

April 26, 1960

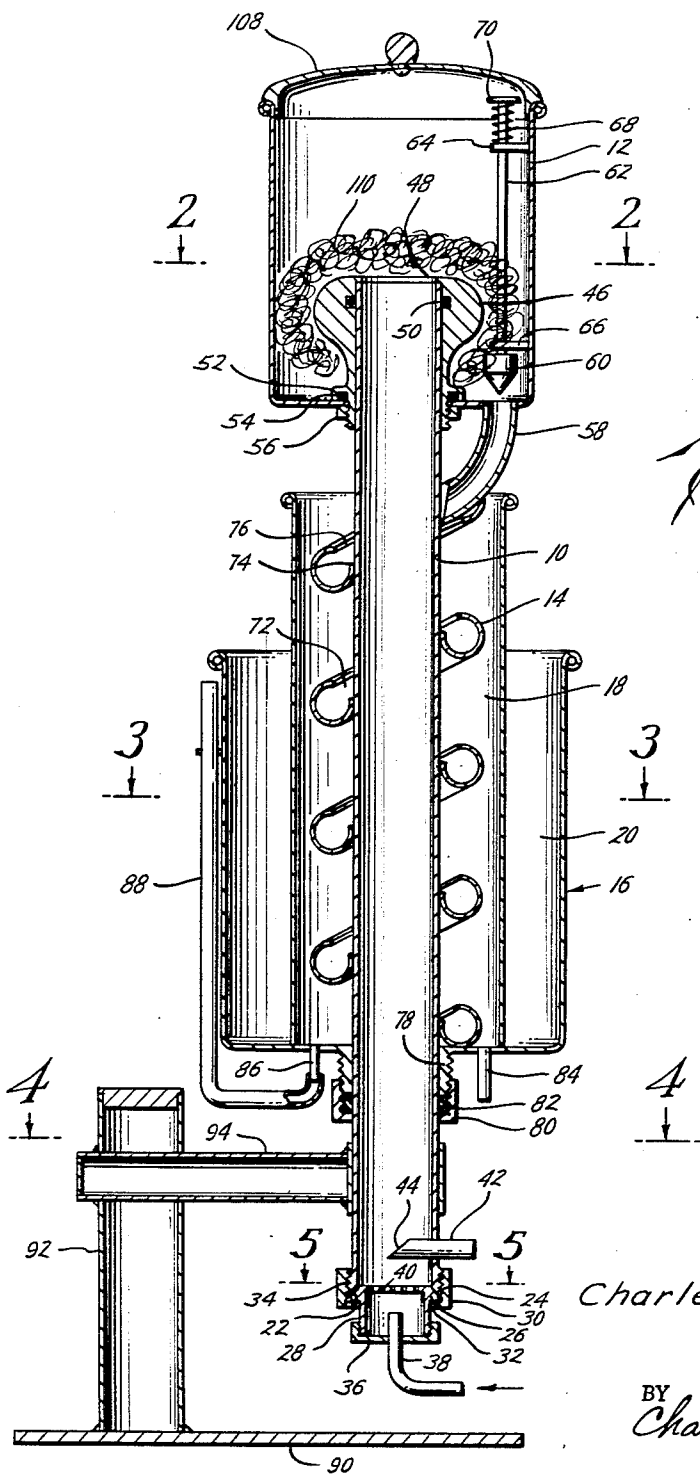
C. L. CALVIN

2,934,067

BLOOD OXYGENATING APPARATUS

Filed Sept. 12, 1957

2 Sheets-Sheet 1



Charles L. Calvin
INVENTOR.

