Oct. 17, 1967 W. HAMILTON 3,347,416

PROPORTIONING APPARATUS

Filed July 7, 1965 3 Sheets-Sheet 1

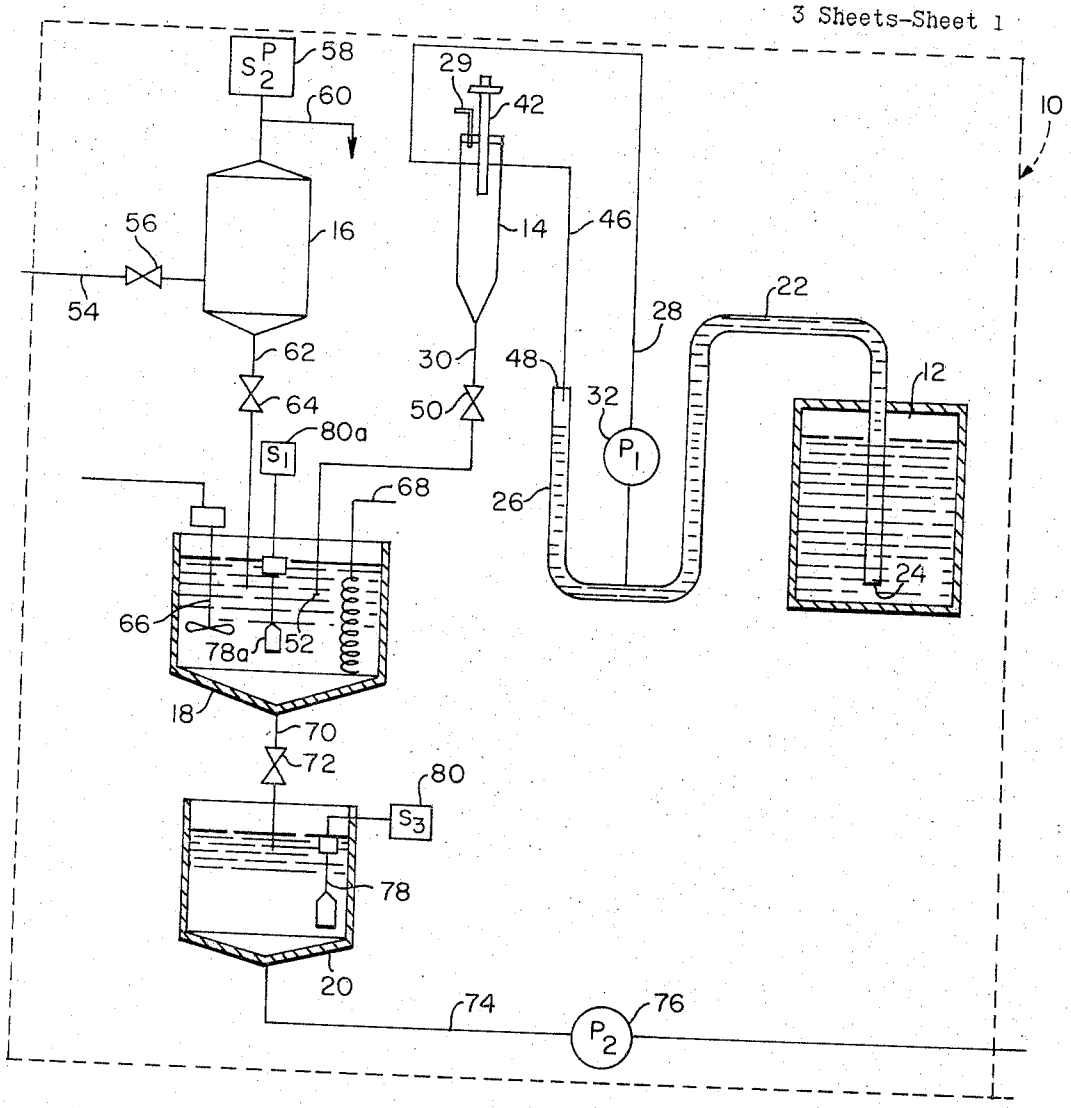


Fig. 1

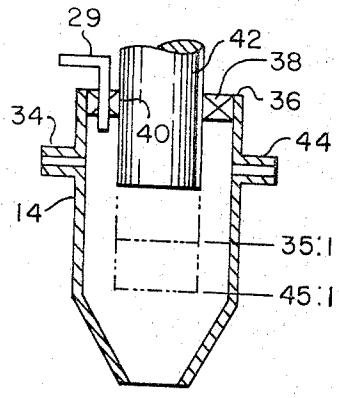


Fig. 2

INVENTOR
WALLACE HAMILTON

