Feb. 15, 1955 J. H. GIBBON, JR., ET AL 2,702,035

OXYGENATING UNIT FOR EXTRACORPOREAL CIRCULATION DEVICES

Original Filed May 28, 1949 2 Sheets-Sheet 1

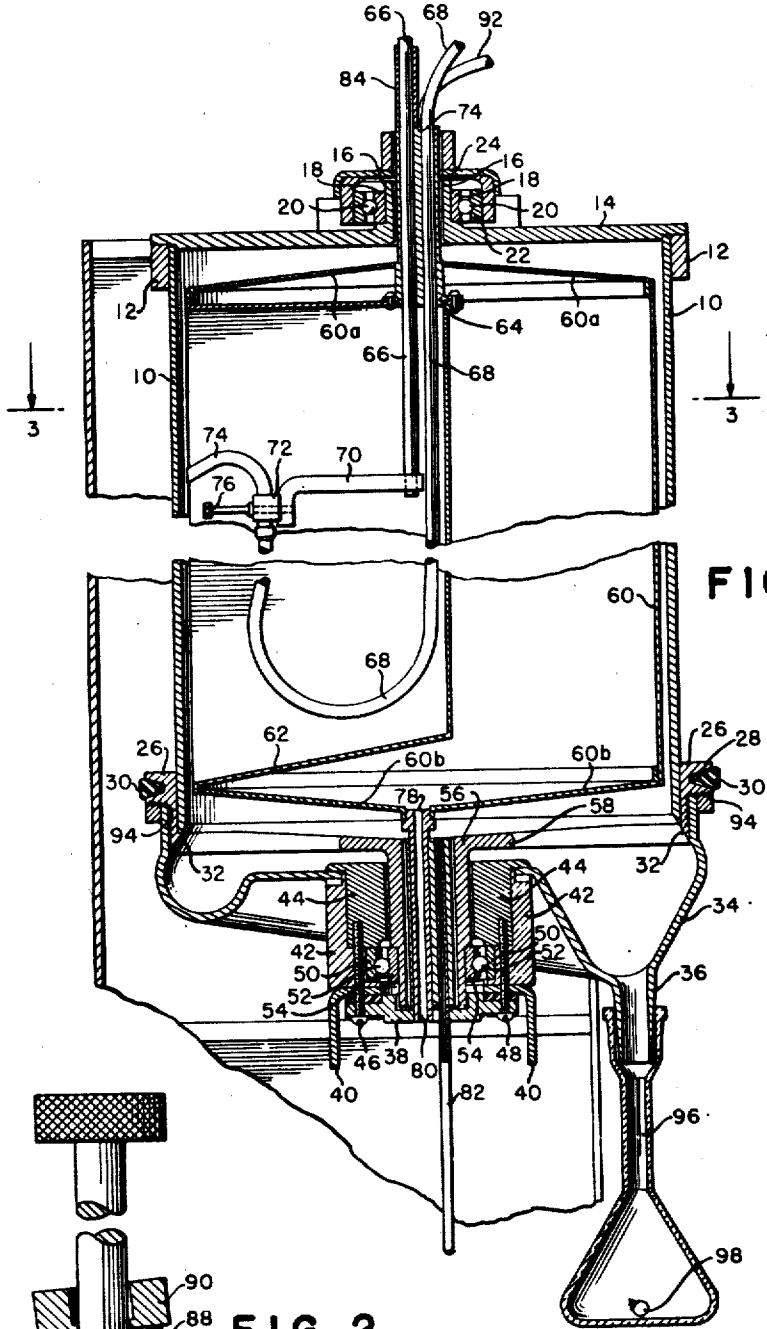


FIG. 1

FIG. 2

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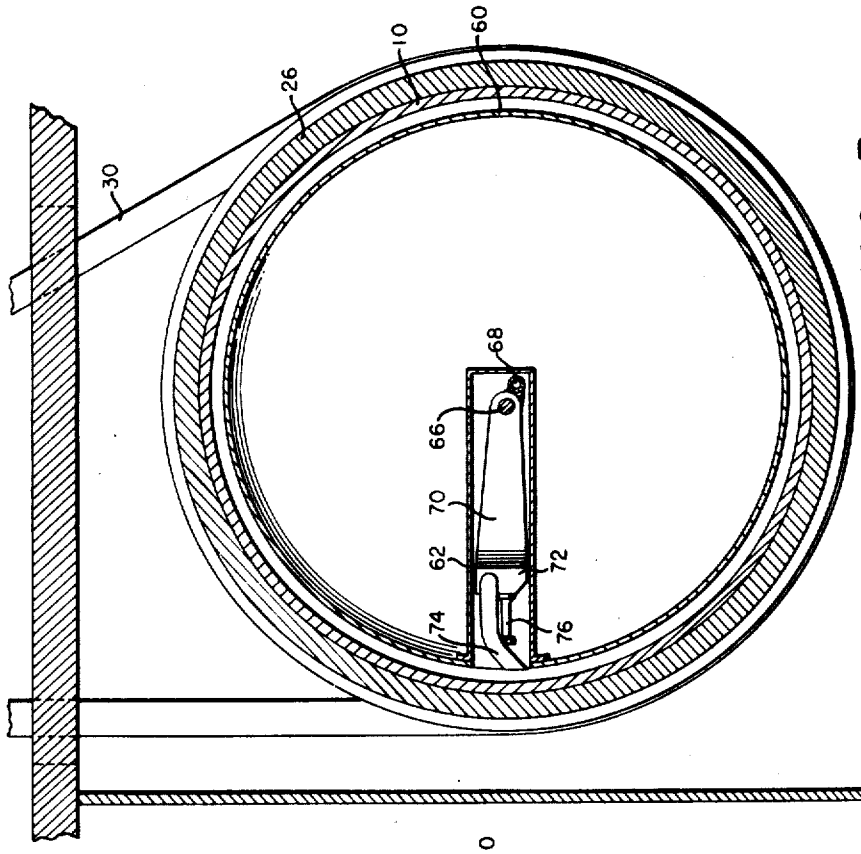


FIG. 3

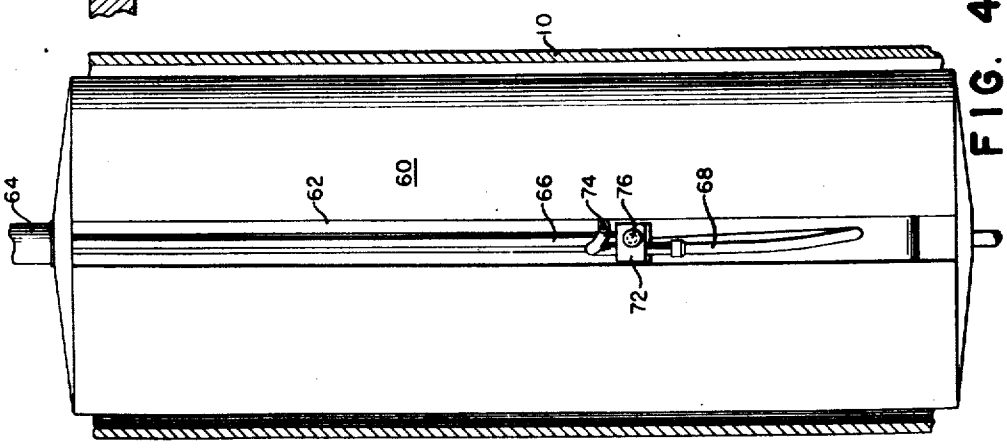


FIG. 4

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OXYGENATING UNIT FOR EXTRACORPOREAL CIRCULATION DEVICES

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Original application May 28, 1949, Serial No. 96,114, now Patent No. 2,659,368, dated November 17, 1953. Divided and this application February 27, 1953, Serial No. 339,244

2 Claims. (Cl. 128—214)

This invention relates to extracorporeal circulation devices and particularly to venous blood oxygenating units adapted for use in extracorporeal circulation devices to temporarily assume the functions of the lungs in a human being or animal.

This application is a division of copending application Serial No. 96,114, filed May 28, 1949, which issued as United States Patent 2,659,368 on November 17, 1953.

Operative procedures upon the heart and its associated vessels could be better performed if the heart was temporarily relieved of its function of pumping blood. If surgical operative procedures are necessary while the heart is pumping blood, the vigorous expansions and contractions of the pulsating member render delicate surgical procedures extremely difficult, if not in many cases practically impossible. Relieving the heart of its normal function of pumping blood, if only for a short period of time, would, of course, relieve many of the attendant surgical operative difficulties. However, in order to maintain life during a temporary cessation of blood flow for an appreciable time, it is necessary to assume the cardiorespiratory functions of the subject by some other means to maintain a life-sustaining flow of blood within the subject's circulatory system.