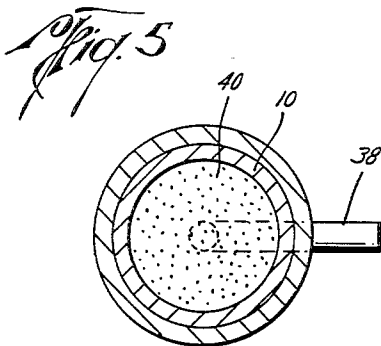
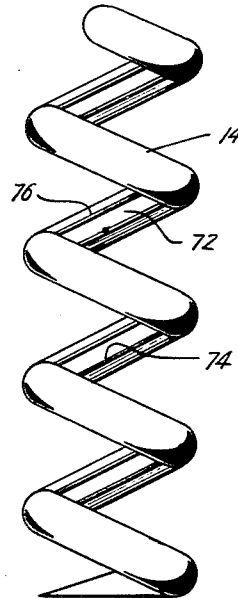
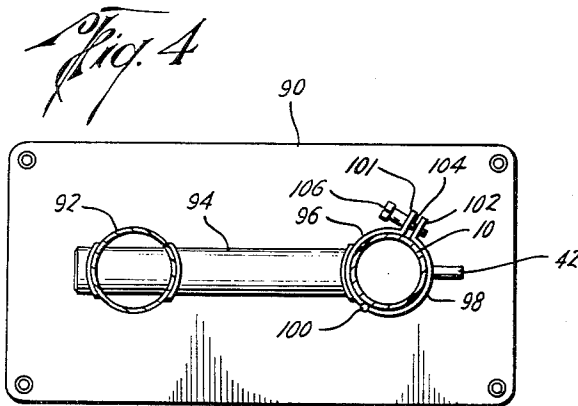
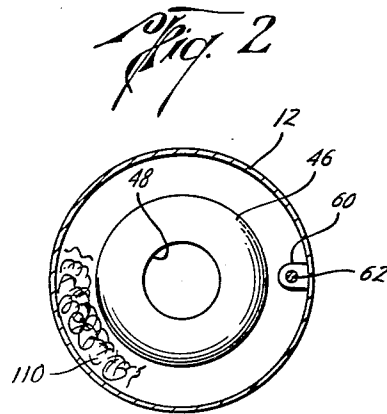
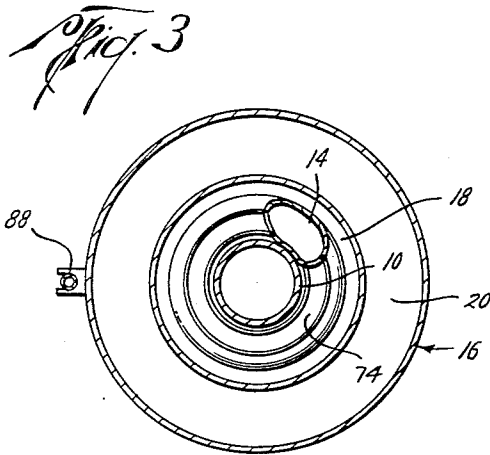
BY
Charles E. Lightfoot
ATTORNEY

2,934,067

BLOOD OXYGENATING APPARATUS

Filed Sept. 12, 1957

2 Sheets-Sheet 2



Charles L. Calvin
INVENTOR.

BY
Charles E. Lightfoot
ATTORNEY

1

2,934,067

BLOOD OXYGENATING APPARATUS

Charles L. Calvin, Houston, Tex.

Application September 12, 1957, Serial No. 683,484

4 Claims. (Cl. 128-214)

This invention relates to blood oxygenating apparatus and more particularly to apparatus for oxygenating blood which has been removed from a patient to condition the blood for recirculation through the patient's body.

The invention finds particular application in connection with the extracorporeal circulation of the blood for cardiopulmonary by-pass in the surgical treatment of cardiovascular disease. In the treatment of cardiovascular disease by surgical methods it has been found necessary in many cases to stop the normal functioning of the patient's heart and lungs for substantial periods of time while providing for extracorporeal circulation and oxygenation of the blood whereby the patient is kept alive during the operation and until the normal functioning of the heart and lungs can be restored.

Heretofore blood oxygenating apparatus of the bubble diffusion type employing plastic tubing and including a diffusion cylinder, defoaming chamber and helical coil in conjunction with a collection chamber, has been successfully employed for the extracorporeal circulation of the blood in the surgical treatment of cardiovascular disease, but apparatus of this kind is subject to the disadvantage that it cannot be satisfactorily sterilized by the usual methods and is too expensive for disposable use. Moreover, the assembling and placing of such apparatus in working condition before each operation is a difficult and time consuming task.

The present invention has for an important object the overcoming of the above mentioned disadvantages by the provision of blood oxygenating apparatus whose principle parts may be fabricated of stainless steel or the like, and which are constructed to be readily assembled and disassembled, whereby the same may be easily cleaned and sterilized by ordinary methods.

Another object of the invention is to provide blood oxygenating apparatus of compact construction which may be sterilized as a unit in an assembled condition, so that it may be placed in operation without handling and without danger of becoming contaminated during the connecting up of the apparatus.

A further object of the invention is the provision of blood oxygenating apparatus which is constructed to permit rapid and complete oxygenation of the blood without breaking or damaging the blood cells, and effectively remove bubbles of gas from the oxygenated blood whereby the formation of bubbles in the circulatory system of the patient is prevented.

A still further object of the invention is to provide blood oxygenating apparatus of the kind referred to which is of simple design and rugged construction capable of withstanding the conditions of hard usage due to repeated assembling, disassembling and sterilizing to which equipment of this character is subjected.

