

July 12, 1955

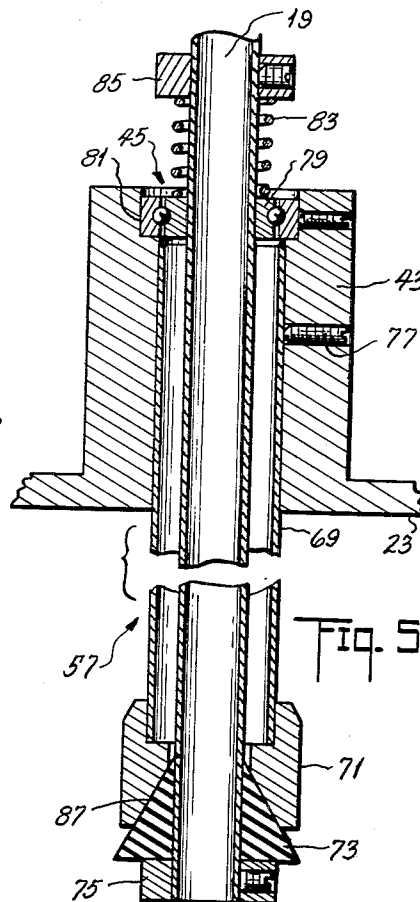
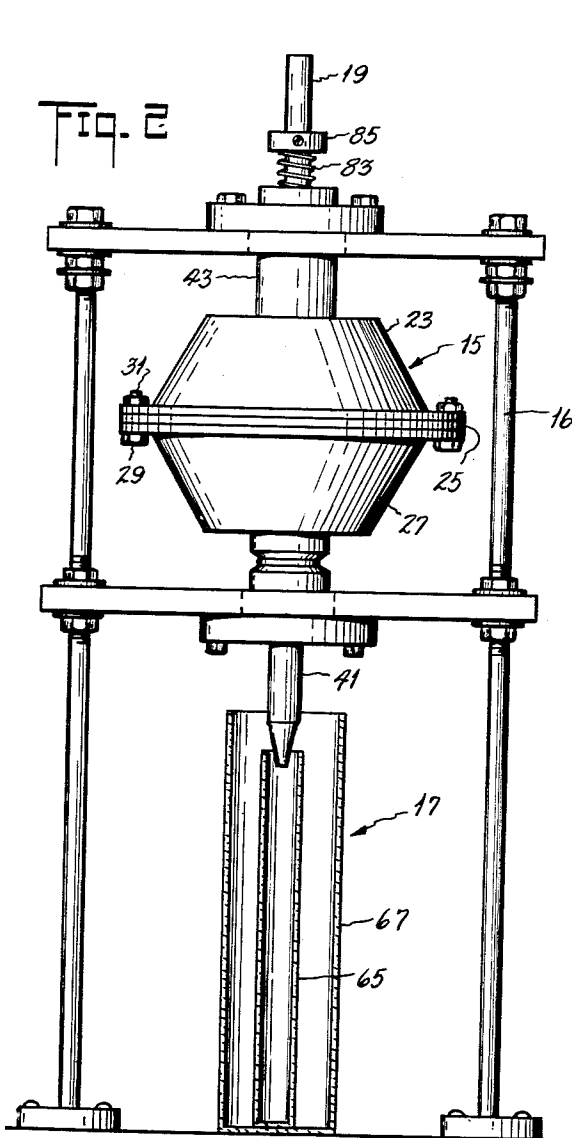
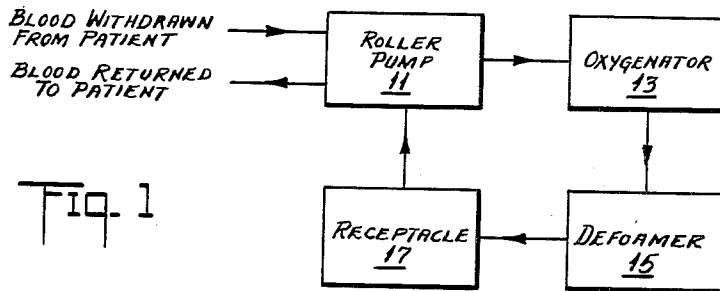
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2,712,897

