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ELONGATED CAPILLARY DIALYZER

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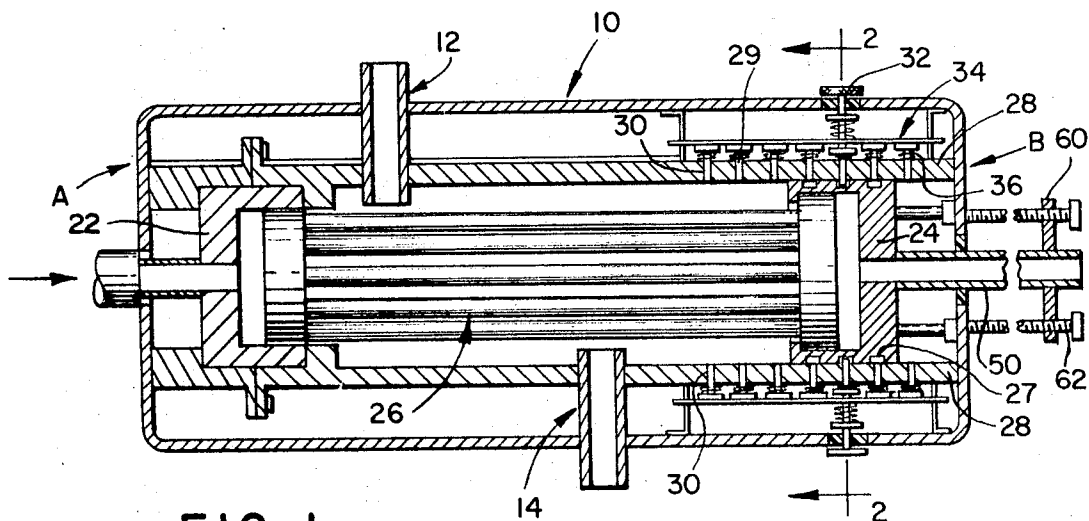


FIG. 1

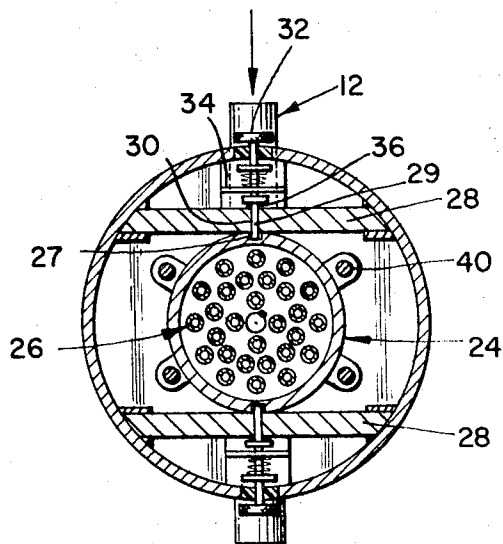


FIG. 2

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ELONGATED CAPILLARY DIALYZER

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6 Claims

ABSTRACT OF THE DISCLOSURE

An improved mass transfer device of the type wherein dialysis of a gas and/or a liquid is achieved by way of diffusion through a plurality of individual permeable capillaries. In one aspect of the invention, improved mass transfer is obtained by employing means to maintain the capillaries in a fixed elongated state during the dialysis operation. In another aspect, improved mass transfer is obtained by employing means to selectively adjust the elongation of the capillaries during the operation.

BACKGROUND OF THE INVENTION

(1) The field of the invention

This invention relates to mass transfer devices. More precisely, the invention disclosed herein relates to improved mass transfer devices of the type wherein a plurality of individual capillaries are employed for the dialysis of multicomponent fluids.

