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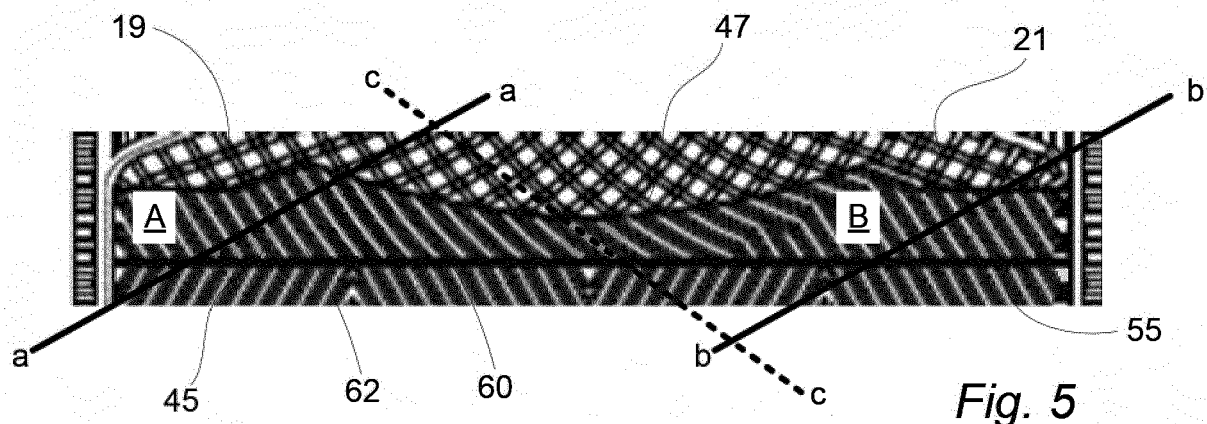
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(54) HEAT TRANSFER PLATE, CASSETTE AND HEAT EXCHANGER

(57) A heat transfer plate (8, 8a), a cassette (57) and a heat exchanger (2) are provided. The heat transfer plate (8, 8a) comprises an upper distribution area (44), an upper transition area (45) and a heat transfer area (46) provided with a heat transfer corrugation pattern, a distribution corrugation pattern and a transition corrugation pattern, respectively. The transition corrugation pattern comprises tops (60) extending in an imaginary top plane (TP) facing the front side (30) of the heat transfer plate (8, 8a) and bottoms (62) extending in an imaginary bottom plane (BP) facing the back side (32) of the heat transfer

plate (8, 8a). A bottom pitch (bp) between the bottoms (62) is essentially constant within more than 50% of the upper transition area (45). The heat transfer plate (8, 8a) is characterized in that a respective largest back cross section (BC) of a back corrugation volume (BV) between each two adjacent ones of the bottoms (62) and enclosed by the bottom plane (BP) and the heat transfer plate (8, 8a), which back cross section (BC) is taken perpendicular to a longitudinal extension (lt) of the top (60) extending between said two adjacent ones of the bottoms (62), is varying.

**Fig. 5****EP 4 571 235 A1**

Description

Technical Field

[0001] The invention relates to a heat transfer plate, a cassette comprising two such heat transfer plates and a heat exchanger comprising a plurality of such cassettes.

Background Art

[0002] Plate heat exchangers, PHEs, typically comprises two end plates in between which a number of heat transfer plates are arranged in an aligned manner, i.e. in a stack or pack. The heat transfer plates of a PHE may be stacked in different ways. In some PHEs, the heat transfer plates are stacked with the front side and the back side of one heat transfer plate facing the back side and the front side, respectively, of other heat transfer plates, and every other heat transfer plate turned upside down in relation to the rest of the heat transfer plates. In other words, every second one of the heat transfer plates is rotated 180 degrees, around its normal, in relation to the rest of the plates. Typically, this is referred to as the heat transfer plates being "rotated" in relation to each other. In other PHEs, the heat transfer plates are stacked with the front side and the back side of one heat transfer plate facing the front side and back side, respectively, of other heat transfer plates, and every other heat transfer plate turned upside down in relation to the rest of the heat transfer plates. In other words, every second one of the heat transfer plates is rotated 180 degrees, around its transverse center axis, in relation to the rest of the plates. Typically, this is referred to as the heat transfer plates being "flipped" in relation to each other. In other PHEs, the heat transfer plates are stacked with the front side and the back side of one heat transfer plate facing the front side and back side, respectively, of other heat transfer plates. In other words, every second one of the heat transfer plates is rotated 180 degrees, around its longitudinal center axis, in relation to the rest of the plates. Typically, this is referred to as the heat transfer plates being "turned" in relation to each other. Parallel flow channels are formed between the heat transfer plates, one channel between each pair of heat transfer plates. Two fluids of initially different temperatures can flow through every second channel for transferring heat from one fluid to the other, which fluids enter and exit the channels through inlet and outlet port holes in the heat transfer plates.

[0003] Typically, a heat transfer plate comprises two end parts and an intermediate center part. The end parts comprise the inlet and outlet port holes and a distribution area pressed with a distribution pattern of projections and depressions, such as ridges and valleys, in relation to a reference plane of the heat transfer plate. Similarly, the center part comprises a heat transfer area pressed with a heat transfer pattern of projections and depressions, such as ridges and valleys, in relation to said reference plane. The ridges and valleys of the distribution and heat

transfer patterns of one heat transfer plate are arranged to contact, in contact areas, an upper and a lower adjacent heat transfer plate, respectively, within their respective distribution and heat transfer areas.

[0004] The main task of the distribution area of the heat transfer plates is to spread a fluid entering the channel across a width of the heat transfer plate before the fluid reaches the heat transfer area, and to collect the fluid and guide it out of the channel after it has passed the heat transfer area. On the contrary, the main task of the heat transfer area is heat transfer. Since the distribution area and the heat transfer area have different main tasks, the distribution pattern normally differs from the heat transfer pattern. The distribution pattern is such that it offers a relatively low flow resistance in its main flow direction. A common distribution pattern is the so-called chocolate pattern offering relatively few, elongate contact areas, arranged along the main flow direction, between adjacent heat transfer plates. The heat transfer pattern is such that it offers the best combination of strength, flow resistance and surface enlargement for a given application or duty. A common heat transfer pattern is the so-called herringbone pattern which is versatile and strong because of its relatively densely arranged elongate corrugations which result in a cross-corrugated pattern of contact areas between adjacent heat transfer plates. The heat transfer plates of a PHE may be of the same type or of two or more different types. If the heat transfer plates are of different types, the difference typically lies in the design of the heat transfer pattern.

[0005] As described in applicant's PCT application WO 2014/067757, at the transition between the distribution area and the heat transfer area, i.e. where the plate pattern changes, the strength of a pack of heat transfer plate may be somewhat reduced as compared to the strength of the rest of the plate pack due to an uneven distribution of contact areas. The more scattered the contact areas are at the transition, the worse the strength may be, since the contact areas locally may be far apart which may result in high loads in individual contact areas. Plate packs of heat transfer plates with similar but mirror inverted patterns of steep, densely arranged ridges and valleys are typically stronger at the transition than plate packs of heat transfer plates with differing patterns of less steep, less densely arranged ridges and valleys. WO2014/067757 presents a solution to this problem by the provision of a transition area between the distribution area and the heat transfer area of a heat transfer plate irrespective of plate type, i.e. what the heat transfer pattern looks like. The transition area is provided with a so called herringbone pattern of steep and densely arranged ridges and valleys. Thereby, a transition to the distribution area from the heat transfer area will be the same, and may be relatively strong, irrespective of which types of heat transfer plates a plate pack contains.

[0006] However, for some combinations of, for example, heat transfer plate channel depth and length/width ratio, the transition area may have a negative impact on

the flow distribution across the heat transfer plate. Typically, there are different flow paths of different lengths across a heat transfer plate, longer flow paths being associated with a lower flow velocity. This may result in an uneven fluid distribution across the heat transfer plate, which, in turn, may negatively effect the heat transfer capacity of the heat transfer plate.

