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(54) **MULTIPATH PLATE-AND-SHELL HEAT EXCHANGER**

(57) The present invention relates to a plate-and-shell heat exchanger (100) comprising a stack of plate pairs (50, 60) positioned in a shell (20), where the stack of plate pairs (50, 60) comprises a plurality of plate pairs of a first type (50) and a plurality of plate pairs of a second type (60). Each plate pair (50, 60) comprises two heat transfer plates (10) being connected to each other and forming a cavity (11) there between, and comprising an inlet opening (13a, 13b) and an outlet opening

(13'a, 13'b). First inner flow paths (12a) are formed through the first inlet openings (13a), the cavities (11) of the plate pairs of the first type (50) and the first outlets (13'a). Second inner flow paths (12b) are formed through the second inlet openings (13b), the cavities (11) of the plate pairs of the second type (60) and the second outlets (13'b). A third outer flow path (22) is defined within the shell and between plate pairs of the first type (50) and plate pairs of the second type (60).

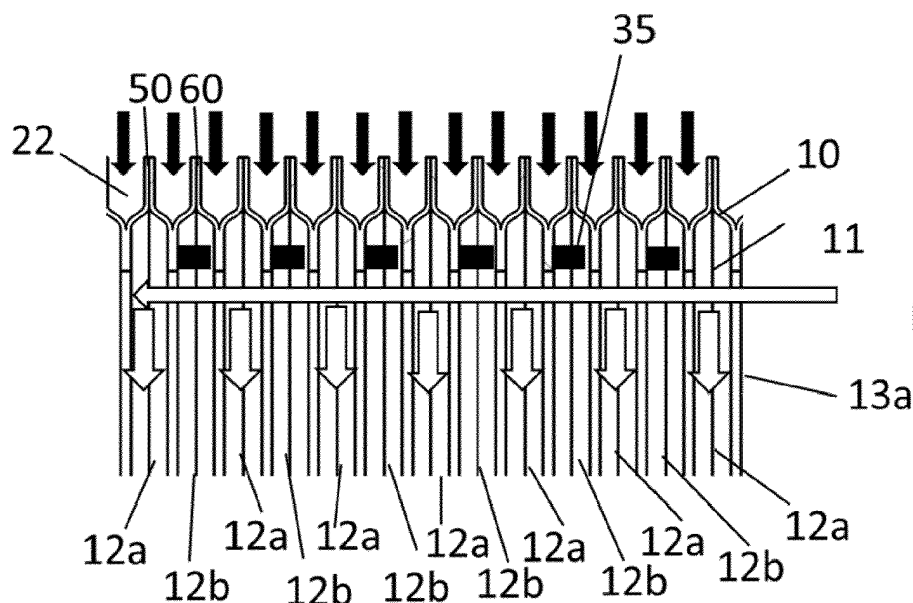


Fig. 5B

Description

FIELD OF THE INVENTION

[0001] The present invention relates to a plate-and-shell heat exchanger and a heat transfer plate for a plate-and-shell heat exchanger.

BACKGROUND OF THE INVENTION

[0002] Plate-and-shell heat exchangers comprise a plurality of stacked structured plates positioned within a shell or casing. The plates are connected in pairs such that a first fluid flow path for a first fluid is provided at least partially within the connected pairs of plates. The pairs of connected plates are designed to fluidly connect a first inlet opening to a first outlet opening of the heat exchanger, thereby forming the first fluid flow path. A second fluid flow path for a second fluid is provided outside of the connected pairs of plates and separated from the first fluid flow path by the plates. The second fluid flow path fluidly connects a second inlet opening to a second outlet opening. Heat exchange takes place between fluid flowing in the first fluid flow path and fluid flowing in the second fluid flow path.

[0003] The second fluid enters the shell of the heat exchanger through the second inlet opening, flows along the complex second fluid flow path inside the shell and out through the second outlet opening. As the second fluid enters the shell of the heat exchanger it undergoes a complex change from a tubular or cylindrical flow through, e.g., a pipe into a branched flow past the various components of the inside of the heat exchanger.

[0004] Depending on the inside layout of the heat exchanger, the first and second fluid flows may be obstructed in some regions and/or guided in a non-uniform way, such that the heat transfer rate between the two fluids inside the heat exchanger is reduced. Further, the pressures, such as the pressures in the areas of the openings and in the centre flow sections of the plates, may be significant, and thus it is a goal to make a better pressure distribution over the plates.

DESCRIPTION OF THE INVENTION

[0005] The invention provides a plate-and-shell heat exchanger comprising a stack of plate pairs positioned in a shell, where the stack of plate pairs comprises a plurality of plate pairs of a first type and a plurality of plate pairs of a second type, wherein:

- each plate pair of the first type comprises two heat transfer plates being connected to each other and forming a cavity there between, and comprising a first inlet opening and a first outlet opening, and
- each plate pair of the second type comprises two heat transfer plates being connected to each other

and forming a cavity there between, and comprising a second inlet opening and a second outlet opening,

wherein the first inlet openings and the first outlet openings of the plate pairs of the first type are connected to each other so as to form first inner flow paths through the first inlet openings, the cavities of the plate pairs of the first type and the first outlets,

wherein the second inlet openings and the second outlet openings of the plate pairs of the second type are connected to each other so as to form second inner flow paths through the second inlet openings, the cavities of the plate pairs of the second type and the second outlets,

and wherein a third outer flow path is defined within the shell and between plate pairs of the first type and plate pairs of the second type.

[0006] Thus, the invention provides a plate-and-shell heat exchanger, i.e. a heat exchanger of the kind which comprises a stack of plates arranged within a shell. In the heat exchanger according to the invention the plates forming the stack of plates are in the form of plate pairs, each plate pair comprising two heat transfer plates being connected to each other in such a manner that a cavity is formed between the heat transfer plates.

[0007] The stack of plate pairs comprises a plurality of plate pairs of a first type and a plurality of plate pairs of a second type. Each plate pair of the first type comprises a first inlet opening and a second inlet opening. Similarly, each plate pair of the second type comprises a second inlet opening and a second outlet opening.

[0008] The first inlet openings and the first outlet openings of the plate pairs of the first type are connected to each other so as to form first inner flow paths through the first inlet openings, the cavities of the plate pairs of the first type and the first outlets. Accordingly, a plurality of parallel first inner flow paths is formed, through the cavities of the plate pairs of the first type. Since the respective first inlets and first outlets are connected to each other, these parallel first flow paths can be connected to the same fluid source, and thereby the same kind of fluid will flow through all of the first inner flow paths during operation of the heat exchanger. In the following this fluid will be denoted the first fluid.

[0009] Similarly, the second inlet openings and the second outlet openings of the plate pairs of the second type are connected to each other so as to form second inner flow paths through the second inlet openings, the cavities of the plate pairs of the second type and the second outlets. Thereby a plurality of parallel second inner flow paths are formed, similarly to the first inner flow paths described above. The remarks set forth above are, accordingly, equally applicable here. The fluid flowing through the parallel second inner flow paths is, in the following, denoted the second fluid.

[0010] Thus, two separate fluids, i.e. the first fluid and the second fluid, are supplied to the first inner flow paths and to the second inner flow paths, respectively, independently of each other.

[0011] Furthermore, a third outer flow path is defined within the shell and between the plate pairs of the first type and plate pairs of the second type. In the following, the fluid flowing in the third outer flow path is denoted the third fluid.

[0012] Thus, during operation of the heat exchanger, heat exchange takes place between, on the one hand, the third fluid and, on the other hand, each of the first fluid and the second fluid. In other words, the third fluid exchanges heat with the first fluid as well as with the second fluid. This provides a compact design of the heat exchanger, while ensuring a suitable temperature of the first fluid as well as of the second fluid, in an easy and efficient manner, and while preventing mixing among the three kinds of fluid.

[0013] Accordingly, a first fluid flowing in the first inner flow paths as well as a second fluid flowing in the second inner flow paths may exchange heat with a third fluid flowing in the third outer flow path.

[0014] Each plate pair of the first type may further be provided with a second inlet opening and a second outlet opening, and the second inlet opening and the second outlet opening of a given plate pair of the first type may be sealed from the first inlet opening, the first outlet opening and the cavity defined by the given plate pair of the first type.

