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(54) **DEVICE, METHOD AND USE**

(57) A device (1, 2), a method for electrolysis and a use of the device to perform electrolysis are provided. The device (1,2) comprises heat transfer plates (5) defining alternately arranged first and second interspaces (I1, I2) and, within these, first and second flow channels (C1, C2). A first fluid path (P1) for conveying a first fluid through the device (1, 2) extends through the first flow channels (C1). The device is characterized in that membanes (45) are arranged in the second flow channels (C2) to divide them into second primary sub channels (C2P) and a second secondary sub channels (C2S). Further, a second fluid path (P2) for conveying the second fluid through the device (1, 2) comprises a second primary fluid path (P2p) and a second secondary fluid path (P2s). The second primary fluid path (P2p) extends into and out of the second primary sub channels (C2P) via the first interspaces (I1) outside the first flow channels (C1). The second secondary fluid path (P2s) extends into and out of the second secondary sub channels (C2S) via the first interspaces (I1) outside the first flow channels (C1).

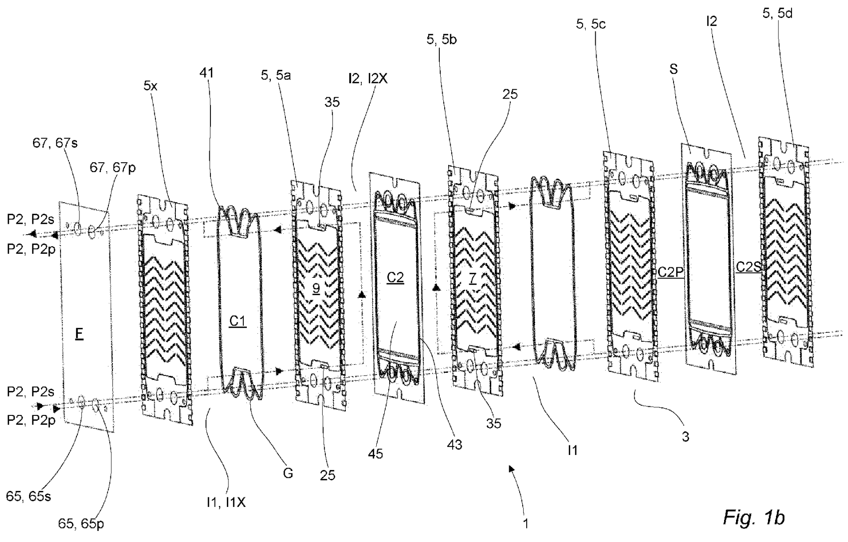

Fig. 1b

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Description

Technical Field

[0001] The invention relates to a device comprising a stack of corrugated heat transfer plates, a method for electrolysis by means of such a device and a use of such a device to perform electrolysis.

Background Art

[0002] Electrolysis is a well known process of using electricity to chemically decompose an electrolyte. For example, electrolysis can be used to split water confined in an electrolyte into hydrogen and oxygen. During electrolysis, heat may be generated, which heat may have to be diverted for maintained electrolysis efficiency.

[0003] EP 4012070 discloses a heat exchanger comprising a stack of heat transfer plates. The heat exchanger is adapted for connection to an electrolyzing device such that fluids circulating in the electrolyzing device are made to pass the heat exchanger for regulation of their temperatures. Typically, the temperature of the fluids gradually increases inside the electrolyzing device. Thus, the heat exchanger receives fluids of relatively high temperature from the electrolyzing device and delivers fluids of relatively low temperature to the electrolyzing device, which means that there will be a temperature difference across the electrolyzing device. This may result in an uneven and non-optimal electrolysis process inside the electrolyzing device. The heat exchanger in EP 4012070 is a so called plate-and-shell heat exchanger. Several other types of heat exchangers exist, for example so-called plate heat exchangers. A plate heat exchanger typically comprises a number of corrugated heat transfer plates arranged aligned in a stack or pack. Sealings between the heat transfer plates define parallel flow channels between the heat transfer plates, one flow channel between each pair of adjacent heat transfer plates. Two fluids of initially different temperatures can be fed alternately through every second flow channel for transferring heat from one fluid to the other.

Summary

[0004] An object of the present invention is to provide a reliable and mechanically uncomplicated device comprising a stack of corrugated heat transfer plates forming alternately arranged first and second plate interspaces, which device may be used for a heat generating process, such as electrolysis, and which device may allow a more uniform and effective cooling of a fluid, such as an electrolyte, and the products formed therefrom, so as to enable a maintained high process efficiency. Objects of the invention are also to provide a reliable and robust method for effective electrolysis by means of the inventive device, and to provide a reliable and robust use of the inventive device to perform effective electrolysis. The basic concept of the invention is to enable the heat generating process in the second interspaces and cooling in the first interspaces and to use the first interspaces to feed fluids into, and out of, the second interspaces.

[0005] The device, method and use may be provided for production of hydrogen.

[0006] A device according to the invention comprises a stack of corrugated heat transfer plates arranged in pairs, wherein every second one of the heat transfer plates is of a first type and the rest of the heat transfer plates are of a second type. A respective first interspace is formed between the heat transfer plates of each pair, and a first sealing within each first interspace defines a respective first flow channel. A respective second interspace is formed between each two adjacent pairs, and a second sealing within each second interspace defines a respective second flow channel. The device further comprises first inlet means for receiving a first fluid, first outlet means for discharging the first fluid, first inlet port means extending through the stack and first outlet port means extending through the stack. A first fluid path for conveying the first fluid through the device extends from the first inlet means, into the first inlet port means, through the first flow channels, into the first outlet port means and to the first outlet means. The device is characterized in that it further comprises a respective membrane arranged between each two adjacent pairs. The membrane extends essentially parallel to the heat transfer plates and within said second sealing to split each of the second flow channels in a second primary sub channel and a second secondary sub channel. The device further comprises second inlet means for receiving a second fluid, a second primary outlet for discharging a primary fraction of the second fluid, a second secondary outlet for discharging a secondary fraction of the second fluid, second inlet port means extending through the stack, a second primary outlet port extending through the stack, and a second secondary outlet port extending through the stack. A second fluid path for conveying the second fluid through the device comprises a second primary fluid path and a second secondary fluid path. The second primary fluid path extends from the second inlet means, into the second inlet port means, into the first interspaces outside the first flow channels, through a respective first transfer hole of the heat transfer plates of the second type into the second primary sub channels, through the second primary sub channels, through a respective second transfer hole of the heat transfer plates of the second type into the first interspaces outside the first flow channels, into the second primary outlet port and to the second primary outlet. The second secondary fluid path extends from the second inlet means, into the second inlet port means, into the first interspaces outside the first flow channels, through a respective second transfer hole of the heat transfer plates of the first type into the second secondary sub channels, through the second secondary sub channels, through a respective first transfer hole of the heat transfer plates of the first type into the first inter-

spaces outside the first flow channels, into the second secondary outlet port and to the second secondary outlet.

[0007] Due to the provision of the first and second transfer holes in the heat transfer plates the second fluid may be fed to opposite sides of the membranes, i.e. into the second primary and the second secondary sub channels within the second plate interspaces, via the first plate interspaces instead of, for example, through the second sealings defining the second flow channels. This enables robust, compact and a mechanically relatively straight forward construction of the device.

[0008] The provision of the membranes in the second flow channels may enable a heat generating process, such as electrolysis, within the second channels. At the same time, the device may function as a traditional heat exchanger allowing heat exchange between the first fluid flowing in the first flow channels and the second fluid flowing in the second channels, for example cooling of the second fluid by means of the first fluid. Thus, cooling may be "integrated" in the heat generating process to ensure effective and sufficient cooling for a maintained and high process efficiency.

[0009] The heat transfer plates of the first type may be different from the heat transfer plates of the second type. Alternatively, the heat transfer plates of the first type and the heat transfer plates of the second type may be similar which means that all the heat transfer plates in the stack are similar. Such an embodiment may enable a cost efficient and structurally relatively uncomplicated device which offers an easy handling.

[0010] In a plate stack, every second one of the heat transfer plates may be rotated, in relation to the rest of the plates, 180 degrees around a respective axis normal to the heat transfer plate. Typically, this is referred to as the heat transfer plates being rotated in relation to each other.

[0011] Alternatively, in a plate stack, every second one of the heat transfer plates may be rotated, in relation to the rest of the plates, 180 degrees around a respective transverse center axis of the heat transfer plate. Typically, this is referred to as the heat transfer plates being flipped in relation to each other.

[0012] The device may be so constructed that the second inlet means comprises a second primary inlet and a second secondary inlet, and the second inlet port means comprises a second primary inlet port and a second secondary inlet port. Then, the second primary fluid path extends from the second primary inlet, into the second primary inlet port, into the first interspaces outside the first flow channels, through the heat transfer plates of the second type into the second primary sub channels, through the second primary sub channels, through the heat transfer plates of the second type into the first interspaces outside the first flow channels, into the second primary outlet port and to the second primary outlet. Further, the second secondary fluid path extends from the second secondary inlet, into the second secondary inlet port, into the first interspaces outside the first flow channels, through the heat transfer plates of the first type into the second secondary sub channels, through the second secondary sub channels, through the heat transfer plates of the first type into the first interspaces outside the first flow channels, into the second secondary outlet port and to the second secondary outlet. In this embodiment the second primary fluid path and the second secondary fluid path are kept separate all the way through the device. Further, this embodiment may enable, at least partly, symmetrically designed heat transfer plates and a stack comprising heat transfer plates which are rotated or flipped in relation to each other. Further, this embodiment may enable a relatively uniform fluid distribution inside the device.

[0013] The device may be so constructed that the first inlet means comprises a first primary inlet and a first secondary inlet, the first outlet means comprises a first primary outlet and a first secondary outlet, the first inlet port means comprises a first primary inlet port and a first secondary inlet port, and the first outlet port means comprises a first primary outlet port and a first secondary outlet port. Further, the first fluid path may comprise a first primary fluid path and a first secondary fluid path. The first primary fluid path may extend from the first primary inlet, into the first primary inlet port, through the first flow channels, into the first primary outlet port and to the first primary outlet. The first secondary fluid path may extending from the first secondary inlet, into the first secondary inlet port, through the first flow channels, into the first secondary outlet port and to the first secondary outlet. According to this embodiment there are two flows of the first fluid through the device. If the first fluid is a cooling fluid, this embodiment may enable a more efficient cooling of the second fluid.

