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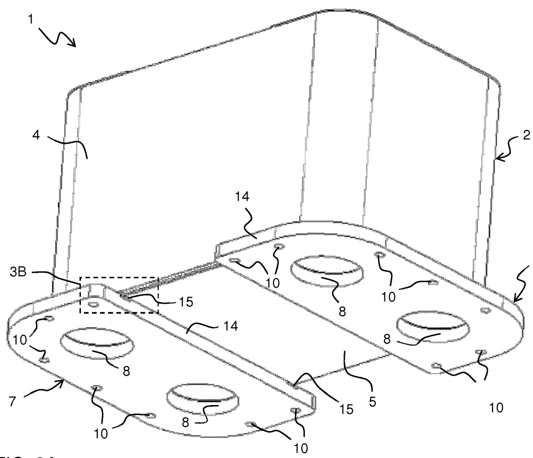
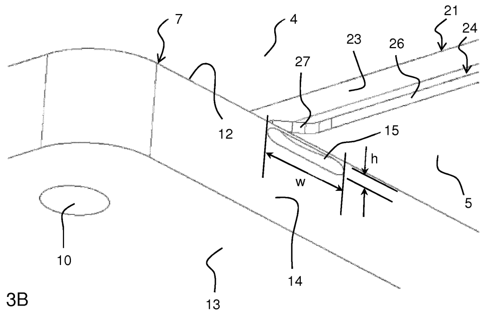
(54) Plate heat exchanger with mounting flange

(57) A plate heat exchanger (1) comprises a plate package (2) of permanently connected heat exchanger plates (3) that defines a surrounding wall (4). Two mounting plates (7) are permanently connected to an end surface (5) of the plate package (2), in spaced relation to each other. Each mounting plate (7) comprises opposing flat engagement surfaces connected by an edge portion that extends along the perimeter of the mounting plate (7). Each mounting plate (7) is arranged with one of its engagement surfaces permanently connected to the end surface (5), such that the perimeter of the mounting plate (7) partially extends beyond the outer periphery of the end surface, to define a mounting flange, and partially extends across the end surface (5) in contact with the same. Each mounting plate (7) has one or more slots (15) in the edge portion located to intersect the perimeter of the surrounding external wall (4) as seen in a normal direction to the end surface (5).





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Description

Technical Field

[0001] The present invention relates to a plate heat exchanger that comprises a plurality of heat exchanger plates which are stacked and permanently connected to form a plate package and a mounting structure which is permanently connected to the plate package for releasable attachment of the plate heat exchanger to an external supporting structure.

Background

[0002] Heat exchangers are utilized in various technical applications for transferring heat from one fluid to another fluid. Heat exchangers in plate configuration are well-known in the art. In these heat exchangers, a plurality of stacked plates having overlapping peripheral side walls are put together and permanently connected to define a plate package with hollow fluid passages between the plates, usually with different fluids in heat exchange relationship in alternating spaces between the plates. Usually a coherent base plate or mounting plate is directly or indirectly attached to the outermost one of the stacked plates. The mounting plate has an extension that exceeds the stack of plates so as to define a circumferential mounting flange. The mounting flange has holes or fasteners to attach the heat exchanger to a piece of equipment. This type of plate heat exchanger is e.g. known from US2010/0258095 and US8181695.

[0003] When fastened on the piece of equipment, the mounting plate may be subjected to a significant pressure and weight load which tends to deform the mounting plate. To achieve an adequate strength and rigidity, the mounting plate needs to be comparatively thick. Such a thick mounting plate may add significantly to the weight of the heat exchanger. Furthermore, the use of a thick mounting plate leads to a larger consumption of material and a higher cost for the heat exchanger.

[0004] The need for a thick mounting plate may be particularly pronounced when the heat exchanger is mounted in an environment which is subjected to vibrations. Such vibrations may e.g. occur when the plate heat exchanger is mounted in a vehicle such as a car, truck, bus, ship or airplane. In these environments, the design of the plate heat exchanger in general, and the design and attachment of the mounting plate in particular, need to take into account the risk for fatigue failure caused by cyclic loading and unloading of the mounting plate by the vibrations. The cyclic stresses in the heat exchanger may cause it to fail due to fatigue, especially in the joints between the plates, even if the nominal stress values are well below the tensile stress limit. The risk for fatigue failure is typically handled by further increasing the thickness of the mounting plate, which will make it even more difficult to keep down the weight and cost of the plate heat exchanger.

Summary

[0005] It is an objective of the invention to at least partly overcome one or more limitations of the prior art.

[0006] Another objective is to provide a plate heat exchanger with a relatively low weight and a relatively high strength when mounted to an external supporting structure.

[0007] A further objective is to provide a plate heat exchanger that can be manufactured at low cost.

[0008] Yet another objective is to provide a plate heat exchanger suitable for use in environments subjected to vibrations.

[0009] One or more of these objects, as well as further objects that may appear from the description below, are at least partly achieved by a plate heat exchanger according to the independent claim, embodiments thereof being defined by the dependent claims.

[0010] A first aspect of the invention is a plate heat exchanger, comprising: a plurality of heat exchanger plates which are stacked and permanently connected to form a plate package that defines first and second fluid paths for a first medium and a second medium, respectively, separated by said heat exchanger plates, said plate package defining a surrounding external wall that extends in an axial direction between first and second axial ends; an end plate permanently connected to one of the first and second axial ends so as to provide an end surface that extends between first and second longitudinal ends in a lateral plane which is orthogonal to the axial direction; and two mounting plates permanently connected to a respective surface portion of the end surface at the first longitudinal end and the second longitudinal end, respectively, such that the mounting plates are spaced from each other in a longitudinal direction on the end surface, wherein the respective mounting plate comprises opposing flat engagement surfaces connected by an edge portion that extends along the perimeter of the mounting plate. The respective mounting plate is arranged with one of its engagement surfaces permanently connected to the end surface, such that the perimeter of the mounting plate partially extends beyond the outer periphery of the end surface, so as to define a mounting flange, and partially extends across the end surface in contact with the same. At least one slot is formed in the edge portion of the respective mounting plate to intersect the perimeter of the surrounding external wall as seen in a normal direction to the end surface.

[0011] The inventive plate heat exchanger is based on the insight that the coherent mounting plate of the prior art may be replaced by two smaller mounting plates that are located at a respective longitudinal end on the end surface on the plate package to provide a respective mounting flange for the heat exchanger. The use of two smaller, separated mounting plates may reduce the weight of the heat exchanger, and also its manufacturing cost, since material is eliminated in the space between the mounting plates, beneath the end surface of the plate package. The inventive heat exchanger is furthermore based on the insight that the use of two separated mounting plates may lead to local stress concentration in the heat exchanger, which may act to reduce the heat exchanger's ability to sustain loads, and in particular cyclic loads. The concentration of stress has been found to originate in the region where the edge portion of the mounting plate intersects the surrounding wall of the plate package. To counteract stress concentration in a simple and efficient way, one or more slots are provided in the edge portion and located to intersect the perimeter of the surrounding wall, as seen in the normal direction of the end surface. The slot or slots provide a locally increased flexibility in the material of the mounting plate without significantly reducing the strength and stiffness of the mounting plate as a whole. The locally increased flexibility serves to distribute the load that is transferred to the mounting plates, the end plate and the plate package via the mounting flanges. The inventive heat exchanger may therefore be designed to achieve a more uniform distribution of stress in the plates of the heat exchanger and in the joints between these plates.

[0012] The distribution of stress may be controlled further by optimizing the design parameters of the heat exchanger in general, and the mounting plates in particular, for example according to the following embodiments.

[0013] In one embodiment, the edge portion comprises an edge surface that extends between the engagement surfaces, the at least one slot being formed in the edge surface. The edge surface may be essentially flat, and preferably perpendicular to the engagement surfaces.

[0014] In one embodiment, the at least one slot extends essentially parallel to the end surface.

[0015] In one embodiment, the at least one slot is located in proximity of and spaced from the engagement surface that faces the end surface. The at least one slot may be spaced from the engagement surface that faces the end surface by a material thickness of less than about 3 mm, preferably less than about 1 mm or about 2 mm.

[0016] In one embodiment, the at least one slot is configured to form a blind-hole that defines an elongated opening in the edge portion, said blind-hole having a bottom wall and first and second side walls, the first and second side walls being spaced from each other in the axial direction and extending from the bottom wall to the elongated opening in the edge portion. The bottom wall may comprise a curved portion, which may be defined by a radius. Alternatively or additionally, the first side wall, which is located closer to the end surface than the second side wall, may connect to the edge portion at the elongated opening so as to define an angle α to the lateral plane, wherein $0° \leq \alpha \leq 45°$, and preferably $0° < \alpha \leq 45°$, as seen in a cross-section perpendicular to the lateral plane. Here, the first side wall may define a straight line from the elongated opening to the bottom wall, as seen in the cross-section perpendicular to the lateral plane. Alternatively or additionally, the bottom wall may define an arc of a circle as seen in a cross-section parallel to the lateral plane.

[0017] In one embodiment, the at least one slot comprises a coherent slot that at least spans the end surface in the transverse direction so as to intersect the perimeter of the surrounding external wall at two opposing sides of the plate package, as seen in the normal direction to the end surface.

[0018] In one embodiment, the end plate is a sealing plate which is permanently and sealingly connected to one of the heat exchanger plates at one of said first and second axial ends.