[0015] According to this embodiment, the first inner flow paths and the second inner flow paths are efficiently separated from each other, thereby preventing mixing of the first fluid and the second fluid. However, since the second inlet openings and the second outlet openings are formed in the plate pairs of the first type, the plate pairs of the first type and the plate pairs of the second type may in fact be designed identically or in a similar manner, the only difference being that in the plate pairs of the first type the cavities are connected to the first inlet openings and the first outlet openings, whereas in the plate pairs of the second type the cavities are connected to the second inlet openings and the second outlet openings. This reduces the manufacturing costs of the heat exchanger.

[0016] Similarly, each plate pair of the second type may further be provided with a first inlet opening and a first outlet opening, and the first inlet opening and the first outlet opening of a given plate pair of the second type may be sealed from the second inlet opening, the second outlet opening and the cavity defined by the given plate pair of the second type. The remarks set forth above with reference to the plate pairs of the first type are equally applicable here.

[0017] The first inlet opening and the first outlet opening may be formed in one of the heat transfer plates of the plate pair, and the second inlet opening and the second outlet opening may be formed in the other of the heat

transfer plates of the plate pair.

[0018] According to this embodiment, it is efficiently ensured that the first inlet/outlet openings and the second inlet/outlet openings do not come into contact with each other, thereby efficiently preventing mixing of the first fluid and the second fluid, also at or near the inlet openings and the outlet openings.

[0019] The plate pairs of the first type and the plate pairs of the second type may be identical, and rotated at an angle relative to each other around a centre axis of the plate pairs. According to this embodiment, an identical design is applied for the plate pairs of the first type and the plate pairs of the second type, respectively, and the orientation of the plate pairs determine whether a given plate pair is regarded as a plate pair of the first type or as a plate pair of the second type. The centre axis of the plate pairs may be an axis of symmetry of the plate pair.

[0020] The plate pairs of the first type and the plate pairs of the second type may be arranged alternately in the stack of plate pairs. According to this embodiment, the plate pairs are arranged in the stack of plate pairs in such a manner that each plate pair of the first type is arranged between two plate pairs of the second type, or between a plate pair of the second type and an end plate, and each plate pair of the second type is arranged between two plate pairs of the first type, or between a plate pair of the first type and an end plate. Thereby the first inner flow paths and the second inner flow paths are also arranged alternately in the heat exchanger. This provides even and appropriate heat exchange with each of the first and second fluids, simultaneously.

[0021] The heat transfer plates forming the plate pairs of the first type and/or the heat transfer plates forming the plate pairs of the second type may be identical, and rotated 180° around a centre axis of the plate pairs.

[0022] According to this embodiment, identical heat transfer plates are applied for forming the plate pairs of the first type and/or the plate pairs of the second type. The heat transfer plates may be regarded as defining a first side and a second, opposite, side. When connecting the heat transfer plates in order to form a plate pair, the heat transfer plates are oriented relative to each other in such a manner that the first sides of the heat transfer plates face each other, and the second sides of the heat transfer plates form outer surfaces of the plate pair. Accordingly, the first sides of the heat transfer plates face the cavity formed between the heat transfer plates, and the second sides face neighbouring plate pairs.

[0023] The plate pairs may have an outer shape which is circular, oval, pentagonal or hexagonal. This allows the stack of plate pairs to define a shape which matches a shape of the shell which accommodates the stack of plate pairs.

[0024] The first inlet openings and the first outlet openings of the plate pairs of the first type may be connected by connection elements, and the second inlet openings and the second outlet openings of the plate pairs of the

second type may be connected by connection elements. This efficiently keeps the respective flow paths separated and prevents unintentional mixing of the various fluids.

[0025] The plate pairs of the first type and the plate pairs of the second type may be sealingly connected to each other at outer rims of the inlet openings and the outlet openings. This efficiently prevents unintentional mixing of the first fluid and the second fluid at the regions near the inlet openings and the outlet openings.

[0026] The plate-and-shell heat exchanger may be connected to an electrolyzer such that a fluid feed to a cathode of the electrolyzer, a fluid feed to an anode of the electrolyzer, as well as a common heating or cooling fluid passes through the plate-and-shell heat exchanger.

[0027] According to this embodiment, the fluid fed to the cathode of the electrolyzer as well as the fluid fed to the anode of the electrolyzer is heated or cooled simultaneously be a heating or cooling fluid flowing in the third outer flow path. Thereby it is ensured that both of the fluids supplied to the electrolyzer have an appropriate temperature, and this is ensured in an easy and efficient manner.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028]

Figs. 1A and 1B illustrate a prior art plate-and-shell kind heat exchanger,

Figs. 2A and 2B illustrate a prior art heat transfer plate and an edge view of connected pairs of connected plates of a plate-and-shell kind heat exchanger,

Fig. 3 illustrates a prior art plate-and-shell kind heat exchanger showing flow distributions at the two sides of a heat transfer plate,

Fig. 4 illustrates a heat transfer plate according to an embodiment of the present invention,

Figs. 5A and 5B illustrate a heat transfer plate and an edge view of connected pairs of connected plates of a plate-and-shell kind heat exchanger according to an embodiment of the present invention, showing a set of inlet openings and outlet openings, where a first inlet opening and a first outlet opening are open, while a second inlet opening and a second outlet opening are closed,

Figs. 6A and 6B illustrate a heat transfer plate similar to the heat transfer plate of Figs. 5A and 5B, but where a second inlet opening and a second outlet opening are closed, while a first inlet opening and a second inlet opening are closed,

Fig. 7 illustrates an embodiment of the present in-

vention with first kind pair of heat transfer plates and second kind pair of heat transfer plates being formed with non-overlapping sections,

5 Fig. 8 is a sideview of a non-overlapping section showing a connection element positioned in relation to an opening,

10 Fig. 9 is a top-view of the first kind pair of heat transfer plates and second kind pair of heat transfer plates being positioned on top of each other, and being formed with non-overlapping sections,

15 Fig. 10 is a sideview of non-overlapping sections of first kind heat transfer plates reaching over the edge of second kind heat transfer plates with their openings connected by connection elements,

20 Fig. 11 illustrates an alternative embodiment of first kind pair of heat transfer plates and second kind pair of heat transfer plates formed with non-overlapping sections, and

25 Fig. 12 illustrates a plate-and-shell heat exchanger according to an embodiment of the present invention used in relation to an electrolyzer.

DETAILED DESCRIPTION OF THE DRAWINGS

30 **[0029]** The detailed description and specific examples indicating embodiments of the invention are given by way of illustration of the basic concept on the invention only.

[0030] Figs. 1A, 1B, 2A, 2B and 3 illustrate an embodiment heat exchanger as it is known from the prior art.

35 **[0031]** Fig. 1A shows an exploded view of a plate-and-shell heat exchanger 100. The heat exchanger 100 comprises a shell 20 and a plurality of sealed pairs of heat transfer plates 10 within the shell 20.

[0032] The shell 20 may be of a hollow cylindrical shape and the plates 10 may be of a corresponding shape and size such that they can be fit into the shell 20. Other shapes of the shell 20 and plates 10 are also possible, however shapes are preferred, which allow for a substantially close positioning of the plates 10 within the shell 20.

40 **[0033]** The plates 10 in the pairs are in the heat transfer sections 32 contacting each other by patterns 30, possible intersecting. This forms fluidly connected first cavities 11 for providing an inner fluid flow path 12 for a first fluid flow indicated by the corresponding arrows. The first fluid flow enters and leaves the heat exchanger 100 through a first inlet opening 23 and a first outlet opening 23'. The first cavities 11 are surrounded by two adjacent plates 10, which are connected to each other, as is shown more clearly in Fig. 1B and as will be described below in more detail below. Fig. 1B shows the heat exchanger 100 in a sectional view and in an assembled state.

55 **[0034]** The plates 10 in the pairs may be connected,

e.g. by welding or brazing, at their plate rims, or outer edges, 14a, possibly also at the connected intersecting patterns 30. Two and two this forms first cavities 11 for a sealed inner fluid flow path 12 from a first inlet opening 23 to a first outlet opening 23'.

[0035] The plates 10 comprise plate openings 13, 13' for connecting fluidly adjacent plates 10 to each other and to the first inlet and outlet opening 23, 23'. The two adjacent plates 10 of two connected pairs may be connected and sealed together by, e.g., a welding or brazing along the opening rim, or opening edge, 14b of the plate openings 13, 13'.