Summary

[0007] An object of the present invention is to provide a heat transfer plate which enables the creation of a plate pack which is strong at the transition to the distribution area from the heat transfer area but still provides an even fluid distribution across the plate surfaces. The basic concept of the invention is to vary the flow resistance along the transition area of the heat transfer plate. Thereby, in a plate pack containing the heat transfer plate, a more even flow velocity along the transition area may be achieved, which may improve the fluid distribution inside the plate pack. Another object of the invention is to provide a cassette comprising two such heat transfer plates and a heat exchanger comprising a plurality of such cassettes. The heat transfer plate, which is also referred to herein as just "plate", the cassette and the heat exchanger are defined in the appended claims and discussed below.

[0008] A heat transfer plate according to the invention has a front side and an opposing back side. It comprises an upper distribution area, an upper transition area and a heat transfer area arranged in succession along a longitudinal center axis of the heat transfer plate. The longitudinal center axis divides the heat transfer plate into a first and a second half. The upper transition area adjoins the upper distribution area along a first borderline and the heat transfer area along a second borderline. The heat transfer area, the upper distribution area and the upper transition area are provided with a heat transfer corrugation pattern, a distribution corrugation pattern and a transition corrugation pattern, respectively. The transition corrugation pattern differs from the distribution corrugation pattern and the heat transfer corrugation pattern. The transition corrugation pattern comprises tops extending in an imaginary top plane facing the front side of the heat transfer plate, and bottoms extending in an imaginary bottom plane facing the back side of the heat transfer plate. A bottom pitch between the bottoms is essentially constant within more than 50% of the upper transition area. The heat transfer plate is characterized in that a respective largest back cross section of a back corrugation volume between each two adjacent ones of the bottoms and enclosed by the bottom plane and the heat transfer plate, which back cross section is taken perpendicular to a longitudinal extension of the top extending between the two adjacent ones of the bottoms, is varying. Expressed differently, each pair of neighboring bottoms within the upper transition area defines, between the heat transfer plate and the bottom plane, a respective

back corrugation volume. This back corrugation volume has a back cross section perpendicular to a longitudinal extension of the respective bottoms. This back cross section has a largest value - the largest back cross section, and may be constant, and thus equal to the largest back cross section, or varying, along the longitudinal extension of the respective bottoms. The largest back cross sections defined by the different pairs of bottoms are differing between the pairs.

[0009] The largest back cross sections defined by the different pairs of bottoms may all be different. Alternatively, some of the largest back cross sections defined by the different pairs of bottoms may be equal to each other and have the same value of two or more different values.

The largest back cross sections defined by the different pairs of bottoms may increase gradually along a longitudinal extension of the upper transition area, i.e. typically in a direction perpendicular to the longitudinal center axis of the heat transfer plate.

[0010] The first borderline between the upper transition area and the upper distribution area, just like the second borderline between the upper transition area and the heat transfer area, may have different forms, such as a straight shape or a curved shape or any combination thereof.

[0011] The transition corrugation pattern, just like the distribution and heat transfer corrugation patterns, may have different designs. For example, at least a majority of the tops and the bottoms of the transition corrugation pattern may be elongate or beam shaped, and/or straight, curved, bent or angled.

[0012] The bottom pitch between the bottoms, i.e. the distance between two adjacent ones of the bottoms, may be essentially constant within essentially the complete upper transition area. A constant bottom pitch may enable a heat transfer plate with back cross sections within the upper transition area which are symmetrical with reference to a respective volume axis extending perpendicular to the longitudinal center axis and a transverse center axis of the heat transfer plate and through a center of the top arranged between the bottoms of the respective pair of bottoms. In turn, this may enable a relatively design-wise uncomplicated heat transfer plate. Further, this may optimize the possible surface enlargement of the transition corrugation pattern.

[0013] In that the largest back cross section is varying between the different pairs of the bottoms within the upper transition area, while the bottom pitch is kept constant within more than half of the upper transition area, the flow resistance along the upper transition area is varying which may optimize the flow distribution across, and thus the heat transfer capability of, the heat transfer plate.

[0014] The heat transfer plate may be so designed that a top pitch between the tops is essentially constant within more than 50% of the upper transition area. The top pitch between the tops, i.e. the distance between two adjacent ones of the tops, may be essentially constant within essentially the complete upper transition area. A con-

stant top pitch may enable a heat transfer plate with front cross sections within the upper transition area which are symmetrical with reference to a respective volume axis extending perpendicular to the longitudinal center axis and a transverse center axis of the heat transfer plate and through a center of the bottom arranged between the tops of the respective pair of tops. In turn, this may enable a relatively design-wise uncomplicated heat transfer plate. Further, this may optimize the possible surface enlargement of the transition corrugation pattern.

[0015] The heat transfer plate may be so designed that the upper transition area comprises a first transition sub area and a second transition sub area. Each of the first and second transition sub areas may extend between the first and second borderlines. The largest back cross section within more than 50% of the first transition sub area may be larger than the largest back cross section within more than 50% of the second transition sub area.

[0016] The largest back cross section within essentially the complete first transition sub area may be larger than the largest back cross section within essentially the complete second transition sub area.

[0017] By this design of the heat transfer plate, the upper transition area may comprise two or more transition sub areas which may define different largest back cross sections designed to optimize the flow distribution across the heat transfer plate. The largest back cross sections within one and the same one of the transition sub areas may be varying or constant.

[0018] The first transition sub area may be a first outermost sub area of the upper transition area and the second transition sub area may be a second outermost sub area of the upper transition area. The first and second transition sub areas may border on each other. In accordance with this embodiment, the upper transition area is constituted of two transition sub areas which may enable a design-wise uncomplicated heat transfer plate.

[0019] The heat transfer plate may be so designed that the largest back cross section is constant within more than 50% of the first transition sub area. Additionally/alternatively, the heat transfer plate may be so designed that the largest back cross section is constant within more than 50% of the second transition sub area. These features may enable a design-wise uncomplicated heat transfer plate.

[0020] The largest back cross section may be constant within essentially the complete first transition sub area. Additionally/alternatively, the largest back cross section may be constant within essentially the complete second transition sub area.

[0021] The heat transfer plate may be such that the first transition sub area constitutes 30-70% of the upper transition area. Such an interval may enable an optimized flow distribution across the heat transfer plate.

[0022] The heat transfer plate may be so designed that a front transition volume within the upper transition area on the first half of the heat transfer plate and between the heat transfer plate and the top plane is different from a

back transition volume within the upper transition area on the first half of the heat transfer plate and between the heat transfer plate and the bottom plane. This design enables a heat transfer plate which is asymmetric within the upper transition area.

[0023] As described by way of introduction, the heat transfer plates of a PHE may be stacked "rotated", "flipped" or "turned" in relation to each other. In a plate pack containing asymmetric similar heat transfer plates, the characteristics of the channels between the plates depend on how the plates are stacked. If the plates are "rotated" in relation to each other, the channels between the plates may all have essentially the same volume. On the contrary, if the plates are "flipped" or "turned" in relation to each other, the channels between the plates may have two different volumes; every second one of the channels having a smaller volume while the rest of the channels have a larger volume.

[0024] A heat transfer plate according to the present invention may comprise an upper end part, a center part and a lower end part arranged in succession along the longitudinal center axis of the heat transfer plate. The upper end part may comprise a first port hole and a second port hole, and the lower end part may comprise a third port hole and a fourth port hole. The center part may comprise the heat transfer area. The heat transfer plate may further comprise, as seen from the front side, a sealing groove. The sealing groove may comprise a field sealing groove portion enclosing the heat transfer area and two of the first, second, third and fourth port holes. The heat transfer plate may further comprise a gasket groove arranged to receive a gasket. The gasket groove may comprise a field gasket groove portion enclosing the heat transfer area and two of the first, second, third and fourth port holes which are not enclosed by the field sealing groove portion. Such a design of the heat transfer plate may enable permanent attachment of it to another heat transfer plate to form a cassette suitable for use in a so-called semi-welded plate heat exchanger.

