Jan. 22, 1963 FRANCISCO MARTINO SAVINO 3,074,559

DIALYZER CHAMBER WITH CAPILLARY SYSTEM

Filed March 17, 1959 2 Sheets-Sheet 1

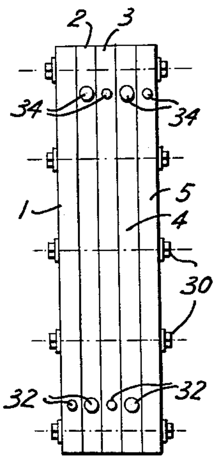

Fig. 1

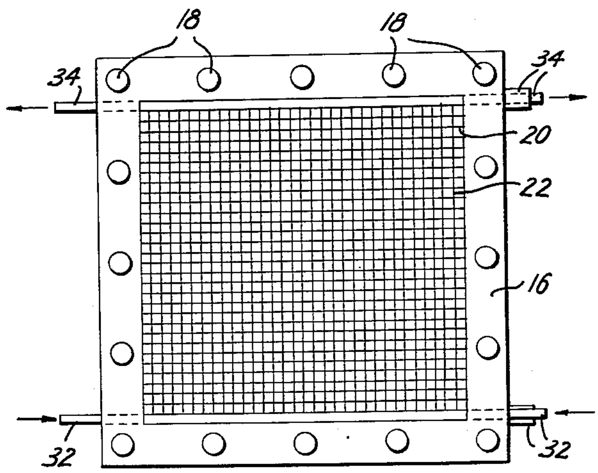

Fig. 2

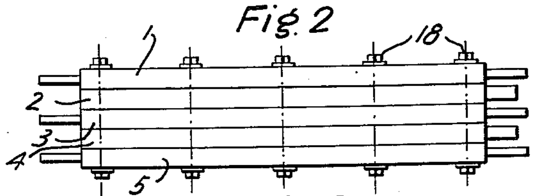

Fig. 3

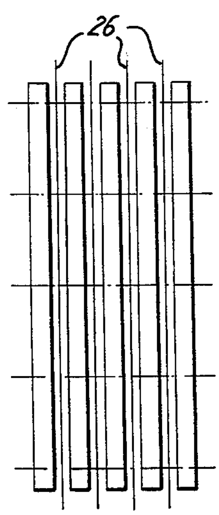

Fig. 4

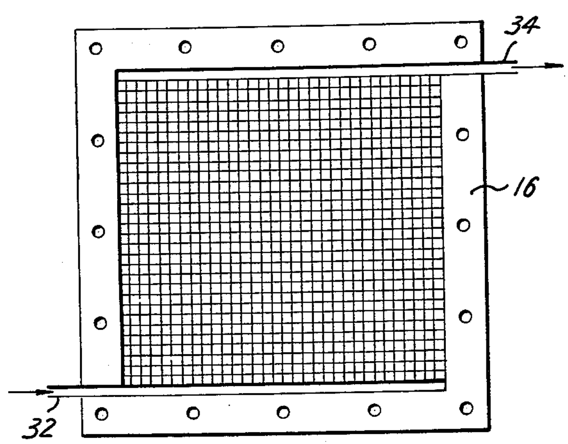

Fig. 5

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Jan. 22, 1963 FRANCISCO MARTINO SAVINO 3,074,559
DIALYZER CHAMBER WITH CAPILLARY SYSTEM
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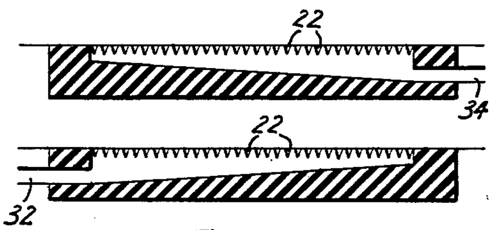

