

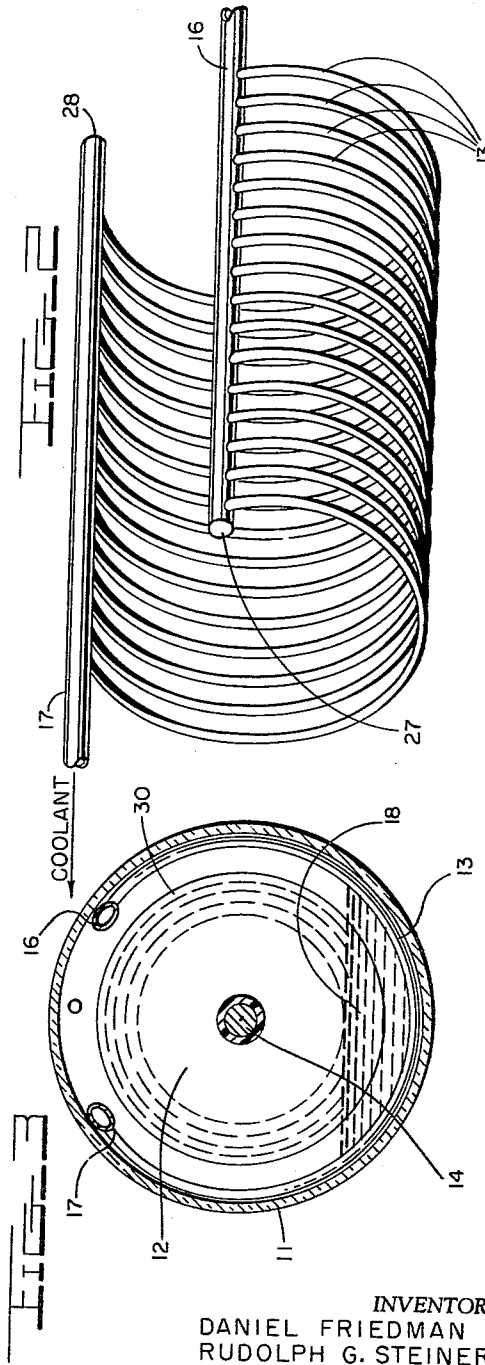
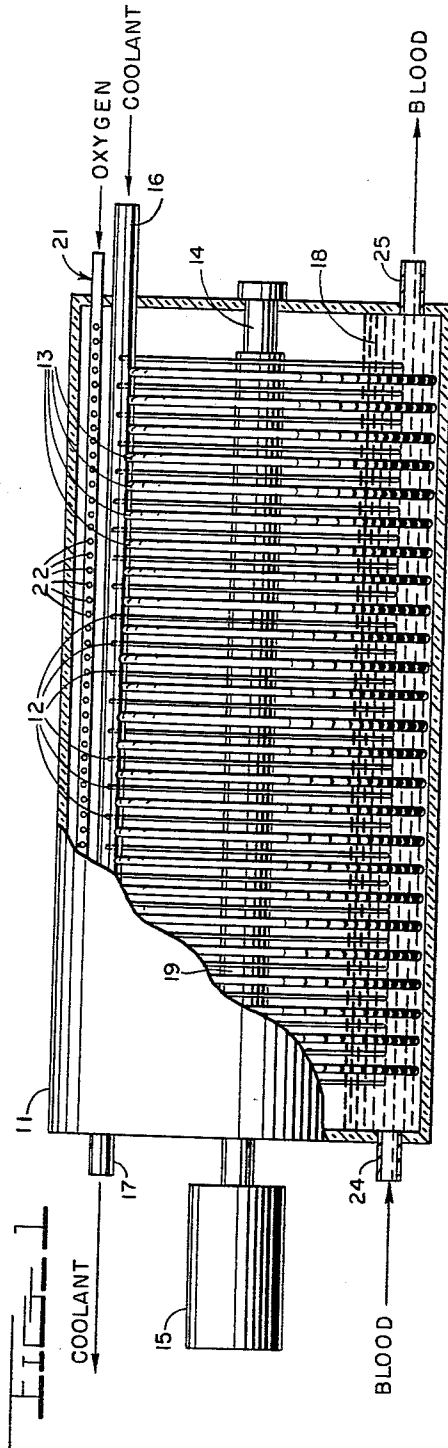
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APPARATUS FOR CONTROLLING BODY TEMPERATURE