[0014] The device may be such that the first inlet port means and the first outlet port means are arranged further away from a longitudinal center plane of the device than the second inlet port means, the second primary outlet port and the second secondary outlet port. Further, the longitudinal center plane of the device may extend between the second primary outlet port and the second secondary outlet port. If the first fluid is a cooling fluid, and the first inlet port means comprises a first primary inlet port and a first secondary inlet port, and the first outlet port means comprises a first primary outlet port and a first secondary outlet port, this embodiment may enable a relatively even cooling fluid distribution and a more efficient cooling of the second fluid.

[0015] Alternatively, the device may be such that the second inlet port means, the second primary outlet port and the second secondary outlet port are arranged further away from a longitudinal center plane of the device than the first inlet port means and the first outlet port means. Further, the longitudinal center plane of the device may extend between the second primary outlet port and the second secondary outlet port. If the first fluid is a cooling fluid, and the first inlet port means comprises a single inlet port and the first outlet port means comprises a single outlet port, this embodiment may enable a more efficient cooling of the second fluid.

[0016] Each of the first sealings within the first interspaces defining the first flow channels may be a permanent binding, such as a weld, of the adjacent heat transfer plates. Alternatively, the device may be so designed that each of the first sealings comprises a first annular field gasket part. Similarly, each of the second sealings within the second interspaces defining the second flow channels may be a permanent binding, such as a weld, of the adjacent heat transfer plates. Alternatively, the device may be so designed that each of the second sealings comprises a second annular field gasket part. If the first sealings comprise first annular field gasket parts and the second sealings comprise second annular field gasket parts, the device may be of so-called gasketed type. If the first sealings comprise welds and the second sealings comprise second annular field gasket parts, or the second sealings comprise welds and the first sealings comprise first annular field gasket parts, the device may be of so-called semi-welded type. Gaskets as sealings may allow non-destructive and simple disassembly of the device which, in turn, may facilitate maintenance and cleaning of the device.

[0017] The device may be so constructed that heat transfer plates of each pair abut each other. Such an embodiment may allow for the abutting heat transfer plates to contact and thus support each other within discrete contact areas distributed across the heat transfer plates, which may improve the strength of the stack of heat transfer plates.

[0018] The device may be so constructed that each two adjacent pairs of the heat transfer plates are separated from each other. Such an embodiment may allow for adjacent plate pairs to be insulated from each other which may enable certain processes, such as electrolysis, to be performed within the second flow channels.

[0019] A method according to the invention is for performing electrolysis by means of a device comprising a stack of corrugated heat transfer plates arranged in pairs. Every second one of the heat transfer plates is of a first type and the rest of the heat transfer plates are of a second type. A respective first interspace is formed between the heat transfer plates of each pair, and a first sealing within each first interspace defines a respective first flow channel. A respective second interspace is formed between each two adjacent pairs, and a second sealing within each second interspace defines a respective second flow channel. The device further comprises a respective membrane arranged between each two adjacent pairs. The membrane extends essentially parallel to the heat transfer plates and within said second sealing to split each of the second flow channels in a second primary sub channel and a second secondary sub channel. The method comprises the steps of

applying a current to the stack of heat transfer plates to make every second one of the heat transfer plates an anode and the rest of the heat transfer plates a cathode,

feeding a first fluid comprising a cooling fluid through the first flow channels,

feeding a second fluid comprising water into the first interspaces outside the first flow channels,

feeding a first part of the second fluid through a respective first transfer hole of the heat transfer plates of the second type into the second primary sub channels,

feeding a second part of the second fluid through a respective second transfer hole of the heat transfer plates of the first type into the second secondary sub channels,

feeding the second fluid through the second flow channels to split water into hydrogen and oxygen and form, of the second fluid, a primary fraction in the second primary sub channels and a secondary fraction in the second secondary sub channels, one of the primary fraction and the secondary fraction containing more oxygen and less hydrogen than the other one of the primary fraction and the secondary fraction,

feeding the primary fraction of the second fluid through a respective second transfer hole of the heat transfer plates of the second type into the first interspaces outside the first flow channels, and

feeding the secondary fraction of the second fluid through a respective first transfer hole of the heat transfer plates of the first type into the first interspaces outside the first flow channels.

[0020] The steps of the method may or may not be performed in the order given above.

[0021] A use of a device according to the present invention is to perform electrolysis.

[0022] The above discussed advantages of the different embodiments of the device according to the invention are also present for corresponding different embodiments of the method and use according to the present invention.

[0023] Still other objectives, features, aspects and advantages of the invention will appear from the following detailed description as well as from the drawings.

Brief Description of the Drawings

[0024] The invention will now be described in more detail with reference to the appended schematic drawings, in which

Figs. 1a and 1b are essentially similar perspective views schematically illustrating a part of a device according to the invention in a disassembled state, and different fluid paths through the device,

Fig. 2 is a schematic plan view of a heat transfer plate of the device in Fig. 1a,

Fig. 3 is a schematic plan view of a part of the device in Fig. 1a ,

Fig. 4 is a schematic plan view of a part of the device in Fig. 1a,

Figs. 5a and 5b are essentially similar perspective views schematically illustrating a part of a device according to another embodiment of the invention in a disassembled state, and different fluid paths through the device,

Fig. 6 is a schematic plan view of a heat transfer plate of the device in Fig. 5a,

Fig. 7 is a schematic plan view of a part of of the device in Fig. 5a, and

Fig. 8 is a schematic plan view of a part of the device in Fig. 5a.

Detailed Description

[0025] Fig. 1a illustrates a part of a device 1 used for producing hydrogen through electrolysis, here alkaline water electrolysis. The device 1 comprises a stack 3 (only partly illustrated) of heat transfer plates 5 of first and second types which each has a front side 7 and an opposing back side 9. In the stack 3, the heat transfer plates 5 are flipped in relation to each other, i.e. arranged front side 7 to front side 7 and back side 9 to back side 9 with every second one of the heat transfer plates 5 turned upside down with respect to the rest of the heat transfer plates 5. This means that every second one of the heat transfer plates 5 is rotated 180 degrees around a respective heat transfer plate longitudinal center axis L, and then rotated 180 degrees around a respective heat transfer plate normal axis N (Fig. 2), with respect to the rest of the heat transfer plates 5.

[0026] One of the heat transfer plates 5 is separately illustrated in Fig. 2 and described in further detail below. It has a first end portion 11, a center portion 13 and a second end portion 15 arranged in succession along the longitudinal center axis L of the heat transfer plate 5, which longitudinal center axis L extends perpendicular to a transverse center axis T of the heat transfer plate 5. The first end portion 11 comprises a first porthole 17, a third porthole 19, a fifth porthole 21, a seventh porthole 23 and a first transfer hole 25, while the second end portion 15 comprises a second porthole 27, a fourth porthole 29, a sixth porthole 31, an eighth porthole 33 and a second transfer hole 35. Every second one of the heat transfer plates 5 in the stack 3 is of the first type illustrated in figure 2, while the rest of the heat transfer plates 5 in the stack 3 are of the second type which is similar to the first type except for that it has the first and second transfer holes 25 and 35 arranged on the opposite side of the longitudinal center axis L.

[0027] As heat transfer plates normally are, the heat transfer plate 5 is pressed with corrugation patterns of ridges and valleys in relation to a respective central extension plane of the heat transfer plate 5, which central extension plane is parallel to the figure plane of Fig. 2. The corrugation patterns within different areas of the heat transfer plate 5 are different. For example, the center portion 13 is pressed with a corrugation pattern of so-called herringbone type. As another example, an edge portion 37 of the heat transfer plate 5 is pressed with alternately arranged ridges and valleys extending from an outer edge 39 of the heat transfer plate 5.

[0028] With reference again to Fig. 1a, the stack 3 of heat transfer plates 5 is arranged between two frame plates F, of which only one is illustrated. The heat transfer plates 5 within the stack 3 are arranged in pairs, wherein heat transfer plates 5b and 5c form one of these pairs, while heat transfer plate 5d forms one of the heat transfer plates of another adjacent one of these pairs. The heat transfer plates of each pair form between them a first interspace 11. Further, a second interspace I2 is formed between each two adjacent pairs of heat transfer plates 5. An outer heat transfer plate 5x, which is similar to the heat transfer plates 5 except for that it lacks the first and second transfer holes 25 and 35, is arranged between the stack 3 and the frame plate F visible in Fig. 1a to form an additional first interspace 11, denoted I1X, as well as a plate pair, with the heat transfer plate 5a. An additional second interspace I2, denoted I2X, is thus formed between the heat transfer plate 5a and the heat transfer plate 5b. An outer heat transfer plate completely lacking holes may be arranged between the stack 3 and the other frame plate which is not visible in Fig. 1a. Further, gaskets, which are not illustrated, may be arranged on the inside of the frame plates F.

[0029] A first sealing 41 in the form of a first annular field gasket part is arranged within each of the first interspaces 11 to define a first flow channel C1 therein. A second sealing 43 in the form of a second annular field gasket part is arranged within each of the second interspaces I2 to define a second flow channel C2 therein. A separation means, which closes a second field gasket area enclosed by the second sealing 43, comprises a hydroxide ion permeable membrane 45, for example made of polyphenylene sulfide fabric which is symmetrically coated with a mixture of a polymer and zirconium oxide. The membrane 45 extends within the second sealing 43 and essentially parallel to the heat transfer plates 5 to split the corresponding second flow channel C2 in a second primary sub channel C2P and a second secondary sub channel C2S, which sub channels are parallel and extend on opposite sides of the membrane 45.

[0030] With reference to Fig. 3, the first sealing 41 is part of a gasket arrangement G which also comprises four first annular ring gasket parts 47 formed integrally with the first sealing 41, i.e. the first annular field gasket part. With reference to Fig. 4, the second sealing 43 and separation means comprising the membrane 45 (not illustrated in Fig. 4) are parts of a sealing arrangement S which also comprises eight second annular ring gasket parts 49 and an insulating outer sheet 51 connecting the second sealing 43, i.e. the second annular field gasket part, and the second annular ring gasket parts 49.

