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(54) **HEAT EXCHANGER CASSETTE, GASKET ARRANGEMENT AND HEAT EXCHANGER CASSETTE ARRANGEMENT**

(57) The present invention relates to a heat exchanger cassette comprising: an upper heat exchanger plate (100, 100:1), and a lower heat exchanger plate (100, 100:2). An edge portion (110) of the lower heat exchanger plate (100:2) comprises an evacuation hole (160) circumscribed by a sealing area (162) formed at the top side (101) of the lower heat exchanger plate (100:2). The sealing area (162) is adapted to seal against an evacuation gasket member (320). The sealing area (162) and the

evacuation hole (160) are disposed at least partially within a cutout area (170) of the upper heat exchanger plate (100:1). A boundary segment (180) of the cutout area (170) extends through the upper heat exchanger plate (100:1) between a first (182) and a second point (184) of an outer perimeter of the upper heat exchanger plate (100:1). A gasket arrangement (300) and a heat exchanger cassette arrangement (400) are also provided.

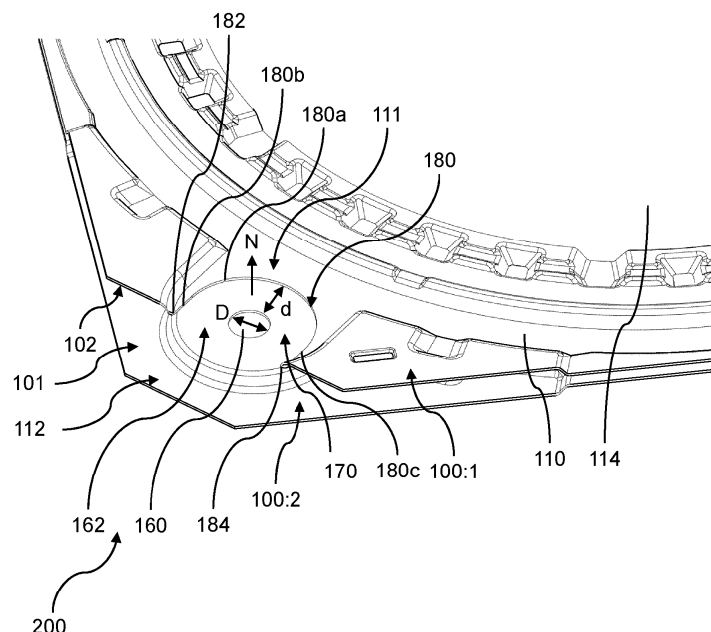


Fig.5

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Description

Technical Field

[0001] The invention relates to the field of plate heat exchangers. More particularly, it is related to heat exchanger cassette for a semi-welded plate heat exchanger, a gasket arrangement for a heat exchanger cassette and a heat exchanger cassette arrangement comprising such a heat exchanger cassette and gasket arrangement.

Background Art

[0002] Plate heat exchangers, PHEs, are used in numerous applications where heat is to be transferred from one fluid to another or vice versa. A typical plate heat exchanger includes two end plates between which a plurality of heat exchanger plates or heat transfer plates or simply plates are arranged in a stacked configuration so as to form a plate stack or plate pack. Generally, a number of heat exchanger plates and gaskets are stacked in an alternating fashion. In this way first plate interspaces and second plate interspaces are alternately formed between the heat exchanger plates. The first plate interspaces and the second plate interspaces are typically separated from each other and are designed to receive a respective fluid between which fluids heat is to be exchanged. Thus, the first plate interspaces and the second plate interspaces form channels for the respective fluids. Further, respective inlet and outlet ports are typically provided to the first plate interspaces and to the second plate interspaces. The inlet and outlet ports are typically formed by aligned portholes extending through the plate stack.

[0003] In a type of common PHE two adjoining heat exchanger plates are welded to each other to form what is generally referred to as a heat exchanger cassette or simply a cassette. The cassettes are in turn stacked with gaskets in between. Such PHEs are generally referred to as semi-welded PHEs. Thus, in semi-welded PHEs, the plate interspaces formed between the heat exchanger plates making up a cassette are sealed off by a weld, whereas the plate interspaces formed between the cassettes are sealed off by gaskets. In other words, a semi-welded PHE includes a combination of welded plate interspaces (welded fluid channels) and gasketed plate interspaces (gasketed fluid channels). However, in semi-welded PHEs, the fluid attributable to the welded plate interspaces of the cassettes is typically sealed off by a ring gasket around the inlet port and a ring gasket around the outlet port in between each one of the cassettes. Thus, even if a fluid is fed through welded plate interspaces it is still sealed off by two gaskets for each cassette.

[0004] Some fluids used in heat exchangers are capable of permeating gaskets meaning that although a generally speaking tight gasket is in place, the fluid will

still permeate through the material of the gasket and escape e.g. to the ambient. Although a semi-welded PHE may significantly reduce the permeation through gaskets owing to the welded plate interspaces or channels, problems related to permeation through the ring gaskets can still be outspoken. For instance, in ammonia applications problems related to permeation through the ring gaskets of a semi-welded PHE can lead to work environment problems and health issues since ammonia e.g. has a pungent smell. Given the problems associated with fluids permeating the ring gaskets of semi-welded PHEs, it is desirable to handle permeated fluid in a safe way.

[0005] To this end, it has been suggested to surround each ring gasket with another gasket to capture the permeated fluid between the gaskets. It has further been suggested to provide the plates of the heat exchanger cassettes with aligning openings located between the gaskets to be able to lead away the permeated fluid in a safe way via the aligning openings. However, in order to lead away the permeated fluid in a safe way and not risk undesired leakage the plates of each heat exchanger cassette must connect to each other in a fluid tight manner around the aligning openings. However, it has proved troublesome to connect the plates of a heat exchanger cassette to each other around the aligning openings in a reliable manner which remain fluid tight over time. The plates of a heat exchanger cassette are typically welded to each other around the aligned openings. Not only is it troublesome to provide a weld around a pair of aligned openings of a relatively speaking small radius. Moreover, such weld risk cracking or breaking over time.

[0006] Hence, there is room for improvement when it comes to handling fluid having permeated through gaskets of a semi-welded PHE.

Summary

[0007] With the above in mind, it is an objective of the present invention to provide an improved heat exchanger cassette for a semi-welded plate heat exchanger, an improved gasket arrangement for a heat exchanger cassette as well as an improved heat exchanger cassette arrangement.

[0008] Another objective is to provide such a heat exchanger cassette which is capable of evacuating permeated fluid, i.e. fluid having permeated a gasket, such as a port hole gasket, in a safe way.

[0009] Another objective is to provide such a heat exchanger cassette which is capable of evacuating permeated fluid in a safe way over time.

[0010] Another objective is to provide such a heat exchanger cassette which is less prone to leaking.

[0011] Another objective is to provide such a heat exchanger cassette which is less prone to cracking or breaking.

[0012] Another objective is to provide such a heat exchanger cassette which is capable of evacuating per-

meated fluid in a safe way while not negatively affecting the heat transfer performance.

[0013] Another objective is to provide such a heat exchanger cassette which is capable of evacuating permeated fluid while not negatively affecting the flow of the fluids between which heat is to be exchanged.

[0014] Another objective is to provide such a heat exchanger cassette which more cost-effective.

[0015] Another objective is to provide such a gasket arrangement which is capable of evacuating permeated fluid in a safe way.

[0016] Another objective is to provide such a gasket arrangement which is capable of evacuating permeated fluid in a safe way over time.

[0017] Another objective is to provide such a gasket arrangement which is capable of evacuating permeated fluid in a safe way while not negatively affecting the heat transfer performance.

[0018] Another objective is to provide such a gasket arrangement which is capable of evacuating permeated fluid while not negatively affecting the flow of the fluids between which heat is to be exchanged.

[0019] Another objective is to provide such a gasket arrangement which is more cost-effective.

[0020] To achieve at least one of the above objects and also other objects that will be evident from the following description, heat exchanger cassette for a semi-welded plate heat exchanger, having the features defined in claim 1, is provided according to the present inventive concept. A gasket arrangement for a heat exchanger cassette is provided according to claim 10. A heat exchanger cassette arrangement comprising a heat exchanger cassette and a gasket arrangement is provided according to claim 15.

[0021] More specifically, according to a first aspect, there is provided a heat exchanger cassette for a semi-welded plate heat exchanger, comprising:

an upper heat exchanger plate, and
a lower heat exchanger plate,

wherein a top side of the lower heat exchanger plate is welded to a bottom side of the upper heat exchanger plate,

wherein an edge portion of the lower heat exchanger plate comprises an evacuation hole circumscribed by a sealing area formed at the top side of the lower heat exchanger plate, the sealing area being adapted to seal against an evacuation gasket member,

wherein the sealing area and the evacuation hole are disposed at least partially within a cutout area of the upper heat exchanger plate, and wherein a boundary segment of the cutout area extends through the upper heat exchanger plate between a first and a second point of an outer perimeter of the upper heat exchanger plate.

[0022] Hereby an improved heat exchanger cassette for a semi-welded plate heat exchanger is provided.

[0023] The heat exchanger cassette is designed for, and hence suitable to be used with, semi-welded PHEs.

[0024] The present invention is based on the realization that by providing an evacuation hole circumscribed by a sealing area in the lower plate (one plate out of two) of a cassette where the evacuation hole and the sealing area are disposed at least partially within a cutout area of the upper plate (the other one of the two plates) of the cassette, fluid having permeated through a gasket, such as a port hole gasket, may be efficiently evacuated in a safe way while the need for a fluid tight connection between the upper plate and the lower plate of the cassette at the evacuation hole may be eliminated. This because, only the lower plate, i.e. the plate being provided with the actual evacuation hole, needs to be involved in evacuating permeated fluid through the evacuation hole since the upper plate, i.e. the plate being provided with the cutout area, is not locally present at the evacuation hole and the sealing area. Put differently, the upper plate has locally an open area at least partially aligning, overlapping with or facing the location of the evacuation hole and the sealing area of the lower plate meaning that the sealing area of the lower plate may seal against an evacuation gasket member such that permeated fluid may be evacuated via the evacuation gasket member and the evacuation hole. In other words, only the lower plate of the cassette needs to seal against such evacuation gasket member. More specifically, only the lower plate needs to provide a fluid tight connection to corresponding plates of adjacent cassettes when used in a stacked configuration in a pack or stack of cassettes in a PHE. In practice, when a plurality of cassettes are used in a pack of a PHE the evacuation holes of the cassettes will align or substantially align. In this way, permeated fluid may be evacuated along a stacking direction of the pack of cassettes via the aligned evacuation holes when a respective evacuation gasket member is stacked between each pair of adjoining cassettes at the respective evacuation holes. Such evacuation gasket member may to this end typically be adapted to seal against the sealing area such that an evacuation space is formed within the evacuation gasket member, at the evacuation hole.

[0025] Further, by the configuration of the evacuation hole and the cutout area permeated fluid may be evacuated through the evacuation hole via an evacuation gasket member with no or minimal impact on the performance of the PHE at hand. This because the evacuation hole is located in an edge portion or region of the lower plate and the cutout area has a boundary segment which extends through the upper plate between a first and a second point of an outer perimeter of the upper plate. Hence, the cutout area may generally speaking be said to be a slot or a cutaway extending through thickness of upper heat exchanger plate. Thus, the evacuation hole and the cutout area will be located in an edge region of the cassette and will consequently not interfere with the flow

of any fluids between which fluids heat is to be exchanged. Put differently, the evacuation hole and cutout area may in practice be located outside of any area forming part of any fluid channel of the cassette. That is, the evacuation hole and the cutout area may not align with any fluid channel of the cassette as seen in a normal direction to a major side surface of the cassette. In practice, the evacuation hole will be accessible from a perimeter or outer edge of the lower heat exchanger plate via the cutout area of the upper heat exchanger plate.

[0026] Moreover, the evacuation hole and the cutout area may be formed with no additional manufacturing steps as compared to a standard cassette. In practice, the evacuation hole and the cutout area may be cut when cutting the plates of the cassette. In this regard, it is to be noted that the upper plate and the lower plate may be of a corresponding design but rotated, flipped or turned in relation to each other such that the evacuation hole and the sealing area faces the cutout area. In other words, as is known in the art, by rotating, flipping or turning identical or similar heat exchanger plates, the heat exchanger plates may interact with each other to form a cassette having desired properties.

[0027] It should be noted that within the context of this application the term "evacuation hole" may here mean any hole or opening extending through the lower heat exchanger plate.

[0028] It should be noted that within the context of this application the term "sealing area" may here mean any area against which a gasket member or gasket may seal. In practice, the sealing area may be adapted to seal against an evacuation gasket member of a gasket arrangement. The sealing area may be a flat or planar surface. However, the sealing area may be a non-flat area. Thus, the sealing area may comprise area portions or surface portions located at different heights or in different planes of the lower heat exchanger plate. For instance, the sealing area may be a corrugated area. i.e. an area having a corrugated surface. For instance, the sealing area may be a stepped area, an inclined area or a wavy area to give a few more nonlimiting examples. In this regard, it is to be understood that the gasket member or gasket which is to seal against the sealing area may to advantage be complementary or substantially complementary to the sealing area.

[0029] It should be noted that within the context of this application the term "cutout area" may here mean any cutout area, cutaway area or open area of the upper heat exchanger plate which at least partially exposes the evacuation hole and the sealing area as seen from a top side of the upper heat exchanger plate, and consequently from a top side of the lower heat exchanger plate, where the cutout area extends to the perimeter or edge of the upper heat exchanger plate. Thus, the cutout area may be any area of the upper heat exchanger plate, where the upper heat exchanger plate is void of material such that the evacuation hole and the sealing area are at least partially exposed, and where the cutout area ex-

tends to the perimeter or edge of the upper heat exchanger plate.

[0030] It is to be noted that the wordings "upper" and "lower" heat exchanger plate are only relative terms used to describe the mutual relationship between the upper and the lower plates of the cassette. This means that which plate of the two plates (upper and lower) is considered to constitute the lower plate is only a matter of perspective. Correspondingly, which plate of the two plates (upper and lower) is considered to constitute the upper plate is only a matter of perspective. Correspondingly, the wordings "top side" and "bottom side" are also only relative terms.

[0031] The cutout area may align with the sealing area as seen in a normal direction of the sealing area. In this way, an evacuation gasket member may seal against the sealing area without contacting or interfering with the lower plate. Thus, the sealing area may allow for that a fluid tight seal is provided between itself and an evacuation gasket member. As a result, the lower plate may not be involved in evacuating permeated fluid at the evacuation hole. In this regard, it is to be noted that the also the evacuation hole will align with the cutout area since the evacuation hole is circumscribed by the sealing area.

[0032] The heat exchanger cassette may further comprise a port hole, the upper heat exchanger plate may comprise a port hole gasket seat provided on a top side of the upper heat exchanger plate and circumscribing the port hole, the port hole gasket seat being adapted to receive a port hole gasket, the upper heat exchanger plate may comprise a permeation barrier seat provided on the top side of the upper heat exchanger plate and at least partially circumscribing the port hole gasket seat, the permeation barrier seat being adapted to receive a permeation barrier gasket member such that a permeation space is defined at the top side of the upper heat exchanger plate between the permeation barrier seat and the port hole gasket seat.

[0033] By the upper heat exchanger plate comprising a port hole gasket seat provided on a top side of the upper heat exchanger plate and circumscribing the port hole, a port hole gasket, also known as a ring gasket, may be received and retained at the porthole seat. In this way, such port hole gasket may seal around the porthole between adjoining cassettes.

[0034] By the upper heat exchanger plate comprising a permeation barrier seat provided on the top side of the upper heat exchanger plate where the permeation barrier seat at least partially circumscribes the port hole gasket seat, a permeation barrier gasket member may be received and retained at the permeation barrier seat. In this way, a permeation space may be defined at the top side of the upper heat exchanger plate between the permeation barrier seat and the port hole gasket seat. In practice, the permeation space will be formed when a port hole gasket is received and retained at the porthole seat and a permeation barrier gasket member is received in the permeation barrier seat.

[0035] The so formed permeation space may in turn be fluidly connected to the to the evacuation hole by means of a channel member and an evacuation gasket member, where the evacuation gasket member is adapted to seal against the sealing area and a channel member is adapted to fluidly connect the permeation space and an evacuation space formed within the evacuation gasket member.

