April 7, 1959 H. E. METZ 2,880,501

ARTIFICIAL KIDNEY MANUFACTURE

Filed July 25, 1956

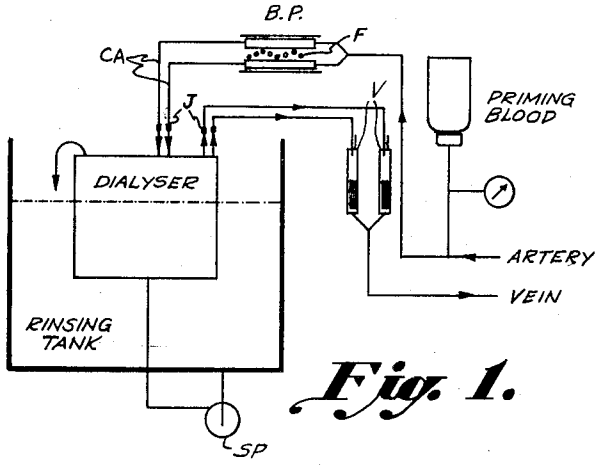

Fig. 1.

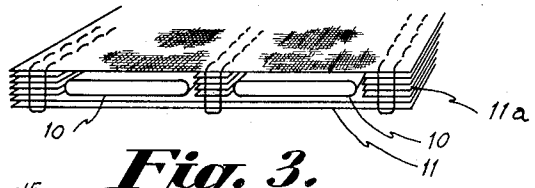

Fig. 3.

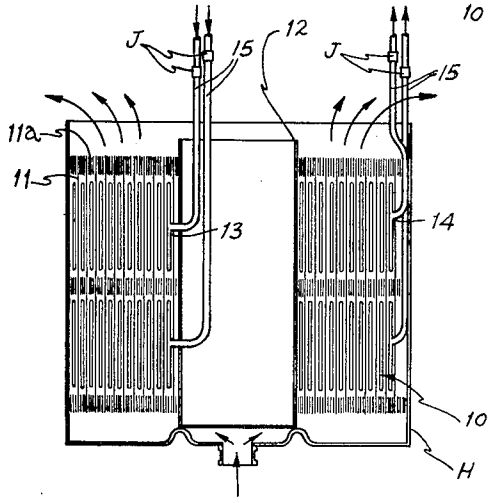

Fig. 2.

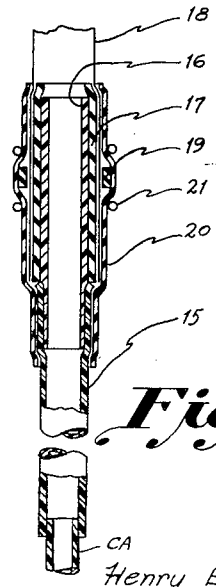

Fig. 4.

Henry E. Metz
INVENTOR.

BY Jerome F. Fallon

United States Patent Office

2,880,501

Patented Apr. 7, 1959

2,880,501

ARTIFICIAL KIDNEY MANUFACTURE

Henry E. Metz, Glenview, Ill., assignor to Baxter Laboratories, Inc., Morton Grove, Ill.

Application July 25, 1956, Serial No. 600,076

3 Claims. (Cl. 29—450)

This invention relates to a method of manufacturing an artificial kidney used in the treatment of human blood to remove therefrom deleterious substances present because of inoperation or malfunctioning of human kidneys.

The need for an artificial kidney has been emphasized by a number of eminent medical authorities speaking primarily through the American Society for Artificial Internal Organs. Prominent among these authorities is Dr. William J. Kolff, and this invention is directed to an improvement in the manufacture of an artificial coiled kidney of his design.

In the past, most artificial kidneys have been cumbersome, intricate, and expensive arrangements of apparatus employed to effect a transfer of urea from the blood into a dialyzing fluid. These mechanisms cost literally thousands of dollars and employed in some instances, extremely large drums wound with a permeable tube through which the blood flowed in a thin film so as to be exposed to a considerable quantity of dialyzing fluid. This invention is directed to the production of a relatively inexpensive, disposable type kidney wherein a length of dialyzing membrane is suitably coiled into a compact, portable structure.

It is to be appreciated that the prime consideration in any artificial kidney is its foolproof operation, and, more especially, the complete integrity of the blood conduit. Presence of leaks in the permeable blood conduit render the device worthless. In the instance of the wound drum type of artificial kidney, it was generally impossible to determine the integrity of the permeable tube until after it was wound. Many other types of artificial kidneys cannot be effectively tested until just before use. It is to be noted that the testing is usually performed by filling the unit with blood since a unit filled with a fluid other than saline or blood could not be used for the dialysis, and since saline does not yield a visual discoloration of the rinsing fluid to evidence a leak.