(2) Description of the prior art

Mass transfer devices useful for dialysis of fluids are known to the art. For example, such devices are employed for the dialysis of blood and like body fluids as well as for the dialysis of diverse other solutions such as saline solutions and the like. As those skilled in the art know, many of these devices employ a plurality of individual permeable capillaries as the dialysis element. For example, such a device is described in U.S. Pat. No. 2,972,349 which relates to a device for oxygenating blood in an extracorporeal circulatory system. Additional details relating to capillary oxygenators can be found in "A Capillary Membrane Oxygenator," Bodel, Bruce R., et al., Journal of Thoracic and Cardiovascular Surgery, vol. 46, No. 5 (November 1963), pp. 639-650. Still other details relating to devices of the type to which the present invention pertains can be found in U.S. Pats. 3,228,876, 3,228,877 and 3,373,876. All of the aforesaid disclosures are incorporated herein by reference.

In devices of the type described above, the mass transfer rate of the liquid gas and/or liquid-liquid exchange is primarily limited by the internal diameter of the individual capillary as well as the thickness of the capillary wall. Other factors which can also affect the rate somewhat include the nature of the fluid involved and the characteristics and velocity of the fluid flow through the capillaries. However, none of such devices presently known permit close adjustment and/or control over the mass transfer rate much less means to adjust or control the rate to a predetermined degree to compensate for variables that may occur during operation. It is to this particular problem that the present invention is addressed to provide a novel mass transfer device wherein the range of operating mass transfer rates is greatly increased and wherein the mass transfer rate can be selectively and precisely controlled and/or adjusted to a predetermined degree during operation.

SUMMARY OF THE INVENTION

In accordance with the practice of the present invention there is presented a novel, improved mass transfer

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device of the type wherein a plurality of capillaries function as the mass transfer element. The improved device of the present invention permits operation over an expanded range of mass transfer rates as well as control and/or adjustment over the rate during operation of the device. In the simplest aspect of the invention the device can be operated over an expanded range of mass transfer rates by operationally arranging the plurality of individual capillaries in combination with means to maintain the capillaries in a fixed elongated state during the mass transfer operation. In another aspect of the invention which constitutes a preferred embodiment thereof, the plurality of individual capillaries are operationally arranged in combination with means which can maintain the capillaries in an elongated state as well as selectively adjust or change the elongation of said capillaries during the dialysis operation. The means to adjust or change the elongation can be such as to permit a random increase and/or decrease in the elongation at any selected time during operation or to permit a controlled increase or decrease in elongation continuously during operation to provide a rhythmic pulsating action for example.

DESCRIPTION OF PREFERRED EMBODIMENT

The invention as well as manners of practicing same will be better understood by reference to the accompanying drawings together with the following description wherein FIG. 1 is a broken out view in elevation of the overall structure of the most basic embodiment of the present invention. FIG. 2 is a cross-sectional view along lines 2-2 of FIG. 1.

Referring now to FIG. 1, there is shown one embodiment of a device of the present invention. The device illustrated is designated in its entirety at 10. The device 10 includes outlet and inlet ports designated as 12 and 14 respectively. These outlets provide illustrative means for introducing an untreated fluid to the internal portions of device 10 and for discharging the treated fluid. Other means normally associated with such outlet or inlet ports such as pumps or the like are now shown. Such means for maintaining the flow of fluid through the device are known and can be integrated with the illustrated embodiment in manners well known to the art. Also, it should be understood that the number of inlet and/or outlet ports and the positioning and/or arrangement thereof can be varied.

Positioned within device 10 are a plurality of capillary tubes 26. Capillary tubes 26 are fabricated of a resilient or elastomeric natural or synthetic polymeric material. Exemplary materials useful in the fabrication of capillaries 26 include among others, natural rubber, silicone rubber, polyvinyl chloride, resilient polymers of the α -mono-olefins, vinylidene chloride, tetrafluoroethylene, trifluorochlorine ethylene or the like. The preferred polymeric materials are those which are non-toxic, sterilizable and exhibit high tensile at high elongation.

Capillaries normally employed in devices of the present invention have original ID's of between about 1 to about 50 mils and original wall thicknesses between about 0.01 to about 3-4 mils. The number of capillaries employed will vary depending upon the particular application in which the device is employed. In some instances as few as a hundred or less capillaries can be involved in the bundle whereas oftentimes several thousand can be employed.