[0036] As a result, fluid having permeated through such porthole gasket may be evacuated through the evacuation hole. In this regard, it is to be understood that the so formed permeation space and the evacuation space will be open in a normal direction of the top side of the upper heat exchanger plate unless arranged in a stack of cassettes. However, when the cassette is arranged in a stack with relevant gaskets in between a gasketed or sealed permeation space will in practice be formed along the top side of the upper heat exchanger plate between the port hole gasket seat and the permeation barrier seat. Correspondingly, a sealed evacuation space will be formed within such evacuation gasket member.

[0037] It should be noted that within the context of this application the term "port hole gasket seat" may here mean any area, groove, set of grooves or similar which is adapted to receive a port hole gasket.

[0038] It should be noted that within the context of this application the term "permeation barrier seat" may here mean any area, groove, set of grooves or similar which is adapted to receive a permeation barrier gasket member, gasket, seal or similar so as to define a permeation space at the first side of the heat exchanger plate between the permeation barrier seat and the port hole gasket seat.

[0039] The cutout area may be located outside of the permeation barrier seat. In this way, the cutout area may not influence or affect how a permeation barrier gasket member received in the permeation barrier seat seals against an adjoining cassette when the cassette is used in a pack of a PHE.

[0040] The boundary segment of the cutout area may be formed by a curved portion, a first and a second linear portion, wherein the first linear portion extends between the first point and a first end of the curved portion, and wherein the second linear portion extends between the second point and a second end of the curved portion. In this way, a cutout area having a shape suitable to receive, but not interfere with, an evacuation gasket member may be realized. Moreover, in this way, a cutout area which is less prone to crack along the boundary segment may be provided mainly owing to the curved portion.

[0041] The curved portion may be a semicircular portion, and the first and second linear portions may extend in parallel.

[0042] The curved portion may be a semicircular portion.

[0043] The first and second linear portions may extend in parallel.

[0044] The boundary segment of the cutout area may

be formed by a linear portion extending between the first and second points. In this way, the cutout area may be efficiently formed with single linear boundary segment. In practice, the cutout area may be formed by a cutout corner region of the lower plate. In other words, the cutout area may be formed by cutting away corner region of the lower plate with a straight cut.

[0045] A minimal distance from the evacuation hole to the boundary segment of the cutout area may correspond to at least 50% of a diameter of the evacuation hole, such as 75% to 150% of the diameter of the evacuation hole. In this way, a minimal extension of the sealing area in any direction from the evacuation hole will likewise correspond to at least 50% of a diameter of the evacuation hole. Hence the sealing area may have a minimal extension of the sealing area in any direction from the evacuation hole which allows for an efficient sealing against an evacuation gasket member. Put differently, the sealing area may be sufficiently large in any direction from the evacuation hole such that an evacuation gasket member may seal thereagainst without interfering with or become influenced by the boundary segment of the cutout area.

[0046] A minimal distance from the evacuation hole to the boundary segment of the cutout area may correspond to at least 50% of a diameter of the evacuation hole.

[0047] A minimal distance from the evacuation hole to the boundary segment of the cutout area may correspond to at least 75% to 150% of a diameter of the evacuation hole.

[0048] The top side of the upper heat exchanger plate may comprise a channel area extending between the permeation barrier seat and the boundary segment of the cutout area. In this way, the cassette may receive a channel gasket member for fluidly connecting a permeation space of the above described type with the evacuation hole. Thus, the channel area may generally speaking be said to be adapted to receive a channel gasket member for fluidly connecting the permeation space and the evacuation hole. To this end, the channel area may be an area of the top side of the upper plate of the cassette which is recessed in relation to a top plane of the upper plate of the cassette. In this way, a channel gasket member for fluidly connecting the permeation space and the evacuation hole may be given room such that it may extend between the permeation barrier seat and the boundary segment without being compressed or without being too compressed when the cassette is used in a pack of a PHE.

[0049] The boundary segment of the cutout area may comprise one or more curved portions.

[0050] The boundary segment of the cutout area may comprise one or more linear portions.

[0051] The boundary segment of the cutout area may be an arch-shaped boundary segment.

[0052] The boundary segment of the cutout area may comprise a semicircular portion.

[0053] The boundary segment of the cutout area may be formed by a semicircular portion, a first and a second

linear portion, wherein the first linear portion extends between the first point and a first end of the semicircular portion, and wherein the second linear portion extends between the second point and a second end of the semicircular portion.

[0054] The boundary segment of the cutout area may comprise a circle sector having a central angle greater than 180 degrees.

[0055] The upper heat exchanger plate may be integrally formed by being cut and pressed from sheet metal, such as stainless steel sheet metal.

[0056] The lower heat exchanger plate may be integrally formed by being cut and pressed from sheet metal, such as stainless steel sheet metal.

[0057] The port hole gasket seat may comprise a groove configured to retain a port hole gasket.

[0058] The permeation barrier seat may comprise a groove configured to retain a permeation barrier gasket member.

[0059] The port hole gasket seat may comprise a plurality of groove sections defined on the top side of the upper plate.

[0060] The port hole gasket seat may comprise a plurality of groove sections defined by protruding portions on the top side of the upper plate.

[0061] The permeation barrier seat may comprise a plurality of groove sections defined on the top side of the upper plate.

[0062] The permeation barrier seat may comprise a plurality of groove sections defined by protruding portions on the top side of the upper plate.

[0063] The lower heat exchanger plate may comprise a port hole gasket seat provided on a bottom side of the lower heat exchanger plate and circumscribing the port hole, the port hole gasket seat being adapted to receive a port hole gasket, the lower heat exchanger plate may comprise a permeation barrier seat provided on the bottom side of the lower heat exchanger plate and at least partially circumscribing the port hole gasket seat, the permeation barrier seat being adapted to receive a permeation barrier gasket member such that a permeation space is defined at a bottom side of the lower heat exchanger plate between the permeation barrier seat and the port hole gasket seat.

[0064] According to a second aspect of the invention, there is provided a gasket arrangement for a heat exchanger cassette, comprising:

a permeation barrier gasket member adapted to be arranged on a top side of an upper heat exchanger plate of the heat exchanger cassette and to at least partially circumscribe a port hole gasket circumscribing a port hole of the heat exchanger cassette such that a permeation space is defined at the top side of the upper heat exchanger plate between the permeation barrier gasket member and the port hole gasket, an evacuation gasket member adapted to seal

against a sealing area circumscribing an evacuation hole of a lower heat exchanger plate of the heat exchanger cassette such that an evacuation space is formed within the evacuation gasket member, at the evacuation hole, and

a channel member adapted to fluidly connect the permeation space and the evacuation space by extending between an outlet opening through the permeation barrier gasket member and an inlet opening through the evacuation gasket member.

[0065] Hereby an improved gasket arrangement for a heat exchanger cassette is provided.

[0066] The gasket arrangement is designed for, and hence suitable to be used with, semi-welded PHEs. In particular, the gasket arrangement is designed to be used with a heat exchanger cassette according to first aspect. Thus, the gasket arrangement is designed to interrelate with a heat exchanger cassette according to the first aspect.

[0067] In general, features of this aspect provide similar advantages as discussed above in relation to the first aspect. Consequently, said advantages will not be repeated in order to avoid undue repetition.

[0068] However, by the evacuation gasket member being adapted to seal against a sealing area circumscribing an evacuation hole of a lower heat exchanger plate of a heat exchanger cassette such that an evacuation space is formed within the evacuation gasket member, at the evacuation hole, permeated fluid may be evacuated from the evacuation space via the evacuation hole, i.e. as have been described above in relation to the first aspect.

[0069] Further, by the gasket arrangement comprising a channel member adapted to fluidly connect the permeation space and the evacuation space by extending between an outlet opening through the permeation barrier gasket member and an inlet opening through the evacuation gasket member, the gasket arrangement may provide a fluid communication between the permeation space and an evacuation hole of a heat exchanger cassette such that fluid having permeated through a port hole gasket may be evacuated through the evacuation hole via the channel member and the evacuation space formed within the evacuation gasket member, i.e. as have been described above in relation to the first aspect.

[0070] Two or more of the permeation barrier gasket member, the evacuation gasket member and the channel member may be integrally formed. In this way, a reliable gasket arrangement which is easy to manufacture may be provided.

[0071] The permeation barrier gasket member, the evacuation gasket member and the channel member may be integrally formed.

[0072] Two or more of the permeation barrier gasket member, the evacuation gasket member and the channel member may be separately formed. In this way, a gasket arrangement with an adaptable design which at the same

time provides for efficient evacuation of permeated fluid may be provided. Further, by two or more of the parts of the gasket arrangement (the permeation barrier gasket member, the evacuation gasket member and the channel member) being separately formed, locations of the respective parts in relation to each other may be adapted. In this way, the gasket arrangement may be adapted to fit heat exchanger cassettes of different designs. Furthermore, the gasket arrangement may at least in part be formed by standard parts, such as standard gaskets. As a result, the gasket arrangement may be cost-effective.

[0073] The permeation barrier gasket member, the evacuation gasket member and the channel member may be separately formed.

[0074] The channel member may comprise a pipe element extending between the outlet opening of the permeation barrier gasket member and the inlet opening of the evacuation gasket member. By the channel member comprising a pipe element extending between the outlet opening and the inlet opening, the channel member may efficiently fluidly connect the permeation space and the evacuation space and hence the evacuation hole. In practice, the member channel may be formed of a pipe element extending between the outlet opening and the inlet opening. However, the channel member may comprise two or more pipe elements connected in series.

[0075] The channel member may comprise an abutment surface adapted to abut and seal against a bottom side of lower heat exchanger plate of an adjoining heat exchanger cassette, wherein the abutment surface comprises a channel groove extending between the outlet opening through the permeation barrier gasket member and the inlet opening through the evacuation gasket member such that the channel groove, when the abutment surface abuts the bottom side of the lower heat exchanger plate of the adjoining heat exchanger cassette, fluidly connects the permeation space and the evacuation space. In this way, the channel member may be formed in a simple yet effective manner. For instance, the channel member may be formed by being molded in a simple yet effective manner. This e.g. because such molding of the channel member may not involve molding any interior or partially closed volumes or spaces. Moreover, channel member may be formed of a flexible or elastic material which is suitable for providing a fluid tight seal when in abutment with the top side of the upper heat exchanger plate.

[0076] The permeation barrier gasket member may be integrally formed.

[0077] The permeation barrier gasket member may comprise a first part and a separate second part.

[0078] A first portion of the permeation barrier gasket member may be adapted to form a barrier between the permeation space and a heat exchange area at the top side of the upper exchanger plate. Thus, the permeation barrier gasket member may in part be common to what is commonly referred to as a field gasket.

[0079] The permeation barrier gasket member may be integrally formed with a gasket member adapted to define a gasketed heat exchange area at the top side of the upper heat exchanger plate.

5 **[0080]** The permeation barrier gasket member may be integrally formed with a field gasket.

[0081] The permeation barrier gasket member and/or the evacuation gasket member and/or the channel member may comprise a material selected from the group consisting of polymer materials, elastomer materials, hydrated nitrile materials, chloroprene materials, ethylene propylene diene monomer materials, nitrile butadiene rubber materials and fluoroelastomer materials.

10 **[0082]** The pipe element may be formed of a plastic material, a metal material or a glass material.

[0083] The pipe element may have a diameter of 1mm to 8mm, such as 1,5mm to 5mm.

[0084] The pipe element may have a diameter of 1mm to 8mm.

20 **[0085]** The pipe element may have a diameter of 1,5mm to 5mm.

[0086] At least a portion of the permeation barrier gasket member may have a generally L-shaped, C-shaped, I-shaped or inverted T-shaped cross section so as to form a passageway along at least a portion of the permeation barrier gasket member.

25 **[0087]** The permeation barrier gasket member may comprise an inlet opening extending therethrough, the inlet opening being adapted to fluidly connect the permeation space with the ambient. By the permeation barrier gasket member comprising an inlet opening extending therethrough, a forced flow of fluid through the permeation space may be achieved. Such forced flow may significantly improve how efficiently permeated fluid may be evacuated.

30 **[0088]** The port hole gasket may be generally ring shaped.

[0089] According to a third aspect of the invention, there is provided a heat exchanger cassette arrangement comprising a heat exchanger cassette according to the first aspect and a gasket arrangement according to the second aspect, wherein the evacuation gasket member is arranged at the sealing area, or wherein the evacuation gasket member is arranged at the evacuation hole on a bottom side of the lower heat exchanger plate.

35 **[0090]** Hereby an improved heat exchanger cassette arrangement is provided.

[0091] The heat exchanger cassette arrangement is designed for, and hence suitable to be used with, semi-welded PHEs.

50 **[0092]** In general, features of this aspect provide similar advantages as discussed above in relation to the first aspect and the second aspect. Consequently, said advantages will not be repeated in order to avoid undue repetition.

55 **[0093]** A semi-welded plate heat exchanger comprising a plurality of heat exchanger cassette arrangement according to the third aspect arranged in a stacked con-

figuration. In general, features of such semi-welded plate heat exchanger provide similar advantages as discussed above in relation to the first aspect and the second aspect. Consequently, said advantages will not be repeated in order to avoid undue repetition.

[0094] A further scope of applicability of the present invention will become apparent from the detailed description given below. However, it should be understood that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the scope of the invention will become apparent to those skilled in the art from this detailed description.

[0095] Hence, it is to be understood that this invention is not limited to the particular component parts of the device described as such device may vary. It is also to be understood that the terminology used herein is for purpose of describing particular embodiments only and is not intended to be limiting. It must be noted that, as used in the specification and the appended claim, the articles "a," "an," "the," and "said" are intended to mean that there are one or more of the elements unless the context clearly dictates otherwise. Thus, for example, reference to "a unit" or "the unit" may include several devices, and the like. Furthermore, the words "comprising", "including", "containing" and similar wordings does not exclude other elements or steps.

Brief Description of the Drawings

[0096] The above and other aspects of the present inventive concept will now be described in more detail, with reference to appended figures showing variants. The figures should not be considered limiting, instead, they are used for explaining and understanding.

[0097] As illustrated in the figures, the sizes of layers and regions may be exaggerated for illustrative purposes and, thus, are provided to illustrate the general structures of variants. Like reference numerals refer to like elements throughout.

Fig. 1 is a schematic front view of a plate heat exchanger in which the present invention may be employed.

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

Fig. 3 is a schematic perspective view of a portion of a pack of heat exchanger cassettes and associated gaskets which may be used in the plate heat exchanger of Figs. 1 and 2.

Fig. 4 is a plane view of a short end portion of a heat exchanger cassette which may be used in the plate heat exchanger of Figs. 1 and 2.

Fig. 5 is a detailed perspective view of a corner region of the heat exchanger plate of Fig. 4.

Figs. 6a-6g illustrate schematic designs of cutout areas.

Fig. 7 is a plane view of a short end portion of a heat exchanger cassette of Figs. 4 and 5 employed with gaskets including a gasket arrangement.

Fig. 8 is a detailed perspective view of a corner region of the heat exchanger cassette of Fig. 7.

Fig. 9 is a cross sectional view of a corner region of a cassettes provided with gaskets including gasket arrangements of the type depicted in Figs. 7-8.

Fig. 10 is a detailed perspective view of a corner region of a heat exchanger cassette employed with a gasket arrangement of a different design.

Fig. 11 is a cross sectional view of a corner region of a cassettes provided with gaskets including gasket arrangements of the type depicted in Fig. 10.

Fig. 12 is a detailed perspective view of a corner region of the heat exchanger cassette employed with a gasket arrangement of yet a different design.

Fig. 13 is a cross sectional view of a corner region of a cassettes provided with gaskets including gasket arrangements of the type depicted in Fig. 12.

Fig. 14 is a detailed perspective view of a corner region of a heat exchanger cassette as seen from a bottom side thereof.

Fig. 15 is a detailed perspective view of the corner region of the heat exchanger cassette of Fig. 14 employed with a gasket arrangement of yet another design.

Fig. 16 is a detailed perspective view of the corner region of the heat exchanger cassette of Fig. 14 employed with a gasket arrangement of yet another design.

Detailed Description

[0098] The present inventive concept will now be described more fully hereinafter with reference to the accompanying drawings, in which currently preferred variants or embodiments of the inventive concept are shown. This inventive concept may, however, be implemented in many different forms and should not be construed as limited to the variants set forth herein; rather, these variants are provided for thoroughness and completeness, and fully convey the scope of the present inventive concept to the skilled person.

