

[54] **TWO-PHASE FLUID FLOW GUIDE FOR BLOOD OXYGENATOR**

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[51] Int. Cl. **A61m 1/03**

[58] Field of Search **195/1.8; 23/258.5; 55/255, 256; 261/DIG. 28; 128/DIG. 3**

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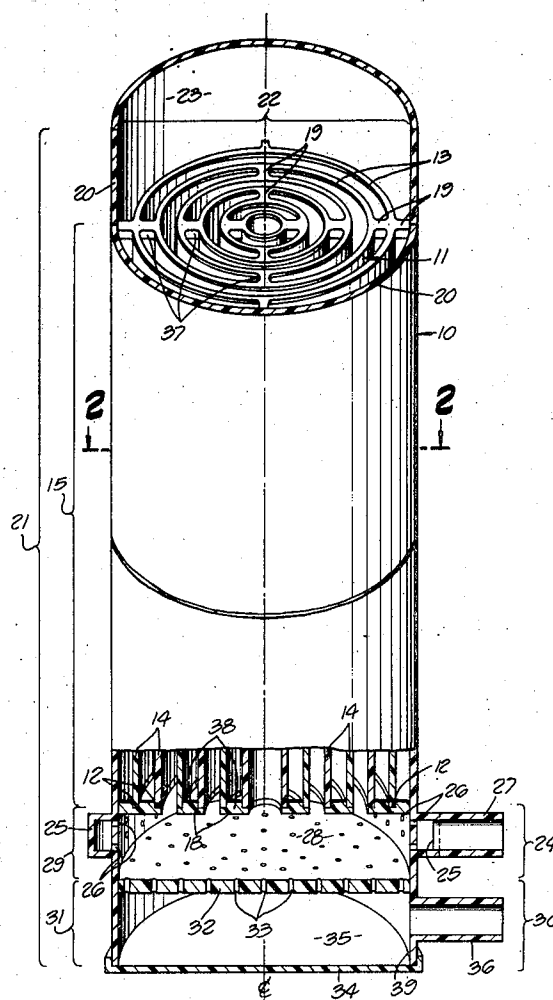
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[57] **ABSTRACT**

Blood flows in extra-corporeal blood circulation into a blood oxygenator. The oxygenating gas enters the blood streams through a means providing oxygenating gas injection, adjacent a means providing blood inlet. The pair of means co-react to provide two-phase flow of blood and oxygenating gas bubbles for the two-phase fluid flow guide. The flow guide has a multiplicity of fluid guide, solid walls of equal length, one wall uniformly closely spaced to another wall. The spaced walls are held in a boundary case by wall securing means which provide a uniform base terminus position and a uniform top terminus position for the walls. The boundary case can have a case length at least equal to the fluid guide wall lengths and greater. The fluid guide solid wall can have multiple, uniform cross section flow control channels disposed in the wall, extending normally to the base terminus and the top terminus of the wall. The flow control channels stabilize the upward flow of the two-phase blood and oxygenating gas combination. The flow control channels stabilize the gas bubble-liquid interface flow geometry, and facilitate the rapid fixation of oxygen by the blood and the release of carbon dioxide into the gas phase exiting from the top terminus of the two-phase fluid flow guide.