BY Schramm, Kramer & Sturges

ATTORNEYS

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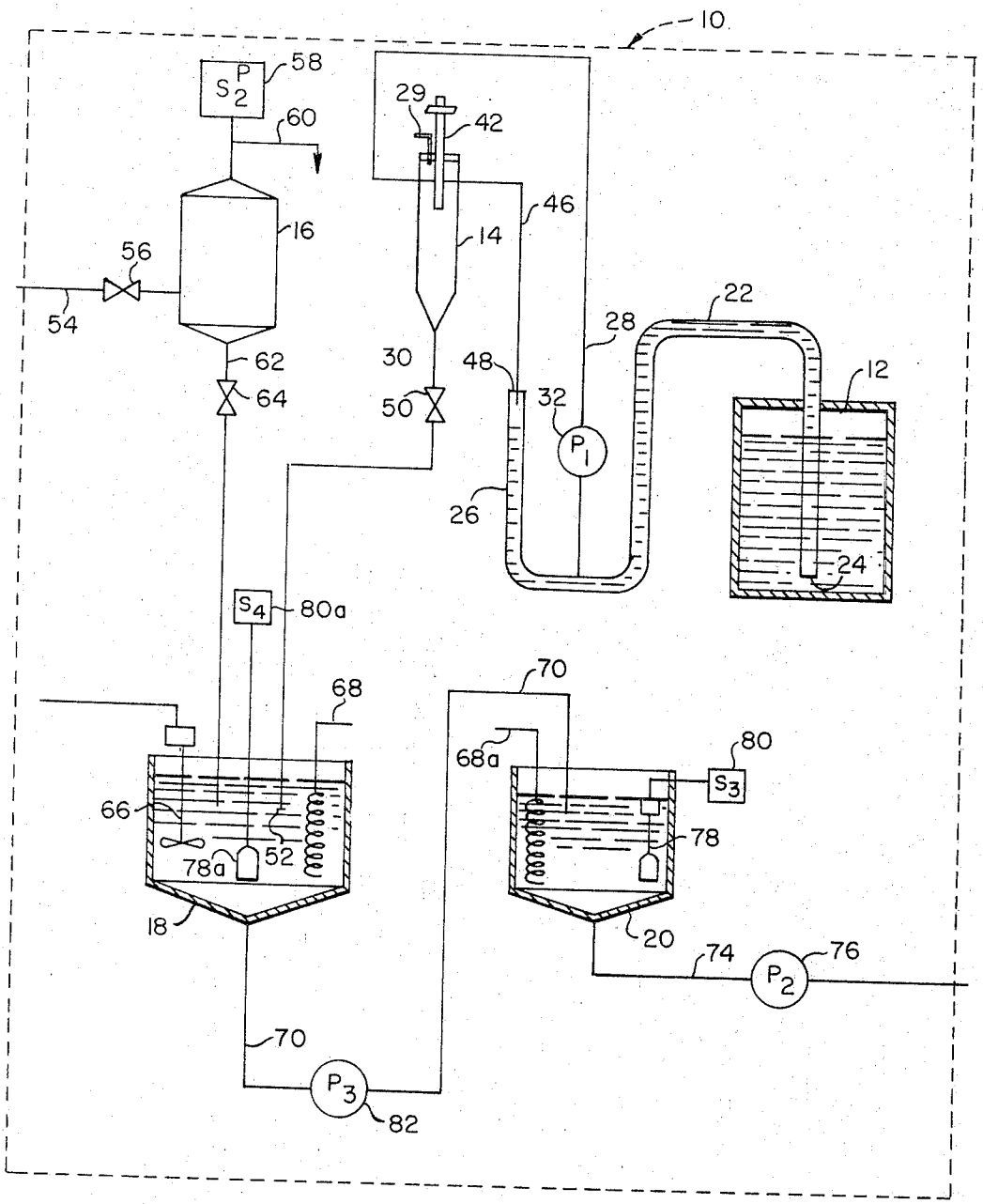


Fig. 3

INVENTOR
WALLACE HAMILTON

BY Schramm, Kramer & Sturges

ATTORNEYS.

