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(72) Inventors:
• **HERMIDA DOMÍNGUEZ, Xoan Xosé**
E-36380 Gondomar-Pontevedra (ES)
• **NOVO, Javier**
E-36209 Vigo (ES)
• **LORENZO GONZÁLEZ, Manuel**
E-36413 Porriño (ES)
• **VARGAS, Alejandro**
E-36210 Vigo (ES)

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(71) Applicant: **BORGWARNER EMISSIONS SYSTEMS SPAIN, S.L.U.**
36315 Vigo Pontevedra (ES)

(74) Representative: **ABG Patentes, S.L.**
Avenida de Burgos, 16D
Edificio Euromor
28036 Madrid (ES)

(54) **HEAT EXCHANGE DEVICE**

(57) The present invention relates to a heat exchange device suitable for cooling recirculated exhaust gases in an EGR (Exhaust Gas Recirculation) system. The invention is characterized by a configuration that allows incorporating the heat exchanger in very small spaces and with the recirculated exhaust gas inlets and outlets not necessarily being aligned. It is also characterized by an inner configuration based on the stack of flat tubes configured by means of die-cut and stamped sheets configuring a complex path of the fluid to be cooled. According to embodiments, the invention is incorporated in a cavity of the engine block of an internal combustion engine with fluid communication with the liquid coolant. The present invention has an impact on protecting the environment.

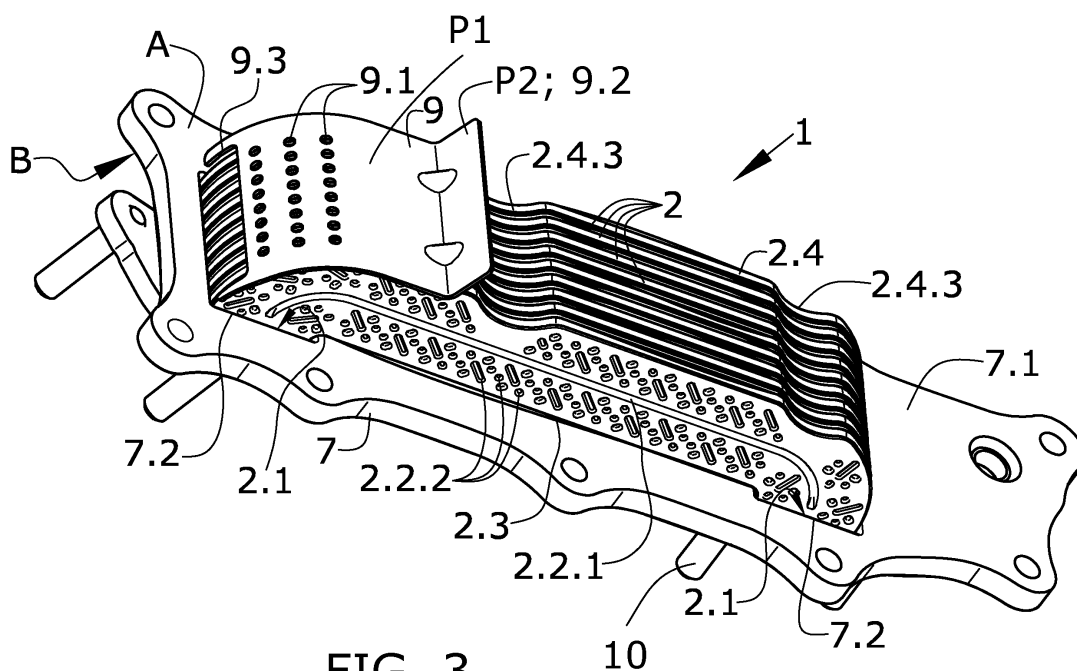
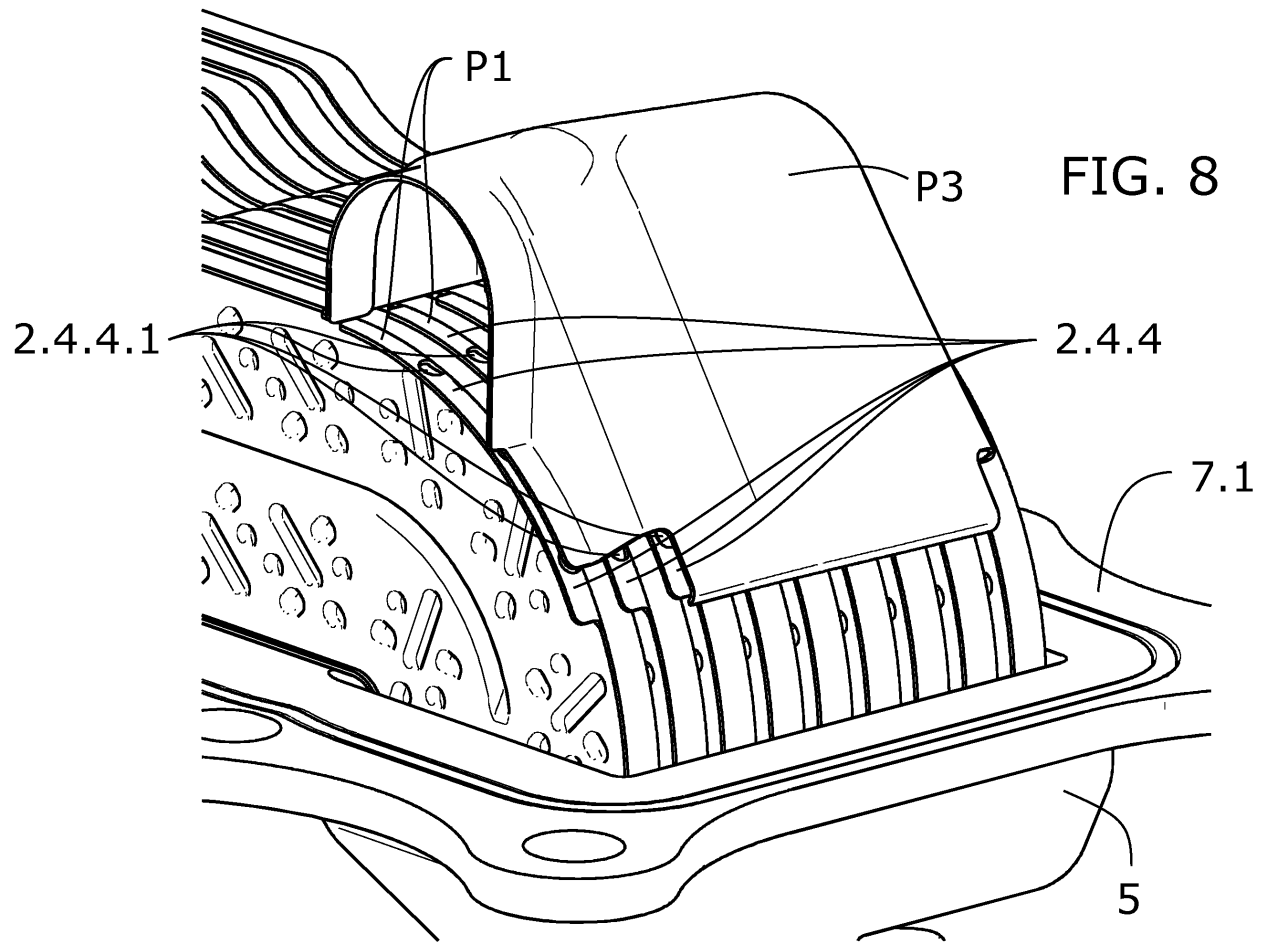


FIG. 3



Description

Object of the Invention

[0001] The present invention relates to a heat exchange device suitable for cooling recirculated exhaust gases in an EGR (Exhaust Gas Recirculation) system.

[0002] The invention is characterized by a configuration that allows incorporating the heat exchanger in very small spaces and with the recirculated exhaust gas inlets and outlets not necessarily being aligned.

[0003] It is also characterized by an inner configuration based on the stack of flat tubes configured by means of die-cut and stamped sheets configuring a complex path of the fluid to be cooled.

[0004] According to embodiments, the invention is incorporated in a cavity of the engine block of an internal combustion engine with fluid communication with the liquid coolant.

[0005] The present invention has an impact on protecting the environment.

Background of the Invention

[0006] One of the technical fields experiencing the most intensive development is that of systems for reducing contaminating emissions in internal combustion engines.

[0007] In particular, EGR systems recirculate exhaust gas by reintroducing a portion of said gas into the intake to reduce the amount of oxygen entering the combustion chambers, and as a consequence reduce nitrogen oxide emission.

[0008] The recirculated gas must be pretreated to prevent it from having dirt particles and to prevent its temperature from being high. These recirculated gas treatments allow preventing the combustion chambers from getting dirty and the intake air temperature from increasing, which gives rise to a reduced filling of the cylinders and therefore a drastic reduction in engine power.

[0009] The devices needed for obtaining this recirculated gas treatment take up space and require conduits conveying the gas from the acquisition point in the exhaust line to the intake, going through each of the components that the EGR system requires.

[0010] One of the greatest drawbacks of incorporating additional components in an internal combustion engine is the little space available in the engine compartment. The packaging required by the addition of components conditions the shape of the devices and their position.

[0011] When two different devices are located in empty areas of the engine compartment of complex configuration, devices such as heat exchangers usually have a gas inlet and gas outlet connected by means of conduits where, in a given device, such inlets and outlets are either aligned or else are parallel to one another.

[0012] In the first case, the gas inlet and gas outlet are aligned due to the straight configuration of the internal

tube bundle. In the second case, the inlet and outlet are on the same side of the device and tubes that are bent until forming a U shape are used, such that the inlet and outlet are parallel to one another.

[0013] When the configuration of the engine compartment does not allow an aligned or parallel gas inlet and gas outlet, then the heat exchange tube bundle extends between an intake manifold and an exhaust manifold of complex configuration, and these manifolds are the ones that modify the gas path in order to be adapted to the orientation imposed by the outer conduits conveying the gas throughout the EGR system.

[0014] In these cases, these complex shapes do not always direct the flow in a sufficiently guided way for all flow regimes, give rise to important pressure drops as well as losses in surface area for heat exchange with the manifolds, and complicate both design and manufacturing.

[0015] In the present invention the adaptation of the gas flow path from the orientation imposed on the inlet to the orientation imposed on the outlet takes place inside the heat exchange tubes by incorporating tubes that are configured according to a directrix connecting the inlet with the outlet, progressively modifying the orientation.

This change in orientation is possible by means of using heat exchange tubes configured by stamped sheets the walls of which can provide complex configurations.

[0016] Throughout this description, it will be said that two directions established on two different points of a given path have a different alignment if the vector defining both directions is different and if they are not on the same straight line. If the directions have a different angle, then it is said that they are misaligned. If the sign of the vector of one direction is opposite the sign of the vector of the other direction, then, by convention, it is also considered that the directions are misaligned. This is the case of an entry direction, for example an inflow direction, parallel to the exit direction but spaced from it. In this case, the orientation is the same but the direction is the opposite, one is for entry and the other for exit. In this case, by convention, it will also be considered that the directions are misaligned.

