

[54] DIALYSIS APPARATUS

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[58] Field of Search 210/96, 321, 22, 87, 86

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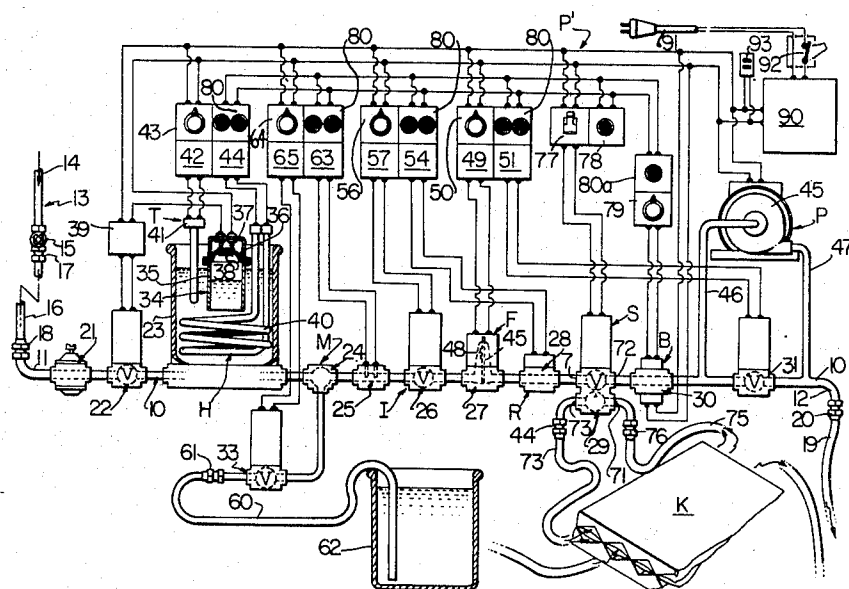
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[57] **ABSTRACT**

A dialysis apparatus comprising an elongate flow passage with inlet and outlet ends; valve controlled recirculating pump means at the outlet end of and establishing a minus pressure in the passage and maintaining the flow of fluid therethrough; a water reservoir with heater means at the inlet end of the flow passage; brine concentrate supply and mixing means communicating with the flow passage downstream of the reservoir; fluid by-pass means in the flow passage downstream of the reservoir and connected with a Kiil device; salinity, flow rate and pressure monitoring means in the flow passage between the brine concentrate supply and mixing means and the fluid by-pass means; valving means related to the monitoring means, blood leak detecting means in the flow passage downstream of the by-pass means and automatic controls for the valving means and responsive to the monitoring and detecting means.

16 Claims, 6 Drawing Figures



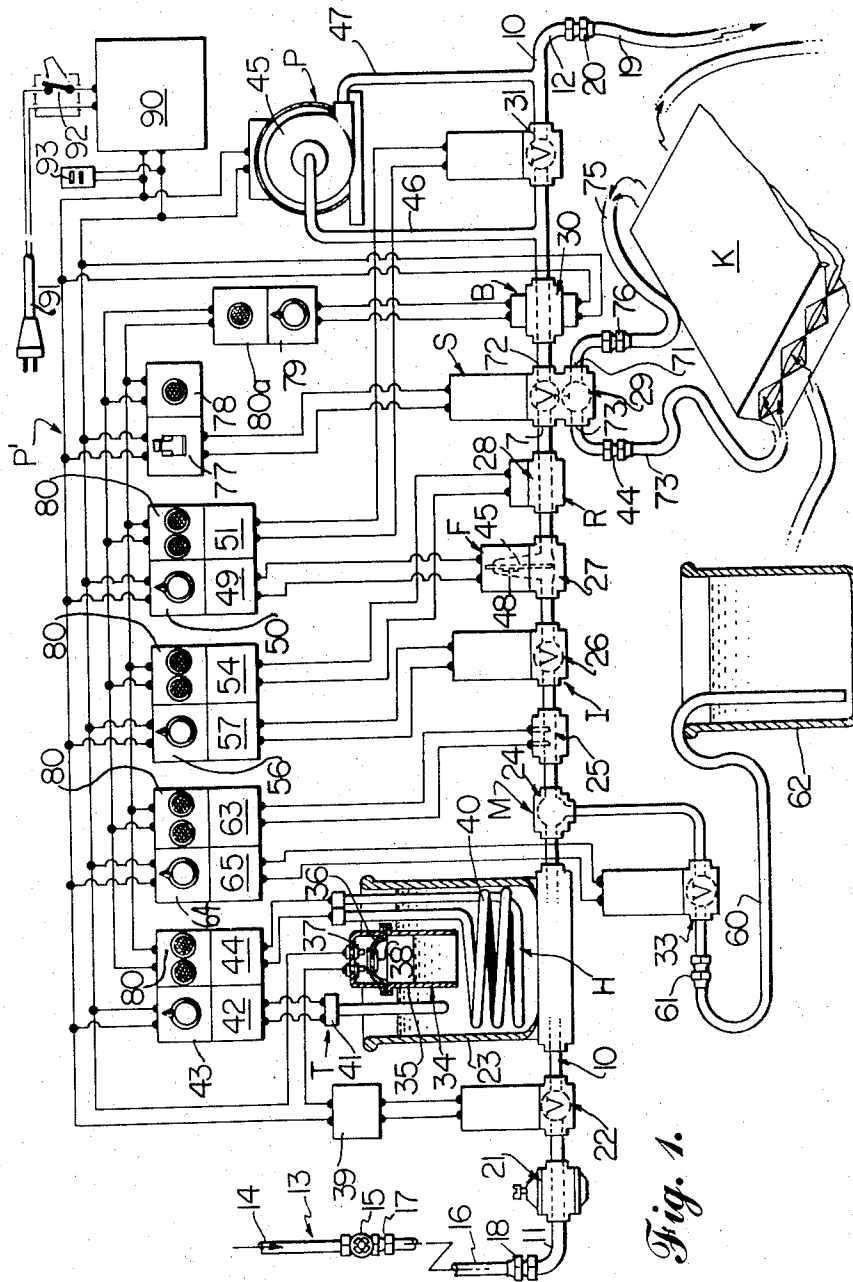
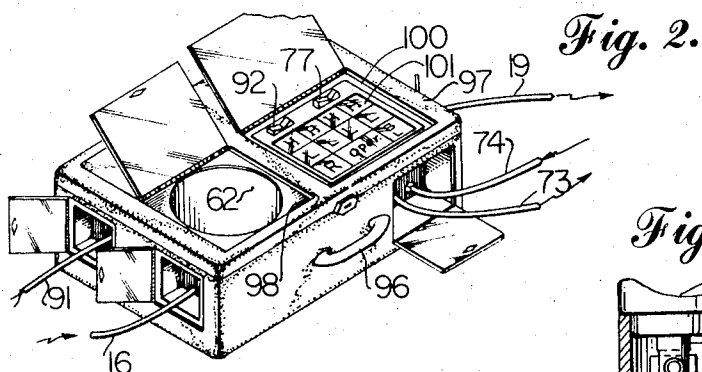
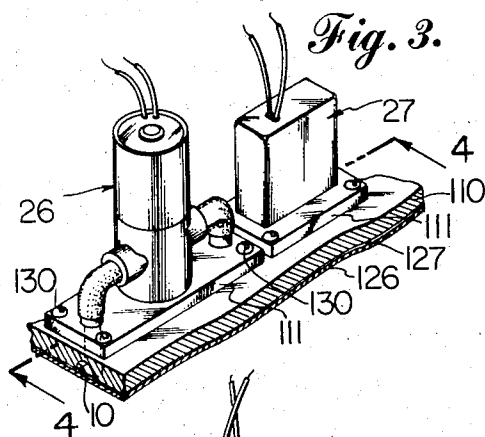
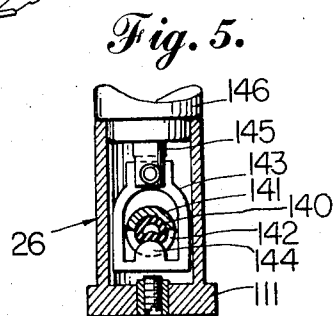
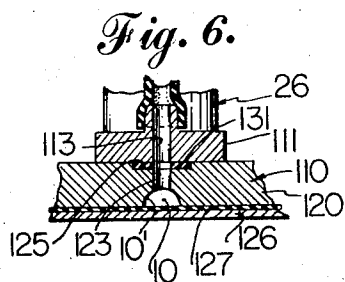
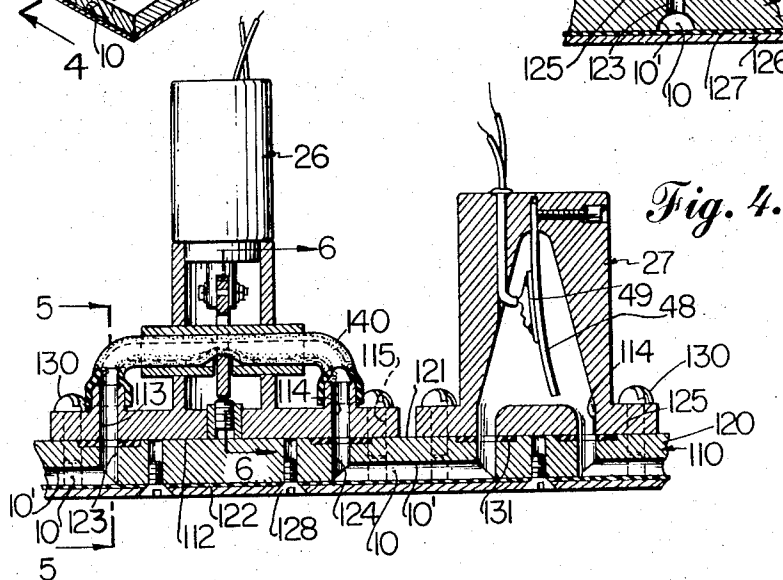