Fig. 6

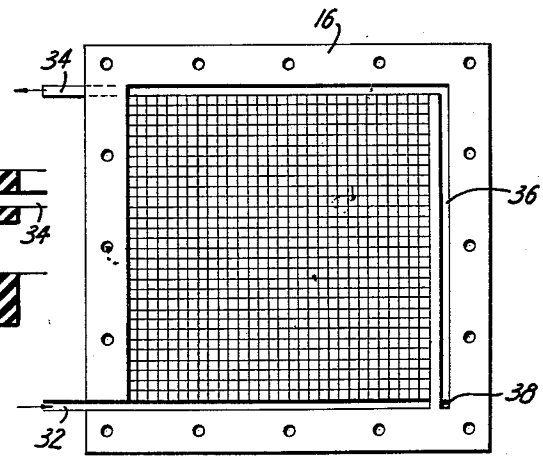

Fig. 7

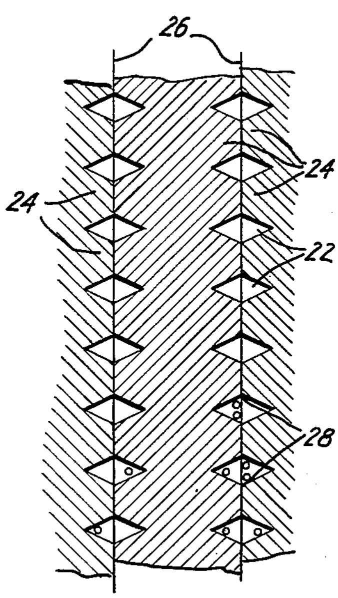

Fig. 8

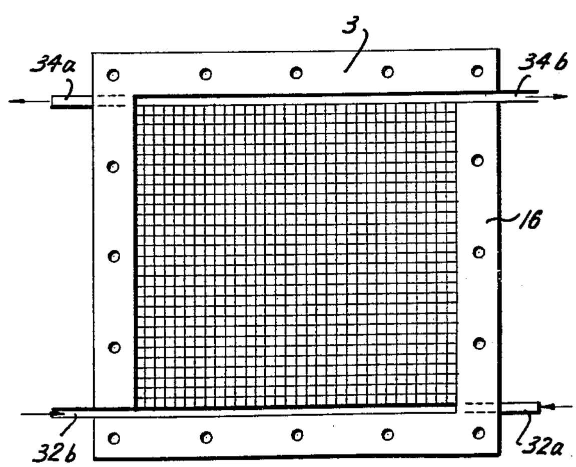

Fig. 9

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DIALYZER CHAMBER WITH CAPILLARY SYSTEM

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The present invention relates to a dialysis type of artificial kidney. More particularly, the invention relates to a dialysis chamber and plates utilized in a dialysis type of artificial kidney.

In order that the invention may be readily carried into effect, it will now be described with reference to the accompanying drawings, wherein:

FIG. 1 is a side view of an embodiment of a plurality of plates of the present invention;

FIG. 2 is a front view of a plate of the present invention;

FIG. 3 is a top view of the plurality of plates of FIG. 1 rotated through an angle of 90°;

FIG. 4 is a side view of the plurality of plates of FIG. 1 with cellophane sheets interposed therebetween;

FIG. 5 is a front view of an end plate of FIG. 1;

FIG. 6 is two sectional views of a plate of FIG. 1 showing an embodiment of an inlet and an outlet conduit;

FIG. 7 is a front view of an intermediate plate of FIG. 1;

FIG. 8 is a transverse sectional view of adjacent intermediate plates of FIG. 1; and

FIG. 9 is a front view of an embodiment of an intermediate plate of the present invention.

The dialysis chamber preferably comprises five square plates (36 cms. each side; 14 mms. thick) of translucent acrylic material numbered from 1 to 5 (FIGS. 1, 3 and 4). The dialysis liquid circulates through the inside surfaces of plates 1 and 5, and through the two surfaces of plate 3, and the blood circulates through the two surfaces of the two plates 2 and 4.