[0017] In the same manner, throughout this description it will be said that a path is curved if at least one segment of said path is curved.

Description of the Invention

[0018] The present invention is a heat exchanger for an EGR system adapted for heat exchange between a first fluid, the exhaust gas of an internal combustion engine, and a second fluid, a liquid coolant. This heat exchanger solves the problems identified above by providing a highly efficient compact device that can be easily manufactured and allows misaligned fluid entry and fluid exit directions without these very restrictive conditions necessarily involving further manufacturing complexity or a reduced performance.

[0019] According to the invention, the heat exchanger comprises:

- a heat exchange tube bundle formed by a stack of flat tubes of rectangular section arranged parallel to one another, extending between an inlet of the first fluid and an outlet of the first fluid, wherein the flat tubes of the tube bundle comprise an expansion at their ends in the direction of the stack of the tube bundle to establish a passage space between tubes for the second fluid;
- an inlet manifold in fluid communication with the inlet of the heat exchange tube bundle,
- an outlet manifold in fluid communication with the outlet of the heat exchange tube bundle,

and wherein

- at least one of the tubes of the tube bundle is configured by the attachment of two flat sheets with bent sides such that an inner face of the bent side of one sheet is attached to the outer face of the bent side of the other sheet; and,
- the directrix D-D' of the tubes of the tube bundle defines a curved path.

[0020] The heat exchange tube bundle is configured by means of flat tubes formed by flat sheets that are easy to manufacture by means of die cutting and bending. At least one of the tubes, preferably all the tubes, are formed by the attachment of two flat sheets with bent sides.

[0021] That is, each of the sheets has a main surface located between the bent sides. The preferred configuration of one sheet is to have the section transverse to the flat tube it configures to be U-shaped, wherein the sides have about the same length and emerge parallel from the main surface.

[0022] The main surface and the bent sides have an inner face and an outer face, the inner face identifying the face oriented towards the inside of the tube once it is formed, and the outer face identifying the opposite face.

[0023] In the preferred configuration, the two sheets are U-shaped. One side of one sheet together with one side of the other sheet give rise to the side of the flat tube such that an inner face of the bent side of one sheet is attached to the outer face of the bent side of the other sheet. On the other side, the attachment is configured in the same manner, wherein the sheet using its inner face can be the same one or the other one.

[0024] The plurality of flat tubes shows the end expansion in the direction of the stack such that in said stack this expansion imposes a separation between the flat tubes to allow the passage of the second fluid, the liquid coolant, between consecutive flat tubes.

[0025] According to the preferred embodiments, the expansions of adjacent tubes are welded to one another, preventing the exit of the second fluid. It is therefore not necessary to use baffles at the ends of the tube bundle.

[0026] Both the inlet and the outlet of the tube bundle are in fluid communication with a manifold, an intake manifold at the inlet of the tube bundle and an exhaust manifold at the outlet of the tube bundle. According to the embodiments described below, the inlet of the tube bundle and the outlet of the tube bundle formed by the stack of the expansions of the flat heat exchange tubes are limited by a plane transverse to the path defining the direction of the flow circulating throughout the tube bundle.

[0027] The flow path throughout the tube bundle is defined by the directrix D-D' of said tubes, said directrix being the path defined by the set of midpoints between the sides of the tubes. In the embodiments described below, the directrix D-D' is equidistant between the sides of the tubes. One side can have a projection or a recess on a given main surface. In this case, the directrix is determined on the main surface, as if there were no projection or recess.

[0028] According to the invention, the path of the directrix D-D' is curved, thereby comprising at least one curved segment.

[0029] In a preferred embodiment, the entry direction and the exit direction of the first fluid are misaligned. The entry direction is evaluated at the point of intersection between the path of the directrix D-D' and the plane transverse to said path located at the inlet. The exit direction is evaluated at the point of intersection between the path of the directrix D-D' and the plane transverse to said path located at the outlet.

[0030] Additionally, the entry direction and exit direction can form a given angle with one another.

[0031] According to the described embodiments, the entry and exit directions are misaligned. In particular, in both cases the transverse entry and exit planes are parallel, as the entry and exit directions are. Nevertheless, the invention can be carried out with an S-shaped path of the directrix D-D' or other more complex shapes which give rise to misaligned or even aligned entry and exit directions of the first fluid but having a directrix D-D' connecting the inlet and the outlet with a curved path.

Description of the Drawings

[0032] These and other features and advantages of the invention will be more clearly understood from the following detailed description of a preferred embodiment, given solely by way of illustrative and non-limiting example in reference to the attached drawings.

Figure 1 shows a perspective view of a single tube of the tube bundle according to an embodiment configured by means of die-cut and stamped plates.

Figure 2 shows a section view of the tube of the preceding figure, showing the attachment of the two sheets in detail.

Figure 3 shows a perspective view of a first embodiment of the invention. This embodiment is a heat

exchanger suitable for being inserted in a cavity of the engine block through which liquid coolant circulates, preventing the need to use shells.

Figure 4 shows a top view based on the same embodiment of the preceding figure. In this figure, two embodiments are depicted with one superimposed on the other, one embodiment being depicted with the exit of the liquid coolant through a duct of the cavity housing the tube bundle and the other embodiment being depicted with the liquid coolant exiting through a tube after going through the structural plate.

Figure 5 shows a lateral view of the same embodiment.

Figure 6 shows a section view of the end of the tube bundle of the same embodiment showing the attachment between the tube bundle and the plate.

Figure 7 shows a perspective view of a second embodiment of the invention. This embodiment is a heat exchanger similar to the first embodiment wherein the deflector for the inlet of the fluid coolant is formed by projections of the plates of the tubes.

Figure 8 shows an enlargement of a portion of the heat exchanger shown in figure 7 allowing to show the details of the deflector and a manifold guiding the coolant towards the deflector.

Figure 9 shows a perspective view of a third embodiment of the invention. This embodiment is a heat exchanger also incorporating the shell through which the fluid coolant circulates and where the shell is also obtained by the attachment of die-cut and stamped parts.

Figure 10 shows a top view of a longitudinal section of the preceding embodiment wherein the main exchange surface of a flat tube and the inside of the shell are shown.

Figure 11 shows a perspective view of the same embodiment, in which now there is visual access to the inside of the heat exchanger as one of the die-cut and stamped parts forming the shell has been removed.

Detailed Description of the Invention

[0033] According to the first inventive aspect, the present invention relates to a device for heat exchange between a first fluid, the exhaust gas of an internal combustion engine, and a second fluid, a liquid coolant. Both the expression "first fluid" and the expression "exhaust gas", or both the expression "second fluid" and the expression "liquid coolant" will be used interchangeably throughout the description.

[0034] This heat exchange device allows being housed in engine compartments where the exhaust gas inlet and outlet are not necessarily aligned. In the two most relevant embodiments described below, the outlet and inlet are parallel to and spaced from one another. According to the definition previously provided, the inlet and outlet

are not aligned.

[0035] Nevertheless, the invention can also be carried out with inlets and outlets having different orientations.

[0036] Figure 1 shows a perspective view of an embodiment of a flat tube (2) configured from the attachment of two flat sheets (2.2) attached to one another. Each of the flat sheets (2.2) has been formed by means of die cutting and stamping in order to give rise to a part with a main surface and two bent sides (2.3, 2.4). Figure 2 shows a section view of the same flat tube (2) configured from two flat sheets (2.2).

[0037] The directrix of the flat tube (2), indicated by means of the discontinuous line D-D', is curved. In this embodiment, said directrix D-D' of the flat tube (2.2) is straight mainly in the central segment according to the longitudinal direction identified as X-X' and graphically depicted by means of a discontinuous straight line. The directrix D-D' is curved at the ends of the flat tube (2), with an arc of curve of 90°, giving rise to an inlet and outlet parallel to and spaced from one another.

[0038] In this embodiment, the inlet and outlet openings of the tube are contained in a common plane for the inlet and for the outlet. These planes can be parallel and different, for example if the inlet or the outlet is prolonged.

[0039] The main surfaces of the flat sheets (2.2) show two sides, an inner side (2.3) of the tube and an outer side (2.4) of the tube. The term "inner" is linked to what corresponds to the side with the smaller radius of curvature, and is therefore located on the inner side of the arc-shaped side surface. The term "outer" is linked to what corresponds to the side with larger radius of curvature, and is therefore located on the side with the outer arc.

[0040] In turn, each sheet (2.2) of the tube has an inner face, i.e., the one that is oriented towards the inside of the tube once it is configured, and an outer face, i.e., the one that is oriented towards the outside of the tube once it is configured.

[0041] According to this nomenclature, and according to Figure 2, each flat sheet (2.2) of the tube has two bent sides (2.3, 2.4) forming a U shape according to the section. The inner face (2.3.1, 2.4.1) of the sides of one sheet is in contact with and attached by welding to the outer face (2.3.2, 2.4.2) of the sides of the other sheet. Although in this embodiment it has been established that the inner faces (2.3.1, 2.4.1) correspond to the sides (2.3, 2.4) of one and the same flat sheet (2.2), is possible in each side (2.3, 2.4) of the tube for it to be a different sheet the inner face (2.3.1, 2.4.1) of which is facing the outer face (2.3.2, 2.4.2) of the other flat sheet (2.2). This alternative allows, for example, the flat sheets (2.2), before welding, not being fitted to one another and making assembly easier. In addition, the first option depicted in Figure 2 allows, for example, a tight fitting that keeps the parts temporarily secured to make welding by brazing easier.

[0042] In this same section, it is observed that the main surface of each sheet (2.2) shows a set of recesses (2.2.2) increasing the turbulence of the first fluid passing through the tube (2), and therefore increasing the rate of

heat transfer. Furthermore, there are recesses (2.2.1) having larger dimensions in the central area, with a configuration coinciding with the directrix D-D', separating the section of the tube in two, forming two channels. A larger number of recesses with this configuration essentially parallel to the directrix D-D' allows dividing the tube into a larger number of channels. The channels allow better guiding, in addition to the guiding caused by side walls of the tube (2), of the first fluid inside the flat tube (2) in order to get the flow to follow the imposed path other than the straight line. Additionally, said channels provide the tube (2) with stiffness such that said tube (2) can withstand the pressure of the exhaust gas and of the fluid coolant, particularly when said tube (2) is welded along the recesses (2.2.1) forming the channels.

[0043] Going back to Figure 1, the ends of the flat tubes (2) are expansions (2.5) in the direction in which said flat tubes (2) are stacked to give rise to the tube bundle (1).

[0044] This expansion (2.5) increases the smaller dimension of the section of the flat tube (2) at the inlet (3) of the first fluid and at the outlet (4) of the first fluid. In the stack, the flat tubes (2) are in contact in these expansions (2.5). In the embodiments, the flat tubes (2) of the tube bundle (1) are welded through contacting surfaces of the expansions (2.5) forming a single inlet (4) with access to each of the flat tubes (2) of the tube bundle (1).