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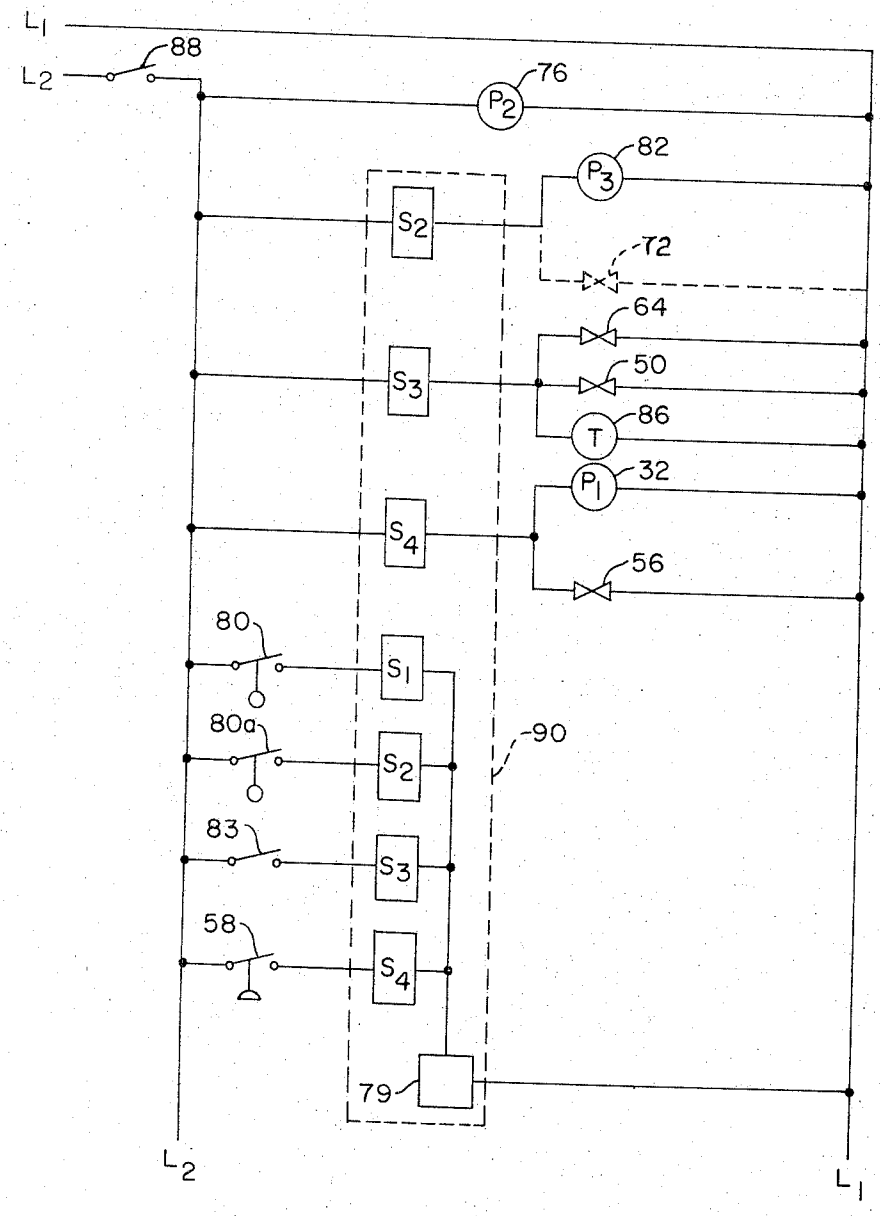


Fig. 4

INVENTOR
WALLACE HAMILTON

BY Schramm, Kramer & Sturges

ATTORNEYS

United States Patent Office 3,347,416
Patented Oct. 17, 1967

3,347,416

PROPORTIONING APPARATUS

Wallace Hamilton, Chagrin Falls, Ohio, assignor to Lewis Welding and Engineering Corporation, a corporation of Ohio

Filed July 7, 1965, Ser. No. 470,002
8 Claims. (Cl. 222—56)

This invention, as indicated, relates to an apparatus for proportioning fluids, and more particularly to an apparatus for diluting or mixing concentrated solutions to be predetermined concentration and dispensing the resultant solution.

