

(10) Internationale Veröffentlichungsnummer
WO 2022/238373 A1

(81) Bestimmungsstaaten (soweit nicht anders angegeben, für jede verfügbare nationale Schutzrechtsart): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK,

(54) Bezeichnung: HOHLFASERMEMBRANFILTER MIT VERBESSERTEN TRENNEIGENSCHAFTEN

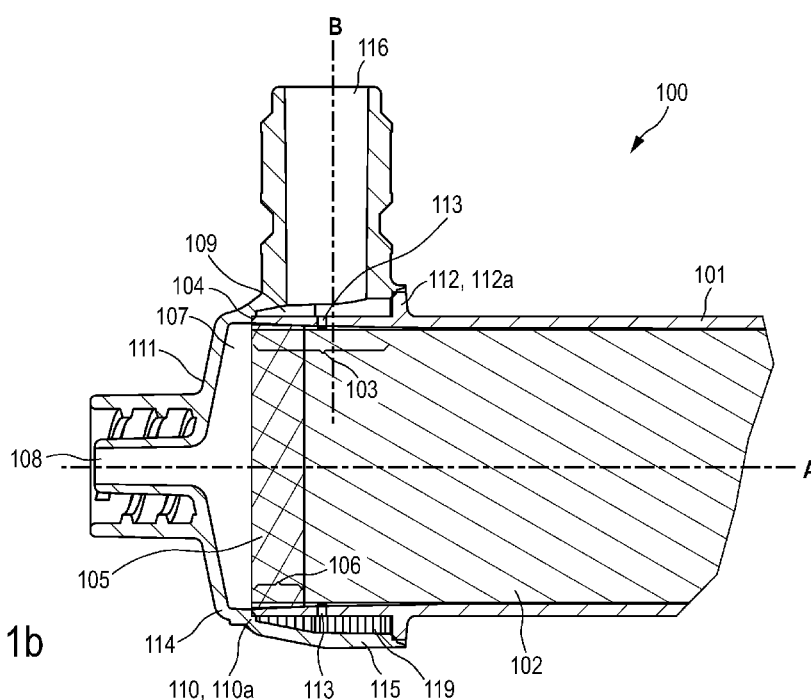


FIG. 1b

(57) Zusammenfassung: Die Erfindung betrifft einen Hohlfasermembranfilter zur Aufreinigung von Flüssigkeiten mit verbesserten Trenneigenschaften, umfassend ein zylindrisches Gehäuse, erste Ein- oder Auströmkammern und zweite Ein- oder Auströmkammern.



DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

- (84) Bestimmungsstaaten** (soweit nicht anders angegeben, für jede verfügbare regionale Schutzrechtsart): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), eurasisches (AM, AZ, BY, KG, KZ, RU, TJ, TM), europäisches (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Veröffentlicht:

- mit internationalem Recherchenbericht (Artikel 21 Absatz 3)
- vor Ablauf der für Änderungen der Ansprüche geltenden Frist; Veröffentlichung wird wiederholt, falls Änderungen eingehen (Regel 48 Absatz 2 Buchstabe h)

die jeweils einen ersten und einen zweiten Endbereich des zylindrischen Gehäuses umgeben, wobei der Hohlfasermembranfilter ein Aspektverhältnis aus effektiver Wirklänge der Hohlfasermembranen und Innendurchmesser des zylindrischen Gehäuses aufweist, so, dass eine verbesserte Anströmung der Hohlfasermembranen im Inneren des zylindrischen Gehäuses mit einer Flüssigkeit erfolgen kann.

HOLLOW-FIBRE MEMBRANE FILTER HAVING IMPROVED SEPARATION PROPERTIES

[0001] The present invention relates to a hollow fiber membrane filter for purifying liquids,
5 particularly for purifying blood.

BACKGROUND

[0002] Hollow fiber membrane filters are used in the purification of liquids. In particular,
hollow fiber membrane filters are used in medical technology for the treatment and
10 decontamination of water and in the treatment of patients with kidney damage through
extracorporeal blood therapy in the form of dialyzers or hemofilters. The hollow fiber
membrane filters generally consist of a cylindrical housing and a plurality of hollow fiber
membranes arranged therein, which are potted at the end of the housing with a potting
compound in a potting zone and are connected to the housing in a sealing manner. It is
15 known that such hollow fiber membrane filters are designed for use in a so-called dead-
end process or in a cross-flow process with two liquids, so that a mass transfer can take
place via the membrane wall of the hollow fiber membranes and a desired purification of
the liquid or of one of the liquids takes place. For this purpose, the hollow fiber membrane
filters are designed in such a way that the lumina of the hollow fiber membranes form a
20 first flow space through which a first liquid flows, and the spaces between the hollow fiber
membranes in the housing of the hollow fiber membrane filter form a second flow space
through which a second liquid can flow. Inflow or outflow spaces having liquid access
points for conducting the first and second liquid into and out of the respective flow spaces
of the hollow fiber membrane filter are disposed in one or both end regions of the hollow
25 fiber membrane filters.

[0003] A multitude of hollow fiber membrane filters exist on the market which have different
designs particularly in terms of the construction of the end regions and their inflow or
outflow spaces connecting to the end. With regard to the development of hollow fiber
30 membrane filters for extracorporeal blood treatment (dialyzers and hemofilters), ongoing
attempts are being made to change and improve the design of the hollow fiber membrane
filters. On the one hand, focus is placed on ensuring that the geometry of the inflow or
outflow spaces of a hollow fiber membrane filter through which blood flows enable it to flow
through the spaces as gently as possible, so that turbulent flows or stagnant flows that can

damage the blood cells can be avoided. As is generally customary in extracorporeal blood purification, the hollow fiber membrane filters are designed in such a way that the patient's blood is conducted through the first flow space — i.e., through the lumina of the hollow fiber membranes.

5

[0004] What is more, a multitude of design proposals exist among commercially available hollow fiber membrane filters for extracorporeal blood treatment that are intended to improve the flow against the hollow fiber membranes in the second flow space. During the therapeutic use of hollow fiber membrane filters for extracorporeal blood treatment, an aqueous, physiologically compatible liquid (dialysis liquid) usually flows through the second flow space. The removal of harmful metabolites from the patient's blood then takes place by means of transmembrane mass transfer. The flow against the hollow fiber membranes in the second flow space, among other things, is crucial for improved separation of the metabolites.

15

[0005] Kunikata et al. (Kunikata; ASAIO Journal, 55 (3), pp. 231-235 (2009), assess the performance data of various commercially available dialyzers with regard to their different designs in the inflow region for the dialysis fluid. In this publication, various design models are shown which are intended to bring about a favorable flow behavior of the dialysis fluid entering the dialyzer, thereby making improved performance characteristics of the hollow fiber membrane filters possible. However, such design proposals often require an elaborate housing design, so that these designs must be regarded as disadvantageous with regard to the high level of productivity that is aspired to on a large scale.

20

[0006] EP 3 238 758 A1 discloses hemodia filters that are characterized by a certain selection of design parameters, of the packing density of the hollow fiber membranes, of the total length of the hollow fiber membranes, of the effective membrane surface area, and of the area ratios of the inner surface of the hollow fiber membranes and the front area of the potting compound. According to EP 3 238 758 A1, the selection of these parameters avoids excessive pressure loss on the blood side and the dialysate side when using the hemofilter, the aim being to reduce the risk of damage to the hollow fiber membranes. EP 3 238 758 A1 addresses in particular the integrity of the hollow fiber membranes in the therapeutic application of hemodiafiltration. EP 3 238 758 A1 discloses the use of hollow fiber membranes with a diameter of 195 to 205 μm .

30

35

[0007] In terms of improved performance characteristics of hollow fiber membrane filters in hemodialysis, it is particularly preferred to use hollow fiber membranes with a diameter of 190 μm or less in combination with a wall thickness of 38 μm and less in order to be able to achieve the high performance characteristics that are desired for hemodialysis.

5 However, a need still also exists to improve the design of hollow fiber membrane filters in such a way that the flow against the hollow fiber membranes in the second flow space is further improved and the performance characteristics of the hollow fiber membrane filter can be further improved.

10 [0008] In view of the designs examined in Kunikata, there was therefore a need to work out an alternative design. In addition, there is also a continuous search for ways to produce hollow fiber membrane filters in a cost-saving manner.

OBJECT OF THE INVENTION

15 [0009] It was therefore the object of the invention to provide a hollow fiber membrane filter having improved flow against the hollow fiber membranes and, as a consequence, improved performance data.

SUMMARY OF THE INVENTION

20 [0010] This object is achieved by a hollow fiber membrane filter with the features of claim 1. Claims 2 to 14 relate to preferred embodiments.