[0045] Since the rest of the flat tube (2) is not expanded, this configuration provides a separation between flat tubes (2) that allows the passage of the second fluid. The second fluid therefore has access to the main surface of the flat tubes (2) of the tube bundle (1) to establish heat exchange, the gas circulating inside the flat tube (2) transferring heat through the main surface of said tube (2) to the fluid coolant.

[0046] Figure 3 shows a perspective view of a first embodiment of a heat exchanger intended for being housed in a cavity, not shown, of an engine block through which the liquid coolant circulates.

[0047] The liquid coolant of the engine block thereby also serves to remove heat from the exhaust gas which is subsequently reintroduced into the intake according to the EGR system.

[0048] The tube bundle (1) is formed from the attachment of a plurality of flat tubes (2) like the one shown in Figure 1.

[0049] The heat exchanger comprises a structural plate (7) that is configured to cover the cavity of the engine block through which the second fluid circulates. This plate is called a structural plate because it possesses strength and stiffness such that it is able to absorb the stresses imposed by the inertial effects as well as the stresses due to thermal expansion of the elements installed on said plate. Additionally, the stiffness of the plate (7) allows improving the seal in the attachment with the engine block, as well as withstanding pressure pulses of the fluid coolant.

[0050] The structural plate (7) has an inner face (A), i.e., the one oriented towards the inside of the cavity in

the operative position, and an outer face (B), i.e., the one oriented towards the outside of the cavity in the same operative position.

[0051] The structural plate (7) has perforations for the passage of clamping bolts. The inner face (A) has a seating surface (7.1) resting in an outer area of the engine block, in a perimetral region of the cavity, the region established as a seat for the heat exchanger, to establish the leak-tight closure preventing liquid coolant leaks.

[0052] The structural plate (7) comprises two perforations (7.2) configured for the passage of both ends of the tube bundle (1), such that the tube bundle (1) is on the side of the inner face (A) and the inlet manifold (5) and outlet manifold (6) of the first fluid are on the side of the outer face (B).

[0053] On the outer face (B), the inlet manifold (5) and the outlet manifold (6) have a perimetral fin (5.1, 6.1) serving as a seat on the outer face (B) of the structural plate (7). The inlet manifold (5) and outlet manifold (6) are prolonged from the perimetral fin (5.1, 6.1) according to a segment (5.2, 6.2) that accepts the end of the tube bundle (1).

[0054] The attachment of the end of the tube bundle (1) is established either with the inner wall of the perforation (7.2) of the structural plate (7), or else with the segment (5.2, 6.2) accepting the end of the tube bundle (1), or else in both.

[0055] According to another embodiment not graphically shown, the inlet manifold (5), the outlet manifold (6), or both pass through the inside of the perforation (7.2) of the structural plate (7), between the inner wall of the perforation (7.2) and the tube bundle (1), until projecting through the inner face (A) of the structural plate (7), such that the perimetral fin (5.1, 6.1) is supported on said inner face (A).

[0056] In another embodiment, the inlet manifold (5), the outlet manifold (6), or both pass through the inside of the perforation (7.2) of the structural plate (7) such that they are flush with same, there not being any element projecting out from the inner face (A).

[0057] According to another embodiment, not shown in the drawings, one or both ends of the tube bundle (1) goes through the structural plate (7), projecting through the outer face (B) thereof. The manifold (5, 6) corresponding with this end is attached to the projecting end of the tube bundle (1) using a flange to secure the fixing between said manifold (5, 6) and the end of the tube bundle (1).

[0058] As shown in Figure 4, although the entry and exit of the first fluid into/out of the tube bundle (1) is in accordance with a directrix D-D' parallel at said points, the inlet manifold (5) has an inlet at an angle with respect to the outlet of the outlet manifold (6).

[0059] In said Figure 4, two embodiments superimposed on one another are depicted. A section of the cavity (C) is depicted using a discontinuous line, as well as a liquid coolant inlet and a liquid coolant outlet. This representation using a discontinuous line shows the liquid

coolant inlet on the hot gas inlet side according to a co-current flow layout. The liquid coolant exit according to one embodiment is produced in the outlet duct of the cavity shown using a discontinuous line, and according to another embodiment, the liquid coolant goes through the structural plate (7) and exits through the tube (10) shown using a solid line and located on the side opposite the inlet.

[0060] The liquid coolant has a path of lower resistance through the space located between the tube bundle (1) and the inner wall of the cavity (C), preventing the liquid coolant from being introduced in the space between tubes (2). That is particularly critical in the hot gas inlet area where cooling must be more efficient, and where said cooling must be optimal such that, since it is the hottest area, the performance of the tubes (2) under fatigue improves.

[0061] For the purpose of cooling said critical area more efficiently, in this embodiment it has been provided with a deflector plate (9) with a special configuration.

[0062] The deflector plate (9) has a deflecting surface comprising a first portion (P1) limiting or preventing the passage of the second fluid to the space or channels located between the tubes (2) of the bundle of tubes (1). Said first portion (P1) of the deflector plate is positioned in correspondence with the inlet of the second fluid.

[0063] In this embodiment the deflector plate (9) is located nearby or in contact with the outer arc-shaped segment of the tube bundle (1). The deflecting surface also comprises a second portion (P2) having the form of a fin (9.2) separated from the tube bundle (1) in order to be abutted against the inner wall of the cavity (C). This second portion (P2) of the deflecting surface limits or prevents the passage of the second fluid throughout the space in-between the bundle of tubes (1) and the wall of the cavity housing said bundle of tubes (1). In this embodiment, the second portion (P2) is located between the inlet and the outlet of the second fluid according to the directrix D-D' of the tubes (2).

[0064] According to another embodiment, the deflector plate (9) is separated from the end of the bundle of tubes (1) allowing the passage of the second fluid to a portion of the outer side (2.4) of the tubes (2) of the bundle of tubes (1).

[0065] In turn, the deflector plate (9) has a window (9.3) close to the end of the tube bundle (1), the one closest to the hot exhaust gas inlet and where the cooling requirements are stricter. The second portion (P2) shown in the form of a fin (9.2) prevents the passage of liquid coolant through the space established between the tube bundle (1) and the inner wall of the cavity (C), forcing the passage through the window (9.3) and also through perforations (9.1) of the deflector plate (9).

[0066] In this embodiment, the deflector plate (9) is welded to the outer side (2.4).

[0067] The passage of the liquid coolant through the window (9.3) introduces the flow between the tubes of the tube bundle (1), increasing the rate of heat exchange

between tubes and liquid coolant.

[0068] The perforations (9.1) also introduce jets of liquid coolant between the tubes as shown in Figure 5, wherein the lateral view allows observing the coincidence between the perforations (9.1) and the spaces between the tubes (2) of the tube bundle (1). Not only do these jets of liquid coolant increase the rate of heat transfer, but they also prevent the formation of stagnation regions in areas inside the tube bundle located adjacent to the deflector plate (9).

[0069] The incorporation of a deflector plate (9) like the one described is also possible in other configurations of the exchanger where, instead of being housed in a cavity (C), it has a shell to allow circulation of the liquid coolant, for example the shell described further below in the third embodiment.

[0070] In this embodiment, recesses (2.4.3) on the outer sides (2.4) of the tubes (2) of the tube bundle (1) allowing insertion into cavities with projections in their inner wall have also been used. These recesses can also be incorporated to throttle one of the channels of the tube (2) in order to favor the passage through other different channels, compensating for the resistance shown by both channels.

[0071] In this same embodiment, the inner side (2.3) of the tubes (2) of the tube bundle (1) is in contact with the inner face (A) of the structural plate (7) and both contacting surfaces are welded by means of brazing. The occurrence of vibrations that may damage the tubes (2) is thereby prevented.

[0072] Figure 6 shows a section of the tubes (2) of the tube bundle housed in the perforation (7.2) of the structural plate (7) as well as the assembly of the manifold (5, 6) supported on the outer face (B) of said structural plate (7). In this embodiment, the tube bundle (1) does not surpass the surface established by the outer face (B) of the structural plate (7) and the attachment between the tube bundle (1) and the structural plate (7) is established on the inner face of the perforation (7.2).

[0073] According to another embodiment, the heat exchanger comprises a bracket (not shown in the drawings) located clamping the tubes (2) of the tube bundle (1), attached to the structural plate (7), and is abutted or attached to the tubes (2) of the tube bundle (1). Any of these attachments can be welded attachments.

[0074] The flat tubes (2) have a smaller geometric moment of inertia according to an axis transverse to the flat tube (2) and contained in the plane of said flat tube (2). This condition makes the tube bundle (1) experience important displacements in the event of inertial loads in the direction perpendicular to the tube bundle (1), and also moments with an axis of rotation coinciding with the longitudinal axis of the tubes resulting in important stresses in the attachment of the ends of the tubes. The bracket prevents both this displacement and rotation by reducing fatigue due to vibrations if the tube bundle (1) is not welded to the structural plate (7).

[0075] Figure 7 shows a perspective view of a second

embodiment of the heat exchanger wherein all the components such as the structural plate (7), the bundle of tubes (1) and the manifolds (5, 6) correspond to those disclosed in figures 3 to 6. In this second embodiment the deflecting elements are different to deflecting elements disclosed in the first embodiment.

[0076] Figure 8 is an enlarged view of the end of the heat exchanger where the deflecting elements are located. In this embodiment the first portion (P1) of the deflecting surface comprises a set of prolongations (2.4.4) of one of the sides (2.4) of the plates (2.2) forming the tubes (2), in particular, prolongations (2.4.4) of the outer side (2.4). Said prolongations (2.4.4) are configured during the die cutting and bending process on the sheet of metal of one of the plates of the tube (2). The prolongations (2.4.4) extend towards the adjacent tube reducing or even closing the access to the space located between adjacent tubes (2) of the bundle of tubes (1).

[0077] In this second embodiment, these prolongations (2.4.4) are located at the curved outer side (2.4) of the tubes (2) and positioned in correspondence with the inlet of the second fluid.

[0078] The prolongations (2.4.4) show perforations (2.4.4.1) introducing jets of liquid coolant between the tubes (2) increasing the rate of heat transfer and preventing the formation of stagnation regions in areas inside the tube bundle located adjacent to the prolongations (2.4.4).

[0079] Additionally, in this second embodiment, a third deflecting surface (P3) is located in the cavity configured as a manifold adapted to guide the inlet flow of the second fluid from the inlet of the second fluid towards the first portion of the deflecting surface (P1).

[0080] Figure 9 shows a perspective view of a third embodiment wherein the heat exchanger has a shell (8). In this embodiment, the structural plate (7) is dispensed with given that the shell (8) acts like a structural element. The shell (8) is formed by two parts of die-cut and stamped sheet (8.1) although it is possible to use additional parts if the configuration is very complex so as to allow deformation imposed by stamping.