Although the description of this invention is described in reference to proportioning and dispensing a solution composed of a single concentrated solution and a single diluting agent, it should be understood that the principles of this invention are applicable in proportioning and mixing together a number of concentrated solutions, or diluting a concentrated solution with different diluents, or a combination of both. For example, the apparatus of this invention might be used in continuously mixing and distributing solutions to baths in which photographic film is processed. This apparatus then, as indicated, is well suited for continuously proportioning, mixing and dispensing various solutions.

A most important utilization of this apparatus is in connection with an artificial kidney. Therefore, its description will be given in relation thereto.

It is well recognized that the kidneys are vital to the health of the body, as they act as dialyzing membranes for removing contaminants in the blood. Without such membranes, the contaminants would cause poisoning of the blood stream which inevitably brings death.

In recent years, an apparatus known as an artificial kidney for conditioning the blood has been developed and is used to bypass defective kidneys permitting them to remain inactive for a period of time sufficient to permit their spontaneous return to normal capacity to function. This apparatus is also employed to remove contaminants and wastes from the blood of people who have no kidneys. The treatment is administered on an average of 1–3 times per week depending on the individual. This treatment is extremely important, as the patient would soon die if it was not avialable.

The artificial kidney is attached to the vascular system at two different points of the body, normally the arms. Blood is pumped from an artery into the artificial kidney, dialyzed and then returned to the body through a vein. The blood must be constantly circulated through the apparatus, i.e. similar to the normal circulation of the blood through the kidneys to reduce the accumulation of deleterious substances in the blood stream.

The blood is submitted to dialysis in conjunction with a diluted solution of one or more salts which is passed through the apparatus and separated from the blood by a dialysis membrane. In one embodiment blood from the patient is passed through an elongated, flattened thin walled spirally wound plastic tube which serves as the dialysis membrane immersed in a circulating salt bath and returned to the patient. The effect of the salt solution and its concentration relative to the blood and the permeability of the tube to the waste materials permits a process known as dialysis to take place to remove waste material from the blood stream. The salt solution once it passes through the apparatus is ordinarily not recycled and reused. Therefore, it is readily understood that there is a need for a constant supply of solution. The solution must be properly proportioned and diluted for conditioning the blood, and it must be also heated to keep the blood at body temperature. A suitable concentrated salt solution is readily available. The problem arises in properly continuously diluting the concentrated solution and supplying it to the artificial kidney.

Many devices presently employed use a proportioning pump to dilute the concentrated salt solution. Because of possible mechanical failures and the relatively high cost of such pumps at the accuracy required, it is desirable to have less complicated and less expensive equipment without any sacrifice in accuracy. This invention provides such an apparatus. Costs are greatly reduced and more machines can be made more widely available to the many people who are suffering kidney disorders. The capacity of the device hereinafter described is based on furnishing 300 cubic centimeters of solution per minute to each of five people. In other words, this metering apparatus provides a properly diluted, mixed and heated salt solution to five artificial kidney elements, each element in turn treating one individual. The capacity of the apparatus can be increased or reduced by increasing or reducing the size of the various tanks as will become apparent from the following description.

To the accomplishment of the foregoing and related ends, said invention, then, consists of the means hereinafter fully described and particularly pointed out in the appended claims, the following description and annexed drawings setting forth in detail certain illustrative embodiments of the invention, such disclosed means constituting, however, but a few of the various forms in which the principle of this invention may be employed.

In the annexed drawings:

FIG. 1 is a diagrammatic view of an embodiment of this invention;

FIG. 2 is an enlarged view of a metering tank for measuring varied amounts of the concentrated salt solution;

FIG. 3 is a diagrammatic view of another embodiment of this invention; and

FIG. 4 is a schematic diagram showing the electrical system for controlling the operation of the various valves and pumps.