[0031] When the device 1 is ready for use, the heat transfer plates 5 and the interposed gasket arrangements G and the sealing arrangements S are compressed between the frame plates F so as to form the first and second flow channels C1 and C2 and also port means for conveying first and second fluids through the device 1. Compressed like that, the heat transfer plates 5 of each of the pairs, such as the heat transfer plates 5b and 5c, abut each other in contact areas, while contact between adjacent pairs of heat transfer plates 5, such as the heat transfer plates 5c and 5d, is prevented by the presence of the sealing arrangements S between the plate pairs. This separation or insulation between the plate pairs is necessary for the device 1 to work properly for electrolysis, which will be further discussed below. The compression is achieved by some kind of tightening means, such as bolts and nuts, which are not illustrated or further described herein. With reference to Fig. 3 which illustrates the heat transfer plates of the device 1 of which only the heat transfer plate 5a is visible, the port means comprise first inlet port means 53 and first outlet port means 55 for the first fluid and second inlet port means 57 and second outlet port means 59 for the second fluid. In turn, the first inlet port means 53 comprises a first primary inlet port 53p and a first secondary inlet port 53s, the first outlet port means 55 comprises a first primary outlet port 55p and a first secondary outlet port 55s, the second inlet port means 57 comprises a second primary inlet port 57p and a second secondary inlet port 57s, and the second outlet port means 59 comprises a second primary outlet port 59p and a second secondary outlet port 59s.

[0032] With reference to Fig. 1a, the first fluid, which is a cooling fluid, for example deionized water, is fed into the device 1 via first inlet means 61 and out of the device 1 via first outlet means 63. The first inlet means 61 comprises a first primary inlet 61p and a first secondary inlet 61s, while the first outlet means 63 comprises a first primary outlet 63p and a first secondary outlet 63s. With reference to Fig. 1b, the second fluid, which is an electrolyte, for example a mixture of water and an alkaline agent, such as potassium hydroxide, is fed into the device 1 via second inlet means 65 and out of the device 1 via second outlet means 67. The second inlet means 65 comprises a second primary inlet 65p and a second secondary inlet 65s, while the second outlet means 67 comprises a second primary outlet 67p and a second secondary outlet 67s.

[0033] A first fluid path P1 for conveying the first fluid through the device 1 comprises a first primary fluid path P1p and a first secondary fluid path P1s. With reference to Figs. 1a and 3, and the dashed lines, the first primary fluid path P1p extends from the first primary inlet 61p, into the first primary inlet port 53p, through the first flow channels C1, into the first primary outlet port 55p and to the first primary outlet 63p. The first secondary fluid path P1s extends from the first secondary inlet 61s, into the first secondary inlet port 53s, through the first flow channels C1, into the first secondary outlet port 55s and to the first secondary outlet 63s. A second fluid path P2 for conveying the second fluid through the device 1 comprises a second primary fluid path P2p and a second secondary fluid path P2s. With reference to Figs.1b and 3, and the dashed lines, the second primary fluid path P2p extends from the second primary inlet 65p, into the second primary inlet port 57p, into the first interspaces I1 outside the first flow channels C1, through the respective first transfer hole 25 of every second one of the heat transfer plates, i.e. plates 5a, 5c,..., into the second primary sub channels C2P, through the second primary sub channels C2P, through the respective second transfer hole 35 of every second one of the heat transfer plates, i.e. plates 5a, 5c..., into the first interspaces I1 outside the first flow channels C1, into the second primary outlet port 59p and to the second primary outlet 67p. The second secondary fluid path P2s extends from the second secondary inlet 65s, into the second secondary inlet port 57s, into the first interspaces I1 outside the first flow channels C1, through the respective second transfer hole 35 of every second one of the heat transfer plates, i.e. plates 5b, 5d,..., into the second secondary sub channels C2S, through the second secondary sub channels C2S, through the respective first transfer hole 25 of every second one of the heat transfer plates, i.e. plates 5b, 5d,..., into the first interspaces I1 outside the first flow channels C1, into the second secondary outlet port 59s and to the second secondary outlet 67s.

[0034] With reference again to Fig. 3, the first fluid, i.e. the cooling fluid, is conveyed through the device 1 in the ports 53s, 53p, 55s and 55p, while the second fluid, i.e. the electrolyte, is conveyed through the device 1 in the ports 57p, 57s, 59p and 59s. The ports 53s, 53p, 55s and 55p are arranged on a larger distance from a longitudinal center plane P of the device 1 than the ports 57p, 57s, 59p and 59s. This means that the cooling fluid is conveyed on the outside of the electrolyte.

[0035] Thus, a method for electrolysis is performed by means of the device 1. The method comprises the step of applying a current to the device 1 to turn every second one of the heat transfer plate of the device 1, including the heat transfer plates 5a and 5c, into anodes and the rest of the heat transfer plates of the device 1, including the heat transfer plates 5b and 5d, into cathodes. As mentioned above, sealing arrangements S insulating between the heat transfer plates 5 are arranged in the second interspaces I2 of the device 1, i.e. between the heat transfer plates 5a and 5b, and between the heat transfer plates 5c and 5d, etc., and split the second flow channels C2 into second primary sub channels C2P and second secondary sub channels C2S. Thereby, electrolysis may be performed within the second flow channels C2 of the device 1.

[0036] As described above, there are two fluid paths for the second fluid, i.e. the electrolyte, through the device 1. Accordingly, the method comprises the step of feeding a first part of the second fluid into the the first interspaces I1 outside the first flow channels C1 and through the first transfer holes 25 of the heat transfer plates 5a, 5c, etc., into the second primary sub channels C2P, and feeding a second part of the second fluid into the first interspaces I1 outside the first flow channels C1 and through the second transfer holes 35 of the heat transfer plates 5b, 5d, etc., into the second secondary sub channels C2S. Further, the method comprises the step of feeding the first and second parts of the second fluid through the second flow channels C2, whereby water in the electrolyte is split into hydrogen and oxygen and a primary fraction is formed in the second primary sub channels C2P and a secondary fraction is formed in the second secondary sub channels C2S, the primary fraction containing more oxygen and less hydrogen than the second fraction. The primary fraction of the second fluid is fed through the second transfer holes 35 of the heat transfer plates 5a, 5c, etc. into the first interspaces I1 outside the first flow channels C1, while the secondary fraction of the second fluid is fed through the first transfer holes 25 of the heat transfer plates 5b, 5d, etc. into the first interspaces I1 outside the first flow channels C1. The primary and secondary fractions are separately discharged from the device 1 via the second primary outlet 67p and the second secondary outlet 67s, respectively. When electrolysis is performed in the second flow channels C2, heat is generated. The method comprises the step of feeding the first fluid, i.e. the deionized water, through the first flow channels C1, i.e. on both sides of the electrolysis channels C2, to effectively and uniformly divert the heat generated through the electrolysis from the device 1.

[0037] It should be stressed that the second fluid is referred to as second fluid even if its characteristics changes when it is fed through the device, and that both the primary fraction and the secondary fraction of the second fluid are referred to as second fluid even if their separate compositions vary and differ from each other and from the original second fluid.

[0038] It should be stressed that all components necessary to make the device work properly, such as power sources, connections, wiring, control units, valves, pumps, gaskets, sensors, pipes, dosing equipment, etc., are not described herein or illustrated in the figures. Further, characteristics of the different components of the device which are not relevant to the present invention are not described or illustrated herein.

[0039] Fig. 5a illustrates a part of a device 2 according to another embodiment of the invention. There are a lot of similarities between the devices 1 and 2 and the above description is, to a large extent, valid also for the device 2. Therefore, hereinafter, the differences of the device 2 as compared to the device 1 will be focused on. The device 2 comprises a stack 3 (only partly illustrated) of heat transfer plates 5 of which one is separately illustrated in Fig. 6. A first end portion 11 of the heat transfer plate 5 comprises a first porthole 17, a third porthole 19 a fifth porthole 21 and a first transfer hole 25, while a second end portion 15 of the heat transfer plate 5 comprises a second porthole 27, a fourth porthole 29, a sixth porthole 31 and a second transfer hole 35.

[0040] With reference again to Fig. 5a, just like in the device 1, the heat transfer plates 5 of the device 2 define first interspaces I1 and second interspaces I2. A gasket arrangement G, illustrated in Fig. 7, comprising a first sealing 41 in the form of a first annular field gasket part, and four first annular ring gasket parts 47, is arranged within each of the first interspaces I1, with the first sealing 41 defining a first flow channel C1 therein. A sealing arrangement S, illustrated in Fig. 8, comprising a second sealing 43 in the form of a second annular field gasket part, six second annular ring gasket parts 49, a connecting insulating outer sheet 51 and a separation means comprising a membrane 45, is arranged within each of the second interspaces I2, with the second sealing part 43 defining a second flow channel C2 therein. The membrane 45 splits the corresponding second flow channel C2 in a second primary sub channel C2P and a second secondary sub channel C2S.

[0041] The device 2 comprises port means for conveying first and second fluids through the device 2. With reference to Fig. 7, the port means comprise first inlet port means 53 and first outlet port means 55 for the first fluid and second inlet port means 57 and second outlet port means 59 for the second fluid. Here, the first inlet port means 53 do not comprise first primary and secondary inlet ports, but only one single inlet port. Similarly, here, the first outlet port means 55 do not comprise first primary and secondary outlet ports, but only one single outlet port. However, the second inlet port means 57 comprises a second primary inlet port 57p and a second secondary inlet port 57s, and the second outlet port means 59 comprises a second primary outlet port 59p and a second secondary outlet port 59s.

[0042] With reference to Fig. 5a, the first fluid is fed into the device 2 via first inlet means 61 and out of the device 2 via first outlet means 63. Here, the first inlet means 61 do not comprise first primary and secondary inlets, but only one single inlet. Similarly, here, the first outlet means 63 do not comprise first primary and secondary outlets, but only one single outlet. With reference to Fig. 5b, the second fluid is fed into the device 2 via second inlet means 65 and out of the device 1 via second outlet means 67. The second inlet means 65 comprises a second primary inlet 65p and a second secondary inlet 65s, while the second outlet means 67 comprises a second primary outlet 67p and a second secondary outlet 67s.

[0043] There is one single first fluid path P1 for conveying the first fluid through the device 2. With reference to Figs. 5a and 7, and the dashed lines, the first fluid path P1 extends from the first inlet 61, into the first inlet port 53, through the first flow channels C1, into the first outlet port 55 and to the first outlet 63. A second fluid path P2 for conveying the second fluid through the device 1 comprises a second primary fluid path P2p and a second secondary fluid path P2s. With reference to Figs. 5b and 7, and the dashed lines, the second primary fluid path P2p extends from the second primary inlet 65p, into the second primary inlet port 57p, into the first interspaces I1 outside the first flow channels C1, through the respective first transfer hole 25 of every second one of the heat transfer plates, i.e. plates 5a, 5c,..., into the second primary sub channels C2P, through the second primary sub channels C2P, through the respective second transfer hole 35 of every second one of the heat transfer plates, i.e. plates 5a, 5c..., into the first interspaces I1 outside the first flow channels C1, into the second primary outlet port 59p and to the second primary outlet 67p. The second secondary fluid path P2s extends from the second secondary inlet 65s, into the second secondary inlet port 57s, into the first interspaces I1 outside the first flow channels C1, through the respective second transfer hole 35 of every second one of the heat transfer plates, i.e. plates 5b, 5d,..., into the second secondary sub channels C2S, through the second secondary sub channels C2S, through the respective first transfer hole 25 of every second one of the heat transfer plates, i.e. plates 5b, 5d,..., into the first interspaces I1 outside the first flow channels C1, into the second secondary outlet port 59s and to the second secondary outlet 67s.