[0025] The field sealing groove and the field gasket groove may at least partly coincide.

[0026] The second and fourth port holes may be dedicated to one and the same fluid while the first and third port holes may be dedicated to one and the same, and another fluid. The second and fourth port holes, just like the first and third port holes, may be arranged on opposite sides of the longitudinal center axis of the heat transfer plate. Such a port hole placement may enable a heat transfer plate of so-called diagonal flow type, and a heat exchanger comprising heat transfer plates according to the invention which are "rotated" in relation to each other. Such a heat exchanger typically demands gaskets of two different designs and it may also require heat transfer plates of two different designs. Alternatively, the first port hole and the third port hole may be arranged on one side of the longitudinal center axis of the heat transfer plate, while the second port hole and the fourth port hole may be arranged on another side of the longitudinal center axis of

the heat transfer plate. Such a port hole placement may enable a heat transfer plate of so-called parallel flow type, and a heat exchanger comprising similar heat transfer plates according to the invention which are "flipped" in relation to each other.

[0027] The heat transfer plate may be so configured that the field sealing groove portion of the sealing groove encloses the second and fourth port holes. Such a configuration may be beneficial for a heat transfer plate arranged to be permanently joined to another heat transfer plate along the sealing groove, for instance by a weld extending within the sealing groove, to form a cassette.

[0028] In a configuration according to the paragraph above, the field gasket groove portion of the gasket groove, which gasket groove, as said above, may be arranged to accommodate a gasket for sealing abutment against another heat transfer plate, may enclose the first port hole and the third port hole.

[0029] The design of the heat transfer plate may be such that a bottom of the field sealing groove portion, along at least more than half of a length of the field sealing groove portion, extends in the bottom plane. Such a design may facilitate permanent joining of the heat transfer plate to another heat transfer plate.

[0030] The heat transfer plate may be such that the sealing groove further comprises, as seen from the front side of the heat transfer plate, a first ring sealing groove portion enclosing the first port hole and a third ring sealing groove portion enclosing the third port hole. A bottom of the first ring sealing groove portion may, along at least more than half of a length of the first ring sealing groove portion, extend in the bottom plane. Further, a bottom of the third ring sealing groove portion may, along at least more than half of a length of the third ring sealing groove portion, extend in the bottom plane. Such a design may facilitate permanent joining of the heat transfer plate to another heat transfer plate.

[0031] The heat transfer plate may be so configured that the gasket groove further comprises a second ring gasket groove portion enclosing the second port hole and a fourth ring gasket groove portion enclosing the fourth port hole. A bottom of the second ring gasket groove portion may, along at least more than half of a length of the second ring gasket groove portion, extend between the top plane and the bottom plane. A bottom of the fourth ring gasket groove portion may, along at least more than half of a length of the fourth ring gasket groove portion, extend between the top plane and the bottom plane. Such a design may enable a fluid flow between the second port hole and the fourth port hole on the back side of the heat transfer plate.

[0032] A cassette according to the invention comprises two heat transfer plates. The back side of one of the two heat transfer plates faces the back side of another one of the two heat transfer plates. The two heat transfer plates are welded to each other along the sealing grooves.

[0033] In the cassette, said another one of the two heat transfer plates may be rotated 180 degrees around a

normal of said another one of the two heat transfer plates. In other words, one of the heat transfer plates may be "flipped" or rotated 180 degrees around its transverse center axis. Alternatively, said another one of the two heat transfer plates may be "turned" or rotated 180 degrees around the longitudinal center axis of said another one of the two heat transfer plates.

[0034] A heat exchanger according to the invention comprises a plurality of heat transfer plates according to the above. The heat exchanger further comprises gaskets. Each of the gaskets may be arranged in the gasket grooves of two adjacent ones of the heat transfer plates.

[0035] In the heat exchanger, the heat transfer plates may be welded in pairs, back side to back side, along the sealing grooves, into cassettes. Further, each of the gaskets may be arranged in the gasket grooves of two adjacent ones of the cassettes.

[0036] The above discussed advantages with the different embodiments of the heat transfer plate are naturally transferable to the cassette and the heat exchanger according to the invention.

[0037] As a general remark, herein, when it is said that some portion, part, section, etc., of the heat transfer plate extends in a certain plane, it is the main extension of the portion, part, section, etc. that is referred to. Naturally, a portion, part, section, etc., may locally have an extension deviating from the main extension, for example at a transition to another adjacent portion, part, section, etc.

[0038] Further, herein, the expression "within more than 50% of" has been used in various places to describe a general or dominant characteristic of a certain area or sub area. Typically, a considerably larger percentage, for example 75% or 90%, or even 100%, of a certain area or sub area has this characteristic, but there may also be deviations in the characteristic resulting in a percentage less than 100%. The present invention covers also these variants.

[0039] It should be stressed that the above discussed advantages of the different embodiments of the heat transfer plate according to the invention appears first when the heat transfer plate is arranged in a PHE together with other heat transfer plates (which possibly also are designed according to the present invention), gaskets and other components needed in a properly functioning PHE.

[0040] 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

[0041] The invention will now be described in more detail with reference to the appended schematic drawings, in which

Fig. 1 is a schematic front view of a heat exchanger according to the invention,

Fig. 2 is schematic side view of the heat exchanger in Fig. 1,

Fig. 3 is a plan view of a heat transfer plate according to the invention,

Fig. 4 is a schematic side view of a portion of a plate pack comprised in the heat exchanger in Fig. 1,

Fig. 5 is an enlargement of a portion of the heat transfer plate in Fig. 3,

Fig. 6a is a cross section taken along the line a-a in Fig. 5,

Fig. 6b is a cross section taken along the line b-b in Fig. 5, and

Fig. 7 is a plan view of a cassette according to the invention.

Detailed description

[0042] Figs. 1 and 2 show a semi-welded plate heat exchanger 2. It comprises a frame plate 4, a pressure plate 6, a pack of heat transfer plates 8, fluid inlets and outlets 10, tightening means 12, an upper bar 14 and a lower bar 16.

[0043] At least a majority of the heat transfer plates 8, hereinafter also referred to as just "plates", are all similar. As will be further discussed below, the plates 8 are welded in pairs, back side to back side, to form tight cassettes, with gaskets arranged between the cassettes. The frame and pressure plates 4 and 6, and therefore the cassettes, are pressed towards each other by the tightening means 12 whereby the gaskets seal between the cassettes. Parallel flow channels are formed between the heat transfer plates 8, one channel between each pair of adjacent heat transfer plates 8. Two fluids of initially different temperatures, which are fed to/from the plate heat exchanger 2 through the fluid inlets and outlets 10, can flow alternately through every second channel for transferring heat from one fluid to the other, which fluids enter/exit the channels through inlet/outlet port holes in the heat transfer plates 8, which inlet/outlet port holes form inlet/outlet ports which communicate with the fluid inlets and outlets 10 of the plate heat exchanger 2.

[0044] One the plates 8 of the plate heat exchanger 2, denoted 8a, is illustrated in further detail in Fig. 3. The plate 8a is an essentially rectangular sheet of stainless steel. It comprises first and second opposing long sides 18, 20 and first and second opposing short sides 22, 24. Further, the plate 8a has a longitudinal center axis L extending parallel to, and halfway between, the long sides 18, 20 so as to divide the plate 8a into a first half 19 and a second half 21. The plate 8a further has a transverse center axis T extending parallel to, and halfway between, the short sides 22, 24 and thus perpendicular to the longitudinal center axis L.