As illustrated in FIGS. 1 and 2 both ends of each capillary are securely attached to holes provided in the back wall members of inlet and outlet chambers 22 and 24 respectively. Chambers 22 and 24 are illustrated as unitary structures and can be cast in this fashion but they can also be assembled from individual components. The

individual capillaries 26 can be securely attached to the holes by adhesives or heat depending upon the particular polymeric materials involved in the fabrication of the chambers or back walls thereof and of the capillaries.

As those skilled in the art will appreciate, the overall length of the assembled bundle of capillaries, e.g. the assembly of the capillaries 26 and the chambers 22 and 24, will not exceed the lengthwise dimensions of the capillaries and the chambers. The assemblies of the capillaries 26 and chambers 22 and 24 will hereinafter be referred to as a "bundle."

In accordance with the practice of the present invention illustrated in FIGS. 1 and 2, the bundle is elongated or stretched to a predetermined extent and maintained in an elongated state during operation. The extent of elongation applied to the bundle will vary depending primarily upon the degree of adjustment desired in the mass transfer rate but in most instances the minimum elongation will be sufficient to stretch the capillaries to a length at least about 10 percent greater than the original length.

Various means can be employed to suitably stretch the bundle and maintain the bundle in an elongated state during operation. A simplified version of such means is illustrated in FIGS. 1 and 2. The illustrated fixed elongation means consists of two substantially flat plates 28 positioned at opposite surfaces of the bundle. Each plate has a plurality of holes 30 spaced apart along at least a portion of the length thereof which can be aligned with holes 27 on opposite walls of chamber 24. Keys or bolts 29 provide means for securing plates 28 to chambers 22 and 24 to maintain the bundle in an elongated state.

In the embodiment shown in FIGS. 1 and 2, inlet chamber 22 is shown restrained in a fixed position adjacent wall A of device 10. Suitable means are operationally connected to chamber 22 to introduce thereto a fluid to be treated such as blood or the like. Chamber 22 is maintained in alignment with chamber 24 by a plurality of alignment bars 40. Means are provided so that chamber 24 can slidably communicate with alignment bars 40 so that chamber 24 can be urged away from chamber 22 and each of the capillaries 26 in the bundle can be elongated to substantially the same extent.

The manner by which chamber 24 can be urged away from chamber 22 to stretch or elongate capillaries 26 can vary. Also, the specific means employed to urge chamber 24 away from chamber 22 and to maintain the capillaries in a fixed elongated position can vary. For example, prior to the assembly of the bundle, e.g. chambers 22 and 24 and capillaries 26, in device 10, the bundle can be stretched or elongated to a predetermined extent and maintained in the elongated state by locking bars or the like.

In the device illustrated in FIGS. 1 and 2, chamber 22 is urged away from chamber 24 by first disengaging control pins 32. Disengagement of control pins 32 releases pressure bar 34 which in turn disengages pins 29 from their respective holes 27. Outlet tube 50 which can slidably pass through wall B is then pulled toward wall B thereby stretching or elongating capillaries 26. When the capillaries are stretched or elongated to the desired or predetermined extent, control pins 32 are engaged to lock chamber 24 to maintain the capillaries 26 in a fixed elongated position.

In one embodiment of the invention, adjustment means are associated with the means to urge chamber 24 away from chamber 22. In FIG. 1 for example, the illustrated adjustment means include an adjustment collar 60 fixed on outlet tube 50 in combination with threaded adjustment members 62. The adjustment means can be employed at any time during the operation of the device by disengaging control pins 32. Also, the adjustment means can function as the sole means for maintaining the bundle in the fixed elongated position. In this fashion, adjustment of the elongation can be conveniently made without engaging control pins 32. Additionally, the adjustment means can be automatic rather than the manual means illustrated. For

example, the adjustment means can be integrated with devices which can monitor flow rates or the like to provide signals which can actuate the adjustment means to compensate for detected variations in operating conditions.

