

May 24, 1960

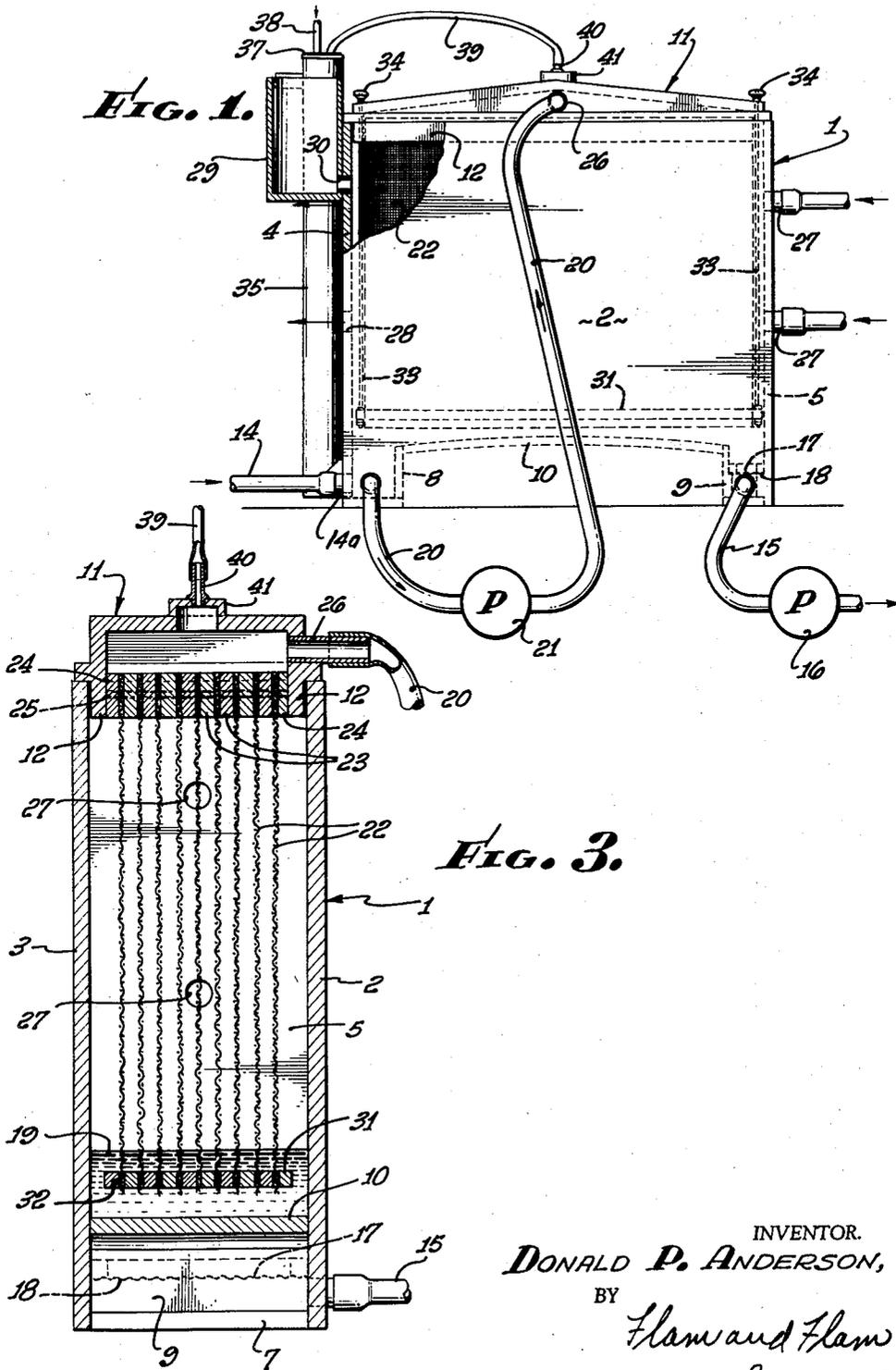
D. P. ANDERSON

2,937,644

BLOOD OXYGENATOR FOR FACILITATING HEART SURGERY

Filed Oct. 15, 1957

2 Sheets-Sheet 1



INVENTOR.  
**DONALD P. ANDERSON,**  
BY  
*Flam and Flam*  
ATTORNEYS.