The surfaces of the plates, except for a narrow margin 16, three cms. wide, where the pressure screws 18 that lock the plates together are located (FIGS. 2, 5, 7 and 9), have horizontal and vertical grooves 20, 22 therein; each groove being a channel of triangular cross-section with an open base at the surface of the plate and 1 mm. depth x 1 mm. base width. These grooves or channels 20, 22 limit square salients or eminences 24 with sides of 1 mm. that face (divided by the cellophane membrane 26) the eminences 24 of the adjacent plate; the grooves of adjacent plates being correspondingly disposed on both sides of the cellophane sheet 26 interposed between said plates (FIG. 8). At the angles formed between the membrane 26 and the eminences, true capillary spaces 28 are created (FIG. 8) as a result of the elimination of the edges by a careful polishing of the plastic material; the capillary spaces being formed in the junctions of the grooves of the plates with the cellophane sheet. The polish avoids the necessity for silicon-treatment of the plates.

Mounting

The dialysis chamber may be assembled in less than 10 minutes. The plates, on one of their faces, are fitted with three projections (not shown) that fit in three grooves (not shown) made in their other face when they are positioned plate to plate. This disposition prevents the rubbing of one plate against the other and subsequently prevents the breaking of the cellophane sheet. Furthermore, the surface of the cellophane sheet undergoing pressure is a groove one mm. wide, quite sufficient for the purpose.

The plate 1 is horizontally placed on a table with its

grooved surface and its three positioning grooves upwards. A square sheet (40 cms. per side) of absolutely dry cellophane 26 is spread on the plate 1. Then plate 2 is positioned on the cellophane with its three projections seated in the three grooves of plate 1 (the projections piercing and fixing the cellophane in position). The process is continued with the remaining cellophane sheets and plates. The final assembly of the dialysis chamber is a compact block pierced by sixteen bolts or screws 18, each having a fixed head 30, which screws may be tightened with a pipe-wrench.

An advantage of the dialysis chamber of the present invention is that cellophane sheets of 20 microns thickness may be used, these sheets being the thinnest available. But it is surely possible to use an even thinner sheet, such as, for example, a sheet 10 microns thick.

Function

The plates are positioned vertically in the dialysis chamber; the liquids or fluids are supplied through an inlet conduit or spout 32 (metallic for the dialysis liquid and plastic for the blood) in the lower part, and removed through an upper outlet conduit or spout 34. To reach the grooved surface the spouts extend through the plate in its ungrooved areas or margins 16. The perfect distribution of the blood and the dialysis liquid or fluid is obtained in the following way. The lower inlet conduit or spout extends in a channel 3 mm. wide. The open end of the inlet conduit to which fluid is supplied is 7 mms. deep and the closed end of said conduit is 1 mm. deep so that the inlet conduit has a cross-sectional area which decreases from a maximum at the open end to a minimum at the closed end (FIG. 6). This insures an even distribution of fluid in all the grooves. The fluid is supplied to the inlet conduit of a surface of the plate, irrigates the grooves in the surface of the plate and is removed by the outlet conduit of that surface of the plate. The outlet conduit extends in a channel having a cross-sectional area which increases from a minimum at the closed end to a maximum at the open end from which the fluid is removed (FIG. 6). The outlet conduit is preferably located at the upper end of the plate. This insures an even removal of fluid from all the grooves.

In the plates 2, 3 and 4, once fluid or the liquid reaches the closed end of the inlet conduit, it flows into a channel 36 (3 mms. wide, 4 mms. deep) opening into the grooves along the vertical margin or area 16. The fluid reaches the lower area or margin of the other surface of the plate through a perforation 38 and the same process is repeated on the other surface of the plate. Plates 2, 3 and 4 therefore have their inlet and outlet spouts or conduits opening at the same margin (FIG. 7).

The patient's blood enters through the lower spout or inlet conduit 32 of plate 2, flows through the grooves in the two surfaces of said plate and leaves through the upper spout or outlet conduit 34 where a rubber tube conveys it to the lower spout or inlet conduit 32 of plate 4. The blood then flows through the grooves in the two surfaces of the plate 4 and leaves through the upper spout or outlet conduit 34, and then is reinjected into the patient. These two plates (and their four surfaces) are "series" connected; and this determines, as blood flow of 200–250 mls./min. being considered, a pressure (at the inlet conduit or spout of the one plate 2) of about 15 cms./Hg.

