygen inlet port and the top of the hood.

2. The combination of claim **1** wherein said control means also includes a valve operable to control said oxygen supplying gaseous stream, and an operator responsive to the output of said sensor to control valve operation to increase and decrease the flow of said stream in response to decrease and increase respectively in the oxygen concentration at said zone.

3. The combination of claim **2** wherein said means to supply oxygen in said stream includes a flow diffuser at said hood and having porting located to direct the stream flow in paths circulating generally transversely under laminar flow conditions in the lower interior of the hood, thereby to produce said layer.

4. The combination of claim **1** wherein said hood comprises transparent plastic sheet material.

5. The combination of claim **4** wherein said sheet is flexible and has joined opposite end portions.

6. The combination of claim **1** including a radiant heater disposed to radiate heat downwardly through the opening proximate the top of the hood.

7. In incubation apparatus, the combination comprising

a. a hood having upright generally curvilinear wall means with aperture means to allow a patient's head to extend into a hood lower interior zone,

b. means including an oxygen inlet port to disperse oxygen in a gaseous stream into the hood and generally tangentially of said wall means for diffusion therein and characterized in that a concentrated oxygen layer forms in the hood lower interior and at said zone, the hood upper and lower interiors each having such communication with the exterior via upper and lower through opening means respectively that displacement gas may enter the hood upper interior to diffuse into said layer at the top thereof, for reducing the oxygen concentration at said zone, and also for downwardly displacing gas in said layer containing breath expelled carbon dioxide for discharge to the hood exterior,

c. control means to sense the oxygen concentration of gas in said layer and to control said oxygen supply thereby to maintain the oxygen concentration at said zone within a predetermined range, said control means including an oxygen sensor effectively located between the levels of the oxygen inlet port and the top of the hood, and

d. a radiant heater overlying the hood to radiate heat downwardly into the hood interior.

* * * * *