DETAILED DESCRIPTION OF THE INVENTION

[0011] The invention relates to a hollow fiber membrane filter comprising a cylindrical housing that extends along a central axis in the longitudinal direction, with a housing interior, a first end region with a first end and a second end region with a second end, and a multitude of hollow fiber membranes having an inner diameter of 150 to 190 μm and a wall thickness of 25 to 38 μm , the hollow fiber membranes being arranged in the cylindrical housing and embedded sealingly therein in a respective potting compound in a respective potting zone in the first end region and in the second end region of the cylindrical housing, the ends of the hollow fiber membranes being open, so that the lumina of the hollow fiber membranes form a first flow space and the housing interior space surrounding the hollow fiber membranes forms a second flow space; first inflow or outflow spaces, each adjoining the first and the second end of the cylindrical housing on the front side and the potting zone, and each being in fluid communication with the first flow space of the hollow fiber membrane filter and having respective first liquid access points for conducting liquid into/out of the first inflow or outflow spaces; second inflow or outflow spaces surrounding the first and the second end regions of the cylindrical housing that are in fluid communication with the second flow region and each having second liquid access points for conducting liquid into/out of the second inflow or outflow spaces; a respective seal that separates the first inflow or outflow spaces from the second inflow or outflow spaces; and passage openings in the end regions of the cylindrical housing that form a fluid connection between the second inflow and/or outflow spaces and the second flow space, characterized in that the aspect ratio of the hollow fiber membrane filter is 8 to 12.

[0012] The hollow fiber membrane filter of the aforementioned type has high performance characteristics with regard to the purification of liquids. Furthermore, the hollow fiber membrane filter has improved flow against the hollow fiber membranes in the second flow space, since the inner diameter is smaller over the defined aspect ratio, while the membrane surface area remains the same. As a result, the liquid entering the second flow space is able to wash around the multitude of hollow fiber membranes more quickly and more effectively. In particular, improved separation performance of the test solutes urea and vitamin B12 is measured for the hollow fiber membrane filters according to the invention. One measure of the separation performance is the clearance, which is determined in accordance with the DIN/EN/ISO 8637:2014 standard.

[0013] In one embodiment, the hollow fiber membrane filter can be embodied as a dialyzer. In terms of the present application, the term “*dialyzer*” is use to represent blood filter devices that are based on the structure of a hollow fiber membrane filter, such as a dialysis filter or a hemofilter. In other applications, the hollow fiber membrane filter according to the invention can also be used as a filter for water treatment.

[0014] The term “*end region of the cylindrical housing*” is to be understood in the context of the present application as a section on the cylindrical housing that extends in the longitudinal direction from the end of the housing to the center of the cylindrical housing.

The term “*end region*” indicates that it is an area on the cylindrical housing that takes up only a small portion compared to the longitudinal extension of the cylindrical housing. In particular, one of these end regions takes up less than one fifth, or less than one eighth, or less than one tenth, or less than one fifteenth of the total length of the cylindrical housing.

[0015] The potting zone is located in a part of the end region of the cylindrical housing. In the context of the present application, the “*potting zone*” is the region in which the hollow fiber membranes of the hollow fiber membrane filter are embedded in a potting compound. The hollow fiber membranes are embedded in the potting compound in such a way that they are fixed to the end regions of the cylindrical housing. The potting compound forms a seal with the end region of the cylindrical housing. In particular, a provision is made that the potting zone takes up less than three quarters, or less than two thirds, or less than half the width of the end region. The potting compound is plate-shaped and arranged in the cylindrical housing perpendicular to the central axis of the cylindrical housing. The term “*central axis*” is to be understood as a middle longitudinal axis that runs in the center of the cylindrical housing of the hollow fiber membrane filter. In the context of the present application, the term “*central axis*” is used for the geometric description of the hollow fiber membrane filter.

[0016] First inflow or outflow spaces are located on the front side adjacent to the potting zones at the respective ends of the cylindrical housing. In the context of the present application, the term “*first inflow or outflow space*” is understood to mean a volume area in the hollow fiber membrane filter into which liquid can enter either before it enters the first flow space of the hollow fiber membrane filter or after it has exited the first flow space of the hollow fiber membrane filter. The first inflow and outflow spaces adjoin the potting zone in a sealing manner via a wall of the end caps, and/or they adjoin the end of the end region

of the cylindrical housing. In a common design, the first inflow or outflow spaces can be embodied as end caps. The end caps are located at the ends of the cylindrical housing and are connected to the cylindrical housing of the hollow fiber membrane filter in a liquid-tight and positive manner via a wall of the end caps. The first inflow or outflow spaces each have a first liquid access point for conducting liquid into/out of the first inflow or outflow spaces. The ends of the hollow fiber membranes in the potting compound are open. The first inflow or outflow spaces are therefore in fluid communication with the first flow space of the hollow fiber membrane filter, which is formed by the lumina of the hollow fiber membranes. In the context of the present application, "*lumina*" or "*lumen*" is understood to mean the cavity of the hollow fiber membranes.

[0017] According to the first aspect, the hollow fiber membrane filter also has second inflow or outflow spaces that surround the respective end regions of the cylindrical housing. In the context of the present application, the term "*second inflow or outflow spaces*" is understood to mean a delimited volume area in the hollow fiber membrane filter into which liquid can enter either before it enters the second flow space of the hollow fiber membrane filter or after it has exited the second flow space of the hollow fiber membrane filter. The second inflow or outflow spaces are each formed by casings that enclose the end regions of the cylindrical housing. A wall of the casings sealingly adjoins the potting zone and/or the end of the end region of the cylindrical housing. The casings can be part of the cylindrical housing and attached thereto, in which case the second inflow or outflow spaces are sealingly enclosed by the casing. Alternatively, the casing can also be formed by separate sleeves or as part of end caps that also enclose the first inflow or outflow spaces. The end caps are then designed such that they sit positively on the ends of the cylindrical housing, adjoin the housing in a liquid-tight manner, and, at the same time, also form the casing of the second inflow or outflow spaces. The second inflow or outflow spaces each have a second liquid access point for conducting liquid into/out of the second inflow or outflow spaces. The second inflow or outflow spaces are in fluid communication with the second flow space of the hollow fiber membrane filter, which second flow space is formed by the housing interior space of the hollow fiber membrane filter surrounding the hollow fiber membranes.

[0018] The first and second inflow or outflow spaces sealingly adjoin the potting zone and/or the end of the end region of the cylindrical housing. The first and second inflow or outflow spaces are therefore separated from one another in a liquid-tight manner at this

location. Some examples of suitable sealing means include O-rings, welding zones, or bonding zones that are arranged between the ends of the end region of the cylindrical housing or of the potting compounds and the wall of the first and second inflow or outflow spaces.

5

[0019] A fluid connection between the second inflow or outflow spaces and the second flow space is formed via the passage openings in the end region of the cylindrical housing. Liquid can thus enter the second flow space or be discharged from the second flow space. The number of passage openings in an end region of the cylindrical housing can be at least 5, or 10, or 15, or 20, or 30, or 40 or 60. The number of passage openings is at most 350, or 300, or 250, or 200, or 180, or 150. The number of passage openings in an end region of the cylindrical housing is preferably between 10 and 350, or between 10 and 40, or between 15 and 300, or between 20 and 250, or between 30 and 200 or between 40 and 180 or between 60 and 180.

15

[0020] In the context of the present application, the “*aspect ratio*” is understood to be the quotient of the actual effective length of the hollow fiber membranes and the inner diameter of the cylindrical housing of the hollow fiber membrane filter. In the context of the present application, the actual “*effective length*” of the hollow fiber membrane filter is understood to be the distance between the potting compounds in which an effective exchange of substances can take place via the hollow fiber membranes. The aspect ratio defined according to the present invention results in improved performance characteristics, particularly in the case of hollow fiber membrane filters with a large membrane surface area. In certain embodiments, the hollow fiber membrane filter according to the present invention has an aspect ratio of 8.5 to 11 or 8.5 to 10 or 9 to 10.

25

[0021] In an advantageous embodiment of the invention, the hollow fiber membrane filter is characterized in that the membrane surface area of the hollow fiber membrane filter is 1.2 to 2 m². In alternative embodiments, the membrane surface area of the hollow fiber membrane filter according to the invention is 1.3 to 1.9 m² or 1.3 to 1.8 m² or 1.4 to 1.7 m². The inner diameter of the cylindrical housing can be reduced to 25 to 35 mm or 25 to 33 mm or 28 to 33 mm within the aspect ratio defined according to the invention, so that an improved flow against the hollow fiber membranes in the second flow space can take place.

35

[0022] An additional advantage of reducing the diameter of the cylindrical housing through the aspect ratio defined according to the invention is that a smaller number of hollow fiber membranes are required in order to produce the same membrane surface area as a commercially available hollow fiber membrane filter with an aspect ratio of less than 8. This can also effectively reduce the amount of potting compound that is necessary in order to secure the hollow fiber membranes in the cylindrical housing. On the one hand, this offers cost advantages and, on the other hand, it also shortens the process step of casting the hollow fiber membrane in the cylindrical housing during the manufacture of the hollow fiber membrane filter.

[0023] In certain embodiments, the hollow fiber membrane filters according to the present invention have an aspect ratio of 8.0 to 10 with a membrane surface area of 1.6 to 2.0 m². In alternative embodiments, the hollow fiber membrane filters have an aspect ratio of 8.5 to 9.5 with a membrane surface area of 1.3 to 1.6 m².

[0024] Accordingly, the actual effective length of the hollow fiber membranes in these embodiments is 270 to 320 mm. In an advantageous embodiment of the invention, the hollow fiber membrane filter is characterized in that the actual effective length of the hollow fiber membranes is 280 to 320 mm, particularly 285 to 310 mm or 290 to 310 mm. In particular, the selection of the aspect ratio, membrane surface area, and actual effective length in the regions described above makes possible the effective removal of middle molecules in therapies for extracorporeal blood purification, such as hemodialysis or hemofiltration. In this context, proteins of the blood serum with a molecular weight of 10,000 daltons to 50,000 daltons are referred to as middle molecules. At the same time, however, an excessively high pressure drop is prevented from occurring on the lumen side over the length of the lumina of the hollow fiber membranes and leading to the problem of excessive hemolysis or membrane clogging.

