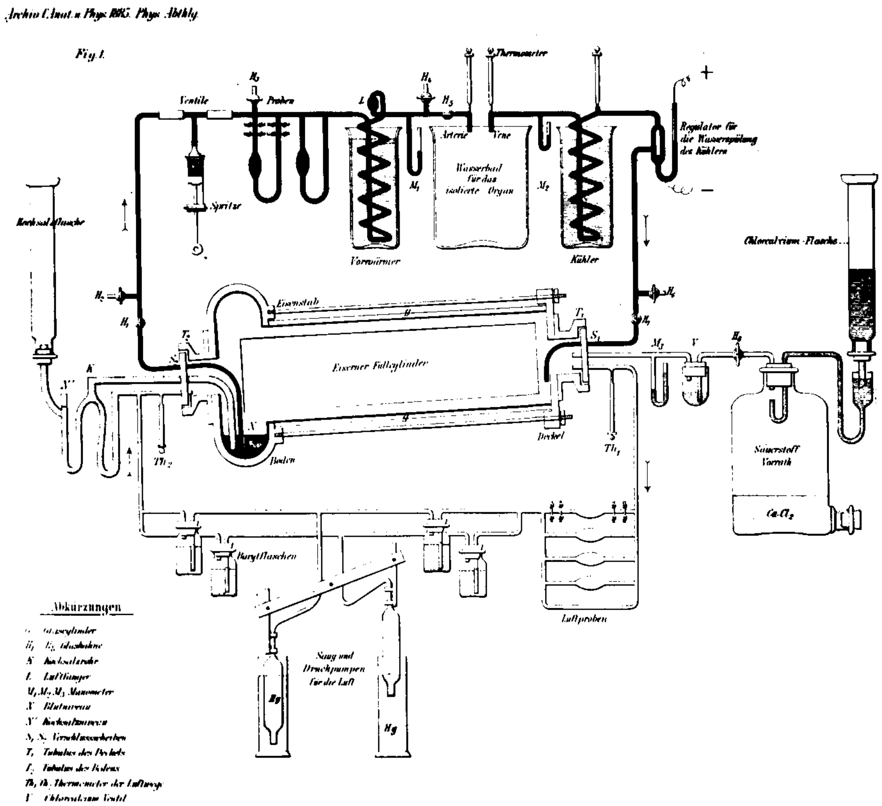

Figure 1 First Film Oxygenator, von Frey and Gruber (7)

Extracorporeal circulation was suggested by Le Gallois in 1812.[1] Developments during the ensuing 150 years made possible surgical correction of congenital and acquired diseases of the heart and great vessels. More recently, use of extracorporeal circulation has been extended to the prolonged support of patients with failing hearts. Cardiac assistance in patients with cardiogenic shock is currently being investigated, and ultimately complete replacement of the diseased heart with an artificial heart may be possible.

Certain advances in extracorporeal circulation are of special historical interest because of their present-day application and refinement. Recent reviews of the history of extracorporeal circulation and the development of oxygenators have appeared elsewhere.[2, 3, 4]

Historical Highlights of Extracorporeal Circulation

by ROBERT L. HEWITT, M.D.
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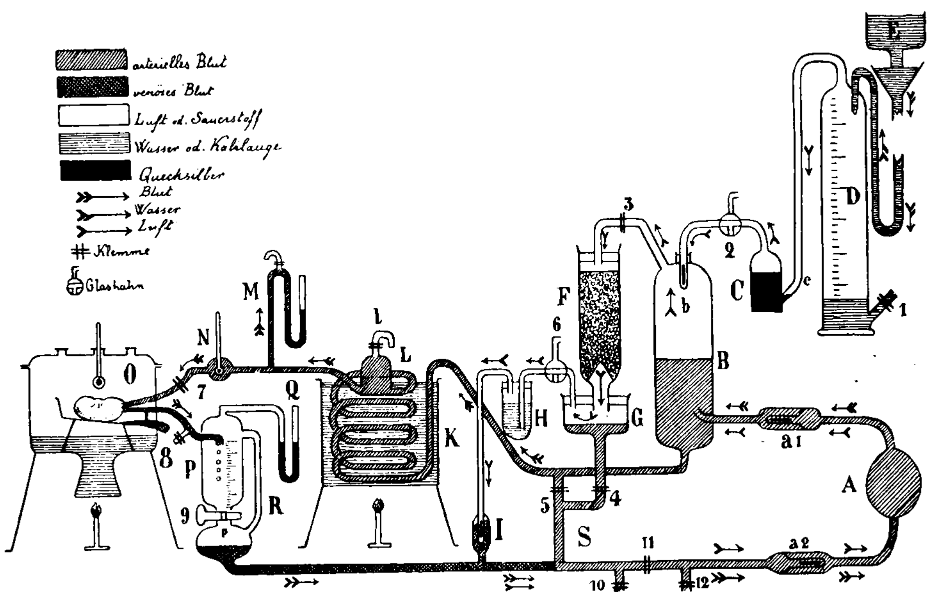