[0036] An outer fluid flow path 22 is formed at the outside surfaces of the plates 10 by the connected patterns 30 projecting outwardly relative to the first cavities 11 of the connected pairs of plates 10, thus at the opposite side of the plates 10. The outer fluid flow path 22, thus, is formed outside of the sealed pairs of plates 10 and inside of the shell 20 and is connected to a second inlet opening 24 and second outlet opening 24'. A second fluid flow enters and leaves the heat exchanger 100 through second inlet opening 24 and the second outlet opening 24', respectively.

[0037] The shell 20 forms a second cavity 21 in which the plates 10 are arranged and in which an outer fluid flow path 22 for a second fluid flow is provided. The second fluid flow enters and leaves the heat exchanger 100 through second inlet opening 24 and the second outlet opening 24', respectively.

[0038] The inner flow path 12 and the outer fluid flow path 22 are separated and sealed from each other, respectively, by the plate pairs being connected at the plate rims 14a and by the plate pairs being connected at their opening rims 14b of the openings 13, 13'. The heat exchange occurs between the two fluids flowing separated from each other, and via the plates 10.

[0039] Fluid for the inner flow path 12 is sealed from the inside of the second cavity 21 inside the shell 20, and therefore from the outer flow paths 22, but each cavity 11 is fluidically contacted with the other cavities 11 of the connected plate 10 pairs in the stack by the openings 13, 13', and thereby also with the first inlet 23 and the first outlet 23'.

[0040] Fluid for the outer flow path 22 is in fluid contact to the second cavity 21, and thereby to the second inlet 24 and the second outlet 24', over the rims 14a of the plates 10, but is sealed from the cavities 11, as the two plates 10 in each pair are connected at their rims 14a, and pairs are connected to neighbouring pairs at the (outer) rims 14b of the openings 13, 13'.

[0041] Fig. 2A shows a detailed view of a heat transfer plate 10 of a prior art plate-and-shell heat exchanger 100. The plate 10 sheet is possibly made of metal.

[0042] The pattern 30 at the heat transfer sections 32 is seen as being corrugated having a series of parallel ridges and grooves. It may be formed by pressing the corrugations into a flat sheet preform. The plates 10 then are connected such that every second plate is turned, or

formed, with the corrugated patterns 30 of neighbouring plates crossing each other rather than extending in parallel. The crossing points then form the contacts of the plates 10 in the heat transfer sections 32.

[0043] Fig. 2B shows a detailed sectional view of a plurality of connected heat transfer plates 10. Two adjacent plates 10 are connected at their outer circumferences, or at the rims 14a of their outer edges. Thus, sealed pairs of connected plates 10 are provided for allowing the first fluid to flow through the inner fluid flow path 12, bounded by the connected pairs of plates 10.

[0044] The outer fluid flow path 22 is guided between two adjacent pairs of connected plates 10 and separated from the inner fluid flow path 12 by the plates 10. It comprises flat, narrow channels between closely positioned plates 10. For efficient heat exchange, the second fluid flow rate in the vertical direction and between the pairs of connected plates 10 as shown in Fig. 2B is essential. This flow component corresponds in approximation to a radial or tangential component of the second fluid flow with respect to the shell 20.

[0045] Fig. 3 is a schematic view of parts of the inner fluid flow path 12 and the outer fluid flow path 22 through the heat exchanger 100, along the heat transfer sections 32. The arrows at the one plate 10 indicate the inner fluid flow path 12 inside a pair of connected plates 10. The inner fluid flow path 12 enters the pair of connected plates 10 through one of the two plate openings 13 and leaves the pair of connected plates 10 through the other of the two plate openings 13'.

[0046] The second plate shows a part of the outer fluid flow path 22 in a cross section of the heat exchanger 100. This time, it is not the inside of a pair of connected plates 10 which is shown, but the space between two such connected pairs of plates 10. The second fluid flow path 22 fills the second cavity 21. The second cavity 21 is bounded by the inside of the shell 20, the outsides of the pairs of connected plates 10, one of which is shown in Fig. 3B, and possibly further structures contained within the shell 20. The outer flow path 22 enters the shell 20 through the second inlet opening 24 and leaves the shell 20 through the second outlet opening 24'. The second inlet opening 24 and the second outlet opening 24' may be positioned on opposite sides of the shell surface.

[0047] Since an inner fluid flow path 12 for a first fluid is formed at the one side of a plate 10, and an outer fluid flow path 22 for a second fluid at the opposite side, the heat transfer between the first fluid inside the first cavity 11 and the second fluid outside the first cavity 11 is hence facilitated over the plate 10. In the present context 'inner' and 'outer' fluid flow paths 12, 22 refers to the first cavities 11 formed by the connected pairs of plates 10, and thus is related to the specific illustrated embodiment. In more general terms, there are two flow paths sealed from each other, one for the first fluid and one for the second fluid.

[0048] To ensure a high efficiency of the heat exchanger 100, the fluids preferably should distribute sufficiently over the entire width of the plates 10.

[0049] Fig. 4 illustrates a top view of a heat transfer plate 10 according to an embodiment of the present invention.

[0050] The plate 10 differs from the prior art plate 10 of Fig. 2A in that it includes respectively a first inlet plate opening 13a, a second inlet plate opening 13b, a first outlet plate opening 13'a, and a second outlet plate opening 13'b.

[0051] In the illustration, the respective first and second inlet and outlet plate openings 13a, 13b, 13'a, 13'b are positioned at the same positions as the plate openings 13, 13' of Fig. 2A, but they could be positioned at any suitable positions and have any suitable sizes, even being differently sized.

[0052] The plate 10 is illustrated as being essentially circular, but could have any suitable form like oval, squared, rectangular, pentagonal, hexagonal, etc.

[0053] The respective first and second inlet and outlet plate openings 13a, 13b, 13'a, 13'b are adapted to be sealed 35 in pairs, such that for one inner fluid flow path 12 the second inlet opening 13b and the second outlet opening 13'b are sealed 35 from the respective inner flow path 12, and for another inner fluid flow path 12 the first inlet opening 13a and the first outlet opening 13'a are sealed 35 from the respective inner flow path 12.

[0054] The first inlet opening 13a and the first outlet opening 13'a are in contact with other first inlet openings 13a and first outlet openings 13'a, and the second inlet opening 13b and the second outlet opening 13'b are in contact with other second inlet openings 13b and second outlet openings 13'b. The first inlet opening 13a and the first outlet opening 13'a are sealed from the second inlet opening 13b and the second outlet opening 13'b.

[0055] This forms a first inner flow path 12a and a second inner flow path 12b, the first inner flow path 12a being in fluid connection to the first inlet opening 13a and the first outlet opening 13'a, and the second inner flow path 12b being in fluid connection to the second inlet opening 13b and the second outlet opening 13'b.

[0056] The sealing 35 may be of any suitable kind. In one embodiment, a sealing element 35, e.g. a rubber gasket, is positioned around the plate openings 13a, 13b, 13'a, 13'b to be sealed, or a metal sealing 35 may be included, possibly welded, brazed or fixed in another manner to the plates 10, e.g. at the opening rims 14b. In one embodiment, the opening rims 14b form flanges 35 to be connected to flanges of the neighbouring plate 10 of a pair, thus forming a sealing 35.

[0057] Fig. 5A illustrates a first pair type 50 of heat transfer plate 10, where the second inlet opening 13b and the second outlet opening 13'b are sealed 35 from the respective first inner flow path 12a, allowing a first fluid entering the first inlet opening 13a to leave via the first outlet opening 13'a without being mixed with a second fluid flowing via the second inlet opening 13b and the second outlet opening 13'b.

[0058] This is also illustrated in Fig. 5B, showing several connected plates 10 forming the first cavities 11, the

first inner flow paths 12a and the second inner flows path 12b, and showing the first inlet openings 13a. The first fluid in the first inlet openings 13a (represented by the white arrows) is seen entering only the first inner flow paths 12a, but not the second inner flow paths 12b.

[0059] Figs. 6A and 6B are similar to Figs. 5A and 5B, with the difference that the first inlet opening 13a and the first outlet opening 13'a are sealed 35 from the second inner flow path 12b, allowing a second fluid entering the second inlet opening 13b to leave via the second outlet opening 13'b without being mixed with a first fluid flowing via the first inlet opening 13a and the first outlet opening 13'a. This provides a second pair type 60 of heat exchanger plates 10.