Fig. 1.



DIALYSIS APPARATUS

This is a divisional application of my co-pending application Ser. No. 40,244 for Dialysis System and Apparatus, filed May 25, 1970.

This invention has to do with an improved system and apparatus for treating the blood of a person suffering from inadequate kidney function, and is that type or class of system and apparatus commonly referred to as a dialysis machine or, more popularly, an artificial kidney machine.

Such systems or machines are provided and employed to treat a person whose kidneys have ceased to function properly and seek to supplement abnormal kidney function to re-establishing and/or maintaining proper blood chemistry of the person treated.

Basically, dialytic systems or machines of the type here concerned with effect separation of crystalloids from colloids in solution by the faster diffusion of crystalloids through a moistened membrane. The above is accomplished by bypassing the blood of a person being treated through an artificial kidney device which includes a moistened membrane, across one surface of which blood is circulated and along the other surface of which a brine solution is circulated. The brine solution is made up of dissolved salts, especially compounded to approximate the sought-after and desired chemical makeup of the blood to be treated. As a result of dialysis, the chemical makeup of the blood flowing across one surface of the membrane is converted or altered, during treatment, until it is balanced with the chemical makeup of the brine.

One, desired form of artificial kidney, referred to as a kiil device, consists of a pair of sheet-like membranes with opposing inner surfaces between which the blood being treated is circulated. The sheets are arranged between a pair of plate-like members having opposing brine conducting channels. The brine is circulated through the channels under a controlled pressure less than the pressure of the blood being treated, with the result that the membranes are drawn a predetermined extent into the channels in the plates to define blood conducting channels in and between the sheets. The minus pressure imposed upon the brine serves to control the rate at which dialysis takes place.

The above brief statement is intended to set forth the principle of operating of an artificial kidney, to provide adequate foundation for the following consideration given to the state of the art, the objects and features of my invention and the subsequent disclosure of the invention.

While artificial kidneys, such as Kiil devices are rather simple and their design is well established, the use of such devices must be carefully guarded, controlled and requires the provision and use of special means and apparatus to insure their proper functioning and to assure proper and safe treatment of the person being treated. The means and apparatus employed in connection with Kiil devices to control and insure their proper functioning are indispensable backup means and are, in fact, an integral part of those systems and apparatus referred to as dialysis or artificial kidney machines. It is such backup means and apparatus with which the present invention is concerned and not artificial kidneys per se.

In the satisfactory operation and functioning of a dialysis system, the chemical makeup and concentration

of the brine must be especially formulated and compounded for the blood which is to be treated, that is, it must be specially formulated for each person who is to be treated.

