April 30, 1946. F. K. DANIEL ET AL 2,399,471

DIALYZERS

Filed Oct. 7, 1943 3 Sheets-Sheet 1

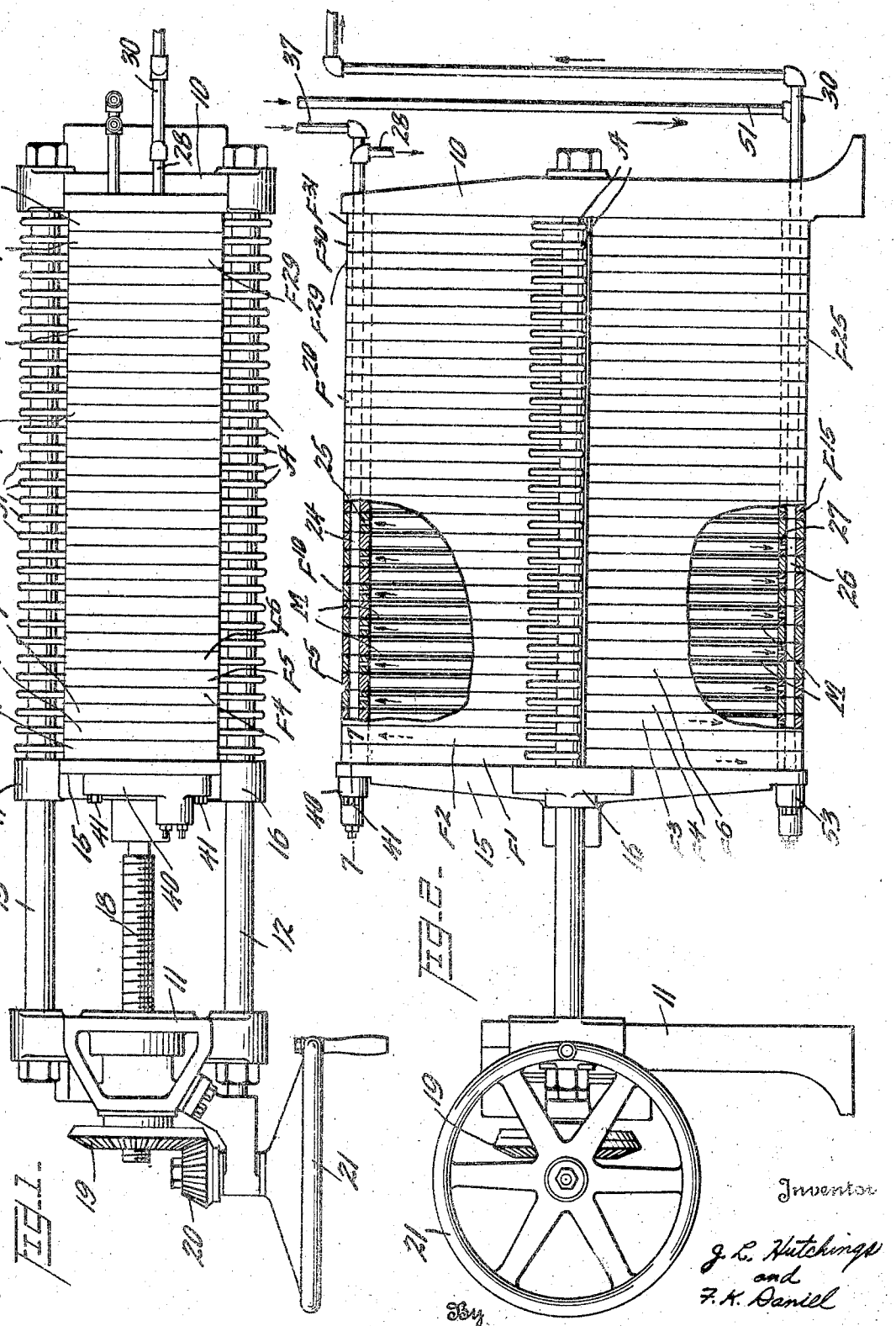


Fig. 1.

Fig. 2.