Figure 2 Bubble Oxygenator, Jacobj (8)

Oxygenators

Blood was first artificially oxygenated by Ludwig and Schmidt[5] in 1869. Defibrinated blood was simply shaken with gas in a balloon during extracorporeal circulation. Von Schroder[6] devised the first bubble oxygenator in 1882 when he introduced air directly into a venous reservoir; the isolated organs were perfused by hydrostatic pressure.

Von Frey and Gruber[7] developed the first film oxygenator in 1885.

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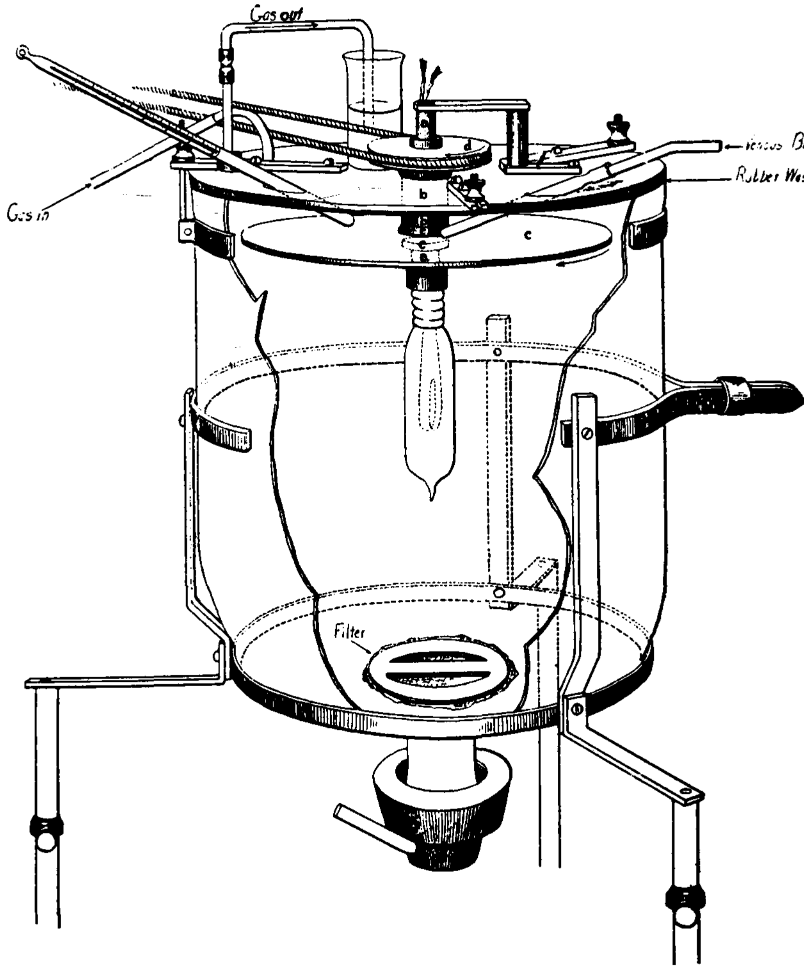


Figure 3 Disk Oxygenator, Hooker (10)

Blood was filmed over a slightly inclined rotating cylinder and helical coils were incorporated for thermal control (Fig. 1). Five years later, Jacobj[8] designed a bubble oxygenator in which air was introduced into a stream of blood propelled to a helical, debubbling reservoir (Fig. 2).

Richards and Drinker[9] in 1915 developed a film oxygenator composed of a perforated silk screen suspended from a glass ring. In the same year Hooker,[10] who had formerly used a bubble oxygenator in studying the effect of pulse pressure on renal function, introduced a film oxygenator which was the forerunner of the modern disk oxygenator (Fig. 3). Blood was oxygenated as it was filmed over a rotating hard rubber disk in an inverted bell jar filled with oxygen.