[0045] The plate 8a has a front side 30 (illustrated in Figs. 3 and 4) and an opposing back side 32 (illustrated in Fig. 4). Further, the plate 8a comprises an upper end part 34, a center part 36 and a lower end part 38 arranged in succession along the longitudinal center axis L of the heat

transfer plate 8a. The upper end part 34 comprises a first port hole 40, a second port hole 42, a first adiabatic area 39, a second adiabatic area 41, an upper distribution area 44 and an upper transition area 45. A first borderline 47 defines a border between the upper distribution area 44 and the upper transition area 45. The center part 36 comprises a heat transfer area 46. A second borderline 55 defines a border between the upper transition area 45 and the heat transfer area 46. The lower end part 38 comprises a third port hole 48, a fourth port hole 50, a third adiabatic area 49, a fourth adiabatic area 51, a lower distribution area 52 and a lower transition area 53. The first and third port holes 40 and 48 are arranged on one side of the longitudinal center axis L while the second and the fourth port holes 42 and 50 are arranged on the other side of the longitudinal center axis L.

[0046] The heat transfer plate 8a is pressed, in a conventional manner, in a pressing tool, to be given a desired structure, such as different corrugation patterns within different portions of the heat transfer plate. The corrugation patterns are optimized for the specific functions of the respective plate portions. Accordingly, the upper and lower distribution areas 44 and 52 each comprises a distribution corrugation pattern adapted for optimized fluid distribution across the heat transfer plate 8a. Further, the heat transfer area 46 comprises a heat transfer corrugation pattern adapted for optimized heat transfer between two fluids flowing on opposite sides of the heat transfer plate 8a. The upper and lower transition areas 45 and 53 comprises a transition corrugation pattern adapted for an optimized combination of strength and fluid distribution. Furthermore, the first, second, third and fourth adiabatic areas 39, 41, 49 and 51 each comprises a corrugation pattern adapted to convey fluid between the port holes and the distribution areas with the lowest possible pressure drop. Moreover, the plate 8a comprises an outer edge part 54 extending along an outer edge 56 of the plate. The outer edge part 54 comprises corrugations 58 extending in and between imaginary parallel top and bottom planes TP and BP (Fig. 4), which top plane TP and bottom plane BP face the front side 30 and the back side 32, respectively, of the plate 8a. These corrugations 58 are arranged to abut corrugations of adjacent plates 8b and 8c in the plate pack of the plate heat exchanger 2. Similarly, with reference to Figs. 3 and 4, the transition corrugation pattern comprises corrugations, more particularly alternately arranged ridges with tops 60 and valleys with bottoms 62 as seen from the front side 30 of the plate 8a, which tops 60 and bottoms 62 extend in the top and bottom planes TP and BP, respectively. These tops 60 and bottoms 62 are arranged to abut tops and bottoms of the adjacent plates 8b and 8c in the plate pack of the plate heat exchanger 2. Also the distribution and heat transfer corrugation patterns comprises corrugations arranged to abut corrugations of the adjacent plates in the plate pack of the plate heat exchanger 2. However, this is not further discussed herein.

[0047] Hereinafter, the transition corrugation pattern will be further described with reference to Figs 5, 6a and 6b. Fig. 5 contains an enlargement of the upper transition area 45 which comprises first and second transition sub areas A and B. The first and second transition sub areas A and B are arranged in succession along the transverse center axis T (Fig. 3) of the plate 8a and each of them extends between the first and second borderlines 47 and 55. A line c-c, which extends between two adjacent ones of the tops 60, defines a border between the first and second transition sub areas A and B. On the specific heat transfer plate 8a, the line c-c extends approximately in a center portion of the plate 8a such that the first transition sub area A extends essentially on the first half 19 of the plate 8a while the second transition sub area B extends essentially on the second half 21 of the plate 8a. Accordingly, the first and second transition sub areas A and B occupy about 50% each of the upper transition area 45 of the plate 8a. However, on another plate designed in accordance with the present invention, the first transition sub area A could occupy anywhere between 30% and 70%, while the second transition sub area B could occupy the rest, of the upper transition area 45.

[0048] With reference to Figs. 6a and 6b, a top pitch tp between the tops 60 is constant within the upper transition area 45, and thus the same within the transition sub areas A and B. Similarly, a bottom pitch bp between the bottoms 62 is constant within the upper transition area 45, and thus the same within the transition sub areas A and B, and equal to the top pitch tp. Still, the transition corrugation pattern is different within the transition sub areas A and B. The upper transition area 45 of the plate 8a defines, together with the top plane TP, a volume comprising front corrugation volumes FV extending between the tops 60, one front corrugation volume FV extending between each two adjacent ones of the tops 60. Similarly, the upper transition area 45 of the plate 8a defines, together with the bottom plane BP, a volume comprising back corrugation volumes BV extending between the bottoms 62, one back corrugation volume BV extending between each two adjacent ones of the bottoms 62. Each of the front corrugation volumes FV has a front cross section FC taken perpendicular to a longitudinal extension lb of the bottom 62 extending between the two adjacent tops 60 defining the respective front corrugation volume FV. The front cross section FC may vary between a smallest front cross section and a largest front cross section, or be constant, like here, along essentially the complete longitudinal extension lb of the respective bottom 62. Each of the back corrugation volumes BV has a back cross section BC taken perpendicular to a longitudinal extension lt of the top 60 extending between the two adjacent bottoms 62 defining the respective back corrugation volume BV. The back cross section BC may vary between a smallest back cross section and a largest back cross section, or be constant, like here, along essentially the complete longitudinal extension lt of the respective top 60.

[0049] Even if the front cross section FC for one and the same of the front corrugation volumes FV is constant, the front cross sections FC between different front corrugation volumes FV vary within the upper transition area 45 so as to have one essentially constant value within the first transition sub area A and another essentially constant value within the second transition sub area B. More particularly, the front cross sections FC are 10-40%, here 30%, larger within the second transition sub area B than within the first transition sub area A. Further, even if the back cross section BC for one and the same of the back corrugation volumes BV is constant, the back cross sections BC between different back corrugation volumes BV vary within the upper transition area 45 so as to have one essentially constant value within the first transition sub area A and another essentially constant value within the second transition sub area B. More particularly, the back cross sections BC are 10-40%, here 30%, larger within the first transition sub area A than within the second transition sub area B.

[0050] With reference to Fig. 3, pressed into the plate 8a, as seen from the front side 30 of the plate, is a sealing groove 64 comprising a field sealing groove portion 64a, a first ring sealing groove portion 64b and a third ring sealing groove portion 64c. The sealing groove 64 is illustrated with lines in Fig. 3. The field sealing groove portion 64a encloses the heat transfer area 46 and the second and fourth port holes 42 and 50. A bottom 66a of the field sealing groove portion 64a extends in the bottom plane BP (Fig. 4) along the complete length of the field sealing groove portion 64a. The first ring sealing groove portion 64b encloses the first port hole 40. A bottom 66b of the first ring sealing groove portion 64b extends in the bottom plane BP along the complete length of the first ring sealing groove portion 64b. The third ring sealing groove portion 64c encloses the third port hole 48. A bottom 66c of the third ring sealing groove portion 64c extends in the bottom plane BP along the complete length of the third ring sealing groove portion 64c.

[0051] Further, with reference to Figs. 3 and 7, pressed into the plate 8a, as seen from the front side 30 of the plate, is also a gasket groove 68 for receiving a gasket 59 (comprising a field gasket portion and two ring gasket portions). The gasket groove 68 comprises a field gasket groove portion 68a, a second ring gasket groove portion 68b and a fourth ring gasket groove portion 68c. The field gasket groove portion 68a encloses the heat transfer area 46 and the first and third port holes 40 and 48. The field gasket groove portion 68a partly coincides with the field sealing groove portion 64a. Therefore, a bottom 70a of the field gasket groove portion 68a extends in the bottom plane BP (Fig. 4) where the field gasket groove portion 68a coincides with the field sealing groove portion 64a. In fact, the bottom 70a of the field gasket groove portion 68a extends in the bottom plane BP everywhere except for at two diagonal sections 68a' of the field gasket groove portion 68a along which the bottom 70a extends between, here halfway between, the top plane TP and the

bottom plane BP. The second ring gasket groove portion 68b encloses the second port hole 42. A bottom 70b of the second ring gasket groove portion 68b extends between, here halfway between, the top plane TP and the bottom plane BP along the complete length of the second ring gasket groove portion 68b. The fourth ring gasket groove portion 68c encloses the fourth port hole 50. A bottom 70c of the fourth ring gasket groove portion 68c extends between, here halfway between, the top plane TP and the bottom plane BP along the complete length of the fourth ring gasket groove portion 68c.