[0019] In an alternative embodiment, the end plate is a reinforcement plate which is permanently connected to a sealing plate on the plate package, wherein the end plate has at least two supporting flanges that extend beyond the perimeter of the surrounding external wall so as to abut on the mounting flange defined by the respective mounting plate. Further, the end plate may comprise, along its perimeter and as seen in the normal direction of the end surface, concave or beveled surfaces adjacent to the supporting flanges, wherein the concave or beveled surfaces may be located to overlap the perimeter of the respective mounting plate at intersection points where the perimeter of the respective mounting plate intersects the perimeter of the surrounding external wall, and the respective concave or beveled surface may be non-perpendicular to the perimeter of the mounting plate at the overlap, as seen in the normal direction to the end surface.

[0020] In one embodiment, at least one of the mounting plates defines at least one through hole that extends between the engagement surfaces and is aligned with a corresponding through hole defined in the end plate and an internal channel defined in the plate package, so as to form an inlet or an outlet for the first or the second medium.

[0021] In one embodiment, the mounting flange comprises a plurality of mounting holes adapted to receive bolts or pins for fastening the plate heat exchanger.

[0022] In one embodiment, the heat exchanger plates are permanently joined to each other through melting of metallic material.

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

Brief Description of Drawings

[0024] Embodiments of the invention will now be described in more detail with reference to the accompanying schematic drawings.

Fig. 1 is a perspective view of a plate heat exchanger according to an embodiment of the invention.

Fig. 2 is a bottom plan view of the plate heat exchanger in Fig. 1.

Fig. 3A is a perspective view onto the end surface of the plate heat exchanger in Fig. 1, and Fig. 3B is an enlarged view of a portion in Fig. 3A to illustrate a juncture between the mounting plate, a reinforcement plate and a sealing plate in the plate heat exchanger.

Fig. 4A is a section view along the line A1-A1 in Fig. 2 to illustrate a slot configuration, Fig. 4B is a bottom plan view of the region in Fig. 4A, and Fig. 4C is a section view corresponding to Fig. 4A to illustrate an alternative slot configuration.

Figs 5A-5B are perspective views from two directions of a mounting plate included in the plate heat exchanger in Fig. 1.

Fig. 6A is an enlarged partial perspective view of the plate heat exchanger in Fig. 1, Fig. 6B corresponds to Fig. 3B, and Fig. 6C is a partial perspective view of a plate heat exchanger with a non-slotted mounting plate.

Fig. 7 is a perspective view of a sealing plate included in the plate heat exchanger of Fig. 1.

Fig. 8 is a perspective view of a reinforcement plate included in the plate heat exchanger of Fig. 1.

Figs 9A-9B are perspective plan views of a plate heat exchanger according to alternative embodiments.

Detailed Description of Example Embodiments

[0025] Embodiments of the present invention relate to configurations of a mounting structure on a plate heat exchanger. Corresponding elements are designated by the same reference numerals.

[0026] Figs 1-3 disclose an embodiment of a plate heat exchanger 1 according to the invention. The plate heat exchanger 1 comprises a plurality of plates which are stacked one on top of the other to form a plate package 2. The plate package 2 may be of any conventional design. Generally the plate package 2 comprises a plurality of heat exchanger plates 3 with corrugated heat transfer portions that define flow passages (internal channels) for a first and second fluid between the heat exchanger plates 3 such that heat is transferred through the heat transfer portions from one fluid to the other. The heat exchanger plates 3 may be single-walled or double-walled. The heat exchanger plates 3 are only schematically indicated in Fig. 1, since they are well-known to the person skilled in the art and their configuration is not essential for the present invention. The plate package 2 has the general shape of a rectangular cuboid, albeit with rounded corners. Other shapes are conceivable. Generally, the plate package 2 defines a surrounding external wall 4 which extends in a height or axial direction A between a top axial end and a bottom axial end. The wall 4 has a given perimeter or contour at its bottom axial end. In the illustrated example, the wall 4 has essentially the same contour along its extent in the axial direction A. The bottom axial end of the plate package 2 comprises or is provided with an essentially planar end surface 5 (Figs 2-3), which may but need not conform to the contour of the wall 4 at the bottom axial end. The end surface 5 extends in a lateral plane. Generally, the plate package 2, and the end surface 5, extends between two longitudinal ends in a longitudinal direction L and between two transverse ends in a transverse direction T (Fig. 2).

[0027] Although not shown on the drawings, the heat transfer plates 3 have in their corner portions through-openings, which form inlet channels and outlet channels in communication with the flow passages for the first fluid and the second fluid. These inlet and outlet channels open in the end surface 5 of the plate package 2 to define separate portholes for inlet and outlet of the first and second fluids, respectively. In the illustrated example, the end surface 5 has four portholes 6 (Fig. 2).

[0028] The plate package 2 is permanently connected to two identical (in this example) mounting plates 7, which are arranged on a respective end portion of the end surface 5. The mounting plates 7 are thereby separated in the longitudinal direction L, leaving a space free of material beneath the center portion of the plate package 2. Compared to using a single mounting plate that extends beneath the entire plate package 2, the illustrated configuration saves weight and material of the heat exchanger 1, and thereby also cost. Each mounting plate 7 has two through-holes 8 which are mated with a respective pair of the portholes 6 of the plate package 2 to define inlet and outlet ports of the heat exchanger 1. The mounting plates 7 are configured for attaching the heat exchanger 1 to an external suspension structure (not shown) such that the inlet and outlet ports mate with corresponding supply ports for the first and second medium on the external structure. Optionally, one or more seals (not shown) may be provided in the interface between the mounting plate 7 and the external structure.

[0029] Each mounting plate 7 defines a mounting flange 9 that projects from the wall 4 and extends around the longitudinal end of the plate package 2. Bores 10 are provided in the mounting flange 9 as a means for fastening the heat exchanger 1 to the external structure. Threaded fasteners or bolts, for example, may be introduced into the bores 10 for engagement with corresponding bores in the external structure.

[0030] The plate package 2 and the mounting plates 7 are made of metal, such as stainless steel or aluminum. All the plates in the heat exchanger 1 are permanently connected to each other, preferably through melting of a metallic material, such as brazing, welding or a combination of brazing and welding. The plates in the plate package 2 may alternatively be permanently connected by gluing.

[0031] The mounting plates 7 are dimensioned, with respect to material, thickness and extent in the longitudinal and transverse directions, so as to have an adequate strength and stiffness to the static load that is applied to the mounting plates 7 when fastened on the external structure. The static load, which tends to deform the mounting plates 7, may originate from a combination of the weight of the heat exchanger 1, internal pressure applied by the media in the heat exchanger 1 and transferred to the mounting plates 7, and compression forces applied to the mounting plates 7, e.g. at the above-mentioned seals, via the fasteners and the bores 10. This static load tend to deform the mounting plates 7. As seen in Figs 1-3, the mounting plates 7 are generally designed to have a significant thickness. As a non-limiting example, the thickness may be 15-40 mm. The bottom of the plate package 2, on the other hand, is normally made of much thinner material.

[0032] If the heat exchanger 1 is installed in an environment where vibrations are transferred to the mounting plate 7 via the external structure, the heat exchanger 1 also needs to be designed to account for the mechanical stresses caused by the cyclic loading of the vibrations, i.e. cyclic stresses. For example, such vibrations occur for heat exchangers that are mounted in vehicles, such as cars, trucks and ships. In one non-limiting example, the heat exchanger 1 is an oil cooler for an engine. When cyclic stresses are applied to a material, even though the stresses do not cause plastic deformation, the material may fail due to fatigue especially in local regions with high stress concentration. The use of stiff thick mounting plates 7 connected to a plate package 2 with a relatively thin bottom is likely to lead to high concentrations of cyclic stress at the interface between the mounting plates 7 and the plate package 2, and possibly also within the plate package 2.

[0033] Embodiments of the present invention are designed to counteract stress concentration that may lead to fatigue failure. To this end, the mounting plates 7 have dedicated slots or notches 15 in the edge portion of the respective mounting plate 7. The slots 15 are arranged to extend below the end surface 5 so as to intersect the surrounding wall 4 of the plate package 2, as seen in the normal direction to the end surface 5. In the embodiment in Figs 1-3, the slots 15 are arranged with their opening at selected intersection points 11 which are formed between the perimeter of the mounting plate 7 and the perimeter of the wall 4 of the plate package 2. As used herein, the "perimeter" designates the outer contour as seen in plan view. In Fig. 2, the intersection points 11 are indicated by black dots. By providing the intersecting slots 15 in the edge surface 14, a locally increased flexibility is achieved in a region around each such intersection point 11 without significantly impairing the stiffness and stability of the mounting plate 7 as a whole. The flexibility results in a favorable load transfer in the interface between the mounting plate 7 and the plate package 2.

[0034] Figs 5A-5B illustrate a mounting plate 7 in more detail. The mounting plate 7 has a generally elongated shape with rounded corner portions, as seen in plan view. The mounting plate 7 has essentially planar top and bottom surfaces 12, 13, where the top surface 12 forms an engagement surface to be permanently connected to the end surface 5 on the plate package 2, and the bottom surface 13 forms an engagement surface to be applied and fixed to the external supporting structure. The through-holes 8 and bores 10 are formed to extend between the top and bottom surfaces 12, 13. At the perimeter of the mounting plate 7, the top and bottom surfaces are connected by a peripheral edge surface 14. The edge surface 14 is essentially planar and right-angled to the top and bottom surfaces 12, 13 and forms the above-mentioned edge portion. In plan view, the corner portions of the mounting plate 7 are connected by essentially straight contour lines, and the contour line of the edge surface 14 that extends across the plate package 2 (Fig. 2) is designed to intersect the wall 4 at approximately right angles. This design is selected to minimize the width of the mounting plates 7 in the longitudinal direction L (Fig. 2). Other designs are conceivable. In the illustrated example, the slots 15 are located along the straight contour line that extends across the plate package 2.

