A New Disposable Membrane Oxygenator With Heat Exchanger

H. Bing Moy
Nancy L. Reidenbach

Some 6 years ago in the laboratories of the Presbyterian Medical Center in San Francisco a search was begun to try and find a disposable membrance oxygenator that would have these characteristics:

(1) small priming volume, (2) oxygen uptake capacity of 150 to 200 ml per minute, (3) an equal carbon dioxide excretion capacity, (4) hemodynamic resistance must be low, (5) blood trauma must be cut to the minimum. (6) changes in the flow and pressure must cause little change in blood volume and (7) all surfaces coming in contact with blood must be disposable.

With this in mind, Mr. M. L. Bramson working with Drs. John Osborn and Frank Gerbode and associates of the Cardiovascular team designed such an oxygenator. Figure 1 shows the oxygenator being used clinically. The oxygenator is circular in design looking like a drum, approximately 24 inches in diameter. The lung is made up of 14 blood cell units, a diffusion area of almost 5.6 square meters with a priming volume of one liter. Each cell is made of two circular discs clamped at the edges. The membrane material is silastic sprayed onto an open weave fiberglass cloth. A screen lies between each two membranes and is put there to keep the edges apart. The screening is made of polyvinyl chloride sprayed on the open weave fiberglass cloth and is put there to create flood flow turbulence and to flush the boundary layer of blood that collects at edges.

Blood Flow: the blood enters each cell at the center and flows to four distinct points at the periphery

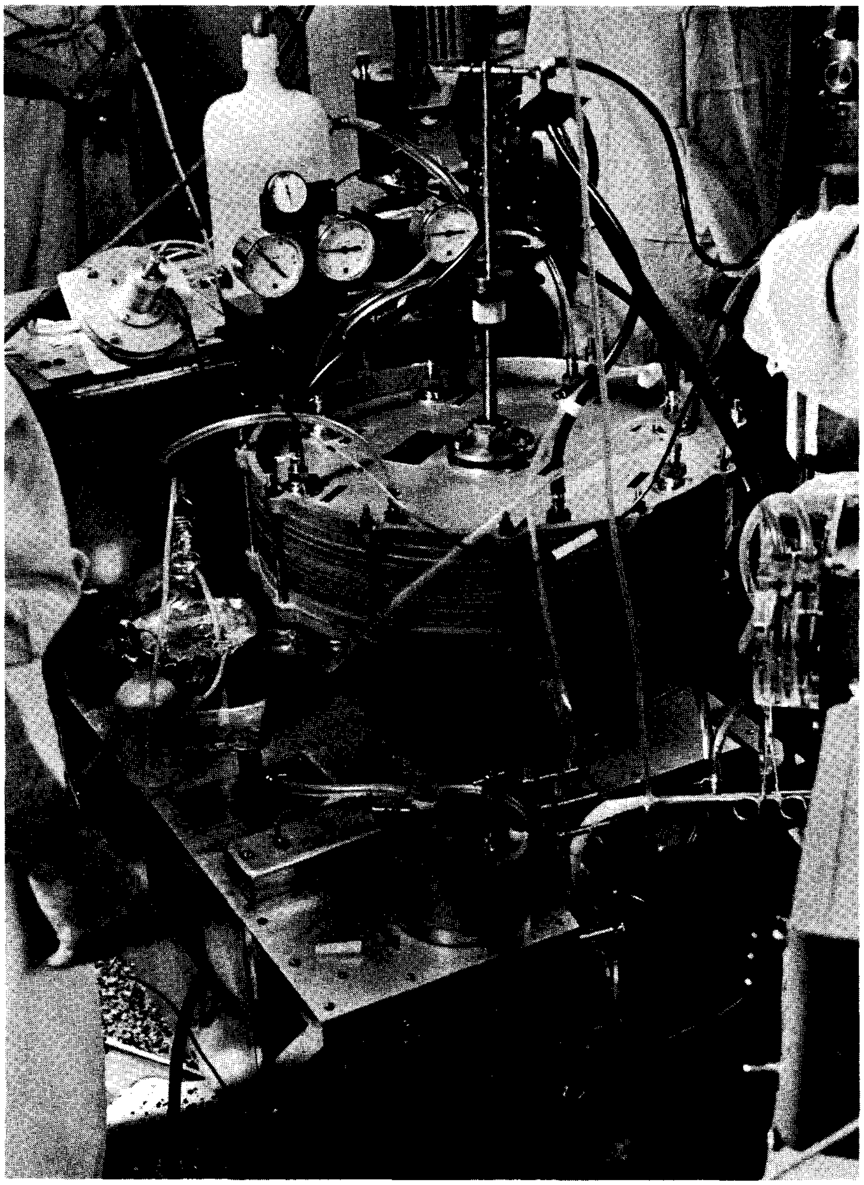

Figure 1.

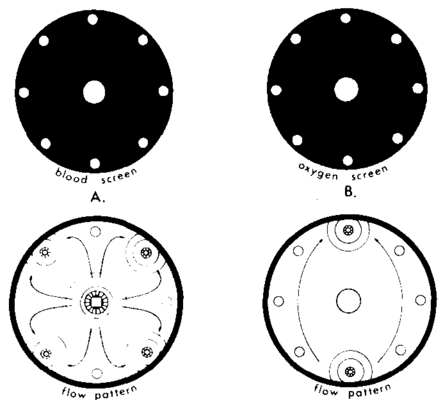

Figure 2.

and leaves. Figure 2 shows the pattern of flow of both the blood and gas.