STEADY FLOW CENTRIFUGAL DEFOAMER

Filed May 14, 1954

2 Sheets-Sheet 1



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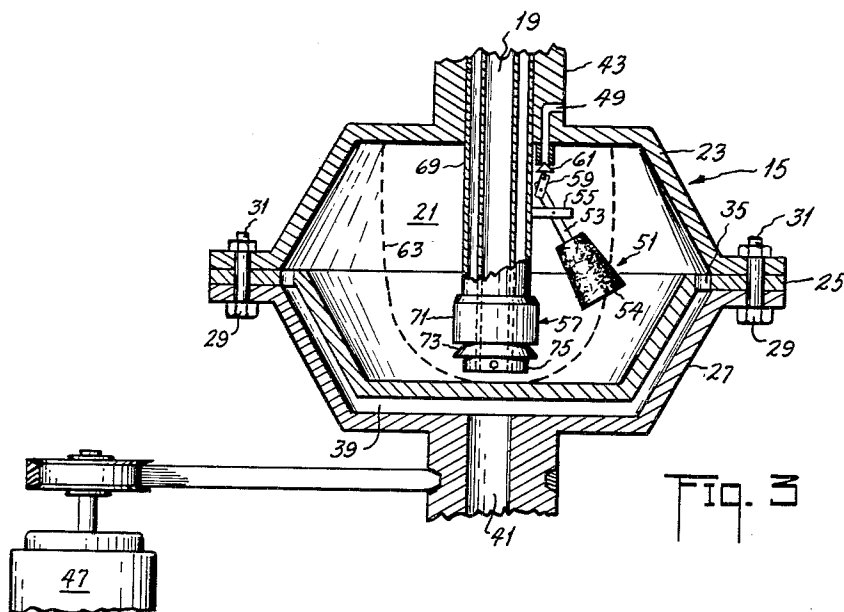


FIG. 3

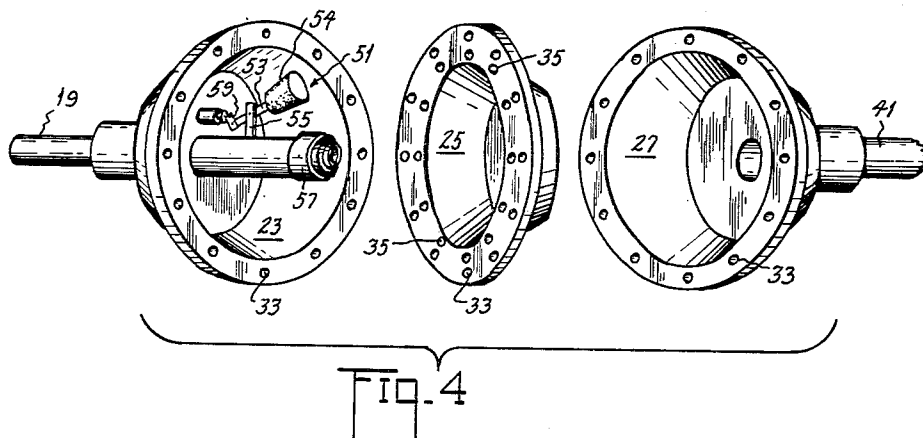


FIG. 4

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STEADY FLOW CENTRIFUGAL DEFOAMER

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7 Claims. (Cl. 233—28)

The present invention relates to a method and apparatus for breaking foam and more particularly to a method and apparatus for removing excess gas from blood.