[0099] Figs. 1 and 2 show a plate heat exchanger 2 or PHE, 2 in form of a semi-welded PHE2. The PHE 2 comprises a frame plate 4 and a pressure plate 6. A pack 8 of heat exchanger plates 100 is sandwiched between the frame plate 4 and the pressure plate 6. More specifically, the heat exchanger plates 100 or plates 100 are welded to each other in pairs so as to form heat exchanger cassettes 200 or cassettes 200. At least a majority of plates 100 of the pack 8 are all similar, which is common practice in semi-welded PHEs 2. The frame plate 4 is provided with fluid inlets and fluid outlets 10. The fluid inlets and fluid outlets 10 are, as is known in the art, configured to receive and eject fluids between which heat is to be transferred. In the depicted PHE 2, one fluid inlet

and one fluid outlet 10 are configured to receive and eject a first fluid, whereas another fluid inlet and another fluid outlet 10 are configured to receive and eject a second fluid. In this way, heat may be transferred between the first fluid and the second fluid. In the depicted PHE 2, the fluid inlet and the fluid outlet 10 to the left in Fig. 1 may be configured to receive and eject a first fluid. Similarly, in the depicted PHE 2, the fluid inlet and the fluid outlet 10 to the right in Fig. 1 may be configured to receive and eject a second fluid. Further, as is known in the art, porthole channels are formed through the pack 8 of heat transfer plates 100, and hence through the stack of cassettes 200, for each one of the fluid inlets and the fluid outlets 10. Generally speaking, the porthole channels are formed by aligned portholes of the heat exchanger plates 100, and hence of the cassettes 200, of the pack 8. The depicted PHE further comprises tightening means 12, an upper bar 14 and a lower bar 16.

[0100] Fig. 3 illustrates how the plates 100 of the pack 8 are welded in pairs, back side to back side, to form fluid tight heat exchanger cassettes 200 or cassettes 200. In other words, each cassette comprises an upper heat exchanger plate 100 and a lower heat exchanger plate 100 wherein a top side of the lower heat exchanger plate 100 is welded to a bottom side of the upper heat exchanger plate 100. In yet other words, each cassette 200 comprises a first heat exchanger plate 100 and a second adjoining heat exchanger plate 100 wherein the second adjoining heat exchanger plate 100 is welded to the first heat exchanger plate 100. Generally speaking, each cassette 200 comprises two plates 100, which are welded to each other as is known in the art. The cassettes 200 of Fig. 4 are alternately stacked with gaskets 13 in between. Hence, gaskets 13 are provided between adjoining cassettes 200. The cassettes 200 of Fig. 4 are schematically illustrated. It is, however, to be understood that the design of the cassettes 200 may vary greatly e.g. depending on application, fluid type, size etcetera. Fig. 3 illustrates how fourteen cassettes 200, each comprising two plates 100 welded to each other, are alternately stacked with gaskets 13 in between. However, in practice, the number of cassettes 200 in the pack 8 may vary greatly.

[0101] Further, the frame plate 4 and pressure plate 6 may be moved or pressed towards each other by tightening the tightening means 12. As a result, the pack 8 may be pressed between the frame plate 4 and pressure plate 6 by tightening the tightening means 12. Thus, the cassettes 200 of the pack 8 may be pressed against each other, whereby the gaskets 13b seal between the cassettes 200.

[0102] In this way parallel fluid channels are formed between the heat exchanger plates 100 of the pack 8. More specifically, one fluid channel is formed between the plates 100 of each cassette 200. Such channels are generally referred to as welded channels. Similarly, one fluid channel is formed between each pair of adjacent cassettes 200. Such channels are generally referred to

as gasketed channels. As a result, a first fluid and a second fluid of initially different temperatures, may be fed to/from the PHE 2 through the fluid inlets and outlets 10, and flow alternately through every second fluid channel for transferring heat from the first fluid to the second fluid or vice versa.

[0103] Now referring to Fig. 4 and 5. Fig. 4 illustrates a top view of portion of a heat exchanger cassette 200 or cassette 200, whereas Fig. 5 illustrates an enlarged perspective view of a region at a corner of the cassette 200 of Fig. 4. More specifically, a region at a short end of a heat exchanger cassette is illustrated in Fig. 4. Thus, Figs. 4 and 5 illustrates portions of a cassette 200 corresponding to a top region of a cassette 200 in Figs. 1-3. In practice, a bottom region at an opposite short end of the cassette 200 may have a corresponding or similar design. As explained above, the cassette 200 comprises an upper heat exchanger plate 100, and a lower heat exchanger plate 100. In the following, the upper plate 100 may wherever appropriate be referred to as the upper plate 100:1 whereas the lower plate 100 may wherever appropriate be referred to as lower plate 100:2. This in order to more easily distinguish the upper plate 100:1 from the lower plate 100:2. However, any of the upper plate 100:1 and the lower plate 100:2 may still be referred to by the reference numeral 100 whenever appropriate.

[0104] A top side 101 of the lower heat exchanger plate 100:2 of the depicted cassette 200 is welded to a bottom side 102 of the upper heat exchanger plate 100:1, i.e. as is known in the art.

[0105] The depicted cassette 200 of Figs. 4 and 5 may be used in a semi-welded PHE 2 of the above described type.

[0106] Further, as is known in the art, a pack 8 of a semi-welded PHE 2 may be formed of cassettes 200 of corresponding design. However, in order to establish desired fluid channels for a first fluid and a second fluid, the cassettes 200 may be rotated, turned or flipped in relation to each other as is known in the art. In this way, a pack 8 may be realized with a single type of cassette 200. However, cassettes of different designs may be used in the pack 8 of the PHE 2.

[0107] The plates 100 (upper plate 100:1 and lower plate 100:2) of the cassette 200 of Figs. 4 and 5 may in practice be formed by being cut from sheet metal which is pressed to become generally speaking corrugated or patterned. The depicted plates 100 may be formed of an essentially rectangular sheet of stainless steel. Other materials are, however, conceivable as is known in the art.

[0108] By the plates 100 being pressed to become corrugated, the plates 100 comprises a plate pattern 105 as is known in the art. The plate pattern 105 is pressed into the material of each one of the plates 100, i.e. as clearly illustrated in Fig. 4. The plate pattern 105 may, as best illustrated in Fig. 4, comprise a patterned heat exchange area 106 and a patterned distribution area 108. In practice, a distribution area 108 is

typically provided at each end of the heat exchange area 106. Heat exchange area 106 and a distribution area 108 are as such known in the art and will not be discussed in greater detail herein.

[0109] Further, the short end region of the cassette 200 illustrated in Figs. 4 and 5 comprises a porthole 114 to the right and porthole 116 to the left (shown in part). The porthole 114 is for receiving or ejecting a first fluid, whereas the porthole 116 is for receiving or ejecting a second fluid, between which fluids heat is to be transferred. The function of the portholes 114, 116 are as such known in the art and will not be discussed in further detail herein. In the following, the porthole 114 to the right will however be discussed to some extent.

[0110] An edge portion 112 of the lower heat exchanger plate 100:2 comprises an evacuation hole 160. The function of evacuation hole 160 will be discussed further below. In Figs. 4 and 5, the evacuation hole 160 is depicted as being located close to a corner or in a corner region of the lower heat exchanger plate 100:2 and hence the cassette 200. In this regard, it is to be noted that the evacuation hole 160 may be located at any suitable location at the edge portion 112. Moreover, the evacuation hole 160 is depicted as being a circular hole. In this regard, it is to be understood that the evacuation hole 160 may have any suitable shape and size. As best illustrated in Fig. 5, the evacuation hole 160 is circumscribed by a sealing area 162. The sealing area 162 is, as best illustrated in Fig. 5, formed at the top side 101 of the lower heat exchanger plate 100:2. Further, as best illustrated in Fig. 5, the sealing area 162 is formed of an exposed portion of the lower plate 100:2. The sealing area 162 is adapted to seal against an evacuation gasket member 320 as will be described herein further below. The depicted sealing area 162 of Figs. 4 and 5 is a flat or planar surface. It is however to be noted that the sealing area 162 may be a non-flat area, such as a corrugated or stepped area.

[0111] Further, as best illustrated in Fig. 5, the sealing area 162 and the evacuation hole 160 are disposed within a cutout area 170 of the upper heat exchanger plate 100:1. The depicted cutout area 170 aligns with the sealing area 162 as seen in a normal direction N of the sealing area 162. More specifically, the evacuation hole 160 is disposed completely within the cutout area 170 whereas the sealing area 162 is partially disposed within the cutout area 170. In this regard, it is to be noted that the evacuation hole 160 may be disposed completely or partially within the cutout area 170. Correspondingly, the sealing area 162 may be disposed completely or partially within the cutout area 170.

[0112] Further, as best illustrated in Fig. 5, a boundary segment 180 of the cutout area 170 extends through the upper heat exchanger plate 100:1 between a first 182 and a second point 184 of an outer perimeter of the upper heat exchanger plate 100:1. Put differently, the boundary segment 180 of the cutout area 170 extends through the upper heat exchanger plate 100:1 between a first

182 and a second point 184 of an overall footprint of the upper heat exchanger plate 100:1. As a result, the cutout area 170 is generally speaking a slot in the outer perimeter of the upper plate 100:1. In this regard, it is to be noted that the cutout area 170 may be any open area at which at least a portion of the sealing area 162 and the evacuation hole 160 are exposed. In practice, the entire the evacuation hole 160 will typically be exposed or else the entire cross sectional area of the evacuation hole cannot be used for evacuating permeated fluid.

[0113] As best illustrated in Fig. 5, the depicted boundary segment 180 of the cutout area 170, i.e. the boundary segment 180 defining the cutout area 170, is formed by a curved portion 180a, a first and a second linear portion 180b, 180c. The first linear portion 180b extends between the first point 182 and a first end of the curved portion 180a. Further, the second linear portion 180c extends between the second point 184 and a second end of the curved portion 180a. More specifically, the depicted curved portion 180a is a semicircular portion. Further, the first and second linear portions 180b, 180c extend in parallel.

[0114] It is however to be noted that the design of the cutout area 170 may vary greatly within the present inventive concept. Given this, highly schematic examples of how the cutout area 170 may be designed will be briefly described below with reference to Figs. 6a-6g. In each one of Figs. 6a-6g it is illustrated how a sealing area 162 and an evacuation hole 160 of a lower plate 100:2 are disposed at least partially within a cutout area 170 of an upper plate 100:1.

[0115] Fig. 6a schematically illustrates how the boundary segment 180 of the cutout area 170 may be formed by a curved portion 180a, a first and a second linear portion 180b, 180c. More specifically, the depicted curved portion 180a is a semicircular portion. Further, the first and second linear portions 180b, 180c extend in parallel.

[0116] Fig. 6b schematically illustrates how boundary segment 180 of the cutout area 170 may be formed by a curved portion 180a. More specifically, the depicted curved portion 180a is a semicircular portion.

[0117] Fig. 6c schematically illustrates how the boundary segment 180 of the cutout area 170 may be formed by a curved portion 180a, a first and a second linear portion 180b, 180c. More specifically, the depicted curved portion 180a is a semicircular portion. Further, the first and second linear portions 180b, 180c do not extend in parallel.

[0118] Fig. 6d schematically illustrates how the boundary segment 180 of the cutout area 170 may be formed by a pair of curved portions 180d, 180e.

[0119] Fig. 6e schematically illustrates how boundary segment 180 of the cutout area 170 may be formed by a linear portion 180e extending between the first and second points 182, 184. In this way, the cutout area 170 may generally speaking be said to be a cutaway area 170. In other words, the cutout area 170 may generally speaking be an open area in form of a cutaway area 170. Thus, as

illustrated in Fig. 6e, the cutout area 170 may be a cut-away corner area 170.

[0120] Fig. 6f schematically illustrates how the boundary segment 180 of the cutout area 170 may be formed by a pair of linear portions 180f, 180g which jointly extend between the first and second points 182, 184. In this way, the cutout area 170 may generally speaking be said to be a cutaway area 170. Thus, as illustrated in Fig. 6f, the cutout area 170 may be a cutaway corner area 170.

[0121] Fig. 6g schematically illustrates how the boundary segment 180 of the cutout area 170 may be formed by a pair of linear portions 180h, 180i which jointly extend between the first and second points 182, 184. In this way, the cutout area 170 may generally speaking be said to be a slot in the upper plate 100:1.

[0122] It is, however, to be noted that, the cutout area 170 may be formed by any combination of one or more linear portions. The cutout area 170 may be formed by any combination of one or more linear curved portions. The cutout area 170 may be formed by any combination of one or more linear curved portions and one or more curved portions.

[0123] In order to provide a sufficiently large sealing area 162, it is currently believed that a minimal distance d from the evacuation hole 160 to the boundary segment 180 of the cutout area 170 may to advantage corresponds to at least 50% of a diameter D of the evacuation hole 160, see Fig. 5. It is currently believed that when the minimal distance d from the evacuation hole 160 to the boundary segment 180 of the cutout area 170 corresponds to 75% to 150% of the diameter D of the evacuation hole 160, an optimal balance between size or extension of the sealing area 162 and the space required for cutout area 170 may be achieved.

[0124] Now also referring to Fig. 7. As best illustrated in Fig. 4, the depicted upper plate 100:1 of the cassette 200 is provided with a port hole gasket seat 118. The port hole gasket seat is provided on the top side 104 of the upper heat exchanger plate 100:1 and circumscribes the port hole 114. The depicted port hole gasket seat 118 is adapted to receive a port hole gasket 350 as illustrated in Fig. 7. The depicted port hole gasket 350 of Fig. 5 is generally speaking a ring shaped gasket which is arranged on the top side 104 of the upper heat exchanger plate 100:1. However, as is known in the art, the shape of the port hole 114 and consequently the port hole gasket 350 may vary. Further, the function of the port hole gasket 350 is known in the art and will not be discussed in greater detail herein. The port hole gasket seat 118 may as illustrated in Fig. 4, comprises a groove configured to retain such port hole gasket 350. It is however to be noted that the port hole gasket seat 118 may be designed such that it partially circumscribes the port hole 114.

[0125] Further, the cassette 200 may, as depicted in Fig. 4 be provided with a permeation barrier seat 110. The depicted permeation barrier seat 110 circumscribes the port hole gasket seat 118. Further, the permeation barrier seat 110 is adapted to receive a permeation barrier

gasket member 310. The function of the permeation barrier gasket member 310 will be described herein further below. The permeation barrier seat 110 may as illustrated in Fig. 4 comprise a groove configured to retain the permeation barrier gasket member 310. In this way, the permeation space 130 may be defined at the first side 104 of the heat exchanger plate 100 between the permeation barrier seat 110 and the port hole gasket seat 118. Thus, in practice, the permeation space 130 may be defined at the first side 104 of the heat exchanger plate 100 between the permeation barrier seat 110 and the port hole gasket seat 118, when the port hole gasket 350 is received in the port hole gasket seat 118 and when the permeation barrier gasket member 310 is received in the permeation barrier seat 110. It is however to be noted that the permeation barrier seat may be designed such that it partially circumscribes the port hole gasket seat 118.

[0126] Further, as illustrated in Fig. 4, a portion 110a of the permeation barrier seat 110 may extend essentially along a perimeter of the plate 100 outside of the porthole gasket seat 118 and serve the purpose of receiving a portion of the permeation barrier gasket member 310. However, another portion 110b of the permeation barrier gasket seat 110 may be defined by a groove 110b adapted to receive a portion of the permeation barrier gasket member 310 which also serves the purpose of sealing against a patterned distribution area 108 and a patterned heat exchange area 106. Thus, such portion 110b may be adapted to receive a portion of a permeation barrier gasket member 310 which also forms part of what is generally referred to as a field gasket.

[0127] Further, as best illustrated in Figs. 4 and 5, the cutout area 170 of the depicted cassette 200 is located outside of the permeation barrier seat 110. That is, the cutout area 170 is located outside of the permeation barrier seat 110 as seen from the evacuation space 130 and the port hole 114. As a consequence, the evacuation hole 160 and the sealing area 162 are also located outside of the permeation barrier seat 110.

[0128] Further, as illustrated in Figs. 4 and 5, the top side 104 of the upper heat exchanger plate 100:1 may typically be provided with a channel area 111 extending between the permeation barrier seat 110 and the boundary segment 180 of the cutout area 170. The channel area 111 may in practice be an area 111 which is recessed in relation to an uppermost plane, top plane or extreme plane of the upper plate 100:1. In this way, a channel member 330 may extend between a permeation barrier gasket member 310 and an evacuation gasket member 320 via the channel area, e.g. as illustrated in Fig. 7. This will be further described below with reference to Fig. 7.