The disadvantages of such a limitation pertain not only to loss of time and money; time for reinstallation, and money for labor and new priming blood, but particularly to endangering the patient's life since postponement of dialysis may be fatal. In some instances this treatment is applied only after all chemotherapeutic expedients have been exhausted and the patient, if unrelieved of his high blood urea content would die within a day or so. Finding worthless the one artificial kidney dialyzer that is relied upon to treat the patient may well provoke the above-mentioned fatal consequences. My invention produces a leakproof kidney that, absent any unusual damage during shipment, should always perform its intended task.

Further, this invention permits the production of an artificial kidney so inexpensive and so easy to install that no proposed dialysis will be halted for the cost of an additional unit or the time to install one.

In general, the criticality of a leakproof kidney can be especially appreciated when it is realized that a patient can bleed to death in a matter of minutes at the flow

rates employed: about 200 cc. per minute. The integrity of the artificial kidney must be of the highest order since a given dialysis runs for a considerable period, four to five hours not being uncommon.

The artificial kidney structure to which my invention applies includes two flat cellulose tubes enveloped between nontoxic fiber glass screens. The tubes and screening assembly is then tightly but uniformly coiled about itself and provided with suitable end connections leading from and to the body of the patient to be treated. Blood is pumped through the cellulose tubing while the rinsing fluid is pumped crosswise through the screening.

My invention will be explained in conjunction with the accompanying drawing in which Fig. 1 is a schematic view of the portable artificial kidney system shown in operative condition; Fig. 2 is a cross-sectional view of the dialyzer portion of an artificial kidney; Fig. 3 is an enlarged view of a portion of Fig. 2; and Fig. 4 is an enlarged, fragmentary, cross-sectional view of one of the connections between the blood conduits leading from and to the patient and the dialyzing membrane of the artificial kidney.

In Fig. 1, a schematic view is shown of an artificial kidney system. Blood taken from an artery, such as the radial artery, is caused to flow into the dialyzer by pump BP. In the preferred embodiment, at least two blood passageways are provided through the dialyzer. Use of a plurality of passageways through the dialyzer permits continued operation irrespective of unexpected leaks developing in one of the passageways as from the above-mentioned rough handling in shipment.

Entrance means are provided ahead of the pumps to permit the addition of priming blood and measurement of pressure within the artificial kidney system. The introduction of priming blood is necessary to fill the unit before it is connected to the patient.

The blood pump, designated BP, is a "finger" pump such as manufactured by Sigmamotor Co., of Middleport, New York. This pump operates externally to the conduit in which the blood flows and thereby eliminates the need for bothersome and costly cleaning of the system. Use of this type of pump in which "finger" members F reciprocate sequentially against a positionable backing-plate to "push" blood along the conduits C_A permits achieving an equal flow in both membranes, irrespective of variations in resistance.

The pressurized blood is then delivered to the dialyzer in which it is contacted with a rinsing or dialyzing solution which generally includes saline and various other physiological salts and nutrients.

A preferred composition of dialyzing fluid includes per liter of water:

	Gm.
NaCl	570
$NaHCO_3$	300
KCl	40
$CaCl_2$	28
$MgCl_2$	15

0.4% Invert sugar.
Bactric acid to adjust pH to 7.4.

The dialyzing fluid, which is circulated by a pump, designated SP, enters the dialyzer at the bottom of a cylindrical enclosure and overflows the top to return to the rinsing tank for recirculating. The fluid is heated to about 39° C. and oxygenated (10% CO_2 in O_2) to maintain the blood in a favorable condition for reintroduction to the body. After contact with the dialyzing fluid through the permeable membrane, the blood is conducted to a pair of air-trap-filter-drip units after which the two streams of blood are united and introduced into a vein of the patient. The air-trap-filter-

drip units are equipped with vents V to exhaust any entrapped bubbles. Indicated by the letter J are joints in the conduits leading to and from the dialyzer permitting ready substitution of an alternate unit.