14 Claims, 6 Drawing Figures



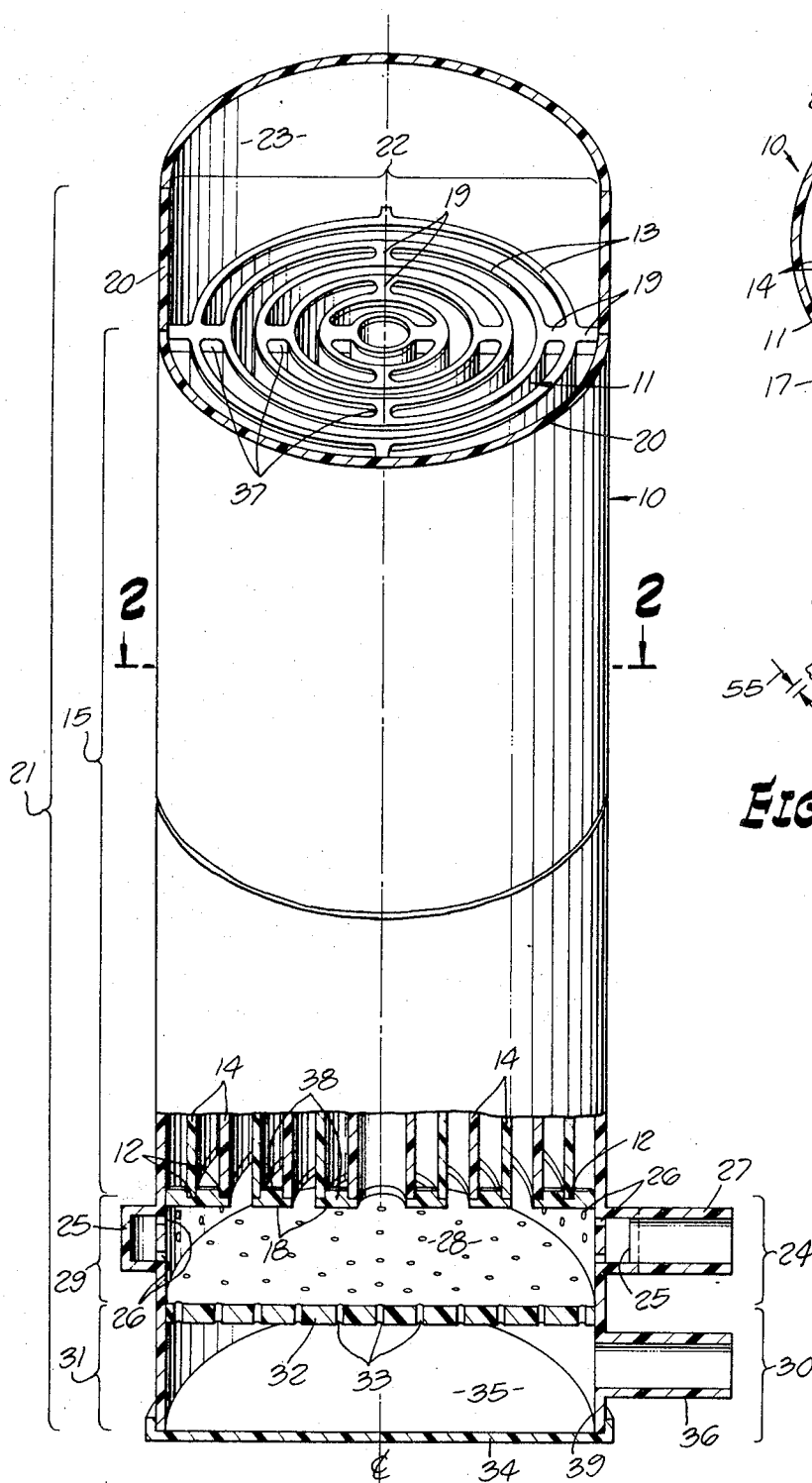


FIG. 1.

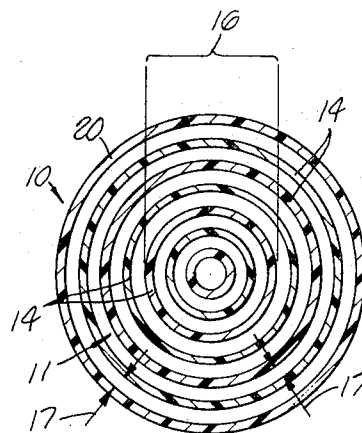


FIG. 2.

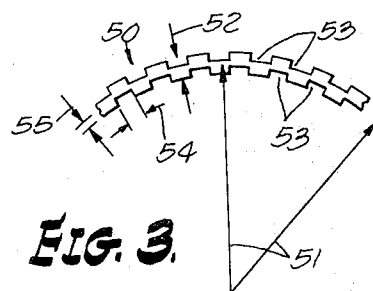


FIG. 3.