The above and other important objects and advantages of the invention may best be understood from the following detailed description, constituting a specification of the same when considered in conjunction with the annexed drawings, wherein—

2

Figure 1 is a vertical, central cross-sectional view of a preferred embodiment of the invention;

Figure 2 is a cross-sectional view, taken along the line 2-2 of Figure 1, looking in the direction indicated by the arrows;

Figure 3 is a cross-sectional view, taken along the line 3-3 of Figure 1, looking in the direction indicated by the arrows;

Figure 4 is a cross-sectional view, taken along the line 4-4 of Figure 1, looking in the direction indicated by the arrows;

Figure 5 is a cross-sectional view, taken along the line 5-5 of Figure 1, looking in the direction indicated by the arrows; and

Figure 6 is a side elevational view of the helical coil of the invention shown separated from the other parts of the apparatus.

Referring now to the drawings in greater detail the blood oxygenating apparatus of the invention comprises an inner cylindrical member 10 forming an oxygenating column, an upper receptacle 12 forming a defoaming chamber into which the upper end of the member 10 is extended, a helical trough 14, surrounding the member 10 beneath the receptacle 12, whose upper end is positioned to receive the oxygenated blood from the receptacle, and a lower receptacle, generally indicated at 16, through which the member 10 passes concentrically and having an inner blood collecting chamber 18 into which the helical trough 14 opens at its lower end and an outer chamber 20, surrounding the inner chamber and forming a jacket for the reception of a heating medium by which the collected oxygenated blood may be maintained at substantially constant temperature.

The cylindrical member 10 has a bevelled end face 22 at its lower end, for engagement with an annular bevelled face 24 of an external annular flange 26, provided on a diffusion plate member 28, of tubular shape, positioned on the lower end of the member 10 and retained thereon by an annular coupling member 30, having an internal annular lower end flange 32, engageable beneath the external flange 26 of the diffusion plate member, and which is internally threaded, as indicated at 34 for threadable attachment to the externally threaded lower end portion of the cylindrical member. The lower end of the diffusion plate member is externally threaded for the connection thereto of a cap 36, having an inlet tube 38 attached thereto which opens into the interior of the diffusion plate member.

The diffusion plate member 28 has an upper end wall 40 forming a diffusion plate, which is provided with numerous tiny openings therethrough through which oxygen may pass from the interior of the diffusion plate member into the cylindrical member 10, to form tiny bubbles in the blood flowing into the oxygenating column. An inlet tube 42 extends laterally through the wall of the cylindrical member 10 near its lower end, through which blood from a patient may flow into the oxygenating column, this tube having a bevelled end 44, positioned above the diffusion plate member in a manner to direct the flow of blood away from the diffusion plate 40 in the diffusion column.

Within the upper receptacle 12 the cylindrical member 10 has a cap 46 surrounding the upper or discharge end of the oxygenating column, which cap has an internal annular upper end flange 48, overlying the upper end face of the cylindrical member, and which flange has an internal diameter which is substantially equal to the internal diameter of the cylindrical member, to provide a smooth surface at the discharge end of the oxygenating column through which the blood may flow. The cap 46 has a rounded external annular surface, surrounding the upper end portion of the cylindrical member 10, to

provide a smooth surface over which blood discharged from the upper end of the oxygenating column may flow. Suitable sealing means, such as an O-ring, indicated at 50, is provided in the cap 46 in an internal groove provided therefor, to form a seal between the exterior of the cylindrical member 10 and the cap. The cap 46 extends through the bottom of the receptacle 12 in surrounding relation to the cylindrical member 10 and is provided with an external annular flange 52, positioned within and seated on the bottom of the receptacle. Suitable packing means, such as an O-ring 54 is provided in the lower surface of the flange 52, in an annular groove provided therefor to form a seal between the flange and the bottom of the receptacle. The portion of the cap 46 extending below the receptacle 12 is externally threaded to receive a nut 56, which may be tightened to securely hold the cap in place.

The helical trough 14 surrounding the cylindrical member 10 within the chamber 18 of the lower receptacle, and the upper receptacle is provided with a discharge spout 58, leading from the bottom of the receptacle and whose lower end fits into the upper end of the trough 14 to conduct blood from the upper receptacle into the trough. Within the upper receptacle a valve 60 is movably positioned for vertical movement into and out of closing contact with the upper end of the discharge spout 58. The valve 60 is attached to a stem 62, which moves vertically through guides 64 and 66, the valve being yieldably held in open position by a coil spring 68, surrounding the stem 62, and which bears at its lower end on the guide 64 and at its upper end on a push button 70 on the upper end of the stem. By this arrangement the valve 60 may be held closed by pressure exerted on the push button 70, and will move to open position as soon as the push button is released.