[0025] In another embodiment of the invention, the hollow fiber membrane filter is characterized in that the ratio of the actual effective length of the hollow fiber membranes to the mean distance between the second liquid access points of the second inflow or outflow spaces is 1 to 1.1 or 1 to 1.05 or 1.0 to 1.03. The mean distance between the second liquid access points of the second inflow or outflow spaces is preferably 270 to 320 mm, or 245 to 290 mm, or 257 to 305 mm, or 262 to 310 mm. The “*mean distance between*

the second liquid access points” is understood to mean the distance between the central axes of the liquid access points.

[0026] In an advantageous embodiment of the invention, the hollow fiber membrane filter is characterized in that the packing density of the hollow fiber membranes is 50 to 70%, preferably 56 to 63%, more particularly between 57 and 63%. In the context of the present application, “*packing density*” is understood to mean the portion in the housing interior of the cylindrical housing that is occupied by the hollow fiber membranes. The packing density is calculated from the percentage ratio of the sum of the cross-sectional areas of the hollow fiber membranes to the cross-sectional area of the cylindrical housing of the hollow fiber membrane filter, the cross-sectional area of the cylindrical housing only being understood to be the cross-sectional area specified by the inner diameter. The packing density has an influence on the transmembrane pressure difference for a given fiber length. Advantageously, fiber length and packing density are coordinated in such a way that, in therapeutic applications of extracorporeal blood purification, effective backfiltration of a substitute can be ensured on the basis of an ultrafiltrate that was previously removed by convection.

[0027] In another embodiment of the invention, the hollow fiber membrane filter is characterized in that the hollow fiber membranes have a wave-like shape; in particular, the amplitude of the wave-like shape of the hollow fiber membranes is 0.1 to 0.5 mm and the wavelength of the wave-like shape of the hollow fiber membranes is 5 to 10 mm. The wave shape of the hollow fiber membranes stiffens the multitude of hollow fiber membranes that are arranged in the cylindrical housing. This is particularly advantageous when processing hollow fiber membrane bundles in the production of hollow fiber membrane filters according to the invention with a high actual effective length and an aspect ratio that is defined according to the invention. In certain embodiments, the amplitude of the wave shape of the hollow fiber membranes is 0.35 to 0.45 mm or 0.38 to 0.43 mm. In alternative embodiments, the wavelength of the wave shape of the hollow fiber membrane is 6 to 9 mm or 7 to 8 mm. In certain embodiments, the amplitude of the wave shape of the hollow fiber membrane is 0.35 to 0.45 mm, and the wave length of the wave shape of the hollow fiber membrane is 6 to 9 mm. In another embodiment, the amplitude of the wave form of the hollow fiber membrane is 0.38 to 0.43 mm, and the wave length of the wave form of the hollow fiber membrane is 7 to 8 mm.

[0028] In another advantageous embodiment of the invention, the hollow fiber membrane filter is characterized in that, in the end regions of the cylindrical housing, the ratio of the sum of the flow cross sections of all passage openings to the flow cross section of the at least one second inflow or outflow space lies in the range of 0.5:1 to 7:1, or 0.75:1 to 5:1, or 1:1 to 3:1.

[0029] According to the above definition of the flow cross sections, an improved flow of a liquid against the hollow fiber membrane occurs in at least one end region of the hollow fiber membrane filter as a result of a liquid flowing through a second connection into the second inflow or outflow space and through the passage openings in the end region of the cylindrical housing into the second flow space.

[0030] The “*sum of the flow cross sections of the passage openings*” is understood to mean the sum of the surface areas of all of the individual passage openings in an end region of the cylindrical housing.

[0031] In the context of the present application, the “*flow cross section of a second inflow or outflow space*” is understood to mean the cross-sectional area of the second inflow or outflow space that is created through formation of a cross section through the hollow fiber membrane filter and through the central axis of the cylindrical housing. The cross section is placed in such a way that the second liquid access points at the second inflow and outflow spaces are not touched. If two cross-sectional areas of the second inflow or outflow space are mapped in the aforementioned cross-sectional view, with the second inflow or outflow spaces having a rotationally symmetrical geometry, for example, only one of these cross-sectional areas is used to determine the flow cross section.

[0032] In an advantageous embodiment of the invention, the hollow fiber membrane filter is characterized in that, in the end regions of the cylindrical housing, the inflow or outflow spaces, starting from the second liquid access point to the central axis of the cylindrical housing, form a rotationally symmetrical circumferential space, particularly an annular gap. By virtue of the rotationally symmetrical geometry of the second inflow or outflow spaces, the components for the hollow fiber membrane filter can be manufactured in a process-optimized manner, particularly using injection molding techniques.

[0033] In another advantageous embodiment of the invention, the hollow fiber membrane filter is characterized in that the passage openings are circular, oval-, or slot-shaped. Depending on the different inner diameters of the cylindrical housing, which are provided for different applications, the number and shape of the passage openings in the end region of the cylindrical housing can vary. This also depends on the manufacturing possibilities of the cylindrical housing, which is preferably manufactured using injection molding technology. It is therefore advantageous to arrange a multitude of passage openings having a circular, oval-, or slot-shaped shape in the end region of the cylindrical housing.

[0034] In another advantageous embodiment of the invention, the hollow fiber membrane filter is characterized in that the passage openings are arranged on isolated and/or opposite sections or evenly around the circumference in the end region of the cylindrical housing.

[0035] In another embodiment, the hollow fiber membrane filter is characterized in that the at least one end region, and optionally the second end region, is divided into a proximal end region, a distal end region, and a transition region disposed between the proximal and distal end regions, wherein one end of the distal end region is the end of the cylindrical housing, and the distal end region has an inner diameter that is at least 2% larger than the inner diameter of the proximal end region. In terms of this embodiment, the proximal end region is proximal to the center of gravity of the cylindrical housing. Accordingly, the distal end region is arranged distal to this center of gravity of the cylindrical housing and is thus located at the ends of the cylindrical housing. Advantageously, the packing density of the hollow fiber membranes arranged in the cylindrical housing of the hollow fiber membrane filter is reduced in the distal end region due to the larger inner diameter of the cylindrical housing in this part of the end region. This offers the advantage that fewer defect points occur when the hollow fiber membranes is potted in the cylindrical housing during the manufacture of the hollow fiber membrane filter. Furthermore, the lower packing density in this distal end region makes the hollow fiber membranes more amenable to flow by dialysis fluid.

[0036] In the transition region of the end region, the inner diameter of the cylindrical housing increases by more than 2%. Preferably, the inner diameter of the cylindrical housing increases in the transition region by more than 3%, or more than 4%, or more than 5% and at most by 10%, or at most by 8%, or at most by 7%, or at most by 6%, in particular

by 2 to 10%, or 3 to 8%, or 4 to 7%. The transition region occupies at least 1/10, or at least 1/12, or at least 1/14, or at least 1/15, or at least 1/17, or at least 1/18, or at least 1/20 and at most 1/40, or at most 1/35, or at most 1/30 or at most 1/25, in particular 1/10 to 1/40, or 1/12 to 1/35, or 1/14 to 1/30, or 1/15 to 1/25, of the total length of the cylindrical housing in the direction of extension of the central axis of the cylindrical housing.

[0037] In a further embodiment of the aforementioned embodiment, the hollow fiber membrane filter is characterized in that the passage openings are arranged at the distal end region. The dialysis fluid entering the second flow chamber can thus be passed directly via the passage openings into that part of the hollow fiber membranes which have a lower packing density. This results in an advantageous circumferentially uniform flow to the hollow fiber membranes in the distal end region, which can also better penetrate the arrangement of hollow fiber membranes due to the lower packing density in this part of the end region before the flow of dialysis fluid enters the part of the hollow fiber membranes with a higher packing density.

[0038] In another advantageous embodiment of the invention, the hollow fiber membrane filter is characterized in that the sum of the flow cross sections of all passage openings is 10 to 350 mm², or 15 to 200 mm², or 15 to 150 mm², or 20 to 110 mm². The envisaged sum of the flow cross sections of all passage openings is dependent on the inner diameter of the cylindrical housing of the hollow fiber membrane filter and, consequently, on the number of hollow fiber membranes. Hollow fiber membrane filters with a larger membrane surface area and a higher number of hollow fiber membranes require a commensurately high flow volume in the second flow space of the hollow fiber membrane filter in order to achieve sufficient filtration performance. In one example, with an arrangement of approx. 10,000 hollow fiber membranes in the second flow space of the hollow fiber membrane filter, the sum of all flow cross sections of the passage openings is in the range of approx. 90 to 150 mm². The inner diameter of the cylindrical housing can be between 28 and 33 mm. The adaptation of the sum of all flow cross sections of the passage openings to the inner diameter of the cylindrical housing is used to regulate a defined inflow of liquid into the second flow space and thus to achieve improved flow against the hollow fiber membranes in the second flow space.