In practice, the brine is established by first combining predetermined quantities of predetermined chemical salts. A predetermined volume or mass of formulated salts, sufficient for one treatment, is then dissolved in water to establish a brine concentrate. The concentrate is next metered into a stream of water to establish a brine of predetermined concentration and chemical makeup which is thereafter circulated through a Kiil device suitably connected with the person to be treated.

The means provided by the prior art to meter the brine concentrate into the stream of water and to establish and maintain a proper concentration of salts in the brine have varied widely but characteristically involve a multiplicity of costly complicated and difficult to maintain and/or control, usually monitored and manually operated, devices and means.

Next, so as not to cause an undue rise or drop in the temperature of the person's blood which is being treated, with resulting discomfort and/or shock to the person, the temperature of the brine entering and flowing through the Kiil device must be carefully and accurately controlled.

The means employed by the prior art to control the temperature of the brine have included such means as external hot and cold supplies under control of manually operable valves, means for mixing the hot and cold water, and visually monitored temperature gauges and the like.

Another factor which must be controlled is the rate of flow of brine through the Kiil device, which flow rate must be regulated in predetermined ratio with the concentration of the brine and in predetermined ratio with the pressure of the fluid and the rate of flow of the blood.

In the prior art systems, the flow rate of brine is sought to be adjusted by means of a manually operable valve means and is visually monitored by suitable meters and the like.

Next, the pressure of the brine must be accurately controlled in proportion to the flow rate and the chemical makeup of the brine and so as to control the rate at which dialysis takes place in the Kiil device.

In the prior art systems, the pressure of the brine is visually monitored by borden tubes or similar means and is controlled by means of additional costly, manually operable valves, pressure regulators and the like.

The dialysis systems provided by the prior art, as a general rule, must be connected with pressurized water service systems and rely upon the pressure of such water systems to establish and maintain flow of water. Since the pressure of the brine flowing through Kiil devices must be less than the blood pressure of the person being treated and is in fact at sub-atmospheric pressure, utilizing standard water service pressure, as noted above, requires the inclusion and use of special and costly flow control means and the exercise of great and special skill in operating the systems.

In addition to the foregoing control means, the ordinary dialysis machine or system is provided with a blood leak detecting means to indicate and warn of a tear or rupture in the membrane of the Kiil device. Such detecting means characteristically involve a pho-

toelectric device which reads or detects the clarity of the brine, downstream of the Kiil device and which warns the technician operating the system if a leak occurs, so that he can shut down the system and make necessary repairs.

The dialysis systems provided by the prior art and characterized by control means such as referred to above involve large, complicated and extremely costly apparatus and are such that they must be operated by specially trained and highly skilled technicians. As a result of the size of such systems, their complexity, high cost and the requirement that specially trained technicians be engaged to operate them, there are few such systems available in comparison to the need and/or demand for such systems.

Those dialysis machines or systems which exist and which are available for treating the ill are, with exceptions, maintained and operated in major hospital facilities. Persons requiring dialytic treatment must therefore make arrangements for admittance into a hospital having such a system available in order to receive necessary treatment. Such admittance must be arranged for on a regular basis and often times requires protracted periods of treatment.

Due to the high cost of such systems, the high cost for the services of specialized technicians in hospitals, the ultimate cost for dialytic treatment is so high that few persons who should be so treated can afford to be treated. Frequently, due to the critical shortage of dialysis machines, those who are fortunate enough to receive treatment are often not treated as they should be to maintain good health, but are only permitted sufficient treatment to sustain life.

An object of my invention is to provide an improved dialysis system and apparatus of the general character referred to which is small, neat and compact; a system and apparatus which is highly effective and efficient in operation, and, a system which is sufficiently easy to operate so that a person, with ordinary skill and requiring dialytic treatment, can easily and safely operate the system and effect self treatment.

More important, it is an object of my invention to provide a small, self-contained, easy to carry and transport dialysis apparatus whereby a person needing treatment and provided with such an apparatus need not arrange for admittance to a hospital, but can administer treatment to himself at home or at any place he might travel to.

Yet another important object of my invention is to provide an apparatus of the character referred to which is economical to manufacture, which lends itself to mass production and which is such that it can be profitably marketed and sold at a price well within the means of most persons who are in need of dialytic treatment.

It is an object of my invention to provide an apparatus of the character referred to which is such that it can be manufactured and marketed for a small fraction of the cost for presently available apparatus for like purpose, whereby economics is not a major deterrent as regards to acquisition of dialysis apparatus by those in need of such apparatus.

A feature of my invention is to provide a system and apparatus of the character referred to which can be housed in a carrying case measuring about $16 \times 14 \times 6$ inches and which weighs less than 30 pounds.

Another object and feature of the present invention is to provide a system and apparatus of the character referred to which is not dependent for operation on pressurized water service, public electric service and/or an external supply of hot and cold water, but is such that it can be selectively operated on public electric service or on battery-supported power systems (such as found in boats, trailers and the like); which includes water heating means and which can receive water from any suitable available supply of fresh water.

It is a further object and feature of the present invention to provide a system and apparatus of the character referred to which is such that it requires about 1 quart of water to charge the system as compared with several gallons of water as is required to charge ordinary dialysis systems provided by the prior art.

Another object and feature of this invention is to provide a dialysis system and apparatus of the character referred to wherein the water, brine concentrate and brine are conducted in and through a flat, plate-like manifold chassis similar in principle with printed electrical circuits, and to provide novel, simple and inexpensive valves, flow metering means and similar components, removably engageable in and with the chassis, in a manner similar to plug-in electrical components used in connection with printed electrical circuits whereby the system and apparatus includes a minimal number of independent fluid conducting pipes, hoses and related couplings and fittings and is such that it requires a minimum expenditure of time, effort and skill to assemble or to disassemble for the purpose of service and repair.

Yet another object and feature of the present invention is to provide a system and apparatus of the character referred to which is such that it can be specially programmed and set for treatment of the individual for whom it is intended and such that it will faithfully, automatically function to effect the desired treatment by operation of but two manually operable switches.

Still further, it is an object and feature of my invention to provide a system and apparatus of the character referred to including means for automatically bypassing the Kiil device when and if any one or more of the controlled factors (temperature, salinity, flow rate and pressure) deviates from its predetermined and set range, which signals or indicates which factor or factors have so deviated and a system which will automatically seek to correct such deviation or deviations and to signal to operator when such correction is made, so that treatment can be continued.