May 24, 1960

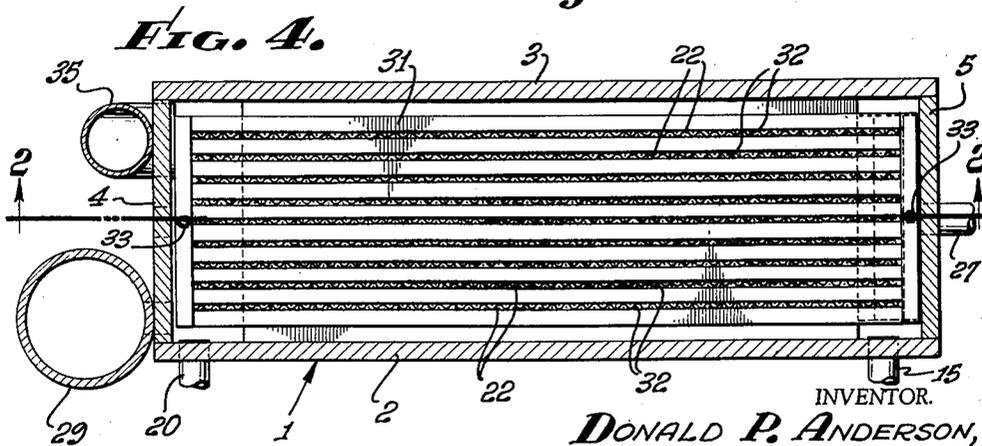
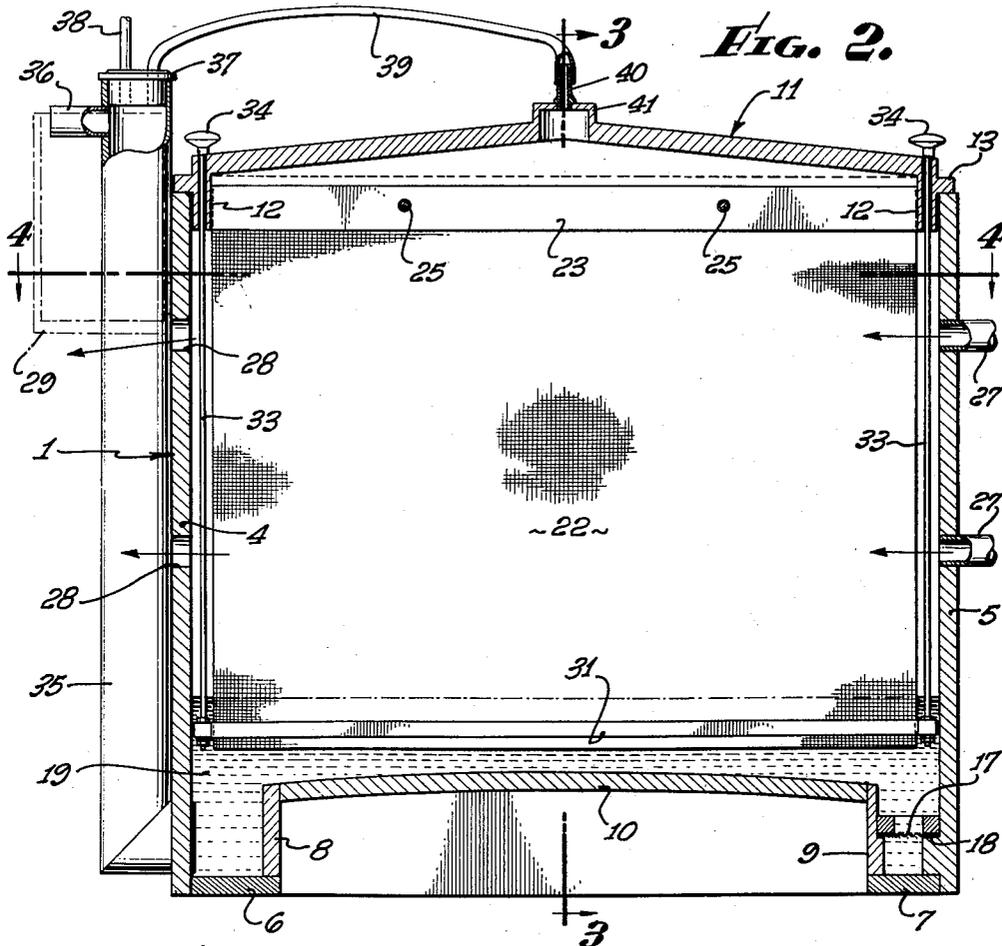
D. P. ANDERSON