For the purpose of obtaining a substantial pressure difference between the blood compartment and that of the dialysis liquid, "two" intakes 32 are provided for the dialysis liquid. The dialysis liquid pump is of the compression rubber tube type and supplies "two" sources of dialysis liquid of 250–300 mls./min. each; the first irrigates the surface of plate 1 and also, through a translucent polyvinyl tube connecting both surfaces, the surface of plate 5. The second irrigates the two surfaces of plate 3. The dialysis liquid therefore enters through the lower spouts or inlet conduits 32 of the plates 1 and 3 and leaves through the upper spouts or outlet conduits 34 of plates 3 and 5 with the urea, etc. dialyzed. In this way the dialysis liquid pressure at the inlet conduits or spouts 32 hardly reaches 8 cms./Hg. It is thus not possible for the dialysis liquid to pass to the blood.

The plate 3 may comprise the embodiment of FIG. 9. In this form the plate 3 has four spouts or conduits. The dialysis liquid enters through the right lower spout or inlet conduit 32*a*, irrigates the one surface of the plate, and leaves through the left upper spout or outlet conduit 34*a*. A plastic tube connects the left upper outlet conduit 34*a* with the left lower spout or inlet conduit 32*b*, irrigates the other surface of the plate, and leaves through the upper right spout or outlet conduit 34*b*.

This is done in order to be able to exclude a membrane, in case of rupture, without interrupting the flow of dialysis liquid, but since there have been 100 dialysis operations realized without any membrane rupture, this precaution is now without value. Nevertheless, it should be borne in mind that to isolate a ruptured membrane, one has only to change, of course, the connections of the tubes that lead to the dialysis liquid. Supposing that the membrane fitted between plates 3 and 4 ruptures (which can be noticed, since the dialysis liquid goes through the translucent plastic tube that connects the two left spouts or conduits of the plate 3) said dialysis liquid is suppressed and said tube connected at the upper right spout or conduit 34*b* of this plate is changed to the upper left spout or conduit 34*a*. Any membrane can therefore remain isolated. This helps the dialysis chamber to go on with its work with the remaining membranes.

The consumption of dialysis liquid in this dialysis chamber is therefore 500–600 mls./min. Subsequently 200 liters of dialysis liquid is enough to assure the performance of the artificial kidney for more than 5 hours.

The dialysis surface is very small as it does not exceed about one thousand eight hundred sq. cms.; this minimizes the possible toxic effect of the cellophane sheets.

As the compartment of the dialysis chamber through which the blood flows has a capacity of 150 mls. it is not necessary to fill it with bank blood; any isotonic solution is adequate for the purpose.

The sterilization of the dialysis chamber is carried out with a profuse washing with Mertiolate, followed by another full washing with sterile water and finally another washing with sterile isotonic saline serum, with which the dialysis chamber is filled, and said chamber is then ready for utilization. The polyvinyl tubes, catheter and the rubber bulbs for pumping the blood, are boiled.

As the dialysis chamber has a great pressure in the blood compartment, the passage of glucose to such compartment is a minimum. During the dialysis, loss in weight of the patients of up to 750 grams has been noticed. When greater spoliations of tisular liquids (treatment of nephritic patients or suffering of acute edema of the lungs) are desired up to 30–40 grams per liter of polyvinylpirrolidon are added to the dialysis liquid. With this method spoliations of up to 2 liters/hour are obtained. Due to the different pressure existing between the blood compartment and the dialysis liquid compartment, the sterilization of same is not necessary.

For the purpose of simplifying the utilization of the dialysis chamber the method of Battezzati of a single catheter for both taking and delivery of blood, to avoid any hemodinamic trouble, is preferably utilized and is carried out by simple phlebotomy of the internal saphenous vein. The polyvinyl catheter utilized has 4 mms. diameter.