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APPARATUS FOR CONTROLLING BODY TEMPERATURE

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The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

This invention relates in general to a device for reducing body temperature and in particular for reducing body temperature in conjunction with the use of an artificial lung during surgical procedures.

In major surgery, the patient's probability of survival is increased if his body temperature is reduced below the normal value of 98.6° F. during the surgical procedures. When an artificial lung or heart is used and blood is circulated outside the body, an excellent opportunity is presented for effecting a reduction in body temperature provided a sufficient degree of cooling can be attained without damaging the blood. Devices in the prior art for cooling or heating the blood while it is circulated outside the body, such as heat exchangers in which the blood is forced through tubing which is cooled by immersion in a coolant, have not achieved a desirable cooling or heating rate without significant blood damage. Other devices for cooling the body during surgery, such as an intragastric cooler which circulates hot or cold water in a balloon inside the patient's stomach, may not damage the blood but fail to provide a sufficient rate of heat transfer. Moreover, no known prior art device is capable of effectively and simultaneously cooling and oxygenating during surgery.

Accordingly, it is an object of this invention to provide a device for cooling the blood at an effective rate while the blood is circulating outside the body.

A further object of this invention is to provide a heat exchanger for cooling or heating blood that can be easily disassembled, cleaned and sterilized.

A further object of the present invention is to provide a device capable of interchangeably cooling or heating blood at a predetermined rate without significant damage to the blood.

A further object of this invention is to provide a blood heat exchanger capable of simultaneously oxygenating the blood without significant damage thereto.

Other objects and advantages of this invention will become apparent upon a careful consideration of the following description when read in conjunction with the following drawings in which like reference numerals designate like parts throughout the figures thereof and wherein:

FIG. 1 shows a schematic diagram partly cut away of an embodiment of the present invention.

FIG. 2 is an isometric view of a portion of a component shown in FIG. 1.

FIG. 3 shows a cross section of a portion of the embodiment shown in FIG. 1.

In accordance with the teachings of the present invention a heat exchanger is provided that will both cool the blood of a person undergoing surgery without damage thereto and simultaneously supply oxygen to the blood. The combined heat exchanger and artificial lung comprises a horizontal cylinder having an inlet for the entrance of blood in the lower portion of one end and an outlet for blood discharge at the other end. The level

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of blood in the cylinder is determined by the point at which there is observed the least amount of foaming of blood, and this level is maintained throughout the operation. The curved portions of heat exchanger tubing passing through the blood and spaced equidistant from each disc cool (or heat) the blood as it circulates, while oxygen introduced through holes in a pipe located above the discs oxygenates the blood at the same time. By means of the foregoing device, a patient's temperature is rapidly reduced prior to or during surgery and is rapidly increased after surgery thereby significantly increasing his chance of survival.

Referring to FIG. 1, chamber 11 of Pyrex or similar transparent, stable and firm material is cylindrical in shape with circular end plates which support at their center the shaft 14. Circular discs 12, shown in cross section in the figure, are mounted on shaft 14 and separated by uniform spacers 19. In a preferred embodiment, the discs 12 are of stainless steel while the spacers 19 are of Teflon, however, different materials not contaminating the blood and of sufficient durability can be substituted within the concept of this invention. Circular tubing elements 13 are spaced one each along the peripheries of discs 12 and follow the contour of chamber 11, one end terminating in supply header 16 and the other in return header 17 (shown in FIG. 2). Pipe 21 has perforations 22 through which oxygen is introduced into the chamber. Rotor 15 can be any conventional means to rotate shaft 14 at the speed desired to reduce foaming while maintaining the oxygen content in the blood. Blood from the patient, designated at 18, is introduced into chamber 11 through stainless steel inlet 24 and exited through outlet 25 also of stainless steel. The rate of flow is determined by a patient's requirements and is provided by a pump not shown.