2,937,644

BLOOD OXYGENATOR FOR FACILITATING HEART SURGERY

Filed Oct. 15, 1957

2 Sheets-Sheet 2



INVENTOR.  
**DONALD P. ANDERSON,**  
BY  
*Flaw and Flaw*  
ATTORNEYS.

1

2,937,644

## BLOOD OXYGENATOR FOR FACILITATING HEART SURGERY

Donald P. Anderson, Los Angeles, Calif., assignor to Corco Incorporated, Los Angeles, Calif., a corporation of California

Filed Oct. 15, 1957, Ser. No. 690,353

5 Claims. (Cl. 128—214)

This invention relates to heart surgery.

Surgery upon the human heart has been recently facilitated by making it possible to by-pass the heart of the patient while the surgery is in progress. A few types of apparatus functioning as oxygenators of venous blood have been developed. They are adapted to receive venous blood from the blood vessel that normally supplies such blood to the heart; they oxygenate this venous blood to convert it to arterial blood; and then the arterial blood is returned to the body.

The oxygenation of the venous blood, and its return to the body, forms the most important functions of such apparatus. In order to effect oxygenation, the blood is caused to flow in a thin film within an oxygen atmosphere. The thin flow, in one form of device, is formed by distributing the venous blood over a wire screen, and oxygen is passed over the film. The film flow is effected by gravity. Unless care is taken, instead of a film flow, the blood flows in rivulets over the wire mesh. Under such uneven flow conditions, the efficiency of the oxygenation is greatly impaired.

In accordance with prior devices providing film flow, the accidental change from that type of flow to the undesired rivulet flow was corrected in an awkward, time consuming manner, corresponding to the procedure required to initiate the operation of the system. Such initiation usually involved the temporary flooding of the screens with a saline solution, the liquid level of which receded in advance of the flow of blood film.

It is one of the objects of this invention to obviate the necessity of such procedure, both for the initiation of the film flow or for re-establishing it.

In order to accomplish this result, a mechanically movable film is used that can be manipulated at any time by the operator of the oxygenator.

In the old process, utilizing a saline starting bath, the blood is diluted by the saline solution. Therefore, an additional advantage is attained by the present invention, for it obviates such dilution.

In prior devices of the character hereinbefore referred to, the apparatus is bulky, expensive and requires a team of operators. By the aid of the present invention, it is possible to provide a relatively simple, inexpensive and compact device, well within the means of a practicing surgeon, and that can be effectively operated by but one individual.

It is another object of this invention to ensure greater safety against failure of operation, thereby increasing the chances of successful surgery on the patient.

An important function of the apparatus is to ensure an adequate reservoir for the blood, from which venous blood may be pumped to a space above the screens, so that in turn an adequate supply of arterial blood is produced, to maintain the feeding of oxygenated blood in accordance with the demands of the body. By the aid of the present invention, connected reservoirs for the venous and arterial blood are compactly arranged in the lower portion of the oxygenation chamber; and yet ve-

2

nous blood is prevented from commingling with the arterial blood by aid of a liquid pressure differential tending to move the venous blood away from the arterial blood.

It is accordingly another object of this invention to provide such a compact device, obviating external blood reservoirs.

Because the apparatus built in accordance with this invention is quite compact; it requires less blood to fill the apparatus, thereby conserving the transfusion blood resources.

Another advantage of the compact arrangement resides in the reduction of surface area of foreign material in contact with the blood. This reduces the rate of disintegration of the blood platelets and thus minimizes the post-operative bleeding problems. It also decreases the chances of contamination and facilitates more thorough cleaning.