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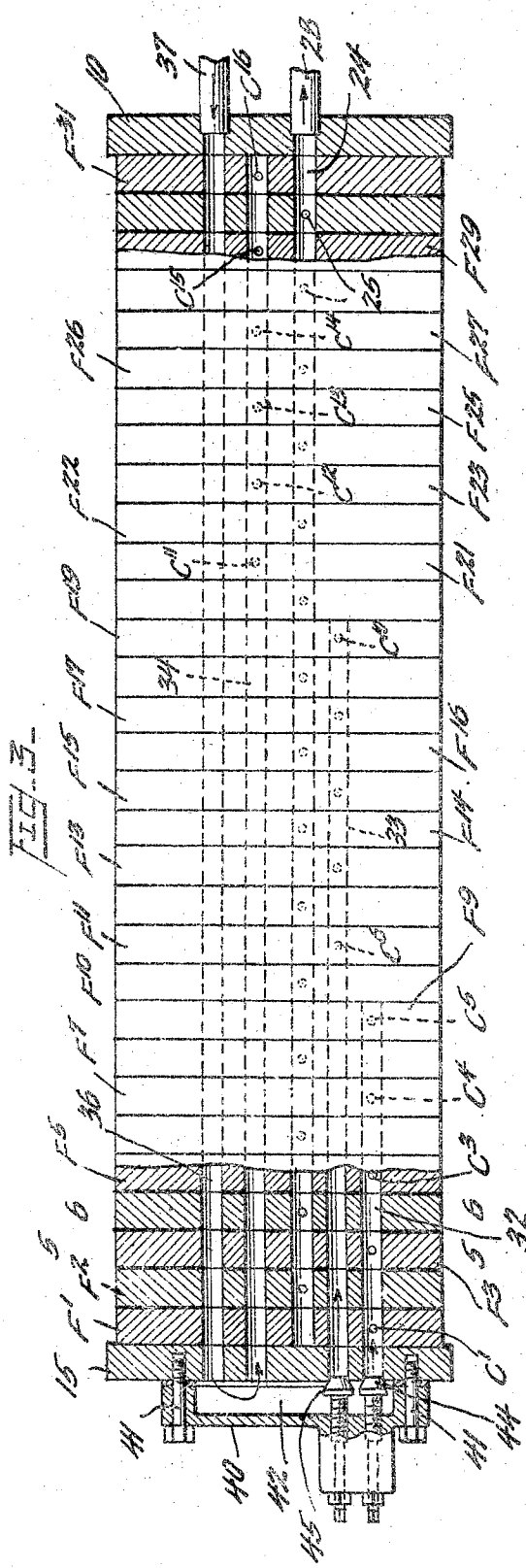


FIG. 3.