[0035] Fig. 3B shows the juncture between the mounting plate 7 and the plate package 2 in greater detail, in a perspective from below, and is taken within the dashed rectangle 3B in Fig. 3A. It is seen that the slot 15 defines an elongated opening in the edge surface 14. The opening has a width w in the peripheral direction of the edge surface 14 and a height h in the thickness direction of the mounting plate 7 (equal to the axial direction A, Fig. 1). In Fig. 3B, the mounting plate 7 is mounted to the end surface 5 of the plate package 1 such that the opening of the slot 15 intersects the wall 4. In this particular example, further structures are located in the interface between the plate package 2 and the mounting plate 7. These structures are by formed a sealing plate 21 and an reinforcement plate 24, which are described below with reference to Figs 7-8.

[0036] As seen in Fig. 3B, the elongated opening of the slot 15 is spaced from and generally parallel to the top surface 12, and thus to the end surface 5. The slot 15 is located close to the top surface 12, so as to form a thinned lip of material between the slot 15 and the top surface 12. This lip is at least partly attached to the end surface 5 and provides a locally increased flexibility for the mounting plate 7 in the region of the intersection point. By arranging the slot 15 parallel to the top surface 12, the lip has a uniform thickness along the width w of the slot 15 which may enable a more uniform distribution of stress.

[0037] It is currently believed that the width w and height h of the respective slot 15 are of lesser importance for the stress distribution and can be selected within relatively broad limits. The width and height may rather be selected to facilitate manufacture while ensuring that the mounting plate 7 has an adequate overall stiffness and strength. In one example, the height h is about 5%-50% of the total thickness of the mounting plate 7, but it may fall outside this range. Depending on implementation, the width w may be at least 2 mm, at least 5 mm or at least 10 mm.

[0038] To further illustrate the configuration of the slot 15, Fig. 4A shows a cross-section in the longitudinal direction L, taken along the line A1-A1 in Fig. 2, and Fig. 4B is a partial plan view of the mounting plate 7 at the location of the slot 15. The slot 15 forms a blind hole, which is defined by a bottom wall 16 and two side walls 17, 18 which extend from the bottom wall 16 to the opening in the edge surface 14. Figs 4A-4B illustrate a number of design parameters that may be adapted, in addition to the width w and the height h, to counteract stress concentration. One such design parameter is the distance t1 between the slot 15 and the top surface 12, and thus the thickness of the above-mentioned lip. The distance t1 is preferably small, e.g. about 3 mm or smaller, and preferably less than about 2 mm or even less than about 1 mm. The slot 15 has a maximum depth d in the longitudinal direction L, i.e. between the bottom wall 16 and the opening in the edge surface 14. This depth d may depend on the shape of the bottom wall. In one example, the slot 15 has the same depth d along its width w. However, in the illustrated example, as seen in Fig. 4B, the bottom wall 16 follows the arc of a circle with a radius R1, as seen in a plane parallel to the end surface 5. The radius R1 is defined with respect to a center line C, which is spaced from the edge surface 14. This configuration of the bottom wall 16 may facilitate the manufacture of the slot 15. Furthermore, the bottom wall 16 has a curved shape in cross-section transverse to the extent of the slot 15, i.e. in a plane perpendicular to the end surface 5 (Fig. 4A). Thereby, the bottom wall 16 forms a trough with smooth transitions to the side walls 17, 18. Such a shape of the bottom wall 16 may further counteract stress concentration. In Fig. 4A, the curvature of the bottom wall 16 is given by a radius R2.

[0039] In Fig. 4A, the side walls 17, 18 extend essentially parallel to the top and bottom surfaces 12, 13 and thereby connect essentially at right angles to the edge surface 14 at the opening of the slot 15. Such a configuration may be preferred to simplify manufacture. However, an alternative configuration that may reduce the stress concentration further is shown in Fig. 4C. Here, the side wall 17 facing the top surface 12, i.e. the side wall 17 that defines the thinned lip, is inclined to the top surface 12. Thereby, the side wall 17 meets the edge surface 14 at an angle α that exceeds 0°. The angle α is defined with respect to the plane of the top surface 12. In the illustrated example, the side wall 17 is flat and thus has a linear extent from the bottom wall 16 to the opening. If the side wall 17 instead is non-flat, e.g. curved, the angle α is given by the direction (tangent) of the side wall 17 at the opening, i.e. at the location where the side wall 17 meets the edge surface 14. In certain implementations, the angle α may be larger than 2°, 5° or 10° to achieve adequate stress distribution. The angle α is preferably less than about 45°. This definition and choice of the angle α is applicable to all embodiments shown herein.

[0040] It should be noted that the slot 15 preferably has the same cross-sectional shape along its extent, i.e. along the width w in Fig. 3B.

[0041] The mounting plate 7 may be initially manufactured with a coherent edge surface 14, e.g. planar and right-angled as shown in the drawings, and the slots 15 may be provided by locally removing material from mounting plate 7 at the edge surface 14. The slots 15 may be formed by machining, e.g. milling, grinding, boring or drilling. For example, the slot 15 in Figs 4A-4B may be formed by a milling cutter located to rotate around the center line C.

[0042] The heat exchanger 1 in Fig. 1 comprises some additional features that may serve to improve stability and durability. Fig. 6A shows the juncture between the mounting plate 7 and the plate package 2 in greater detail and is taken within the dashed rectangle 6A in Fig. 1. In this example, a sealing plate 21 is connected to the stack of heat exchanger plates to define a bottom surface of the plate package 2. The sealing plate 21, as shown in Fig. 7, is generally planar and has through-holes 22 at its corners to be mated with corresponding through-holes in the heat exchanger plates 3. The perimeter of the sealing plate 21 is bent upwards to form a surrounding flange 23 which adapted to abut on and be fixed to a corresponding flange of an overlying heat exchanger plate, as is known in the art. Thus, the perimeter of the sealing plate 21 generally conforms to the perimeter of the surrounding wall 4, although the surrounding flange 21 may project slightly beyond the perimeter of the surrounding wall 4 as defined by the heat exchanger plates. In certain embodiments, the mounting plates 7 may be directly attached to the sealing plate 21. In such embodiments, the sealing plate 21 is an end plate that defines the end surface 5.

[0043] However, in the illustrated embodiment, an additional plate 24 is attached intermediate the sealing plate 21 and the mounting plate 7 for the purpose of reinforcing the bottom surface of the plate package 2. Thus, the end surface 5 is defined by this additional reinforcement or supporting plate 24. The use of such a reinforcement plate 24 may be advantageous when the working pressure of one or both of the media conveyed through the heat exchanger 1 is high or when the working pressure for one or both of the media varies over time. The reinforcement plate 24, which is shown in greater detail in Fig. 8, has a uniform thickness and defines through-holes 25 which are matched to the portholes in the plate package 2. The perimeter of the reinforcement plate 24 may be essentially level with the perimeter of the sealing plate 21 or the perimeter of the wall 4 of the plate package 2. However, in the illustrated example, the reinforcement plate 24 is adapted to locally project from the perimeter of the wall 4, and thus from the perimeter of the sealing plate 21. Specifically, the reinforcement plate 24 is provided with cutouts 26 that are located to extend in the longitudinal direction between the intersection points 11 on a respective transverse side of the plate package 2 so as to be essentially level with the axial wall 4. Thereby, the longitudinal end points of the cutouts 26 define a respective transition 27 to a projecting tab portion 28, where the transitions 27 are located to overlap the perimeter of the mounting plate 7 in proximity to the intersection points 11 and are shaped to be non-perpendicular to the perimeter of the mounting plate 7 at the overlap, as seen in a direction towards the bottom of the heat exchanger 1. This configuration of the reinforcement plate 24 will locally decrease the stress in the reinforcement plate 24 at the intersection points 11. The transitions 27 may e.g. form a bevel or a curve from the cutout 26 to the tab 28. In the illustrated example, see Fig. 6A, the tab portions 28 protrude from the plate package 2 to essentially coextend with and abut against a respective mounting plate 7. This has been found to result in a favorable distribution of stress between the mounting plate 7, the reinforcement plate 24 and the sealing plate 21 especially at the corners of the plate package 2. It will also increase the strength of the joint between the reinforcement plate 24 and the mounting plate 7 due to the increased contact area between them. In an alternative implementation, not shown, the reinforcement plate 24 projects from the plate package 2 around its entire perimeter except for small notches that are located in the proximity of the intersection points 11 to provide transitions 27 that are appropriately shaped to be non-perpendicular to the perimeter of the mounting plate 7.

[0044] The design of the mounting plate 7, and the reinforcement plate 24 if present, may be optimized based on the general principles outlined above, by simulating the distribution of stress in the heat exchanger structure. Such simulations may serve to adapt one or more of the thickness and width of the mounting plates 7, the width w and the height h of the slots 15, the depth d of the slots 17, the thickness t1 of the attachment lip formed by the slot 15, as well as further parameters related to the internal shape of the slot 15, such as the above-mentioned parameters R1, R2 and α. The simulations may be based on any known technique for numerical approximation of stress, such as the finite element method, the finite difference method, and the boundary element method.