Furthermore, there are fewer devices to maintain in operative condition and thus heart surgery is made safer. For example, there is no need for a hose coupling on the arterial side, thus eliminating a source of leaks or the like.

The single chamber, which is made of transparent material, makes it easy to observe at all times the shift, if any, of blood either to or from the patient. In this way, the optimum volume of blood passed to the patient can be easily maintained, reducing the danger of overloading or underloading the patient.

As hereinabove stated, it has been necessary to load prior devices with a saline solution for establishing a film flow. As much as ten to fifteen liters of such solution would be necessary. By the aid of this invention, the need of such a solution is obviated. This results in several further important advantages over the saline method.

Thus the loss of blood during filming is eliminated.

Blood film flow can be quickly established.

Blood can be added before the by-pass around the heart need be started; and the entire apparatus can be prepared for instant effective operation preliminary to the by-pass. Thus, there is no need of running the apparatus for long, futile periods prior to by-pass. Undue damage to the blood from long recirculation is prevented.

This invention possesses many other advantages, and has other objects which may be made more clearly apparent from a consideration of one embodiment of the invention. For this purpose, there is shown a form in the drawings accompanying and forming a part of the present specification. This form will now be described in detail, illustrating the general principles of the invention; but it is to be understood that this detailed description is not to be taken in a limiting sense, since the scope of this invention is best defined by the appended claims.

Referring to the drawings:

Figure 1 is an elevation, partly broken away, illustrating apparatus embodying the invention in use in a heart by-pass;

Fig. 2 is an enlarged vertical section of the container embodying the invention, taken along a plane corresponding to line 2—2 of Fig. 4;

Fig. 3 is a vertical sectional view, taken along a plane corresponding to line 3—3 of Fig. 2; and

Fig. 4 is a horizontal section, taken along a plane corresponding to line 4—4 of Fig. 2.

The important elements constituting the invention are embodied in a container or reservoir 1. All of the walls of this container, including the top and bottom, are made of translucent plastic material, such as Lucite, to enable the operation of the device to be readily viewed,

3

as well as readily to perceive any departure from normal operation.

The container 1 has four vertical walls 2, 3, 4 and 5 shown most clearly in Fig. 4. The bottom wall is partly defined by a pair of narrow horizontal strips 6 and 7 extending inwardly from the walls 4 and 5, respectively. Vertically disposed on these narrow strips 6 and 7 are upright members 8 and 9 forming wells. Joining these upright members to complete the bottom wall is an arcuate wall 10. The configuration of this lower wall structure is shown to best advantage in Fig. 2.

The various elements forming the walls are attached together in any appropriate manner, as by cementing, or by the aid of machine screws or the like.

The container 1 is provided with a cover member 11 also preferably made of translucent or transparent plastic material, such as Lucite. This cover member has a depending flange 12 telescoping within the open top of the container 1 and having a horizontal flange 13 resting on the top edges of the walls 2, 3, 4 and 5.

The container 1 is connected to the body of the patient so that venous blood may enter the container 1, as by way of a hose 14 (Fig. 1). This hose connects to a nipple 14a at the lower left-hand portion of the container, and opposite the upright wall 8. The oxygenated or arterial blood is discharged from the container 1 via a hose connection 15 and a pump 16 to the artery system of the patient. The pump 16 may be of the type commonly used in this form of apparatus, in which no moving parts other than the walls of the hose 15 are in contact with the blood.

The path through the container 1 forms a by-pass for the heart. The venous blood is converted to arterial blood by process to be hereinafter described, which process takes place within the container 1.

The hose connection 15 (Figs. 1 and 4) connects with the interior of the container 1 adjacent the bottom of the wall 5. The arterial blood before passing through the connection 15 is screened as by the aid of an appropriate screening device 17 (Fig. 2) held in place upon a shoulder 18 formed on the wall 5, as well as a corresponding shoulder formed on the upright wall member 9.

In normal operation, a pool of blood 19 (Fig. 2) extends over the bottom wall member 10. This bottom member 10, together with upright members 8 and 9, forms a barrier between the left and right-hand side of the container 1, as viewed in Fig. 2.