[0081] In this embodiment, a piece of sheet (8.1) is configured as a housing for the entire tube bundle (1) and another piece of sheet (8.1) is configured as a cover.

[0082] As shown in the section view of Figure 10, the ends of the tube bundle (1) are prolonged by means of the inlet manifold (5) and the outlet manifold (6), and the shell (8) surrounds this area of attachment by means of respective openings (8.2) establishing the leak-tightness of the liquid coolant.

[0083] In this embodiment, the configuration of the shell (8) is such that it is abutted to the tube bundle (1) on the inner side walls (2.3) and on the outer side walls (2.4), except in two expansions (8.5) of the shell (8). These expansions (8.5) are located in the area of the outer surface (2.4) of the tubes (2) of the tube bundle (1).

[0084] In this embodiment there is no space between the tube bundle (1) and the shell (8), so a deflector plate

(9) has not been incorporated, although it is possible to incorporate it according to any of the deflectors disclosed in the first and the second embodiments if the flow is to be introduced through given windows (9.3) or perforations (9.1).

[0085] The expansion (8.5) of the shell (8) corresponding to the liquid coolant inlet introduces the liquid coolant through spaces between tubes (2) through the arc-shaped segment of the outer side walls (2.4). The liquid coolant outlet is in a similar region at the opposite end, through spaces between tubes (1) flowing out through the arc-shaped segment of the outer side walls (2.4).

[0086] Each of the expansions (8.5) has a liquid coolant inlet (8.3) and liquid coolant outlet (8.4).

[0087] In this embodiment, the entry and the exit of the first fluid takes place through the inlet of the inlet manifold (5) and the outlet of the outlet manifold (6) configured by means of an attachment flange wherein both flanges are coplanar and the entry and exit flows are parallel.

[0088] These same details can be observed in Figure 11, wherein the piece of sheet of the shell (8.1) configured as a cover has been removed to have visual access to the inside thereof.

[0089] In all the embodiments tubes with two channels, formed by a single recess (2.2.1) extending along the directrix D-D' of the tube (2), have been used; nevertheless, it is possible to use more than one channel parallel to said directrix D-D'.

[0090] Likewise, it is possible to use patterns of recesses (2.2.2) to cause turbulence inside the tubes (2) of the tube bundle (1) other than those shown in the embodiments without changing the essence of the invention.

In a preferred illustrative embodiment identified as "embodiment 1", it is presented a heat exchanger for an EGR system adapted for heat exchange between a first fluid, the exhaust gas of an internal combustion engine, and a second fluid, a liquid coolant. Further embodiments identified as "embodiment 2", "embodiment 3" and so on will be disclosed. The heat exchanger of embodiment 1 comprises:

- a heat exchange tube bundle (1) formed by a stack of flat tubes (2) of rectangular section arranged parallel to one another, extending between an inlet (3) of the first fluid and an outlet (4) of the first fluid, where the flat tubes (2) of the tube bundle (1) comprise an expansion at their ends (2.1) in the direction of the stack of the tube bundle (1) to establish a passage space between tubes for the second fluid;
- an inlet manifold (5) in fluid communication with the inlet (3) of the heat exchange tube bundle (1),
- an outlet manifold (6) in fluid communication with the outlet (4) of the heat exchange tube bundle (1),

and wherein

- at least one of the tubes (2) of the tube bundle (1) is configured by the attachment of two flat sheets (2.2)

with bent sides (2.3, 2.4) such that an inner face (2.3.1, 2.4.1) of the bent side (2.3, 2.4) of one sheet (2.2) is attached to the outer face (2.3.2, 2.4.2) of the bent side (2.3, 2.4) of the other sheet (2.2); and,

- the directrix D-D' of the tubes (2) of the tube bundle (1) defines a curved path.

[0091] Embodiment 2 is a heat exchanger according to the embodiment 1, wherein the path of the directrix D-D':

- either comprises a mainly longitudinal segment X-X',
- or else it is an S-shaped path.

[0092] Embodiment 3 is a heat exchanger according to the embodiment 2, wherein one or both ends (2.1) of the tubes (2) show the sides (2.3, 2.4) as curved-shaped arcs, one having a greater radius than the other, the path of the directrix D-D' comprising a mainly longitudinal segment X-X', and additionally comprising a curved segment at the inlet and at the outlet of the end (2.1) of the tube.

[0093] Embodiment 4 is a heat exchanger according to the embodiment 3, wherein the two ends (2.1) of said tubes (2) show the sides (2.3, 2.4) in a curve, the curve contained in the main plane of the flat tube (2), establishing a transition between the mainly longitudinal segment X-X' and the curved segment at the inlet and at the outlet of the path of the directrix D-D' at 90°, such that the entry direction and the exit direction of the first fluid are parallel.

[0094] Embodiment 5 is a heat exchanger according to the embodiment 3, wherein

- the ends (2.1) of the tubes (2) of the tube bundle (1) at the inlet (3) and the ends (2.1) of the tubes (2) of the tube bundle (1) at the outlet (4) have coplanar cross sections;
- said exchanger comprises a structural plate (7) which:

o is configured to cover a cavity in an engine block through which the second fluid circulates, and such that it has an inner face (A) and an outer face (B), the inner face (A) configured for being oriented towards the cavity, and wherein said plate (7) comprises on its inner face (A) a seat (7.1) configured for resting on the peripheral seat of the cavity of the engine block;

o comprises two perforations (7.2) configured for the passage of both ends of the tube bundle (1) such that the tube bundle (1) is on the side of the inner face (A) and the inlet manifold (5) and outlet manifold (6) of the first fluid are on the side of the outer face (B).

[0095] Embodiment 6 is a heat exchanger according to the embodiment 5, wherein one side of the tubes (2) of the tube bundle (1) is welded to the structural plate (7).

[0096] Embodiment 7 is a heat exchanger according

to the embodiment 3, wherein

- the tube bundle (1) is housed in a shell (8) surrounding said tube bundle (1);
- the shell (8) is made up of at least two die-cut and bent sheets (8.1) attached to one another such that they configure two openings (8.2), each of the openings (8.2) surrounding the perimeter of the ends (2.1) of the expanded tubes (2) of the tube bundle (1);
- the shell (8) comprises an inlet (8.3) and an outlet (8.4) of the second fluid located in an expansion (8.5) of said shell (8), this expansion (8.5) of each inlet/outlet (8.3, 8.4) located on the outer face (2.3.2, 2.4.2) of the side (2.3, 2.4) as a curve-shaped arc having a larger radius of the ends (2.1) in a curve of the tubes (2) of the tube bundle (1).

[0097] Embodiment 8 is a heat exchanger according to any of the preceding embodiments, particularly the embodiment 3, wherein at least one sheet (2.2) of one of the tubes (2) of the tube bundle (1) comprises one or more recesses (2.2.1) reaching the opposite sheet (2.2), with attachment by welding between both sheets (2.2), forming channels inside the flat tube (2), according to the directrix D-D'.

[0098] Embodiment 9 is a heat exchanger according to any of the preceding embodiments, particularly the embodiment 3, wherein

- the inlet of the second fluid is located in the vicinity of the sides (2.4) as a curve-shaped arc having a larger radius of the ends (2.1) of the tubes (2) of the tube bundle (1) corresponding to the inlet (3) of the first fluid; and,
- where said heat exchanger comprises a deflector plate (9) which:

o is configured as a curve-shaped arc, abutted to the sides (2.4) as a curve-shaped arc of the ends (2.1) of the tubes (2) of the tube bundle (1), o is spaced from the ends of the tube bundle (1) to allow the passage of the second fluid to a portion of the sides (2.4) as a curve-shaped arc of the ends (2.1) of the tubes (2) of the tube bundle (1).

[0099] Embodiment 10 is a heat exchanger according to the embodiment 9, wherein the deflector plate (9) comprises a window (9.3) located in the area adjacent to the end (2.1) of the tubes (2) of the tube bundle (1) corresponding to the inlet (3) of the first fluid, to allow the entry of the second fluid into the space between tubes (2) of the tube bundle (1).

[0100] Embodiment 11 is a heat exchanger according to the embodiment 9 or the embodiment 10, wherein the deflector plate (9) shows a plurality of perforations (9.1) in the segment as a curve-shaped arc to allow a smaller flow eliminating stagnation areas in the space between

tubes (2) of the tube bundle (1).

[0101] Embodiment 12 is a heat exchanger according to any of the embodiments ranging from embodiment 9 to embodiment 11, wherein the deflector plate (9) is prolonged into a fin (9.2) reaching the wall where the tube bundle (1) is housed to force the flow of the second fluid through the channels between tubes (2) of the tube bundle (1).

[0102] Embodiment 13 is a heat exchanger according to any of the preceding embodiments, wherein the tubes (2) of the tube bundle (1) comprise recesses (2.2.2) distributed along the length of the tube (2) to increase the rate of heat transfer between the first fluid and the wall of the tube (2).

[0103] Embodiment 14 is an EGR system comprising a heat exchanger according to any of the preceding embodiments.

[0104] Embodiment 15 is an internal combustion engine comprising an EGR system according to the embodiment 13.

Claims

1. A heat exchanger for an EGR system adapted for heat exchange between a first fluid, the exhaust gas of an internal combustion engine, and a second fluid, a liquid coolant, comprising:

- a heat exchange tube bundle (1) formed by a stack of flat tubes (2) of rectangular section arranged parallel to one another, extending between an inlet (3) of the first fluid and an outlet (4) of the first fluid, where the flat tubes (2) of the tube bundle (1) comprise an expansion at their ends (2.1) in the direction of the stack of the tube bundle (1) to establish a passage space between tubes for the second fluid;
- an inlet manifold (5) in fluid communication with the inlet (3) of the heat exchange tube bundle (1),
- an outlet manifold (6) in fluid communication with the outlet (4) of the heat exchange tube bundle (1),

and wherein

- at least one of the tubes (2) of the tube bundle (1) is configured by the attachment of two flat sheets (2.2) with bent sides (2.3, 2.4) such that an inner face (2.3.1, 2.4.1) of the bent side (2.3, 2.4) of one sheet (2.2) is attached to the outer face (2.3.2, 2.4.2) of the bent side (2.3, 2.4) of the other sheet (2.2); and,
- the directrix D-D' of the tubes (2) of the tube bundle (1) defines a curved path.

2. The exchanger according to claim 1, wherein the path of the directrix D-D':

- either comprises a mainly longitudinal segment X-X',
- or else it is an S-shaped path.

3. The exchanger according to claim 2, wherein one or both ends (2.1) of the tubes (2) show the sides (2.3, 2.4) as curved-shaped arcs, one having a greater radius than the other, the path of the directrix D-D' comprising a mainly longitudinal segment X-X', and additionally comprising a curved segment at the inlet and at the outlet of the end (2.1) of the tube.

4. The exchanger according to claim 3, wherein the two ends (2.1) of said tubes (2) show the sides (2.3, 2.4) in a curve, the curve contained in the main plane of the flat tube (2), establishing a transition between the mainly longitudinal segment X-X' and the curved segment at the inlet and at the outlet of the path of the directrix D-D' at 90°, such that the entry direction and the exit direction of the first fluid are parallel.