[0129] Now especially referring to Figs. 7-9. Figs. 7 and 8 illustrates how a gasket arrangement 300 has been arranged in an intended position on the top side 104 of the upper plate 100:1 of the cassette 200 of Figs. 4 and 5. Fig. 9 illustrates a cross sectional view through three cassettes 200 and two associated gasket arrangements 300 in a location corresponding to the line A-A in Fig. 8. It is

however to be noted that there is no gasket arrangement 300 present on the uppermost cassette 200 in Fig. 9. In Fig. 9 it is rather illustrated how a respective gasket arrangement 300 is sandwich between adjoining cassettes 200. Further, the gasket arrangement 300 is designed to interrelate with the cassette 200. Moreover, a heat exchanger cassette 200 and a gasket arrangement 300 may jointly be said to form a heat exchanger cassette arrangement 400, when the evacuation gasket member 320 is arranged at the sealing area 162.

[0130] As illustrated in Figs. 7-9, the gasket arrangement 300 comprises a permeation barrier gasket member 310. The depicted permeation barrier gasket member 310 is arranged on the top side 104 of the upper heat exchanger plate 100:1 of the cassette 200. Further, the permeation barrier gasket member 310 circumscribes the port hole gasket 350. Thus, the permeation barrier gasket member 310 circumscribes the port hole gasket 350 as well as the port hole 114. In this way, a permeation space 130 is defined at top first side 104 of the upper heat exchanger plate 100:1 between the permeation barrier gasket member 310 and the port hole gasket 350. In practice, the permeation space 130 is formed at the top side 104 of the upper plate 100:1 between the port hole gasket 350 and the permeation barrier gasket member 310, when the porthole gasket 350 and the permeation barrier gasket member 310 of the gasket arrangement 300 are arranged on the top side 104 of the upper plate 100:1. In this regard, it is to be understood that the so formed permeation space 130 will be open in a normal direction N of the top side 104 unless arranged in a stack of cassettes 200. However, when the cassette 200 and hence the upper heat exchanger plate 100:1 is arranged in a pack 8 of a PHE 2 a gasketed or sealed permeation space 130 will be formed along the top side 104 of the upper heat exchanger plate 100:1 between the port hole gasket 350 and the permeation barrier gasket member 310. It is, however, to be noted that the permeation barrier gasket member 310 may be adapted to at least partially circumscribe the port hole gasket 350 to define a permeation space 130 between the port hole gasket 350 and the permeation barrier gasket member 310.

[0131] Further, the depicted gasket arrangement 300 of Figs. 7-9 comprises an evacuation gasket member 320. The evacuation gasket member 320 may, as best illustrated in the enlarged view of Fig. 8, be arranged on the sealing area 162 of the lower heat exchanger plate 100:2 in such a way that it circumscribes the evacuation hole 160 in the lower heat exchanger plate 100:2. As is clearly illustrated in the enlarged view of Fig. 8 an evacuation space 150 is formed within the evacuation gasket member 320, at the evacuation hole 160. In this regard, it is to be noted that the evacuation gasket member 320 is sandwiched between a pair of lower heat exchanger plates 100:2 without interacting with any upper heat exchanger plate 100:1. This due to the fact that the evacuation gasket member 320 is received in the cutout area 170 of the relevant upper plate 100:1. More speci-

fically, the evacuation gasket member 320 is received in the cutout area 170 of the relevant upper plate 100:1 without contacting the same. It is however to be noted that the evacuation gasket member 320 may be received in the cutout area 170 of the relevant upper plate 100:1 while at the same time contacting the same.

[0132] Further, the so formed evacuation space 150 is fluidly connected to the evacuation hole 160 of the lower plate 100:2. In this regard, it is to be understood that the so formed evacuation space 150 of Fig. 5 will be open in both normal directions N of the sealing area 162 of the lower plate 100:2. However, when the cassette 200 and the gasket arrangement 300 of Figs. 7-9 are arranged in a pack 8 of cassettes 200 the evacuation gasket member 320 will in practice be sandwiched between a pair of lower heat exchanger plates 100:2 of adjoining cassettes 200. In this way, the so formed evacuation space 150 will in practice be fluidly connected to an evacuation hole 160 of each one of the lower plates 100:1 of the cassettes 200 between which the evacuation gasket member 320 is sandwiched, i.e. as illustrated in Fig. 9. Thus, the evacuation space 150 will in practice connect to a pair of corresponding evacuation spaces 150 of adjoining evacuation gasket members 320 of adjoining gasket arrangements 300. This is clearly illustrated in Fig. 9. In this way an evacuation space or joint evacuation space may be formed along a stacking direction of a pack 8 of cassettes 200.

[0133] Further, the depicted gasket arrangement 300 of Figs. 7-9 comprises a channel member 330. The channel member 330 is adapted to fluidly connect the permeation space 130 and the evacuation space 150. To this end, the channel member 330 extends between the permeation barrier gasket member 310 and the evacuation gasket member 320. More specifically, the channel member 330 extends between an outlet opening 312 through the permeation barrier gasket 310 member and an inlet opening 322 through the evacuation gasket member 320. The design of the channel member 330 is best illustrated in Fig. 9. As indicated above, Fig. 9 illustrates a cross sectional view through two gasket arrangements 300, two port hole gaskets 350 and three cassettes 200 in a location corresponding to the line A-A indicated in Fig. 8. Thus, in Fig. 9 it is clearly illustrated how each channel member 330 fluidly connects a respective permeation space 130 and a respective evacuation space 150 by extending between the outlet opening 312 through the permeation barrier gasket member 310 and the inlet opening 322 through the evacuation gasket member 320.

[0134] Further, the permeation barrier gasket member 310, the evacuation gasket member 320 and the channel member 330 of the gasket arrangement 300 of Figs. 7-9 are separately formed. Thus, the permeation barrier gasket member 310, the evacuation gasket member 320 and the channel member 330 of the gasket arrangement 300 have been formed temporally and/or spatially separately. This means that the gasket arrangement 300

may be assembled from separately formed parts or that the gasket arrangement 300 may be assembled while forming one or more parts thereof. In this regard, it is to be noted that two or more of the permeation barrier gasket member 310, the evacuation gasket member 320 and the channel member 330 may be separately formed.

[0135] According to an example, the gasket arrangement 300 may be assembled from a channel member 330 which is molded into the material of the permeation barrier gasket member 310 and into the material of the evacuation gasket member 320. In practice, a first end portion of the channel member 330 may be molded into the material of the permeation barrier gasket member 310 and a second end portion of the channel member 330 may be molded into the material of the evacuation gasket member 320. In this way, a channel member 330, such as a pipe, may be molded into the molded into the material of the permeation barrier gasket member 310 while forming the permeation barrier gasket member 310. Correspondingly, the channel member 330 may be molded into the material of the evacuation gasket member 320 while forming the evacuation gasket member 320.

[0136] According to another example, the gasket arrangement 300 may be assembled by inserting the first end portion of the channel member 330 into the outlet opening 312 of the permeation barrier gasket member 310 and inserting the second end portion of the channel member 330 into the inlet opening 322 of the evacuation gasket member 320. In this way, the first end portion of the channel member 330 may be inserted into a premade outlet opening 312 of the permeation barrier gasket member 310. Correspondingly, the second end portion of the channel member 330 may be inserted into a premade inlet opening 322 of the of the evacuation gasket member 320. Thus, the gasket arrangement 300 may be assembled from premade or prefabricated parts.

[0137] When the gasket arrangement 300 is fabricated and assembled according to the above examples, the channel member 330 may be formed of a material different from a material of the permeation barrier gasket member 310 and from a material of the evacuation gasket member 320. The permeation barrier gasket member 310 and the evacuation gasket member 320 of Figs. 7-9 may typically be made of flexible materials which are suitable to seal against the plates 100:1, 100:2 of the cassette 200 and plates 100:1, 100:2 of an adjoining cassette 200. To this end, the permeation barrier gasket member 310 and the evacuation gasket member 320 may typically be made of polymer materials and/or elastomer materials. Suitable examples of materials for the permeation barrier gasket member 310 and the evacuation gasket member 320 include but are not limited to hydrated nitrile materials, chloroprene materials, ethylene propylene diene monomer materials, nitrile butadiene rubber materials and fluoroelastomer materials. Further, the permeation barrier gasket member 310 and the evacuation gasket member 320 may typically be molded into a desired shape. On the other hand,

channel member 330 may be made of a material suitable for forming a fluid channel or passage. In other words, the channel member 330 may be made of a material suitable for fluidly connecting the permeation space 130 and the evacuation space 150. Suitable materials for the channel member 330 include but are not limited to plastic materials, metal materials, glass materials, stainless steel, aluminum, silicone materials and laminated materials. Thus, the channel member 330 may be made of a rigid material or a semirigid material. In this way the channel member 330 may be made relatively speaking narrow while preventing or counteracting that the channel member 330 collapses and cuts of the fluid connection between the permeation space 130 and the evacuation space 150.

[0138] In practice, and as best illustrated in Figs. 8 and 9, the channel member 330 may be formed of, or comprise, a pipe element 331. Such pipe element 331 may as best illustrated in Fig. 9 extend between the outlet opening 312 of the permeation barrier gasket member 310 and the inlet opening 322 of the evacuation gasket member 320. In this way, the pipe element 331 may provide for a fluid connection between the permeation space 130 and the evacuation space 150. It is currently believed that when such pipe element 331 has a diameter in a range of 1mm to 8mm a good balance between establishing a sufficient fluid connection and stability may be achieved. Further, when such pipe element 331 has a diameter in a range of 1,5mm to 5mm it is currently believed that an optimal balance between establishing a sufficient fluid connection and stability may be achieved. Other diameters of such pipe element 331 are however conceivable.

[0139] As best illustrated in Fig. 8, the evacuation gasket member 320 may be provided with a support member 324. The depicted support member 324 is designed to be inserted between the upper plate 100:1 and the lower plate 100:2. In this way, the evacuation gasket member 320 may be held in position by the support member 324 engaging the plates 100:1, 100:2. In general terms, the support member 324 is adapted to engage with one or both heat exchanger plates 100:1, 100:2 for supporting the evacuation gasket member 320. It is to be noted that the evacuation gasket member 320 may comprise more than one support member 324.

[0140] Further, it is to be noted that the evacuation gasket member 320 may be void of any support member 324. In such case, the evacuation gasket member 320 may simply be sandwiched between a pair of lower plates 100:2 of adjacent cassettes 200. However, the evacuation gasket member 320 may be glued to the sealing area 162 so as to be supported or fixed in relation to the lower plate 100:2. Moreover, the evacuation gasket member 320 may be supported or fixed in relation to the sealing area 162 by tape, such as double-sided tape.

[0141] Further, the channel member 330 may be formed of or comprise two or more parts jointly fluidly connecting the permeation space 130 and the evacua-

tion space 150. According to an example, the channel member 330 may comprise two or more pipe elements 331 connected in series. In this way, a first pipe element may be molded into the permeation barrier gasket member 310 and a second pipe element may be molded into the evacuation gasket member 320. The first and second pipe elements may then be connected to each other when assembling the gasket arrangement 300. According to an example, the first pipe element may be inserted into the second pipe element or vice versa. According to another example, the first and second pipe elements may be inserted into a third pipe element.

[0142] According to an example, the channel member 330 may comprise two or more pipe elements 331 connected in parallel.

[0143] Now turning to Figs. 10 and 11. Figs. 10 and 11 illustrates how a gasket arrangement 300 of a design similar to the above described gasket arrangement 300 is used in conjunction with cassettes 200 of generally the above described type. Given the similarities, mainly relevant differences will be described in the following. Fig. 10 is in large similar to Fig. 8. Fig. 11 is in large similar to Fig. 9.

[0144] In Figs. 10 and 11, mainly the design of the channel member 330 has been altered. In this regard, the permeation barrier gasket member 310, the evacuation gasket member 320 and the channel member 330 are integrally formed in the gasket arrangement of Figs. 10-12. More specifically, the permeation barrier gasket member 310, the evacuation gasket member 320 and the channel member 330 may typically be integrally formed of flexible materials which are suitable to seal against the plates 100:1, 100:2 of the cassette 200 and plates 100:1, 100:2 of an adjoining cassette 200. Thus, the permeation barrier gasket member 310, the evacuation gasket member 320 and the channel member 330 may in practice be integrally formed from the materials described above in conjunction with the permeation barrier gasket member 310 and the evacuation gasket member 320.

[0145] As best illustrated in Fig. 10, the channel member 330 comprises an abutment surface 332. The abutment surface 332 is adapted to abut and seal against a bottom side 103 of lower heat exchanger plate 100:2 of an adjoining heat exchanger cassette 200, i.e. as illustrated in Fig. 11. Thus, in Fig. 11 it is illustrated how the channel member 330 of each one of the two depicted gasket arrangements 300 is sandwiched between adjoining cassettes 200. The abutment surface 332 comprises a channel groove 333 extending between the outlet opening 312 through the permeation barrier gasket member 310 and the inlet opening 322 through the evacuation gasket member 320. In this regard, as illustrated in Figs. 10 and 11, the outlet opening 312 through the permeation barrier gasket member 310 and the inlet opening 322 through the evacuation gasket member 320 may be formed by respective groove sections. In this way, an overall groove extending between the permeation space 130 and the evacuation space 150 may be formed.

Put differently, by the channel groove 333 extending between the outlet opening 312 through the permeation barrier gasket member 310 and the inlet opening 322 through the evacuation gasket member 320, that the channel groove 333 may, when the abutment surface 332 abuts the bottom side 103 of the lower heat exchanger plate 100:2 of the adjoining heat exchanger cassette 200, fluidly connect the permeation space 130 and the evacuation space 150, i.e. as best illustrated in Fig. 11.

[0146] Now turning to Figs. 12 and 13. Figs. 12 and 13 illustrates how a gasket arrangement 300 of a design similar to the above described gasket arrangement 300 of Figs. 10 and 11 is used in conjunction with cassettes 200 of generally the above described type. Given the similarities, mainly relevant differences will be described in the following. Fig. 12 is in large similar to Figs. 8 and 10. Fig. 13 is in large similar to Figs. 9 and 11.

[0147] As illustrated in Figs. 12 and 13, a flexible member or lip 313 may be provided at the outlet opening 312 which extends through the permeation barrier member 310. In this regard, it is to be noted that such lip 313 may likewise be provided along the channel groove 333 or at the inlet opening 322 which extends through the evacuation gasket member 320.

[0148] As best illustrated in Fig. 13, the lip 313 adapted to abut and seal against the bottom side 103 of the lower plate 100:2 of an adjacent cassette 200. However, owing to the design and flexibility of the lip 313, the lip 313 may act as a seal as long as a pressure difference between the permeation space 130 and the evacuation space 150 does not exceed a certain level or threshold. However, when the pressure difference between the permeation space 130 and the evacuation space 150 becomes sufficiently large, i.e. when the threshold is exceeded, the lip will flex thereby providing a fluid connection between the permeation space 130 and the evacuation space 150. Put differently, the lip 313 will provide a certain level of sealing. As a result, the lip 313 will flex and leak if the pressure in the permeation space 130 increases. This will typically happen when fluid permeates through the port hole gasket 350 and enters into the permeation space 130. Similarly, the lip 313 will flex and leak if the pressure in the evacuation space 150 decreases. Such pressure decrease in the evacuation space 150 may for instance occur by some sort of suction action applied to the evacuation space 150. Thus, by the provision of the lip 313 the evacuation and the level of permeation may be controlled or at least controlled to some degree.

[0149] Now turning to Figs. 14-16. Fig. 14 illustrates a corner region of a cassette 200 generally of the above described type. However, in Fig. 14, the cassette has been tuned upside-down such that the bottom side 103 of the lower plate 100:2 is mainly shown. Thus, it is illustrated how the evacuation hole 160 is provided through the lower plate 100:2. The lower plate 100:2 may as depicted be provided with a notch 115. The notch 115 may be configured to interact with a support member 324 of a gasket arrangement 300.

[0150] In Fig. 15 it is illustrated how a gasket arrangement 300 generally of the type described above in conjunction to Figs. 7-9 is arranged on the bottom side 103 of the lower plate 100:2. For this reason, the gasket arrangement 300 of Fig. 15 has a differently designed support member 324 which is configured to engage the notch 115 of the lower plate 100:2. In this way, the cassette 200 and the gasket arrangement 300 of Fig. 15 may be said to form a heat exchanger cassette arrangement 400. In such a heat exchanger cassette arrangement 400, the evacuation gasket member 320 is consequently arranged at the evacuation hole 160 on a bottom side 103 of the lower heat exchanger plate 100:2, i.e. as illustrated in Fig. 15.