In general, the concept of extracorporeal circulation devices is old in the art. This invention is directed towards a mechanical blood oxygenating device to approach, if not attain, an equivalent functional replacement for the lungs in the oxygenation of venous blood.

The introduction of oxygen into venous blood in a mechanical device adapted to provide a functional replacement for the lungs is a problem beset by many difficulties. In order to introduce adequate and predetermined amounts of oxygen into venous blood, it is necessary to provide a large surface area for oxygenating purposes and to manipulate the blood thereon in such manner as to form a continuous thin film of blood of controllable surface area to provide high oxygenation efficiency and yet utilize only a small volume of blood at any given instant passing through the oxygenating atmosphere at a relatively high flow rate without any detrimental foaming or bubbling of the blood in its passage through the unit. In every unit of this type a basic and essential operational requirement is the manipulation of the blood in such a manner as to preclude foaming or bubbling thereof and detrimental hemolysis resulting from trauma in passage through the unit.

Another problem attendant the utilization of venous blood oxygenating in extracorporeal circulation devices is the attaining of a continuous, uniform and thin film of blood over the oxygenating surfaces. Rivulet flow of blood over the oxygenating surfaces greatly reduces the available blood surface area and reduces the oxygenation efficiency to negligible amounts.

In all devices of this type there must, in addition, be a simplicity and durability of construction that permits easy and repeated assembly and disassembly operations without damage to critically contoured components which must also be designed to permit easy cleaning and sterilization.

The method utilized in this device for obtaining a large surface area from a small volume of blood is to evenly distribute the blood on the inner surface of a vertical

rotating cylinder. The centrifugal force insures the maintenance of a thin film of blood on the inner surface of the cylinder. The blood passes, under the influence of gravity, downwardly along the inner surface of the rotating cylinder and is collected in a stationary receptacle, into which the lower extremity of the revolving cylinder extends. The presently preferred structure, as illustrated in the drawings, is an improved device, which provides an oxygenating system of large surface-to-volume ratio and oxygenates the venous blood with a minimum of frothing and hemolysis.

The object of this invention is the provision of an improved venous blood oxygenating unit adapted for use in extracorporeal circulation devices.

Referring to the drawings:

Fig. 1 is a side sectional view of the venous blood oxygenating device;

Fig. 2 is a side view, partially in section, of a preferred form of locking clamp;

Fig. 3 is a section on the line 3—3 of Fig. 1; and

Fig. 4 is a side view, partially in section, of a portion of the device illustrated in Fig. 1.

Turning to the drawings, the oxygenating device consists of a vertical rotatable external cylinder **10**, having an upper collar **12** peripherally disposed on the upper extremity of the cylinder. Engaging the collar **12** and serving as an upper mounting member is an upper cover **14**. The upper cover **14** terminates in a centrally disposed vertical sleeve **16**, which serves as a mount for a rotating raceway **18**, which forms a part of the upper bearing **20**. The stationary raceway **22** is mounted on a non-rotating external support member **24**.

The lower extremity of the cylinder **10** is peripherally encircled by a lower collar **26**. The lower collar **26** has a peripheral receptacle **28** disposed to contain a V-belt **30** utilized to rotate the cylinder **10**. The lower end of the cylinder **10** terminates in an outwardly tapered edge **32** continuously formed by the wall of the cylinder **10** and a portion of the lower collar **26**. The lower end of the cylinder **10**, including the tapered portion **32**, extends into an annular stationary collector receptacle or bowl **34**. The collector bowl **34** is shaped so that the blood draining from the rotating cylinder **10** via the tapered edge **32** is thrown tangentially on to the adjacent surface of the bowl **34** with a minimum of impact and change of direction, i. e., the blood is flung tangentially from the cylinder into the collector bowl **34**, which is shaped to receive the blood with a minimum of impact. Also, the walls and bottom of the collector bowl **34** are sloped to make the blood flow to a tapered outlet spout **36** disposed in the lowest portion of the bowl **34**.

The rotating cylinder **10** and the stationary collector bowl **34** are supported by a lower mounting assembly disposed to support said bowl **34** and said cylinder **10** in non-rotating and rotating engagement, respectively, which comprises a main base and support segment **38** supported by the main mounting struts **40**. Disposed above the mounting struts **40** is a non-rotating cylindrical support member **42**, which engages and supports the underside of the outer surface of the collector bowl **34**. Disposed adjacent to the cylindrical support member **42**, and in clamping engagement with the inner surface of the collector bowl **34**, is a non-rotating internal support member **44**. The base segment **38**, the mounting struts **40**, the cylindrical support member **42**, and the internal supporting member **44**, are held in compressive assembled engagement by the bolts **46** and **48**.