[0060] Similarly to Fig. 5B, Fig. 6B shows several connected plates 10 forming the inner cavities 11, the first inner flow path 12a and the second inner flow path 12b, but showing the second inlet openings 13b. The second fluid in the second inlet openings 13b (represented by the white arrows) is seen entering only the second inner flow paths 12b, but not the first inner flow paths 12a.

[0061] The third fluid (represented by black arrows in Fig. 5B as well as in Fig. 6B) enters the outer flow paths 22 formed in the spaces between the two connected pairs of plates 10, and is distributed by the inner cavity of the shell 20, forming part of the outer flow path 22. Usually, the plates 10 will not extend to the inner surface of the shell 20, at least not in the region close to the first inlet opening 23, thus forming a chamber for distribution of the third fluid.

[0062] The third fluid then is shared for the first and second fluids, flowing respectively in the first inner flow path 12a and the second inner flow path 12b. The third fluid could be a heating or cooling fluid to heat or cool the first and second fluids, and could also be referred to as a common heat exchanging fluid for the fluids in the first inner flow path 12a and the second inner flow path 12b.

[0063] In the illustrations of Figs. 5B and 6B, the first inner flow path 12a and the second inner flow path 12b of respectively the first 50 and second 60 pair types are seen positioned in succession of each other, such that every second of the first cavities 11 forms a first inner flow path 12a and every second forms a second inner flow path 12b. In other embodiments 'bundles' of first pair types 50 and second pair types 60 may be positioned in succession of each other, e.g. 2 or 3 or 4 or more first pair types 50 and correspondingly 2 or 3 or 4 or more second pair types 60, possible then followed by 2 or 3 or 4 or more plates of the first pair types 50 etc.

[0064] In some embodiments the number of first pair types 50 may differ from the number of second pair types 60. This could, e.g., be the bundles of pair types 50, 60 differing from each other.

[0065] The first pair type 50 and second pair type 60 could be identical, the one simply being rotated relative to and/or oriented differently from the other.

[0066] The presented embodiment has the advantage

that the shape of the plates 10 can be maintained and the heat transferring efficiency can be optimised.

[0067] Fig. 7 shows an alternative embodiment of first 50 and second 60 pair types. The first pair type 50 is formed with one first inlet opening 13a and one first outlet opening 13'a, and the second pair type 60 is formed with one second inlet opening 13b and one second outlet opening 13'b. The first 50 and second 60 pair types could be identical, the one simply being rotated and/or oriented differently.

[0068] The openings 13a, 13'a, 13b, 13'b of the first 50 and second 60 pair types in the illustrated embodiment are each positioned within non-overlapping sections 40 reaching out of the main part of the heat transfer plates 10, or the main part of the heat transfer sections 32.

[0069] Fig. 8 is a side view of a two such non-overlapping sections 40 connected into a first 50 or second 60 pair type. Connection elements 45 are positioned in contact with the plate openings 13a, 13'a, 13b, 13'b.

[0070] Fig. 9 illustrates a first 50 and second 60 pair type positioned on top of each other, such that their non-overlapping sections 40 with respective plate openings 13a, 13'a, 13b, 13'b are not covered by the other of the pairs.

[0071] Fig. 10 is a side view of a section of first 50 and second 60 pair types stacked with the non-overlapping sections 40 of the one pair type 50, 60 reaching outside the other pair type 60, 50. The respective plate openings 13a, 13'a, 13b, 13'b are connected by connection elements 45 positioned between the non-overlapping sections 40.

[0072] This embodiment efficiently enables a first fluid in the first pair type 50 to be distributed to the following first pair types 50 without being mixed with the second fluid in the second pair types 60, and correspondingly for the second pair types 60.

[0073] The embodiment of Figs. 7 and 9 could be formed such that, when combined as illustrated in Fig. 9, the overall shape fits into a standard shell 20, e.g. having a combined circular shape (or oval, squared, pentagonal, hexagonal, etc.).

[0074] Fig. 11 shows an alternative embodiment where the non-overlapping sections 40 are positioned like 'ears' or extensions to an otherwise standard shaped heat transfer plate 10. Again, the first 50 and second 60 pair types could be identical, the one simply being rotated relatively to the other, e.g. positioned in a mirrored orientation relative to their non-overlapping sections 40, to allow positioning of the connection elements 45.

[0075] One example embodiment where the heat exchanger 100 according to the present invention with advantage could be used, is in electrolyzers 200, such as devices that use electricity to drive an electrochemical reaction in order to produce hydrogen and oxygen from, e.g., water.

[0076] Such electrolyzers 200 are for example used within 'Power-to-X' which relates to electricity conversion, energy storage, and reconversion pathways that

use surplus electric power, typically during periods where fluctuating renewable energy generation exceeds load.

[0077] The hydrogen produced from an electrolyzer 200 is perfect for use with hydrogen fuel cells. The reactions that take place in an electrolyzer are very similar to the reactions taking place in fuel cells, except the reactions that occur in the anode and cathode are reversed. In a fuel cell, the anode is where hydrogen gas is consumed, and in an electrolyzer 200, the hydrogen gas is produced at the cathode. A very sustainable system can be formed when the electrical energy needed for the electrolysis reaction comes from renewable energy sources, such as wind or solar energy systems.

[0078] Direct current electrolysis (efficiency 80-85% at best) can be used to produce hydrogen which can, in turn, be converted to, e.g., methane (CH₄) via methanation, or converting the hydrogen, along with CO₂ to methanol, or to other substances.

[0079] The energy, such as hydrogen, generated in this manner, e.g. by wind turbines, can thereby be stored for later usage.

[0080] Electrolyzers 200 can be configured in a variety of different ways and are generally divided into two main designs: unipolar and bipolar. The unipolar design typically uses liquid electrolyte (alkaline liquids), and the bipolar design uses a solid polymer electrolyte (proton exchange membranes).

[0081] Alkaline water electrolysis has two electrodes operating in a liquid alkaline electrolyte solution of potassium hydroxide (KOH) or sodium hydroxide (NaOH). These electrodes are separated by a diaphragm, separating the product gases and transporting the hydroxide ions (OH⁻) from one electrode to the other.

[0082] Other fuels and fuel cells include phosphoric acid fuel cells, molten carbonate fuel cells, solid oxide fuel cells and all their subcategories as well. Such fuel cells are adaptable for use as an electrolyzer as well.

[0083] It is an advantage if the fluid solutions operating in the plant are within given temperatures to optimize the efficiency. It is also an advantage if the plant could be compact and scalable.

[0084] The principle of using the present invention in such an electrolyzer 200 - or fuel cell, is illustrated in Fig. 12, showing a plant 200, such as an electrolyzer or fuel cell, equipped with a heat exchanger 100 according to the present invention. In general, in the following example, the plant 200 is referred to as an electrolyzer 200, such as an alkaline electrolyzer for producing hydrogen, but the term 'electrolyzer' 200 refers in common to electrolyzers for producing fuels, or fuel cells using such fuels.

[0085] The embodiment shows an electrolyzer 200 comprising an electrolyzing device 202 formed of an assembly of diaphragms, etc. Regulating elements 203 may be connected with the electronics, etc., such as to form the control and regulation of operation of the electrolyzer 200.

[0086] The right-hand side of Fig. 12 shows an embodiment of the present invention, where the electrolyzer 200

is seen from the side and illustrating a heat exchanger 100 connected at its one end. The fluid solutions circulating in the electrolyzing device 202 pass the heat exchanger 100 in order to regulate their temperatures. The first inner flow path 12a of the heat exchanger 100 then would convey one of the fluids for the electrolyzer 100, and the second inner flow path 12b would convey the second of the fluids for the electrolyzer 100. The outer fluid flow path 22 then would convey a heating or cooling medium.

[0087] The fluid solutions circulating in the electrolyzing device 200 thus pass the heat exchanger 100 in order to regulate their temperatures.

[0088] The left part of Fig. 12 shows the electrolyzer 200 seen from the front, where the electrolyzing device 202 appears circular, though it naturally could have other shapes, such as oblate, oval, squared, polygonal, etc. The heat exchanger 100, and possibly the heat transfer plates 10, could have a corresponding shape, thus this could be related to make the electrolyzing device 202 and heat exchanger 100 appearing as a single unit, and the functioning of the heat exchanger 100.

[0089] The heat exchanger 100 may be connected to provide the desired operating temperature.