[0045] A simulation of the stress distribution within the structure in Fig. 6A, for one specific vibration load condition, indicates that stresses are well-distributed without any significant peaks in the interface between the reinforcement plate 24 and the sealing plate 21. For this particular simulation, the maximum stress levels are distributed along arrow L1, at which the stress values are approximately 100 N/mm^2 (MPa). The simulation also indicates that stresses are equally well-distributed in the interface between the mounting plate 7 and the reinforcement plate 24, with maximum stress levels of approximately 80-90 N/mm^2 being distributed along arrow L2 in Fig. 6B, which is a reproduction of Fig. 3B. For comparison, the stress distribution has also been simulated, for the same vibration load condition, within a heat exchanger provided with a mounting plate 7 without slots in the edge surface 14, as shown in the enlarged perspective view in Fig. 6C. In this example, the reinforcement plate 24 has the same extension as the sealing plate 21. The simulation indicated a significant stress concentration at the juncture of the mounting plate 7 and the reinforcement plate 24, with a maximum stress value of about 310 N/mm^2 in region L3.

[0046] While the invention has been described in connection with what is presently considered to be the most practical and preferred embodiments, it is to be understood that the invention is not to be limited to the disclosed embodiments, but on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and the scope of the appended claims.

[0047] For example, the edge surface 14 may have any shape and angle to the top and bottom surfaces 12, 13 of the mounting plate 7.

[0048] It should be noted that the openings of the slots 15 need not exactly overlap the intersection points 11, as seen in the normal direction to the end surface 5. For example, if the edge surface 14 is non-perpendicular to the top and bottom engagement surfaces 12,13, the openings of the slots 15 may be separated from perimeter of the respective mounting plate 7 as seen in said normal direction, and thus from the intersection points 11 (which are given by the perimeter of the respective mounting plate 7). In other words, when projected onto the lateral plane of the heat exchanger 1, the slots 15 may be spaced from the perimeter of the respective mounting plate 7.

[0049] Although all illustrated examples involve slots 15 that extend on both sides of their respective intersections with the surrounding wall 4, it may be possible to achieve a sufficient stress distribution by confining the slots 15 within the perimeter of the wall 4, or by confining the slots to the mounting flange 9 that projects from the wall 4, as long as the slots 15 extend to intersect the perimeter of the surrounding wall 4. It is also conceivable to provide the heat exchanger with mounting plates 7 having much wider slots 15 than those shown in Figs 1-5. Fig. 9A illustrates a mounting plate 7 with a slot 15 that extends from the nearest corner portion of the mounting plate 7 to a location further towards the center of the plate package 2 compared to the embodiment in Fig. 3B. It is also conceivable to provide the mounting plate 7 with a single slot 15 long enough to intersect the surrounding wall 4 at both transverse sides of the plate package 2. Fig. 9B shows such a mounting plate 7, in which a coherent slot 15 is formed to extend along the entire edge surface 14 that faces the other mounting plate 7.

[0050] As used herein, "top", "bottom", "vertical", "horizontal", etc merely refer to directions in the drawings and does not imply any particular positioning of the heat exchanger 1. Nor does this terminology imply that the mounting plates 7 need to be arranged on any particular end of the plate package 2. Reverting to Fig. 1, the mounting plates may alternatively be arranged on the top axial end of the plate package 2 and may be permanently connected either to a sealing plate or to a reinforcement plate overlying the sealing plate. Furthermore, the mounting plates 7 may be arranged on an end of the plate package

2 that lacks portholes or on which each or at least one porthole 6 is located intermediate the mounting plates 7.

Claims

1. A plate heat exchanger, comprising:

a plurality of heat exchanger plates (3) which are stacked and permanently connected to form a plate package (2) that defines first and second fluid paths for a first medium and a second medium, respectively, separated by said heat exchanger plates (3), said plate package (2) defining a surrounding external wall (4) that extends in an axial direction (A) between first and second axial ends,

an end plate (21; 24) permanently connected to one of the first and second axial ends so as to provide an end surface (5) that extends between first and second longitudinal ends in a lateral plane which is orthogonal to the axial direction (A), and

two mounting plates (7) permanently connected to a respective surface portion of the end surface (5) at the first longitudinal end and the second longitudinal end, respectively, such that the mounting plates (7) are spaced from each other in a longitudinal direction (L) on the end surface (5), wherein the respective mounting plate (7) comprises opposing flat engagement surfaces (12, 13) connected by an edge portion (14) that extends along the perimeter of the mounting plate (7),

wherein the respective mounting plate (7) is arranged with one of its engagement surfaces (12, 13) permanently connected to the end surface (5), such that the perimeter of the mounting plate (7) partially extends beyond the outer periphery of the end surface (5), so as to define a mounting flange (9), and partially extends across the end surface (5) in contact with the same, and wherein at least one slot (15) is formed in the edge portion (14) of the respective mounting plate (7) to intersect the perimeter of the surrounding external wall (4) as seen in a normal direction to the end surface (5).

2. The plate heat exchanger of claim 1, wherein the edge portion comprises an edge surface (14) that extends between the engagement surfaces (12, 13), the at least one slot (15) being formed in the edge surface (14).

3. The plate heat exchanger of claim 2, wherein the edge surface (14) is essentially flat, and preferably perpendicular to the engagement surfaces (12, 13).

4. The plate heat exchanger of any preceding claim, wherein the at least one slot (15) extends essentially parallel to the end surface (5).

5. The plate heat exchanger of any preceding claim, wherein the at least one slot (15) is located in proximity of and spaced from the engagement surface (12, 13) that faces the end surface (5).

6. The plate heat exchanger of claim 5, wherein the at least one slot (15) is spaced from the engagement surface (12, 13) that faces the end surface (5) by a material thickness (t1) of less than about 3 mm, preferably less than about 1 mm or about 2 mm.

7. The plate heat exchanger of any preceding claim, wherein the at least one slot (15) is configured to form a blind-hole that defines an elongated opening in the edge portion (14), said blind-hole (15) having a bottom wall (16) and first and second side walls (17, 18), the first and second side walls (17, 18) being spaced from each other in the axial direction (A) and extending from the bottom wall (16) to the elongated opening in the edge portion (14).

8. The plate heat exchanger of claim 7, wherein the bottom wall (16) comprises a curved portion.

9. The plate heat exchanger of claim 8, wherein the curved portion is defined by a radius (R2).

10. The plate heat exchanger of any one of claims 7-9, wherein the first side wall (17), which is located closer to the end surface (5) than the second side wall (18), connects to the edge portion (14) at the elongated opening so as to define an angle α to the lateral plane, wherein $0° < \alpha \leq 45°$, and preferably $0° < \alpha \leq 45°$, as seen in a cross-section perpendicular to the lateral plane.

11. The plate heat exchanger of claim 10, wherein the first side wall (17) defines a straight line from the elongated opening to the bottom wall (16), as seen in the cross-section perpendicular to the lateral plane.

12. The plate heat exchanger of any one of claims 7-11, wherein the bottom wall (16) defines an arc of a circle as seen in a cross-section parallel to the lateral plane.

13. The plate heat exchanger of any preceding claim, wherein the at least one slot comprises a coherent slot (15) that at least spans the end surface (5) in the transverse direction (T) so as to intersect the perimeter of the surrounding external wall (4) at two opposing sides of the plate package (2), as seen in the normal direction to the end surface (5).

14. The plate heat exchanger of any preceding claim, wherein the end plate (21) is a sealing plate which is permanently and sealingly connected to one of the heat exchanger plates (3) at one of said first and second axial ends.

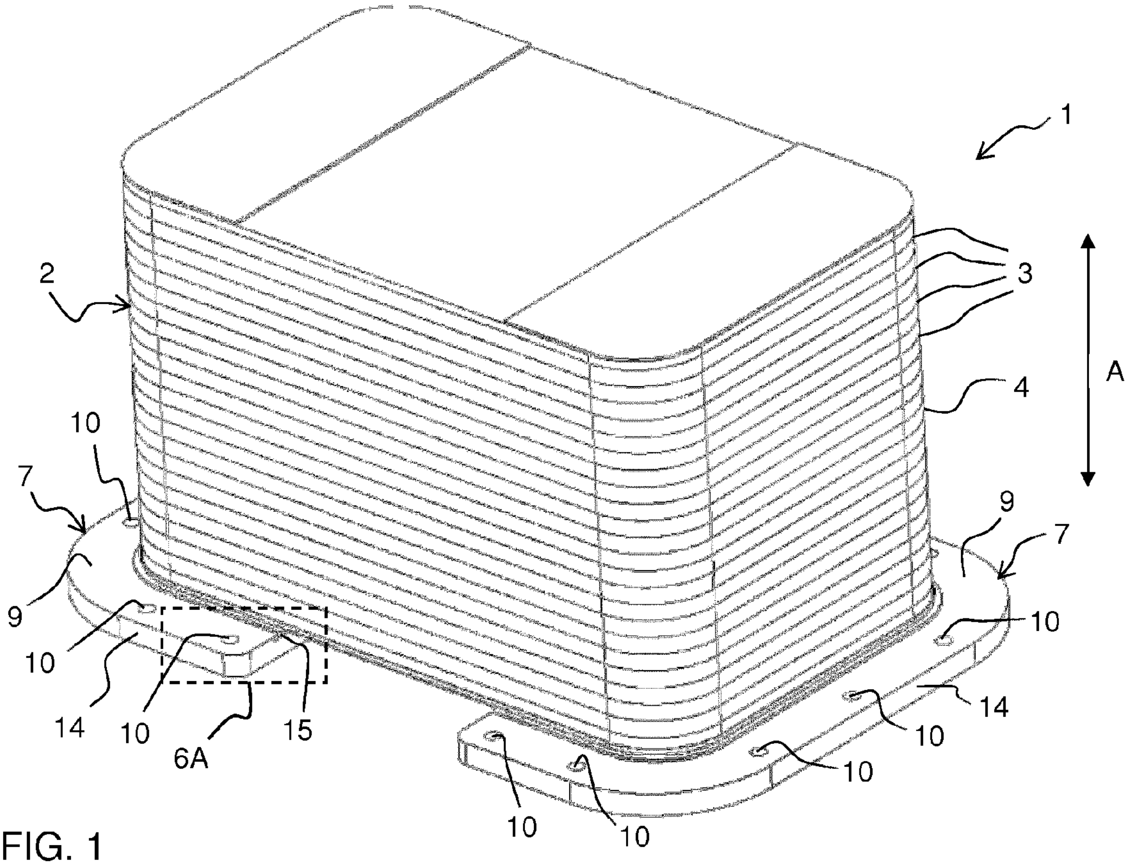
15. The plate heat exchanger of any one of claims 1-13, wherein the end plate (24) is a reinforcement plate (24) which is permanently connected to a sealing plate (21) on the plate package (2), wherein the end plate (24) has at least two supporting flanges (28) that extend beyond the perimeter of the surrounding external wall (4) so as to abut on the mounting flange (9) defined by the respective mounting plate (7).