5. The exchanger according to any of claims 1 to 4, wherein it further comprises:

- a deflecting surface (9),
- the deflecting surface (9) comprises a first portion (P1) limiting or preventing the passage of the second fluid to the space located in-between the tubes (2) of the bundle of tubes (1), and
- the first portion (P1) is located in correspondence to the inlet of the second fluid.

6. The exchanger according to claim 5, wherein the deflecting surface (9) comprises a second portion (P2) being prolonged as a fin (9.2) intended to abut the wall of the cavity or to abut the housing of the heat exchanger limiting or preventing the passage of the second fluid throughout the passage located between the bundle of tubes (1) and the wall of the cavity or the wall of the housing where the bundle of tubes (1) is housed and wherein said second portion (P2) is located between the inlet and the outlet of the second fluid.

7. The exchanger according to claims 5 or 6, wherein the inlet of the second fluid is located in the proximities of the outer sides (2.4) configured as curved-shaped arcs at the end of the tubes (2) of the bundle of tubes (1).

8. The exchanger according to claims 5 to 7, wherein the first portion (P1) of the deflecting surface (9) is:

- either a plate (9) next to the bundle of tubes (1), or
- at least one prolongation (2.4.4) of the outer side (2.4) of the tubes (2) of the bundle of tubes (1) being the at least one prolongation (2.4.4)

prolonged towards the adjacent tube (2).

9. The exchanger according to claim 8, wherein the first portion (P1) of the deflecting surface (9) is a plate configured as a curve-shaped arc, abutted to the sides (2.4) as a curve-shaped arc of the ends (2.1) of the tubes (2) of the tube bundle (1) and wherein the deflecting surface (9) is spaced from the ends of the tube bundle (1) allowing the passage of the second fluid to a portion of the sides (2.4) of the tubes (2) of the tube bundle (1). 5
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10. The exchanger according to claim 8, wherein the deflecting surface (9) is at least one prolongation (2.4.4) of the outer side (2.4) of the tubes (2) prolonged towards the adjacent tube (2) and configured as a curve-shaped arc in correspondence to the curve-shaped arc of one of the ends of the tubes (2) of the bundle of tubes (1). 15
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11. The exchanger according to any of claims 7 to 10, wherein the deflecting surface (9) comprises a window (9.3) located in the area adjacent to the end (2.1) of the tubes (2) of the tube bundle (1) corresponding to the inlet (3) of the first fluid, allowing the entry of the second fluid into the space between tubes (2) of the tube bundle (1). 25

12. The exchanger according to any of claims 7 to 11, wherein the first portion (P1) of the deflecting surface (9) shows a plurality of perforations (9.1) allowing the entry of the second fluid into the space between tubes (2) of the tube bundle (1). 30

13. The exchanger according to any of claims 5 to 12 wherein the deflecting surface (9) comprises a third portion (P3) configured as a manifold adapted to guide the inlet flow of the second fluid from the inlet of said second fluid towards the first portion (P1) of the deflecting surface (9). 35
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14. The exchanger according to any of the preceding claims, wherein the tubes (2) of the tube bundle (1) comprise recesses (2.2.2) distributed along the length of the tube (2) to increase the rate of heat transfer between the first fluid and the wall of the tube (2). 45

15. An EGR system comprising a heat exchanger according to any of the preceding claims. 50

16. An internal combustion engine comprising an EGR system according to claim 15. 55

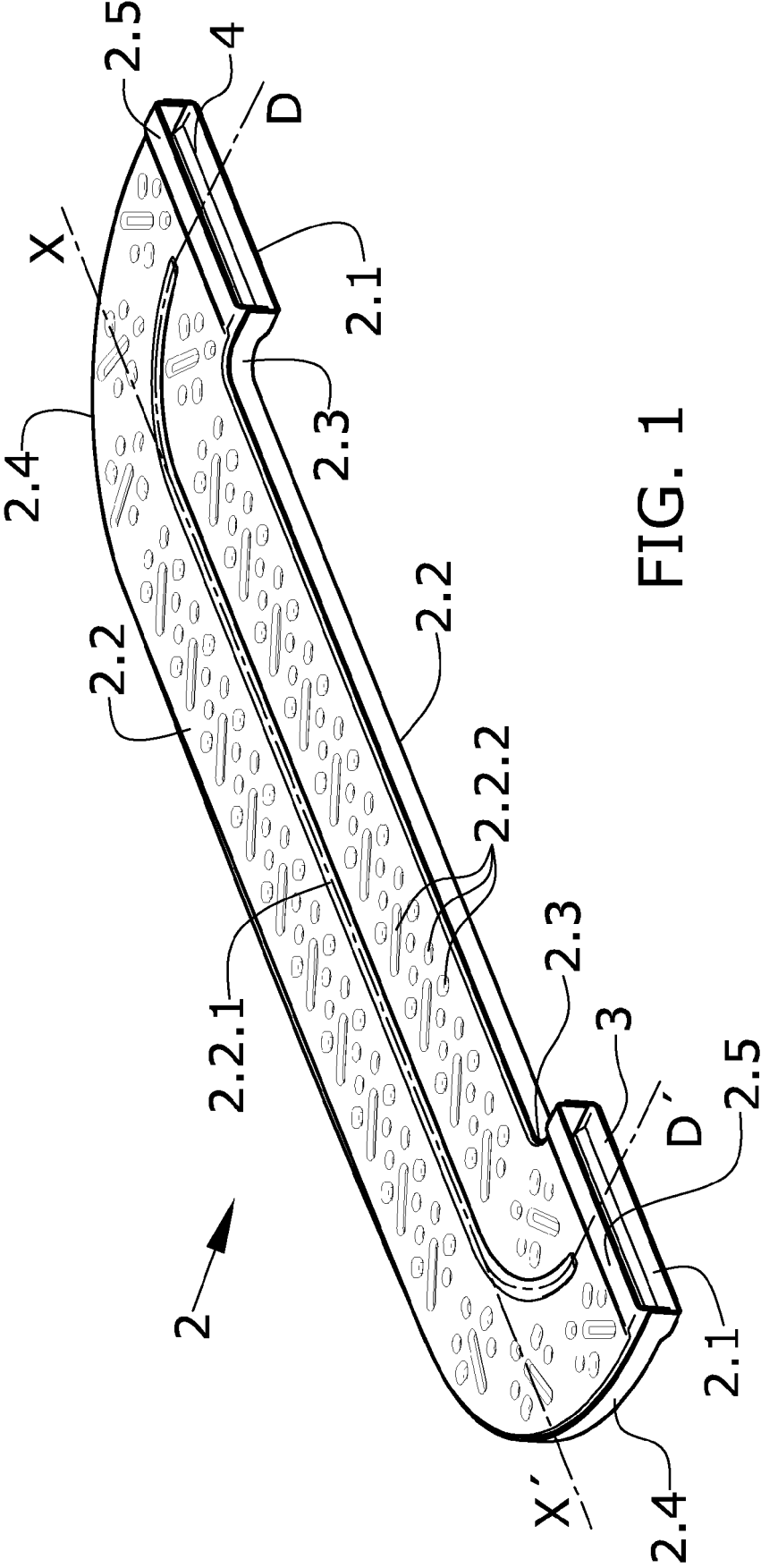


FIG. 1

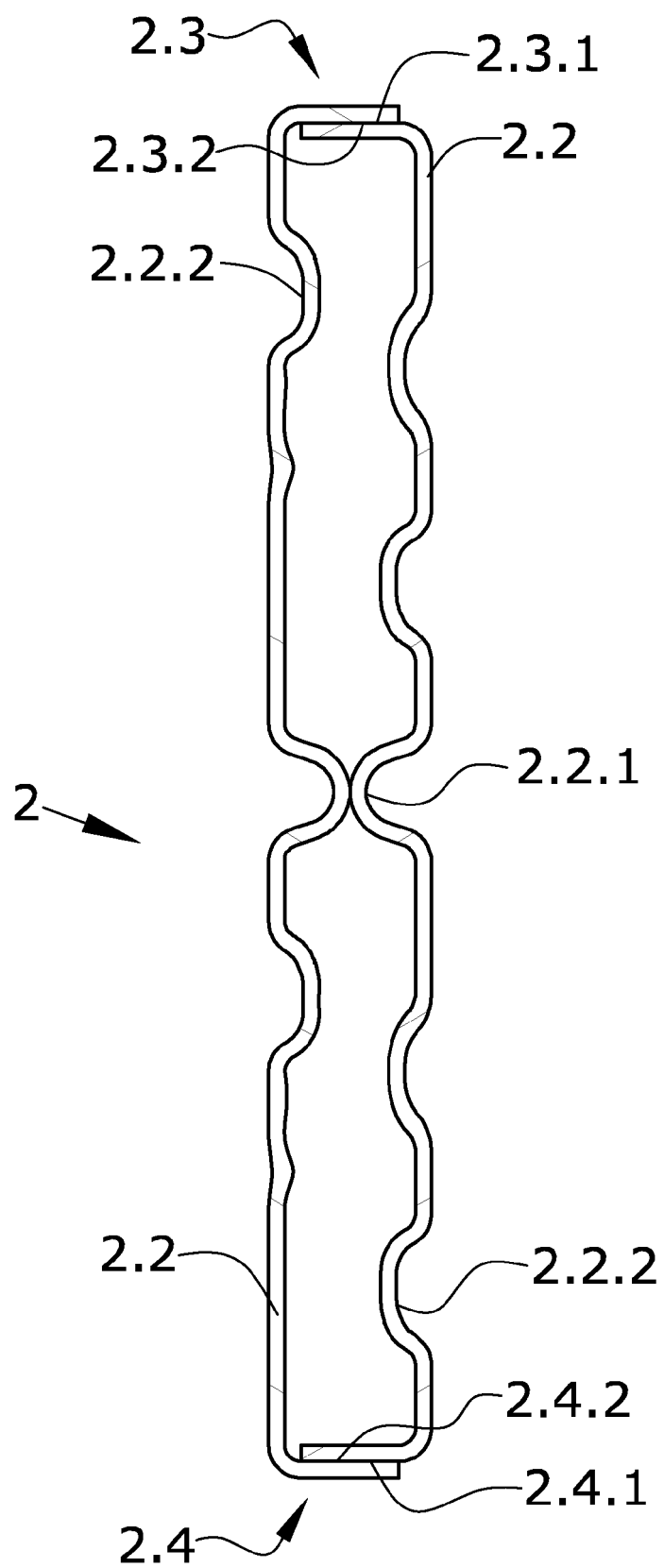
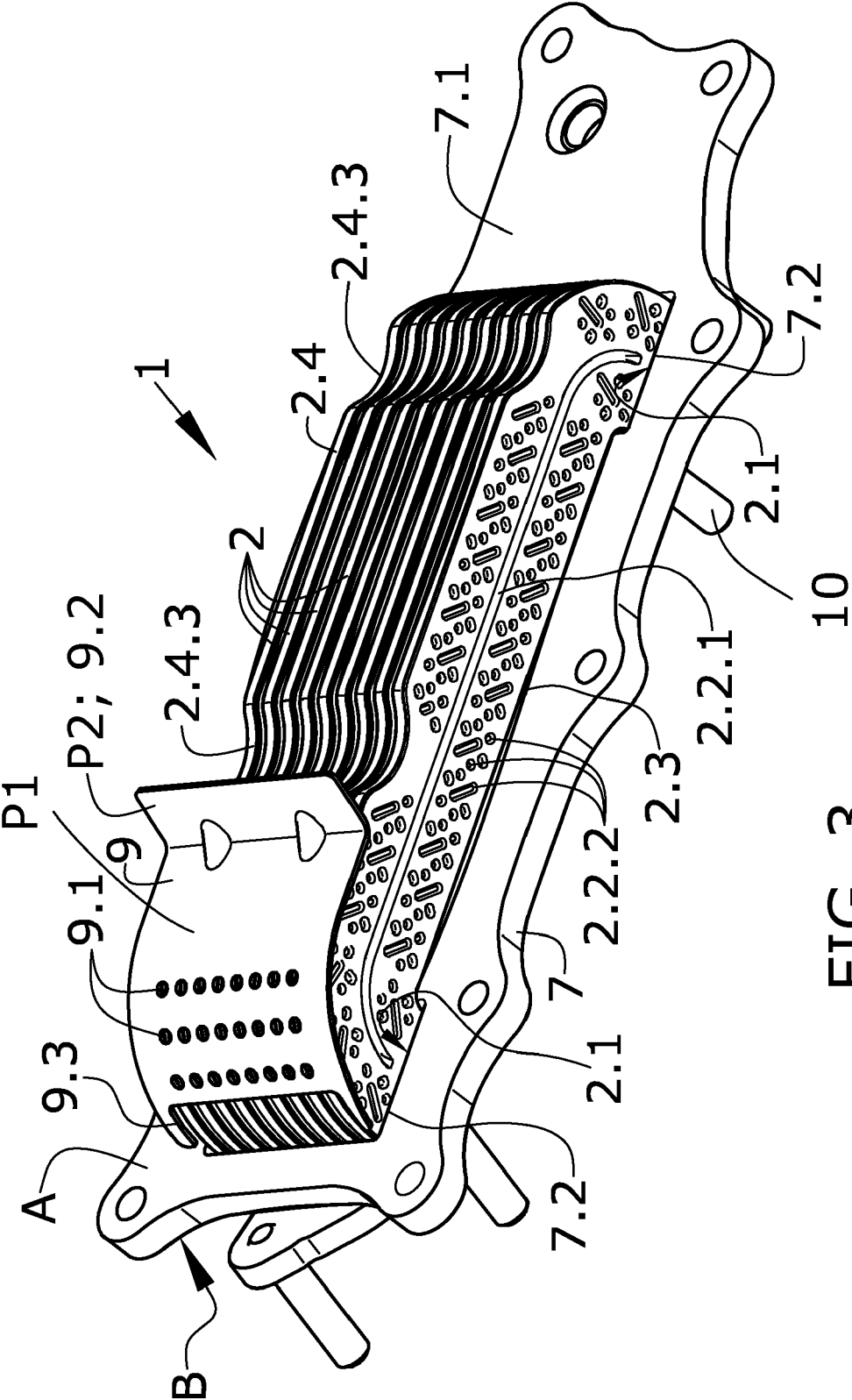