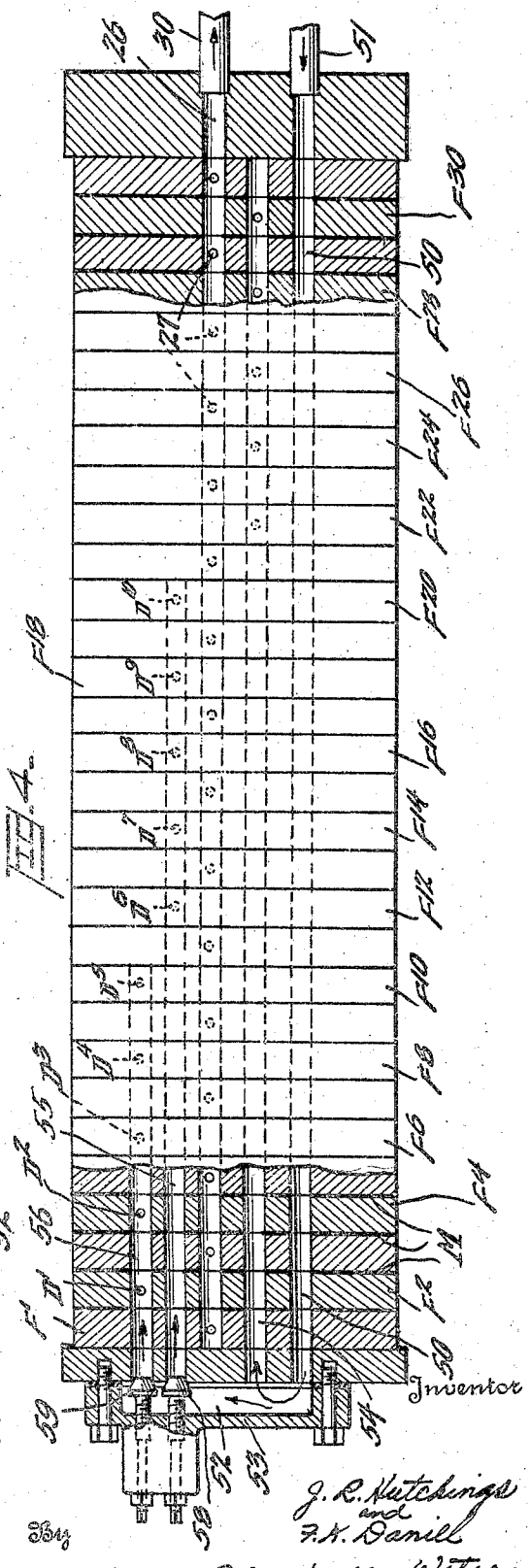


FIG. 4.

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DIALYZERS

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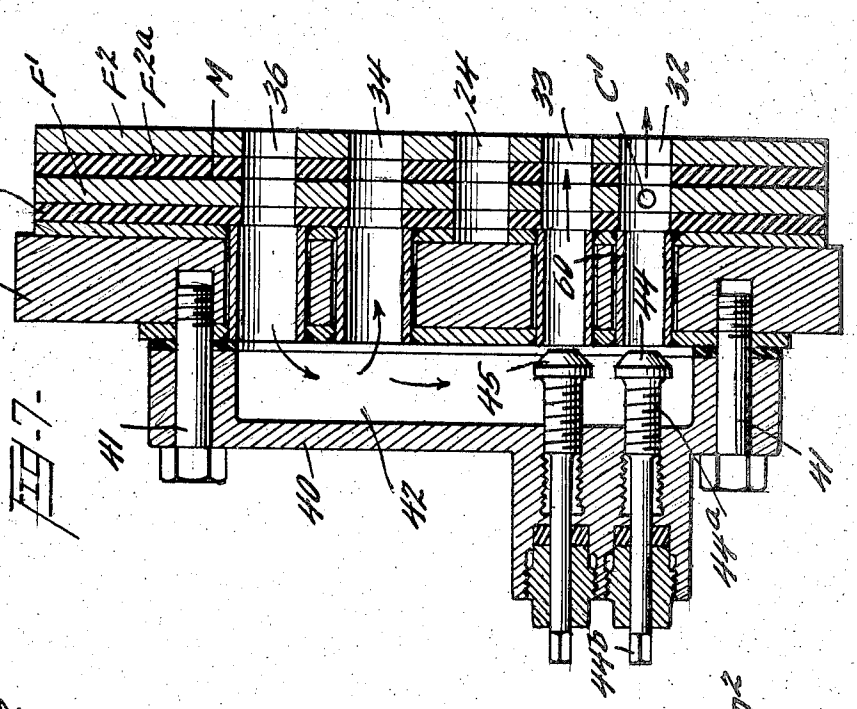


FIG. 7.

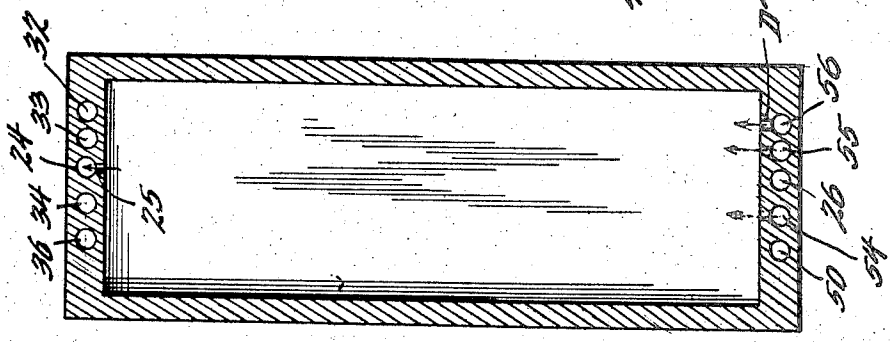


FIG. 6.