16. The plate heat exchanger of claim 15, wherein the end plate (24) comprises, along its perimeter and as seen in the normal direction of the end surface (5), concave or beveled surfaces (27) adjacent to the supporting flanges (28), wherein the concave or beveled surfaces (27) are located to overlap the perimeter of the respective mounting plate (7) at intersection points (11) where the perimeter of the respective mounting plate (7) intersects the perimeter of the surrounding external wall (4), and wherein the respective concave or beveled surface (27) is non-perpendicular to the perimeter of the mounting plate (7) at the overlap, as seen in the normal direction to the end surface (5).

17. The plate heat exchanger of any preceding claim, wherein at least one of the mounting plates (7) defines at least one through hole (8) that extends between the engagement surfaces (12, 13) and is aligned with a corresponding through hole (22; 25) defined in the end plate (21; 24) and an internal channel defined in the plate package (2), so as to form an inlet or an outlet for the first or the second medium.

18. The plate heat exchanger of any preceding claim, wherein the mounting flange (9) comprises a plurality of mounting holes (10) adapted to receive bolts or pins for fastening the plate heat exchanger.

19. The plate heat exchanger of any preceding claim, wherein the heat exchanger plates (3) are permanently joined to each other through melting of metallic material.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14
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15
14
6A
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FIG. 1

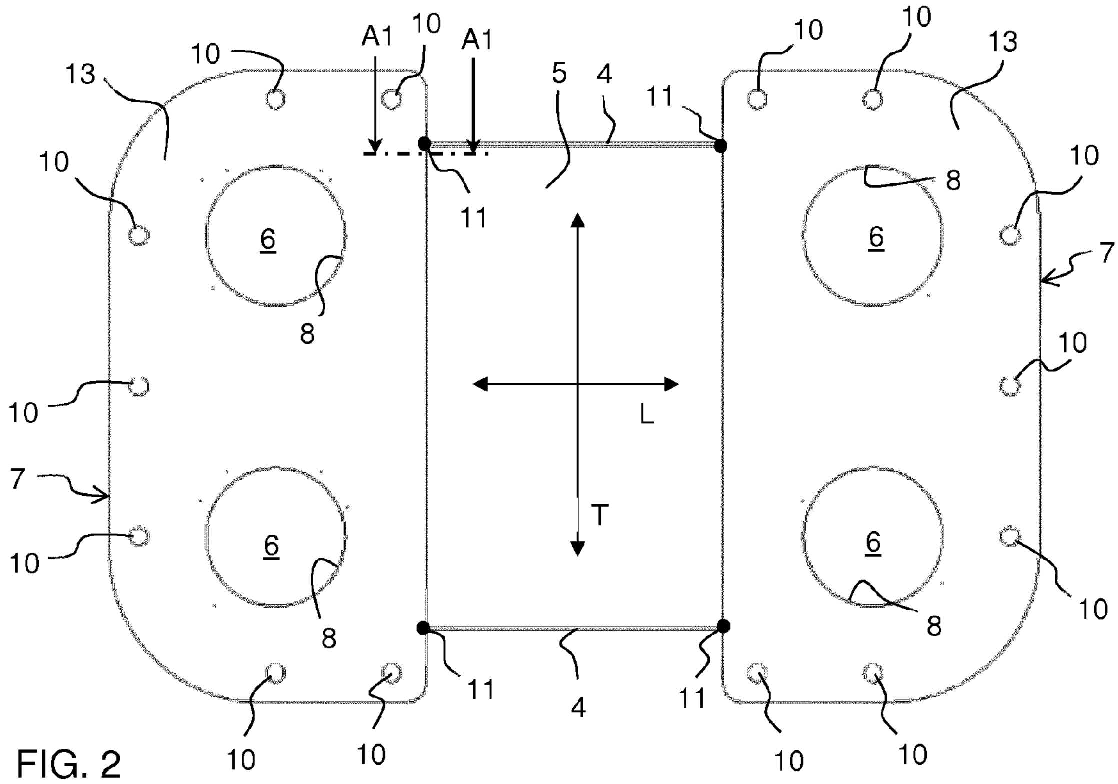
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FIG. 2