Several types of gravitational and chemical defoaming systems have been developed for defoaming blood but with limited success. Such systems are used in conjunction with pump-oxygenator equipment for performing cardiovascular surgery, whereby the blood of the patient is shunted around the heart and lungs permitting the surgeon to operate on a heart, whose chambers are relatively bloodless, under direct vision. In delicate operations of this nature it is absolutely essential that all excess of gas be removed from the blood before its return to the animal lest fatal air embolus occurs. Adequate removal of the excess gas implies that two conditions must be fulfilled, namely, (1) the gaseous phase or foam be separated from the liquid blood phase, and, (2) the foam, after its separation be destroyed at a rate equal to or greater than the rate of its formation. If the second condition is not met, the circulating blood volume will gradually be displaced into foam. Also, because the blood lipids and proteins, surface active compounds in blood, preferentially migrate into the foam, there is additional danger that the loss of blood will be an unbalanced one, i. e. relatively more protein and lipid will be lost than other components. Thus, foam or bubble excess must not only be separated, but also destroyed.

One object of the present invention is to provide a method and apparatus for effecting a separation and destruction of blood foam.

Another object is to provide a device for defoaming liquids utilizing the principle of centrifugal force.

A further object is to provide defoaming apparatus that will accommodate high flow rates of blood without employing potentially toxic substances.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

Fig. 1 is a schematic diagram of a pump-oxygenator system showing the flow of blood from the patient through the equipment and return.

Fig. 2 is an elevational view of the centrifugal defoamer of Fig. 1.

Fig. 3 is a cross-sectional elevational view of the defoamer apparatus of Fig. 2.

Fig. 4 is an exploded view of the centrifuge consisting of the upper, middle and lower sections.

Fig. 5 is a detailed view in section of the movable air-tight seal included in the invention of Figs. 2, 3 and 4.

As shown schematically in Fig. 1, a typical pump-oxygenator system includes a double-tracked roller pump 11 that is capable of delivering blood withdrawn from the vascular system of a patient to an oxygenator 13 wherein aeration of the blood takes place. Blood is then passed from oxygenator 13 to a centrifugal defoamer 15 where the excess gas is removed. After processing in defoamer 15, the blood is delivered to a glass cylindrical receptacle 17 and then returned to the patient via the second track of said pump.

As stated hereinbefore, it is absolutely essential that all excess of gas be removed from the blood before its

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return to the patient. Successful separation and destruction of the blood foam has been accomplished by utilizing centrifugal force. In Figs. 2 through 4, inclusive is shown defoamer apparatus for accomplishing the gas separation. The centrifuge or defoamer 15 is suitably mounted on a frame 16 and includes an inner stationary inlet tube 19 through which blood to be defoamed is pumped from the oxygenator into a receptacle 21, consisting of an upper section 23, a middle section 25 and lower section 27 suitably connected together by means of bolts 29 and nuts 31. Said sections 23, 25 and 27 are constructed in the shape of shallow dishes or truncated cones having equal diameters at their flanges with holes 33 therein for easy assemblage. Flow of blood from said receptacle 21 is accomplished through exit or peripheral holes 35 in the flange of middle section 25 into a passage 39 formed between sections 25 and 27, and then into an outlet tube extension 41 of section 27.

A tubular sleeve 43 in upper section 23 contains bearings 45 enabling centrifuge 15 to rotate around stationary tube 19. Said centrifuge is driven by a quarter horsepower, variable-speed, electric motor 47, by means of a V-belt pulley attached to section 27 (see Fig. 3). Channelled in the upper portion of section 23 near its center of rotation is a gas escape exit 49, which is opened and closed by means of a valve 51. Valve 51 is composed of a lower lever 53 rotatably mounted on an extension 55 fixedly secured to an air-seal 57 on inner tube 19, a cork 54 mounted on one end of said lever 53, a second lever 59 one end of which is rotatably secured to the other end of lever 53, and a V-shaped valve seat 61 secured to the other end of lever 59 and adapted to seat in escape exit 49 under certain conditions during operation of centrifuge 15. (See Fig. 3).