The filming of blood over a rotating disk was further refined by Bayliss and associates[11] who used a column of cones that rotated on a vertical axis within a series of stationary plates. Blood was centrifugally filmed over the stationary plates. Daly and Thorpe[12] modified the Hooker disk apparatus by using three oxygenators arranged concentrically. Cruickshank[13] used a nickel-plated sheet of hard drawn copper rolled into a spiral th rotated magnetically in a glass cylinder (Fig. 4). Blood and oxygen entered the oxygenator centrally through tubing in the axle.

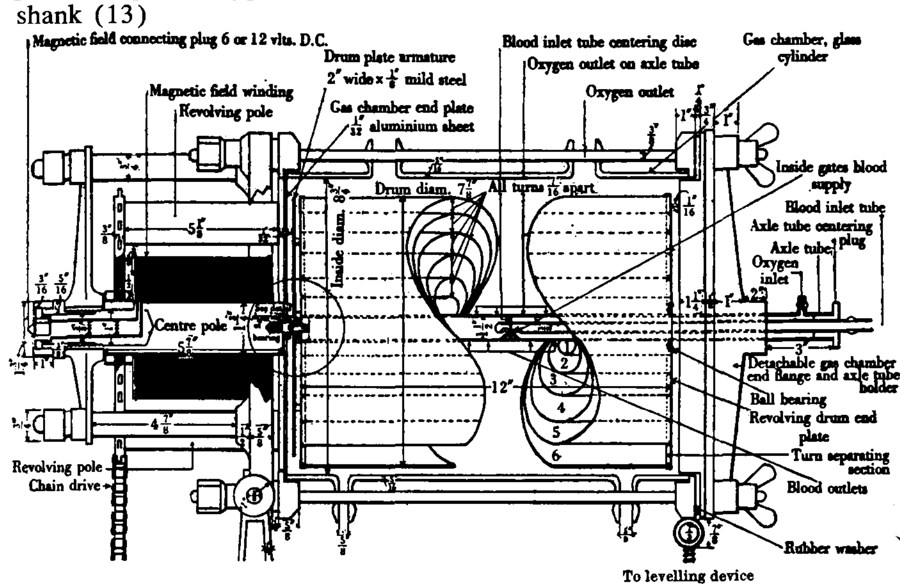
The greatest single advance in extracorporeal circulation became possible because of the availability of heparin. The first experimental total bypass of the heart and lungs was performed in heparinized animals by Gibbon,[14] who used a vertical rotating cylinder for filming blood (Fig. 5).

Bjork[15] in 1948 described the modern rotating disk oxygenator consisting of a trough with a series of vertical rotating disks (Fig. 6). Several years later Cross and Kay[16] further refined the rotating disk oxygenator for total-body perfusion by substituting stainless steel, Teflon-coated disks and a Pyrex silicone-coated chamber.

Jongbloed[17] in 1949 developed a film oxygenator with multiple rotating spiral coils in parallel system (Fig. 7). He considered using the pump in pa tients for support of the failing hea as well as for repair of congenital heart defects.

Clark and associates[18] in 1950 dispersed oxygen through a sintered glass filter to transmit minute bubbles into venous blood. These classic experiments refined the bubble oxygenator and introduced use of siloxine, which

Figure 4 Spiral Oxygenator, Cruickshank (13)



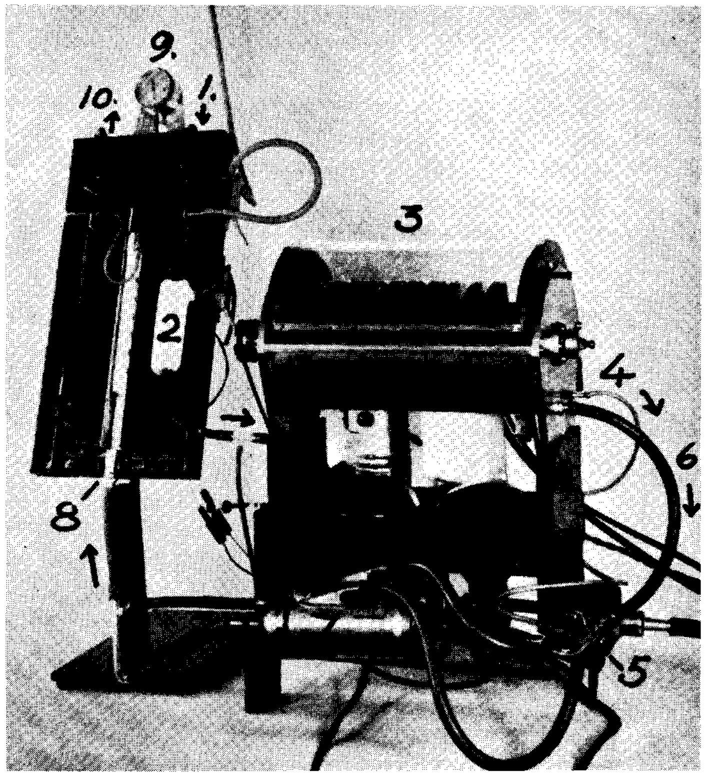


Figure 6 Modern Disk Oxygenator, Bjork (15)