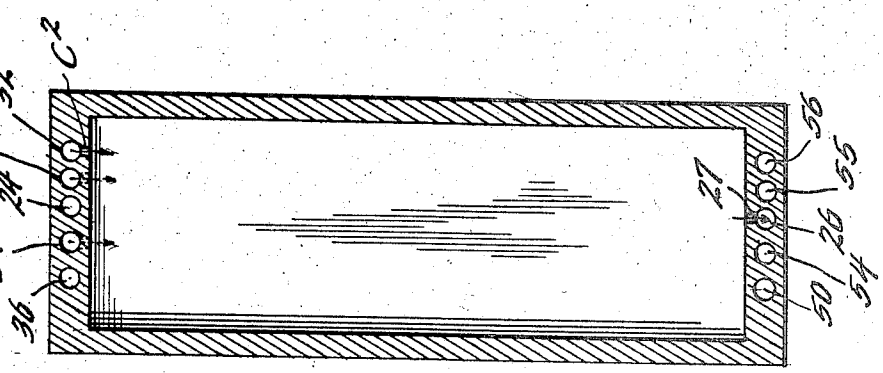


FIG. 5.

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UNITED STATES PATENT OFFICE

2,399,471

DIALYZER

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Application October 7, 1943, Serial No. 505,396

7 Claims. (Cl. 210—8.5)

The present invention relates to dialyzing apparatus and its purpose is to provide an apparatus of this character which is so designed and constructed that it will operate efficiently and at full capacity with liquids which vary widely in viscosity, up to the heaviest and most viscous liquids which are ordinarily subjected to the process of dialysis.

The conventional dialyzer includes a substantial number of liquid cells, adjacent cells being separated by a common membranous dividing wall, there being sometimes more than one hundred cells, such cells being arranged in a series. Each cell of the series is in constant communication with a liquid delivery and a liquid discharge conduit. The liquid to be dialyzed, hereinafter known as the dialysate, is conventionally introduced into alternate cells at the lower ends thereof and flows upwardly through such cells to escape through apertures at the tops to immediately enter a liquid discharge conduit. Dialyzing liquid, conventionally water, hereinafter known as diffusate, is introduced into the intermediate cells at the upper ends thereof and passes downwardly escaping through ports formed in the bottoms of the intermediate cells into liquid off-take conduit. In accordance with prior practice dialyzers have been so constructed that the recovery liquid or diffusate is discharged into a single off-take conduit and all of the alternate cells of the series discharge into a single off-take conduit for the dialysate, these conduits extending longitudinally of the dialyzer.

This type of dialyzing apparatus has been employed with eminent success in the dialysis of many liquids. Whenever there is passed through the dialyzer either a heavy or viscous solution to be dialyzed, or a heavy or viscous recovery liquid, the overall efficiency and output of the machine falls off very substantially, the very viscosity of the liquid preventing the proper distribution of the viscous liquid to many of the cells. Thus, by reason of the fact that all of the alternate cells are supplied with liquid from a single liquld delivery conduit which extends longitudinally of the dialyzer and is connected to the liquid supply conduit at one end only, those cells of the dialyzer which are remote from that end of the liquid delivery conduit which is immediately connected to the source of supply are only partially supplied with the liquid to be dialyzed if, indeed, it is possible to force the viscous liquid through these relatively remote cells at all. It will be appreciated that a heavy or viscous liquid will, like any other liquid, seek the path of least resistance between the point of introduction and the point of withdrawal from the dialyzer. The cells immediately adjacent the point of introduction of the viscous liquid into the dialyzer provide the path of least resistance, those cells which are more remote from the point of introduction of liquid into the dialyzer offer pathways of greater resistance. It will be appreciated, of course, that while all cells offer equal resistances to flow of liquid therethrough, being similar in shape and dimension, the opposition to the flow of the liquid to be dialyzed through the delivery conduit will increase as the distance from its point of introduction increases. It is sometimes found that only a relatively few cells of a dialyzer, immediately adjacent the point of introduction of the viscous liquid, are transmitting proper volumes of liquid and operating at full efficiency and that the efficiency of operation of the remaining cells is gradually diminishing, those toward the rear of the machine being sometimes practically inactive.