The means illustrated in FIGS. 1 and 2 for maintaining the capillaries 26 in a fixed elongated position and to adjust the elongation are admittedly presented in a simplified fashion. However, the simplified fashion is employed in order that the essence of the invention presented can be properly emphasized and superfluous matter eliminated or minimized. The essence of the present invention resides in the appreciation and discovery that the operational range for the mass transfer rate of existing tubular capillaries can be increased as well as selectively and precisely controlled by elongating or stretching the capillaries to a predetermined degree and maintaining the capillaries in the elongated position and/or adjusting the elongation. Diverse specific means can be employed for maintaining the elongation or adjusting the elongation during operation to obtain the advantages in the practice of the present invention. These variations will arise primarily by reason of differences in design features of the various dialysis devices and differences in the desired manner of integrating specific means for maintaining the capillaries in a fixed elongation position or adjusting the elongation during operation. Accordingly, various modifications of the specific means offered for the purpose of illustrating the invention can be employed without departing from the spirit and scope of the invention defined in the appended claims.

Included among such modifications are those mentioned hereinbefore as well as the use of rods, pistons or the like actuated or controlled by gears or motors as means for adjusting the elongation during operation. The manners by which the elements of such equivalent means can be integrated with other elements of the device to accomplish the function can be performed by those skilled in the art. Also, it is to be understood that the extent of elongation applied to the bundle during operation can vary. For example, the adjustment means employed can be such as to provide a rhythmic adjustment of elongation so as to provide a pulsating action of the bundle during operation.

Many advantages will be obtained in practicing the aspect of the present invention illustrated in FIGS. 1 and 2. Chief among these is that the illustrated embodiment presents means for selectively adjusting and/or predetermining the mass transfer rate for devices of the type involved. Such adjustment is not possible in devices of the prior art wherein mass transfer rates are primarily fixed by the ID and wall thickness of the capillaries. Also since the adjustment and control of mass transfer rate is obtained by stretching the normally very expensive capillaries, the overall advantages of the invention can be obtained in an economical fashion.

Having described the invention together with preferred embodiments thereof as well as manners of practicing same what is declared as new and desired to be secured by U.S. Letters Patent is as follows:

1. In a dialysis device wherein dialysis is achieved by way of diffusion of a fluid through a plurality of individual permeable capillaries and said device includes means to conduct a fluid through a chamber wherein said capillaries are arranged and means to conduct a fluid through said capillaries, the improvement wherein said device includes means to maintain said capillaries in an elongated state during operation and said capillaries are in an elongated state compared to their original length.

2. The device of claim 1 further including means to adjust the elongation of said capillaries during operation.

3. The device of claim 1 in which the capillaries are elongated to a length at least 10% greater than their original length.

4. A dialysis device wherein dialysis is achieved by way of diffusion of a fluid through a plurality of individual

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permeable capillaries and said device includes means to conduct a fluid through a chamber wherein said capillaries are arranged and means to conduct a fluid through said capillaries, the said capillaries being fixed to holes in the wall members of inlet and outlet chambers, at least one of such chambers having members with holes which can be aligned with spaced apart holes in stationary members parallel with such members, and means for insertion into such aligned holes to maintain said members and stationary members in fixed position to maintain said capillaries in elongated state, the said inlet and outlet chambers being maintained in alignment by alignment bars and at least one of said chambers being in slidable communication by suitable means with such alignment bars so that it can be moved away from the other chamber and elongate each of said capillaries to substantially the same extent.

5. The device of claim 4 in which a control pin is provided for engagement of a pressure bar which is in posi-

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tion and adapted to press the said means for insertion into aligned holes to so engage said means.

6. A method of dialysis involving diffusion of a fluid through a plurality of individual permeable capillaries which are arranged in a chamber through which another fluid is conducted, and in which the capillaries are adjustably elongated beyond their original length to obtain desired mass transfer rates.

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FRANK A. SPEAR, JR., Primary Examiner

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