Figure 5 Vertical Rotating Cylinder, Gibbon (14)

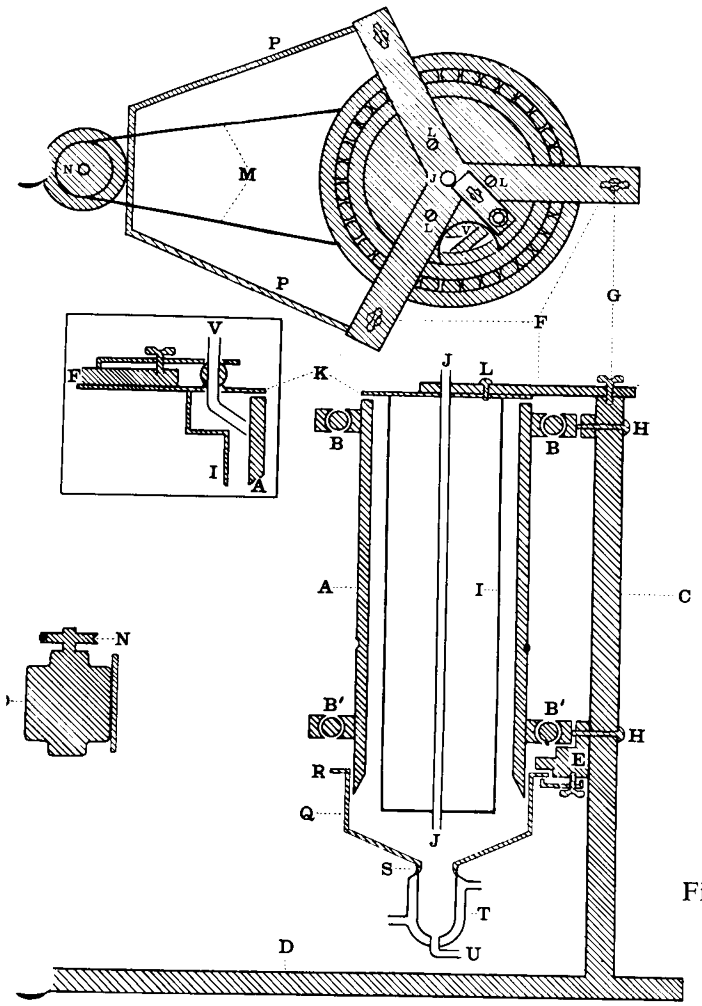
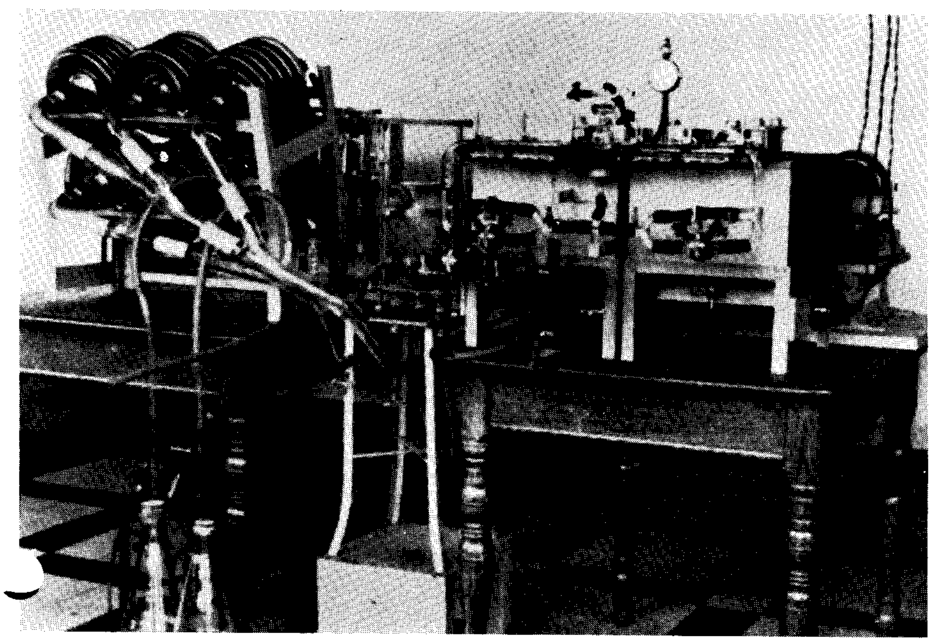


Figure 7 Film Oxygenator, Jongbloed (17)

permitted dispersion of oxygen into blood without foaming.