It is highly important to note that a person requiring dialytic treatment is generally advised that he will have to subject himself to regularly scheduled dialytic treatments for the remainder of his life. With such knowledge, the prospect of having to be hospitalized and subjected to treatment by those large and complicated apparatus provided by the prior art, on a regular basis, is always depressing and frequently results in serious psychological complications. With the system and apparatus that applicant provides, the possibility of such psychological complications is materially reduced, as the apparatus may be said to be a slave to and under control of the person to receive treatment thereby, rather than the contrary, as is the case of the prior art systems and apparatus.

The foregoing and other objects and features of my invention will be apparent and will be fully understood

from the following detailed description of a typical preferred form and application of the invention, throughout which reference is made to the accompanying drawings, in which:

FIG. 1 is a diagrammatic view of the system and apparatus provided by the present invention;

FIG. 2 is an isometric view of a portable case in which my new system and apparatus is housed;

FIG. 3 is an isometric view of a portion of my new apparatus showing certain special components and structural details;

FIG. 4 is a sectional view taken as indicated by line 4-4 on FIG. 3;

FIG. 5 is a sectional view taken as indicated by line 5-5 on FIG. 4; and

FIG. 6 is a sectional view taken as indicated by line 6-6 on FIG. 4.

Referring to FIG. 1 of the drawings, my new system includes an elongate fluid conducting flow line or passage 10 having an inlet end 11 and a discharge end 12.

The inlet end 11 of the passage 10 is adapted to connect with a suitable water supply 13 which supply can be a pressurized municipal water service, storage tank or vessel with gravity-fed delivery means, or any other suitable and available source of water.

In the case illustrated, the water supply is shown as including a supply pipe 14 with a valve 15 at the delivery end thereof and a connecting hose 16 extending between the valve 15 and the inlet end of the passage and connected therewith by suitable conventional coupling means 17 and 18.

The discharge end of the passage 10 discharges waste or spent fluid and can be connected with a suitable external drain or waste pipe (not shown) by means of a discharge hose 19 connected with the discharge end of the passage 10 by coupling means 20.

Arranged in the flow passage 10, between the ends thereof and progressing from the inlet to the discharge ends thereof, is a pressure regulator 21, a shut-off valve 22, a reservoir 23, a fluid blender 24, a salinity detector 25, a flow metering valve 26, a flow rate detector 27, a pressure detector 28, a by-pass valve 29, a blood leak detector 30 and a flow control valve 31.

Also related to and communicating with the flow passage 10 is a brine concentrate conductor 32 under control of a metering valve 33 connected with the fluid blender 24 and a suitable supply of brine concentrate, an artificial kidney K connected with the bypass valve 29 and fluid pump means P connected with passage 10 upstream and downstream of the flow control valve 31 or in bridged relationship thereacross.

The pressure regulator 21 is adapted to limit and regulate the pressure of the water introduced into the inlet end of the system and is particularly necessary when the water supply 13 with which the system is connected is a high pressure supply system, such as is common in municipal water services in the United States.

The shut-off valve 22 is an electrically operated valve adapted to control the flow of water into the reservoir 23 and is under control of a fluid level sensing means or device 34 related to the reservoir.

The reservoir is a simple open tank or vessel with an inlet opening communicating with the passage 10 downstream of the valve 22 and an outlet opening which connects with the passage 10 downstream of the reservoir.

The fluid level sensing means 34 can be of any suitable form, type or style and is shown as including a downwardly opening bell chamber 35 supported in the reservoir with its lower rim portion submerged in water in the reservoir and having a flexible diaphragm 36 in its upper portion. The top of the bell is vented and carries a pair of contact posts 37 connected in and with separate sections of one leg of the power supply to the valve 22. The diaphragm carries a contact plate 38.

As the water level in the reservoir rises above the lower rim of the bell, the pressure of the air trapped in the bell is increased. When the level reaches a predetermined point, the air pressure urges the diaphragm and plate up to a point where the plate contacts the posts, closing the circuit to the valve, which is normally open, thereby actuating and closing the valve and stopping the flow of water into the reservoir.

So as to prevent the fluid level control means from establishing a semi-balanced condition in which the valve would be rapidly cycled open and closed, continuously, I provide a time delay device 39 in the power supply to the valve, which device serves to hold the power supply to the valve 22 closed a short, predetermined period of time, after the fluid level in the reservoir has dropped sufficiently to permit breaking of contact between the posts and plate.

With the means thus far described, it will be apparent that the reservoir 23 is effectively maintained with an adequate and desired supply or volume of water.

The reservoir 23 is unpressurized so as to provide a supply of water under neutral pressure and serves as an element of a water heating means H of my new system; that is, it serves as a water heater tank.

The water heating means H referred to above comprises a resistance heater 40 arranged in the reservoir 23 and a temperature sensing device 41, such as a pyrometer in the reservoir and controlling the operation of the heater.

The temperature sensing device 41 is adapted to develop a voltage which is linear to the temperature of the water being measured. This voltage is fed into an amplifier section 42. A reference voltage, provided by a manually adjustable potentiometer 43 is fed into the amplifier 42. The error or difference in voltage output of the amplifier 42 is fed into a second amplifier 44, the output of which proportionately controls the power going into the heater 40.

When the heater has elevated the temperature of the water sufficiently, the temperature sensing device voltage and the reference voltage become equal or neutral, which shuts off the power to the heater.

With the means H, set with above, it will be apparent that the temperature of the water in the reservoir can be and is effectively and accurately controlled, whereby the temperature of the fluid throughout the system, downstream of the reservoir can be and is controlled, as desired and as circumstances require.

The flow of heated or temperature controlled water flowing from the reservoir, downstream through the system is induced by the fluid pump means P and is controlled by flow regulating means F.

The pump means P comprises a positive displacement, constant speed, continuous operating motor driven fluid pump 45, the suction side of which is connected with the passage 10 upstream of the valve 31 by a suction line 46 and the outlet or exhaust side of which is connected with the passage 10 downstream of the

valve 31 by delivery line 47. The valve 31 is a variable flow bearing device and serves to effect a flow and pressure drop between the lines 46 and 47.

The pump 45 draws fluid from the reservoir 23 through the passage 10 to the upstream side of valve 31, establishing a minus pressure in the system between the reservoir and valve 31 and re-introduces the fluid into the passage 10 downstream of the valve 31 at increased or, relatively high pressure.