In order to make it possible to fully utilize all of the cells of a dialyzer, regardless of the sluggishness or excessive viscosity of the dialysate, or of a recovery liquid, or diffusate, and without surrendering any advantage inherent in the design and construction of the conventional type of dialyzer, which has been in successful use for many years, we provide a simple but effective means which may be incorporated in the conventional dialyzer and which, when so incorporated, will make it easily possible to pass through the apparatus liquids of great viscosity without loss of operating efficiency or volume of production. In accordance with our invention we divide the entire series of liquid cells into groups and supply these groups individually through separate liquid delivery conduits, each of these conduits being in communication with a common source of supply of liquid, and means being provided for separately controlling the flow of liquid from the source of supply into the several delivery conduits. By observing the rates of flow of liquid through the cells of the series, and by adjusting the flow control means, we can effectively bring about substantial equality of operation of the several groups of cells so that each group will function, in substance, similarly to the other groups, approximate equalization of flow through all cells of the entire series brought about. Various regulating or controlling means may be employed, a preferred embodiment being illustrated in the accompanying drawings, in which

Figure 1 is a top plan view of the dialyzer;

Figure 2 is a side elevation of the same, partly broken away to show in part, its interior construction;

Figures 3 and 4 are top plan and bottom views, respectively, of the series of dialyzer frames, portions of the frames being broken away in order that the liquid passages formed therein may be more clearly perceived;

Figures 5 and 6 are sections on lines 5—5 and 6—6 respectively, of Figure 3; and

Figure 7 is a section on line 7—7 of Figure 2, upon a somewhat larger scale.

The dialyzer may be said to comprise a front end frame or pedestal indicated at 10, which is ordinarily stationary, a rear pedestal or frame member 11, likewise stationary, and frame supporting rods 12 and 13, respectively, the ends of these rods passing through suitable apertures formed in the frame members 10 and 11 and being rigidly supported thereby in horizontal spaced relationship. A movable dialyzer head is indicated at 15, this head having bearing portions 16 and 17 provided with cylindrical bores through which the rods 12 and 13 extend, the head 15 being slidable along these rods and a driving or adjusting means being provided. This means includes the telescoping thrust rod 18 having fixed on one end a gear 19, the teeth of which mesh with those of a pinion 20, which pinion may be rotated by means of a hand wheel 21.

Dialyzer frames are indicated by the reference numerals F^1 to F^{31}, inclusive, each of these frames having two laterally extending arms of brackets A which extend over and slidably rest upon the horizontal rods 12 and 13, respectively, the various frames being thus slidably supported by the rods 12 and 13. They may be forced into intimate contact by advancing the pressure head 15 toward the front end frame member 10, diaphragms or membranes, indicated at M in Figure 2, being clamped between the respective frame and the entire space within and defined by the rectangular frames being divided by the membranes M into a series of narrow vertically disposed parallel cells, each membrane comprising a common wall between adjacent cells. The entire series of thirty-one cells may be considered as comprising alternate and intermediate cells, the intermediate cells being indicated by the reference numerals F^1, F^3, F^5, etc., and the alternate cells by the reference numerals F^2, F^4, F^6, etc.

As clearly shown in Figures 3 and 4 of the drawings the top and bottom, or horizontal, members of some frames are each provided with a series of circular apertures, five in number, four in number and three in number, and when the frames are arranged as shown in Figures 3 and 4, the uppermost apertures of the series of frames are in registration to form five, four and three elongated continuous channels or conduits, respectively. The same is true of the apertures in the lower cross members of the frames. The continuous aperture or duct which is indicated by the numeral 24, comprising thirty-one registering apertures formed in the series of frames, is provided for the removal of liquid from the apparatus and may be said to be a dialysate conduit for leading liquid which has been subjected to the dialyzing process from the apparatus to a point of disposal. Conduit 24 is in communication with the alternate cells through the relatively small or restricted apertures 25 formed in the upper cross members of the frames defining those cells. The generally similar conduit indicated at 26 and which comprises registering apertures formed in the lower cross members of the frames, is for the recovery liquid or diffusate intermediate cells being in communication with this conduit through restricted aperture 27. The dialysate conduit 24 communicates with the offtake pipe 28. The conduit 26 is in communication with a pipe 30 by means of which the recovery liquid or diffusate may be withdrawn from the apparatus and conducted away. It is thus seen that each cell of the entire series is provided with an outlet port which leads to a conduit for the removal of liquid.