In 1951 Dennis[19] and associates used a rotating screen disk oxygenator in repairing an atrial septal defect, the first total cardiopulmonary bypass (Fig. 8), but the patient died. Gibbon[20] in 1953 performed the first successful total cardiopulmonary bypass in repairing an atrial septal defect. The oxygenator consisted of vertical stainless steel wire screens in a plastic container (Fig. 9). Modification of this system has resulted in the modern Mayo-Gibbon Oxygenator.

The famous helical reservoir bubble oxygenator, described in 1955 by DeWall[21] and associates, answered the need for a practical oxygenator. Simplicity of design and operation made it widely acceptable (Fig. 10). Venous blood returned by gravity to a reservoir, from which the blood was pumped to ascend through a vertical oxygenator column to be filmed in surface of large bubbles of oxygen entering the column. The original oxygenator has been modified to consist of a disposable polyethylene bag containing the



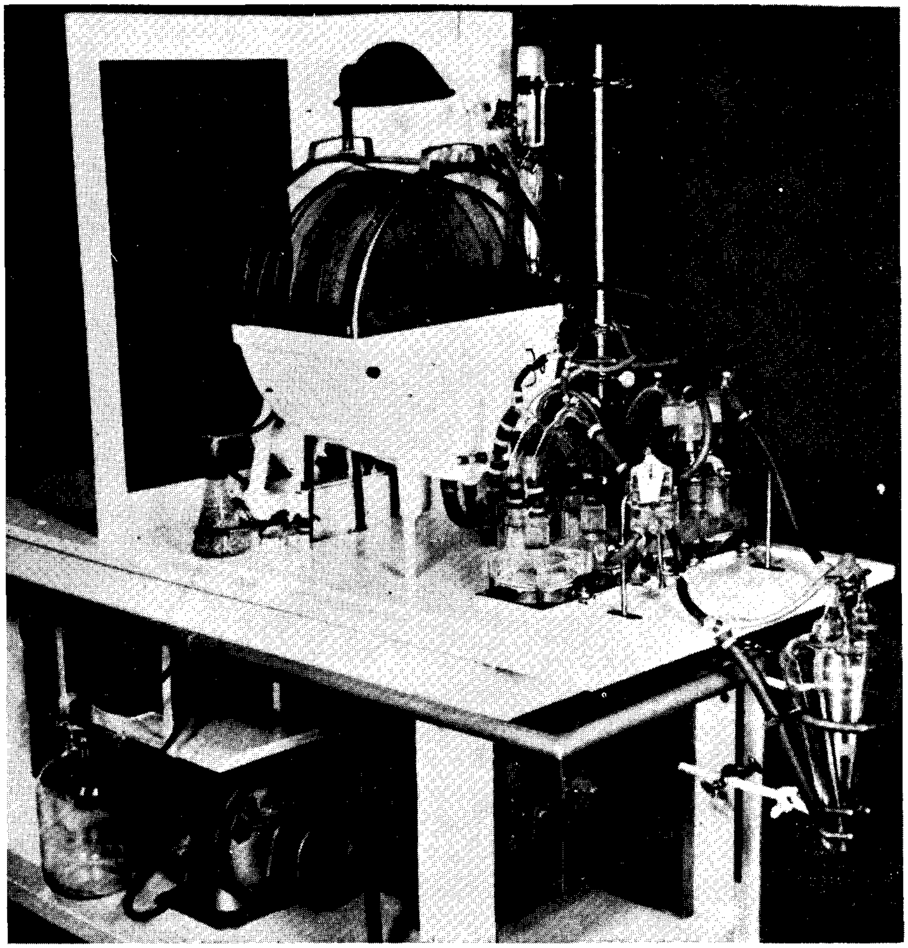


Figure 8 Screen Disk Oxygenator, Dennis (19)

vertical debubbling chamber and th helical coil.