Briefly stated, this invention is an apparatus for diluting, mixing and heating a concentrate and metering the diluted solution to an apparatus, such as an artificial kidney, which utilizes such solution. The apparatus includes: A tank in which the concentrate solution is stored; a tank in which is measured a fixed amount of the diluent or solvent, e.g. water; a tank in which is measured a proportionate amount of the concentrated salt or active ingredient solution; a mixing tank in which the fixed amount of diluent and the proportionate amount of concentrate are placed, mixed and heated; and, means for dispensing the diluted, heated solution to the apparatus. The dispensing tank and mixing tanks are located relative to each other and the measuring tanks, that the concentrate and diluent preferably flow by gravity. The fluid conduits or the means for regulating the flow between the various tanks will hereinafter be more fully described.

Referring generally to FIGS. 1–3, and more particularly to FIGS. 1 and 2 of the annexed drawings, there is shown a proportioning device or apparatus, generally indicated at **10**. The apparatus **10** contains a plurality of tanks, e.g. a concentrate solution storage tank **12**, a metering or measuring tank **14**, for the concentrate solution, a separate metering or measuring tank **16** for the diluent or solvent, a mixing tank **18** and a dispensing tank **20**. As shown in the drawing, the tanks **14** and **16** each have single compartments which are fixed in size.

In the illustrative embodiment, storage tank **12** contains in concentrated form a salt solution used in an artificial kidney (not shown) for removing contaminents from the blood as above described. A portion of the concentrated salt solution is forced, by any suitable means, e.g. pump **32**, into the metering tank **14**, where it is

measured for dilution with a proportionate amount of water, measured in the tank **16**. In the embodiment shown, the concentrated salt solution is pumped into tank **14**, from an S-shaped siphon tube **22** having its tube end **24** extending into the tank **12** and the salt solution therein. As the salt solution will seek its own level in the siphon tube **22**, the level of the salt solution in the upstanding portion **26** of tube **22**, acts as a scale indicating the level of the concentrated salt solution in the storage tank **12**.

The metering tank **14** (FIG. 2) has an inlet **34** and an overflow **44**, which for convenience of manufacture are axially aligned. A piece of tubing or line **28** secured to the inlet **34** communicates with the siphon tube **22** adjacent its upstanding portion **26**. The pump **32** is interposed in the line **28**, and serves to pump the concentrated salt solution from the siphon tube **22** and storage tank **12**, into the measuring tank **14**. Tank **14** is preferably vented, e.g. vent **29**.

This invention contemplates variable means to be used to measure the amount of concentrated solution in variable volume tank **14**. For example, the tank **14** (FIG. 2) has its open end **36** sealed by a top or ring **38** having a centrally or eccentrically disposed opening **40** extending therethrough. A plunger **42** is inserted through the opening **40** into the tank **14**. The volume of the diluent or water is preferably kept constant in the tank **16**. Therefore, the concentration of the final solution is controlled by varying the volume of concentrated salt solution. This is accomplished with the plunger **42**. The further the plunger **42** is inserted into the tank **14**, i.e. the greater its displacement, the less volume of concentrated solution will be used. A scale (not shown) indicating the number of parts of water per part of concentrated salt solution, e.g. the positions of plunger **42** shown in dotted lines and indicated for example, proportions of 35:1 and 45:1, i.e. 35 or 45 parts of dilute solution to one part of concentrated solution, may be placed on the plunger **42**, or the tank **14**, or cooperate with the plunger **42**, whichever is more convenient. The plunger **42** may be raised or lowered in the tank **14** by any suitable means. A piece of tubing or line **46** (FIG. 1) is secured to and communicates with the overflow **44**. The free end of the line **46** extends into the mouth **48** of the siphon tube **22**. In this manner, the excess or displaced fluid is taken from the tank **14**, and restored in the tank **12** and siphon tube **22** for reuse.

A piece of plastic tubing or line **30**, e.g. polyethylene tubing, is secured to, communicates with and extends from the lowest drainage point of tank **14** into the mixing tank **18**. A flow valve **50** disposed in the line **30**, regulates the flow of the metered solution from the tank **14** into the tank **18**.