FIG. 2



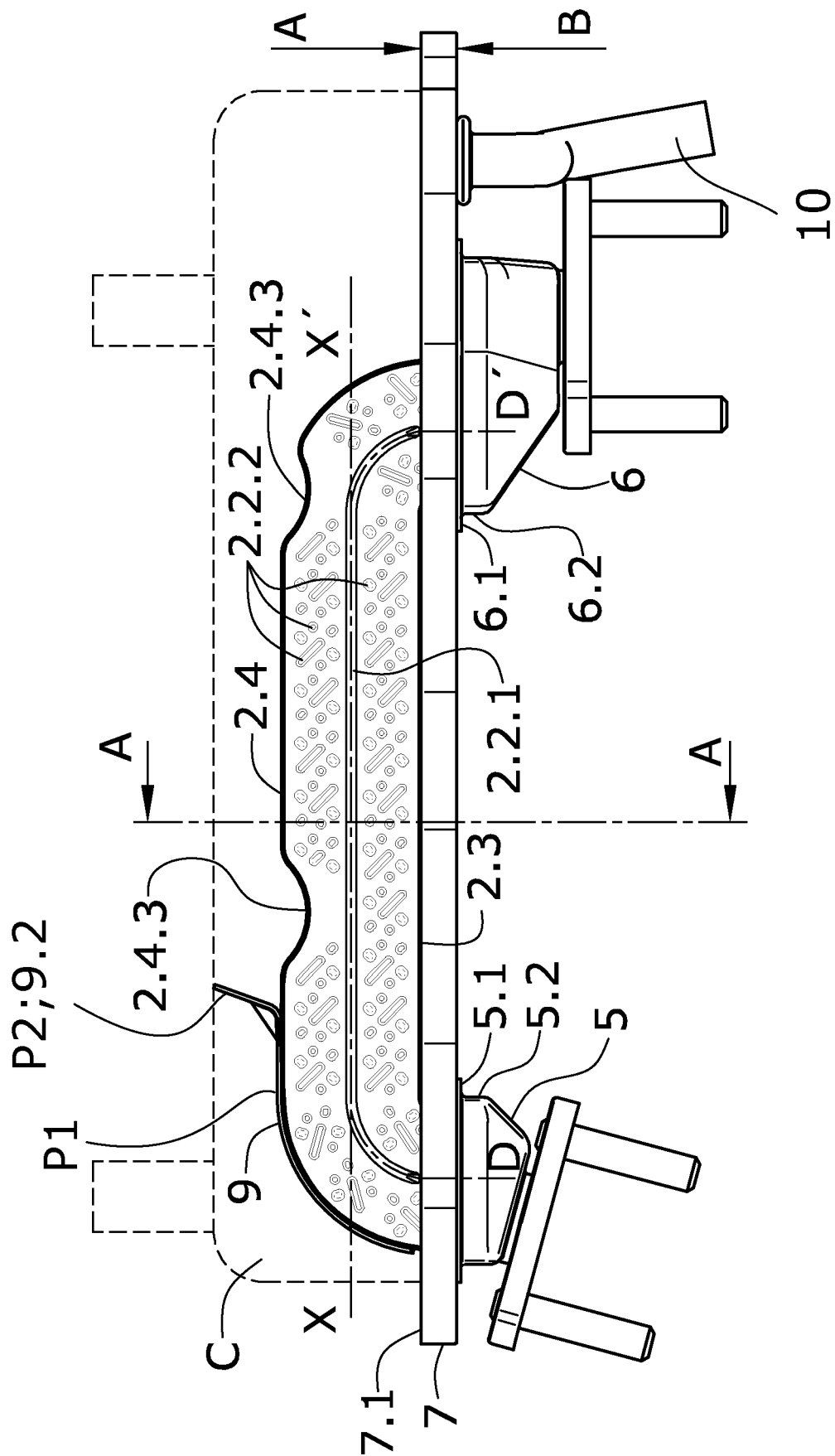


FIG. 4

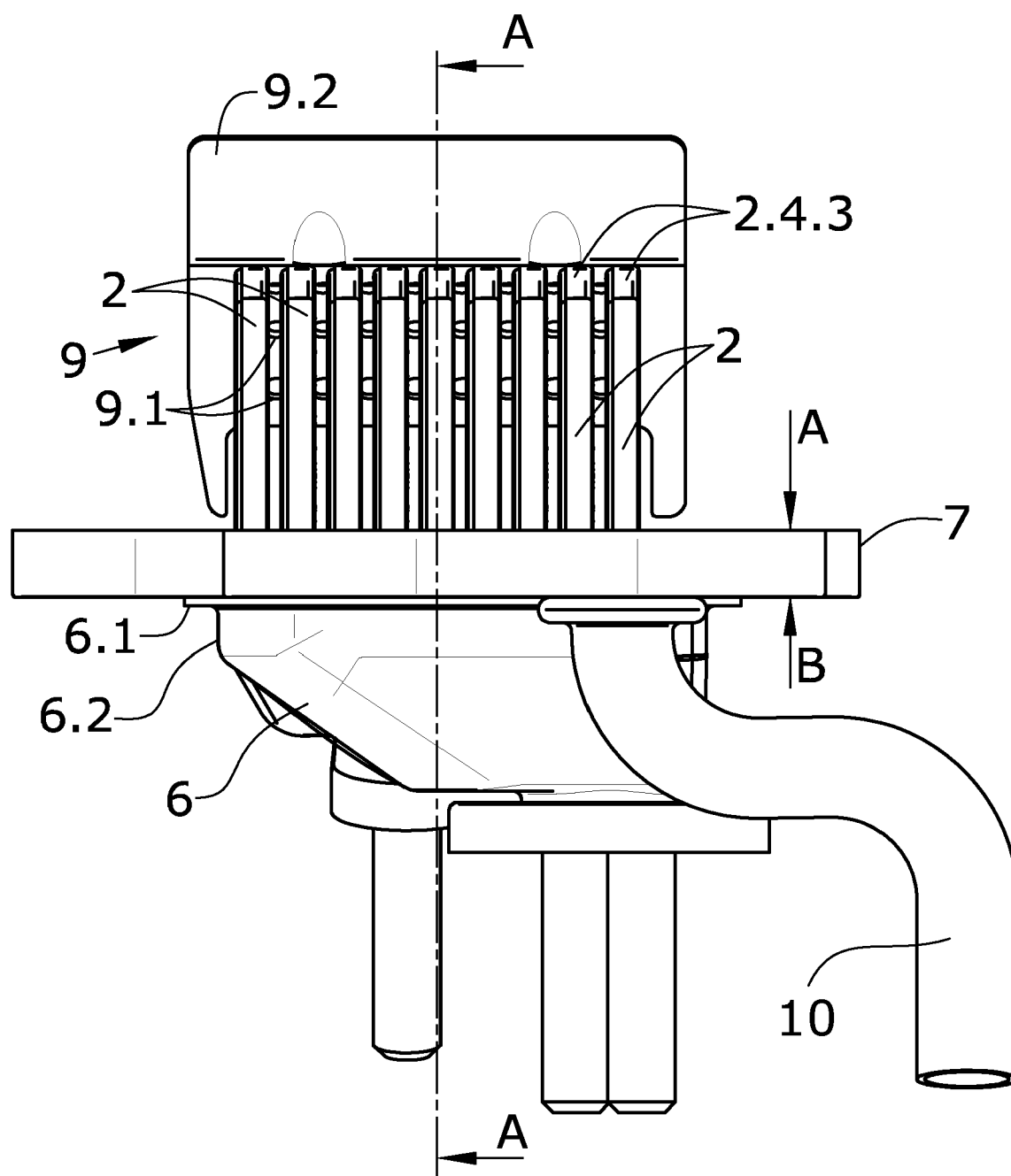


FIG. 5