[0151] In Fig. 16 it is illustrated how a gasket arrangement 300 generally of the type described above in conjunction to Figs. 10 and 11 is arranged on the bottom side 103 of the lower plate 100:2. For this reason, the gasket arrangement 300 of Fig. 16 has a support member 324 corresponding to the support member 324 of the gasket arrangement of Fig. 15. Thus, the support member 324 of Fig. 16 is configured to engage the notch 115 of the lower plate 100:2. In this way, the cassette 200 and the gasket arrangement 300 of Fig. 16 may be said to form a heat exchanger cassette arrangement 400. In such a heat exchanger cassette arrangement 400, the evacuation gasket member 320 is consequently arranged at the evacuation hole 160 on a bottom side 103 of the lower heat exchanger plate 100:2, i.e. as illustrated in Fig. 16.

[0152] In the following the main aspects of the interplay between the different elements and features of the cassette 200 and the gasket arrangement 300 will be briefly discussed. As already explained, fluid may permeate the port hole gasket 350 meaning that fluid may escape through the material of the port hole gasket 350 although the port hole gasket as such is intact. By the permeation barrier gasket member 310 being received in the permeation barrier seat 110 such that it circumscribes (or at least partially circumscribes) the port hole gasket 350, fluid having permeated through the port hole gasket 350 may be caught in the permeation space 130, i.e. between the port hole gasket 350 and the permeation barrier gasket member 310. Such permeated fluid may then reach the evacuation hole 160 via the channel member 330 and evacuation space 150. The fluid may then be evacuated from the pack 8 of the PHE 2 at hand via a plurality of aligned or substantially aligned evacuation holes 160 of the cassettes 200 of the pack 8. To this end, the frame plate 4 of the PHE 2 at hand may be provided with an evacuation outlet. Such an evacuation outlet may for instance be connected to a vacuum source, such as a vacuum pump, or may be connected to a funnel for ventilating the permeated fluid to a safe location, such as to the outside of a room where the PHE 2 is located. Moreover, if the permeation barrier gasket member 310 is provided with one or more inlet openings extending therethrough and being in fluid communication with the ambient, a forced flow of air may be provided through the

permeation space 130 and out of the evacuation hole 160 via the channel member 330 and the evacuation space 150.

[0153] However, the elements and features of the cassette 200 and the gasket arrangement 300 may be used in different ways. For instance, an inert gas, such as nitrogen, may be provided to the permeation space 130 via the evacuation hole 160, the evacuation space 150 and the channel member 330. In this way, the port hole gasket 350 may be prevented or counteracted from being affected by substances present in the ambient surrounding the PHE 2 at hand. In such a case, the permeation barrier gasket member 310 may to advantage be void of any inlet openings extending therethrough.

[0154] Another use for the elements and features of the cassette 200 and the gasket arrangement 300 is to pressurize the permeation space 130 by forcing a gas into the permeation space 130 via the evacuation hole 160, the evacuation space 150 and the channel member 330. By providing an overpressure to the permeation space 130 a significant reduction of fluid permeating through the port hole gasket 350 may be achieved since the overpressure will act as counterpressure. In such a case, the permeation barrier gasket member 310 may to advantage be void of any inlet openings extending therethrough.

[0155] 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. Some details in the figures may also be exaggerated for the sake of clarity. 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.

[0156] It will be appreciated that the present inventive concept is not limited to the variants and examples shown. Several modifications and variations are thus conceivable within the scope of the invention which thus is defined by the appended claims.

Claims

1. A heat exchanger cassette (200) for a semi-welded plate heat exchanger (2), comprising:

an upper heat exchanger plate (100, 100:1), and
a lower heat exchanger plate (100, 100:2),

wherein a top side (101) of the lower heat exchanger plate (100:2) is welded to a bottom side (102) of the upper heat exchanger plate (100:1),

wherein an edge portion (112) of the lower heat exchanger plate (100:2) comprises an evacuation hole (160) circumscribed by a sealing area (162) formed at the top side

- (101) of the lower heat exchanger plate (100:2), the sealing area (162) being adapted to seal against an evacuation gasket member (320), wherein the sealing area (162) and the evacuation hole (160) are disposed at least partially within a cutout area (170) of the upper heat exchanger plate (100:1), and wherein a boundary segment (180) of the cutout area (170) extends through the upper heat exchanger plate (100:1) between a first (182) and a second point (184) of an outer perimeter of the upper heat exchanger plate (100:1).
2. The heat exchanger cassette (200) according to claim 1, wherein the cutout area (170) aligns with the sealing area (162) as seen in a normal direction (N) of the sealing area (162).
 3. The heat exchanger cassette (200) according to claim 1 or 2, further comprising a port hole (114), wherein the upper heat exchanger plate (100:1) comprises a port hole gasket seat (118) provided on a top side (104) of the upper heat exchanger plate (100:1) and circumscribing the port hole (114), the port hole gasket seat (110) being adapted to receive a port hole gasket (350), wherein the upper heat exchanger plate (100:1) comprises a permeation barrier seat (110) provided on the top side (104) of the upper heat exchanger plate (100:1) and at least partially circumscribing the port hole gasket seat (118), the permeation barrier seat (110) being adapted to receive a permeation barrier gasket member (310) such that a permeation space (130) is defined at the top side (104) of the upper heat exchanger plate (110:1) between the permeation barrier seat (110) and the port hole gasket seat (118).
 4. The heat exchanger cassette according to claim 3 wherein the cutout area (170) is located outside of the permeation barrier seat (110).
 5. The heat exchanger cassette (200) according to any one of claims 1-4, wherein the boundary segment (180) of the cutout area (170) is formed by a curved portion (180a), a first and a second linear portion (180b, 180c), wherein the first linear portion (180b) extends between the first point (182) and a first end of the curved portion (180a), and wherein the second linear portion (180c) extends between the second point (184) and a second end of the curved portion (180a).
 6. The heat exchanger cassette (200) according to claim 5, wherein the curved portion (180a) is a semi-circular portion, and wherein the first and second linear portions (180b, 180c) extend in parallel.
 7. The heat exchanger cassette (200) according to any one of claims 1-4, wherein the boundary segment (180) of the cutout area is formed by a linear portion (180e) extending between the first and second points (182, 184).
 8. The heat exchanger cassette (200) according to any one of the preceding claims, wherein a minimal distance (d) from the evacuation hole (160) to the boundary segment (180) of the cutout area (170) corresponds to at least 50% of a diameter (D) of the evacuation hole (160), such as 75% to 150% of the diameter (D) of the evacuation hole (160).
 9. The heat exchanger cassette (200) according to claim 3, wherein the top side (104) of the upper heat exchanger plate (100:1) comprises a channel area (111) extending between the permeation barrier seat (110) and the boundary segment (180) of the cutout area (170).
 10. A gasket arrangement (300) for a heat exchanger cassette (200), comprising:
 - a permeation barrier gasket member (310) adapted to be arranged on a top side (104) of an upper heat exchanger plate (100:1) of the heat exchanger cassette (200) and to at least partially circumscribe a port hole gasket (350) circumscribing a port hole (114) of the heat exchanger cassette (200) such that a permeation space (130) is defined at the top side (104) of the upper heat exchanger plate (100:1) between the permeation barrier gasket member (310) and the port hole gasket (350),
 - an evacuation gasket member (320) adapted to seal against a sealing area (162) circumscribing an evacuation hole (160) of a lower heat exchanger plate (100:2) of the heat exchanger cassette (200) such that an evacuation space (150) is formed within the evacuation gasket member (320), at the evacuation hole (160), and a channel member (330) adapted to fluidly connect the permeation space (130) and the evacuation space (150) by extending between an outlet opening (312) through the permeation barrier gasket member (310) and an inlet opening (322) through the evacuation gasket member (320).
 11. The gasket arrangement (300) according to claim 10, wherein two or more of the permeation barrier gasket member (310), the evacuation gasket mem-

ber (320) and the channel member (330) are integrally formed.

12. The gasket arrangement (300) according to claim 10, wherein two or more of the permeation barrier gasket member (310), the evacuation gasket member (320) and the channel member (330) are separately formed. 5

13. The gasket arrangement (300) according to any one of claims 10-12, wherein the channel member (330) comprises a pipe element (331) extending between the outlet opening (312) of the permeation barrier gasket member (310) and the inlet opening (322) of the evacuation gasket member (320). 10
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14. The gasket arrangement (300) according to any one of claims 10-12, wherein the channel member (330) comprises an abutment surface (332) adapted to abut and seal against a bottom side (103) of lower heat exchanger plate (100:2) of an adjoining heat exchanger cassette (200), wherein the abutment surface (332) comprises a channel groove (333) extending between the outlet opening (312) through the permeation barrier gasket member (310) and the inlet opening (322) through the evacuation gasket member (320) such that the channel groove (333), when the abutment surface (332) abuts the bottom side (103) of the lower heat exchanger plate (100:2) of the adjoining heat exchanger cassette (200), fluidly connects the permeation space (130) and the evacuation space (150). 20
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15. A heat exchanger cassette arrangement (400) comprising a heat exchanger cassette (200) according to any one of claims 1-9 and a gasket arrangement (300) according to any one of claims 10-13, wherein the evacuation gasket member (320) is arranged at the sealing area (162), or wherein the evacuation gasket member (320) is arranged at the evacuation hole (160) on a bottom side (103) of the lower heat exchanger plate (100:2). 35
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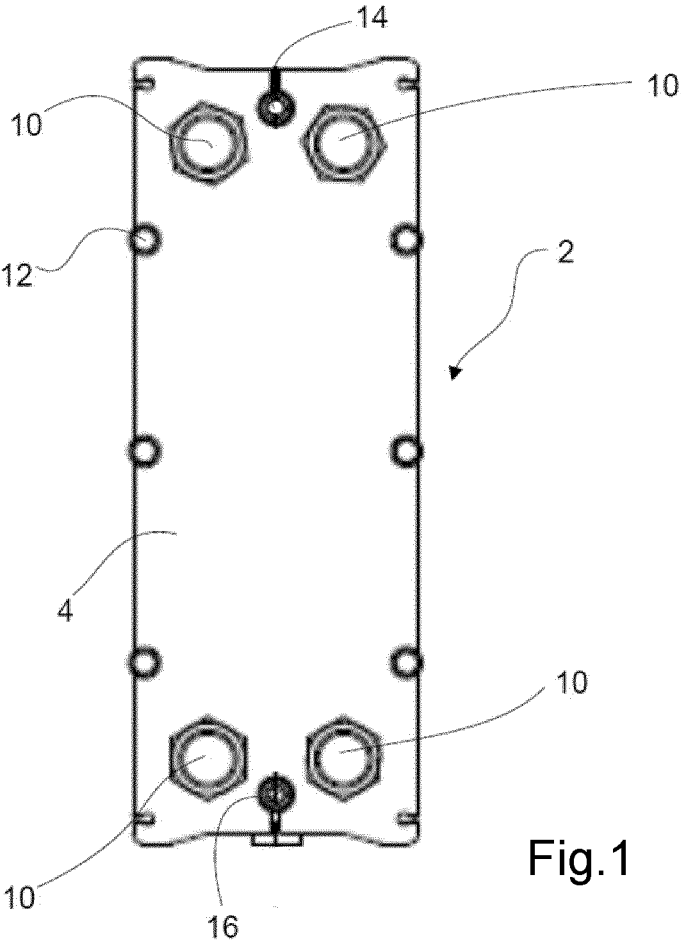