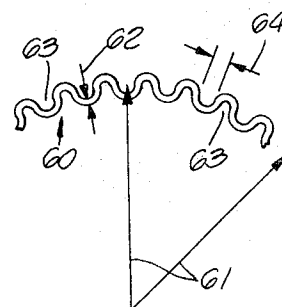


FIG. 4.

FIG. 5.

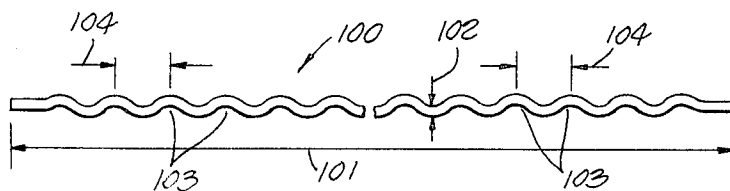
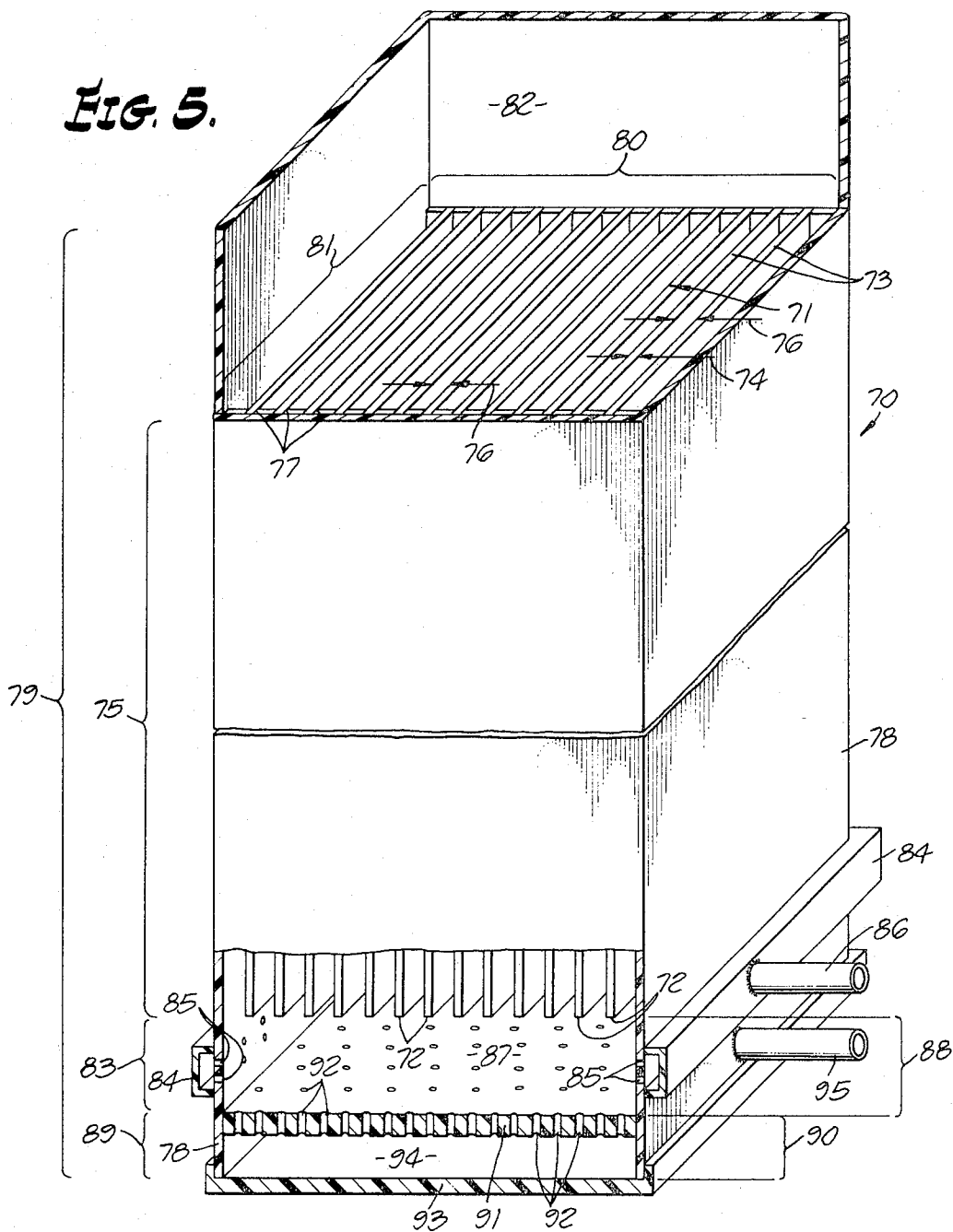