[0044] With reference again to Fig. 7, the first fluid is conveyed through the device 2 in the ports 53 and 55, while the second fluid is conveyed through the device 2 in the ports 57p, 57s, 59p and 59s. The ports 57p, 57s, 59p and 59s are arranged on a larger distance from a longitudinal center plane P of the device 2 than the ports 53 and 55. This means that the second fluid is conveyed on the outside of the first fluid.

[0045] The above described embodiments of the present invention should only be seen as examples. A person skilled in the art realizes that the embodiments discussed can be varied in a number of ways without deviating from the inventive conception.

[0046] As an example, the heat transfer plates of the device need not be of two different types but may be of one, three, or even more, different types.

[0047] The heat transfer plates of the device need not be flipped in relation to each other like in the embodiments described above, but could instead be rotated in relation to each other. More particularly, the heat transfer plates could be arranged front side to back side, with every second one of the heat transfer plates turned upside down with respect to the rest of the heat transfer plates.

[0048] Other electrolytes than a mixture of water and potassium hydroxide may be used as the second fluid.

[0049] Other fluids than deionized water may be used as the first fluid, for example ordinary water or transformer oil.

[0050] The membrane may be of other types than described above, especially in devices of other types than the ones described above. As an example, the membrane may be permeable to protons or anions instead of hydroxide ions, or other ions than hydroxide ions.

[0051] In the above described embodiments, contact between adjacent pairs of heat transfer plates is prevented by the presence of the sealing arrangements between the plate pairs, which sealing arrangements comprises insulating outer sheets connecting the second annular field gasket part and the second annular ring gasket parts. In alternative embodiments, the insulating outer sheets could be omitted and the heat transfer plates could instead be suitably locally coated with insulating material to prevent contact between adjacent pairs of heat transfer plates.

[0052] In the above described embodiment, the heat transfer plates 5a and 5c, etc., function as anodes while the heat transfer plates 5b and 5d, etc., function as cathodes, so as to produce a primary fraction containing more oxygen and less hydrogen than the secondary fraction. In an alternative embodiment, the heat transfer plates 5a and 5c, etc., could instead function as cathodes while the heat transfer plates 5b and 5d, etc., could function as anodes so as to produce a secondary fraction containing more oxygen and less hydrogen than the primary fraction.

[0053] In the above described embodiments, the device comprises six or eight ports for conveying the first and second fluids through the device. The device may comprise more or less ports, even an odd number of ports, for example in embodiments where the second inlet port means do not comprise second primary and secondary inlet ports, like in the above described embodiments, but one single second inlet port only communicating with the second primary and secondary outlet ports.

[0054] In the above described embodiments, the first fluid flows from top to bottom in the first flow channels while the second fluid flows from bottom to top in the second flow channels. In other embodiments, it may be the other way around, or both the first fluid and the second fluid may flow, in the first flow channels and the second flow channels, respectively, in the same direction.

[0055] The device may be used for another type of electrolysis than alkaline water electrolysis, for example chlor-alkali electrolysis. Further, the device may be used for other applications than electrolysis, for example as a fuel cell.

[0056] It should be stressed that the attributes first, second, third, ... , primary, secondary, and A, B, C, ... , etc. are used herein just to distinguish between species and not to express any kind of mutual order between, or attribute any special characteristics to, the species.

[0057] It should be stressed that "receiving", "feeding", "communicating" etc., throughout the text, means "receiving directly or indirectly" and "feeding directly or indirectly" and "communicating directly or indirectly", respectively.

[0058] It should be stressed that a description of details not directly relevant to the present invention has been omitted and that the figures are just schematic and not drawn according to scale. It should also be said that some of the figures have been more simplified than others. Therefore, some components may be illustrated in one figure but left out on another figure.

Claims

1. A device (1, 2) comprising a stack (3) of corrugated heat transfer plates (5) arranged in pairs, wherein every second one of the heat transfer plates (5) is of a first type and the rest of the heat transfer plates (5) are of a second type, a respective first interspace (I1) being formed between the heat transfer plates (5) of each pair, a first sealing (41) within each first interspace (I1) defining a respective first flow channel (C1), a respective second interspace (I2) being formed between each two adjacent pairs, and a second sealing (43) within each second interspace (I2) defining a respective second flow channel (C2), the device (1, 2) further comprising first inlet means (61) for receiving a first fluid, first outlet means (63) for discharging the first fluid, first inlet port means (53) extending through the stack (3) and first outlet port means (55) extending through the stack (3), a first fluid path (P1) for conveying the first fluid through the device (1, 2) extending from the first inlet means (61), into the first inlet port means (53), through the first flow channels (C1), into the first outlet port means (55) and to the first outlet means (63), **characterized in that** the device (1, 2) further comprises a respective membrane (45) arranged between each two adjacent pairs, which membrane (45) extends essentially parallel to the heat transfer plates (5) and within said second sealing (43) to split each of the second flow channels (C2) in a second primary sub channel (C2P) and a second secondary sub channel (C2S), wherein the device (1, 2) further comprises second inlet means (65) for receiving a second fluid, a second primary outlet (67p) for discharging a primary fraction of the second fluid, a second secondary outlet (67s) for discharging a secondary fraction of the second fluid, second inlet port means (57) extending through the stack (3), a second primary outlet port (59p) extending through the stack, and a second secondary outlet port (59s) extending through the stack, a second fluid path (P2) for conveying the second fluid through the device (1, 2) comprising a second primary fluid path (P2p) and a second secondary fluid path (P2s), the second primary fluid path (P2p) extending from the second inlet means (65), into the second inlet port means (57), into the first interspaces (I1) outside the first flow channels (C1), through a respective first transfer hole (25) of the heat transfer plates (5) of the second type into the second primary sub channels (C2P), through the second primary sub channels (C2P), through a respective second transfer hole (35) of the heat transfer plates (5) of the second type into the first interspaces (I1) outside the first flow channels (C1), into the second primary outlet port (59p) and to the second primary outlet (67p), and the second secondary fluid path (P2s) extending from the second inlet means (65), into the second inlet port means (57), into the first interspaces (I1) outside the first flow channels (C1), through a respective second transfer hole (35) of the heat transfer plates (5) of the first type into the second secondary sub channels (C2S), through the second secondary sub channels (C2S), through a respective first transfer hole 235) of the heat transfer plates (5) of the first type into the first interspaces (I1) outside the first flow channels (C1), into the second secondary outlet port (59s) and to the second secondary outlet (67s).

2. A device (1, 2) according to claim 1, wherein the heat transfer plates (5) of the first type and the heat transfer plates of the second type are similar.

3. A device (1, 2) according to claim 2, wherein every second one of the heat transfer plates (5) in the stack (3) is rotated, in relation to the rest of the heat transfer plates (5), 180 degrees around a respective axis (N) normal to the heat transfer plate (5).

4. A device (1, 2) according to claim 2, wherein every second one of the heat transfer plates (5) in the stack (3) is rotated, in relation to the rest of the heat transfer plates (5), 180 degrees around a respective transverse center axis (T) of the heat transfer plate (5).

5. A device (1, 2) according according to any of the preceding claims, wherein the second inlet means (65) comprises a second primary inlet (65p) and a second secondary inlet (65s), and the second inlet port means (57) comprises a second primary inlet port (57p) and a second secondary inlet port (57s),

the second primary fluid path (P2p) extending from the second primary inlet (65p), into the second primary inlet port (57p), into the first interspaces (I1) outside the first flow channels (C1), through the heat transfer plates (5) of the second type into the second primary sub channels (C2P), through the second primary sub channels (C2P), through the heat transfer plates (5) of the second type into the first interspaces (I1) outside the first flow channels (C1), into the second primary outlet port (59p) and to the second primary outlet (67p),

and the second secondary fluid path (P2s) extending from the second secondary inlet (65s), into the second secondary inlet port (57s), into the first interspaces (I1) outside the first flow channels (C1), through the heat transfer plates (5) of the first type into the second secondary sub channels (C2S), through the second secondary sub channels (C2S), through the heat transfer plates (5) of the first type into the first interspaces (I1) outside the first flow channels (C1), into the second secondary outlet port (59s) and to the second secondary outlet (67s).

6. A device (1, 2) according to any of the preceding claims, wherein the first inlet means (61) comprises a first primary inlet (61p) and a first secondary inlet (61s), the first outlet means (63) comprises a first primary outlet (63p) and a first secondary outlet (63s), the first inlet port means (53) comprises a first primary inlet port (53p) and a first secondary inlet port (53s), and the first outlet port means (55) comprises a first primary outlet port (55p) and a first secondary outlet port (55s), the first fluid path (P1) comprising a first primary fluid path (P1p) and a first secondary fluid path (P1s), the first primary fluid path (P1p) extending from the first primary inlet (61p), into the first primary inlet port (53p), through the first flow channels (C1), into the first primary outlet port (55p) and to the first primary outlet (63p), and the first secondary fluid path (P1s) extending from the first secondary inlet (61s), into the first secondary inlet port (53s), through the first flow channels (C1), into the first secondary outlet port (55s) and to the first secondary outlet (63s).

7. A device (1) according to any of the preceding claims, wherein the first inlet port means (53) and the first outlet port means (55) are arranged further away from a longitudinal center plane (P) of the device (1, 2) than the second inlet port means (57), the second primary outlet port (59p) and the second secondary outlet port (59s), the longitudinal center plane (P) of the device (1, 2) extending between the second primary outlet port (59p) and the second secondary outlet port (59s).

8. A device (2) according to any of claims 1-6, wherein the second inlet port means (57), the second primary outlet port (59p) and the second secondary outlet port (59s) are arranged further away from a longitudinal center plane (P) of the device (2) than the first inlet port means (53) and the first outlet port means (55), the longitudinal center plane (P) of the device (2) extending between the second primary outlet port (59p) and the second secondary outlet port (59s).