The filling of the measuring tank **16** is substantially simultaneous with the filling of tank **14**. A pipe or line **54** communicates between a source of water supply, e.g. a tap or faucet (not shown), and the measuring tank **16**. A valve **56** is disposed in the line **54** to regulate the flow of water into the measuring tank **16**. When the valve **56** is open, water is forced into the measuring tank **16** by any suitable means. In most instances, the line pressure is sufficient to cause the water to flow into the tank **16**.

The top of the tank **16** is provided with a vent line **60** forming a restricted orifice where the line is joined to the top. As tank **16** fills, air is vented through this orifice or opening. When water reaches the orifice, the effect of the restriction on the flow causes an increase in pressure within the water body which is utilized to actuate a pressure sensitive switch **58** which closes the valve **56** cutting off the flow of water into the tank **16**. The pressure switch **58** is also utilized to shut-off pump **32**. The tank **14** has a smaller volume than tank **16** and is therefore filled before tank **16**. The concentrate is continuously pumped or circulated through tank **14** until the switch **58** is activated to shut off pump **32**.

A pipe or line **62** is secured to, communicates with, and extends from the lowest drainage point of the tank **16** into the mixing tank **18**. A valve **64** disposed in the line **62** regulates the flow of water between the measuring tank **16** and the mixing tank **18**.

The mixing tank **18** is preferably disposed below the measuring tanks **14** and **16**, respectively. When the valves **50** and **64**, respectively, are opened, the measured amounts of concentrated salt solution and water, respectively, flow from tanks **14** and **16** into the mixing tank **18**. The water and the concentrated salt solution are thoroughly mixed in the mixing tank **18** by any suitable means, e.g. a mixer or stirrer **66**.

The solution in tank **18**, is simultaneously heated by any suitable means, e.g. a thermostatically controlled heat coil **68**. When used in conjunction with an artificial kidney, it is necessary to heat the diluted salt solution to temperatures ranging from about 100° F. to about 105° F., so that when it passes through the artificial kidney, the blood will be maintained near body temperature. Depending on the process for which the apparatus **10** is used, the mixed solution may be kept at room temperture, heated, or cooled.

In the illustrative embodiment, the dispensing tank or reservoir **20** is disposed below the mixing tank **18**. A piece of tubing or line **70** is secured to, communicates with, and extends from the lowest drainage point of the tank **18**, into the dispensing tank **20**. A valve **72** disposed in the line **70**, regulates the flow of fluid between the tanks **18** and **20**, respectively. A piece of tubing or line **74** is secured to, communicates with, and extends from the lowest drainage point of the dispensing tank **20**. The line **74** extends from the proportioning apparatus **10** for attachment to the artificial kidney. A pump **76** disposed in the line **74** regulates the flow of the diluted salt solution from the dispensing tank **20** into the artificial kidney.

As previously indicated, the capacity of the unit is based on furnishing 300 cc. per minute to each of 5 people. To accomplish this, the variable volume tank **14** has a capacity of about 0.3 liter, the measuring tank **16** a capacity of about 7.5 liters, the mixing tank **18** a capacity of about 10 liters, and the dispensing tank **20** a capacity of about 11 liters.

Although the valves controlling the flow of fluid between the tanks may be manually operated, it is desirable to have them responsive to electrically activated devices to control their opening and closing. Programming devices also control the operation of pump **32**. The operation of such devices will hereinafter be more fully described.

The embodiment of the proportioning apparatus **10**, shown in FIG. 3, is essentially the same with a few improvements. A thermostatically controlled heat coil **68***a* is disposed in the reservoir or dispensing tank **20**, and helps keep the mixed and diluted solution at a predetermined desired temperature, e.g. about 102° F., the heat coil **68** in tank **18** keeping the temperature of the solution at about 103° F., whereby the temperature of the diluted solution is kept between about 100° F. and 105° F. The heating of the diluted solution can be aided, for example, by preheating the diluent. For example, when water is then diluent, both hot and cold water from their respective faucets or taps could be supplied to the measuring tank **16**.

The dispensing tank **20**, for convenience, is disposed adjacent the mixing tank **18**, and not below it. Therefore, a pump **82** must be disposed in the line **70** to pump the solution from tank **18** into tank **20**.