In FIG. 2, tubing 13 is shown schematically as it is assembled in chamber 11 to form a heat exchanger. The supply header 16 has soldered to it, or otherwise secured in watertight fittings, stainless steel tubing 13 which in turn are soldered or otherwise secured to return header 17. Ends 27 and 28 of headers 16 and 17, respectively, are adapted to fit into the ends of chamber 11 where they are held in position by fittings not shown.

In FIG. 3, a cross section in part of the embodiment shown in FIG. 1 depicts a disc 12 having a film of blood indicated by dotted lines at 30 thereon. Chamber 11 contains blood, indicated by dotted lines at 18, to a depth determined by the least amount of foaming noted when the discs are rotated at a representative speed, and headers 16 and 17 suspend tubing 13 in place in the chamber.

In operation, blood is circulated through chamber 11 by a conventional pump, not shown, which is inserted in the supply line attached at inlet 24 or in the return line attached at outlet 25, or both. The displacement of the pump or pumps is regulated to the requirements of the patient. Rotor 15 is set in motion rotating discs 12 at a selected rate, each disc being coated to the extent of its dip into the blood, with a film of blood indicated at 30. Cooling water introduced into header 16 at a predetermined rate and temperature lowers the temperature of the blood in the chamber through direct contact with that in the bottom of the chamber. The thickness of the blood in the bottom of the chamber causes it to be dragged along by the discs 12, which motion causes the blood to flow across the surfaces of tubing 13 thereby effecting a very much greater heat transfer than ordinarily would be realized. The amount of heat transfer is increased by increasing the speed of the discs, however, it has been noted that a median speed exists above and below which increased foaming occurs. This median speed is maintained throughout the operative proceed-

ings, the rate of flow and/or temperature of the heat exchange fluid being adjusted to produce a desired change in the temperature of the blood.

Where it is possible to adapt means other than visual to determine the speed at which least foaming occurs it is, of course, not necessary to have the chamber made of Pyrex or similar material. It is also not necessary that the coils 13 span the entire array of discs 12 for all applications of the invention, it being sufficient that where the coils do not span all discs the portion of discs partially enclosed by coils should have a continuous coil, disc, coil etc., arrangement leaving the discs at either end of the exchanger assembly shown in FIG. 2 unenclosed by coils.

As pointed out above, a tremendous improvement in the rate of heat exchange has been obtained by the use of the structure shown in the drawings. This improvement may be attributed to several features of the invention but the exact contribution of each of these features has not been positively ascertained at this time. It will be appreciated that the rotation of the discs serves to greatly increase the rate of flow of the blood across the surface of the heat exchanger element within the blood pool without disturbing the rate of flow through the body of the patient and without disturbing the consistency of the blood by foaming. In this manner an improved conduction type heat transfer is obtained between the heat exchanger element and the blood. At the same time, the rotation of the discs serves to distribute the blood over a greater surface area in the form of a film and in this manner an improved convection type heat transfer is obtained between the filmed blood and the surrounding air currents.

It will be appreciated that oxygen may be introduced through pipe 21 to react with the filmed blood such that the chamber acts as an artificial lung as well as a heat exchanger. In addition, the heat exchanger tubing has been noted as reducing the tendency of blood to foam, which in turn reduces blood damage and destruction of red cells. It will also be appreciated that while the present invention has been described primarily as a heat exchanger for cooling blood and reducing body temperature, it is interchangeably a heater for heating blood and increasing body temperature following surgery. Heating is accomplished by merely forcing water or other liquid heated to a predetermined temperature through the coils in lieu of the coolant used to reduce body temperature.