The artificial kidney described by Kolff and Berk[22] in 1944 represented the first membrane oxygenator. Cellophane tubing served as the membrane. Subsequently, Karlson[23] and associates developed a cellulose membrane oxygenator. Clowes[24] and associates used an oxygenator composed of Teflon membranes. More recently Pierce[25] has refined a membrane oxygenator which may have practical application for long periods of respiratory support. A membrane oxygenator described by Brahmson and Gerbode[26] is currently being used clinically. A suitable membrane oxygenator will make cardiopulmonary bypass more applicable to patients with failing circulation.

Pumps

The DeBakey Roller Pump[27] has become standard for most modern pump oxygenator systems. The pump, consisting of a circular base plate and a compressible tube, was designed i 1934 for direct blood transfusions (Fig. 11). Flow is essentially nonpulsatile and no valves are needed. This pump was used with a vertical screen oxygenator by Dr. Gibbon[20] in 1953 when he performed the first successful open heart operation.

Various pulsatile pumps have been developed. A glass syringe was used in the first film oxygenating system by Von Frey and Gruber.[1] Jacobj[8] used a balloon pump to create pulsatile flow in his early bubble oxygenator. Piston pumps were used by Hooker,[10] Richards and Drinker[9] and others.[28]

In 1928, Dale and Schuster[29] devised an ingenious piston pump (Fig. 12). The mechanism consisted of a crankshaft driven by pulley, which moved a vertical pumping rod connected to a diaphragm. The diaphragm moved water into and out of a vertical finger stall, which alternately expanded to force blood from the glass dome