[0090] In the illustrated embodiment the heat exchanger 100 is connected to the electrolyzing device 202 by squeezing them between flanges 300 held together by rods 310. Alternatively, they could be connected by screws, brazed together, etc.

References

[0091]

10 - Heat transfer plates
 11 - First cavities
 12 - Inner fluid flow path
 12a - First inner flow path
 12b - Second inner flow path
 13, 13' - Plate openings
 13a - First inlet opening
 13b - Second inlet opening
 13'a - First outlet opening
 13'b - Second outlet opening
 14a - Plate rim/outer edge
 14b - Opening rim/opening edge
 20 - Shell
 21 - Second cavity
 22 - Outer fluid flow path
 23 - First inlet opening
 23' - First outlet opening
 24 - Second inlet opening
 24' - Second outlet opening
 30 - Patterns
 32 - Heat transfer sections
 35 - Sealing
 40 - Non-overlapping sections
 45 - Connection elements

50 - First pair type
 60 - Second pair type
 100 - Plate-and-shell heat exchanger
 200 - Electrolyzer
 202 - Electrolyzing device
 203 - Regulating elements
 300 - Flange
 310 - Rod

Claims

1. A plate-and-shell heat exchanger (100) comprising a stack of plate pairs (50, 60) positioned in a shell (20), where the stack of plate pairs (50, 60) comprises a plurality of plate pairs of a first type (50) and a plurality of plate pairs of a second type (60), wherein:

- each plate pair of the first type (50) comprises two heat transfer plates (10) being connected to each other and forming a cavity (11) there between, and comprising a first inlet opening (13a) and a first outlet opening (13'a), and

- each plate pair of the second type (60) comprises two heat transfer plates (10) being connected to each other and forming a cavity (11) there between, and comprising a second inlet opening (13b) and a second outlet opening (13'b),

wherein the first inlet openings (13a) and the first outlet openings (13'a) of the plate pairs of the first type (50) are connected to each other so as to form first inner flow paths (12a) through the first inlet openings (13a), the cavities (11) of the plate pairs of the first type (50) and the first outlets (13'a),

wherein the second inlet openings (13b) and the second outlet openings (13'b) of the plate pairs of the second type (60) are connected to each other so as to form second inner flow paths (12b) through the second inlet openings (13b), the cavities (11) of the plate pairs of the second type (60) and the second outlets (13'b),

and wherein a third outer flow path (22) is defined within the shell and between plate pairs of the first type (50) and plate pairs of the second type (60).

2. A plate-and-shell heat exchanger (100) according to claim 1, wherein a first fluid flowing in the first inner flow paths (12a) as well as a second fluid flowing in the second inner flow paths (12b) exchange heat with a third fluid flowing in the third outer flow path (22).

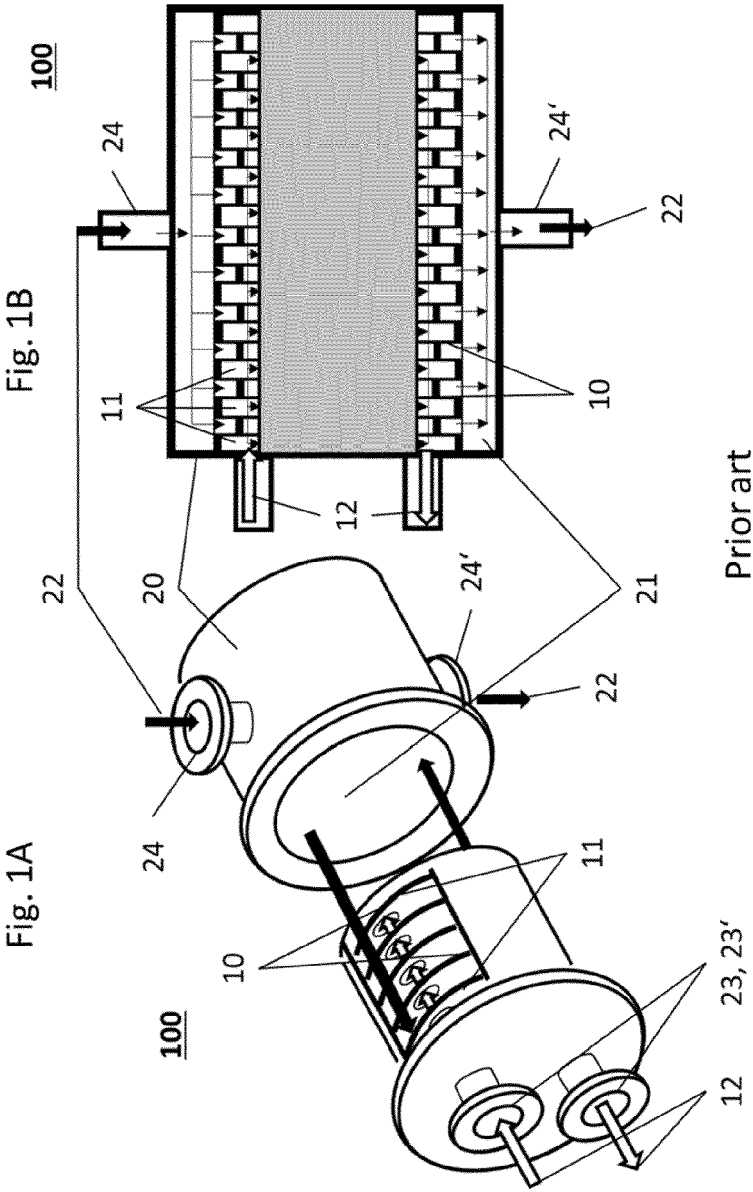
3. A plate-and-shell heat exchanger (100) according to claim 1 or 2, wherein each plate pair of the first type (50) is further provided with a second inlet opening

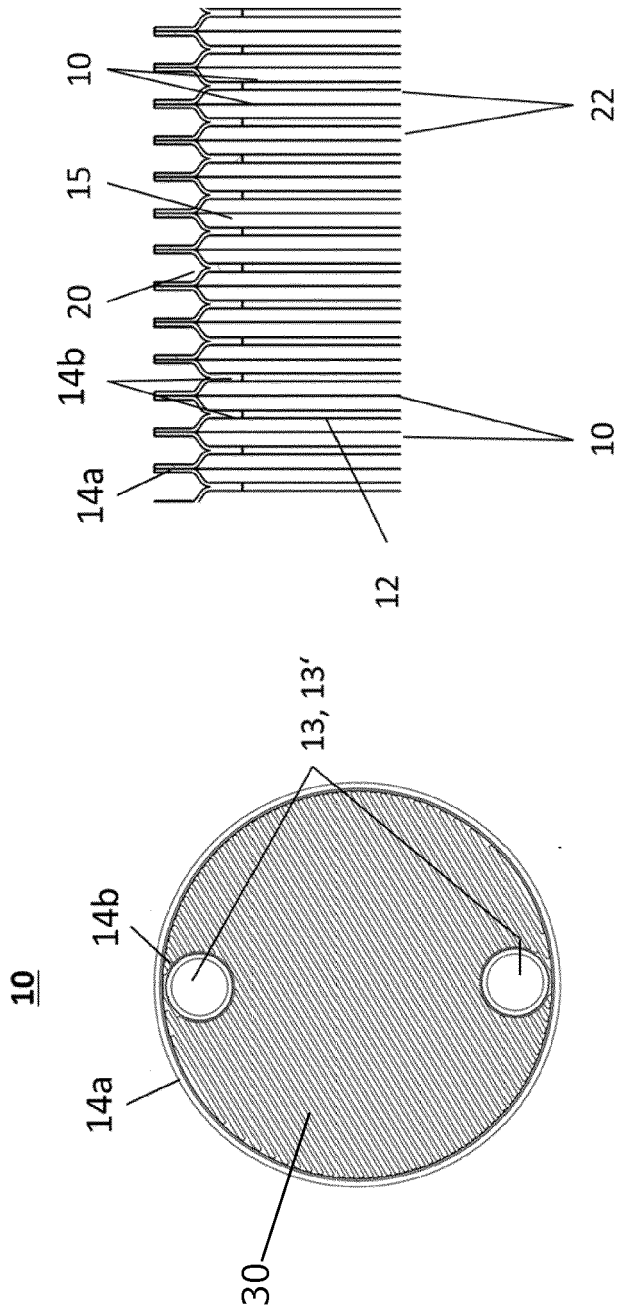
(13b) and a second outlet opening (13'b), and wherein the second inlet opening (13b) and the second outlet opening (13'b) of a given plate pair of the first type (50) are sealed from the first inlet opening (13a), the first outlet opening (13'a) and the cavity (11) defined by the given plate pair of the first type (50).