The intermediate cells F^1, F^3, F^5, etc., are supplied with liquid through apertures formed in the upper members of the frames of the intermediate cells, these apertures being indicated by the reference numerals C^1 to C^{16}, inclusive, Figure 3. The apertures just referred to are, however, not in communication with a single delivery conduit, apertures C^1 to C^5, inclusive, being in communication with delivery conduit 32, apertures C^6 to C^{10}, inclusive, with delivery conduit 33, and aperture C^{11} to C^{16}, inclusive, with conduit 34. Conduits 32, 33 and 34 are, however, all in communication with a single fluid delivery conduit, which conduit is indicated at 36 and is shown to be connected to a supply pipe 37 at one end and to communicate with the hollow interior of a cross block 40 at the opposite end, the block 40 being rigidly attached by means of bolts 41 to the shiftable head 15 of the dialyzer and defining, with the adjacent outer face of head 15, a channel 42 for liquid.

It will be observed that liquid passing through supply pipe 37 in the direction of the arrow shown in Figure 3 will enter the supply conduit 36 at its front end, pass through this conduit into the space 42 and from there pass into the several delivery conduits 32, 33 and 34. Such liquid may pass freely at all times into the open end of delivery conduit 34 and thus be conducted to the cells which are defined, in part, by the frames F^{21}, F^{23}, F^{25}, F^{27}, F^{29} and F^{31}, through apertures C^{11} to C^{16}, respectively. Similarly liquid from the supply pipe 37 may enter conduits 32 and 33, when valves 44 and 45 are adjusted to permit such entry, and pass downwardly into the cells defined by the groups of frames F^1, F^3, F^5, F^7, F^9, and F^{11}, F^{13}, F^{15}, F^{17}, and F^{19}, respectively. It will thus be seen that by the system of conduits and connecting apertures just described liquid issuing from a single source of supply and passing through conduit 36 is divided into three separate currents which pass, respectively, through the three laterally spaced delivery conduits 32, 33 and 34 into the upper ends of the cells of three different groups of cells, the groups being approximately equal, containing five each with the exception of the right-hand group which contains six.

For supplying the cells of the three groups of alternate cells F^2, F^4, F^6, F^8, F^{10}; F^{12}, F^{14}, F^{16}, F^{18}, F^{20} and F^{22}, F^{24}, F^{26}, F^{28}, F^{30}, with regulated currents of liquid a similar series of liquid delivery conduits are formed by registering apertures provided in the lower cross members of the several dialyzer frames. Here the main supply conduit 50, which is connected to a supply pipe 51, conducts liquid to the chamber 52 of block 53, from which chamber the liquid may enter each of the three fluid delivery conduits 54, 55 and 56 each of which supplies a different group of alternate cells. The ports leading to the first group of alternate cells are indicated by the reference symbols D^1, D^2, D^3, D^4, and D^5. By regulating the valves 58 and 59 the effective areas of the entrance ports of the conduits 55 and 56 may be varied as desired and, by so doing the relative rates of flow into the three conduits 54, 55 and 56 may be varied. Where the groups are substantially equal in numbers of cells, as is the case in this instance, it will of course be desirable to

divide the incoming current of solution to be dialyzed into three streams delivering equal volumes of liquid per unit of time. Despite the fact that the conduits 54, 55 and 56 are unequal in length this objective may be readily realized by manipulating the valves until the port areas of these conduits bear the proper relationship to each other.

The dialyzer thus includes means for insuring that each alternate and intermediate cell may be supplied with its full liquid requirement for perfect functioning of the machine even though either or both such liquids may be viscous to an extreme degree. Ordinarily the recovery liquid will be water and regulation of its flow into the intermediate cells by means of valves 44 and 45 will be unnecessary. It will be appreciated that the cells may be divided into any number of groups and that the number of cells in the various groups may be unequal in number if desired. Other types of flow regulating devices may be employed in lieu of the valves shown, these being set forth by way of example only.