Seal 57 comprises an outer moving tube or sleeve 69 coaxial with and spaced from inner stationary tube 19, a steel seal or valve seat 71 within which sleeve 69 is drive fit and a truncated, conically-shaped Rulon plastic seal 73 which is drive fit onto tube 19. Collar 75 adjustably mounted on the lower end of tube 19 prevents slippage of plastic seal 73. Outer moving tube 69 is secured to upper section 23 by means of a set screw 77 and rotatable therewith. Bearing 45 consists of an inner stationary sleeve 79 into which tube 19 is inserted, said tube being capable of vertical movement therewith, and an outer moving part 81 which is secured in a seat in tubular sleeve 43 of upper section 23. A compression spring 83 is located on tube 19 and bears against the upper surface of inner bearing sleeve 79 and a collar 85 adjustably secured to said tube.

As centrifuge 15 rotates about inner stationary tube 19, valve seat 71 rotates about seal 73 and there is formed a moving interface 87. Rulon seal 73 is a plastic bearing material requiring no oil and having a low coefficient of friction. Seal 73 is maintained in tight apposition to steel seat 71 by the action of spring 83. This spring action imparts an upward thrust to tube 19 maintaining the moving interface 87 during rotation. Movement of collar 85 up or down on tube 19 diminishes or increases the tension in spring 83 and thereby the tightness of the seal 57 at the lower end.

The operation of the device is as follows: Blood is pumped from oxygenator 13 into centrifuge 15 by way of inner stationary tube 19 in the upper section 23. At the lower end of tube 19 is air-tight movable seal 57. Said seal is essential because slight positive pressure is necessary to drive the blood through centrifuge 15. After delivery to receptacle 21, the blood and its contained bubbles are acted upon differentially by centrifugal force with the blood seeking the periphery of the centrifuge and the gas bubbles forced to aggregate at the center. Since

each bubble is bounded by a film that is essentially a thin layer of liquid and since all of the liquid mass in the system, either in the body of the blood or around a bubble as film, seeks the periphery of the receptacle 21, centrifugation tends to destroy by collapse, as well as to separate bubbles. After the blood is separated from the gas, it is forced through peripheral holes 35 in middle section 25 into passage 39 between middle section 25 and lower section 27. From passage 39 the blood is driven down outlet tube 41 into a glass receptacle 17 from which it is returned, bubble free, to the patient via the second track of pump 11. The blood is given directional flow through centrifuge 15 because it is constantly being displaced by incoming blood and gas from oxygenator 13.

As a result of both blood and gas being pumped into centrifuge 15, a volume of gas is built up in receptacle 21, collecting near the center of said receptacle. A manner of escape must be provided for this volume of gas, otherwise, the gas would soon, because of the constant addition thereto, encroach upon the peripheral layer of blood, ultimately displacing it, and would then be pumped out with the incoming blood-gas mixture. Such a build-up of gas is prevented by valve-controlled escape exit 49 (see Fig. 3). It is evident that the portion of receptacle 21 near the center of rotation of centrifuge 15 is where little or no blood is found because of the centrifugal forces. Valve 51 is so constructed that when centrifuge 15 is in operation and blood flows through the apparatus, it is alternately opened and closed. During the open phase gas escapes from receptacle 21 through exit 49. In Fig. 3, it is apparent that escape exit 49 is open or closed depending upon the position of levers 53 and 59 attached to valve seat 61. The position of levers 53 and 59 are determined, in turn, by the position of cork 54 attached to lever 53. Cork 54 being less dense than blood moves with the blood boundary or blood-gas interface 63, said boundary being nearly vertical when centrifuge 15 is running.

As the gas builds up to a greater and greater volume centrally, blood-gas interface 63 recedes toward the periphery of receptacle 21 and cork 54 moves in the same direction. As cork 54 continues its outward movement, a point is reached when valve seat 61 is displaced downward from escape exit 49 and the gas (which is under slight pressure) escapes. The escapement of gas permits newly-entering blood opportunity to accumulate slightly again, displacing blood boundary 63 back toward the center. Cork 54 moves inward with the displacement of boundary 63 closing escape exit 49. With exit 49 closed off, the gas again builds up centrally, and the cycle repeats itself. Thus it is seen that valve 51 provides a means for permitting gas to escape from receptacle 21, and also for controlling the position of blood-gas boundary 63, or to put it another way, the volume of blood in centrifuge 15 is controlled.