[0052] The lower end part 38 of the plate 8a is a mirroring, along the transverse center axis T of the plate 8a, of the upper end part 34 of the plate 8a. Further, the plate 8a is a so-called asymmetric plate which means that a front volume defined between the plate 8a and the top plane TP is different from a back volume defined between the plate 8a and the back plane BP. Looking at the upper transition area 45, a front transition volume on the first half 19 of the plate 8a, which essentially is the aggregated volume of the front corrugation volumes FV within the first transition sub area A, is different from a back transition volume on the first half 19 of the plate 8a, which essentially is the aggregated volume of the back corrugation volumes BV within the first transition sub area A. Similarly, still looking at the upper transition area 45, a front transition volume on the second half 21 of the plate 8a, which essentially is the aggregated volume of the front corrugation volumes FV within the second transition sub area B, is different from a back transition volume on the second half 21 of the plate 8a, which essentially is the aggregated volume of the back corrugation volumes BV within the second transition sub area B.

[0053] In the plate pack of the plate heat exchanger 2, the plates 8 are arranged with the front side 30 and the back side 32 of one plate 8 facing the front side and the back side, respectively, of the neighboring heat transfer plates. Further, every second plate 8 is turned upside-down or rotated 180 degrees, in relation to a reference orientation, around a normal direction N which is normal to the figure plane of Fig. 3. In other words, every second plate 8 is "flipped", i.e. rotated 180 degrees around its transverse center axis, in relation to the rest of the plates.

[0054] As mentioned above, the plates 8 of the plate pack are welded together in pairs, back side 32 to back side 32, along their respective sealing grooves 64, to form cassettes 57. Fig. 7 shows one of the cassettes 57 comprising the plate 8a illustrated in Fig. 3 and the plate 8c visible in Fig. 4 (but not in Fig. 7). The plate 8c is "flipped" in relation to the plate 8a. In the plate pack of the plate heat exchanger 2, the welded cassettes 57 are separated by gaskets 59, at least a majority of which gaskets 59 are similar, one of these gaskets 59 being illustrated in Fig. 7. In line with the above, the gaskets 59 are accommodated in the gasket grooves 68 of the plates 8, as is illustrated in Fig. 7. Thus, the heat exchanger 2 comprises channels of two different types; welded channels inside the cassettes 57 and gasketed channels

between the cassettes 57.

[0055] The plates 8 contact each other in contact areas. Within the upper and lower distribution areas 44 and 52, which are provided with a distribution corrugation pattern of so-called chocolate type, the contact areas are elongate. Within the heat transfer area 46, which is provided with a heat transfer corrugation pattern of so-called herringbone type, the contact areas are point shaped. Within the upper and lower transition areas 45 and 53, which are provided with a transition corrugation pattern of elongate beams, the contact areas are point shaped. In line with the initial discussions, the provision of the upper and lower transition areas 45 and 53 on the plates 8 makes the plate pack mechanically strong between the heat transfer area and each of the upper and lower distribution areas. Further, since the transition corrugation pattern is designed, as described above, so as to provide a varying flow resistance within the upper and lower transition areas 45 and 53, the fluid flow distribution inside the channels of the plate pack is improved. More particularly, with reference to Figs. 3 and 5, there are an endless number of different, indiscrete flow paths for a fluid to be conveyed from the first port hole 40, across the front side 30, to the third port hole 48, of the plate 8a. A shorter flow path leads along the first long side 18, and through the first transition sub area A of the upper and lower transition areas 45 and 53, of the plate 8a, while a longer flow path leads along the second long side 20, and through the second transition sub areas B of the upper and lower transition areas 45 and 53, of the plate 8a. The inventive design of the transition corrugation pattern will vary the flow resistance through the upper and lower transition areas 45 and 53 of the plate 8a such that the shorter flow path is given a higher flow resistance and the longer flow path is given a lower flow resistance. In turn, this will optimize the flow distribution across the front side 30 of the plate 8a. In a corresponding way, there will be shorter and longer flow paths from the fourth port hole 50, across the back side 32, to the second port hole 42, of the plate 8a. The flow resistance will be higher for the shorter flow path and lower for the longer flow path which will optimize the flow distribution across the back side 32 of the plate 8a.

[0056] The above described embodiment of the present invention should only be seen as an example. A person skilled in the art realizes that the embodiment discussed can be varied and combined in a number of ways without deviating from the inventive conception.

[0057] As an example, the above specified distribution, transition and heat transfer corrugation patterns are just exemplary. Naturally, the invention is applicable in connection with other types of corrugation patterns. As an example, the transition corrugation pattern may consist of straight beams which all extend with the same angle of inclination in relation to the longitudinal center axis of the heat transfer plate, instead of beams of which only some extend with the same angle of inclination in relation to the longitudinal center axis as in the figures. The transition

corrugation pattern may also consist of beams which all extend with different angles of inclination in relation to the longitudinal center axis of the plate. As another example, the transition corrugation pattern may comprise beams, and thus tops and bottoms, in the shape of arrows pointing towards one of the first and the second long sides of the heat transfer plate, or pointing towards one of the first and the second short sides of the heat transfer plate.

[0058] The upper transition area of the plate illustrated in the drawings comprises first and second, i.e. two, transition sub areas. Therefore, the first transition sub area is a first outermost sub area, and the second transition sub area is a second outermost sub area, of the upper transition area, and the first and second transition sub areas border on each other. However, alternative designs of the upper transition area are possible. For example, a plate according to the present invention may comprise more than two transition sub areas with different values of the largest back cross section. The largest back cross sections within one and the same of the transition sub areas may be constant or varying. The largest back cross sections within one or more of the transition sub areas may be varying while the largest back cross sections within one or more of the transition sub areas may be constant.

[0059] The first borderline of the plate illustrated in the figures has curved, as well as straight, portions, while the second borderline is straight. The first and/or second borderlines may have alternative designs on other plates according to the invention. As an example, both the first and second borderlines may be straight. As another example, both the first and the second borderlines may be curved. The first and second borderlines may be parallel.

[0060] The plate heat changer above comprises one plate type only. Naturally, the plate heat exchanger could instead comprise two or more different types of alternately arranged heat transfer plates. Further, the heat transfer plates could be made of other materials than stainless steel.

[0061] The present invention could be used in connection with other types of plate heat exchangers than semi-welded ones, such as all-welded, (all-) gasketed and brazed plate heat exchangers.

[0062] The bottom of the field gasket groove portion need not extend halfway between the top plane and the bottom plane at the two diagonal sections of the field gasket groove portion but may instead extend closer to one of the top and bottom planes. Similarly, the bottom of the second ring gasket groove portion, just like the bottom of the fourth ring gasket groove portion, need not extend halfway between the top plane and the bottom plane along their complete lengths but may instead, along part of their lengths or their complete lengths extend in another plane, for example closer to the top plane than the bottom plane. If the present invention is used in connection with a gasketed plate heat exchanger, the bottom of the field gasket groove portion need not extend in the

bottom plane at all, but instead between the top plane and the bottom plane along its complete length.

[0063] It should be stressed that the attributes front, back, upper, lower, first, second, third, etc. is used herein just to distinguish between details and not to express any kind of orientation or mutual order between the details.