With the pump means P thus provided, it will be apparent that a constant flow of fluid is induced through the system, from the reservoir 23 to the discharge end of the flow passage 10, and thence into and through the discharge hose 19.

The means F includes the flow metering valve 31 and the flow rate detector 27.

The valve 31 is an electrically operated variable flow valving structure or means, the details of which will be briefly described in the following.

The flow rate detector 27 can be of any suitable form and in the case illustrated is a novel device comprising basically a resilient reed 48 disposed normal to and extending across the stream of fluid conducted by the passage 10 and having a stain gauge 49 fixed thereto and responsive to the deflection or bending of the reed, induced by the passage of fluid thereby.

The flow rate detector detects the amount of fluid flowing through the passage 10 and converts this to an electrical signal which is fed into an amplifier section 49. A reference voltage, provided by a manually adjustable potentiometer 50, is fed into the amplifier 49. The error or different voltage output of the amplifier 49 is fed into a second amplifier 51, the output of which controls operation of the valve 31, opening or closing the valve 31 as required.

The required valve 31 is opened and closed to permit a necessary amount of fluid at the high pressure, or downstream side of the valve, to be drawn upstream and recirculated through the pump 45. The difference between the amount of fluid that is allowed to recirculate in the above manner and the volume of fluid moved by the pump represents or establishes the flow rate through the system. Hence, the actual flow rate through the system is adjusted by the reference voltages established by the potentiometer 50 and is maintained automatically by the valve 31.

The system next includes pressure regulating means R to establish a predetermined, desired negative or minus pressure in the system, upstream of the valve 31 and pump means P and which includes the valve 26 and pressure sensing device 28 in the flow passage 10, between the reservoir 23 and upstream of the connection between the flow passage 10 and suction line 46.

The valve 26 is the same or similar to valves 22 and 31.

The pressure sensing device 28 is positioned downstream of the valve 26 and is, in the preferred carrying out of the invention, adapted to sense the pressure in the passage 10 and to transmit a voltage signal proportional to said pressure. The voltage from the device 28 is fed to an amplifier 55. A reference voltage signal, provided by a manually adjustable potentiometer 56 is fed into the amplifier 55. The error or difference voltage output of the amplifier 55 is fed into a second control amplifier 57, the output of which controls operation of the valve 26. As the valve 26 is caused to open the negative pressure downstream thereof drops,

whereas, closing of the valve caused the pressure to rise. When the pressure rises or drops to that point where the voltage from the detector 28 is equal to the reference signal, the desired negative pressure in the system is attained and will be automatically maintained.

Upstream of the means valve 26 of the means R and downstream of the reservoir 23, I provide proportioned mixing means M which functions to mix brine concentrate with the heated water drawn by the pump means P from the reservoir and to establish a brine of predetermined salinity. The means M includes the fluid blender 24 in the flow passage 10, the salinity detector 25 in the flow passage 10 downstream of the blender 24; the brine concentrate duct 32 which is connected with the blender and the metering valve 33, each of which elements was previously referred to.

The blender 24 can be any suitable structure which serves to combine and to mix together two streams of fluid. The blender can be established simply by the intersection of the duct 32 and the flow passage 10, by properly orienting and/or disposing the passage and duct relative to each other in such a manner as to effect blending of the fluid streams flowing therethrough and combining.

In the diagram, the blender is indicated as a simple T-fitting in the passage 10 and connected with the duct.

The detector 25 is a conductivity cell in the passage 10 and through which mixed water and brine concentrate, downstream of the blender flows and in its simplest form comprises a pair of spaced electrodes projecting into the flow stream of brine. The changes in the proportioning of water and brine concentrate varies the resistivity or conductivity of the resulting brine which is measured by the cell and converted into an electrical or voltage signal.

The valve 33 is similar to each of the valves 22, 26 and 31.

The free end of the duct 32 is connected with a suction hose 60 by means of a suitable coupling 61. The hose extends into a tank or vessel 62 in which salts have been dissolved to establish the necessary and desired brine concentrate.

In practice, the tank can be incorporated as an integral part of the apparatus embodying the present invention and in which case, the duct 32 would communicate with the bottom of the tank and the hose 60 and coupling 61 would be eliminated.

The voltage signal from the cell 25 is conducted to an amplifier 63. A reference signal from a manually adjustable potentiometer 64 is also conducted into the amplifier 63. The difference or error signal from the amplifier 63 is fed into a second amplifier 65, the output of which controls opening and closing of valve 33.

With the means M provided, the strength of the brine, downstream of the blender 24 is predetermined and controlled by the adjusted and set reference signal. While the chemical makeup of the salts dissolved to establish the brine concentrate must be controlled, the strength of or the salt content of the concentrate in the tank or vessel 62 can vary without adverse effects, as the sensing device 25, valve 33 and the circuitry related thereto function to admit or introduce only that amount or volume of brine concentrate into the primary system of water to establish the desired brine, re-

ardless of the strength or concentration of dissolved salts in the concentrate.

It is to be noted that the minus pressure in the flow passage 10 upstream of the pump 45 and which draws water from the reservoir 23, also draws brine concentrate from the vessel 62, through the duct 32, under control of the valve 33.

The system and apparatus provided next includes what will be termed service means S, which means is adapted to place or set the apparatus in service operation with the artificial kidney or Kiil device and which includes the bypass valve 29, which valve is arranged in the flow passage 10 upstream of the valve 31 and pump means P and downstream of the several other means thus far described.

The valve 29 is an electrically operated valve having primary and secondary inlets 70 and 71 and primary and secondary outlets 72 and 73. When the valve is in its normal or unactuated position, the primary inlet 71 and primary outlet 72 with which the flow passage 10 connect, are in communication. When the valve is actuated, the primary outlet 70 and secondary outlet 73 communicate with each other and the secondary inlet 71 and primary outlet 72 communicate with each other.

The secondary outlet 73 is connected with the brine inlet side or end of the Kiil device by means of a suitable hose 73 and related couplings and/or fittings 74 and the secondary inlet 71 is connected with the brine outlet side or end of the Kiil device by means of a suitable hose 75 and related couplings and/or fittings 76.