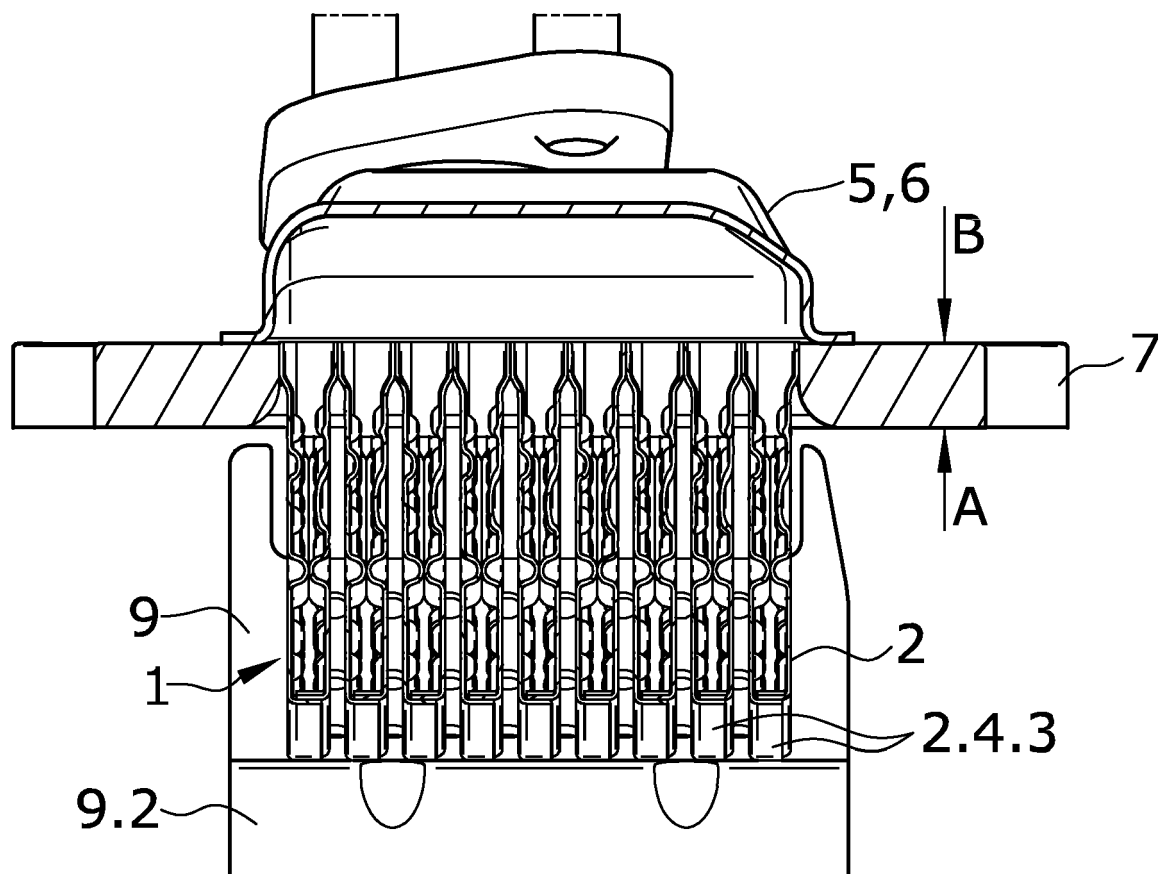


FIG. 6

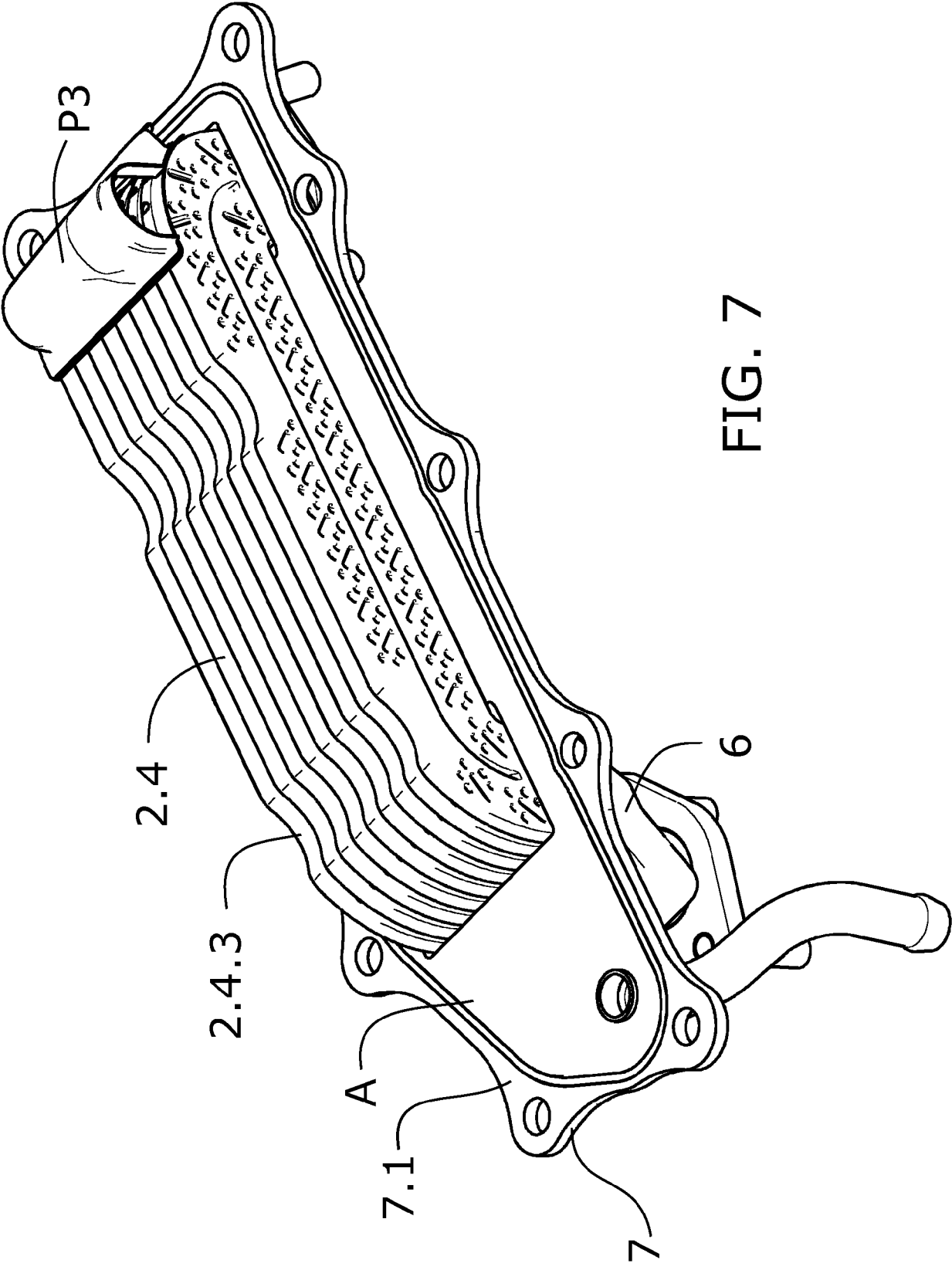
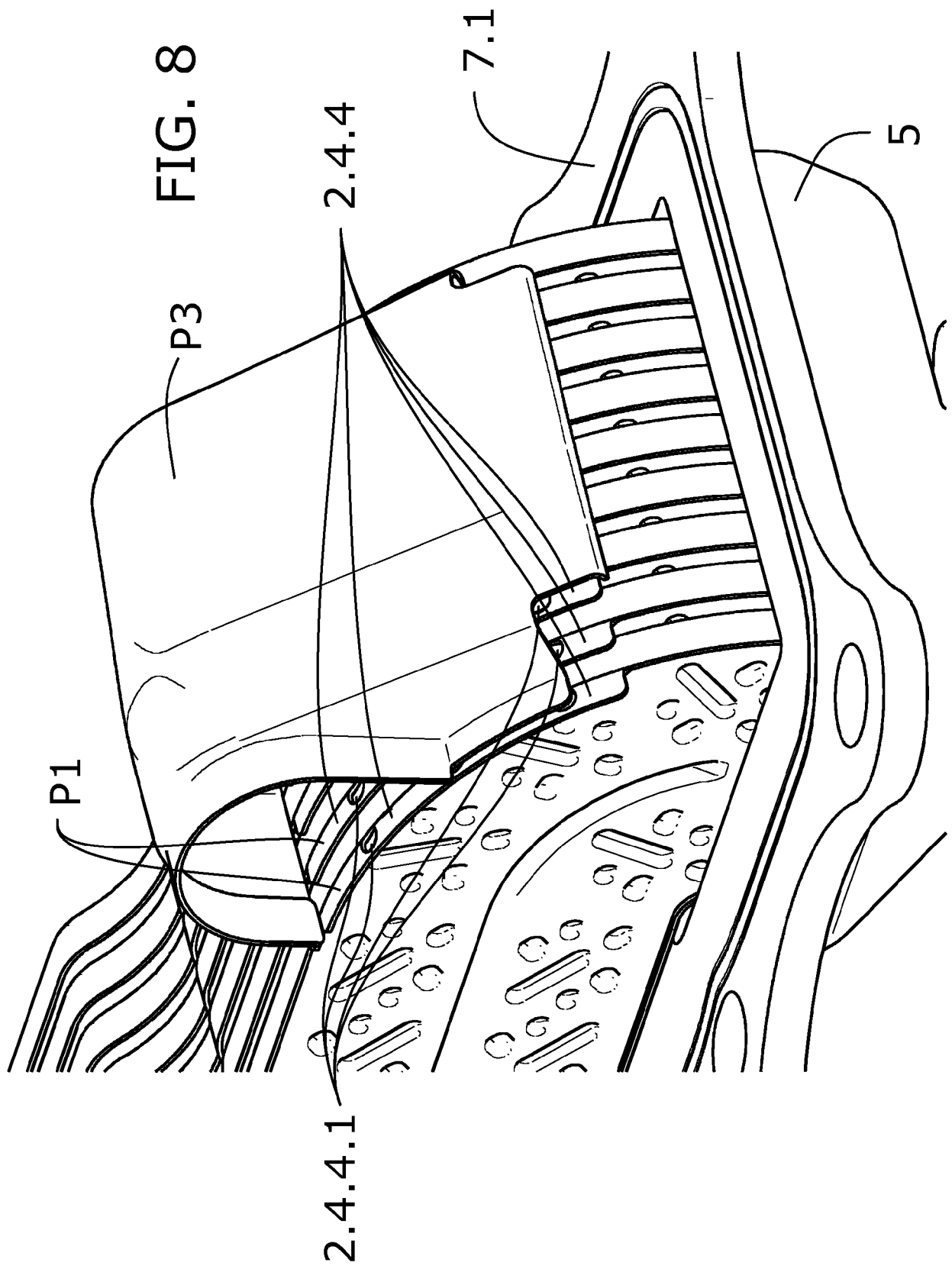