[0039] In another advantageous embodiment of the invention, the hollow fiber membrane filter is characterized in that the flow cross section of one of the second or two second

inflow or outflow spaces is 20 to 50 mm², 20 to 40 mm², or 25 mm². Here, too, the flow cross section of the inflow or outflow spaces can be adapted to the inner diameter of the cylindrical housing of the hollow fiber membrane filter and thus also take on different values for the number of hollow fiber membrane filters. In one example, with an arrangement of
5 approximately 10,000 hollow fiber membranes in the second flow space of the hollow fiber membrane filter, the flow cross section of the inflow or outflow spaces is 20 to 30 mm². The adaptation of the flow cross section of the inflow or outflow spaces to the inner diameter of the cylindrical housing results in an efficient distribution of the liquid flowing into the second inflow or outflow space, so that when the liquid enters the second flow
10 space, a uniform flow against the hollow fiber membranes can be achieved.

[0040] The inside diameter of a hollow fiber membrane filter according to the invention is 25 to 35 mm in one embodiment. In particular, 6000 to 12000 hollow fiber membranes can be arranged in the cylindrical housing of the hollow fiber membrane filter, so that the hollow
15 fiber membrane filter can have a membrane surface area of 1.2 to 2.0 m². The “*membrane surface area*” is calculated from the product of the inner surface area of the hollow fiber membrane and the number of hollow fiber membranes that are arranged in the cylindrical housing of the hollow fiber membrane filter. The inner surface area of the hollow fiber membrane is calculated from the product of the inner diameter of a hollow fiber membrane,
20 the circle constant π , and the actual effective length.

[0041] Hollow fiber membranes made of polysulfone and polyvinylpyrrolidone are preferably used to construct a hollow fiber membrane filter according to the invention.

25 [0042] The potting compounds with which the hollow fiber membranes are embedded and sealed in the respective end regions of the cylindrical housing are preferably made of polyurethane.

[0043] The cylindrical housing and end caps are preferably made of a polypropylene
30 material. A housing made of polypropylene is advantageously suitable for receiving long fiber bundles in a reliable manner during manufacturing.

[0044] In another advantageous embodiment of the invention, the hollow fiber membrane filter is characterized in that the first and the second inflow or outflow space in the first end
35 region of the cylindrical housing and the first and the second inflow or outflow space in the

second end region of the cylindrical housing are respectively enclosed by a first and a second end cap. The end caps are advantageously integrally formed. The end caps are designed in such a way that one wall of the end cap encloses the first inflow or outflow space and another wall forms a casing that encloses the second inflow or outflow space.

5 The end caps are geometrically shaped in such a way that they sit in a positive manner on the end regions of the cylindrical housing and are rendered liquid-tight by seals. The end caps are advantageously manufactured by injection molding. The production of a hollow fiber membrane filter using the end caps defined here contributes to the process-optimized production of the hollow fiber membrane filter. First and second liquid access points are
10 disposed on the end caps.

[0045] In another advantageous embodiment of the invention, the hollow fiber membrane filter is characterized in that the first end cap positively adjoins, particularly in a liquid-tight manner, an annular, outer circumferential projection on the first end region of the cylindrical
15 housing. In particular, the second end cap also positively adjoins an annular, outer circumferential projection on the second end region of the cylindrical housing, particularly in a liquid-tight manner. End caps and cylindrical housing are thus connected in a liquid-tight manner along the outer circumferential projection. A seal can be made by welding or gluing.

20 [0046] In another advantageous embodiment of the invention, the hollow fiber membrane filter is characterized in that the first end cap positively adjoins the first end of the cylindrical housing, particularly in a liquid-tight manner, along an inner circumferential circular line. In particular, the second end cap also positively adjoins the second end of the cylindrical
25 housing, particularly in a liquid-tight manner, along an inner circumferential circular line. The inner circumferential circular line can be embodied, for example, as a circular bead or projection on the inside of the end caps. Alternatively, however, the inside of the wall of the end caps can connect directly to the end of the cylindrical housing. The connection of the circular line of the end caps to the ends of the cylindrical housing creates a liquid seal
30 between the first inflow and outflow space and the second inflow and outflow space by means of welding, gluing, or O-rings.

[0047] In another advantageous embodiment of the invention, the hollow fiber membrane filter is characterized in that the capacity of one or both of the second inflow or outflow
35 spaces is between 1.5 and 5 cm³. By means of a delimited volume area of the second

inflow and/or outflow spaces, it can be ensured, in particular, that the liquid entering the second inflow or outflow spaces can be uniformly distributed as a function of the inner diameter of the cylindrical housing. This also prevents flows from stagnating in regions of the at least one second inflow or outflow space and flowing inhomogenously against the hollow fiber membranes in the second flow region.

[0048] In another advantageous embodiment of the invention, the hollow fiber membrane filter is characterized in that the cylindrical housing and the end caps are made of a thermoplastic material, particularly of polypropylene. The cylindrical housing and the end caps can thus be advantageously produced using a process-optimized injection molding process. Furthermore, the selection of the materials also results in the advantage that the cylindrical housing and the end caps can be connected to one another in a positive and sealing manner through a welding process.

DESCRIPTION OF THE INVENTION ON THE BASIS OF THE FIGURES

[0035] Fig. 1a shows a cross section of a hollow fiber membrane filter according to the invention through the central axis A of the cylindrical housing.

[0036] Fig. 1b shows another cross section of a hollow fiber membrane filter according to the invention, which runs through both the central axis A of the cylindrical housing and the central axis B of the second liquid access point.

[0037] Fig. 2 shows a side view of a cylindrical housing of a hollow fiber membrane filter according to the invention, the end region of the cylindrical housing being depicted.

[0038] Fig. 2b shows a side view of another embodiment of a cylindrical housing of a hollow fiber membrane filter according to the invention, wherein the end region of the cylindrical housing is shown. The illustration according to Fig. 2b is provided with dimensioning. The values of the dimensions refer to the unit millimeter (mm).

[0039] Fig. 3 shows a schematic representation of a cross section of a commercially available FX60 hollow fiber membrane filter from Fresenius Medical Care Deutschland GmbH, which runs through both the central axis A of the cylindrical housing and the central axis B of the second liquid access point.

[0040] Fig. 4 shows a side view of a cylindrical housing of a commercially available FX60 hollow fiber membrane filter from Fresenius Medical Care.

[0041] Fig. 5a shows a schematic illustration of a lateral cross-sectional illustration of a commercially available FX 60 hollow fiber membrane filter.

[0042] Fig. 5b shows a schematic representation of a hollow fiber membrane filter according to the invention;

[0043] Fig. 1a shows a cross section of a hollow fiber membrane filter **100** according to the invention along the central axis **A** of the cylindrical housing **101**. Only a portion of the hollow fiber membrane filter is shown in Fig. 1a, which illustrates a first end **104** on the cylindrical housing **101** with a first end region **103**. A portion of the end region **103** is occupied by a potting zone **106** in which a potting compound **105** is disposed on the front side relative to the longitudinal orientation, i.e., perpendicular to the central axis **A** of the cylindrical housing, which potting compound **105** is respectively embedded in hollow fiber membranes (not shown in Fig. 1a) in the housing interior space **102** in the first end region **103** and in the second end region (not shown) of the cylindrical housing **101** so as to form a seal with the housing **101**. Also shown is an end cap **111** with a wall **114** that encloses the first inflow or outflow space **107**, as well as a casing region **115** that encloses the second inflow or outflow space **109**. The surface of the flow cross section of the second inflow or outflow space **109** is indicated by parallel lines in Fig. 1a. A liquid access point **108** is also shown. In the illustration, the liquid access point **108** exhibits the typical details of a blood connection of a dialyzer. The liquid access point **108** forms a liquid access point to the first inflow or outflow space **107**. The end cap **111** shown in Fig. 1 is integrally formed, so that the wall **114** and the casing **115** are part of the end cap. According to the arrangement shown in Fig. 1a, the space of the first and second inflow or outflow spaces (**107**, **109**) is enclosed by the end cap **111**, the cylindrical housing **101**, and the potting compound **105**. The first inflow or outflow space is sealed off at the end **104** of the cylindrical housing **101** by means of a circumferential seal **110**. An inner circular circumference **110a** of the end cap **111**, which is only shown in cross section in Fig. 1, is used for this purpose. In the embodiment shown in Fig. 1, the inner circumference **110a** of the end cap **111** sits in a positive manner on the end **104** of the cylindrical housing **101**, so that the seal **110** is created between the end **104** of the cylindrical housing and the end cap **111**. Liquid that flows into the first inflow or outflow space **107** through the liquid access point **108** flows into the lumina of the hollow fiber membranes and thus into the first flow space exclusively via the open ends of the hollow fiber membranes in the potting compound **105** (not shown in Fig. 1a). Another circumferential liquid seal **112** is created by the annular outer circumferential projection **112a** on the cylindrical housing **101** that adjoins the casing **115** of the end cap **111** in a positive and liquid-tight manner.

[0044] Fig. 1b shows another cross section of a hollow fiber membrane filter **100** according to the invention, which runs through both the central axis **A** of the cylindrical housing and the central axis **B** of the second liquid access point. The central axis **B** runs centrally in the second liquid access point **116**, which adjoins the second inflow or outflow space **109**.