The valve 29 is controlled by a suitable manually operable switch 77 which switch is normally open and is such that it will, when closed and subjected to predetermined voltage or control signals, open automatically. The switch 77 can be in the nature of a circuit breaker switch and is related directly to a control signal receiver section 78 which section is a part of a control means C and is adapted to receive control signals from within the system and to transmit an actuating voltage or signal to the switch 77, to cause said switch to remain open or to cause said switch to open, if previously closed, when a control signal is received by the section 78.

With the means S that I provide, it is such that when the system is first energized, the valve 29 is in normal position. Subsequent to the system being energized and when the temperature, pressure, salinity and flow rate of the fluid in the system have reached or established predetermined values, the switch 77 can be manually actuated and circulation of the brine of fluid can be and is established through the Kiil device to effect dialytic treatment of the person to which the Kiil is connected.

The system of the present invention next includes a blood leak detecting means B which serves to detect the presence of blood in the brine, downstream of the valve 29 and Kiil K and which operates to open the switch 77 and place the system out of operation when and if the Kiil develops a leak which results in the introduction of blood into the brine.

The means B includes the blood leak detector 30 which detector is in the flow passage 10 at any desired location downstream of the valve 20. The detector 30 can be any suitable device or means capable of detecting the presence of blood in the brine and is, in the pre-

ferred carrying out of the invention, a photo-electric means or device which responds to the clarity or light conducting capacity of the brine. Should blood leak into the brine, the coloring of the brine by the blood reduces light transmission therethrough. Such reduction in light transmission results in a variation of the voltage or electrical signal transmitted by the device 30.

The signal from the device 30 is conducted a suitable amplifier 79 for subsequent modification and transmission to the control means C to effect opening of switch 77 and placing the system out of operation should a blood leak develop in the Kiil.

The control means C referred to above includes a control signal generator and signalling section 80 related to each of the related amplifier sections 42 and 44 of the means H, 63 and 65 of the means M, 55 and 57 of the means F, 49 and 51 of the means R and a control signal generator and signalling section 80a related to the amplifier 79 of the means B.

The several sections 80 and the section 80a receive the signals from their related amplifiers and convert those signals into control signals which are transmitted to the control signal receiver section 78 related to the switch 77.

The sections 80 are preferably provided with a pair of signal lamps one of which lamps, when lighted, indicates that the temperature, salinity, pressure or flow rate, whichever of these factors it is related to, is too high and the other of which lamps, when lighted, indicates that the temperature, salinity, pressure or flow rate, whichever of these factors it is related to, is to be too low.

When the operating conditions of the apparatus is such that one or the other of the lamps of one or more of the sections 80 is lighted, the section or sections 80 also transmit a control signal to the section 78 which causes the switch 77 to open and remain open. When both of the lamps of each section 80 is out, the system is known to be in proper operating condition and the switch 77 can be manually closed and will remain closed, to start and carry out dialytic treatment.

The section 80a related to the blood detector 30 is provided with a signal lamp which is lighted when the section 80a, as a result of a flood leak, transmits a signal to the section 78 to effect opening of the switch 77.

With the control means C set forth above, it will be apparent that one can visually monitor the system and can readily determine when the system is ready to be put into operation.

If during the operation of the system one of the control sections or means H, M, F or R mal functions or otherwise fails to maintain the system in proper balance, the system is automatically put out of operation and one of the lamps of the section 80 of the control section which has changed or deviated from its predetermined, set, operating condition, will light, indicating to the operator of the system which control section is not operating within its set limit or range and whether it has exceeded or has fallen below the desired range of operation.

Finally, the system is provided with a suitable low voltage power supply means P. In practice, it is desirable that the system be operated on sufficiently low voltage so that in the event of a short or grounding out in any component, sufficient current is not available to cause physical harm or damage to the person under

treatment. To this end, I provide a standard or conventional 110V a/c or 220 V a/c to 24 V d/c power supply section 90, a service cord 91 to connect the section 90 with a suitable power service and under control of a manually operable on and off switch 92. The section 90 is suitable connected with and supplies operating current to each of the electrical sections and components of the system referred to above and as shown in FIG. 1 of the drawings.

If desired, a plug fitting 93 or the like can be arranged in the power supply means P to facilitate connecting the system with a service of 24V d/c, such as the d/c power source of a boat or trailer.

In the case illustrated, the motor driven pump 45 of the means P is shown as a connected in and as receiving power from the power supply means P.

In practice, the motor could be safely powered by 110V or 220 V a/c, since the motor for the pump can be effectively electrically isolated from the remainder of the system. If the motor is operated on a/c current, and the system is connected with a d/c power source, an a/c to d/c converter must be provided to drive the pump motor.

Referring to FIG. 2 of the drawings, I have illustrated one typical form or embodiment of my invention wherein the apparatus is housed in a suitable carrying case 95 with a carrying handle 96. The case is shown provided with compartments about its perimeter or sides to normally receive and house the service cord 91, water supply hose 16, Kiil connecting hoses 73 and 74 and the discharge hose 19. The cord and hoses referred to above extend through openings in the compartment to the interior of the case where they are suitably connected with their related parts and portions of the system and extend outwardly from the compartment when in use.

The compartments are provided with suitable closures, pivotably carried by the case, to close the compartments and retain the line and hoses therein when the apparatus is not in use.

The case is shown provided with a removable, manually locked and secured top 97 with an access opening 98 which is normally closed by a suitable hinged closure and in which the brine tank 62 is arranged and accessible.

The top 97 is further provided with a recessed control and monitoring panel 100 and a door or closure to overly and cover the panel when the apparatus is not in use.

The panel 100 arranges and presents the switches 77 and 92 for convenient access and operation and includes a divided or sectioned translucent light panel 101 below which the several signal lamps of the signaling sections 80 and 80a for the means H, M, F, R and B arranged for visual monitoring the operation of the system. The several sections of the panel 101 are provided with suitable and appropriate legend and are preferably color coded so that no difficulty is likely to be experienced by the person operating the apparatus in determining when the apparatus is functioning properly and in determining what part or section of the system is not functioning properly, should a section fail to permanently or temporarily support operation of the system.

It is to be noted that only the switches 77 and 92 are accessible and need be operated in the normal use of the machine.

The several manually operable potentiometers provided in the system and provided to adjust and set the parameters of operation of the several parts, portions and/or sections of the system are accessible within the case, beneath the locked and secured case top and are not readily available to be tampered with or otherwise inadvertently moved out of adjustment.