FIG. 6.

TWO-PHASE FLUID FLOW GUIDE FOR BLOOD OXYGENATOR

CROSS REFERENCES TO RELATED APPLICATIONS

This application is related to my copending application entitled Blood Oxygenator and Thermoregulator Apparatus filed Aug. 26, 1971, Ser. No. 175,182. This apparatus is also related to my copending application entitled Blood Oxygenator Flow Guide filed Nov. 11, 1971, Ser. No. 196,458.

BACKGROUND OF THE INVENTION

Blood oxygenators useful in extra-corporeal treatment of patient's blood are classified in Class 23, Subclass 258.5. The improvement taught in this invention is so classified.

Reference is made to my earlier application, Ser. No. 175,182 for a description of the typical blood oxygenator to which this invention can be applied.

The two-phase fluid flow guide of this invention can be usefully applied to other blood oxygenators in Class 23, Subclass 258.5.

SUMMARY OF THE INVENTION

The two-phase fluid flow guide of this invention accepts venous patient blood circulating extra-corporeally. A two-phase flow of venous patient blood and oxygenating gas bubbles is initially formed and circulated up through the blood oxygenator fluid flow guide. The two-phase fluid flow guide has a multiplicity of fluid guide solid walls of equal lengths, one wall uniformly closely spaced from another wall, the walls disposed in a boundary case. Each one of the fluid guide solid walls has a base terminus and a top terminus. A wall terminus means secures the multiplicity of fluid guide solid walls in a uniform base terminus position and a uniform top terminus position in the boundary case. The boundary case can have a case length which is at least equal to the fluid guide wall length. The boundary case can extend above the top terminus of the flow guide, providing a defoaming volume. The boundary case can also extend below the base terminus of the flow guide, forming a portion of a means providing a patient blood inlet container. A further boundary case extension below the base terminus can also form a means providing oxygenating gas injection into the patient circulating blood. The multiplicity of fluid guide solid walls can each have uniform cross section flow control channels disposed on the walls normal to the base terminus and top terminus which provide additional wall area useful in stabilizing the upward flow of the two-phase combination of liquid blood and oxygenating gas bubbles. The multiple channel walls provide additional stabilizing wall areas for the two-phase flow.

Included in the objects of this invention are:

To provide a simple, accurately aligned, easily assembled blood oxygenator two-phase fluid flow guide.

To provide a blood oxygenator two-phase fluid flow guide efficient in the gas exchange process, minimizing damage to formed blood elements.

To provide a blood oxygenator flow guide providing a large surface/volume ratio of gas phase to blood phase, minimizing coalescence of oxygenating gas bubbles during its operation.

Other objects and advantages of this invention are taught in the following description and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The description of this invention is to be read in conjunction with the following drawings:

FIG. 1 is an elevational perspective partial sectional view of the two-phase fluid flow guide for a blood oxygenator.

FIG. 2 is a cross sectional view of a flow guide tube through 2—2 of FIG. 1.

FIG. 3 is an enlarged sectional partial view of another flow guide tube modification, shown in a cross sectional view similar to that of FIG. 2.

FIG. 4 is a fragmentary cross sectional view illustrating the cross sectional geometry of another flow guide tube which can be usefully employed in the con-centric configurations similar to FIGS. 1 and 2.