Water Mattresses: (Figure 3). The purpose of the water mattresses which is placed between each blood

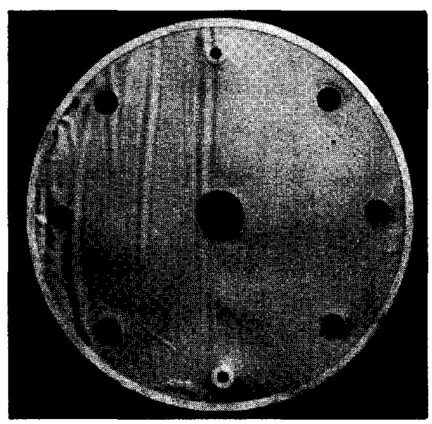

Figure 3.

cell and its neighbor is to keep the volume of blood both small and constant and the flow uniformly dispersed. The membrane also helps to support the maximum blood pressure occurring anywhere in the lung. The mattress is made of an aluminum ring with a polyvinyl chloride disc cemented to each side. The holes are heat-sealed with the exception of the two water holes from which the water enters and leaves, not only does it pressurize the water in the mattress, it also acts as a heat exchanger.

Gas Flow: In order to insure that oxygen reaches the outside surfaces of each blood cell, screens like the blood screens are placed between the membranes and the water mattresses. An inlet and an outlet are placed opposity each other and through this the oxygen and excreted carbon dioxide can flow at a high rate of speed and turbulence. The oxygen flows at rate of 15

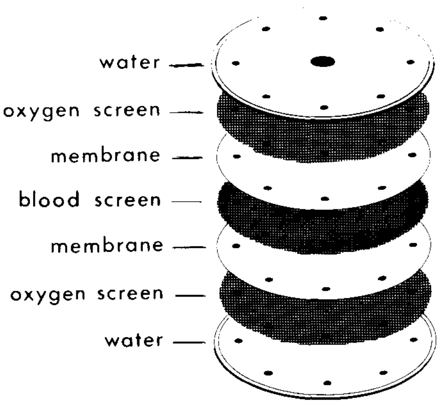

Figure 4.

liters per minute. Figure 4 shows the way the membrane and screens are put together.

Through the center of the oxy-genator is a metal bolt through which the blood travels. There are eight bolts which allow the gas to enter and leave; the water to enter and leave by four outlets. This center bolt which acts as a suspension point for the lung is made in such a way that it allows blood gas and water to flow through the distributing rings and parallel through the blood cells, gas screens and water mattresses. The injection moldings are made in such a way that one nut on each bolt will tighten all joints. (Figure 5).

Blood Circuit: the surgical sash is made up of two tubes; one in-

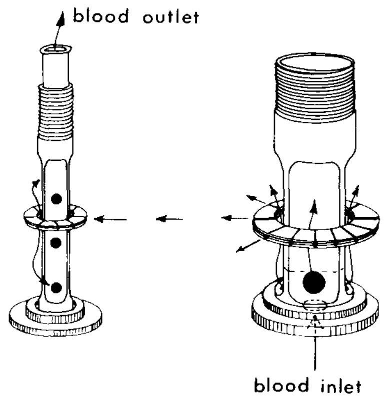

Figure 5.

serted inside the other. One is the venous return and the other is the arterial line to the patient. The venous return is connected to a sensing bladder which is a slack plastic bladder. This is connected also to the priming reservoir by means of a T-connector. The object of the bladder is to keep the blood volume constant and blood level maintained. Also connected is a small sensing bladder in which the blood level is sensed by a photocell. This controls an amplifier and regulates the speed of the arterial pump—the only pump in the circuit. From the pump it passes through the center bolt and all 14 cells. It emerges from the four blood outlet manifold bolts into 4 plastic tubes which are joined together in a disposable bubble trap. The blood flow changes direction and flows downward through a tubular filter and back into the patient. Gauges are connected to the inlet and outlet pressure and there is an alarm and circuit breaker which prevents a pre-set line pressure from being exceeded.

Oxygen Circuit: in preliminary priming 96% oxygen and 4% carbon dioxide is used. One hundred percent oxygen from the tank enters one of the manifold bolts and passes through the 28 oxygen screens and out through the other oxygen bolt into the atmosphere. To keep the PCO2 in the gas as close to zero as possible, oxygen is forced through at 15 liters per minute.

Water Circuit: water from a priming and pressurized tank flows through a copper coil into a heat exchange tank to a centrifugal pump. From there it goes through the 15 water mattresses which are connected in parallel and comes out the other water bolt and re-enters the pressuring tank. This tank can be filled with either cold or hot water depending on which you desire. A 3-way valve maintains a constant excess of mattress pressure over the blood inlet pressures.

Clinical perfusions: to date, 37 perfusions have been carried out, from 28 minutes to 12 hours. Of the 37 cases, 3 died and 2 of the 3 died of surgical reasons and all others did well and recovered without incidents. This is a small report on our disposable membrane oxygenator and we are doing one case a week at the present time, but hope to step it up in the near future.