Fig.1

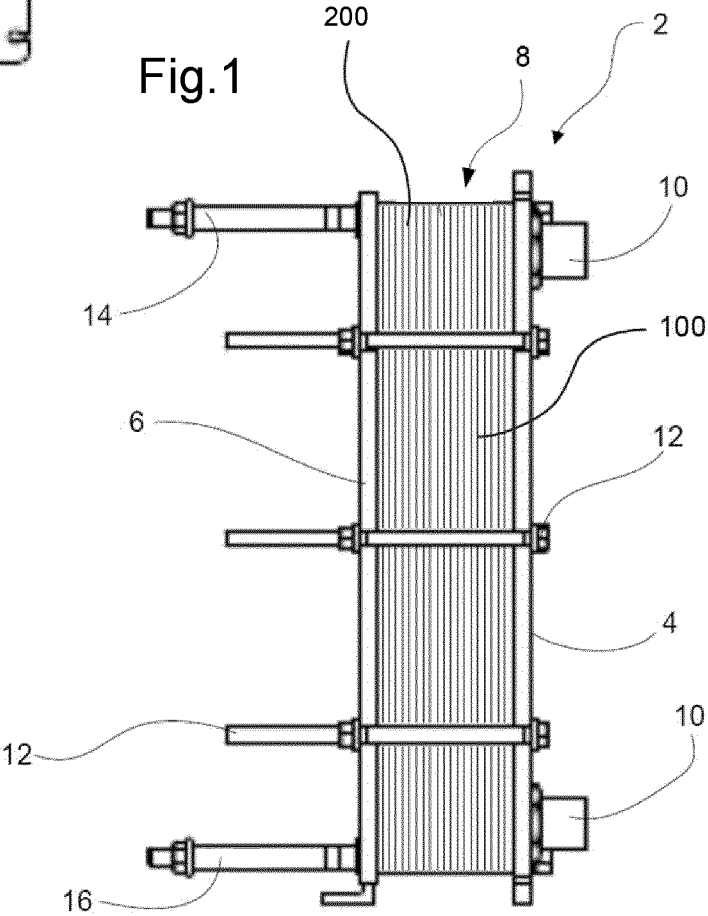


Fig.2

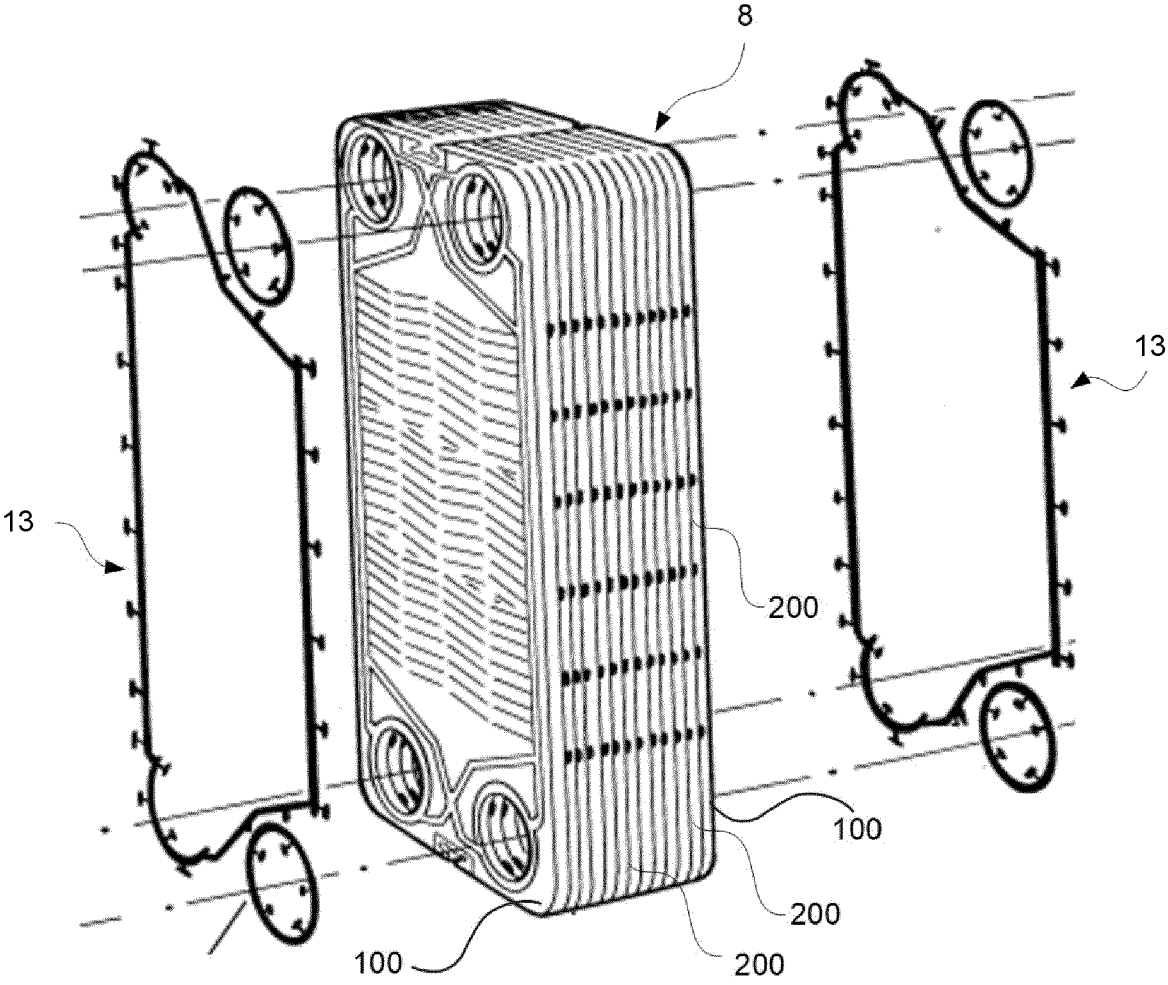


Fig.3

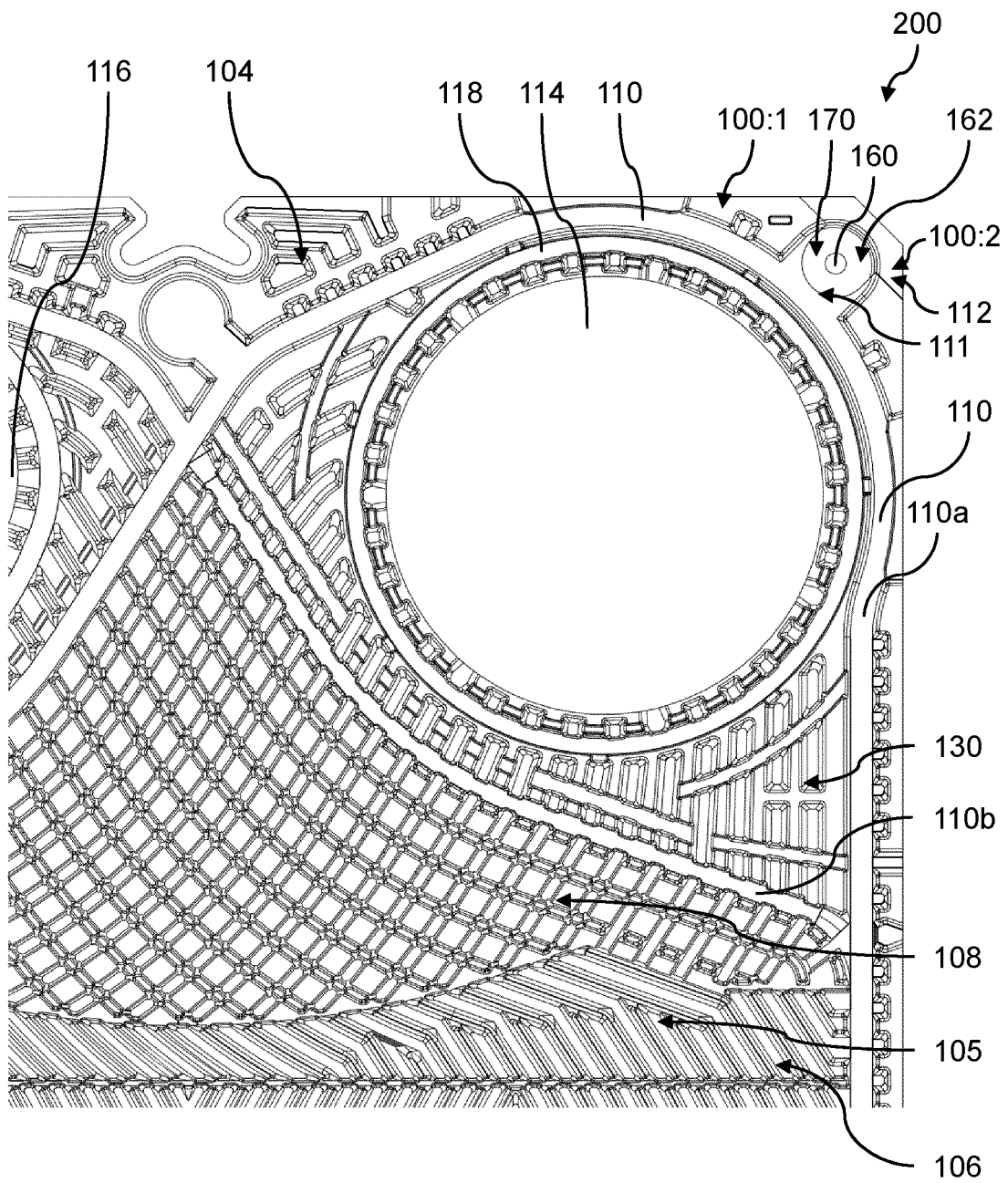


Fig.4

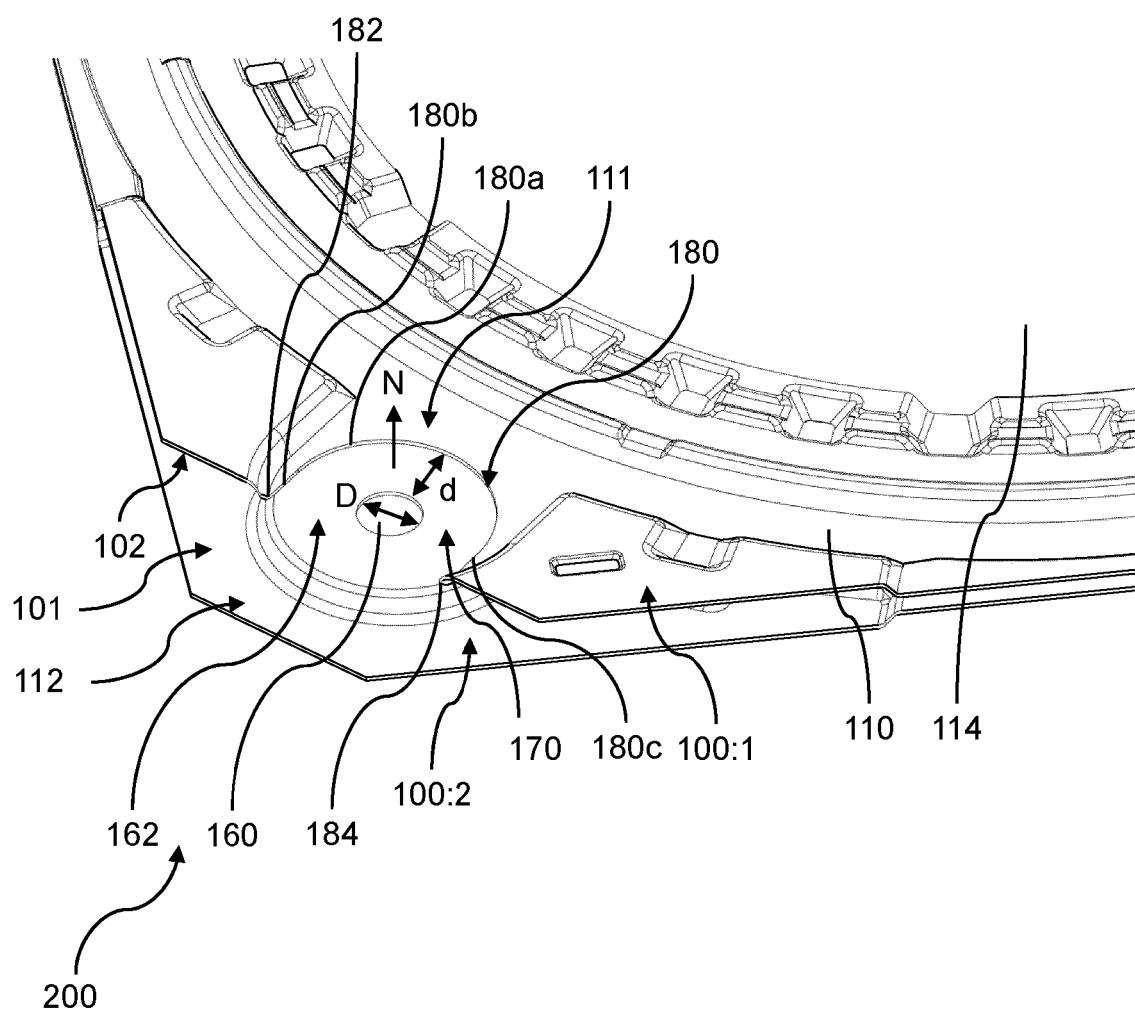


Fig.5

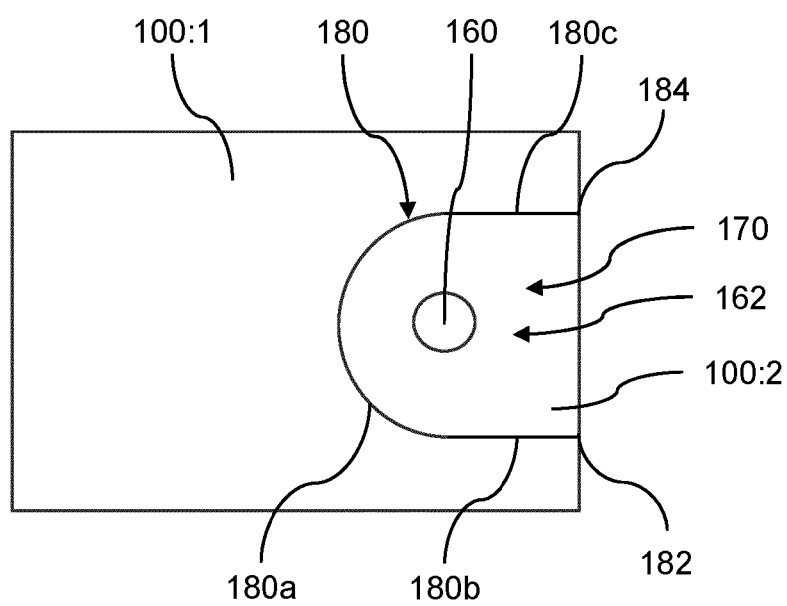


Fig.6a

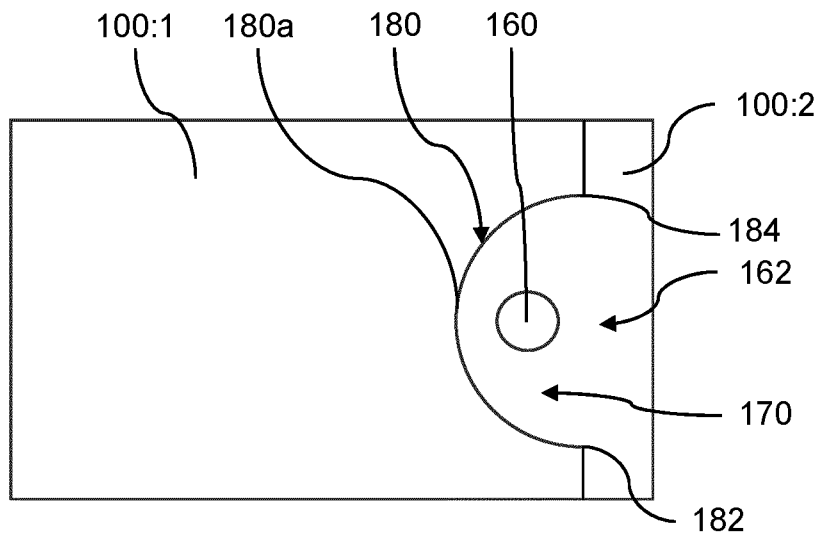


Fig.6b

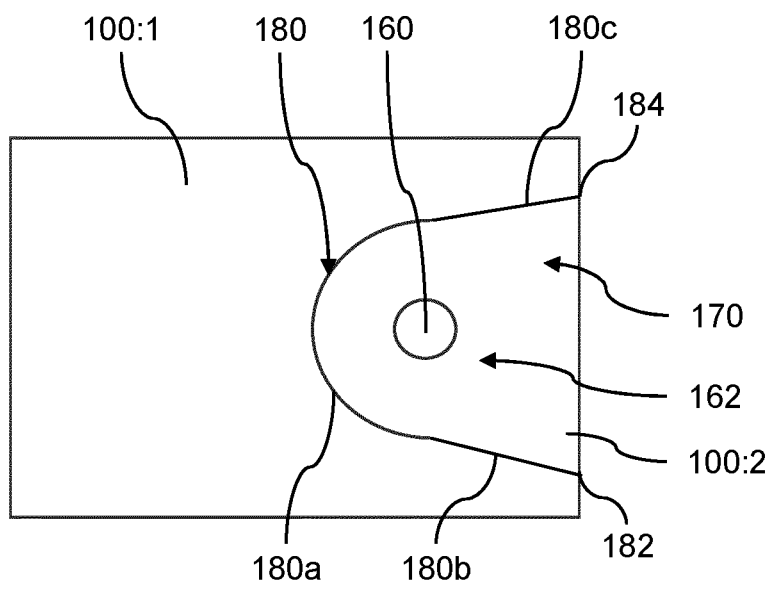


Fig.6c

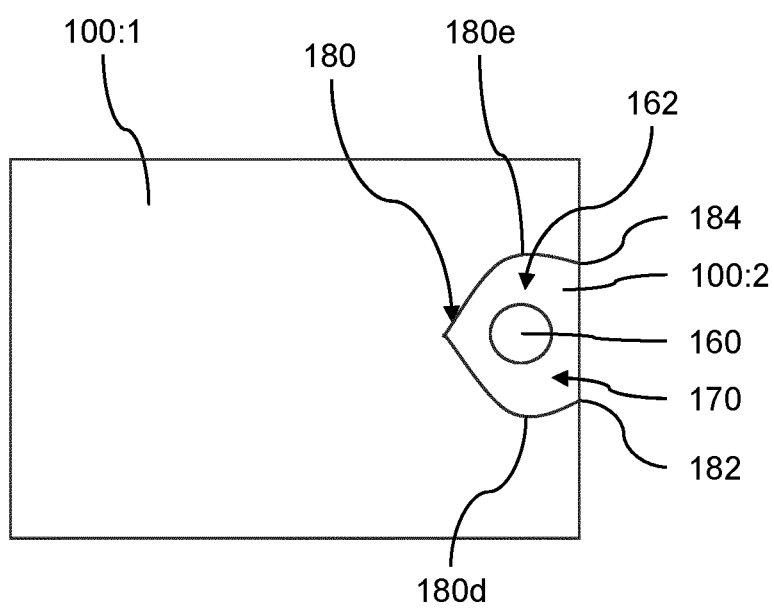