FIG. 7



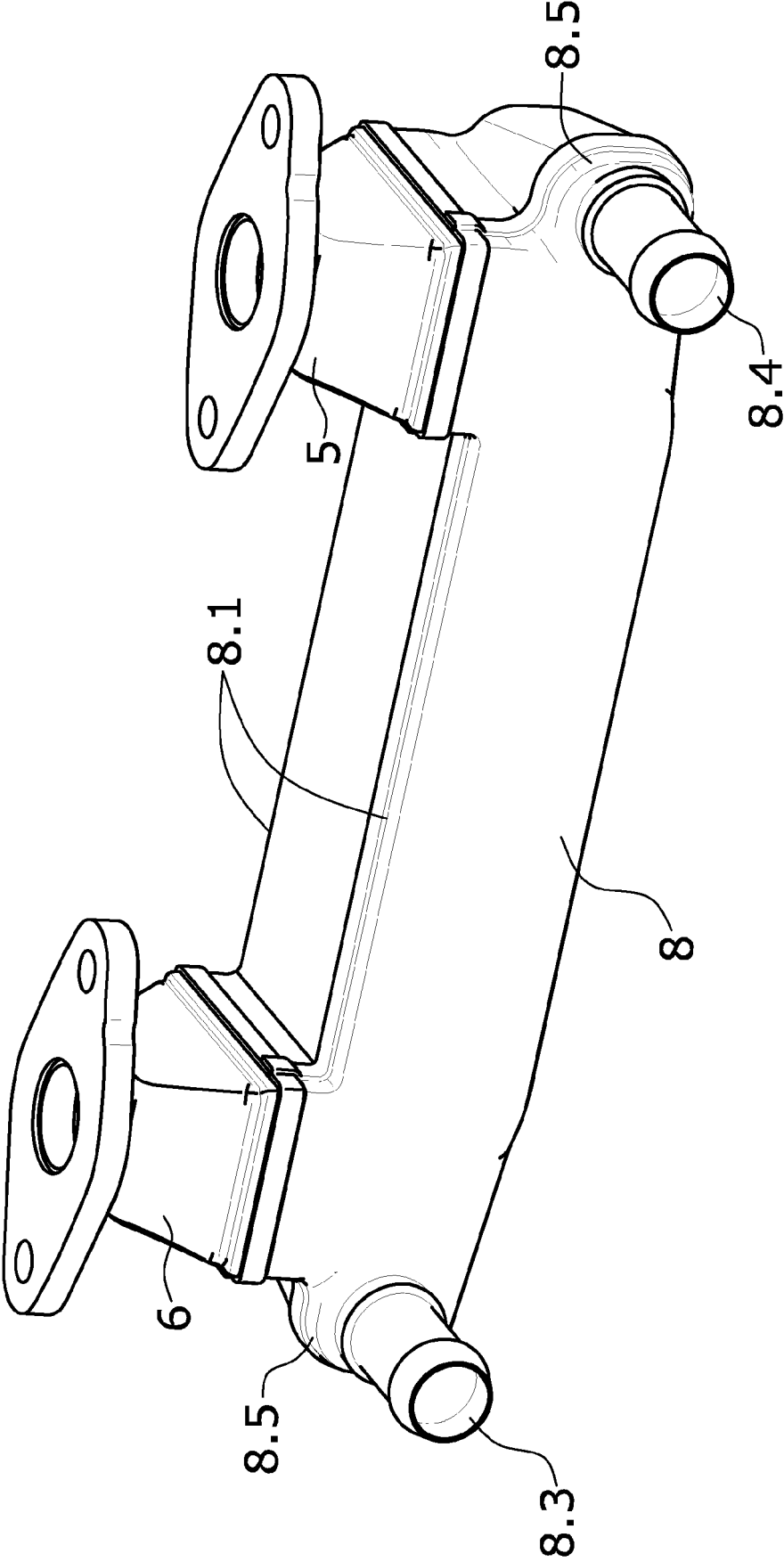


FIG. 9

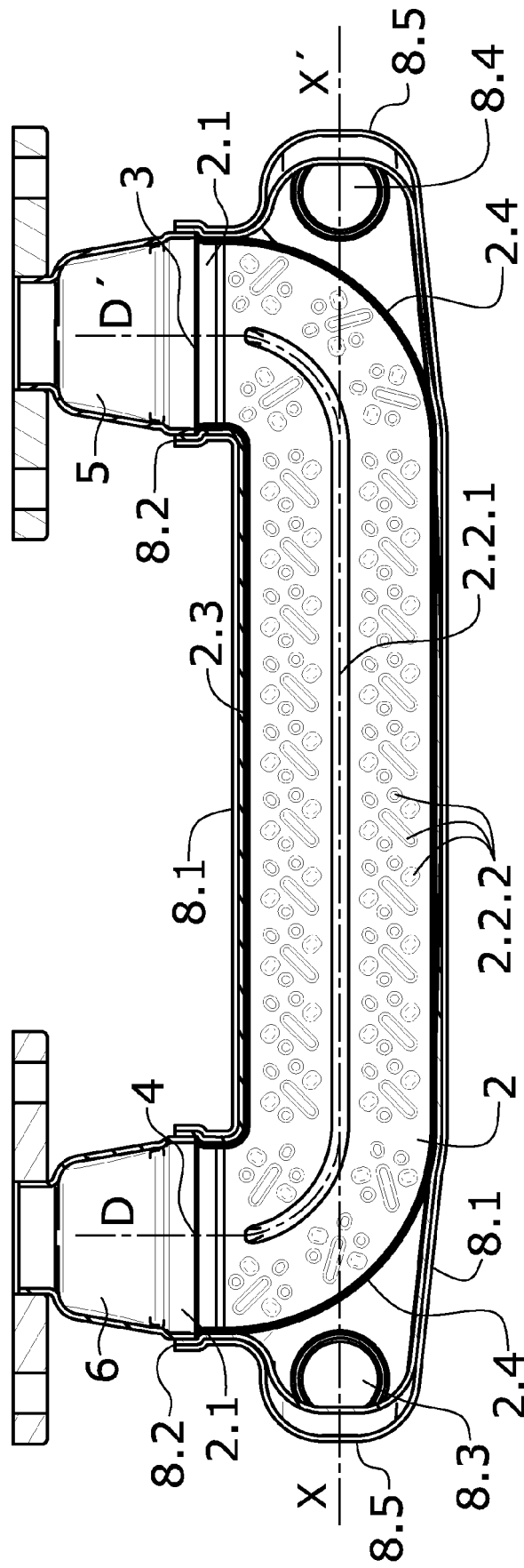


FIG. 10

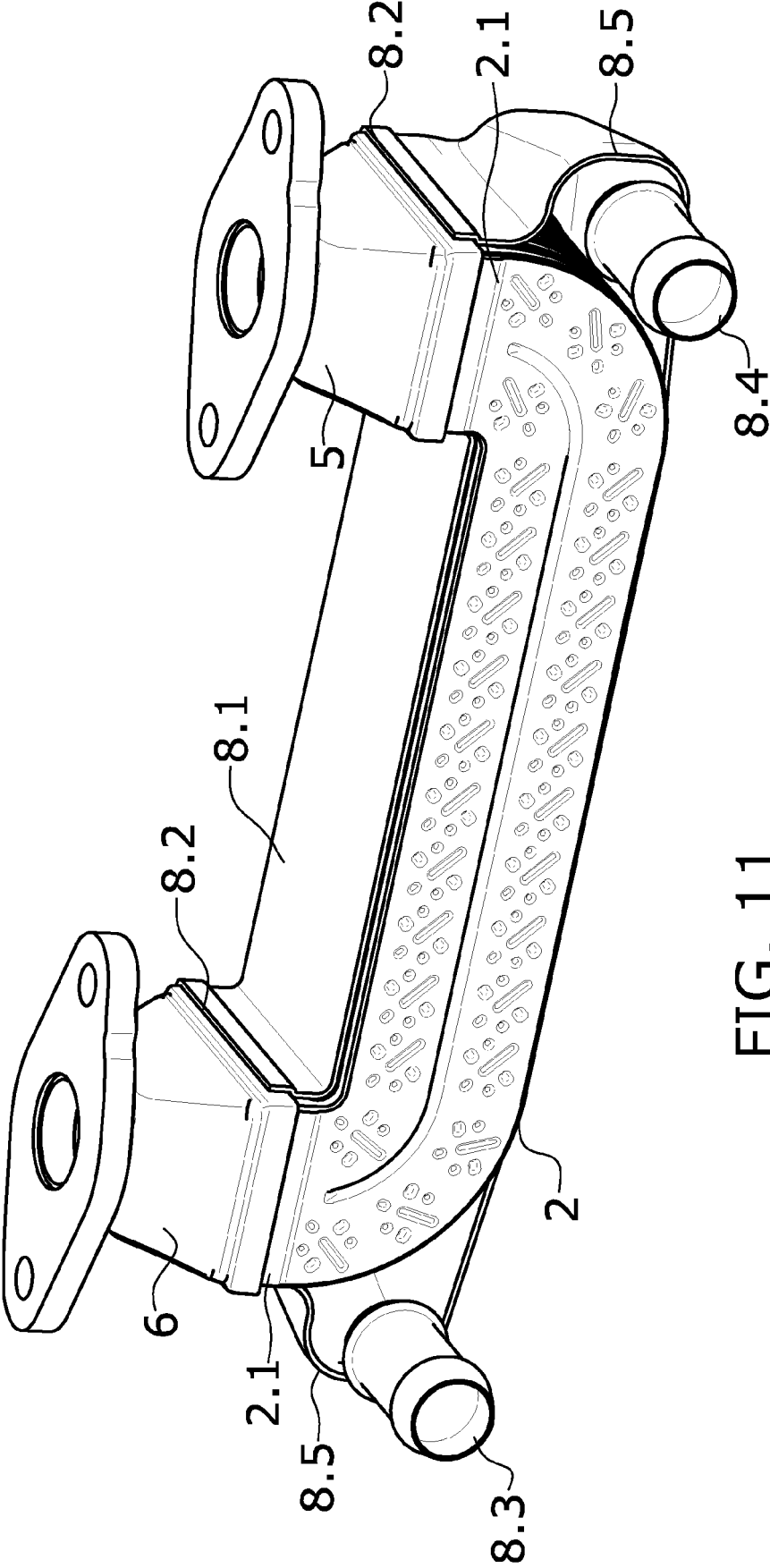


FIG. 11



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Place of search Munich		Date of completion of the search 19 May 2017	Examiner Martínez Rico, Celia
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