The connection 14, as shown in Fig. 1, leads the venous blood to the space between the walls 4 and 8 and adjacent the bottom of the pool 19. A hose connection 20 (Figs. 1 and 4) leads the venous blood from the bottom of the pool 19 near the inlet 14, into the cover 11. The hose 20, as shown most clearly in Fig. 3, is disposed over a nipple 26 projecting from the side of the cover 11.

This connection 20 includes a pump 21 for raising the venous blood to a position adjacent the top of the container 1.

Thence the venous blood is distributed over a series of closely spaced parallel fine wire mesh screens 22 (Figs. 3 and 4). Nine such screens of rectangular form are illustrated in the present instance, corresponding to the desired areas of the blood films flowing over these screens.

The screens 22 are supported on the flange 12 of the cover 11. The supporting structure is shown most clearly in Fig. 3. The screens are separated by spacers 23; and end spacers 24 are disposed between the flange 12 and the end screens 22. Fastening means, such as rivets 25 (see also Fig. 2) serve to hold the screens in proper spaced position. These rivets pass through the spacers 23, 24 and flange 12.

The discharge of the venous blood into the cover 11 via hose 20 and nipple 26 serves to deposit the blood in the space above the screens 22. This nipple forms a

4

blood inlet to the container 1. Thence the blood flows along the screen downwardly by gravity into the pool 19. The lower edges of the screens 22 (Fig. 2) are immersed in this pool.

To provide the oxygenation, one or more oxygen inlet nipples 27 (Figs. 1 and 2) are provided. These nipples are arranged in spaced relation along the wall 5. Oxygen from any appropriate source is supplied to the nipples. The blood flowing down the screen 22 is thus exposed to an oxygen atmosphere. Exit openings 28 for the gases in the container 1 may be provided in the opposite wall 4.

The pool 19 thus receives the oxygenated blood from the screen 22. It also receives at the left-hand side of the barrier 8-9-10 the venous blood via the connection 14. On the right-hand side of the barrier arterial blood is drawn off via the connection 15. Venous blood is kept from commingling with the arterial blood by virtue of the pump 21 which is so arranged that it causes the flow of blood to be away from the right-hand side of the container 1, as viewed in Fig. 2, and toward the left-hand side. In other words, pump 21 creates preponderance of fluid pressure, causing the current of blood to flow from right to left as viewed in Fig. 2. No venous blood accordingly can commingle with the arterial blood located in the space below the screen 17. Thus, although there is a common pool 19, the intermixing of venous and arterial blood takes place remote from the outlet 15. The pool 19 forms the essential blood reservoir into which the flow from the screens 22 empties. Since such reservoir must always be provided in systems such as this, there is a considerable saving in space by using the bottom of container 1 for the reservoir.

To start the operation of the by-passing system, the container 1 is first charged with blood as by way of a receiver 29 (Figs. 1 and 4) mounted near the upper end of the wall 4 and having an open upper end into which blood may be poured. The blood passes into the container 1 by way of the passage 30.

It is important that the blood flow over the screens 22 be in sheet-like or film form rather than in rivulet form. In prior devices and in order to secure this result, it was necessary to charge the apparatus with a large quantity of saline solution to a level above the screens. Such a solution diluted the blood and had other disadvantages as hereinbefore set forth. By the aid of the present invention, it is unnecessary to provide a starting saline solution. Instead the blood is merely deposited above the screens 22 by way of the nipple 26 and is caused to assume the sheet form by a filmer now to be described.

A plastic strip 31 (Figs. 2 and 3) is disposed near the bottom of the container 1 and in the pool 19. It is provided with narrow slots 32 through which the screens 22 pass. The slots are so narrow that when blood flows between the screens and the slots, capillary attraction is sufficient to keep the slots 32 filled with blood. Normally the filmer strip 31 is maintained below the level of the blood pool 19. When it is desired to film the blood over the screens 27, the strip 31 is moved from the blood pool 19 and upwardly over the entire areas of the screen 22. The filmer strip 31 has the effect of smoothing out the flow of blood along the screen to form a thin even sheet or film of blood.