5 The designations **100** to **111** and **114** and **115** in Fig. 1b are identical to the designations from Fig. 1a. Also, as shown in Fig. 1a, the flow cross section of the second inflow or outflow space **109** is indicated in Fig. 1b with parallel lines. In addition, in this cross-sectional illustration, the passage openings **113** can be seen on opposite sides of the end region **103** of the cylindrical hollow fiber membrane filter. This figure shows that the second
10 liquid access point **116** is in fluid communication with the second inflow or outflow space **109**, and that there is still a fluid connection to the second flow space in the housing interior **102** of the hollow fiber membrane filter **100** via the passage openings **113**. In an embodiment shown in Fig. 1b, a multitude of passage openings, of which only two are visible in the cross-sectional view of Fig. 1b, are arranged opposite one another on the
15 end region **103** of the cylindrical hollow fiber membrane filter.

[0045] Fig. 2a shows a schematic representation of a portion of a cylindrical housing **101** of a hollow fiber membrane filter according to the invention in a side view. In the illustration of Fig. 2a, the portion with the first end **104** of the cylindrical housing **101** is shown. Fig. 2a
20 also shows the annular, outer circumferential projection **112a** on the cylindrical housing **101**, which is provided for the purpose of producing a seal **112** on a casing **115** of an end cap **111**. Reference **103** denotes the end region of the cylindrical housing **101**. Reference **106** denotes the potting zone in the end region, a potting compound **105** *per se* not being shown in Fig. 2a. The central axis **A** indicates the longitudinal orientation of the cylindrical
25 housing; however, in the side view that is shown, it lies below the plane of the drawing of the depicted surface of the cylindrical housing. In the side view, a plurality of passage openings **113** is shown, which form in the hollow fiber membrane filter the connection between the second inflow or outflow space **109** and the second flow space (neither shown in Fig. 2a). In the illustration shown, the passage openings are depicted as circular, but
30 they can also have the shape of an oval, slot, or U. The flow cross sections of the passage openings **113** result from the sum of the flow cross sections of all of the individual passage openings **113**. The embodiment shown in accordance with Fig. 2a has twenty-two passage openings **113** in the end region **103** of the cylindrical housing **101**, of which only half — i.e., 11 — are visible in Fig. 2. An additional eleven passage openings are located on the
35 opposite side of the end region **103** of the cylindrical housing **101**.

[0046] Fig. 2b shows in schematic view an embodiment of a part of a cylindrical housing **101** of a hollow fiber membrane filter according to the invention in a lateral view. In the illustration of Fig. 2b, the part with the first end **104** of the cylindrical housing **101** is shown. Further shown in Fig. 2b is the annular outer circumferential projection **112a** on the cylindrical housing **101**, which is provided for making a seal **112** on a casing **115** of an end cap **111** (not shown in Fig. 2b). Further shown in Fig. 2b are **103** - the end region of the cylindrical housing **101**, the central axis A, **113** - circular through openings.

[0047] In the embodiment shown, the distance from the center of the passage openings **113** to the end **104** of the cylindrical housing **101** is 10 mm. At the end **104** of the cylindrical housing, the diameter of the opening of the cylindrical housing is 34 mm. In the embodiment shown, the end region **103** of the cylindrical housing is divided into a proximal end region **103a** and a distal end region **103b**. In the embodiment shown, the proximal end region **103a** is disposed adjacent to the annular outer circumferential projection **112a** and is thus proximal to a center of gravity of the cylindrical housing in terms of the embodiment shown in Fig. 2b. In the embodiment shown in Fig. 2b, the inner diameter of the distal end region **103b** of the cylindrical housing is larger than that of the proximal end region **103a**. The proximal end region and the distal end region adjoin each other through a transition region **103c**. In the transition region **103c** of the end region **103**, the inner diameter of the cylindrical housing increases by more than 3%. In particular, according to the embodiment shown in Fig. 2b, the diameter of the distal end region **103b** at the end of the cylindrical housing is 34 mm, whereas the inner diameter of the distal end region **103b** subsequently at the transition portion **103c** is 33.5 mm. The inner diameter of the cylindrical housing **101** at the proximal end region is 31.9 mm in the shown embodiment of Fig. 2b. Accordingly, the increase in inner diameter from the proximal **103a** to the distal **103b** end region is 1.6 mm in the embodiment shown. The inner diameter of the cylindrical housing **101** is 31.4 mm in a central region. From the dimensions shown in Fig. 2b, it can be seen that the inner diameter in each of the distal **103b** end region and the proximal end region **103a** is further tapered toward the central portion of the cylindrical housing. The conical shape of the inner diameter of the individual regions of the cylindrical housing **101**, illustrated according to Fig. 2b, results from the need to be able to demold the cylindrical housing as an injection molded part from an injection molding machine. Such required geometries of injection molded parts are known in injection molding technology. The change in internal diameter at the transition region **103c** must be distinguished from these necessary conically extending changes in internal diameter. The transition region **103c** occupies an area of less than 2 mm in the direction of extension of the center axis A in the

shown embodiment of Fig. 2b, in which the inner diameter of the proximal end region increases from 31.9 mm to the inner diameter of the distal end region of 33.5 mm. The transition area occupies about only 1/15 of the total length of the cylindrical housing.

[0048] In one embodiment of a hollow fiber membrane filter according to the invention, which is worked according to the details shown in Figs. 1a, 1b and 2, the sum of the flow cross sections of all passage openings can be 17 mm², for example. Furthermore, in this embodiment, the flow cross section of the second inflow or outflow space can then be approximately 26 mm². The ratio of the sum of the flow cross sections of all passage openings to the flow cross section of the at least one second inflow or outflow space is 0.65:1.

[0049] Fig. 3 shows a schematic representation of portion of a cross section of a commercially available FX hollow fiber membrane filter from Fresenius Medical Care, the cross section running through both the central axis **A** of the cylindrical housing and the central axis **B** of the second liquid access point. Analogously to the previous figures, Fig. 3 shows:

300 a hollow fiber membrane filter

301 a cylindrical case

302 a housing interior space of the cylindrical housing for receiving a plurality of hollow fiber membranes (not shown in Fig. 3)

303 an end region of the cylindrical housing

304 a first end of the cylindrical housing

305 a potting compound,

306 a potting zone,

307 a first inflow or outflow space,

308 a first liquid access point to the first inflow or outflow space,

309 a second inflow or outflow space,

310 a circumferential seal, embodied as an O-ring,

310a an inner circumference in the end cap,

311 an end cap,

312a an annular outer circumferential projection,

314 a wall of the end cap,

315 a casing of the end region of the cylindrical housing on the end cap,

316 a second liquid access point.

[0050] As can be seen from Fig. 3, the hollow fiber membrane filters shown in Figs. 1a, 1b, and 3 differ structurally in terms of the construction of the second inflow and outflow space. The passage openings that connect the second inflow or outflow spaces to the second flow region of the hollow fiber membrane filter (not shown) are not visible in Fig. 3.

5

[0051] Fig. 4 shows a schematic representation of a side view of a cylindrical housing **401** of a commercially available FX hollow fiber membrane filter from Fresenius Medical Care, which has a potting compound **405** in a potting zone **406**. Fig. 4 shows an annular, outer circumferential projection **412a**. The side view also shows the passage openings **413**, which are arranged circumferentially on the end region **403** of the housing **401**. The FX60 hollow fiber membrane filter illustrated according to Figs. 3 and 4 has a flow cross section of the second inflow or outflow space of 26 mm². In the same embodiment of the FX hollow fiber membrane filter, the sum of the flow cross sections of all passage openings is 392 mm². The ratio of the sum of the flow cross sections of all passage openings to the flow cross section of the at least one second inflow or outflow space is 15:1.

10

15

[0052] Fig. 5a shows a schematic illustration of a lateral cross-sectional illustration of a commercially available FX 60 hollow fiber membrane filter **300** from Fresenius Medical Care. Structural details of the hollow fiber membrane filter shown in Fig. 5a correspond to Fig. 3. Fig. 5a shows second liquid access points **316a** and **316b**, the potting compounds **305a** and **305b**, and a cylindrical housing **301**. The total length of a hollow fiber membrane filter shown in Fig. 5a is 292 mm. The mean distance between the second liquid access points is 248 mm. The actual effective length of the hollow fiber membranes is 228 mm. The inner diameter of the cylindrical housing is 34 mm. The aspect ratio of the depicted hollow fiber membrane filter is 6.71. The ratio of the actual effective length of the hollow fiber membranes to the mean distance between the second liquid access points **316a** and **316b** is 0.92.

20

25

[0053] Fig. 5b shows a schematic representation of a hollow fiber membrane filter **100** according to the invention. Structural details of the hollow fiber membrane filter shown in Fig. 5b correspond to Fig. 1. Fig. 5b shows second liquid access points **116a** and **116b**, the potting compounds **105a** and **105b**, and a cylindrical housing **101**. The total length of a hollow fiber membrane filter depicted according to Fig. 5b is 333 mm. The mean distance between the second liquid access points is 285 mm. The actual effective length is 280 mm. The inner diameter of the cylindrical housing is 31 mm. The aspect ratio of the depicted

30

35

hollow fiber membrane filter is 9.1. The ratio of the actual effective length of the hollow fiber membranes to the mean distance between the second liquid access points **116a** and **116b** is 1.018.

5

EXAMPLES

Determination of Clearance

[0054] The clearance is determined in accordance with the DIN/EN/ISO 8637:2014 standard, with a blood flow of 300 ml/min and a dialysate flow of 500 ml/min being set in the examples. Aqueous solutions of 16.7 mmol/l urea (Merck) and 36.7 µmol/l vitamin B12 (BCD Chemie, Biesterfeld) on the blood side and distilled water on the dialysate side are used as test solutions. The concentration of vitamin B12 is determined photometrically at 361 nm. The Cobas Integra 400 plus device with the UREAL test (Roche Diagnostics, Germany) is used to determine the urea.