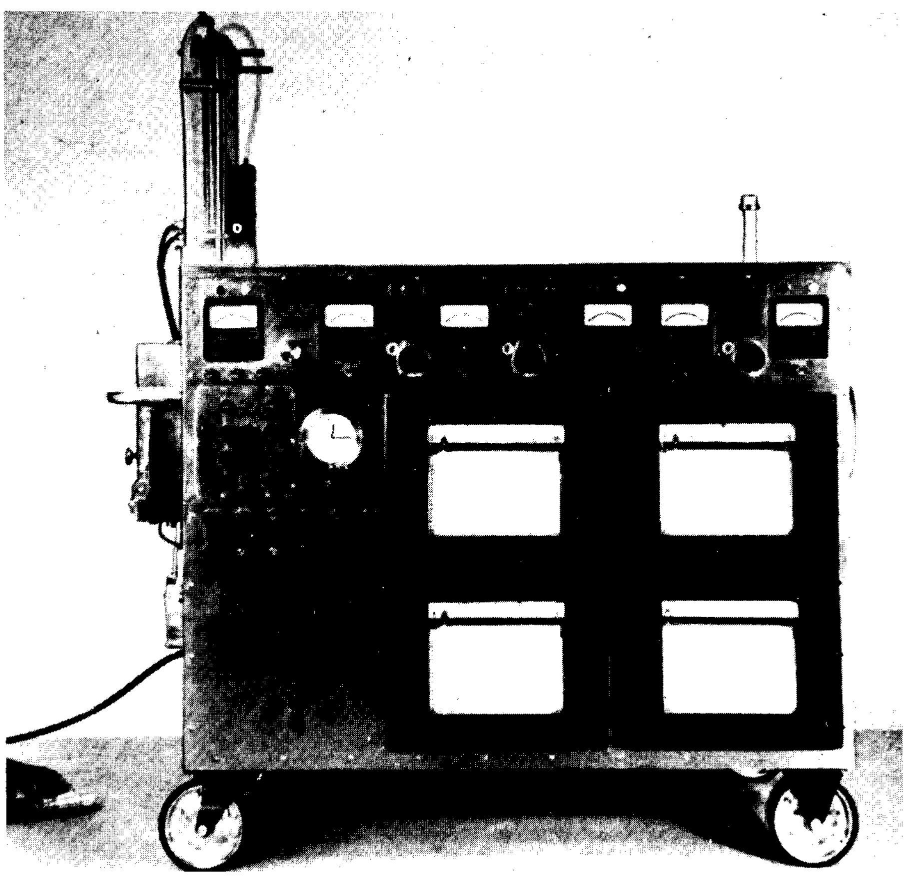


Figure 9 Gibbon (20) Screen Oxy genator

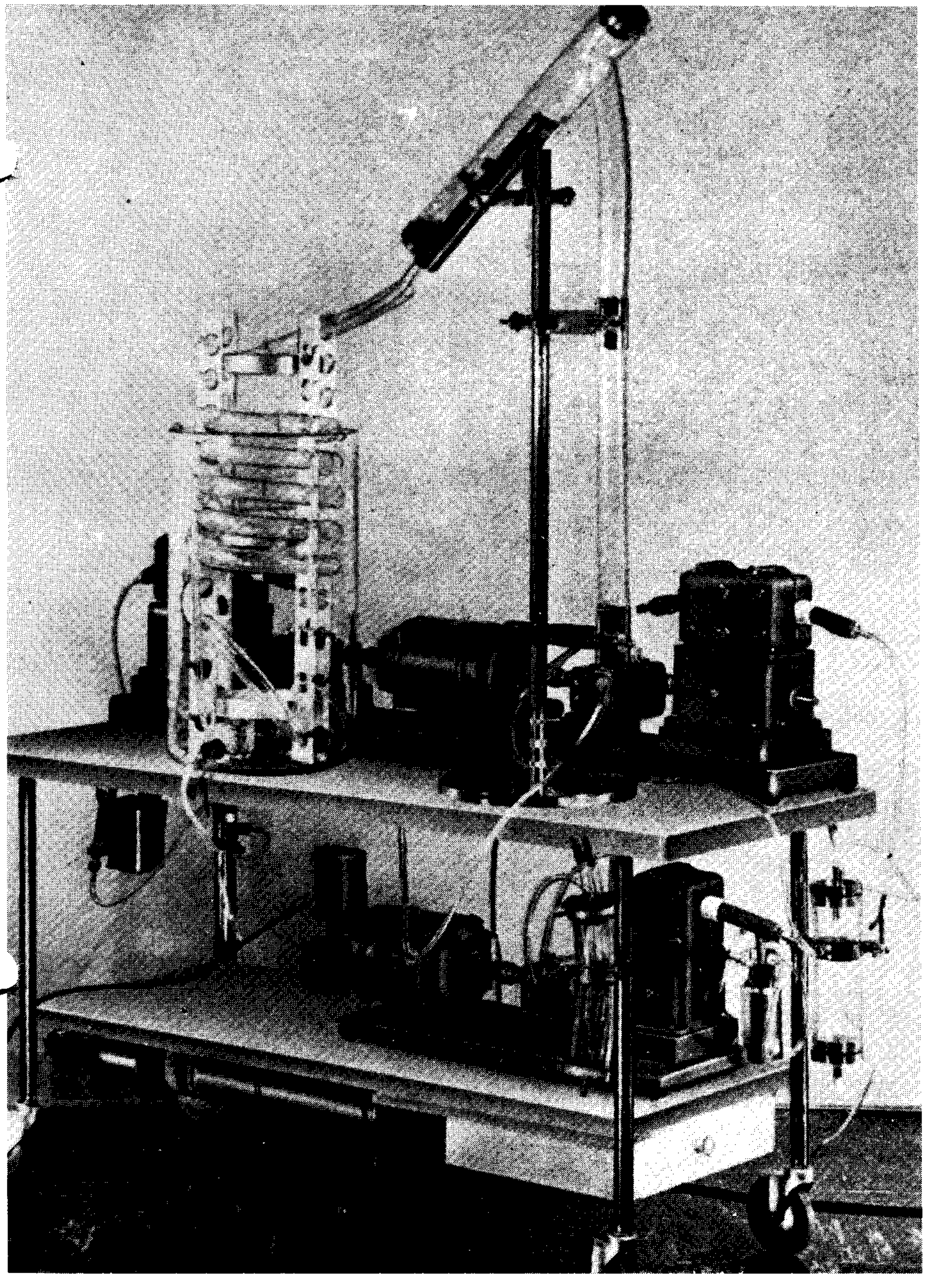


Figure 10 DeWall (21) Bubble Oxygenator

cylinder and contracted to allow filling. This pump was used experimentally by Daily and Thorpe,[12] Jongbloed,[17] Gibbon,[14] and Clowes[30] and clinically by Dodrill[31] who performed the first successful complete bypass of the right side of the heart in repair of congenital pulmonary stenosis. Dennis[19] also used a Dale-Schuster Pump in the first clinical total cardiopulmonary bypass mentioned previously. Recently, a hydraulically driven diaphragm pump generator has been used for support of the heart.[32, 33]

Pumps operated by compressed air were used by Bjork[15] for his classical oxygenator and by Charles A. Lindbergh,[34] the famous aviator who became a biochemical assistant to Carrel at the Rockefeller Institute and described a system for isolated organ perfusion. The Army Pulsatile Heart Pump, a modern development, is powered by compressed air.[35] It may have certain clinical application because of its versatility in synchronous cardiac assistance.[36]