A portion of the dialyzer is shown in Fig. 3. It is to be appreciated that the dialyzer includes an open-topped outer enclosure H suitable for containing the dialyzing or rinsing fluid which is circulated by pump SP (seen in Fig. 1), the path of the fluid being indicated by arrows in Fig. 2. The operative portion of the dialyzer includes a pair of tubes constructed of a transparent, flexible, permeable membrane, the membrane permitting passage therethrough in either direction of ionic substances such as the above-mentioned saline or the deleterious urea contained within the blood but does not permit passage therethrough of larger molecules such as proteins, and, of course, blood cells. In the pictured embodiment, two lengths of tubing **10**, each approximately thirty feet long, and constructed of cellulose tubing such as Visking XM–151, are sandwiched within vinyl-coated fiber glass screening **11**. The preferred embodiment has two layers of screening on one side of tubings **10** and one on the other, the layers being maintained in spaced relation by four strip layers of similar screening inserted between the screening layers **11** as at **11***a*. When the screening is coiled, three thicknesses of screening will separate each convolution of tubing **10** so as not to unduly obstruct the flow of rinsing fluid. The screening is sewn along its top and bottom edges and along its median to provide a perforate chambered, flat tubular housing or envelope for the two cellulose dialyzing tubes **10**.

Inlet connections are made as at **13** and outlet connections as at **14**, the structure of both connections being essentially that shown in larger scale in Fig. 4.

The structure of Fig. 4 includes vinyl tubing **15** which refers to both the tubing leading from pump BP or the tubing leading to the air-trap-filter-drip units. I have found that these connections (tubing **15** to casings **10**) are especially critical in the manufacture of a leakproof dialyzer.

In the usual assembly, this tubing has a bore of about 0.140 inch and a wall thickness of about 0.035 inch. Inserted into the end of vinyl tubing **15** is rigid adapter **16**, constructed of nylon in the pictured embodiment. Adapter **16** has a somewhat larger O.D. than the I.D. of tubing **15** so as to be held tightly therein. The mounting of adapter **16** in tubing **15** is such that it extends a substantial distance external to tubing **15** and the extended portion thereof is covered by elastic sleeve **17**; elastic sleeve **17** is constructed of rubber and is of somewhat smaller I.D. than the O.D. of adapter **16** so as to be ensleeved on adapter **16** by a squeeze fit.

Wrapped over tubing **17** is cellulose casing **18**, being slightly larger than one inch in diameter in an expanded condition and of such thickness (approximately .001 inch) so as to lay flat, in which condition it has a width of about 1¾ inches.

In manufacture, casing **18** is wrapped uniformly about ensleeved adapter **16** so as to minimize stress since it is at this particular point that leaks are apt to occur. Loosely wrapped casing **18** is held in place thereon by elastic collar **19**.

Elastic collar **19** in the preferred embodiment is similar to elastic sleeve **17**, being constructed of rubber and having identical inner and outer diameters so as to achieve a tight squeeze-fit on casing **18**. Elastic collar **19** is readily assembled as shown by mounting it on tubing **15** over the unattached end provided with connector J.

Co-operating with elastic collar **19** in tightly securing casing **18** against elastic sleeve **17** is a second elastic sleeve **20** also assembled by ensleeving over tubing **15** from the free end equipped with joint J. Sleeve **20** is constructed of rubber, but of smaller I.D. than sleeve **17** and collar **19** thereby securing casing **18** to sleeve **17** by a squeezing pressure uniform along the length of adapter **16** ensleeved with sleeve **17**. In manufacture, sleeve **20** is rolled on itself and mounted on tubing **15** before casing **18** is wrapped on elastic sleeve-equipped adapter **16**. Thus, immediately after collar **19** is placed on casing **18** to hold it in place, the additional and uniform pressure of sleeve **20** can be brought to bear.

To yet further anchor casing **18** in place on adapter **16** in leakproof mounting, inelastic bands **21** (as by knotting lengths of thread) are placed over sleeve **20**. Thread bands **21** are spaced apart, being on either side of collar **19**.

Thus, a rubber-cellulose-rubber joint is effected which permits uniform compressive forces to be exerted on the permeable membrane, substantially eliminating the possibility of leakage. Also the formation of a joint connecting the ends of tubing **15** and casing **18** permits straight-through flow of blood that does not result in uneven stresses being applied to casing **18** during dialysis. A joint in the wall of casing **18** might produce such stresses that would result in rupture of casing **18** during the long period of dialysis.

Inasmuch as the achievement of an absolutely leakproof structure is essential, the long tubing-screening assembly achieved as above is next dilated by momentarily applying air pressure of the order of 0.5 p.s.i. If this step is omitted, I have found that subsequent pressure testing when the assembly is coiled, produces tiny perforations in the cellulose housing.

In the manufacture of the dialyzer unit, a compact structure is provided out of the thirty-foot long assembly by winding screening **11** on itself around a cylinder **12**. For optimum results this winding should be performed under constant tension. After rolling, the unit is pressure-tested with air at a pressure of about 3½ p.s.i., after which the unit is gas-sterilized and packaged to prevent contamination, sterile cotton being placed in the ends of tubing **15** at joints J. The coil is maintained as such by suitable band or enclosure means about its circumference which are also designated to protect it during shipment.