The non-rotating cylindrical support member **42** provides a mounting for a stationary raceway **50** for the lower bearing **52**. Disposed adjacent to the stationary raceway **50** and separated therefrom by the rolling members of the bearing is a rotating raceway **54**, which is mounted on a rotating sleeve **56**. The rotating sleeve **56** supports the rotating cylinder **10**. The rotating sleeve **56** is integrally connected via the struts **58** to the periphery of the rotating cylinder **10** and through said struts **58** supports the weight of said cylinder **10**.

Within the rotating cylinder **10** and concentric with it is a stationary cylinder **60** closed at each end, as at **60***a* and **60***b*. This cylinder is so spaced within the rotating cylinder **10** so as to provide a narrow annular

space between the external surface of the internally disposed non-rotating cylinder **60** and the internal surface of the externally disposed rotating cylinder **10**. Disposed within the stationary cylinder is a narrow vertical pocket **62**, which serves as a receptacle for the blood inlet jet assembly. Axially disposed on the upper surface of the internal non-rotating cylinder **60** is a shaft **64** held in non-rotative arrangement axially within the rotating sleeve **16**. Slidably disposed within the shaft **64** is a vertical jet positioning rod **66**. Disposed adjacent to the jet positioning rod **66** within the shaft **64** is a venous blood supply tube **68**. Mounted on the lower end of the jet positioning rod **66** is a horizontal jet mounting bracket **70** which terminates in the mount **72** for the jet nozzle **74** and the blood supply tube **68**. The mount **72** includes a knurled thumbscrew **76** for fastening the nozzle **74** to the mounting bracket **70**. The nozzle **74** is disposed adjacent to the inner surface of the rotating cylinder **10**. For the rates of flow utilized in the device the nozzle is designed to give the venous blood a velocity approximating that of the periphery of the rotating cylinder. In addition, the nozzle is preset in position so the direction of the blood flow is approximately tangential to the cylinder periphery. Thus, the blood leaving the nozzle is approximately the same in magnitude and direction as the peripheral velocity of the cylinder **10**. Therefore, only slight impact occurs as the blood transfers to the cylinder. The lessening of the impact reduces hemolysis and frothing of the blood.

The jet assembly is slidably contained within the vertical pocket **62** and provides a positive means for forming a thin film of blood on the entire inner surface of the rotating cylinder **10**. The rotation of the cylinder **10** and the slidability of the jet assembly aid in the formation of a uniform film of blood without the formation of rivulets and provide for an even discharge of blood over the entire periphery of the cylinder. By raising the jet nozzle **74** gradually while the cylinder **10** is rotating, the blood issuing from the jet **74** contacts every inch of the surface of the cylinder **10** and forms a uniform thin film without rivulet formation. Once the cylinder surface is wetted, the film will remain as long as the blood flows and the cylinder rotates. Moreover, provision has been incorporated to position the jet assembly at any intermediate level, thus giving the oxygenating device a variable oxygenating capacity.

The internal non-rotating cylinder **60** is mounted on the lower support shaft **78**, which is contained within a non-rotating central supporting member **80**. The non-rotating central supporting member **80** is secured to the lower base segment **38** in non-rotative engagement and is axially disposed within the rotating sleeve **56**. Disposed within the central support member **80** adjacent to the lower support shaft **78** is the oxygen inlet tube **82**. The lower mounting arrangement thus provides for a positively rotating outer cylinder **10**, a non-rotating collector bowl **34**. and a non-rotating inner cylinder **60**.

Figure 2 shows the presently preferred construction for locking the jet assembly at any desired level. There is provided a sleeve **84** enclosing the slidable jet positioning rod **66**. Secured to the sleeve **84** is a collar **86**. The collar **86** serves as a mount for a vertically protruding pin **88**. Disposed above the collar **86** and fitting loosely on the rod **66** is a locking collar **90**. The pin **88** serves as a fulcrum to tilt the locking collar **90** into tight frictional contact with the jet positioning rod **66**. Thus, whenever it is desired to lock the jet assembly in a raised position, the locking collar **90** is permitted to tilt on the pin **88**. The resultant cramping action between the locking collar **90** and the jet positioning rod **66** is sufficient to hold the jet assembly **74** at any desired elevational location.