FIG. 5 is an elevational, perspective partial sectional view of another modification of the blood oxygenator two-phase fluid flow guide of this invention.

FIG. 6 is still another cross sectional view illustrating the cross sectional geometry of a fluid guide plate wall modification useful in this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the elevational perspective partial sectional view of FIG. 1, together with the cross sectional view of FIG. 2, the fluid flow guide 10 has a multiplicity of fluid guide tubes 11 concentrically coaxially disposed therein. The multiplicity of fluid guide tubes 11 can be the number of tubes 11 required to provide the necessary blood oxygenation rate at the required extra-corporeal blood circulation rate of flow required for the specific surgical procedure.

FIG. 1 illustrates the base terminus 12 of the fluid guide tubes 11 have a uniform position, and the top terminus 13 of the guide tubes 11 also have a uniform top terminus. Typically, each single fluid guide tube 11 has a tube wall thickness 14 which can typically be 0.010 to 0.030 inches. A uniform spacing 17 between each tube 11 is required, for uniform closely spaced alignment of the concentric tubes 11. Each single fluid guide tube 11 has a tube length 15 which can typically range from 4 to 24 inches. Each concentric fluid guide tube in the multiplicity of tubes 11 has an exterior tube diameter 16 whose numerical value is fixed to provide the uniform annular spacing 17 between concentric neighboring tubes in the multiplicity of tubes 11. The numerical value of the uniform annular spacing 17 can typically range from one-sixteenth to one-fourth inches, the value of 17 being selected to provide optimum two-phase flow for a specific range of blood and oxygenating gas flow rates.

A pair of tube terminus means 18 and 19 provide uniformly spaced securing means for the multiplicity of concentric fluid guide tubes 11. The tube base terminus means 18, shown in cross sectional view, provides a securing means for the base terminus 12 of each of the multiplicity of guide tubes 11. Alternately angularly spaced tube terminus means securing ribs 37 are shown as a part of the top terminus means 19. Similar ribs 38 form a component of the sectional illustration of the tube terminus means 18 at the base terminus of the tube 11. Each of the tube terminus means 18 and 19 secure the multiplicity of fluid guide tubes 11 in annular alignment, and the tube terminus means 18 and 19 are in turn secured to the boundary case 20, as by cement-

ing or other forms of sealing. The boundary case 20 has a boundary case length 21 and a boundary case inner diameter 22. A blood defoaming volume 23 extends above the tube top terminus 19, inside the boundary case 20. A means 24 provides a blood inlet container, having a blood inlet manifold ring channel 25 encircling the boundary case 20 and integrally secured to the case 20. Multiple blood inlet apertures 26 are normally disposed in the boundary case 20. A blood inlet conduit 27 conducts venous blood from the patient into the ring channel 25, which in turn conducts blood through the multiple inlet aperture 26, into the blood inlet container volume 28. The boundary case extension 29 provides the case extension for the means 24. The combination of the conduit 27, the ring channel 25 secured to the boundary case 20 and the multiple apertures 26 disposed in case 20, provide an advance in the art of smoothly conducting venous blood in an oxygenator, without introducing marked turbulence. Further, the multiple apertures 26 provide a numerical safety factor, in the event one aperture becomes plugged.

A means 30 provides oxygenating gas bubble injection into the blood flowing into the means 24. The boundary case extension 31 for the means 30 has a gas injection manifold plate 32 disposed normally to the cylindrical axis of the boundary case 20. Multiple gas injection apertures 33 normally penetrate the manifold plate 32. A closure 34 seals the base 39 of the boundary case 20 providing a gas injection container 35 which is conductively fed by the gas inlet conduit 36.

FIGS. 3 and 4 represent in cross sectional views separate tubular portions of other guide tubes, which provide additional tubular surface area as uniform flow control channels. Referring to FIG. 3 in detail, the sectional partial view of the tube 50 has an average radius 51 which extends to the center of the total wall thickness 52 of the tube. A multiplicity of rectangular cross section channels 53 are shown, each having a channel width 54 and a channel depth 55. The multiple channels 53 are alternatively disposed on opposed sides of the tube wall thickness 52, providing multiple shallow flow control channels which can guide the two-phase flow of blood and oxygenating gas through the oxygenator.