Example 1: Hollow fiber membrane filter according to the invention

[0055] A hollow fiber membrane filter with the structural details according to Figs. 1a, 1b, and 5b and the parameters shown in Table 1 was produced. Corrugated polysulfone/polyvinylpyrrolidone hollow fiber membranes were used, which are particularly built into the FX60 filter from Fresenius Medical Care. The hollow fiber membrane filter was manufactured according to methods known in the prior art.

The hollow fiber membrane filter according to the invention was sterilized using a steam sterilization method that is known in the prior art and is described in application laid open DE 10 2016 224 627 A1. Clearance and sieve coefficients were examined on the sterile as well as on the non-sterile embodiment. The results are shown in Table 2.

Comparative Example 1: FX60 hollow fiber membrane filter

An FX60 hollow fiber membrane filter from Fresenius Medical Care was used as a comparative embodiment. The structural details of the FX 60 hollow fiber membrane filter are shown schematically in Fig. 3, Fig. 4, and 5a. The technical parameters of the FX60 filter are shown in Table 1.

The FX60 hollow fiber membrane filter was sterilized using the same steam sterilization process that was used for the hollow fiber membrane filter according to the invention. The

clearance determined using the hollow fiber membrane filter was examined on the sterile as well as on the non-sterile embodiment. The results are shown in Table 2.

5 Table 1

Parameter	Characteristic	Example 1	Comparative example 1
1	Number of hollow fiber membranes	8448	10752
2	Actual effective length of hollow fiber membranes	285 mm	228 mm
3	Membrane surface area	1.4 m ²	1.4m ²
4	Inner diameter of hollow fiber membranes	184 μm	184μm
5	Wall thickness Hollow fiber membranes	37 μm	37μm
6	Amplitude of hollow fiber membranes	0.41 mm	0.41 mm
7	Wavelength	7.5 mm	7.5 mm
8	Inner diameter of cylindrical housing	31 mm	34 mm
9	Σ Flow cross sections of all passage openings	24.1 mm ²	315.3 mm ²
10	Flow cross section of the second inflow or outflow space	23.6 mm ²	26.4 mm ²
11	Quotient from parameters 9 and 10	1.02: 1	11.9: 1
12	Aspect ratio	9.19	6.71

Hollow fiber membranes originating from the same production were used for the hollow fiber membrane filter according to the invention according to Example 1 and for the FX 60 hollow fiber membrane filter according to Comparative Example 1. These hollow fiber
10 membranes match in terms of diameter, wall thickness, pore properties, and material composition. The number of hollow fiber membranes in Example 1 and Comparative Example 1 was adjusted so that the respective hollow fiber membrane filters each had the same membrane surface area of 1.4 m².

15 Table 2

	Ex. 1, sterile	Comp.Ex. 1, sterile	Ex. 1, non-sterile	Comp.Ex. 1, non-sterile
Clearance, urea	273 ml/min	267 ml/min	276 ml/min	274 ml/min
Clearance, Vit. B12	175 ml/min	169 ml/min	176 ml/min	169 ml/min

The results from Table 2 show that the clearance of sterile and non-sterile hollow fiber membrane filters according to Example 1 for urea and vitamin B12 is higher than for the FX60 hollow fiber membrane filter of Comparative Example 1. In addition, the example according to the invention shows only a slight decrease in urea clearance after sterilization.

Claims

1. A hollow fiber membrane filter (100), comprising

5 a cylindrical housing (101) that extends along a central axis (A) in the longitudinal direction, with a housing interior space (102), a first end region (103) with a first end (104), and a second end region with a second end,

10 a plurality of hollow fiber membranes having an inner diameter of 150 to 190 μm and a wall thickness of 25 to 38 μm , the hollow fiber membranes being arranged in the cylindrical housing (101) and embedded in a sealing manner in the first end region (103) and in the second end region of the cylindrical housing in a respective potting compound (105) in a potting zone (106), and the ends of the hollow fiber membranes being open so that the lumina the hollow fiber membranes form a first flow space and the housing interior space (102) surrounding the hollow fiber membranes forms a second flow space,

15 first inflow or outflow spaces (107), each adjoining with their front end the first (104) and second end of the cylindrical housing (101) and the potting zone (106), which are in fluid communication with the first flow space of the hollow fiber membrane filter and each of which has first liquid access points (108) for conducting liquid into/out of the first inflow or outflow spaces (107),

20 second inflow or outflow spaces (109) surrounding the first and the second end region of the cylindrical housing (101) which are in fluid communication with the second flow region and each of which has second liquid ports (116) for conducting liquid into/out of the second inflow or outflow space (109),

25 a respective seal (110) that separates the first inflow or outflow spaces (107) from the second inflow or outflow spaces (109),

passage openings (113) in the end regions (103) of the cylindrical housing (101) that form a fluid connection between the second inflow and/or outflow spaces (109) and the second flow space,

characterized in that

30 that the aspect ratio of the actual effective length of the hollow fiber membranes and the inner diameter of the cylindrical housing is 8 to 12.

2. The hollow fiber membrane filter (100) as set forth in claim 1, characterized in that the membrane surface area of the hollow fiber membrane filter is 1.2 to 2 m².

3. The hollow fiber membrane filter (100) as set forth in claim 1 or 2, characterized in that the effective length of the hollow fiber membranes is 270 to 320 mm.

4. The hollow fiber membrane filter (100) as set forth in at least one of the preceding claims, characterized in that the inner diameter of the cylindrical housing (101) is 25 to 35 mm.

5. The hollow fiber membrane filter (100) as set forth in at least one of the preceding claims, characterized in that the packing density of the hollow fiber membranes is 50 to 70%.

6. The hollow fiber membrane filter (100) as set forth in at least one of the preceding claims, characterized in that the hollow fiber membrane filter is characterized in that the hollow fiber membranes have a wave-like shape, particularly wherein the amplitude of the wave-like shape of the hollow fiber membranes is 0.1 to 0.5 mm and the wavelength of the wave-like shape of the hollow fiber membranes is 5 to 10 mm.

7. The hollow fiber membrane filter as set forth in at least one of the preceding claims, characterized in that, in the end regions of the cylindrical housing, the ratio of the sum of the flow cross sections of all passage openings (113) to the flow cross section of the at least one second inflow or outflow space (109) lies in the range of 0.5:1 to 7:1, or 0.75:1 to 5:1 or 1:1 to 3:1. 8.

The hollow fiber membrane filter (100) as set forth in claim 7, characterized in that, in the end regions of the cylindrical housing (101), the inflow or outflow spaces (109), starting from the second liquid access point to the central axis (A) of the cylindrical housing (101), form a rotationally symmetrical circumferential space, particularly an annular gap..

9. The hollow fiber membrane filter (100) as set forth in at least one of the preceding claims, characterized in that the passage openings (113) are arranged on isolated

and/or opposite sections or circumferentially on the end region (103) of the cylindrical housing (101).

- 5 10. A hollow fiber membrane filter as set forth in at least one of the preceding claims, characterized in that said at least one end region (103), and optionally said second end region, is divided into a proximal end region (103a), a distal end region (103b), and a transition region (103c) disposed between said proximal and distal end regions, wherein one end of the distal end regions (103b) of the first and/or second end region (103) corresponds to the respective end of the cylindrical housing (104),
10 and the distal end region has an inner diameter at least 2% larger than the inner diameter of the proximal end region.
- 15 11. The hollow fiber membrane filter (100) as set forth in at least one of the preceding claims, characterized in that the sum of the flow cross sections of all passage openings (113) is 10 to 350 mm², or 15 to 200 mm², or 15 to 150 mm², or 20 to 110 mm².
- 20 12. The hollow fiber membrane filter (100) as set forth in at least one of the preceding claims, characterized in that the flow cross section of the second inflow or outflow spaces is 20 to 50 mm², 20 to 40 mm², or 20 to 25 mm².
- 25 13. The hollow fiber membrane filter (100) as set forth in at least one of the preceding claims, characterized in that the first (107) and the second inflow or outflow space (109) in the first end region (103) of the cylindrical housing (101) and the first and the second inflow or outflow space in the second end region of the cylindrical housing are respectively enclosed by a first and a second end cap (111).
- 30 14. The hollow fiber membrane filter (100) as set forth in claim 8, characterized in that the first and the second end cap (111) adjoin an annular outer circumferential projection (112a) on the first (103) and on the second end region of the cylindrical housing (101) in a positive, particularly liquid-tight manner.
15. The hollow fiber membrane filter (100) as set forth in claim 8 or 9, characterized in that the first and the second end cap (111) positively adjoin the first end (104) and

the second end, respectively, of the cylindrical housing (101), particularly in a liquid-tight manner, along an inner circumferential circular line (110a).