Many modifications and variations of the present invention are possible pursuant to 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 is:

1. An extracorporeal circulation device for oxygenating blood and controlling body temperature through controlling blood temperature comprising an elongated chamber, means for inducing a flow of blood through said chamber, conduit means in said chamber, a heat exchange fluid and means for inducing a flow of said fluid through said conduit means for controlling the temperature of the blood in said chamber, and means for imparting motion to the blood in said chamber substantially transverse to the longitudinal axis thereof and substantially parallel to said conduit means.

2. An extracorporeal circulation device for controlling body temperature through control of blood temperature comprising an elongated chamber, means for inducing a flow of blood through said chamber, means for imparting motion to the blood in said chamber substantially transverse to the longitudinal axis thereof, and means in said chamber for controlling the temperature of the blood therein, said means for controlling temperature including a plurality of spaced fluid conducting members each extending substantially around the inner periphery of said chamber and adjacent thereto.

3. An extracorporeal circulation device for controlling body temperature through controlling blood temperature

comprising an elongated chamber, means for inducing a flow of blood through said chamber, means for imparting motion to the blood in said chamber substantially transverse to the longitudinal axis thereof, means in said chamber for controlling the temperature of the blood therein, said means for controlling temperature including a plurality of spaced substantially parallel heat exchange members each extending substantially around the inner periphery of said chamber, and means for circulating oxygen through said chamber such that oxygen is absorbed by the blood filmed on surfaces in said chamber.

4. An extracorporeal circulation device for controlling body temperature through controlling blood temperature comprising an elongated chamber, means for introducing blood into said chamber, means for imparting motion to said blood substantially transverse to the longitudinal axis of said chamber, means for controlling the temperature of the blood while in said chamber, said means for controlling temperature including a plurality of substantially parallel spaced fluid conducting members disposed adjacent to the inner periphery of said chamber transverse to said longitudinal axis, connecting means for connecting said conducting members to heat exchange medium supply and discharge lines, and exiting means for exiting the blood from said chamber, said introducing means and said exiting means cooperating to maintain a selected level of blood within said chamber, said level providing for immersion of a selected portion of said conducting members in the blood.

5. An extracorporeal circulation device for controlling body temperature through controlling blood temperature comprising an elongated chamber, means for introducing blood into said chamber, rotary means in said chamber for imparting motion to the blood in said chamber substantially transverse to the longitudinal axis thereof, means for controlling the temperature of the blood while in said chamber, said means for controlling temperature including a plurality of substantially parallel heat exchange members disposed adjacent to the inner periphery of said chamber substantially transverse to longitudinal axis thereof, connecting means for connecting said conducting members to coolant supply and discharge lines, and exiting means for exiting the blood from said chamber, said introducing means and said exiting means cooperating to maintain a selected level of blood within said chamber, said level providing for immersion of a selected portion of said conducting members in the blood, said heat exchange members and said rotary means disposed in planes parallel to one another and perpendicular to said longitudinal axis.

6. An extracorporeal circulation device for controlling a patient's body temperature through controlling the temperature of his blood comprising an elongated chamber, means for providing a flow of blood from the patient to said chamber, a plurality of rotatable disc surfaces positioned in said chamber for imparting motion to said blood transverse to the longitudinal axis of said chamber, means for rotating said disc surfaces, temperature control means for controlling the temperature of said blood, said temperature control means including a plurality of spaced heat exchange members each extending substantially around the inner periphery of said chamber and adjacent thereto, circulating means for circulating oxygen through said chamber such that oxygen is absorbed by the blood on surfaces in said chamber, and means for conveying the temperature-controlled and oxygenated blood to said patient.