4. A plate-and-shell heat exchanger (100) according to any of the preceding claims, wherein each plate pair of the second type (60) is further provided with a first inlet opening (13a) and a first outlet opening (13'a), and wherein the first inlet opening (13a) and the first outlet opening (13'a) of a given plate pair of the second type (60) are sealed from the second inlet opening (13b), the second outlet opening (13'b) and the cavity (11) defined by the given plate pair of the second type (60). 5
5. A plate-and-shell heat exchanger (100) according to claim 3 or 4, wherein the first inlet opening (13a) and the first outlet opening (13'a) are formed in one of the heat transfer plates (10) of the plate pair (50, 60), and the second inlet opening (13b) and the second outlet opening (13'b) are formed in the other of the heat transfer plates (10) of the plate pair (50, 60). 10
6. A plate-and-shell heat exchanger (100) according to any of the preceding claims, wherein the plate pairs of the first type (50) and the plate pairs of the second type (60) are identical, and rotated at an angle relative to each other around a centre axis of the plate pairs (50, 60). 15
7. A plate-and-shell heat exchanger (100) according to any of the preceding claims, wherein the plate pairs of the first type (50) and the plate pairs of the second type (60) are arranged alternately in the stack of plate pairs (50, 60). 20
8. A plate-and-shell heat exchanger (100) according to any of the preceding claims, wherein the heat transfer plates (10) forming the plate pairs of the first type (50) and/or the heat transfer plates (10) forming the plate pairs of the second type (60) are identical, and rotated 180° around a centre axis of the plate pairs (50, 60). 25
9. A plate-and-shell heat exchanger (100) according to any of the preceding claims, wherein the plate pairs (50, 60) have an outer shape which is circular, oval, pentagonal or hexagonal. 30
10. A plate-and-shell heat exchanger (100) according to any of the preceding claims, wherein the first inlet openings (13a) and the first outlet openings (13'a) of the plate pairs of the first type (50) are connected by connection elements (45), and the second inlet openings (13b) and the second outlet openings 35

(13'b) of the plate pairs of the second type (60) are connected by connection elements (45).

11. A plate-and-shell heat exchanger (100) according to any of the preceding claims, wherein the plate pairs of the first type (50) and the plate pairs of the second type (60) are sealingly connected to each other at outer rims of the inlet openings (13a, 13b) and the outlet openings (13'a, 13'b). 40
12. A plate-and-shell heat exchanger (100) according to any of the preceding claims, wherein the plate-and-shell heat exchanger (100) is connected to an electrolyzer (200) such that a fluid feed to a cathode of the electrolyzer (200), a fluid feed to an anode of the electrolyzer (200), as well as a common heating or cooling fluid passes through the plate-and-shell heat exchanger (100). 45