Receptacle 17 into which the defoamed blood flows consists of two concentric glass cylinders (see Fig. 2) 65 and 67 closed at the bottom and open on top. Blood flows into the smaller cylinder 65 from tube 41 where its rotational motion is lost. It then flows over the side of said cylinder 65 into outer cylinder 67 from where it is returned by pump 11 to the patient.

It is to be noted that centrifugal separation is not unduly traumatic to the blood cells because the blood is both introduced and withdrawn at the center of rotation where linear velocity of any particle is small despite a high angular velocity. When the blood particle moves outwardly toward the periphery of the centrifuge where its linear velocity becomes high, it moves with the surrounding blood and the centrifuge as a unit; i. e., there is always little or no motion of a particle of blood relative to its immediate surroundings. Samples of blood after the defoaming operation have on gross inspection shown no evidence of excessive hemolysis.

The specific centrifuge described herein can be con-

structed of stainless steel or other suitable metals or plastics that are capable of undergoing a sterilization process. The capacity of the defoamer to handle large volumes of blood at high flow rates is limited primarily by the size of the centrifuge and capacity of the pump. While the invention disclosed herein has dealt specifically with defoaming of blood, such apparatus can be used as an oil defoamer for use in internal-combustion engines or other engines and can also be used for other processes requiring removal of gas from liquids.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed:

1. A device for separating excess gas from liquids comprising a receptacle for accommodating a liquid-gaseous mixture, axial inlet means inserted within said receptacle, means for rotating said receptacle around said axial inlet means, liquid-gaseous regulator means for automatic removal of excess gas, and outlet means for withdrawing liquid from said receptacle.

2. A device for separating excess gas from liquids comprising a receptacle for accommodating a liquid-gaseous mixture, stationary inlet means coaxial with said receptacle and inserted therein, said receptacle being rotatable around said inlet means, means for rotating said receptacle, valve means associated in part with said receptacle for enabling excess gas to escape from said receptacle, and outlet means for withdrawing liquid from said receptacle.

3. A device for separating gas from liquids comprising a receptacle having upper, middle and lower sections coupled together, axial inlet means inserted within the upper section of said receptacle, said receptacle adapted for rotation about said inlet means, means for rotating said receptacle, valve means in such upper section for enabling excess gas to escape from said receptacle, and outlet means for withdrawing liquid from said receptacle.

4. The invention as defined in claim 3 wherein an air-seal circumscribes said axial inlet means.

5. The invention defined in claim 4 wherein said air-seal comprises a sleeve coaxial with and spaced from said axial inlet means, a valve-seat mounted on said sleeve, and a plastic cone attached to said axial inlet means and adapted for surface contact with said valve-seat, whereby a movable interface is formed.

6. A device for separating gas from liquids comprising an upper section, a middle section and a lower section, said upper, middle and lower sections adapted to be coupled together to form a receptacle, axial inlet means inserted within said upper section, whereby the receptacle is capable of rotation around said inlet means, air-seal means circumscribed around said axial inlet means, means for rotating said receptacle, rotatable valve-regulator means for automatic removal of excess gas from said receptacle, and outlet means for withdrawing liquid from the receptacle.

7. The invention as defined in claim 6 wherein said valve-regulator means comprises a channel in said upper section and lever means connected to said air-seal means for alternately opening and closing said channel.

References Cited in the file of this patent

UNITED STATES PATENTS

240,175	Pedersen et al.	Apr. 12, 1881
489,197	Peck	Jan. 3, 1893
2,519,971	Le Clair	Aug. 22, 1950
2,648,496	Cresswell	Aug. 11, 1953
2,675,000	Ford	Apr. 13, 1954

FOREIGN PATENTS

373,560	Great Britain	May 26, 1932
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