In order to manipulate the filmer 31, a pair of rods 33 (Fig. 2) is provided, passing through the flange 12 of the cover 11 and joined at their lower ends to the strip 31. Manipulating knobs 34 may be provided exteriorly of the cover 11 for manual operation.

The filmer 31 may be operated quickly and readily without the necessity of shutting down the apparatus. Even if this filming may be required while the surgical operation is in progress, there need be no interruption since the operation of filming of the blood by filmer 31 takes place rapidly. It is thus a simple matter to re-establish the thin film of blood on the screens 22.

5

A vertical pipe 35 is provided adjacent the left-hand side of the apparatus as viewed in Figs. 1 and 2. This pipe discharges into the bottom of the pool 19 and is intended to receive blood from the patient that may be collected during the surgical operation. In this way, a saving of blood is effected.

The blood may be passed to the pipe 35 by way of a nipple 36 or through a cover 37 via a connection 38 (Figs. 1 and 2). In order to ensure that air will be drawn off from the blood as it enters the pipe 35, a hose connection 39 may be provided through the cover 37 between the interior of the pipe 35 and the cover 11. This is effected by the aid of a nipple 40 joined to a hollow boss 41 formed on the cover 11.

By the aid of this invention the apparatus may be prepared and ready to be utilized even prior to the actual surgical operation. This is simply effected by providing a sufficient pool of blood 19 and by passing oxygen through the nipples 27 into the container 1. The pumps 16 and 21 may be set into operation quite promptly and the filmer strip 31 can be expeditiously operated also to effect the filming of the blood.

The inventor claims:

1. A blood oxygenator having: a container; one or more sheets of wire mesh material disposed so as to cause blood deposited thereon to flow downwardly and to be guided by the sheet or sheets, the blood collecting in the bottom of the container; means for supplying venous blood to the sheet or sheets; means for supplying oxygen to the container; and means movable over the surfaces of the sheet or sheets for filming the blood.

2. The combination as set forth in claim 1, in which the filming means is a member having a slot or slots through which the sheet or sheets extend, said slot or slots having edges closely spaced to the screen surfaces.

3. The combination as set forth in claim 1, in which the filming means is a member having a slot or slots through which the sheet or sheets extend, said slot or slots having edges closely spaced to the screen surfaces; with the addition of manually operable means extending out of the container, connected to the member for raising and lowering the member.

4. In apparatus of the type described: a container

6

having side walls and a bottom wall forming a continuous single reservoir, said bottom wall having two separate spaced wells formed therein constituting a small portion of the area of the bottom wall and having a surface contoured to drain towards both said wells; means forming an oxygen inlet to the container; means for filming blood to subject it to the oxygen in a downward flow from the top of the container and causing it to collect in said reservoir to form a continuous pool of oxygenated blood therein; means forming a venous blood intake to said reservoir connected to one of said wells; means forming an oxygenated blood outlet from said reservoir connected to the other of said wells; and pump means connected to said one well for withdrawing blood from said reservoir and supplying it to the blood filming means; whereby a mixture of venous and oxygenated blood is continuously supplied to said pump means.

5. A blood oxygenator, comprising a container having side walls and a bottom wall forming a continuous single reservoir, said bottom wall having two separate spaced wells formed therein constituting a small portion of the area of the bottom wall and depressed below the level of the remainder of the bottom wall so that blood collected in said reservoir flows over the bottom wall surface into both said wells; means forming an oxygen inlet to the container; means for filming the blood to subject it to the oxygen in a downward flow from the top of the container and causing it to collect in said reservoir to form a single continuous pool of oxygenated blood therein; means forming a venous blood intake to said reservoir connected to one of said wells; means forming an oxygenated blood outlet from said reservoir connected to the other of said wells; and pump means connected to said one well for withdrawing blood from said reservoir and supplying it to the blood filming means; whereby a mixture of venous and oxygenated blood is continuously supplied to said pump means.

#### References Cited in the file of this patent

##### UNITED STATES PATENTS

2,705,493	Malmros et al. _____	Apr. 5, 1955
2,847,008	Taylor et al. _____	Aug. 12, 1958