The dialysis chamber of the present invention is suitable for clinic research, for example, to carry out dialysis for two or more hours in dogs, always utilizing 500 mls.

of dialysis liquid that are not renewed during the dialysis. This dialysis liquid may be vacuum concentrated if desired.

The clearance of the dialysis chamber is 100–125 mls./min.; the dialysis liquid shows urea concentrations of 60 milligrams/100. At the beginning of the dialysis in patients with uremia of 400 milligrams/100 the dialysis liquid has shown concentrations up to 110 milligrams/100. As the flow of dialysis liquid is about 550 mls./min., the dialysis chamber extracts from 20 to 35 gms. urea/hour, and this permits the spacing of the applications in cases requiring the repetition of same (crush, poisoning, etc.)

Up to date, more than 100 applications have been carried out and no breach of the membrane has been noticed (the passage of blood to the dialysis liquid remains constantly clear and translucent, with no traces of albumin)—neither hemolysis (if any) over the permissible limit of 200 mgrs./100 nor blood coagulations that have prevented its use has been noticed. The artificial kidney is fitted with a little ampoule for driving out coagulum and bubbles; the best device for this purpose is the dialysis chamber itself that stops the small coagulum that may be formed or any solid element contained in the blood. The groove containing the coagulum is by this fact out of use, but the remaining part of the plate continues its functions). Without further analysis the foregoing will so fully reveal the gist of the present invention that others can by applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed and desired to be secured by Letters Patent is:

1. In a dialysis type of artificial kidney, the combination of at least two plates each having two sets of grooves of equal depth intersecting each other at an angle, the grooves of each of the two sets of grooves being equally spaced from each other and substantially parallel to each other; a cellophane sheet interposed between said plates and in substantial contact therewith, the grooves of said plates being correspondingly disposed on both sides of said cellophane sheet; and means for providing a circulating fluid flow through the grooves of each of said plates, said fluid flow circulating means comprising an inlet conduit for each of said plates for supplying fluid to at least one set of grooves of each of said plates, each said conduit having an open end to which said fluid is supplied and a closed end and a cross-sectional area which decreases in magnitude from a maximum at said open end to a minimum at said closed end, the grooves of said one set of grooves opening into each said conduit along its length between the said open end and the said closed end thereof.

2. In a dialysis type of artificial kidney, the combination of at least two plates each having two sets of grooves of equal depth intersecting each other at an angle, the grooves of each of the two sets of grooves being equally spaced from each other and substantially parallel to each other; a cellophane sheet interposed between said plates and in substantial contact therewith, the grooves of said plates being correspondingly disposed on both sides of said cellophane sheet; and means for providing a circulating fluid flow through the grooves of each of said plates, said fluid flow circulating means comprising an outlet conduit for each of said plates for removing fluid from at least one set of grooves of each of said plates, each said conduit having an open end from which said fluid is removed and a closed end and a cross-sectional area which decreases in magnitude from a maximum at said open end to a minimum at said closed end, the grooves of said one set of grooves opening into each said conduit along its length

between the said open end and the said closed end thereof.

3. In a dialysis type of artificial kidney, the combination of at least two plates each having two sets of grooves of equal depth intersecting each other at an angle, the grooves of each of the two sets of grooves being equally spaced from each other and substantially parallel to each other, a cellophane sheet interposed between said plates and in substantial contact therewith, the grooves of said plates being correspondingly disposed on both sides of said cellophane sheet; and means for providing a circulating fluid flow through the grooves of each of said plates, said fluid flow circulating means comprising an inlet conduit for each of said plates for supplying fluid to at least one set of grooves of each of said plates, each said inlet conduit having an open end to which said fluid is supplied and a closed end, and an outlet conduit for each of said plates for removing fluid from said one set of grooves of each of said plates, each said outlet conduit having an open end from which said fluid is removed and a closed end, each said inlet and outlet conduit having a cross-sectional area which decreases in magnitude from a maximum at said open end to a minimum at said closed end, the grooves of said one set of grooves opening into each said inlet and outlet conduit along its length between the said open end and the said closed end thereof.