Operation

The dialyzing tube is first fully wetted by causing rinsing fluid to flow. Then an electrolyte solution is pumped through the dialyzing tube to gradually distend it. The salt content of the electrolyte solution is immaterial since it will quickly reach equilibrium with the dialyzing fluid. However, the last six liters of the electrolyte solution should be isotonic (i.e., 0.7% NaCl) and no air should be pumped into the kidney. If desired the dialyzer may be tested for leaks by pumping about 100 cc. of heparinized blood, followed by more saline. To this last saline a small quantity of heparin should be added.

The patient is canulated about an hour prior to connecting to the artificial kidney to minimize chances of clotting in the wounds. The venous canula is inserted first, each canula containing saline and a small quantity of heparin, the venous connection being somewhat higher than the arterial connection to simulate resistance that may be encountered later in the vein. Prior to the arterial canulation, the patient is heparinized, (about 80 mg. per average patient).

The artificial kidney is then primed with about a liter of citrated bank blood, also containing a small quantity of heparin.

The patient's blood is then caused to flow through the kidney, the rate being determined by visual examination of the air-trap-filter-drip units and regulated by conventional tubing clamps. Heparin in small quantity is usually administered during the dialysis, the patient's clotting time being checked from time to time.

The foregoing detailed description has been given for clearness of understanding only and no unnecessary limitions are to be inferred therefrom.

I claim:

1. In a method of artificial kidney manufacture, the steps of sandwiching a lay-flat, flexible, transparent, permeable tube between flat, nontoxic, perforate members arranged in spaced-apart, face-to-face relation, said tube and said members having lengths substantially greater than their widths, securing the longer edges of said members together to form a flat envelope for said tube, wrapping each end of said tube about a rigid tubular element connected to a length of resilient tubing, resiliently securing the wrapped ends of said tubes to said elements, temporarily dilating said tube, coiling said envelope about itself with the unattached ends of said lengths of tubing extending outward of the coiled envelope and securing said coiled envelope in a coiled condition, pressurizing said tube to test its integrity, and sterilizing the assembly thus achieved.

2. In a method of artificial kidney manufacture, the steps of introducing in spaced, edge-to-edge relation a pair of lay-flat, flexible, transparent, permeable tubes between nontoxic, flat screen members arranged in spaced, face-to-face relation, said tubes and said members having lengths substantially greater than their widths, securing the longer edges and median of said members together to form a flat chamber envelope for said tubes, wrapping the end of each tube about a portion of a rigid, tubular element, said element having been previously ensleeved with a tight-fitting sleeve of plastic material over the portion thereof to be wrapped with said tube and the remaining portion being inserted partway into a tight fitting length of resilient tubing, ensleeving the wrapped portion of said element with a second tight fitting sleeve of elastic material, banding said ensleeved, wrapped element portion to provide a leakproof joint, temporarily dilating said tubes, coiling said envelope about itself under constant tension with the unattached ends of said lengths of tubing extending outward of the coiled envelope and securing the coiled envelope in a coiled condition, pressurizing the inside of said tubes to test their integrity, and sterilizing the assembly thus achieved.

3. In a method of artificial kidney manufacture, the steps of introducing in spaced, edge-to-edge relation a pair of lay-flat, flexible, transparent, permeable tubes between flat, nontoxic screen members arranged in spaced, face-to-face relation, said tubes and said members having lengths substantially greater than their widths, securing the longer edges and median of said members together to form a flat chambered envelope portion for said tubes, wrapping the end of each tube about a portion of a rigid, tubular element, said element being rubber-covered over the portion thereof to be wrapped with said tube and the remaining portion being inserted partway into a tight-fitting length of resilient tubing, banding a portion of said wrapped portion of said element with a tight-fitting rubber collar, ensleeving the wrapped portion of said element with a tight-fitting rubber sleeve, banding said ensleeved wrapped element portion with an elastic band to provide a leakproof joint, temporarily dilating said tubes by internally pressurizing them to the order of about 0.5 p.s.i., coiling under constant tension said envelope about itself with the unattached ends of said lengths of tubing extending outwardly of the coiled envelope and securing the coiled envelope in a coiled condition, internally pressurizing said tubes to the order of about 3.5 p.s.i. to test their integrity, and sterilizing the assembly thus achieved.

References Cited in the file of this patent

UNITED STATES PATENTS

2,341,114	Novak	Feb. 8, 1944
2,650,709	Rosenak	Sept. 1, 1953
2,664,395	Marchand	Dec. 29, 1953
2,720,879	Gasca	Oct. 18, 1955