Fig.6d

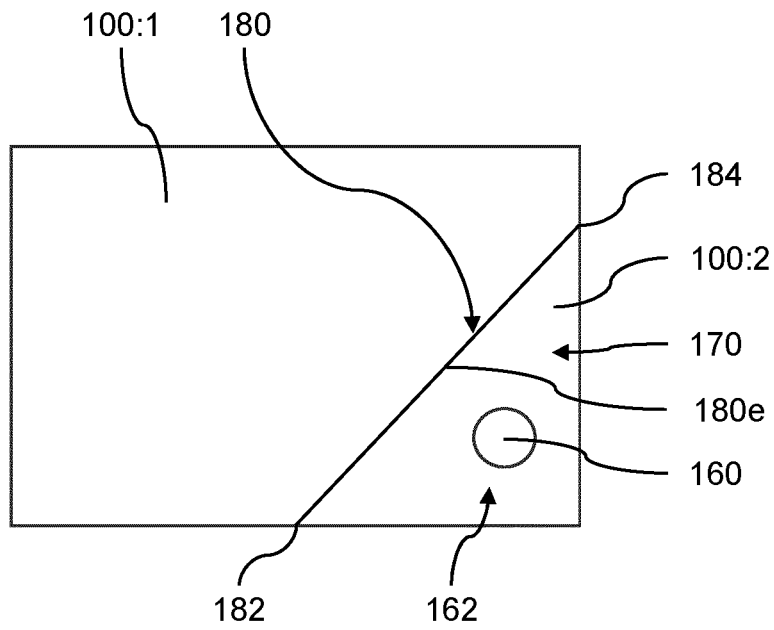


Fig. 6e

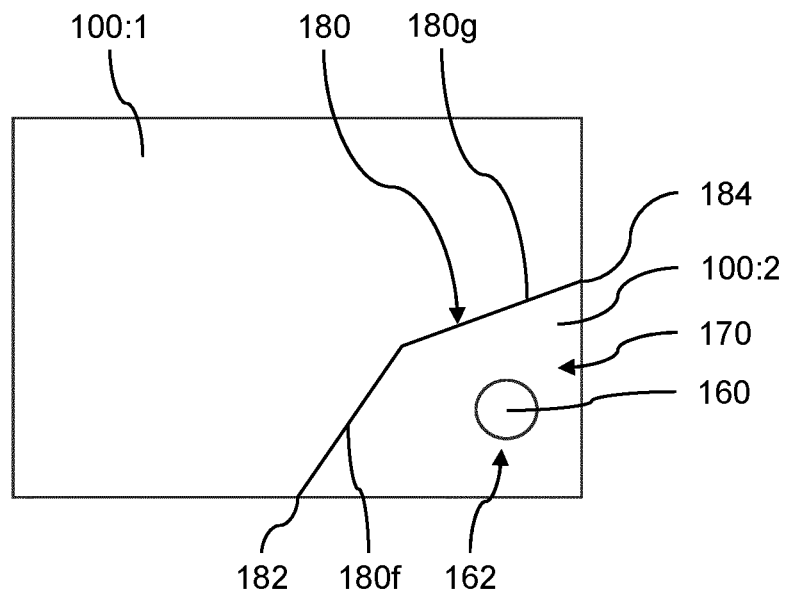


Fig. 6f

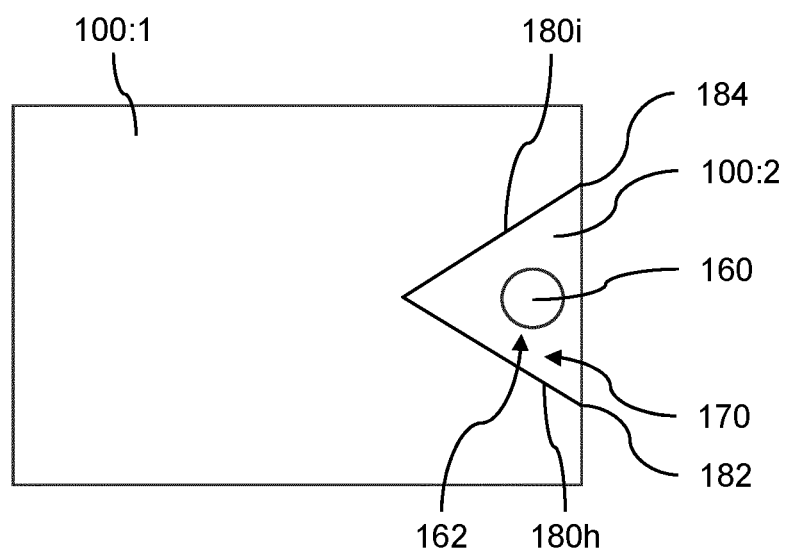


Fig. 6g

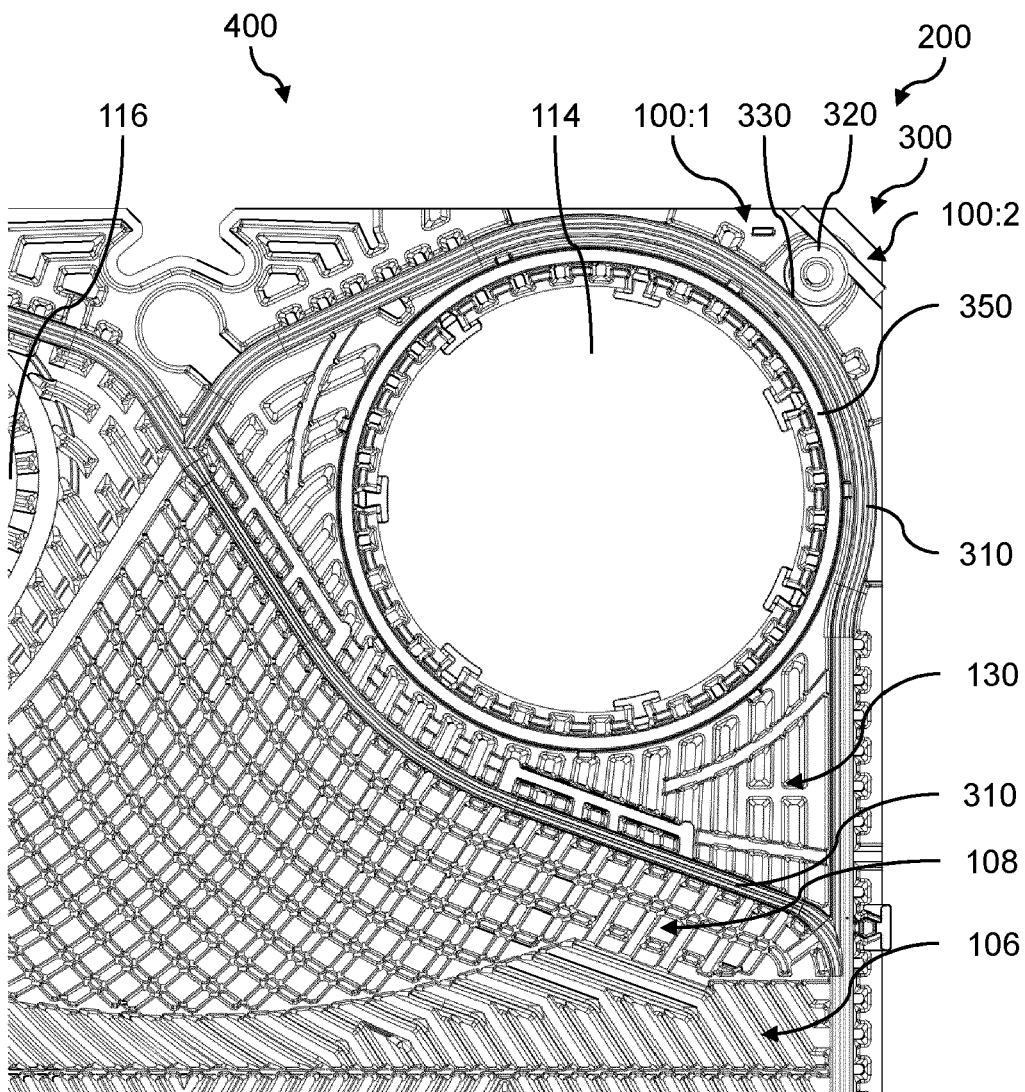


Fig.7

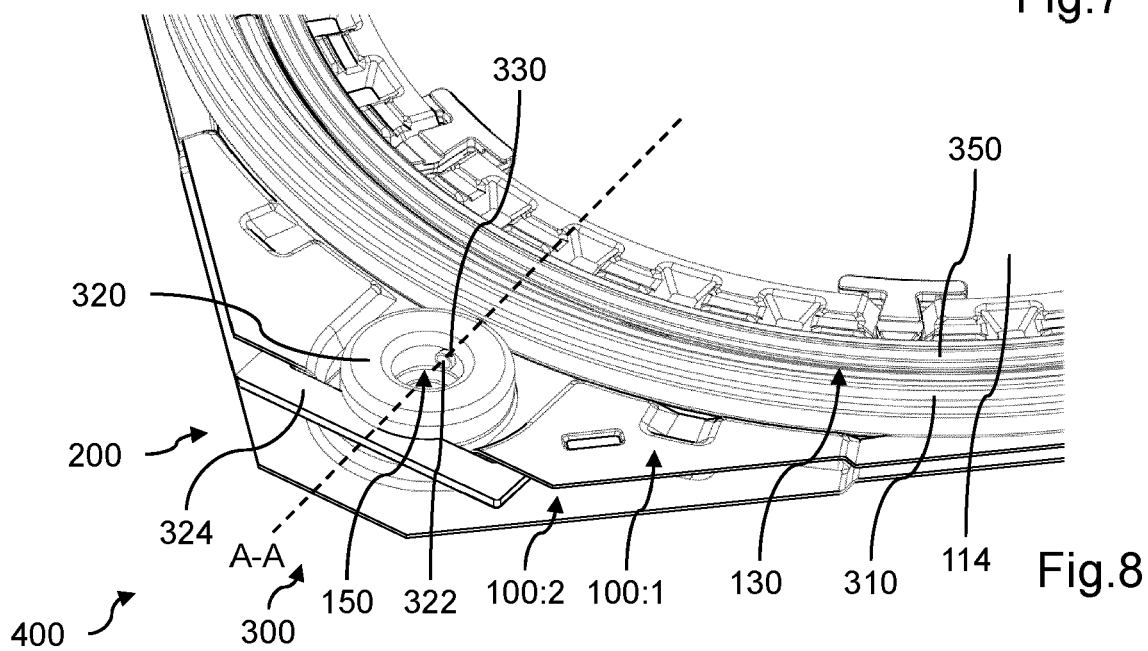


Fig.8

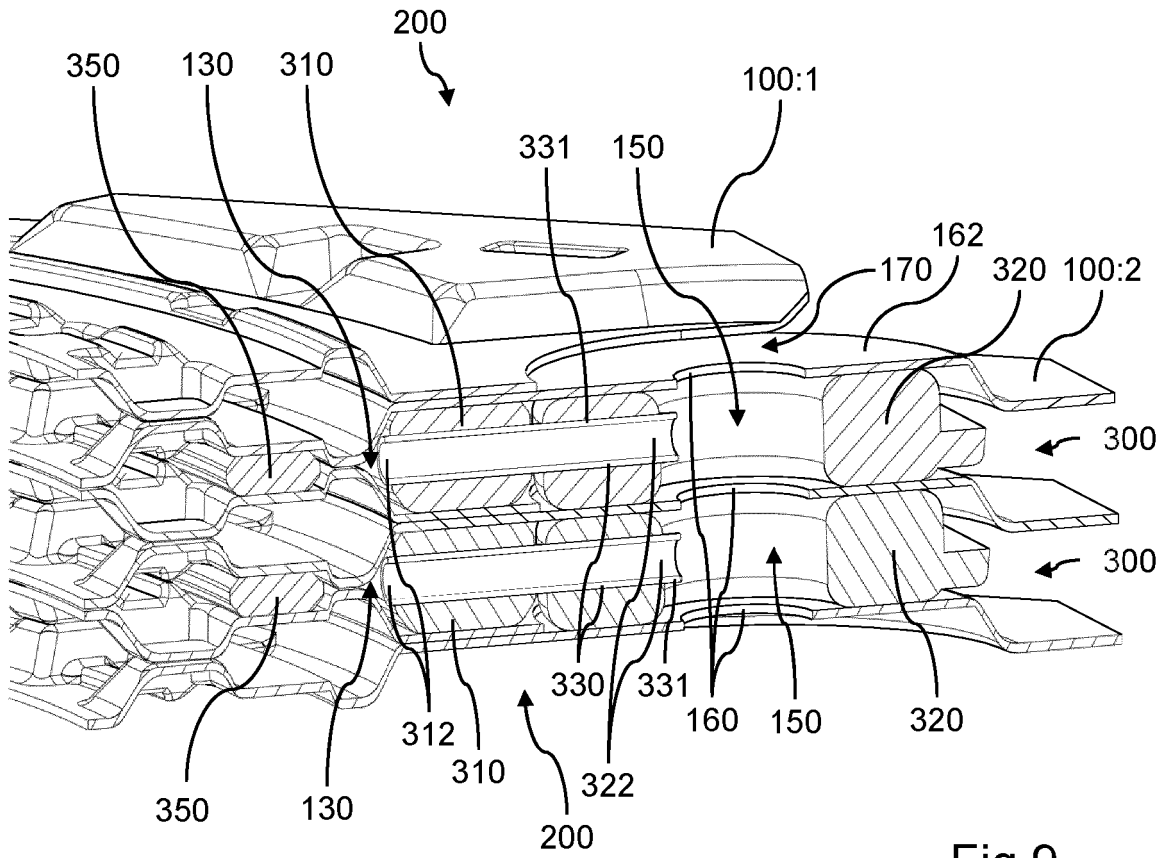


Fig.9

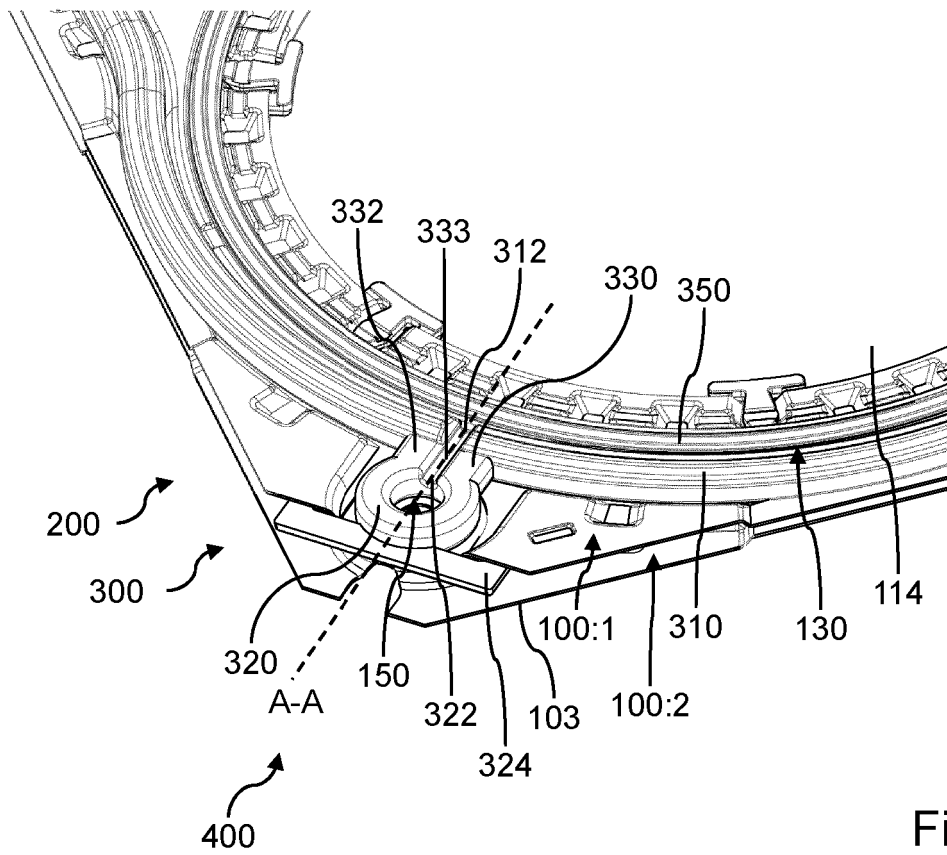