[0064] Further, it should be stressed that a description of details not 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 heat transfer plate (8, 8a) having a front side (30), a back side (32) and comprising an upper distribution area (44), an upper transition area (45) and a heat transfer area (46) arranged in succession along a longitudinal center axis (L) of the heat transfer plate (8, 8a) which divides the heat transfer plate into a first half (19) and a second half (21), the upper transition area (45) adjoining the upper distribution area (44) along a first borderline (47) and the heat transfer area (46) along a second borderline (55), the heat transfer area (46), the upper distribution area (44) and the upper transition area (45) being provided with a heat transfer corrugation pattern, a distribution corrugation pattern and a transition corrugation pattern, respectively, the transition corrugation pattern differing from the distribution corrugation pattern and the heat transfer corrugation pattern and comprising tops (60) extending in an imaginary top plane (TP) facing the front side (30) of the heat transfer plate (8, 8a) and bottoms (62) extending in an imaginary bottom plane (BP) facing the back side (32) of the heat transfer plate (8, 8a), a bottom pitch (bp) between the bottoms (62) being essentially constant within more than 50% of the upper transition area (45), **characterized in that** a respective largest back cross section (BC) of a back corrugation volume (BV) between each two adjacent ones of the bottoms (62) and enclosed by the bottom plane (BP) and the heat transfer plate (8, 8a), which back cross section (BC) is taken perpendicular to a longitudinal extension (lt) of the top (60) extending between said two adjacent ones of the bottoms (62), is varying.
2. A heat transfer plate (8, 8a) according to claim 1, wherein a top pitch (tp) between the tops (60) is essentially constant within more than 50% of the upper transition area (45).
3. A heat transfer plate (8, 8a) according to any of the preceding claims, wherein the upper transition area (45) comprises a first transition sub area (A) and a

second transition sub area (B), each of the first and second transition sub areas (A, B) extending between said first and second borderlines (47, 55), wherein said largest back cross section (BC) within more than 50% of the first transition sub area (A) is larger than said largest back cross section (BC) within more than 50% of the second transition sub area (B).

4. A heat transfer plate (8, 8a) according to claim 3, wherein the first transition sub area (A) is a first outermost sub area of the upper transition area (45) and the second transition sub area (B) is a second outermost sub area of the upper transition area (45) and the first and second transition sub areas (A, B) borders on each other.
5. A heat transfer plate (8, 8a) according to any one of claims 3-4, wherein said largest back cross section (BC) is constant within more than 50% of the first transition sub area (A).
6. A heat transfer plate (8, 8a) according to any claims 3-5, wherein said largest back cross section (BC) is constant within more than 50% of the second transition sub area (B).
7. A heat transfer plate (8, 8a) according to any of claims 3-6, wherein the first transition sub area (A) constitutes 30-70% of the upper transition area (45).
8. A heat transfer plate (8, 8a) according to any of the preceding claims, wherein a front transition volume within the upper transition area (45) on the first half (19) of the heat transfer plate (8, 8a) and between the heat transfer plate (8, 8a) and the top plane (TP) is different from a back transition volume within the upper transition area (45) on the first half (19) of the heat transfer plate (8, 8a) and between the heat transfer plate (8, 8a) and the bottom plane (BP).
9. A heat transfer plate (8, 8a) according to any of the preceding claims, comprising an upper end part (34), a center part (36) and a lower end part (38) arranged in succession along the longitudinal center axis (L) of the heat transfer plate (8, 8a), the upper end part (34) comprising a first port hole (40) and a second port hole (42), the lower end part (38) comprising a third port hole (48) and a fourth port hole (50) and the center part (36) comprising the heat transfer area (46), wherein the heat transfer plate (8, 8a) further comprises, as seen from the front side (30), a sealing groove (64) comprising a field sealing groove portion (64a) enclosing the heat transfer area (46) and two of the first, second, third and fourth port holes (40, 42, 48, 50), and wherein the heat transfer plate (8, 8a) further comprises a gasket groove (68) comprising a field gasket groove portion (68a) enclosing the heat

transfer area (46) and two of the first, second, third and fourth port holes (40, 42, 48, 50) which are not enclosed by the field sealing groove portion (64a).

10. A heat transfer plate (8, 8a) according to claim 9, wherein the first port hole (40) and the third port hole (48) are arranged on one side of the longitudinal center axis (L) of the heat transfer plate (8, 8a), and the second port hole (42) and the fourth port hole (50) are arranged on another side of the longitudinal center axis (L) of the heat transfer plate (8, 8a).
11. A heat transfer plate (8, 8a) according to any of the claims 9-10, wherein the field sealing groove portion (64a) encloses the second port hole (42) and the fourth port hole (50).
12. A heat transfer plate (8, 8a) according to any of the claims 9-11, wherein a bottom (66a) of the field sealing groove portion (64a), along at least more than half of a length of the field sealing groove portion (64a), extends in the bottom plane (PB).
13. A heat transfer plate (8, 8a) according to any of the claims 9-12, wherein the sealing groove (64) further comprises, as seen from the front side (30) of the heat transfer plate, a first ring sealing groove portion (64b) enclosing the first port hole (40) and a third ring sealing groove portion (64c) enclosing the third port hole (48), wherein a bottom (66b) of the first ring sealing groove portion (64b), along at least more than half of a length of the first ring sealing groove portion (64b), extends in the bottom plane (PB), and a bottom (66c) of the third ring sealing groove portion (64c), along at least more than half of a length of the third ring sealing groove portion (64c), extends in the bottom plane (PB).
14. A cassette (57) comprising two heat transfer plates (8, 8a) according to any of the claims 9-13, wherein the back side (32) of one of the two heat transfer plates (8, 8a) faces the back side (32) of another one of the two heat transfer plates (8, 8a) and the two heat transfer plates (8, 8a) are welded to each other along the sealing grooves (64).
15. A heat exchanger (2) comprising a plurality of heat transfer plates (8, 8a) according to any of the claims 1-13 and gaskets (59), each of the gaskets (59) being arranged in the gasket grooves (68) of two adjacent ones of the heat transfer plates (8, 8a).