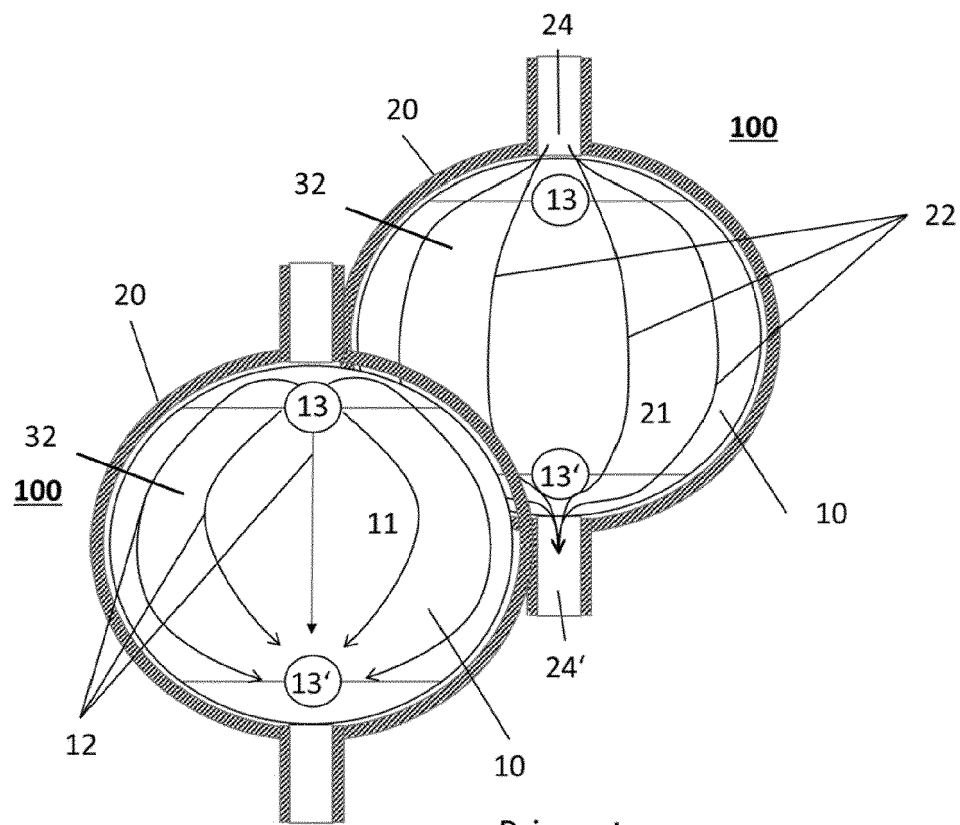




Prior art

Fig. 2B

Fig. 2A



Prior art
Fig. 3

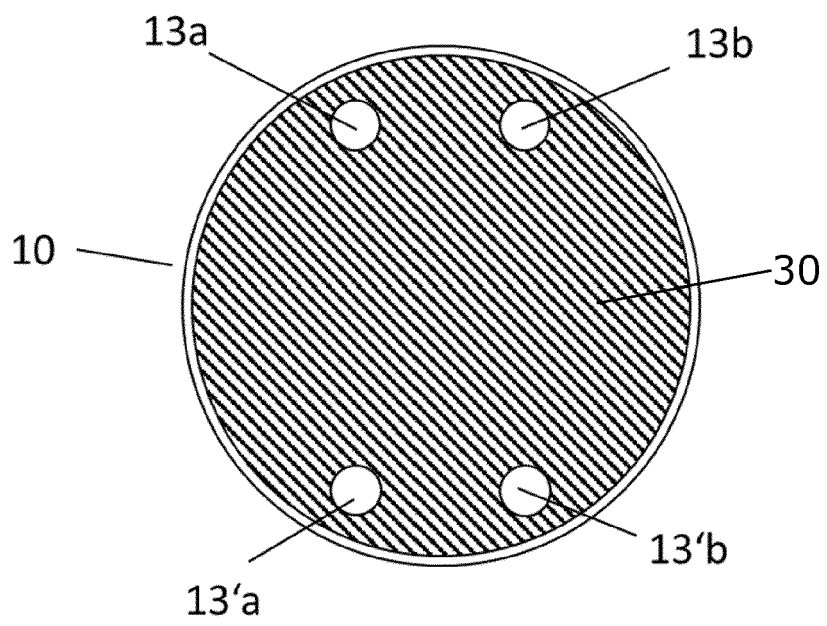
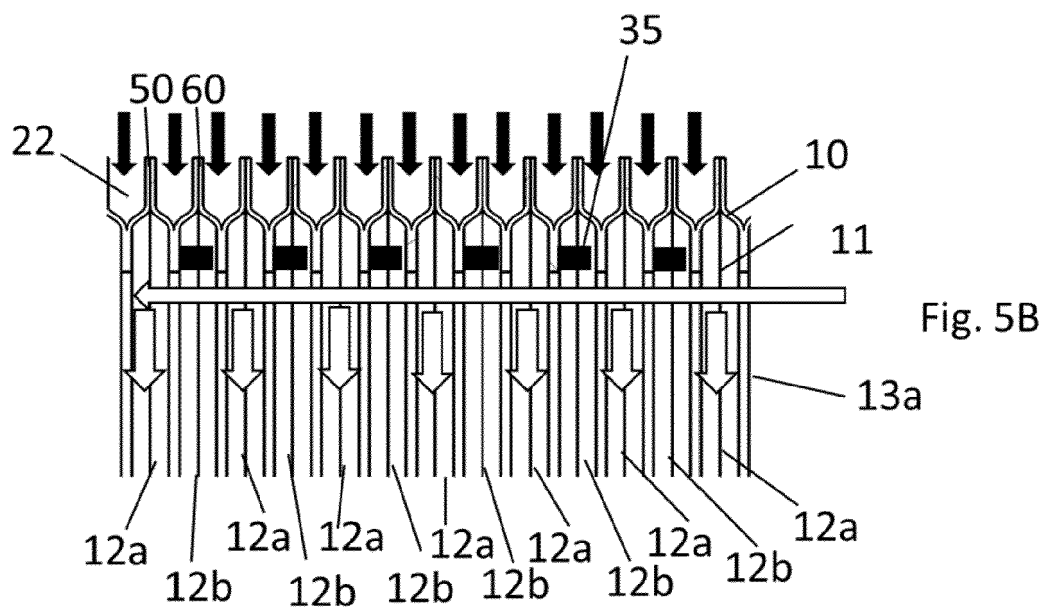
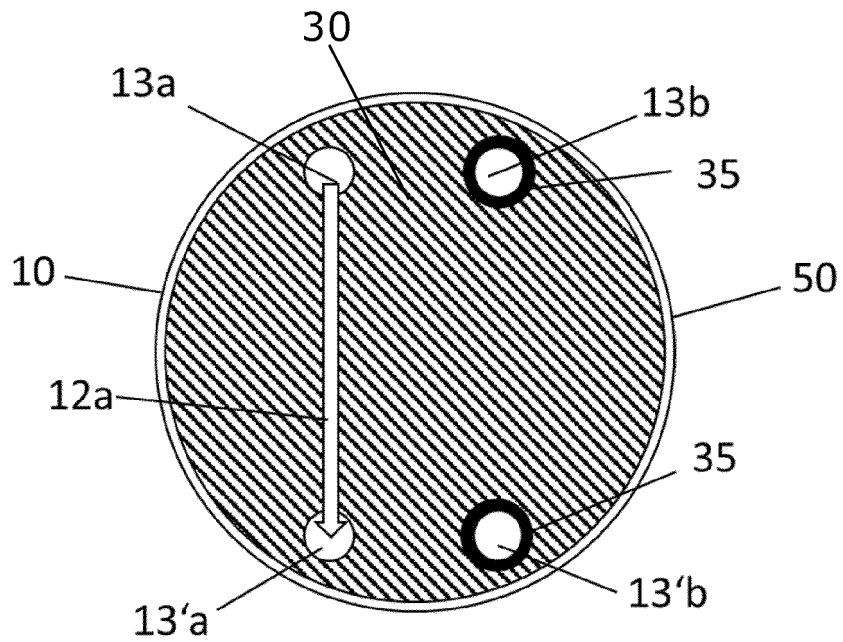