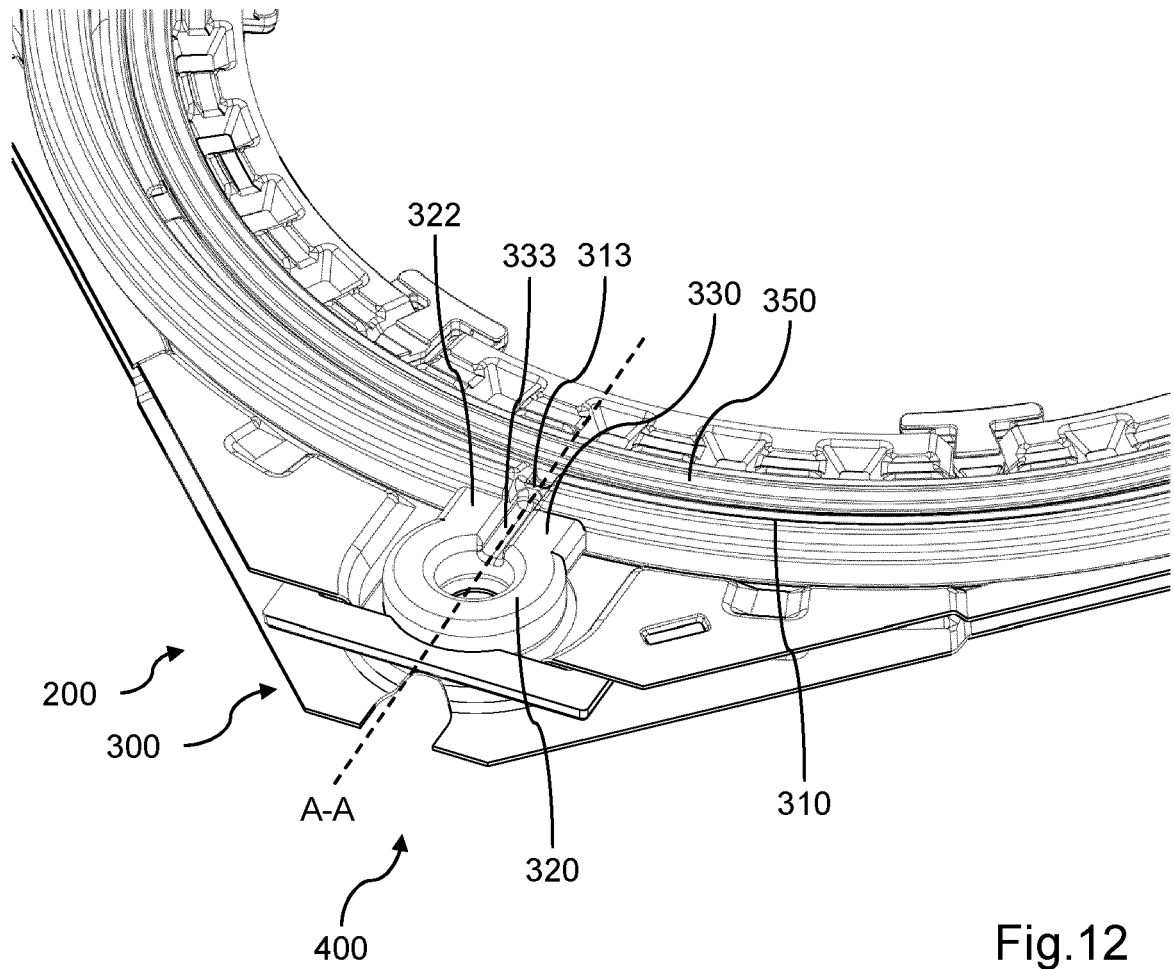
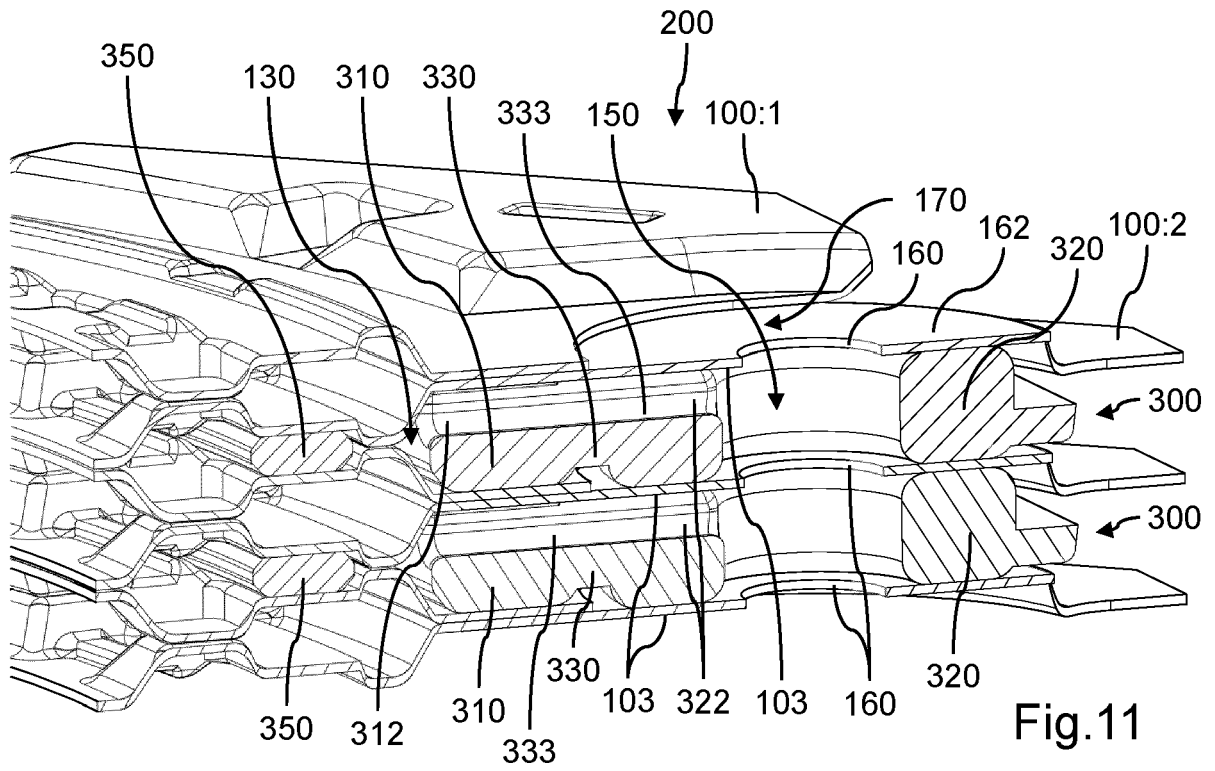
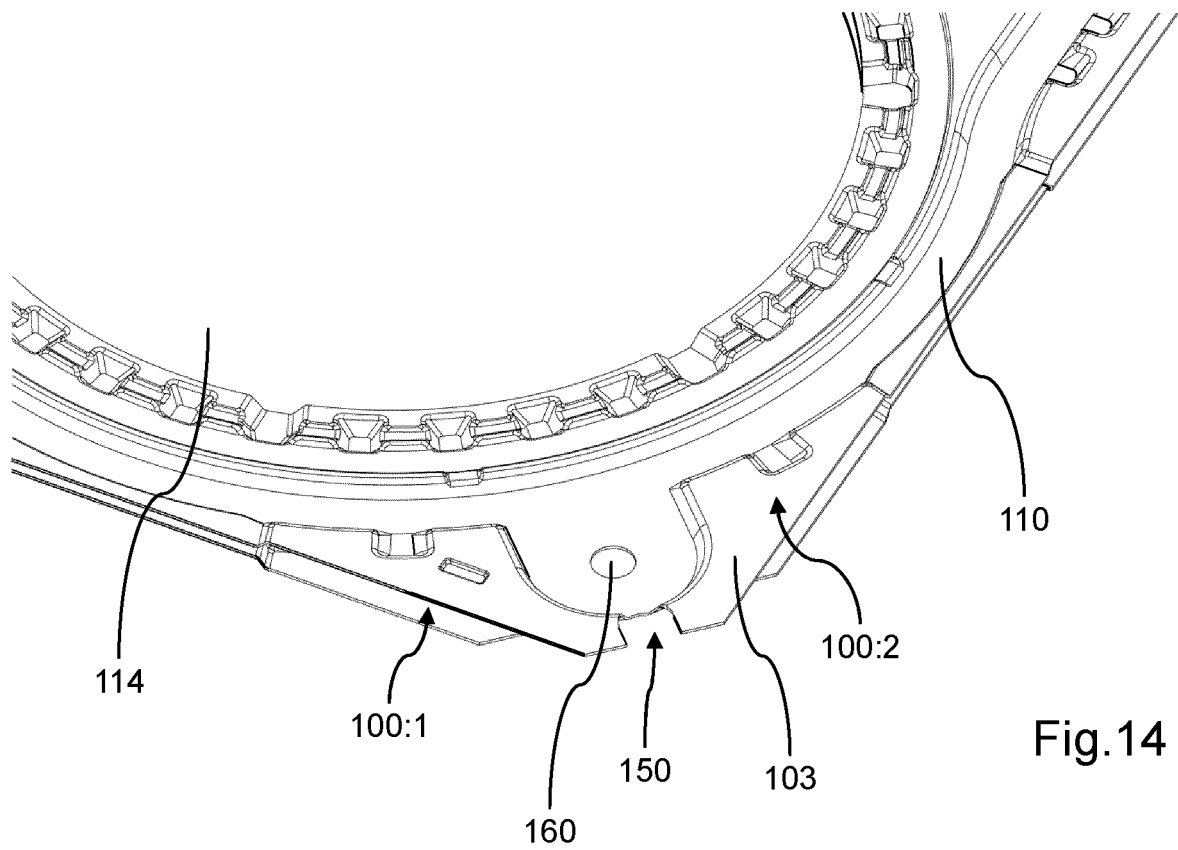
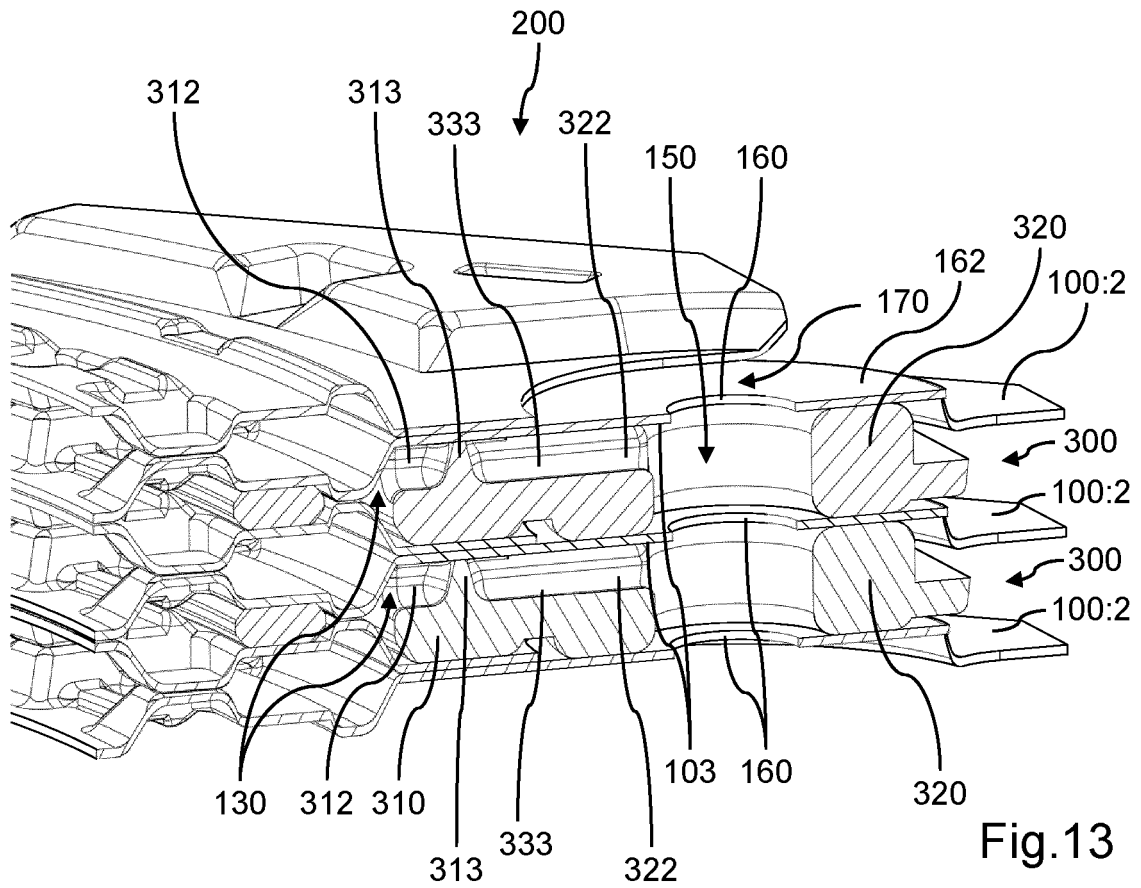


Fig.10





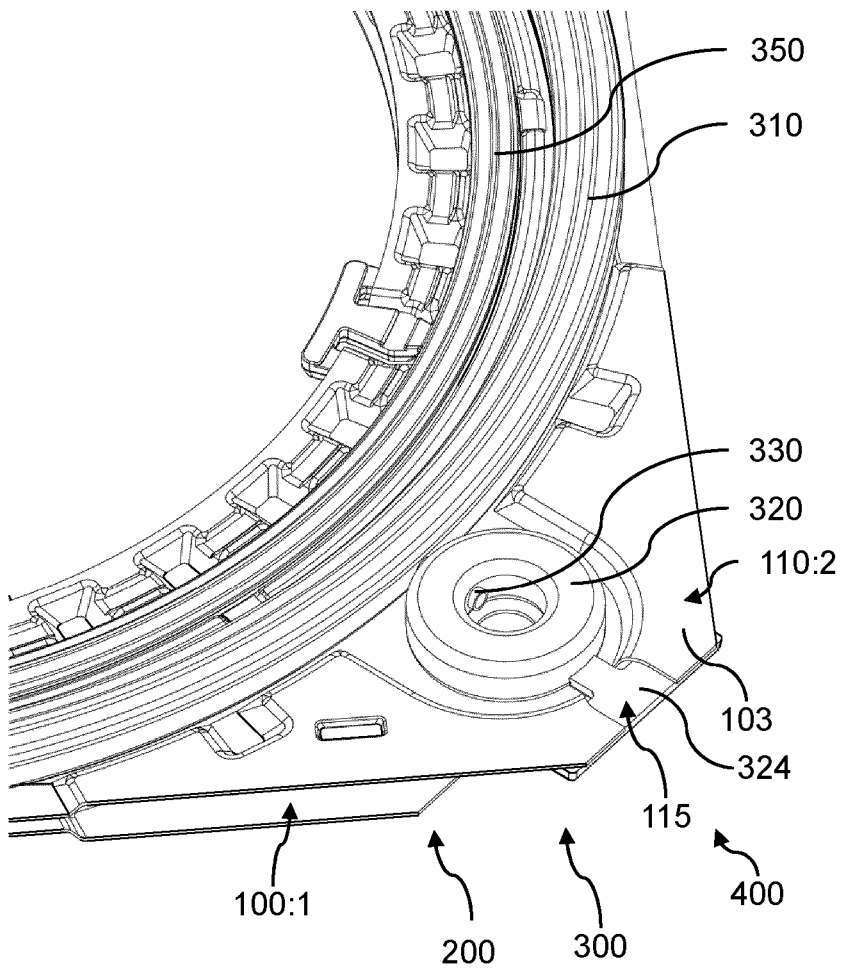


Fig.15

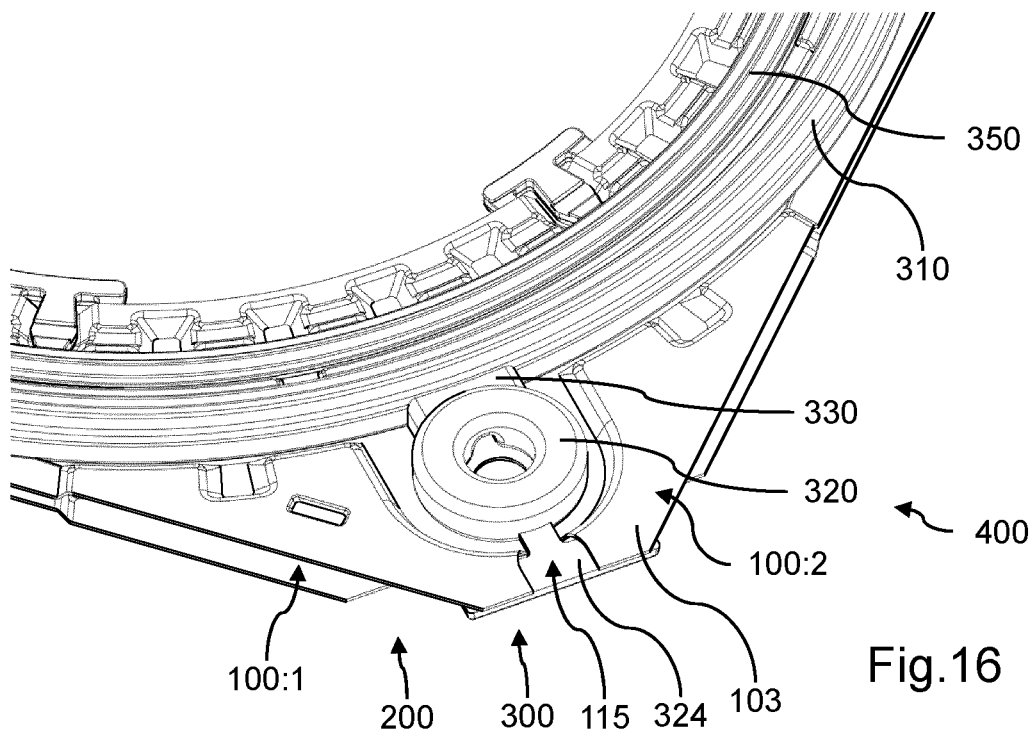


Fig.16



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Application Number

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