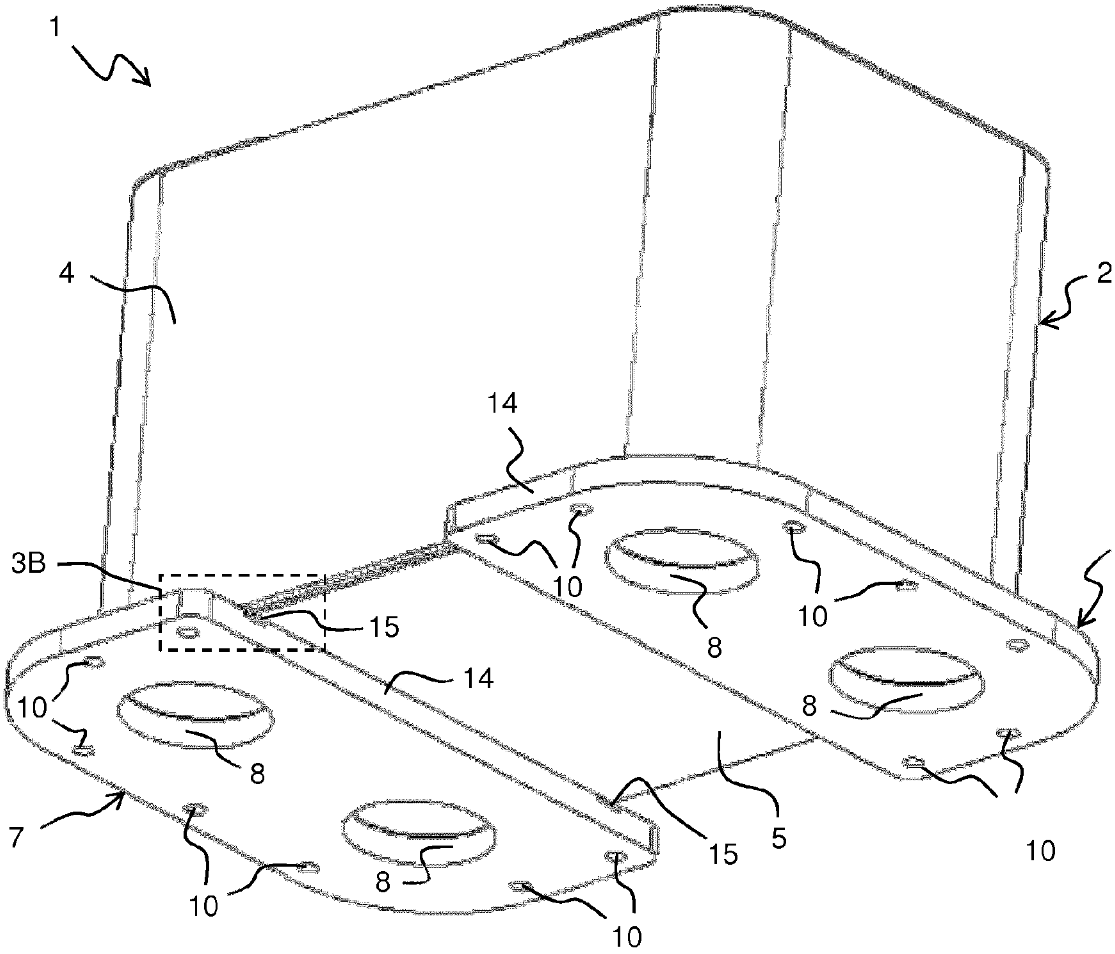


FIG. 3A

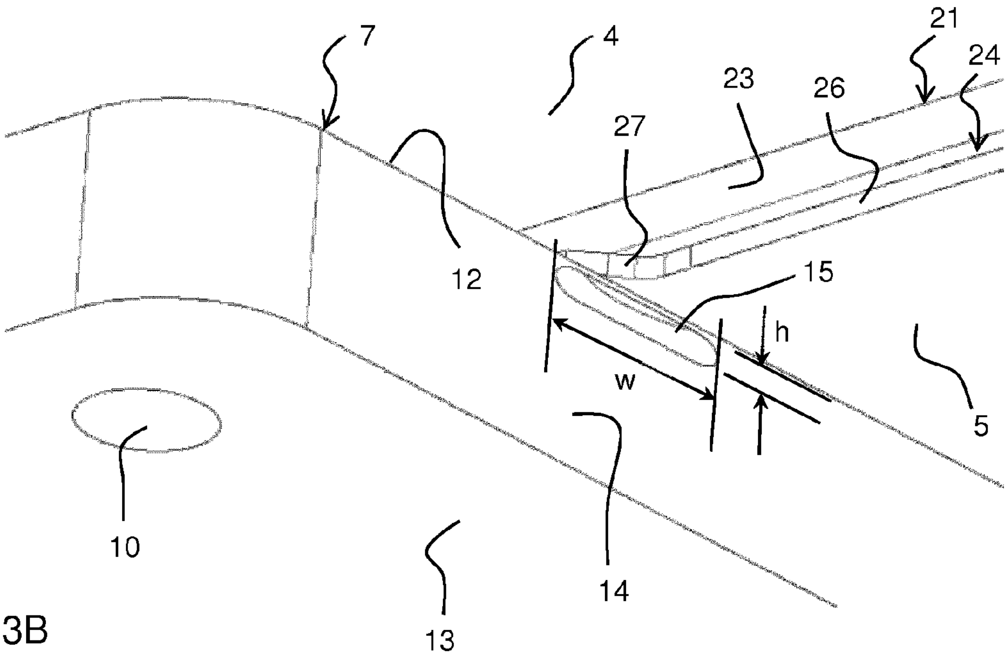


FIG. 3B

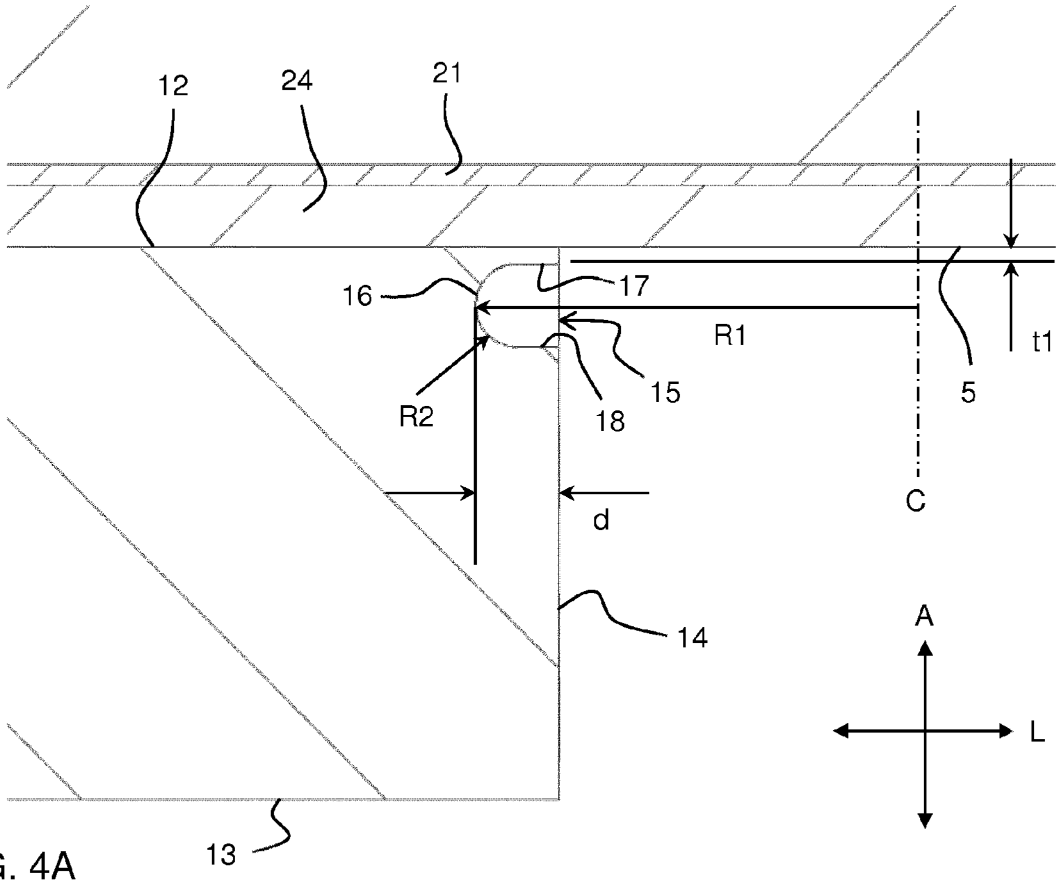


FIG. 4A

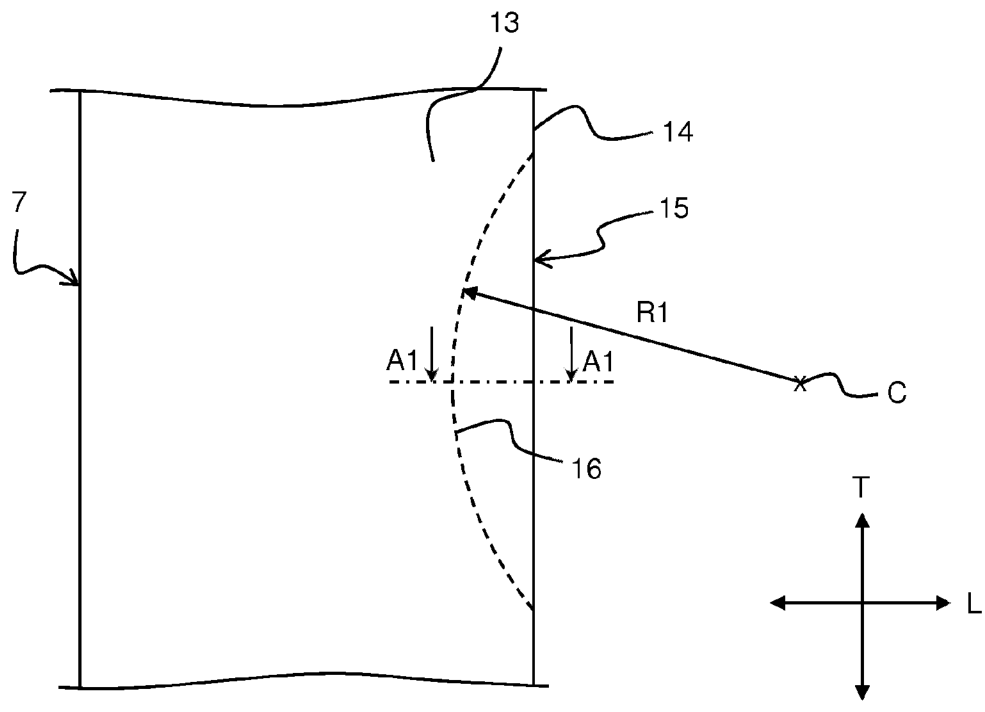
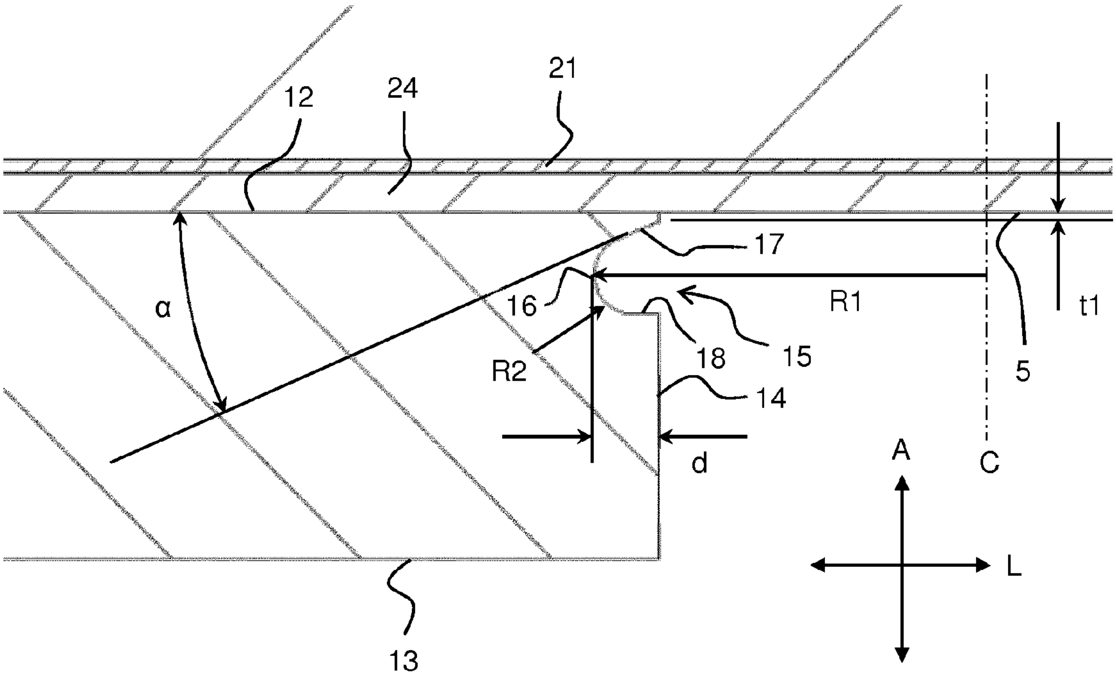