Fig. 4



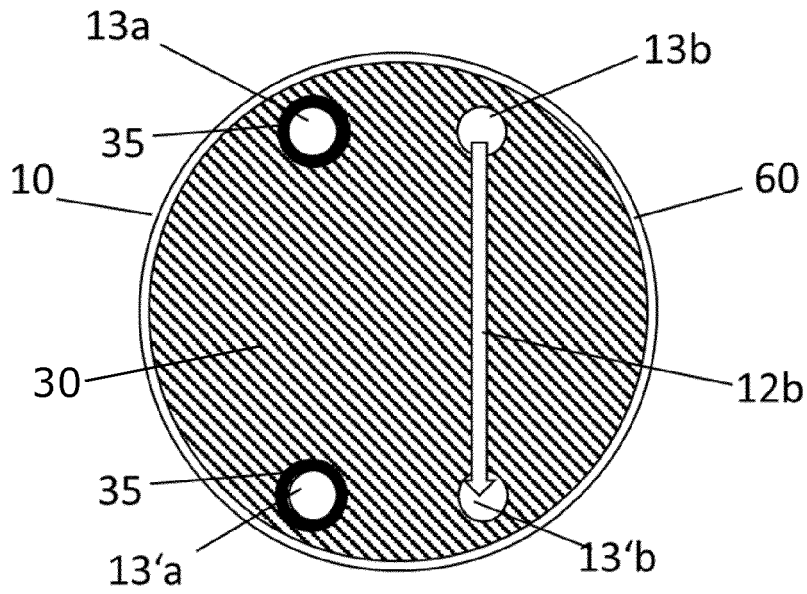


Fig. 6A

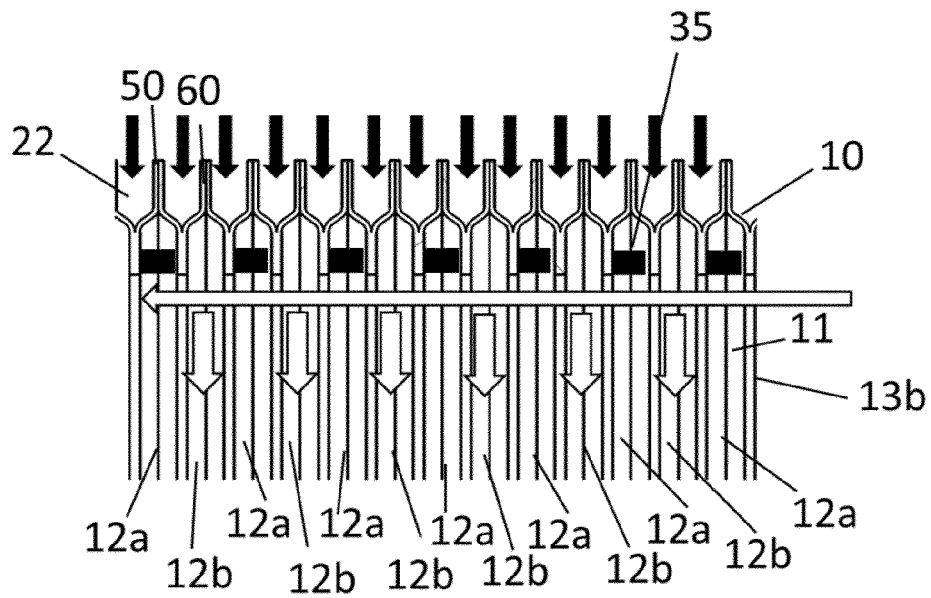


Fig. 6B

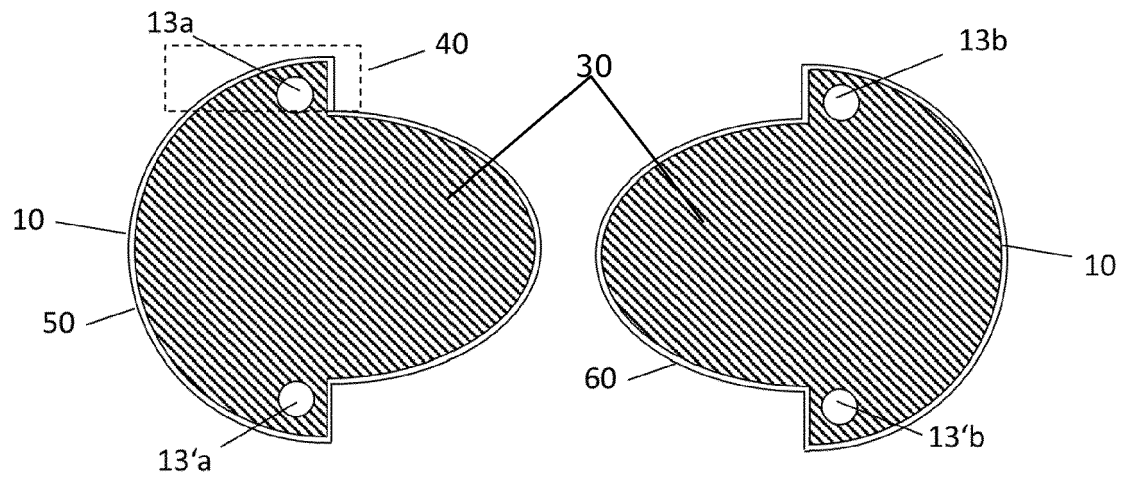


Fig. 7

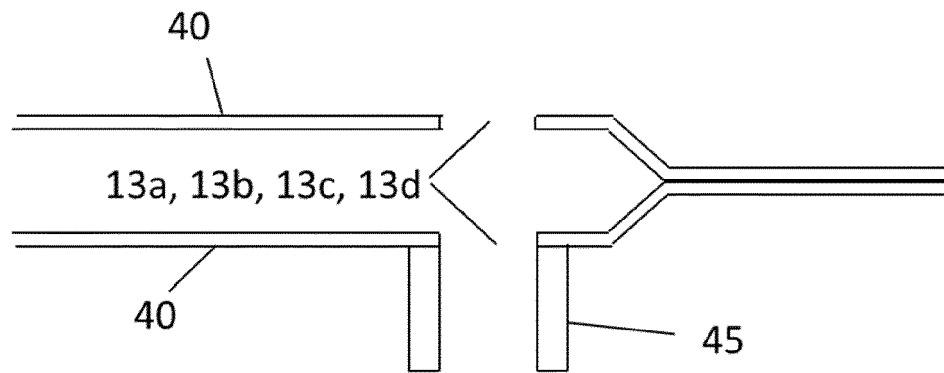


Fig. 8

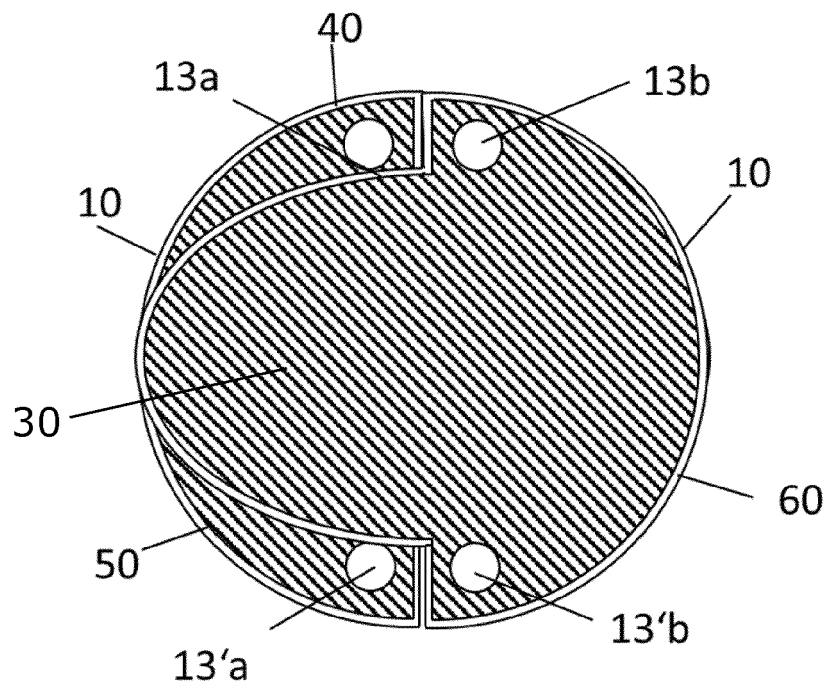


Fig. 9

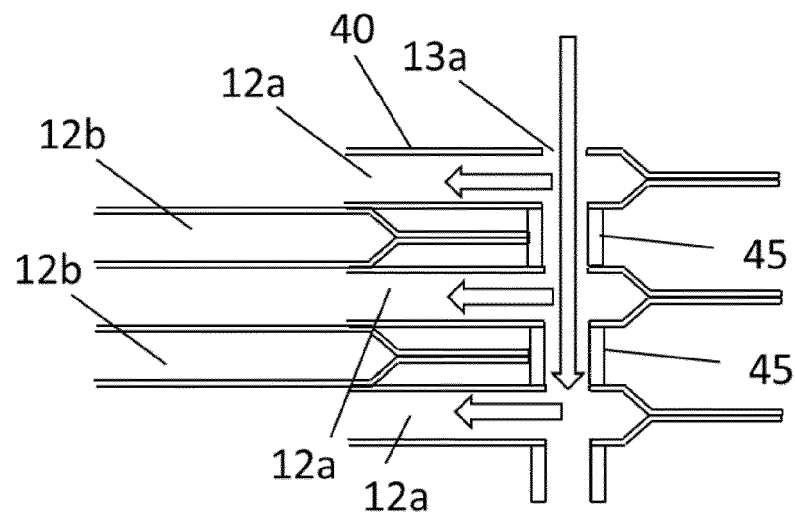


Fig. 10

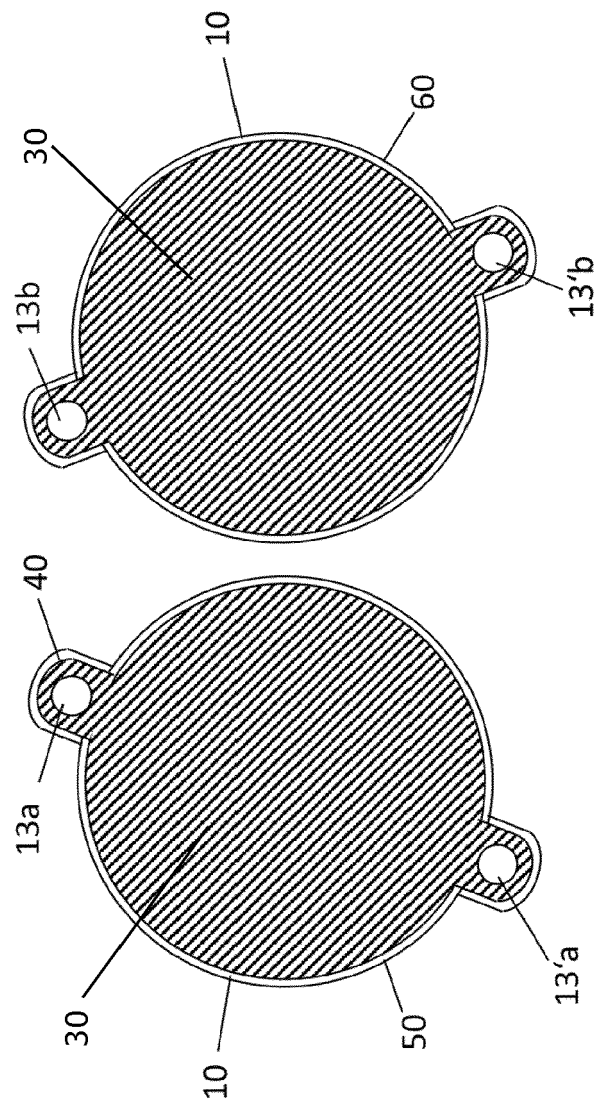


Fig. 11

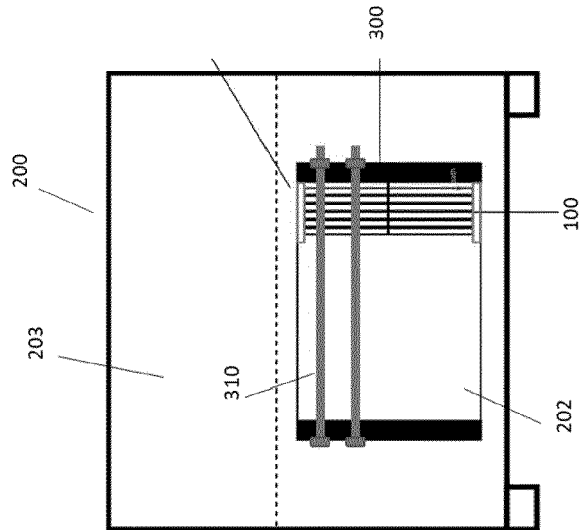
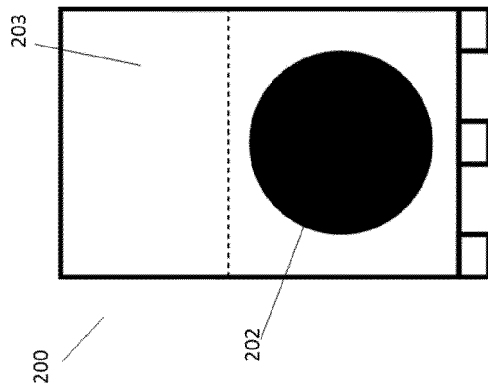


Fig. 12





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