FIG. 4 illustrates in detail a tubular portion of the cross section of the fluid guide tube 60, having an average tube radius 61 and a tube wall thickness 62. Uniform semi-circular corrugations 63 are disposed on the tube wall, each corrugation having a corrugation diameter 64. Thus the multiple corrugations 63 provide increased surface and channels for the guide tube 60, stabilizing the upward two-phase flow of blood and oxygenating gas bubbles.

In general, the coaxially concentric fluid guide tubes can be uniformly and accurately manufactured in tubular dimension by an extrusion process utilizing thermoplastic compositions compatible with blood. The tubes can be right cylinders with straight walls or they can be extruded with uniform rectangular channels or uniform corrugations providing flow control channels therein. These extrusions can be easily cut to a uniform length dimension, aligned and secured in the base tube terminus means 18 and the top tube terminus means 19. Well known sealing techniques provide quickly assembled, relatively inexpensive fluid guide tubes secured in a boundary case.

FIG. 5 illustrates another fluid flow guide 70, having a multiplicity of fluid guide plate walls 71 of uniform plate wall lengths 75. The multiplicity of fluid guide plate walls 71 are uniformly closely spaced parallel one wall to another wall, with the uniform spacing 76 between single plate walls. The multiplicity of plate walls 71 have a uniform base terminus 72 and a uniform top terminus 73. The multiplicity of wall terminus means 77, each one securing one of the plate walls 71, can be close fitting recesses 77 provided in the boundary case 78. The boundary case 78 has a boundary case length 79 together with a boundary case width 80 and a boundary case depth 81. A blood defoamer volume 82 is provided inside the boundary case 78 which extends above the top terminus 73 of the plate walls.

A means 83 provides a blood inlet container volume 87. A blood inlet manifold ring channel 84 circumscribes the boundary case 78, and multiple blood inlet apertures 85 are provided in the boundary case 78 enclosed by the ring channel 84. Blood flows through the inlet conduit 86, through the ring channel 84, and then through the multiple inlet apertures 85 into the blood inlet container volume 87, secured in the boundary case extension 88. A means 89 provides oxygenating gas injection into the blood inlet container volume 87. The boundary case extension 90 secures a gas injection manifold plate 91 which has multiple gas injection apertures 92 normally disposed through the manifold plate 91. The gas inlet conduit 95 secured to the boundary case 78 provides for conductively injecting oxygenating gas into the gas injection volume 94 which is disposed between the gas manifold plate 91 and the case closure 93. Thus oxygenating gas passes from the gas injection volume 94 through the multiple gas injection apertures 92 into the blood flowing through the blood inlet container volume 87, forming a two-phase flow of oxygenating gas bubbles and fluid blood which are displaced upward through the channels 76 formed by the multiplicity of fluid guide plate walls 71.

FIG. 6 illustrates in detail a corrugated fluid guide plate wall 100 having a wall plate depth 101 equivalent to 81, and a wall plate thickness 102. The wall plate corrugations 103 illustrated are semicircular, having circular diameters 104. Thus when the multiplicity of fluid guide plate walls 100, have uniform spacings equivalent to 76 between the plate walls, the two-phase fluid flow is stabilized in the corrugated channels. The fluid guide plate walls can likewise have rectangular channels disposed therein equivalent in cross section to the rectangular channels illustrated in the cross sectional view of FIG. 4. In my earlier copending application, filed Aug. 26, 1971, Ser. No. 175,182 and in my further copending application, filed Nov. 11, 1971, Ser. No. 196,458 I have discussed in detail the importance of wall area in stabilizing two-phase flow of blood and oxygenating gas bubbles. The earlier teachings are incorporated herein by reference.