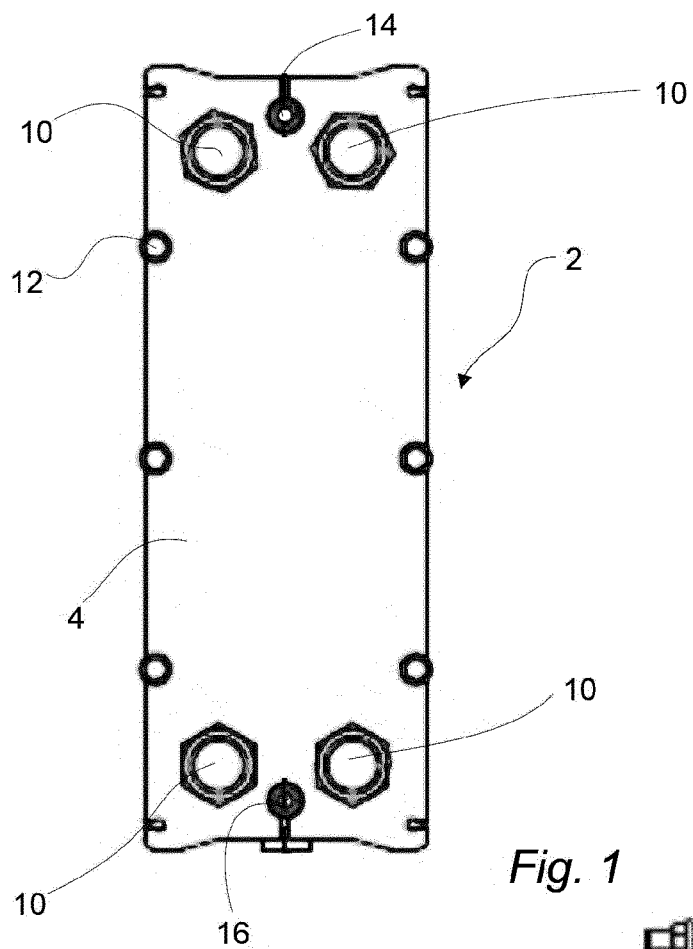


Fig. 1

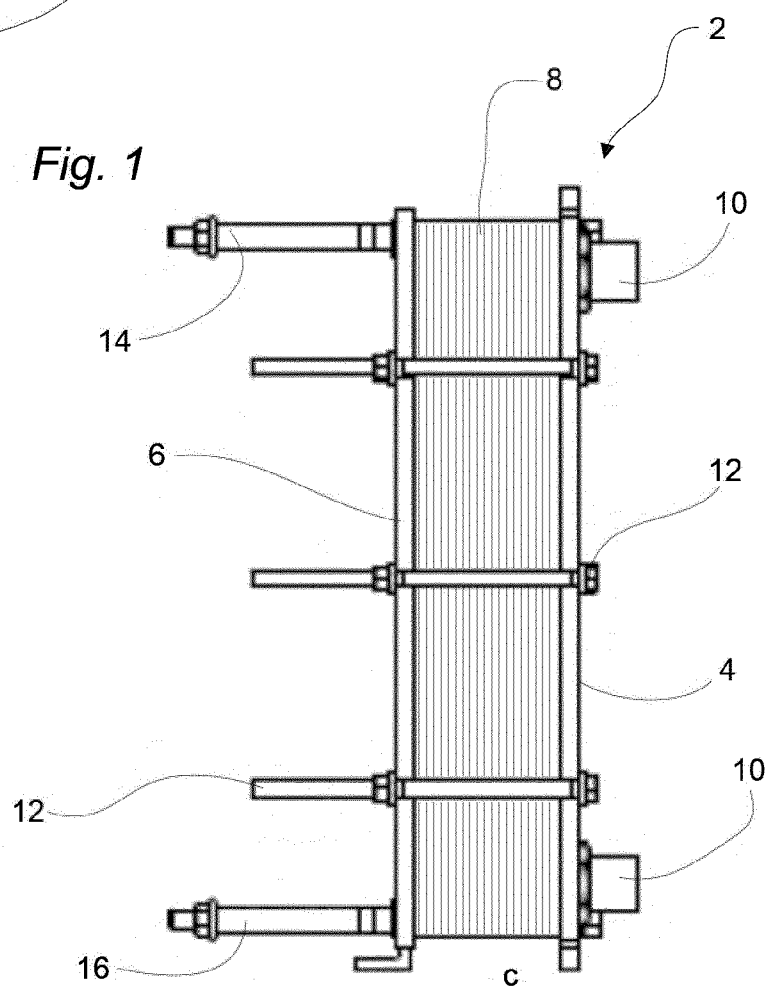


Fig. 2

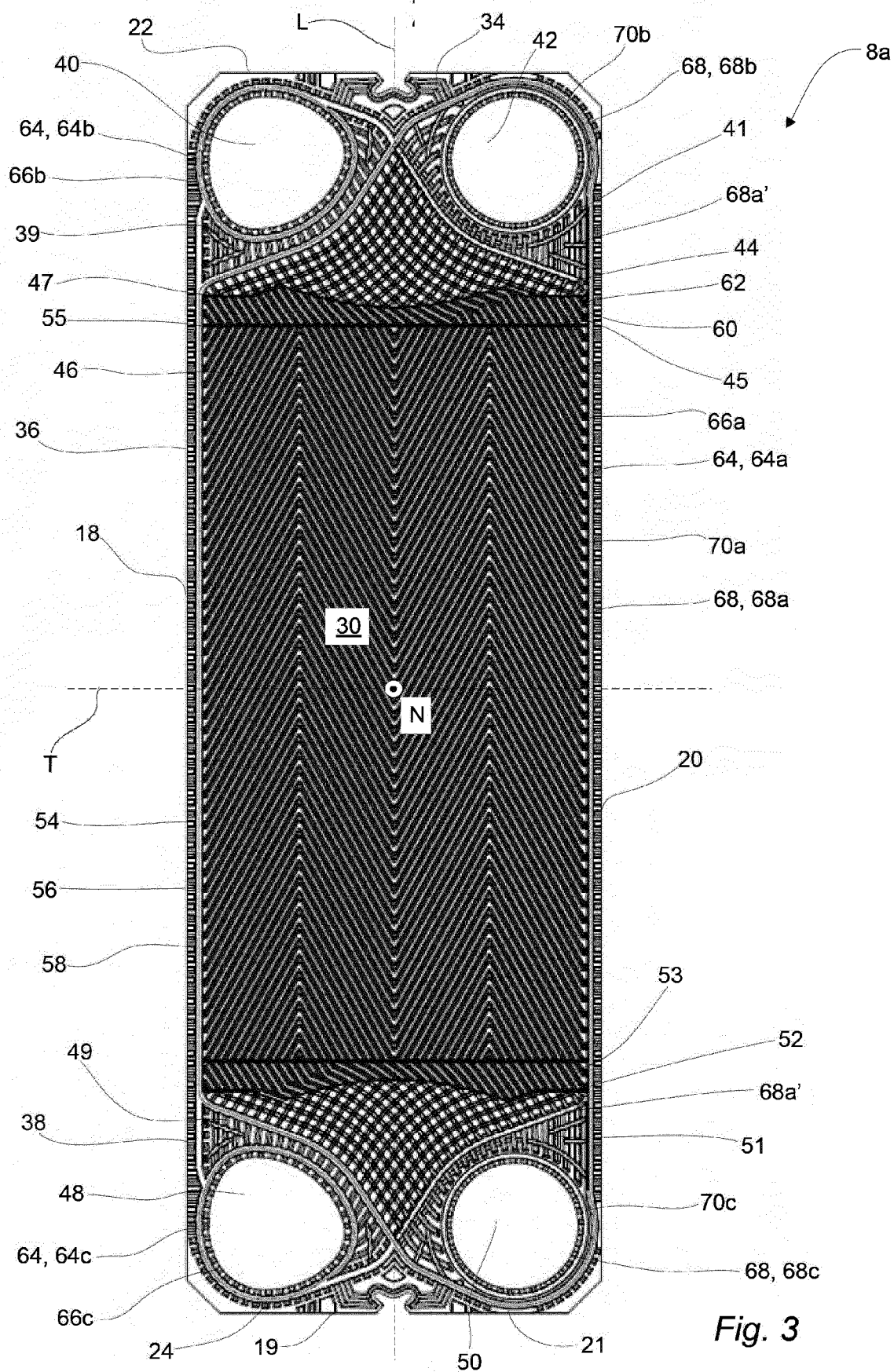


Fig. 3

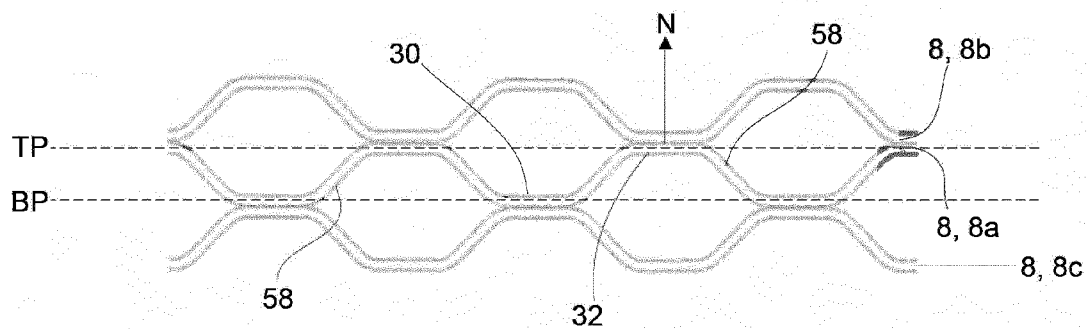


Fig. 4

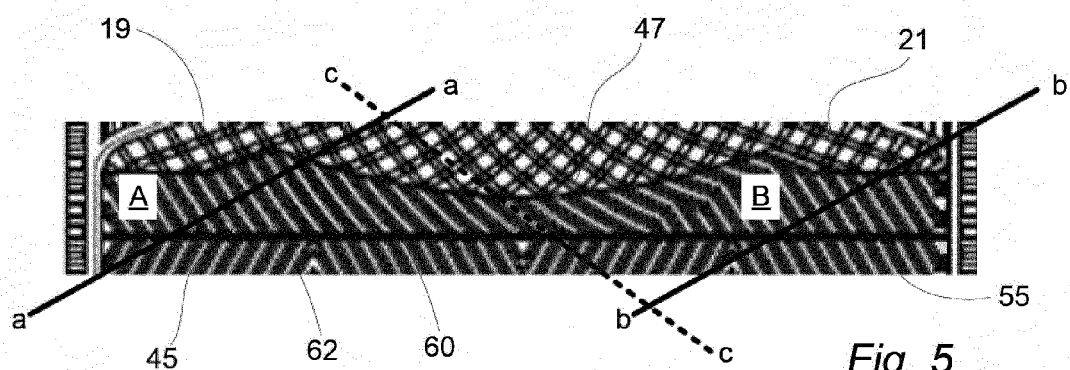


Fig. 5

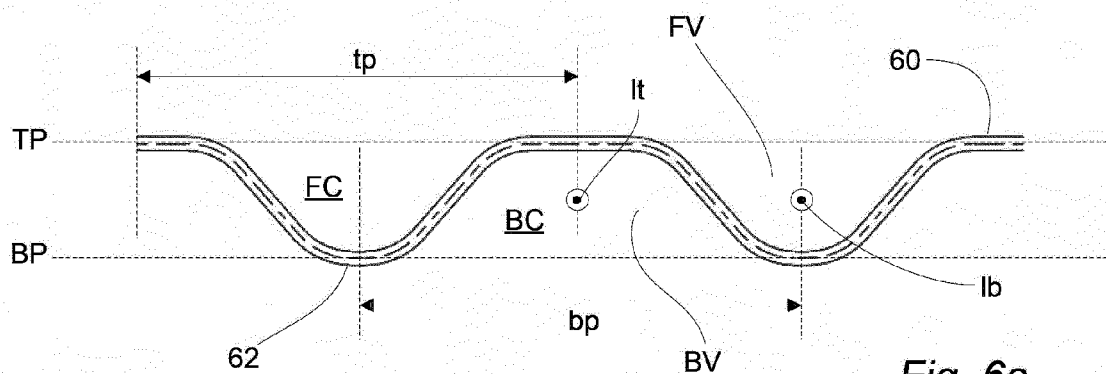


Fig. 6a

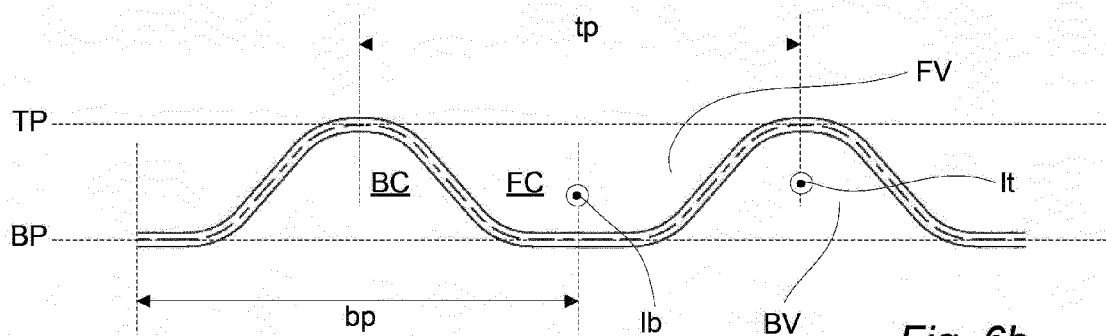


Fig. 6b