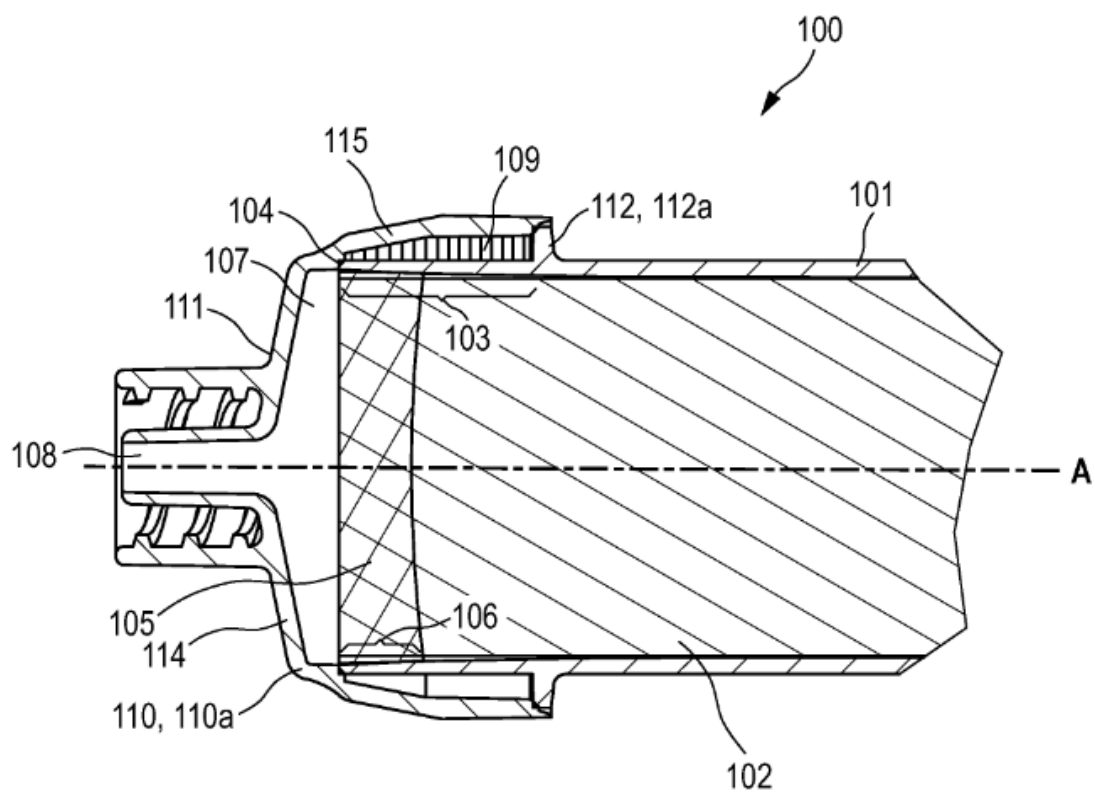
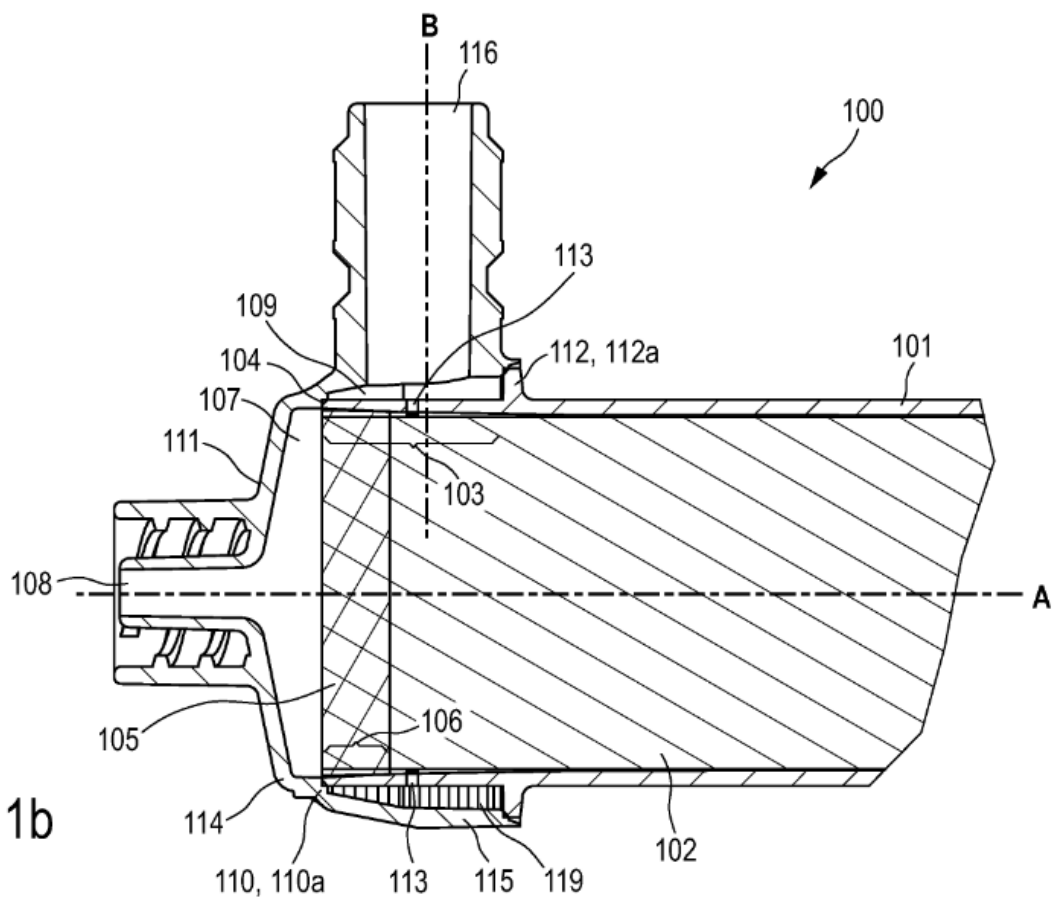
Figures