From the aforementioned description of the parts of the apparatus **10**, and their positions relative to each other, it is apparent that the rate of flow into tanks **18** and **20** must be greater than the rate of flow from the tank **20**. Otherwise the tank **18** would be dry at times, and not able to supply the solution to the tank **20**. This problem is overcome in a number of ways. For example, the pump **76** is made to pump at a slower rate, or the tank

20 made larger to increase the amount of reserve solution, or pumps used to pump the solution from tanks 14 and 16, respectively, into tank 18. The actuating and programming devices may be more fully understood by having reference to FIG. 4, which is a schematic drawing of a system employing a conventionally designed step switch 90 for controlling the operation of the valves and pumps in the proportioning apparatus 10 of FIGS. 1 and 3. This system conveniently operates on 110 volts and comprises power leg L_2 and neutral leg L_1.

The step switch 90 is disposed in the circuit for controlling the sequential operations of filling and emptying the various tanks. To begin operation of the apparatus 10, it is assumed that the various tanks are filled, the valves closed and the pumps shut off. A switch 88, controlling the normal operation of the apparatus 10, is turned to its on position closing the electrical circuit. The pump 76 begins pumping solution from the reservoir or dispensing tank 20. At this point the step switch is in its first position or station S_1. When the solution reaches a predetermined level within tank 20, the float 78 activates float switch 80. An electrical impulse is sent from switch 80 through a stepping mechanism 79 moving the step switch 90 to its second position or station S_2.

In this position, the circuits to valve 72 or pump 82, are closed and the valve 72 opens or the pump 82 begins pumping the solution from tank 18 into the reservoir 20. When the solution in tank 18 reaches a predetermined level, the float 78*a* activates float switch 80*a*. An electrical impulse is sent from switch 80*a* through the stepping mechanism 79 moving step switch 90 to its third position or station S_3.

In this position the electrical circuits controlling the operation of valve 72 or pump 82 are broken, and valve 72 closes or pump 82 shuts off. Also valves 50 and 64 are opened and a timing device 86 is activated. The timing device is set to permit tanks 14 and 16, respectively, to empty. After the allotted time has passed, an electrical impulse is sent from timer switch 83 through the stepping mechanism 79 moving step switch 90 to its fourth position or station S_4.

In this position, the electrical circuits controlling the operation of valves 50 and 64, respectively, and timing device 86 are broken, and the valves close and the timing device is shut off. Simultaneously, pump 32 and valve 56 are activated, and concentrate is pumped from the storage tank 12 into the measuring tank 14, and the diluent flows through valve 56 into measuring tank 16, respectively. The pressure switch 58 is activated when the tank 16 is filled with diluent. An electrical impulse is sent from switch 58 through the stepping mechanism 79 moving and returning the step switch 90 to its first position S_1. In this position, the electrical circuit to the pump 32 and valve 56, respectively, is broken and pump 32 shuts off and valve 56 closes. The cycle is repeated when pump 76 pumps solution from the tank 20 down to the predetermined level for activating float 78.

Although the proportioning apparatus 10, because of its simplicity, is relatively free from malfunctions, it must, nevertheless, have a system for warning of any such malfunctions or breakdowns. Any suitable means may be used to accomplish this. For example, different colored lights might provide warnings that different tanks are not filling or emptying properly. This type of system would immediately pinpoint the trouble area, and instant action could be taken to correct the difficulty. Such a warning system is extremely important when the apparatus 10 is used in conjunction with the artificial kidney.

As previously indicated, when the apparatus 10 is used in conjunction with the artificial kidney, the temperature of the dispensed diluted solution must be from about 100° F. to about 105° F. A safety device (not shown) must be provided to insure that the temperature of the dispensed solution is in the prescribed range. Any suitable means may be used to accomplish this. For example,

a thermostatically controlled valve could be disposed in the line 74 leading from the apparatus 10. If the solution were not within the prescribed range, the valve would operate to close line 74 leading to the artificial kidney, and open a bypass conduit leading to a drain or other means for disposing the improperly heated solution. The valve would only permit the passage of properly heated solution to the artificial kidney.

When used in conjunction with the artificial kidney, the apparatus 10 must be periodically sterilized. This is accomplished by passing and holding liquids, e.g. water, heated to a temperature of about 200° F., in the apparatus for a period of time, and then flushing it with cool or cold water.