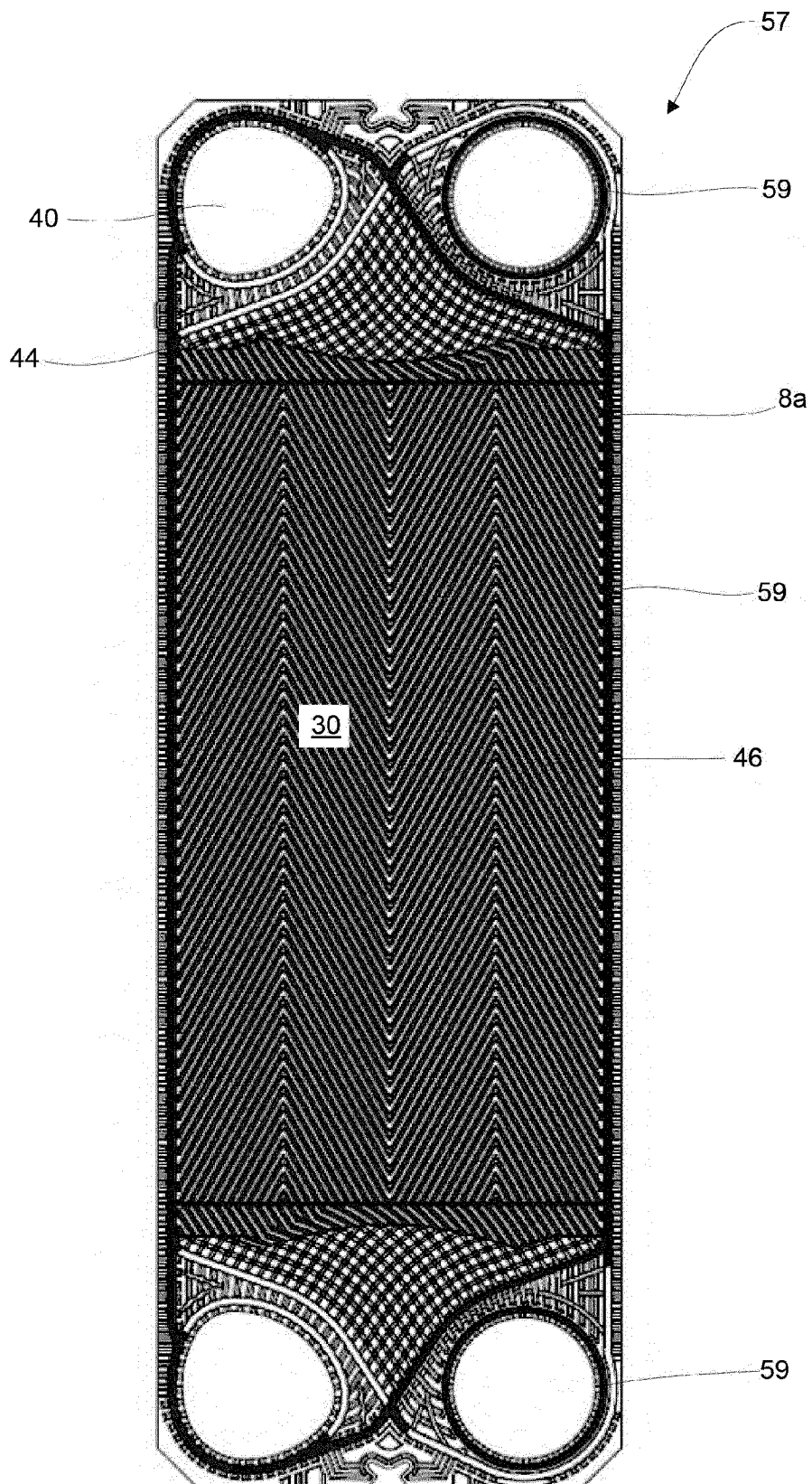


Fig. 7



EUROPEAN SEARCH REPORT

Application Number

EP 23 21 6948

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			F28F
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
Munich		10 April 2024	Martínez Rico, Celia
CATEGORY OF CITED DOCUMENTS			
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