It is contemplated, in the normal use of the present invention, that the apparatus is to be and will be adjusted and set to operate by the physician caring for the person who is to be treated, or will be adjusted and set by a technician in accordance with the physician's prescription, thereby relieving the person to be treated of all responsibility and/or concern with respect to such details and making normal operation of the apparatus extremely easy and convenient.

In FIGS. 3 through 6 of the drawings, I have shown a portion of my apparatus for the purpose of illustrating certain novel, desired and preferred structural details which I employ to establish my apparatus and which make possible the attainment of certain sought-after ends, such as compactness, economy of manufacture, ease and convenience of service and the like.

In FIGS. 3 and 4, I have shown the valve 26 and the flow rate sensing device 27 related to and carried by a flat, plate-like manifold chassis 110 which defines the flow passage 10 of the system.

The valve 26 and sensing system 27 are both provided with and characterized by mounting plates 111 with flat, downwardly disposed bottom surfaces 112, a pair of spaced, vertical, downwardly opening passages 113 and 114, and a plurality of spaced vertical screw fasteners receiving openings 115.

The manifold chassis 110 comprises a molded body 120 with flat top and bottom surfaces 121 and 122, a plurality elongate, straight and/or curved downwardly opening flow passage forming channels 10' formed in the bottom surface of the body 120, vertical ports 123 and 124 at the opposite ends of the flow passage sections, opening upwardly at the top surface 121 of the body; annular, upwardly opening, sealing ring receiving recesses 125 in the top surface 121 about each port 123 and 124, a cover plate 126 overlying the bottom surface 127, a sealing gasket 127 between the plate 126 and the bottom surface 127 and a plurality of screw fasteners releasably securing the plate and washer in tight sealing engagement with the body to close the channels 10' and define the sections of the flow passage 10.

The ports 123 and 124 in the manifold chassis are spaced to register with the passages 113 and 114 in the mounting plates 111 of the valve and sensing device.

The mounting plates 111 of the valve and device are arranged with their bottom surfaces 112 in flat bearing engagement with the top surface 121 of the chassis body and with their related ports and passages 113-123 and 114-124 in register. The plates are releasably secured in fixed position on the chassis by screw fasteners 130 engaged through the openings 115 in the plates and in registering opening 115' in the chassis body.

Suitable sealing rings 131 are arranged in the recesses 125 to establish a fluid tight seal between the plates and chassis, about the related passages and ports.

All or any desired number of the noted separable and distinct components in and communicating with the flow passage 10 of my system is or can be provided with a mounting plate similar to the mounting plates 111 described above and related to the chassis body 110 and

with related sections of the flow passage 10 in the chassis body in the same or similar manner as are the plates 111 described above.

With the structure thus provided, it will be apparent that the entire flow passage and/or fluid circuit is established in and by the manifold body and the components with mounting plates 111, and that the structure is substantially void of the multitude of pipes, intermediate hoses, couplings and fittings which complicate and characterized those dialysis systems and apparatus provided by the prior art.

The valve structure 26 shown in FIGS. 3 through 6 of the drawings is similar to the valves 22, 31 and 33 employed in establishing my new apparatus.

The valve structure referred to above includes a central flow tube 140 of resilient rubber, the ends of which communicate with the passages 113 and 114 in the plate 111. The tube 140 extends through a retaining sleeve 141 which is provided with a transverse slot 142 about its lower half. A yoke 143 is engaged about the sleeve 141 and carries a semi-circular tube engaging shoe 144 which projects upwardly into the slot to engage the tube. The resiliency of the tube normally yieldingly urges and holds the shoe and yoke down. The upper end of the yoke is connected with the lower end of a vertically extending armature 145 of an electromagnetic, linear drive motor 146, supported above the plate 111 by a support structure formed integrally with the plate and which also carries and supports the sleeve 141.

The slotted sleeve 141 and the shoe 144 cooperated to control deformation of the tube 140 in a predetermined manner when the shoe is urged downwardly, against the resiliency of the tube, to effect deformation of the tube and reduction or shutting off the flow of fluid therethrough. The force required to deform the tube increases substantially linearly with the extent to which the tube is deformed.

The motor 146 is such that the force exerted thereby is variable and is controlled by the amount of current delivered to it. Accordingly, sufficient current can be delivered to the motor 146 to effect present and complete closing of the tube 140 or, a sufficient amount of current can be delivered to the motor so that the upward force generated thereby is equal to and balances the downward force exerted by the tube, when the tube is deformed to an extent to restrict the flow of fluid therethrough to a desired extent.

With the above valve structure, it will be apparent that the said valve structure is suitable for use as a simple on-and-off valve and is equally suitable for use as a variable flow and/or metering valve.

In practice, the manifold chassis body and the major portions of the valves and other components which are engaged with and secured to the manifold chassis can be molded or cast of metal or plastic and are such that their manufacture is not complicated or costly.

In practice, since the system is intended to conduct and handle a brine solution which is corrosive to most metals and for ease of manufacture, reduction of weight and other such factors, it is preferred that all elements and parts of the apparatus, where possible be molded of a suitable plastic.

In FIG. 1 of the drawing, the reservoir 23 is shown as an open vessel. In practice however, the reservoir can be and is preferably provided with a top closure or lid with a vent opening, which opening is provided with a

suitable dust shield or the like. The closure and shielded vent opening serve to prevent spillage of water from the reservoir and or contamination thereof.

In practice, brine concentrate for dialysis apparatus is available and marketed in solution, in suitable containers. To make convenient use of such supplies of brine concentrate, such concentrate can be poured into the vessel 26 illustrated and protected from contamination by the case cover of the door related thereto or, if desired, a suction hose can be provided to extend from the case to extend to the interior and bottom of the containers in which the concentrate is supplied. In such a case, an extendable suction hose, such as the hose 60 in FIG. 1, can be releasably connected with an outlet opening at the bottom of the vessel 62 shown in FIG. 2 of the drawings by coupling means, such as the means 61 shown in FIG. 1 of the drawings. In such a case, the vessel 62 in FIG. 2 of the drawings is utilized as a holder for the hose 60 and can be used as the principle brine concentrate vessel, when desired and when, for instance, the brine concentrate is established by dissolving prescribed salts in water, at the site of the apparatus.