Conclusion

No recent development in surgery has been as spectacular as that of extracorporeal circulation. The ultimate challenge, perfection of an intracorporeal heart, will no doubt be met in the future. The design of such a pump will be secondary to the problem of power supply.[37]

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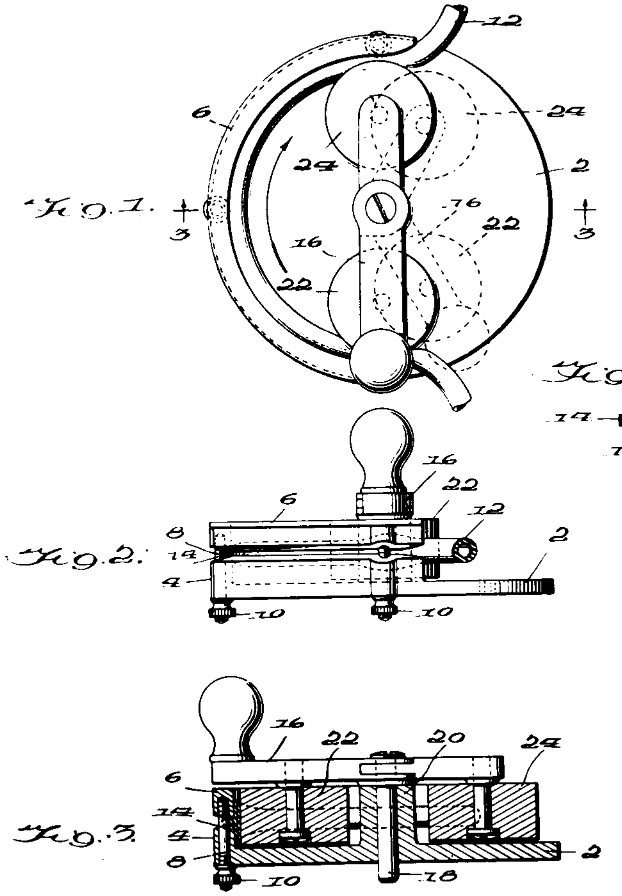

Figure 1. Plane view. Diagrammatic representation of instrument.
Figure 2. Side view of instrument.
Figure 3. Cross-section of instrument.
Figure 3a. Cross-sectional representation of tube.

Figure 11 DeBakey (27) Roller Pump

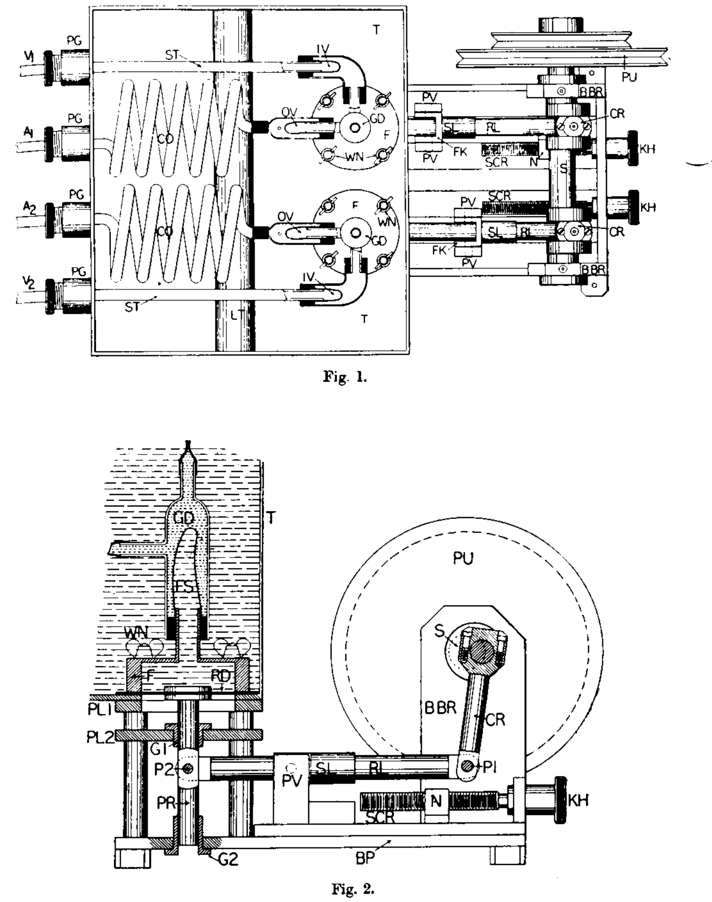

Figure 12 Dale-Schuster (29) Pump

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