9. A device (1, 2) according to any of the preceding claims, wherein said first sealing (41) comprises a first annular field gasket part.

10. A device (1, 2) according to any of the preceding claims, wherein said second sealing (43) comprises a second annular field gasket part.

11. A device (1, 2) according to any of the preceding claims, wherein the heat transfer plates (5) of each pair abut each other.

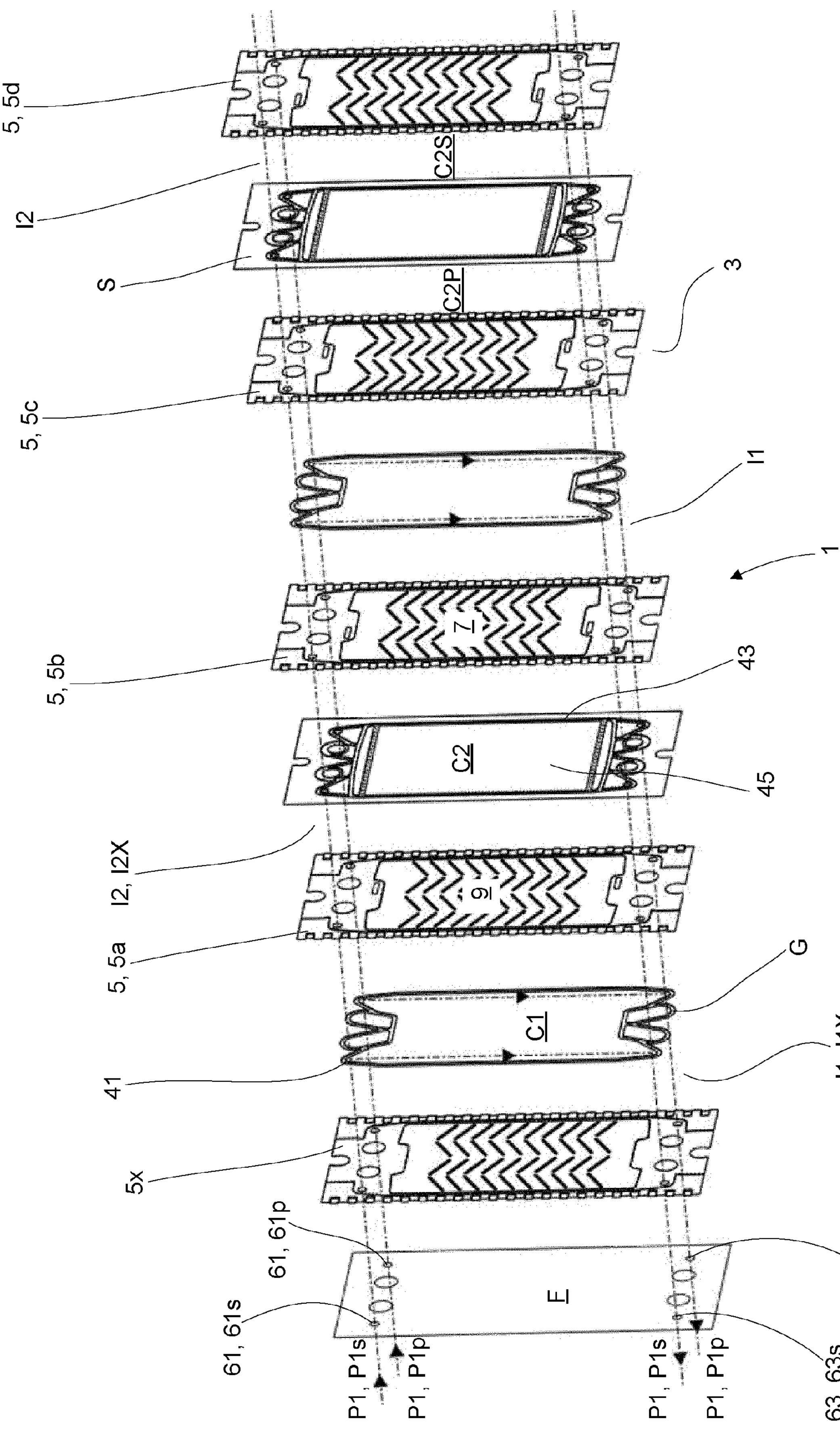
12. A device (1, 2) according to any of the preceding claims, wherein each two adjacent pairs of the heat transfer plates (5) are separated from each other.

13. A method for electrolysis by means of a device (1, 2) comprising a stack of corrugated heat transfer plates (5) arranged in pairs, wherein every second one of the heat transfer plates (5) is of a first type and the rest of the heat transfer plates (5) are of a second type, a respective first interspace (I1) being formed between the heat transfer plates (5) of each pair, a first sealing (41) within each first interspace (I1) defining a respective first flow channel (C1), a respective second interspace (I2) being formed between each two adjacent pairs, and a second sealing (43) within each second interspace (I2) defining a respective second flow channel (C2), which device (1, 2) further comprises a respective membrane (45) arranged between each two adjacent pairs, which membrane (45) extends essentially parallel to the heat transfer plates (5) and within said second sealing (43) to split each of the second flow channels (C2) in a second primary sub channel (C2P) and a second secondary sub channel (C2S), the method comprising

applying a current to the stack (3) of heat transfer plates (5) to make every second one of the heat transfer plates (5) an anode and the rest of the heat transfer plates (5) a cathode,
feeding a first fluid comprising a cooling fluid through the first flow channels (C1),
feeding a second fluid comprising water into the first interspaces (I1) outside the first flow channels (C1),
feeding a first part of the second fluid through a respective first transfer hole (25) of the heat transfer plates (5) of the second type into the second primary sub channels (C2P),
feeding a second part of the second fluid through a respective second transfer hole (35) of the heat transfer plates (5) of the first type into the second secondary sub channels (C2S),
feeding the second fluid through the second flow channels (C2) to split water into hydrogen and oxygen and form, of the second fluid, a primary fraction in the second primary sub channels (C2P) and a secondary fraction in the second secondary sub channels (C2S), one of the primary fraction and the secondary fraction containing more oxygen and less hydrogen than the other one of the primary fraction and the secondary fraction,
feeding the primary fraction of the second fluid through a respective second transfer hole (35) of the heat transfer plates (5) of the second type into the first interspaces (I1) outside the first flow channels (C1), and

feeding the secondary fraction of the second fluid through a respective first transfer hole (25) of the heat transfer plates (5) of the first type into the first interspaces (I1) outside the first flow channels (C1).

14. Use of a device (1, 2) according to any of claims 1-12 to perform electrolysis.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9
5, 5a
G
C1
41
I1, I1X
5x
61, 61p
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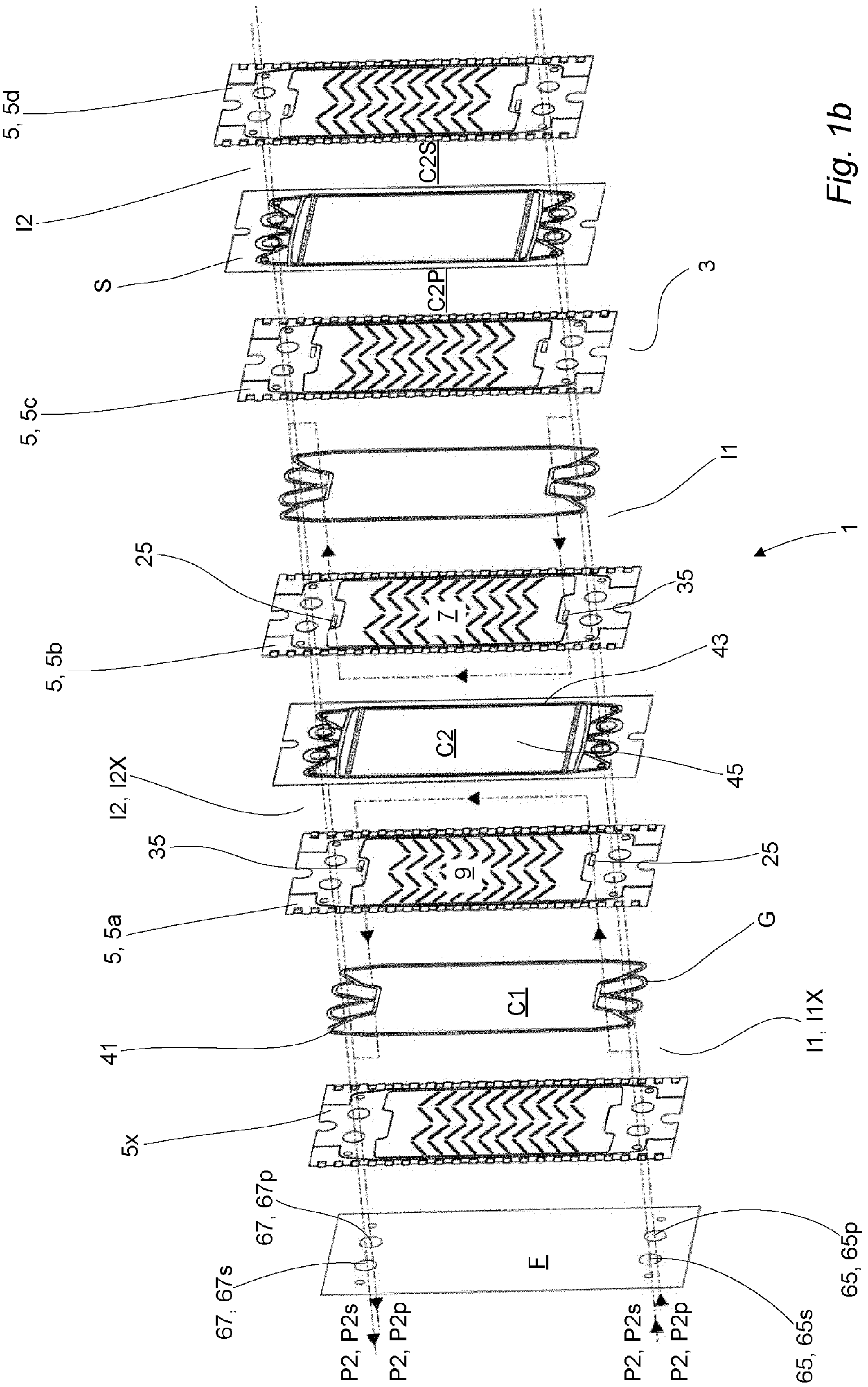
63, 63s

Fig. 1a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G
C1
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I1, I1X
5x
67, 67p
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P2, P2s
P2, P2p