7. An extracorporeal circulation device for controlling a patient's body temperature through control of his blood temperature comprising an elongated chamber, means for conveying blood from the patient to said chamber, a plurality of rotatable discs positioned in said chamber, means for rotating said discs, temperature control means for controlling the temperature of the blood in said chamber, said temperature control means including a plurality of

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arcuate members, positioned parallel to one another and connected at opposite ends to an inlet header and an outlet header, said discs adapted to impart a motion to said blood transverse to the longitudinal axis of said chamber and parallel to said temperature control means, circulating means for circulating oxygen through said chamber in the vicinity of said discs such that oxygen is absorbed by the blood on said discs, and means for conveying said temperature-controlled and oxygenated blood to said patient.

8. An extracorporeal circulation device for controlling body temperature through control of blood temperature comprising an elongated chamber substantially circular in transverse section, means for inducing a flow of blood from a patient into said chamber, rotary means in said chamber for imparting motion to the blood therein substantially transverse to the longitudinal axis thereof, said rotary means including a plurality of disc surfaces substantially parallel to one another, heat exchange means in said chamber for controlling the temperature of the blood therein, said heat exchange means including a plurality of conducting members disposed adjacent to the inner periphery of said chamber and extending transverse to the longitudinal axis thereof, means connecting said conducting members to a heat exchange source exterior to said chamber, said conducting members disposed one each in a plane between and substantially parallel to the planes of a pair of successive discs surfaces, and exiting means for exiting the blood from said chamber to the patient, said inducing means and said exiting means cooperating to maintain a selected level of blood within said chamber, said level providing for immersion of a selected portion of said disc surfaces and said conducting members in the blood in said chamber whereby the temperature of said blood is controlled.

9. An extracorporeal circulation device for controlling body temperature through control of blood temperature comprising an elongated chamber substantially circular in transverse section, means for conveying blood to said chamber, means for exiting blood from said chamber, said means for conveying blood and exiting blood cooperating to maintain the blood in said chamber substantially at a selected level, means for imparting motion to the blood in said chamber substantially transverse to the longitudinal axis thereof, said means for imparting motion including a plurality of rotatable surfaces positioned substantially parallel to and substantially equidistant from one another in said chamber, means for rotating said surfaces, and temperature control means including a plurality of coils for controlling the temperature of the blood in said chamber, said plurality of coils positioned one each substantially equidistant from the peripheries of successive pairs of said surfaces, said plurality of coils being positioned such that the motion imparted to the blood by said surfaces causes the blood to be washed along a portion of said coils thereby effecting a high heat transfer between the blood and the coils.

10. An extracorporeal circulation device for oxygenating blood and controlling body temperature through control of blood temperature comprising an elongated chamber substantially circular in transverse section, means

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for conveying blood from a patient to said chamber, means in said chamber for filming the blood therein, said means for filming including a plurality of rotatable surfaces positioned substantially symmetrically in said chamber, means for rotating said surfaces, temperature control means positioned within said chamber for controlling the temperature in said chamber, said temperature control means including a heat exchange fluid, conduit means and means for inducing a flow of said fluid through said conduit means, circulating means for circulating oxygen through said chamber in the vicinity of said surfaces such that the oxygen is absorbed in the blood substantially while in its filmed state, and means for exiting the blood from said chamber.

11. An extracorporeal circulation device for controlling body temperature through control of blood temperature comprising an elongated chamber substantially circular in transverse section, means for conveying blood to said chamber, filming means for filming the blood conveyed to said chamber, said filming means including a plurality of rotatable surfaces substantially parallel to one another, means for rotating said surfaces, heat exchange means in said chamber for controlling the temperature of the blood therein, said heat exchange means including a plurality of conducting members disposed adjacent to the inner periphery of said chamber and extending transverse to the longitudinal axis thereof and means connecting said conducting members to a heat exchange source exterior to said chamber, said conducting members disposed substantially one each in planes between the planes of substantially successive surfaces, exiting means for exiting the blood from said chamber to the patient, said means for conveying and said exiting means cooperating to maintain a selected level of blood within said chamber, and circulating means for circulating oxygen through said chamber such that oxygen is absorbed by the blood on surfaces in said chamber whereby the temperature and the oxygen content of the blood is controlled.

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