The helical trough is of generally circular shape in cross-section, and is provided with an opening 72 in the form of a slot extending from end to end of the helix and positioned along the upper inner portion of each of the turns of the helix. By this arrangement the trough is shaped to prevent the overflow of blood flowing downwardly through the trough due to centrifugal force while at the same time the interior of the trough is easily accessible through the slot for the purpose of cleaning the same. It is to be noted that the inner edge 74 of the opening of the trough 14 is substantially in contact with the external surface of the cylindrical member 10 throughout the length of the helix, when the trough is in position on the member in the chamber 18, while the outer edge 76 of the opening of the trough is spaced radially away from the external wall of the cylindrical member 10 and is located above the inner edge 74 throughout the length of the helix.

The cylindrical member 10 passes through the bottom of the lower receptacle 16 through a stuffing box formed by an annular, downwardly projecting, externally threaded member 78 attached to the receptacle and an annular internally threaded member 80 threadably connected thereto. Suitable packing, such as that indicated at 82, is provided between the members 78 and 80 within the stuffing box to form a seal between the cylindrical member 10 and the lower receptacle.

The lower receptacle has a discharge outlet 84 from the bottom of the inner chamber 18, through which blood may flow back to the patient. An outlet 86 is also provided from the bottom of the inner chamber 18, to which a liquid level indicating tube 88, preferably formed of transparent plastic material, is connected, which tube extends upwardly along the outside of the receptacle, and is open at its upper end.

The apparatus is conveniently supported on a standard having a flat base 90, from which an upright 92 extends, which is provided with a support arm 94, whose outer end carries a hinged clamp formed in two semi-cylindrical sections 96 and 98 connected together at one

end by a hinge 100, and whose other ends are formed with perforated extensions 101 and 102, through which a screw bolt 104 may be extended having thumb nut 106 thereon, whereby sections of the clamp may be clamped about the lower portion of the cylindrical member 10, to support the apparatus in an upright position above the base plate.

The upper receptacle 12 may have a removable cover 108 provided thereon.

All of the parts of the apparatus, constructed as described above, with the exception of the packing elements and the liquid level indicating tube 88, may be formed of a relatively durable material, such as stainless steel, which may be readily sterilized, and which is easily cleaned.

In making use of the apparatus, constructed and arranged as described above, the parts which have been thoroughly cleaned may be assembled in the manner shown in Figure 1, and a mass of stainless steel wool 110 which has been coated with a suitable antifoam material, as by spraying with a composition containing a silicone such as that commonly known as Dow-Corning antifoam A, is placed in the upper receptacle about the cap 46 therein in a position such that blood flowing out of the upper discharge end of the oxygenating coil may flow downwardly through the steel wool. The entire apparatus with the plastic tube 88 removed may then be suitably sterilized as by subjecting the same to heat in an autoclave. When the apparatus has thus been sterilized it may be carried by the supporting stand to the location where it is to be used without touching the apparatus. The liquid level tube 88 may then be attached to the outlet 86, the inlet tube 42 may be connected to suitable apparatus by which blood is withdrawn from the patient and supplied to the oxygenating column, the outlet 84 may be connected to suitable apparatus whereby oxygenated blood is returned to the patient and the oxygen inlet tube 38 may be connected to a source of oxygen under pressure.

Prior to placing the apparatus in use saline solution at a temperature of approximately 112° F. may be poured into the apparatus to fill the same to warm the entire oxygenator and maintain the temperature of the blood during oxygenation of the same. Before supplying the apparatus with blood the rate of outflow from the apparatus is adjusted or calibrated by circulating the saline solution through the apparatus, the valve 60 being held closed for a predetermined length of time while reading the fall in the level of the liquid indicated by the indicator tube 88, and the restoration of the level of the liquid after the valve has been allowed to open. With the oxygenating column, upper receptacle, helical tray and inner collecting chamber 18 emptied of saline solution, fresh heparinized warm blood maintained at body temperature is used to prime the system by filling the oxygenating column and the inner chamber 18. Blood from the patient is then pumped into the oxygenating column through the inlet pipe 42 while oxygen is admitted into the oxygen inlet pipe at a rate of about ten times the calculated rate of flow of the blood while blood from the inner chamber 18 is returned to the patient through the outlet 84. As the blood from the patient flows into the lower end portion of the oxygenating column oxygen is admitted to the lower end of the column through the numerous tiny perforations in the diffusion plate 40 to form tiny bubbles which pass upwardly with the blood to flow into the upper receptacle. During the oxygenation of the blood in this manner foaming of the blood takes place, which is carried into the upper receptacle. The blood then flows downwardly through the mass of steel wool 110 whereby defoaming of the blood takes place without breaking or damaging the blood cells. The blood then passes downwardly from the bottom of the upper receptacle through the spout 58 into the helical trough 14, any entrained gas in the blood escaping during the