Fig. 1b

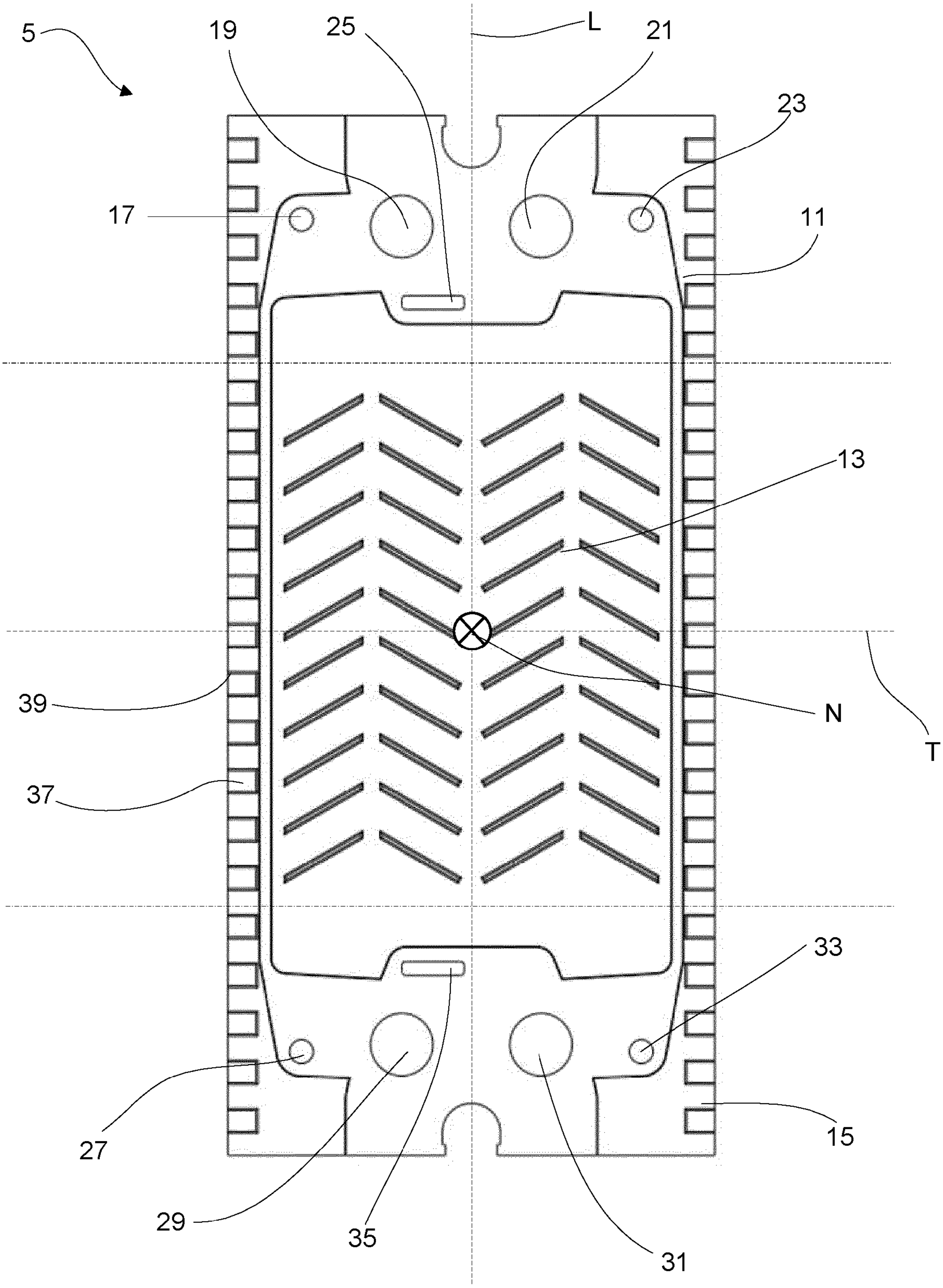
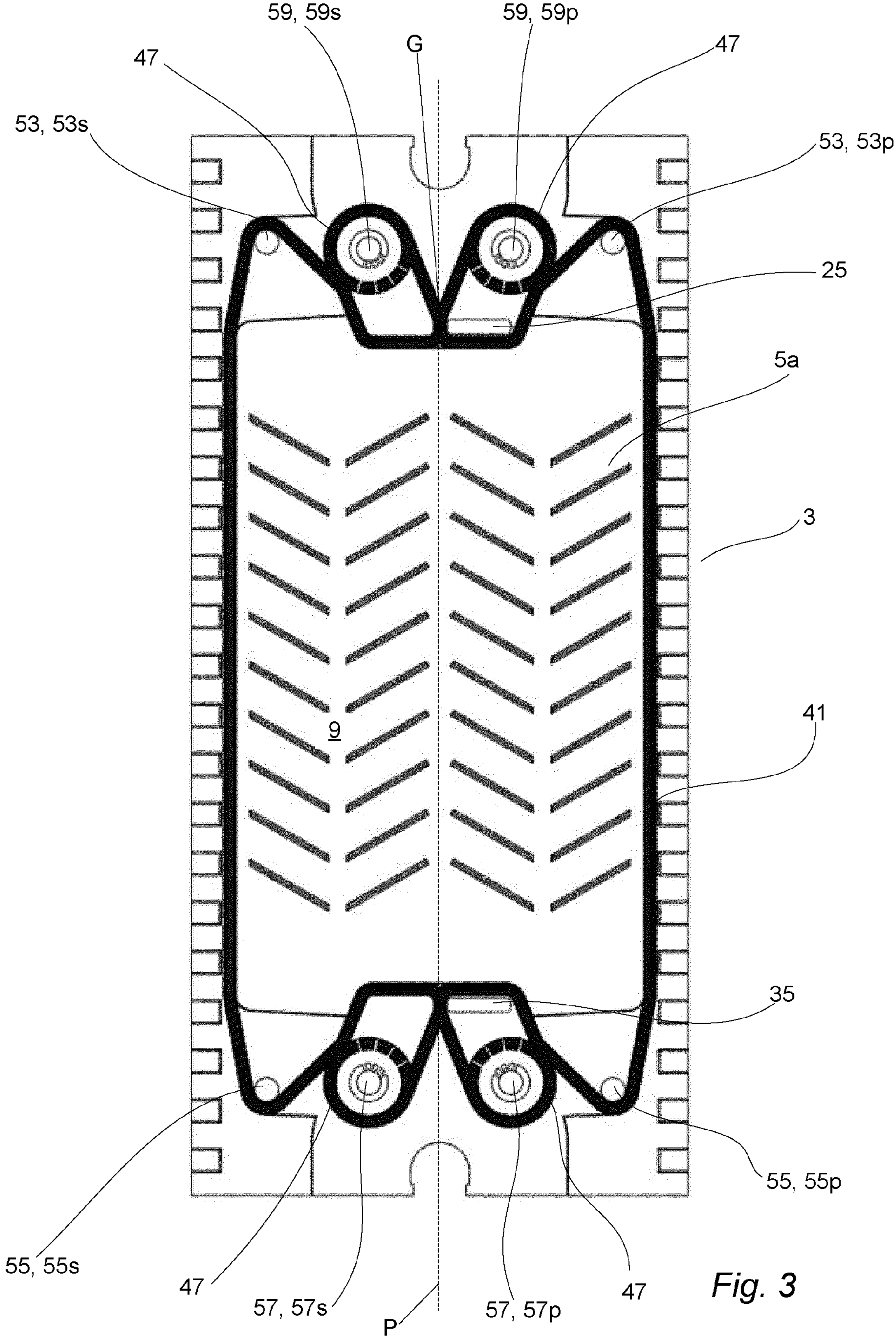