Thus, there has been provided a new and novel apparatus for diluting and/or mixing concentrated solutions. The parts of the proportioning apparatus may be made of any suitable materials depending on the type of solutions diluted and/or mixed. However, when used with the artificial kidney, it is mandatory that only certain materials be used, e.g. non-corrosive metals, glass and some clinically tested and approved plastics. In this case, the apparatus performs a lifesaving function, and to eliminate any breakage or malfunctions of the parts, it is preferable that they be made of stainless steel. The parts of this apparatus are simply designed and economically manufactured. As seen in FIG. 1, the comparatively simple design of the metering apparatus makes it readily free from malfunctions which, as previously indicated, is most important when used with the artificial kidney.

Other modes of applying the principle of this invention may be employed instead of those specifically set forth above, changes being made as regards the details herein disclosed, provided the elements set forth in any of the following claims, or the equivalent of such, be employed.

It is, therefore, particularly pointed out and distinctly claimed as the invention:

1. An apparatus for proportioning at least two liquids, comprising:

(a) a first tank having a single compartment whose volume is fixed and unadjustable for measuring a fixed amount of the first of said two liquids;

(b) a storage tank for storing a second liquid;

(c) a second tank having a single fixed compartment for measuring a proportionate amount of the second of said two liquids;

(d) a plunger adjustable in the second tank for varying the amount of liquid therein relative to the fixed amount of liquid in said first tank;

(e) a third tank for receiving by gravity, the liquid from said first and second tanks;

(f) means coacting with the first tank for regulating the flow of the first liquid into the first tank, the means responsive to the filling of the first tank and the emptying of the third tank;

(g) means coacting between the storage tank and the second tank for regulating the flow of the second liquid between the tanks, the means responsive to the filling of the first tank and emptying of the third tank;

(h) means disposed in the third tank for mixing the liquids together;

(i) means disposed in the third tank for regulating the temperature of the liquid in the third tank;

(j) means coacting between the first and second tanks, respectively, and the third tank for regulating the flow of the liquids between the tanks, whereby the third tank is filled and the first and second tanks are emptied, the means responsive to the emptying of the first, second and third tanks;

(k) a reservoir for receiving and storing the liquid from the third tank until it is dispensed;

(l) means coacting between the reservoir and third

tank, for regulating the flow of the liquids therebetween, the means responsive to the emptying of the reservoir and third tank; and

(m) means for regulating the flow of liquid from the reservoir.

2. The apparatus of claim **1**, wherein the means for varying the volume of the second tank includes a plunger reciprocable in the second tank for displacing a volume of the second liquid and means for removing the displaced volume of the second liquid from the tank.

3. The apparatus of claim **2**, wherein the volume of the reservoir is greater than that of the third tank.

4. The apparatus of claim **3**, wherein the means for regulating the flow of liquid from the third tank to the reservoir includes separate means disposed in the reservoir coacting with the liquid in the reservoir to activate the flow means when the solution reaches a predetermined level in the tank.

5. The apparatus of claim **4**, wherein the means for regulating the flow of the first and second liquids into the third tank includes separate means disposed in the third tank coacting with the liquid in the third tank to activate the flow means when the liquid reaches a predetermined level in the third tank.

6. An apparatus for proportioning at least two liquids, comprising in combination:

(a) a first tank having a single compartment whose volume is fixed and unadjustable for measuring a fixed amount of the first of said two liquids;

(b) a second tank having a single fixed compartment for measuring a proportionate amount of the second of said two liquids;

(c) a plunger adjustable in the second tank for varying the amount of liquid therein relative to the fixed amount of liquid in said first tank;

(d) a third tank for receiving by gravity, the liquid from said first and second tanks, said liquids being mixed in said third tank to form a solution;

(e) means for dispensing at least a portion of the solution from said third tank; and

(f) means responsive to said dispensing means (e) for regulating the receiving of liquids into said third tank.

7. The apparatus of claim **6**, which includes:

(i) means disposed in the third tank for mixing the predetermined volumes of the liquids together.

8. The apparatus of claim **6**, which includes:

(j) means disposed in the third tank for regulating the temperature of the liquid.

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ROBERT B. REEVES, *Primary Examiner.*

HADD S. LANE, *Examiner.*