The uniform spacing 17 or the like between coaxially concentric fluid guide tubes 11, together with the uniform spacing 76 between the multiplicity of fluid guide plate walls 71 are those numerical values required to provide stabilized two-phase flow. Typically 17 and 76 can range in values from one-tenth to five-sixteenths inch. The precise dimensions of the rectangular flow control channels 53, the corrugations 63, and the corrugations 103 are those values which are required to suitably stabilize the two-phase flow of blood and oxy-

generating gas in the fluid guides, and minimize gas bubble coalescence.

The wall terminus means securing the fluid guide walls can typically be a spider terminus, such as 18 and 19, or it can be a wall recess such as 77, or the like. Typically the wall terminus means secures the solid guide walls in the boundary case without impeding the flow of the two-phase combination of oxygenating gas and blood.

The flow control channels can be disposed on one or both faces of a fluid guide wall, as are required by the necessary flow rates of oxygenating gas and blood.

The blood flow rate required in an extra-corporeal circulating system can be supplied in a specific blood oxygenator fluid flow guide by providing the number of fluid guide solid walls in a boundary case sufficient to assure the required rate of oxygenation of the blood and necessary release of carbon dioxide from the patient's blood. Typically, the blood flow rate can vary from 500 ml/min to 7,500 ml/min. The oxygenating gas flow rate can vary from 1 to 4 times the blood flow rate. Typically the initial oxygenating gas contains 98 percent oxygen and 2 percent carbon dioxide.

For the patient's safety it is necessary that the chemical composition and the physical structure of the components in the two-phase fluid flow guides be compatible with the patient's circulating blood, preventing clotting and the like damage. The mechanical structure of the flow guide components can be selected from rigid polyvinyl chloride, high density polyethylene, polypropylene, polycarbonate, and other rigid plastic compositions which meet the required chemical and physical compatibility requirements. The apparatus of this invention can be quickly, reliably and accurately assembled from injection molded component parts, requiring a minimum of labor. The concentric coaxially disposed fluid guide tubes and the fluid guide plate walls, having multiple uniform corrugation, or alternatively, uniform multiple rectangular channels disposed therein, provide for a multiplicity of uniform flow control channels in a relatively small number of components which are required to be assembled in a two-phase fluid flow guide apparatus.

In operation the two-phase flow of blood and oxygenating gas, formed in the blood inlet chamber, flow upward through the fluid flow guide as earlier described, the blood absorbing oxygen and concurrently evolving carbon dioxide, which diffuses into the exiting gas bubble. After oxygenation is completed at the top of the fluid guide, the blood foam is then separated in a defoaming chamber, freeing the fluid blood from entrained gas bubbles.

Many modifications and variations in the improvement in the blood oxygenator two-phase fluid flow guide can be made in the light of my teachings. It is therefore understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

I claim:

1. An extra-corporeal blood oxygenator fluid flow guide suitable for exchanging oxygen for carbon dioxide in patient circulating blood, comprising in combination:

a multiplicity of fluid guide solid walls of equal length, each one of said solid walls uniformly closely cooperatively spaced adjacent to another said solid wall, each one of said wall lengths having

a base terminus and a top terminus, said fluid guide solid walls having multiple, uniform cross section, flow control channels disposed on said solid wall, said multiple channels aligned normal to said base terminus and said top terminus of said wall,

wall terminus means securing said multiplicity of fluid guide solid walls in a uniform base terminus position and a uniform top terminus position, a boundary case securing said multiplicity of fluid guide walls and said wall terminus means, said boundary case having a case length at least equal to said fluid guide wall lengths,

means providing a single common patient blood inlet container, said means disposed conductively adjacent to said base terminus of said multiplicity of fluid guide walls, and

means providing oxygenating gas bubble injection, said means providing oxygenating gas bubble injection into said patient blood disposed in said blood inlet container,

whereby said fluid flow guide provides wall stabilized two-phase flow of oxygenating gas bubbles and blood from said fluid guide wall base terminus to said fluid guide wall top terminus.

2. A combination as set forth in claim 1 wherein said flow control channels have semi-circular cross-sections, whose diameters range from one-eighth to five-sixteenths inch.