FIG. 1a



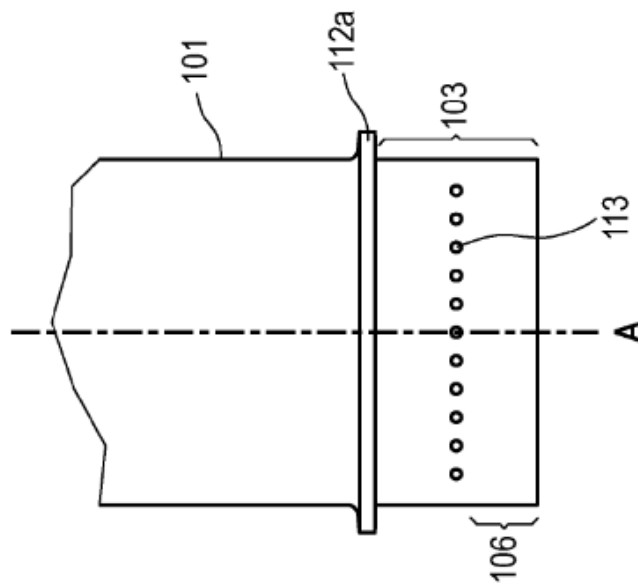


FIG. 2a

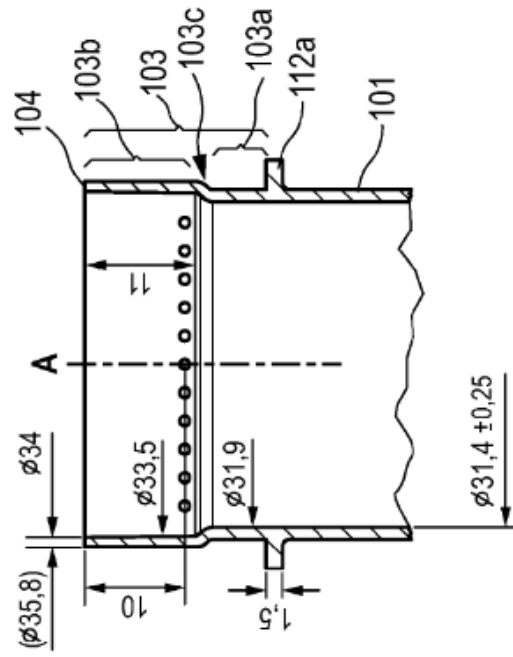


FIG. 2b

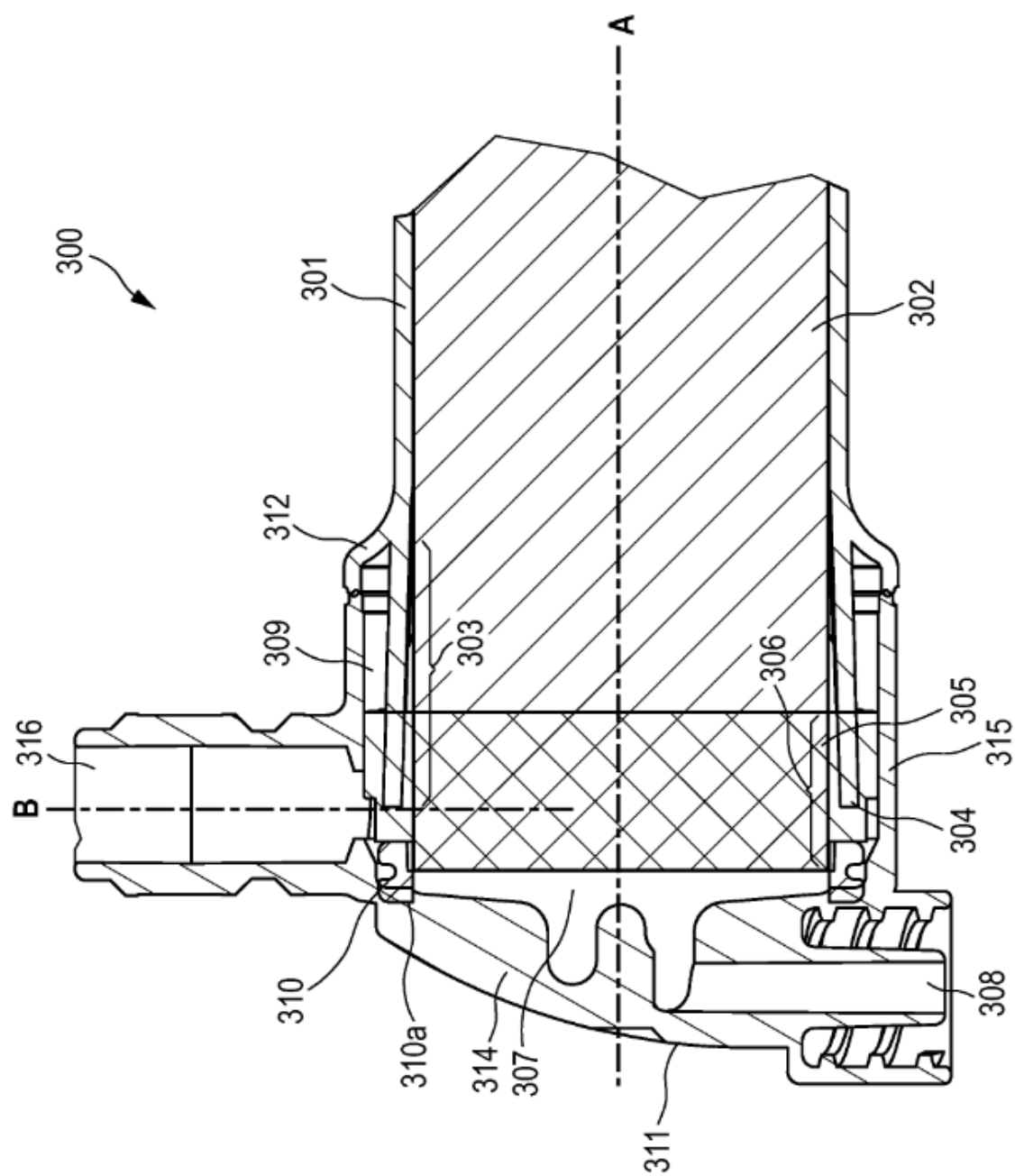


FIG. 3

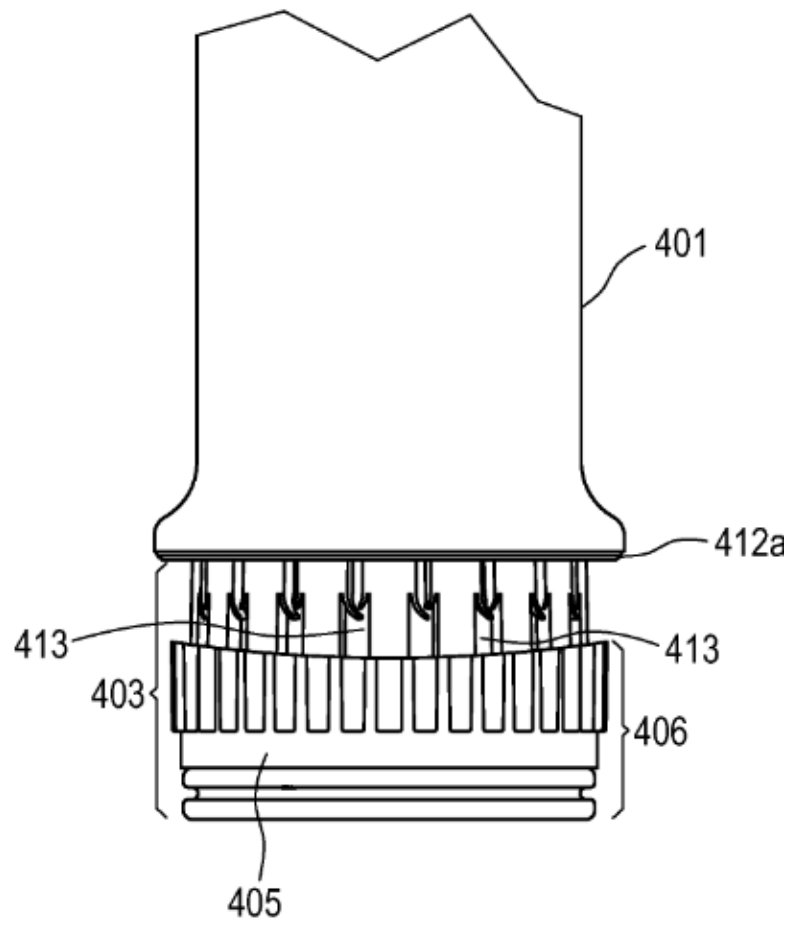


FIG. 4

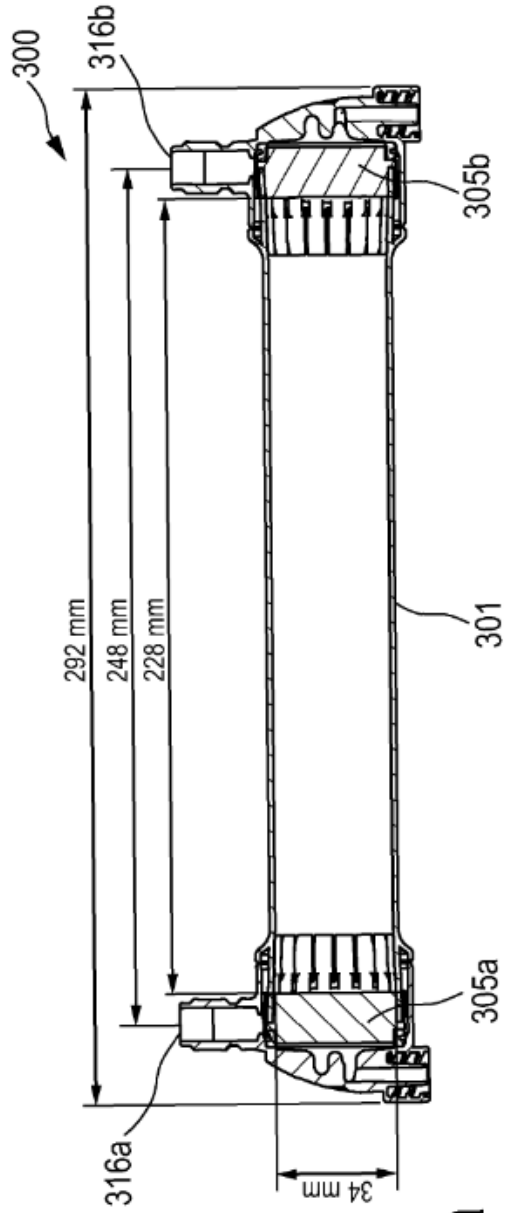


FIG. 5a

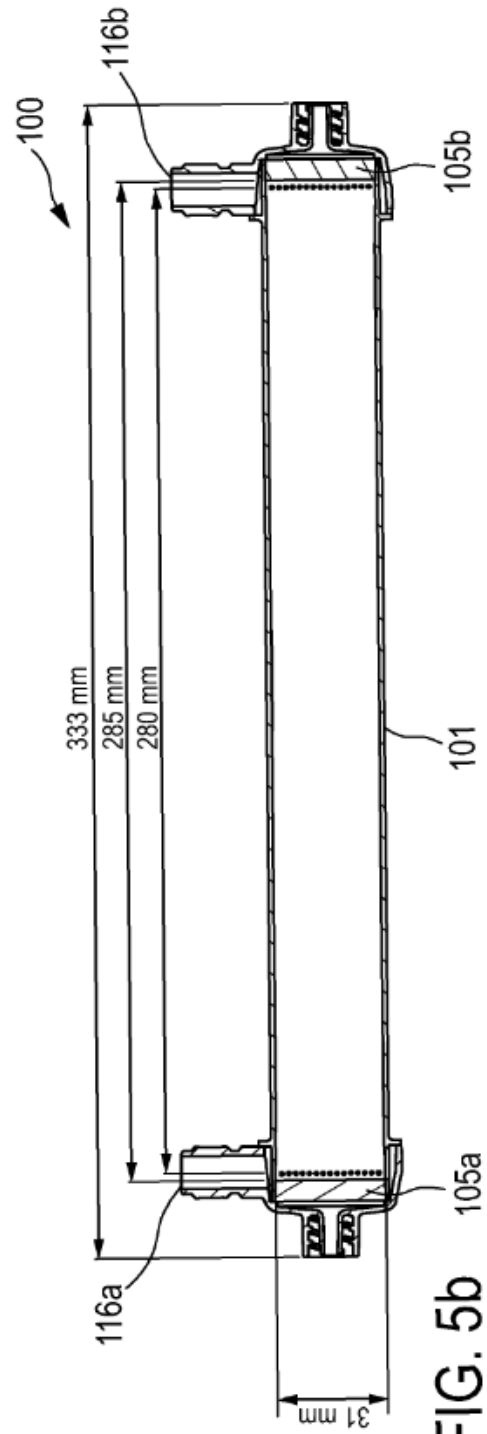


FIG. 5b