FIG. 4B



21
12
24
17
16
R1
α
R2
18
15
5
t1
14
d
A
C
L
13

FIG. 4C

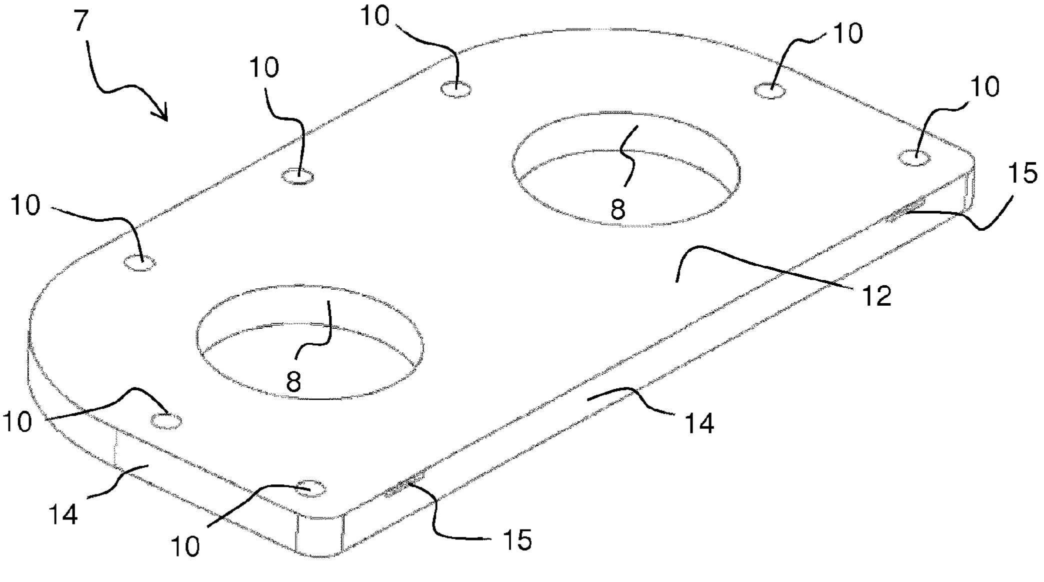


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FIG. 5A

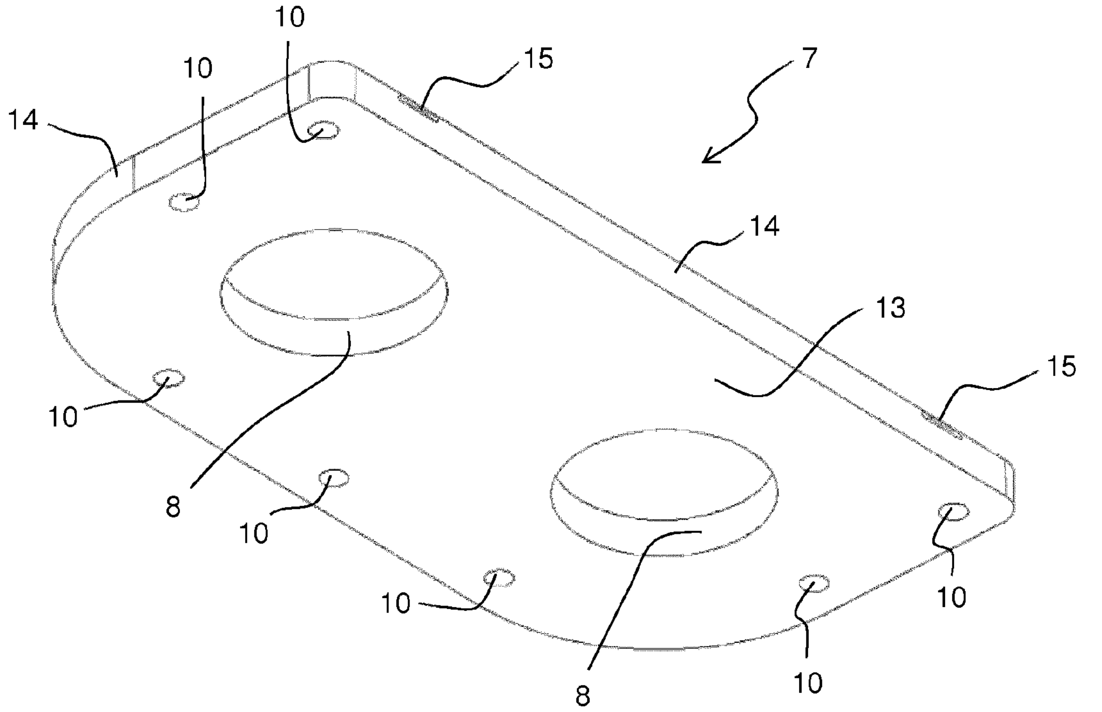
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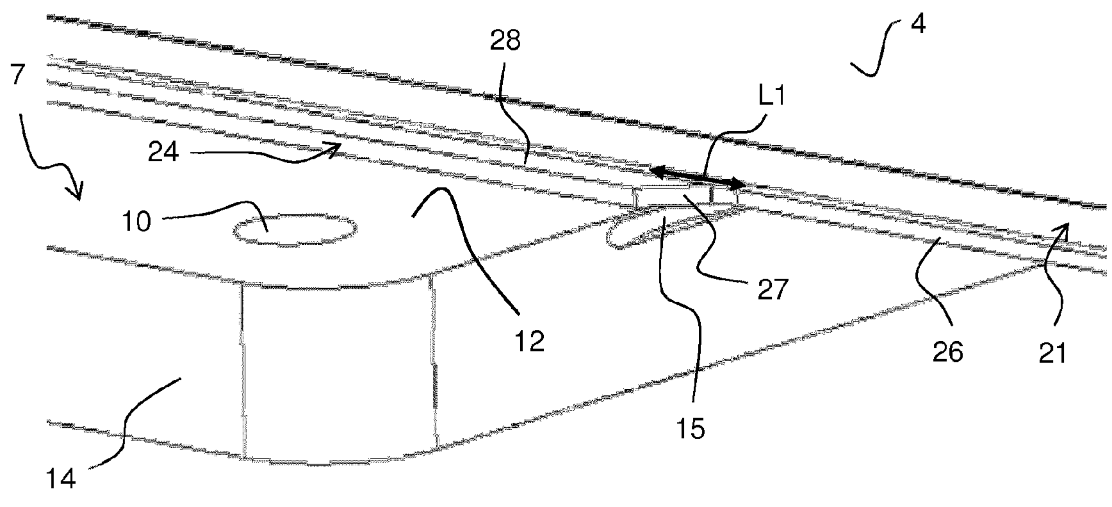
FIG. 5B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L1
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21
15
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FIG. 6A