The above-described oxygenating device is the "lung" of an oxygenator assembly. In operation the outer cylinder **10** is rotated by the action of the V-belt **30**, and the venous blood is evenly distributed by the jet **74** upon the inside surface of the rotating cylinder **10**. The rotating cylinder **10** and the stationary cylinder **60** mounted concentrically within the outer rotating cylinder **10** provide an annular space between the two cylinders. The gas, principally oxygen with some carbon dioxide, water vapor, and ether, enters the bottom of the oxygenating device through the tube **82** and passes upward through the annular space. Since the annular space is small, all the gas in its upward flow in this space has an excellent opportunity for contacting the downwardly flowing film of blood. During this passage the oxygen is transferred to the blood and the downwardly flowing venous blood is thereby oxygenated. The gas leaves the annular space at the top of the assembly and is drawn off through an air exhaust system via the tube **92**.

It is desirable to prevent the escape of the oxygen and, the other gases from the space between the rotating and stationary members in the oxygenating device during operation. To prevent the escape of the gases, annular grooves, such as **94**, are included between the adjacent surfaces of the stationary collector bowl **34** and the rotating collar **26** as partial gas seals. These seals, while not as effective as a sliding type seal, are presently preferred because of reduced frictional effects and the ever-present possibility of combustion in an atmosphere of high oxygen concentration.

The entire oxygenating device, except for the rubber tubing **68** in the slidable jet assembly, the bearings **20** and **52**, is preferably made of Inconel. This metal was preferred and used because of its very high resistance to corrosion from blood. Inconel is an alloy having the following composition:

79.50% nickel
13.00% chromium
6.50% iron
.25% manganese
.85% silicon
.08% carbon
.20% copper

Disposed beneath the drain **36** of the collector bowl **34** is a suitable flask or container such as the long-necked flash **96** provided with a suitable drainage opening **98** for removal of the collected blood.

In accordance with the provisions of the patent statutes, we have herein described principle of operation of this invention, together with the elements which we now consider the best embodiments thereof, but we desire to have it understood that the structure disclosed is only illustrative and the invention can be carried out by other means. Also, while it is designed to use the various features and elements in the combinations and relations described, some of these may be altered and modified without interfering with the more general results outlined and the invention extends to such use within the scope of the appended claims.

Having thus described our invention, we claim:

1. In an extracorporeal circulation device of the type described, an assembly for introducing oxygen into a thin continuous film of venous blood, comprising, an annular oxygenating chamber wherein an upwardly moving stream of oxygen is passed over a downwardly moving continuous film of blood, said annular oxygenating chamber formed by a rotatable cylindrical shell open at both extremities and a non-rotatable cylinder concentrically disposed within said shell, means for initially forming said continuous film of blood on the inner surface of said rotatable cylindrical shell, including, a vertical jet assembly receiving channel disposed in the non-rotatable cylinder, a jet assembly connected to a source of venous blood mounted on a slidable vertical positioning rod contained therein whereby said jet may be vertically positioned at any location therein, and a non-rotatable annular blood collecting bowl outwardly encompassing the lower extremity of said rotatable shell.

2. In an extracorporeal circulation device of the type described, an assembly for introducing oxygen into a thin continuous film of venous blood, comprising, an annular oxygenating chamber wherein an upwardly moving stream of oxygen is passed over a downwardly moving continuous film of blood, said annular oxygenating chamber formed by a rotatable cylindrical shell open at both extremities and a non-rotatable cylinder concentrically disposed within said shell, means for forming said continuous film of blood on the inner surface of said rotatable cylindrical shell including a vertical jet assembly receiving channel disposed in said non-rotatable cylinder, a jet assembly connected to a source of venous blood mounted on a slidable vertical positioning rod contained therein, said jet assembly including a nozzle shaped to distribute the venous blood tangentially upon the inner surface of said rotatable shell at a velocity approaching the peripheral velocity of said shell, a horizontal adjustable mounting bracket intermediate said

nozzle and said vertical positioning rod; means externally of said outer shell for securing the vertical positioning rod at any desired position in said vertical jet assembly receiving chamber, a non-rotatable annular blood collecting bowl encompassing the lower extremity of said rotatable shell, said inner surface of said rotatable shell being outwardly tapered at its lower extremity, and said adjacent surfaces of said collector bowl shaped to receive the downwardly flowing blood from said tapered surface with a minimum of impact.

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