3. A combination as set forth in claim 1 wherein said flow control channels have alternatively reversed semi-circular corrugation cross sections, whose diameters range from one-eighth to five-sixteenths inch.

4. A combination as set forth in claim 1 wherein each said flow control channel has a rectangular cross section ranging from a channel width value of one-eighth to five-sixteenths inch and a channel depth value ranging from one-sixteenth to five thirty-seconds inch.

5. An extra-corporeal blood oxygenator fluid flow guide suitable for exchanging oxygen for carbon dioxide in patient circulating blood, comprising in combination:

a multiplicity of fluid guide solid plate walls of equal length, one wall uniformly closely spaced parallel to another wall, each one of said plate wall lengths having a base terminus and a top terminus,

wall terminus means securing said multiplicity of fluid guide plate walls in a uniform base terminus position and a uniform top terminus position,

a boundary case securing said multiplicity of fluid guide plate walls and said wall terminus means, said boundary case having a case length at least equal to said fluid guide wall lengths,

means providing a single common patient blood inlet container, said means disposed conductively adjacent to said base terminus of said multiplicity of fluid guide plate walls, and

means providing oxygenating gas bubble injection, said means providing oxygenating gas bubble injection into said patient blood disposed in said blood inlet container,

whereby said fluid flow guide provides wall stabilized two-phase flow of oxygenating gas bubbles and blood from said fluid guide plate base terminus to said fluid guide plate top terminus.

6. A combination as set forth in claim 6 wherein said fluid guide solid plate walls have multiple, uniform cross section, flow control channels disposed on said

solid wall, said multiple channels aligned normal to said base terminus and said top terminus of said wall.

7. A combination as set forth in claim 6 wherein said flow control channels have semi-circular cross sections, whose diameters range from one-eighth to five-sixteenths inch. 5

8. A combination as set forth in claim 6 wherein said flow control channels have alternatively reversed semi-circular corrugations cross sections, whose diameters range from one-eighth to five-sixteenths inch. 10

9. A combination as set forth in claim 6 wherein each said flow control channel has a rectangular cross section ranging from a channel width value of one-eighth to five-sixteenths inch and a channel depth value ranging from one-sixteenth to five thirty-seconds inch. 15

10. An extra-corporeal blood oxygenator flow guide suitable for exchanging oxygen for carbon dioxide in patient circulating blood, comprising in combination:

a multiplicity of fluid guide tubes having thin solid walls and selected tube diameters, said tubes selected and disposed to provide uniform closely annularly spaced cylindrically concentric tubes of equal length, each one of said tubes having a base terminus and a top terminus, 20

tube terminus means securing said multiplicity of fluid guide tubes in a uniform base terminus position and a uniform top terminus position, 25

a boundary case securing said multiplicity of fluid guide tubes and said tube terminus means, said boundary case having a case length at least equal to said fluid guide tube length, 30

means providing a single common patient blood inlet

container, said means disposed conductively adjacent to said base terminus of said multiplicity of fluid guide tubes, and

means providing oxygenating gas injection, said means providing oxygenating gas bubble injection into said patient blood disposed in said blood inlet container,

whereby said fluid guide provides wall stabilized two-phase flow of oxygenating gas and blood from said fluid guide tube base terminus to said fluid guide tube top terminus.

11. A combination as set forth in claim 10 wherein said solid walls of said fluid guide tubes have multiple uniform cross section, flow control channels disposed on said solid wall, said multiple channels aligned normal to said base terminus and said top terminus of said wall. 15

12. A combination as set forth in claim 11 wherein said flow control channels have semi-circular cross sections, whose diameters range from one-eighth to five-sixteenths inch. 20

13. A combination as set forth in claim 11 wherein said flow control channels have alternatively reversed semi-circular corrugations cross sections, whose diameters range from one-eighth to five-sixteenths inch. 25

14. A combination as set forth in claim 11 wherein each said flow control channel has a rectangular cross section ranging from a channel width value of one-eighth to five-sixteenths inch and a channel depth value ranging from one-sixteenth to five thirty-seconds inch. 30

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