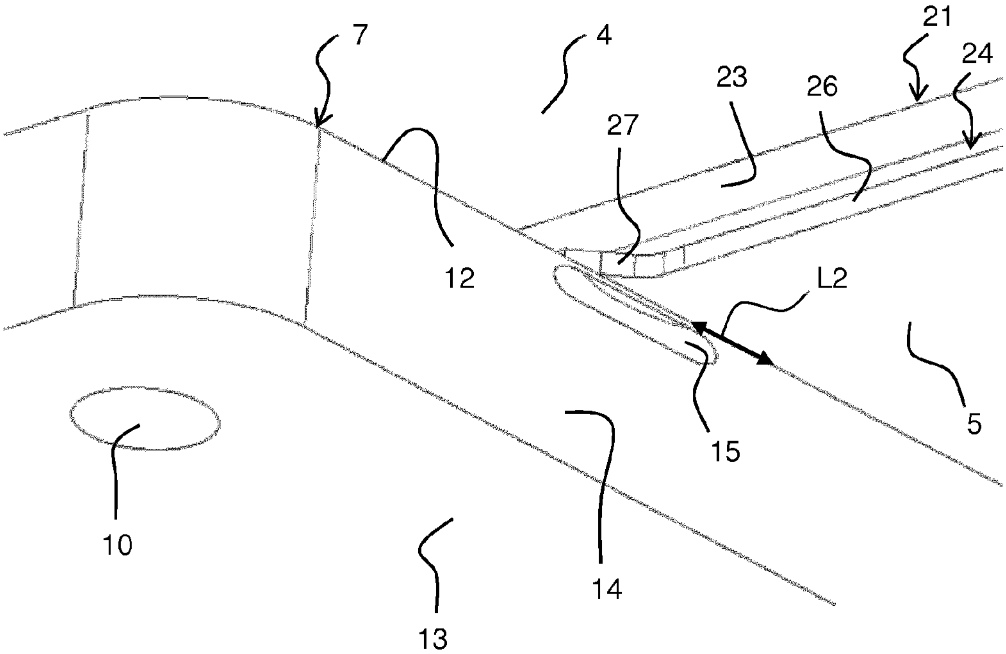

FIG. 6B

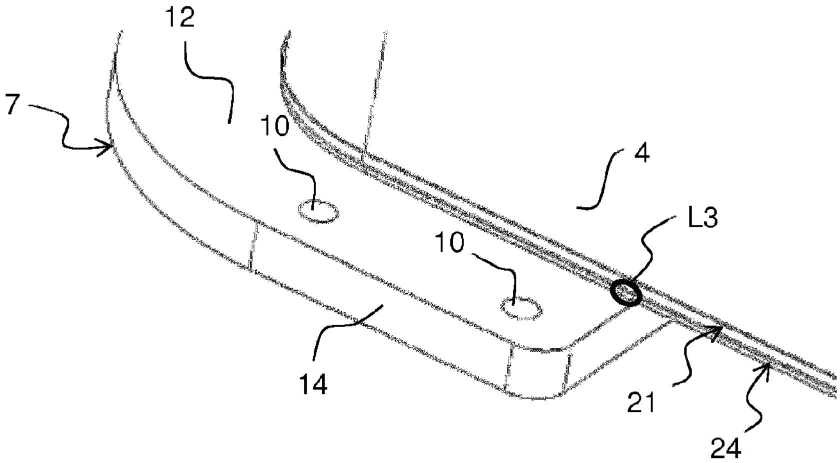

FIG. 6C

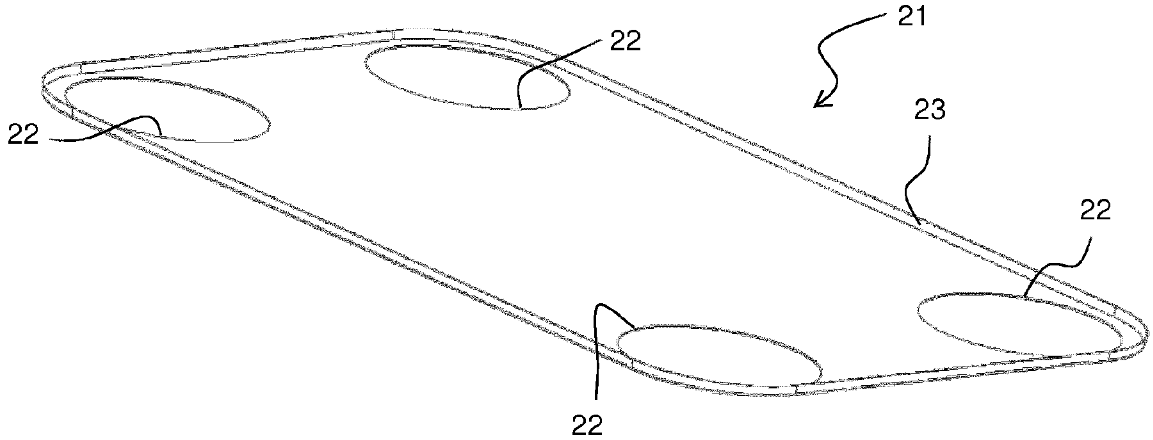

FIG. 7

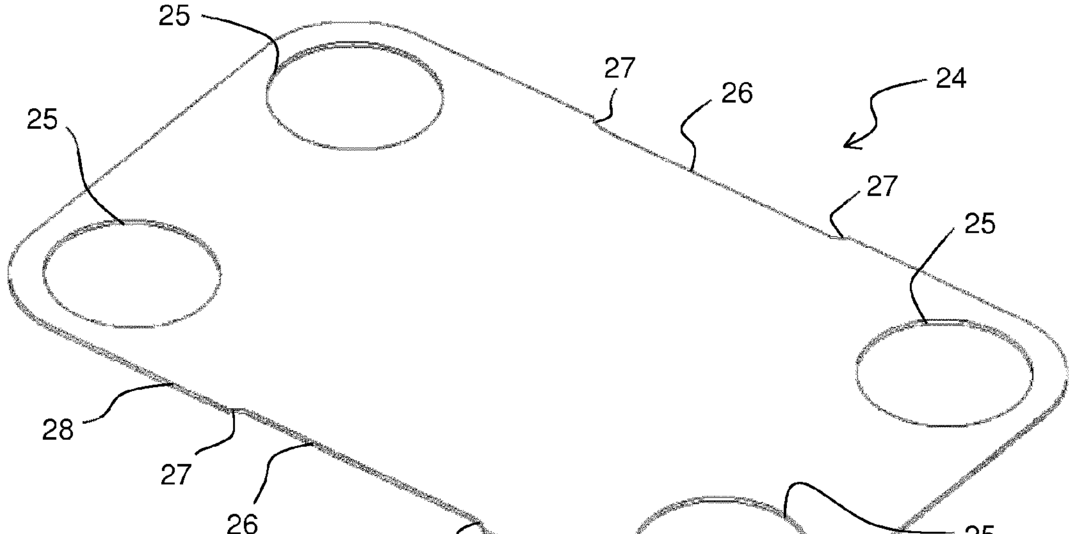

FIG. 8

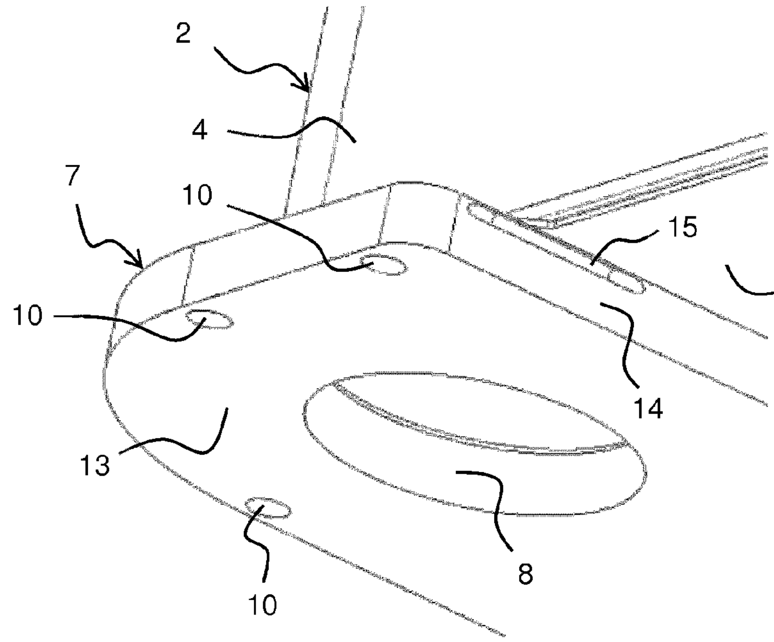

FIG. 9A

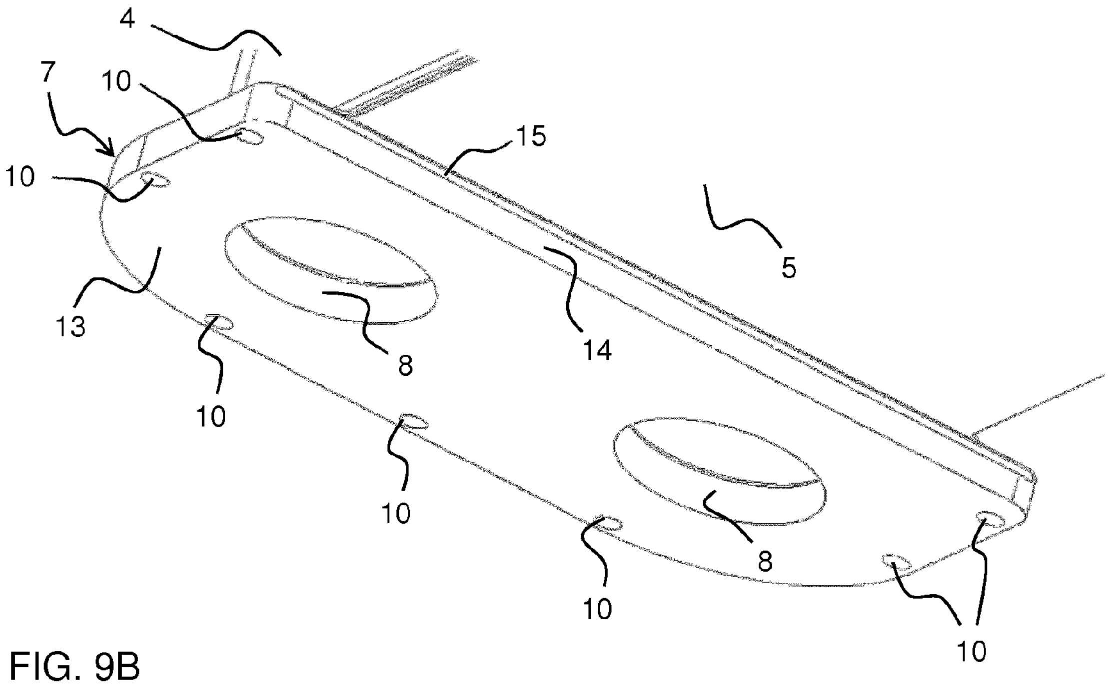

FIG. 9B

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EUROPEAN SEARCH REPORT

Application Number
EP 13 19 8881

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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Y	WO 2011/009412 A1 (CATERPILLAR INC [US]; LIU GENGXIN [CN]; LI GUOCHAO [CN]; XU KESHENG [C) 27 January 2011 (2011-01-27) * paragraph [0021] - paragraph [0023]; figures 1-3 * -----	1-3,5, 13-15, 17-19	
A	US 2006/115393 A1 (REINKE MICHAEL J [US] ET AL) 1 June 2006 (2006-06-01) * paragraph [0047]; figure 1 * -----	1	

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F28D
F28F

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	22 May 2014	Mootz, Frank

CATEGORY OF CITED DOCUMENTS

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22-05-2014

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