5

downflow of the blood through the trough, such further removal of entrained oxygen being aided by the centrifugal force exerted on the blood during the downflow through the helical trough. The defoamed oxygenated blood is collected in the inner chamber 13 and is then re-circulated to the patient through the outlet 84. It will be apparent that due to the shape of the trough 14 and the position of the opening 72 of the trough, the blood may readily flow downwardly through the trough and is prevented from overflowing the trough under the influence of the centrifugal force as the blood flows about the turns of the helix.

The apparatus may be maintained at constant temperature during its operation by suitable heating means positioned in the outer chamber 20, which may take the form of an electrical heating coil, not shown, or other convenient heating media.

It will thus be seen that the invention, constructed and operated in the manner described above, provides blood oxygenating apparatus having parts which may be completely disassembled and easily cleaned, which are easily sterilized by usual methods without injury, and which may be sterilized in an assembled condition thus eliminating danger of contamination by handling of the apparatus prior to placing the same in use.

While the invention has been disclosed herein in connection with a certain specific embodiment of the same it will be understood that this is intended by way of illustration only, and that various changes can be made in the construction and arrangement of the parts within the spirit of the invention and the scope of the appended claims.

Having thus clearly shown and described the invention, what is claimed as new and desired to secure by Letters Patent is:

1. Blood oxygenating apparatus comprising an upright tubular member forming an oxygenating column having an inlet, means for introducing oxygen under pressure into said member below said inlet, means forming an upper chamber into which the member opens above said inlet and having an outlet, a trough-like element of helical shape opening upwardly throughout its length surrounding the member below said upper chamber and in communication at its upper end with said outlet and means forming a lower chamber in communication with the lower end of said element.

2. Blood oxygenating apparatus comprising an upright tubular member forming an oxygenating column having an inlet, means for introducing oxygen under pressure into said member below said inlet, means forming an upper chamber into which the member opens at its upper end and having an outlet below said upper end, defoaming material positioned in the path of flow of fluid from said upper end to said outlet, a trough-like element of helical shape opening upwardly throughout its length

6

surrounding the member below said upper chamber and in communication at its upper end with said outlet and means forming a lower chamber into which said element opens at its lower end.

3. Blood oxygenating apparatus comprising an upright tubular member forming an oxygenating column having an inlet located below its upper end, means for introducing oxygen under pressure into the member below said inlet, means forming an upper chamber into which the upper end portion of the member extends and having an outlet below the upper end of the member, means forming a lower chamber below said upper chamber, a hollow element of helical shape in the lower chamber in communication at its upper end with said outlet and whose lower end opens into said lower chamber, said element having an upwardly opening slot extending from end to end thereof and whose outer edge is spaced radially outwardly from and above the inner edge of the slot.

4. Blood oxygenating apparatus comprising an upright tubular member forming an oxygenating column having an inlet adjacent its lower end whose upper end is open, means for introducing oxygen under pressure into said member below said inlet, means forming a chamber into which the upper end portion of said member extends and having an outlet located below the upper end of the member, means surrounding the upper end of said member in said chamber and having a smooth, rounded, external surface over which fluid may flow from said upper end to said outlet, defoaming material in the chamber positioned in the path of flow of fluid from said upper end to said outlet, a hollow element of helical shape surrounding said member below and in communication at its upper end with said outlet and having an upwardly opening slot extending from end to end of the element, the outer edge of said slot being spaced radially outwardly from and above the inner edge thereof and a receptacle positioned to receive fluid from the lower end of said element.

References Cited in the file of this patent

UNITED STATES PATENTS

1,708,029 Pardee ----- Apr. 9, 1929

FOREIGN PATENTS

752,969 Great Britain ----- July 18, 1956

OTHER REFERENCES

Lillehei et al.: "Direct Vision Intercardiac Surgery," Diseases of the Chest, volume 29, No. 1, January 1956, pp. 1-8 (p. 2 relied on). (Available in National Institute of Health Library and Division 55.)

De Wall et al.: "The Helix Reservoir Pump-Oxygenator," Surgery, Gynecology and Obstetrics, volume 104, No. 6, June 1957, pages 699-710 (p. 701 relied on). (Available in Science Library.)