4. In a dialysis type of artificial kidney, the combination of at least two plates each having two parallel surfaces and each having in each of its surfaces two sets of grooves of equal depth intersecting each other at an angle, the grooves of each of the two sets of grooves being equally space from each other and substantially parallel to each other; a cellophane sheet interposed between said plates and in substantial contact therewith, the grooves of opposing surfaces of said plates being correspondingly disposed on both sides of said cellophane sheet; and means for providing a circulating fluid flow through the grooves of each of the surfaces of said plates, said fluid flow circulating means comprising an inlet conduit for each of the surfaces of each of said plates for supplying fluid to at least one set of grooves of each of the surfaces of said plates, each said inlet conduit having an open end to which said fluid is supplied and a closed end, and an outlet conduit for each of the surfaces of each of said plates for removing fluid from said one set of grooves of each of the surfaces of said plates, each said outlet conduit having an open end from which said fluid is removed and a closed end, each said inlet and outlet conduit having a cross-sectional area which decreases in magnitude from a maximum at said open end to a minimum at said closed end, the grooves of said one set of grooves of each of the surfaces of the plates opening into their associated inlet and outlet conduit along its length between the said open end and the said closed end thereof.

5. In a dialysis type of artificial kidney, the combination of a plurality of plates each having two parallel surfaces and each having in each of its surfaces two sets of grooves of equal depth and a width at the surface of the plate equal to said depth intersecting each other at an angle, the grooves of each of the two sets of grooves being equally space a distance equal to their depth from each other and substantially parallel to each other; a plurality of cellophane sheets each interposed between adjacent plates and in substantial contact therewith, the grooves of opposing surfaces of said adjacent plates being correspondingly disposed on both sides of each of said cellophane sheets; and means for providing a circulating fluid flow through the grooves of each of the surfaces of said plates, said fluid flow circulating means comprising an inlet conduit for each of the surfaces of each of said plates for supplying fluid to at least one set of grooves of each of the surfaces of said plates, each said inlet conduit having an open end to which said fluid is supplied and a closed end, and an outlet conduit for each of the surfaces of each of said plates for removing fluid from said one set of grooves of each of the surfaces of said plates, each said outlet conduit having an open end from which said fluid is removed and a closed end, each said inlet and outlet conduit having a cross-sectional area which decreases in magnitude from a maximum at said open end to a minimum at said closed end, the grooves of said one set of grooves of each of the surfaces of the plates opening into their associated inlet and outlet conduit along its length between the said open end and the said closed end thereof.

6. In a dialysis type of artificial kidney, the combination of a plurality of plates each having two parallel surfaces and each having in each of its surfaces two sets of grooves of one millimeter depth and one millimeter width at the surface of the plate intersecting each other at an angle, the grooves of each of the two sets of grooves being spaced one millimeter from each other and substantially parallel to each other; a plurality of cellophane sheets each interposed between adjacent plates and in substantial contact therewith, the grooves of opposing surfaces of said adjacent plates being correspondingly disposed on both sides of each of said cellophane sheets; and means for providing a circulating fluid flow through the grooves of each of the surfaces of said plates, said fluid flow circulating means comprising an inlet conduit for each of the surfaces of each of said plates for supplying fluid to at least one set of grooves of each of the surfaces of said plates, each said inlet conduit having an open end to which said fluid is supplied and a closed end, and an outlet conduit for each of the surfaces of each of said plates for removing fluid from said one set of grooves of each of the surfaces of said plates, each said outlet conduit having an open end from which said fluid is removed and a closed end, each said inlet and outlet conduit having a cross-sectional area which decreases in magnitude from a maximum at said open end to a minimum at said closed end, the grooves of said one set of grooves of each of the surfaces of the plates opening into their associated inlet and outlet conduit along its length between the said open end and the said closed end thereof.

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