The stem of each valve shown is elongated and includes a threaded portion and a squared portion to be engaged by a turning tool. In the case of valve 44 (and all are alike) the threaded portion is indicated at 44^a and a squared end at 44^b. The threaded part has threaded engagement with a threaded bore formed in the block 40 so that, when the valve stem is rotated the valve, which is of the conical type, is axially advanced or retracted with respect to its seat. The valve stem is suitably packed to prevent fluid leakage. Preferably the valve seat is formed on the end of a stainless steel tube 60 extending through an aperture formed in the head 15, all parts exposed to the liquids passing through the machine being preferably fabricated of incorrodible material. While the end of tube 60 has been described as a valve seat it will of course be understood that the valve will rarely, if ever, be fully seated. In the enlarged Figure 7 the rubber facings of the frames F^1 and F^2 are indicated at F^{1a} and F^{2a}, respectively, but these facings are omitted from the frames in Figures 2, 3 and 4, for the sake of clarity.

Having thus described the invention, what is claimed as new and desired to be secured by Letters Patent is:

1. In a dialyzer, in combination, means defining a plurality of groups of liquid cells, each two adjacent cells of each group having a common membranous dividing wall, and means for passing liquid to be dialyzed through alternate cells, and recovery liquid through intermediate cells, of each group, said last mentioned means including a liquid supply conduit, a liquid delivery conduit for each group of cells, each such conduit being adapted to deliver liquid from said supply conduit to the cells of one cell group, and a single conduit to receive and conduct away the liquid escaping from all of the cells.

2. In a dialyzer, in combination, means defining a plurality of groups of liquid cells, each two adjacent cells of each group having a common membranous dividing wall, and means for passing liquid to be dialyzed through alternate cells, and recovery liquid through intermediate cells, of each group, said last mentioned means including a liquid supply conduit, a liquid delivery conduit for each group of cells, each such conduit being adapted to deliver liquid from said supply conduit to the cells of one cell group, and means to insure delivery of liquid to the cell groups in such relative volumes that the rate of flow of liquid through all cells of the dialyzer will be substantially the same.

3. In a dialyzer, in combination, means defining a plurality of groups of liquid cells, each two adjacent cells of each group having a common membranous dividing wall, and means for passing liquid to be dialyzed through alternate cells, and recovery liquid through intermediate cells, of each group, said last mentioned means including a liquid supply conduit, a liquid delivery conduit for each group of cells, each such conduit being adapted to deliver liquid from said supply conduit to the cells of one cell group, and valve means for regulating the relative rates of flow of liquid through said delivery conduits, respectively, to the cell groups.

4. In a dialyzer, in combination, means defining a plurality of groups of liquid cells, each two adjacent cells of each group having a common membranous dividing wall, and means for passing liquid to be dialyzed through alternate cells, and recovery liquid through intermediate cells, of each group, said last mentioned means including a liquid supply conduit, a liquid delivery conduit for each group of cells, each such conduit being adapted to deliver liquid from said supply conduit to the cells of one cell group, said delivery conduits being parallel and a control valve for positively regulating the flow of liquid through each of a plurality of said delivery conduits.

5. In a dialyzer, in combination, means defining a series of cells for the reception of liquids, said series being divided into a plurality of groups of cells, liquid supply and offtake means associated with each cell group for passing liquid through alternate cells in a common direction, and through intermediate cells, each such means including a liquid delivery conduit communicating with alternate cells, and a common liquid supply source in communication with the inlet ends of the delivery conduits of the several cell groups.

6. In a dialyzer, in combination, means defining a series of cells for the reception of liquids, said series being divided into a plurality of groups of cells, liquid supply and offtake means associated with each cell group for passing liquid through alternate cells in a common direction, and through intermediate cells, each such means including a liquid delivery conduit communicating with alternate cells, a common liquid supply source in communication with the inlet ends of the delivery conduits of the several cell groups, and means for regulating the relative rates of flow of liquid through the several supply conduits.

7. In a dialyzer, in combination, means defining a series of cells for the reception of liquids, said series being divided into a plurality of groups of cells, liquid supply and offtake means associated with each cell group for passing liquid through alternate cells in a common direction, and through intermediate cells, each such means including a liquid delivery conduit communicating with alternate cells, a common liquid supply source in communication with the inlet ends of the delivery conduits of the several cell groups and means for regulating the flow of liquid into the supply conduit of each cell group.

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