Fig. 2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57, 57s
57, 57p
P

Fig. 3

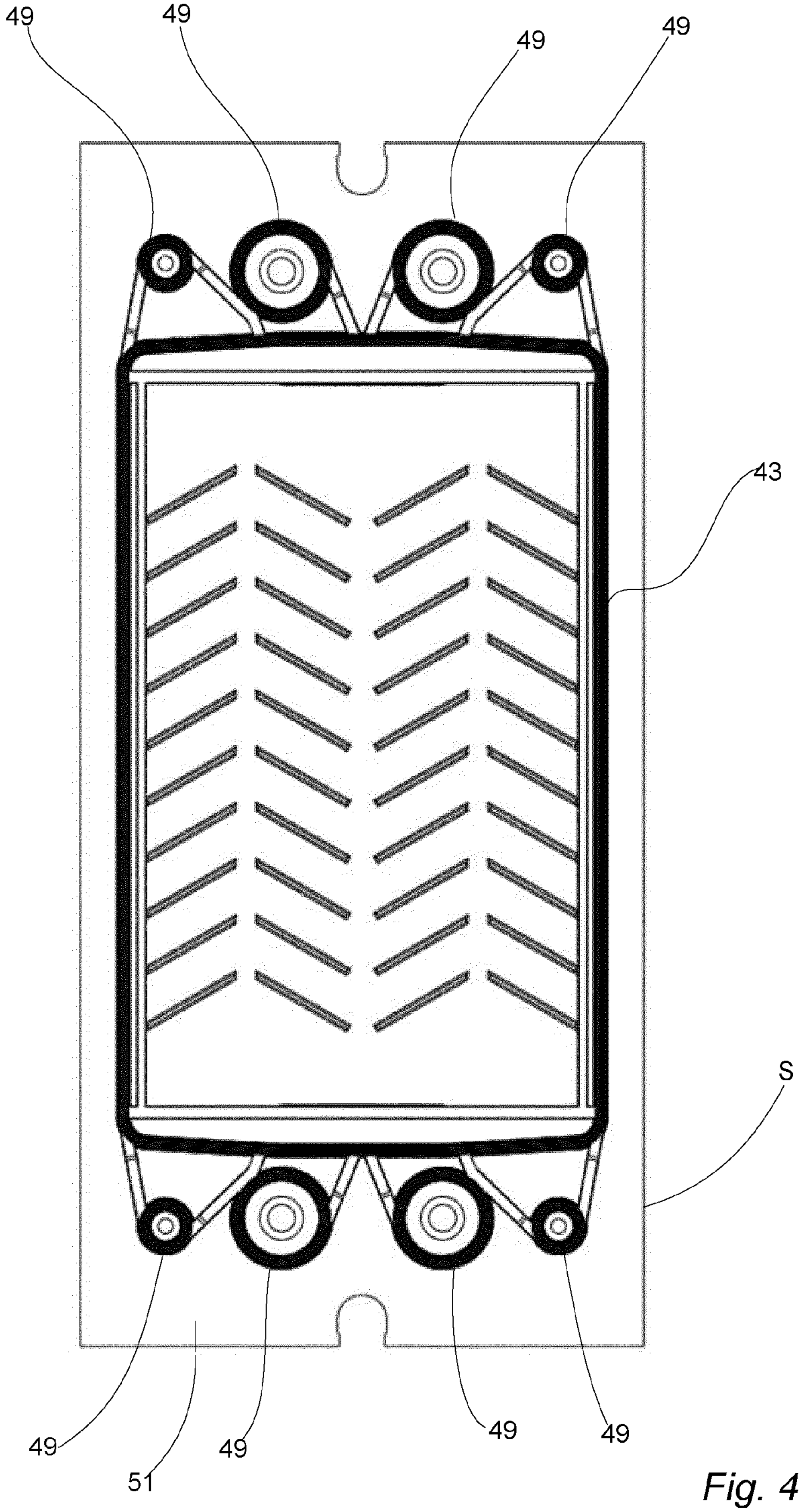
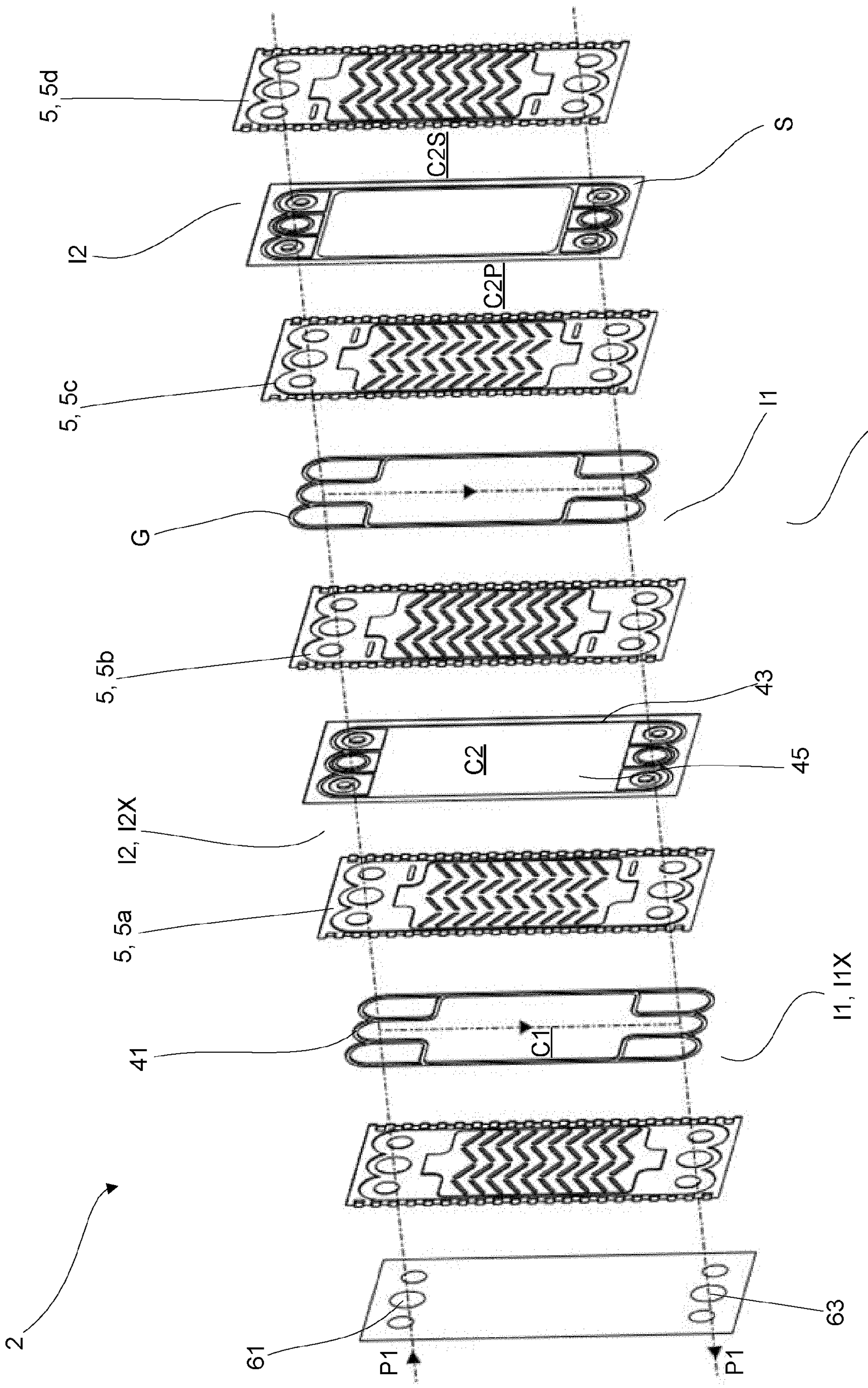


Fig. 4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S
I2
C2P
5, 5c
I1
3
G
5, 5b
43
C2
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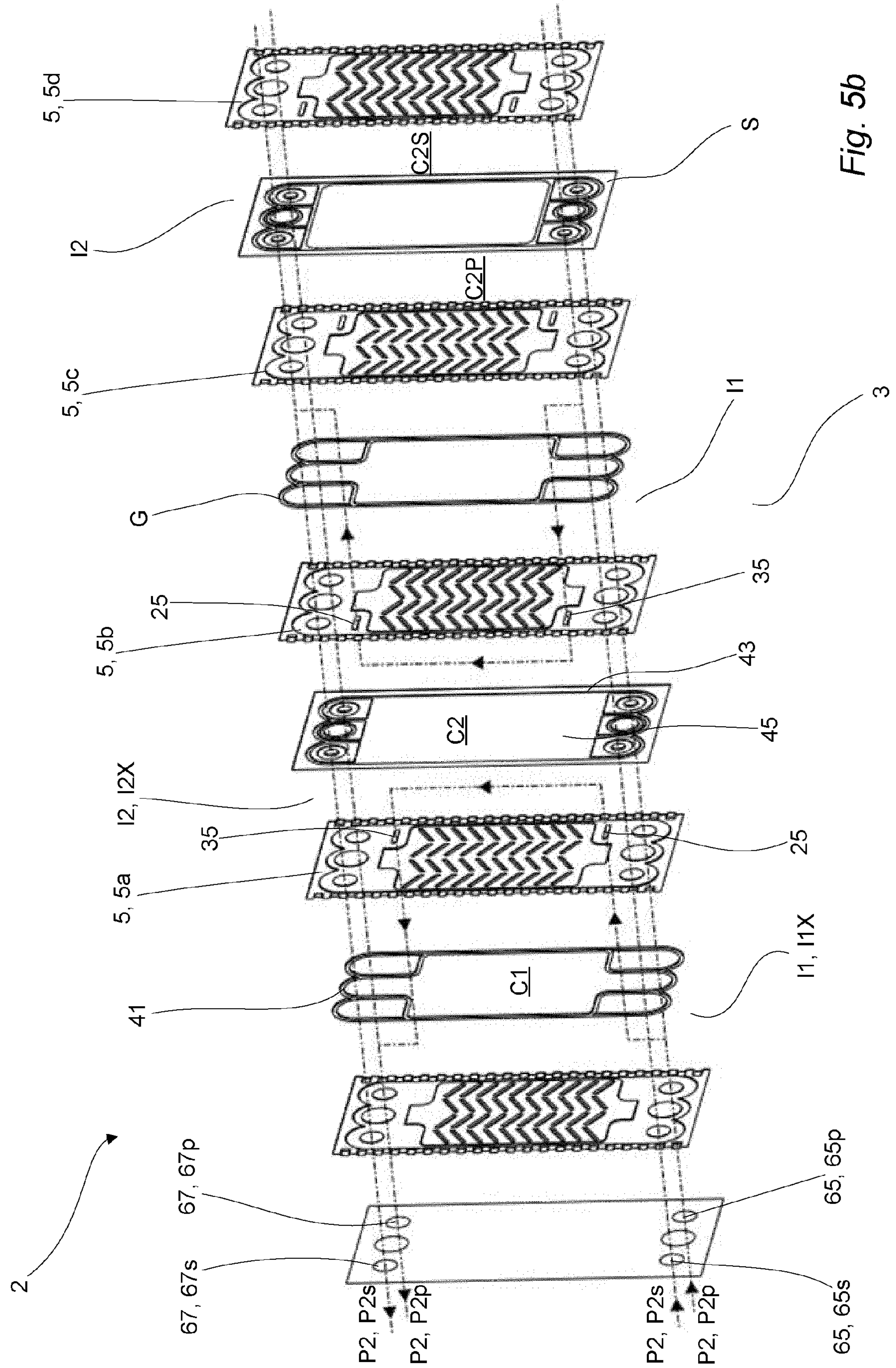
5, 5a
I1, I1X
41
C1
2
61
63
P1
P1

Fig. 5a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35
25
5, 5a
I1, I1X
C1
41
2
67, 67p
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P2, P2s
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P2, P2s
P2, P2p