Having described only one form and carrying out of my invention, I do not wish to be limited to the specific details set forth above, but wish to reserve to myself any variation and/or modification that fall within the scope of the following claims.

Having described my invention, I claim:

1. A dialysis apparatus comprising an elongate flow passage with a water inlet at its upstream end and a brine discharge at its downstream end, coupling means at said inlet communicating with a water supply, a reservoir between and communicating with portions of the passage downstream of the inlet, water level control means to control the water level in the reservoir, liquid pump means in and related to the passage upstream of the discharge and including a variable flow valve in said passage and a constant flow liquid pump having a greater flow rate than the rate of flow through the passage and having a suction side communicating with the passage upstream of the variable flow valve and a discharge side communicating with the passage downstream of the variable flow valve, flow control means in the passage between the reservoir and pump means and connected with the variable flow valve to control opening and closing of said valve to control the rate and volume of fluid drawn upstream through the variable flow valve and recirculated through said pump and affect control of the flow of fluid moved through the passage upstream of the pump means, a duct communicating with the passage between the reservoir and upstream of the flow control means and extending to and communicating with a body of liquid brine concentrate, salinity control means in and between the duct and the passage downstream of the duct to control the amount of concentrate flowing through the duct into the passage, liquid bypass means in the passage between the pump means and the flow control means including a bypass valve with a liquid outlet to connect with the inlet of a hemo dialysis device and a liquid outlet to connect with the outlet of the dialysis device and operable to selectively bypass fluid moving through the passage through said device, said water level control means including a shut-off valve in the passage upstream of the reservoir, a liquid level responsive means in the reservoir connected with said shut-off valve.

8. An apparatus as set forth in claim 1 wherein said salinity control means includes a salinity sensing means in the passage, an electrically operated adjustable flow valve in the duct and an electric control circuit be-

12. An apparatus as set forth in claim 1 wherein said salinity control means includes a salinity sensing means in the passage, an electrically operated adjustable flow valve in the duct and an electric control circuit between and connected with the salinity sensing means and the adjustable flow valve and including manually operable means to adjust and set the volume of flow of brine concentrate relative to the volume of flow of water and thereby adjust and set the salinity of the fluid downstream of the salinity sensing means, said apparatus further including thermostatically controlled electric water heating means in the reservoir, and fluid pressure control means to control the fluid pressure in the passage between the reservoir and pump means and including a fluid pressure sensing means in the flow passage between the bypass valve and the duct, an electrically operated metering valve in the passage between the duct and fluid pressure sensing means and an electric control circuit between and connected with the pressure sensing means and the metering valve and including manually operable means to adjust and set the pressure in the system.

13. An apparatus as set forth in claim 1 wherein said system further includes thermostatically controlled electric water heating means in the reservoir and fluid pressure control means to control the fluid pressure in the passage between the reservoir and pump means and including a fluid pressure sensing means in the passage between the bypass valve and the duct, an electrically operated metering valve in the passage between the duct and fluid pressure sensing means and an electric control circuit between and connected with the pressure sensing means and the metering valve and including manually operable means to adjust and set the pressure in the system, and blood leak detecting means downstream of the bypass valve and including a photo-electric means in the passage responsive to the light conductivity of the fluid in the passage and electric control and signaling means connected with the photo-electric means.

14. An apparatus as set forth in claim 1 wherein said flow control means includes a flow rate sensing means in the passage; electric operating means to vary opening of the variable flow valve and an electric control circuit between and connected with the flow rate sensing means and electric operating means and including manually operable means to adjust and set the rate of flow, said apparatus further including thermostatically controlled electric water heating means in the reservoir, and fluid pressure control means to control the fluid pressure in the passage between the reservoir and pump means and including a fluid pressure sensing means in the passage between the bypass valve and the duct, an electrically operated metering valve in the flow passage between the duct and fluid pressure sensing means and an electric control circuit between and connected with the pressure sensing means and the metering valve and including manually operable means to adjust and set the pressure in the system, and blood leak detecting means downstream of the bypass means and including a photo-electric means in the passage responsive to the light conductivity of the fluid in the passage and electric control and signaling means con-

nected with the photo-electric means.

15. An apparatus as set forth in claim 1 wherein said flow control means includes a flow rate sensing means in the passage, electric operating means to vary opening of the variable flow valve and an electric control circuit between and connected with the flow rate sensing means and electric operating means and including manually operable means to adjust and set the rate of flow, said salinity control means including a salinity sensing means in the passage, an electrically operated adjustable flow valve in the duct and an electric control circuit between and connected with the salinity sensing means and the adjustable flow valve and including manually operable means to adjust and set the volume of flow of concentrate relative to the volume of flow of water and thereby adjust and set the salinity of the fluid downstream of the salinity sensing means, said apparatus further including thermostatically controlled electric water heating means in the reservoir, and fluid pressure control means to control the fluid pressure in the passage between the reservoir and pump means and including a fluid pressure sensing means in the passage between the bypass valve and the duct, an electrically operated metering valve in the passage between the duct and fluid pressure sensing means and an electric control circuit between and connected with the pressure sensing means and the metering valve and including manually operable means to adjust and set the pressure in the system, and blood leak detecting means downstream of the bypass valve and including a photo-electric means in the passage responsive to the light conductivity of the fluid in the passage and electric control and signaling means connected with the photo-electric means.

16. An apparatus as set forth in claim 1 wherein said salinity control means includes a salinity sensing means in the passage, an electrically operated adjustable flow valve in the duct and an electric control circuit between and connected with the salinity sensing means and the adjustable flow valve and including manually operable means to adjust and set the volume of flow of brine concentrate relative to the volume of flow of water and thereby adjust and set the salinity of the fluid downstream of the salinity sensing means, said apparatus further including thermostatically controlled electric water heating means in the reservoir, and fluid pressure control means to control the fluid pressure in the passage between the reservoir and pump means and including a fluid pressure sensing means in the passage between the bypass valve and the duct, an electrically operated metering valve in the passage between the duct and fluid pressure sensing means and an electric control circuit between and connected with the pressure sensing means and the metering valve and including manually operable means to adjust and set the pressure in the system, and blood leak detecting means downstream of the bypass valve and including a photo-electric means in the passage responsive to the light conductivity of the fluid in the passage and electric control and signalling means connected with the photo-electric means.

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