Fig. 5b

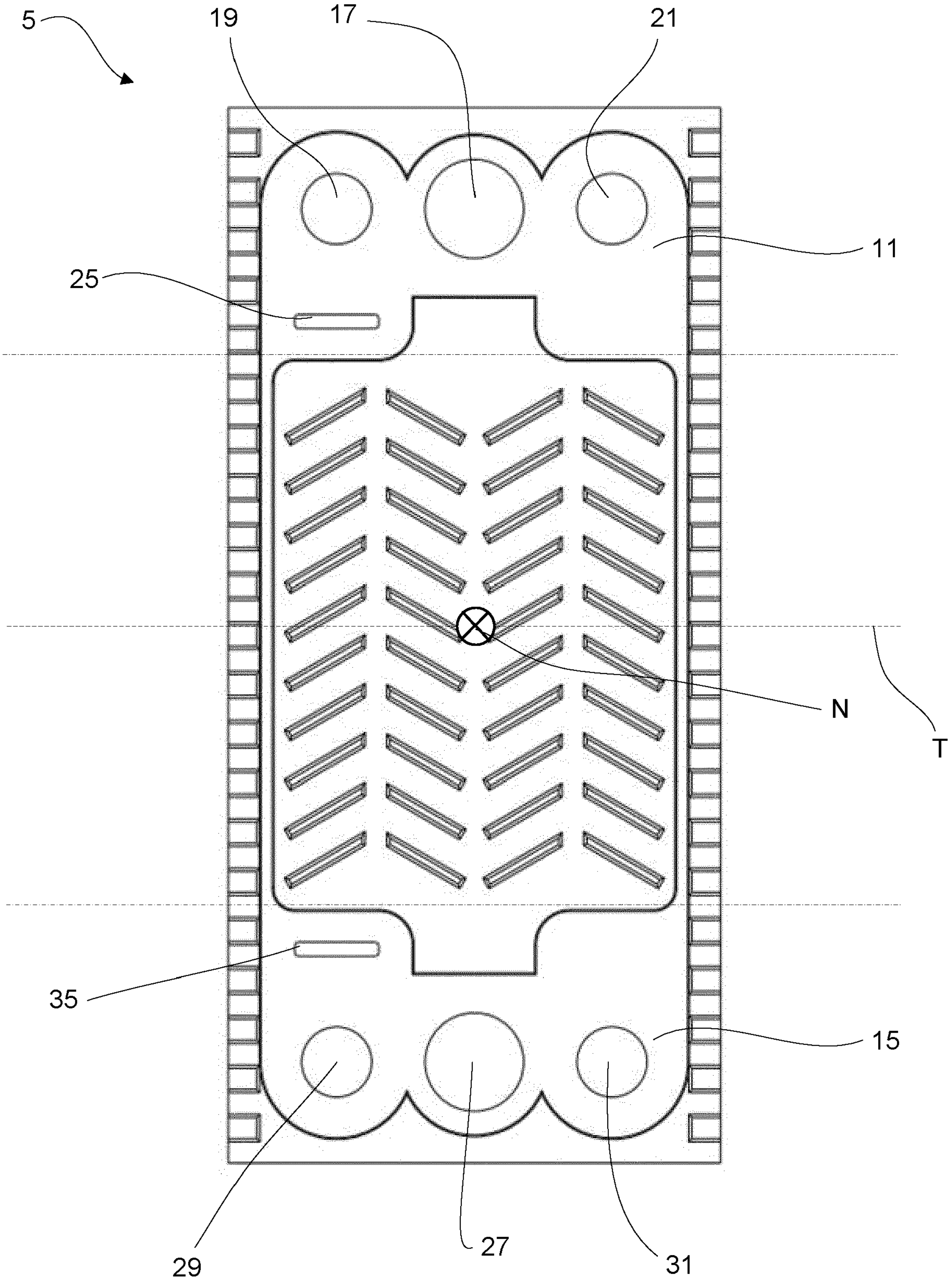

Fig. 6

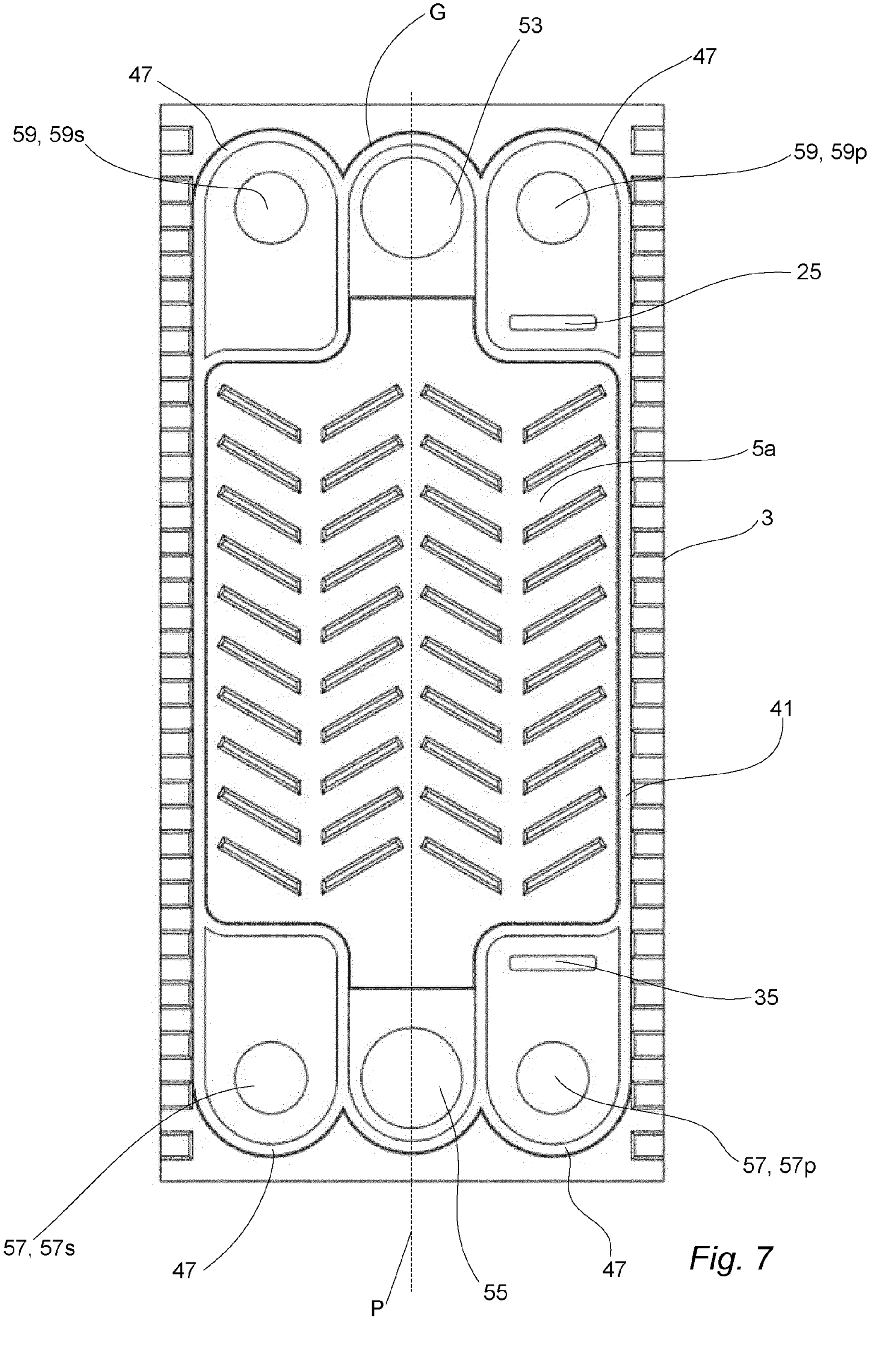

Fig. 7

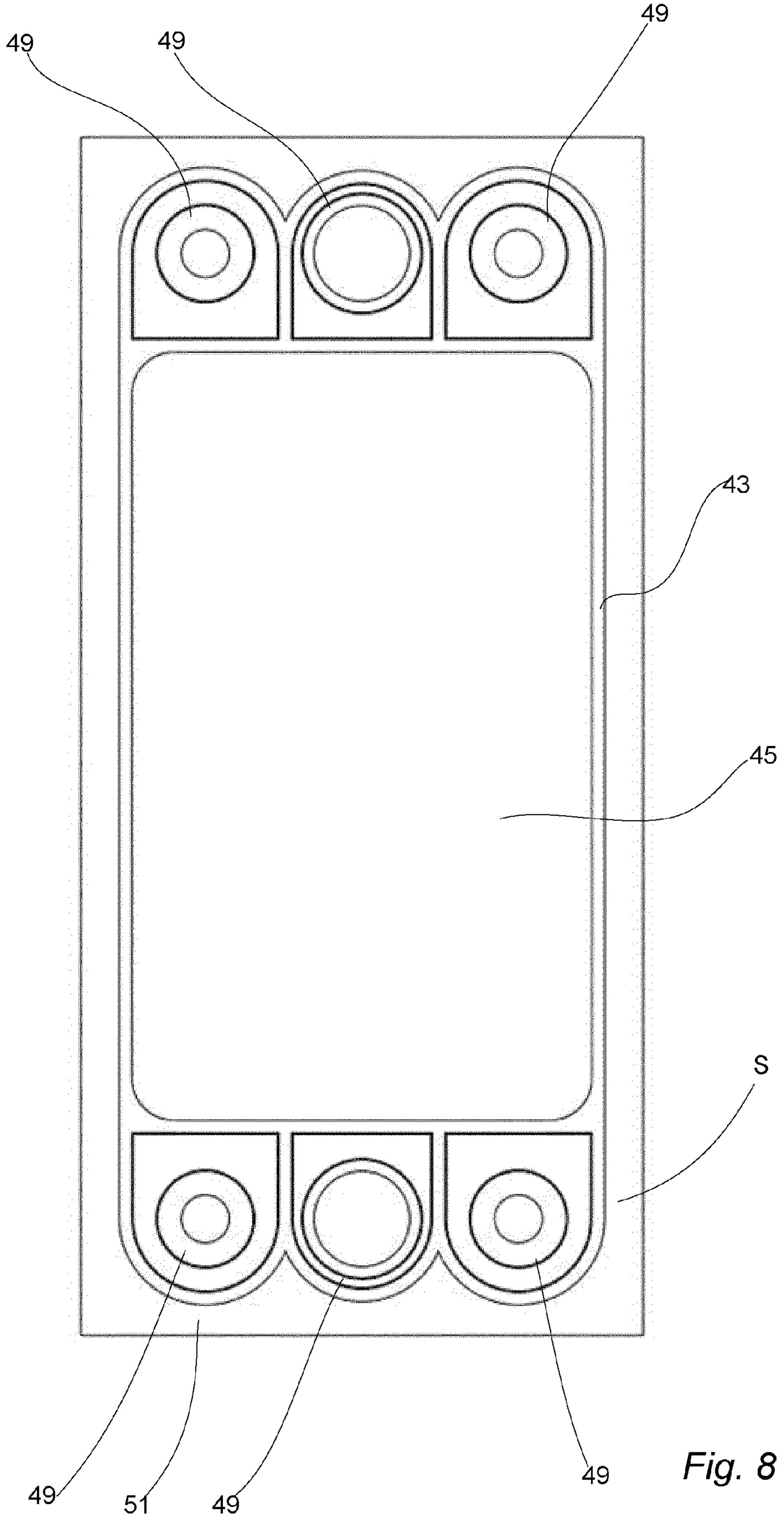

Fig. 8

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EUROPEAN SEARCH REPORT

Application Number
EP 22 21 5786

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C25B
F28F
F28D
H01M

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	25 October 2023	Leu, Oana

CATEGORY OF CITED DOCUMENTS

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