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(54) **A MULTI-CIRCUIT HEAT EXCHANGER SYSTEM**

(57) A multi-circuit heat exchanger system, hereinafter referred to as a "system" is disclosed in accordance with an embodiment of the present invention. The "system" includes a plurality of sets of tubular elements to configure fluid flow passages for a refrigerant and a plurality of first cooling panels and second cooling panels to configure independent fluid flow passages for a first coolant and a second coolant respectively, wherein the first cooling panels and the second cooling panels are so arranged with respect to the sets of tubular elements that at least one set of tubular elements is sandwiched between each of the adjacent first cooling panels and second cooling panels.

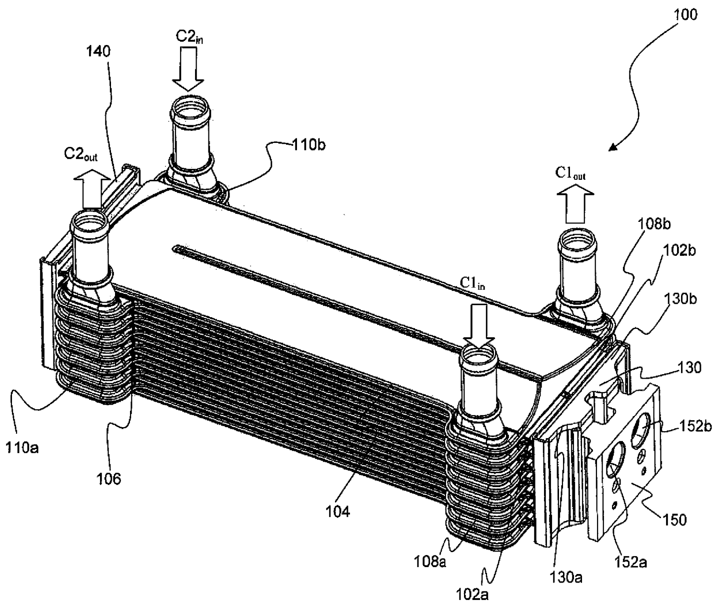


Fig. 2

EP 3 671 093 A1

Description

[0001] The present invention relates to a heat exchanger system, particularly, the present invention relates to a multi-circuit heat exchanger system for vehicles.

[0002] With evolution of vehicles toward hybrid and pure electric vehicles, there is need for cooling of power electronics and battery packs powering such vehicles along with a Heating Ventilation and Air Conditioning (HVAC) system for such vehicles. Accordingly, there is need for complex heat exchangers, particularly, multi-circuit heat exchangers that can operate either as water cooled condenser using R1234yf refrigerant or as a gas cooler using R744 refrigerant or as a water chiller depending on the requirements. The water cooled condenser / gas cooler can be generally used in Heating Ventilation and Air Conditioning (HVAC) system and the water chiller can be used for at least one of battery cooling, facilitating cabin cooling or cooling of power electronic based elements depending on the requirements. The multi-circuit heat exchanger involves at least three heat exchange media, two coolants and one refrigerant, and configures refrigerant circuit disposed between the coolant circuits. The coolant circuits facilitate cooling of coolants flowing there-through and the refrigerant circuit facilitates in condensing of a refrigerant fluid such as for example R1234yf or cooling of another refrigerant fluid such as for example R744, particularly, high pressure refrigerant fluid flowing through the refrigerant circuit. More specifically, depending upon whether the refrigerant flowing through the refrigerant circuit is R744 or R1234yf, the refrigerant is either cooled without phase change or condensed with phase change respectively. For, example, in case R744 refrigerant is flowing through the refrigerant circuit, the R744 refrigerant is cooled without undergoing phase change, i.e. the R744 refrigerant remains in gas phase and the refrigerant circuit acts as a gas cooler, whereas in case the R1234yf is flowing through the refrigerant circuit, the R1234yf undergoes condensation, phase change of R1234yf from gas to liquid phase occurs and the refrigerant circuit acts as the condenser of the air conditioning system.

[0003] Specifically, when the multi-circuit heat exchanger operates as the water chiller, the coolants in liquid state at relatively low operating pressures of 0.5 to 3 bars and flowing through the independent coolant circuits respectively reject heat to the high pressure refrigerant fluid flowing through the refrigerant circuit configured between the coolant circuits for achieving cooling of the two coolants either one at a time or simultaneously. With such configuration, cold refrigerant flowing through the refrigerant circuit can be used for simultaneously cooling two different coolants flowing through the two different coolant circuits. The cooled coolants received from the two different coolant circuits can be used differently. For example, one coolant can be used for battery cooling. In this way, the coolants after extracting heat from the battery pack are cooled by the refrigerant from the refrigerant circuit for ensuring a regular supply of cool coolant to the battery pack. The regular cooling of the battery pack prevents damage thereof due to over-heating and also ensures efficient operation thereof. The other coolant can be used for other applications such as facilitating cooling of the air supplied to vehicle cabin or for cooling power electronics based elements such as controllers.

[0004] Further, when the multi-circuit heat exchanger operates as the condenser using R1234yf as the refrigerant and gas cooler using R744 refrigerant, the high pressure refrigerant operating at high pressures up to 170 bars reject heat to the coolants flowing through the coolant circuits for achieving condensation /gas cooling of the high pressure refrigerant. In this way, the high pressure refrigerant loses heat energy by heat exchange with the coolants and either gets condensed into liquid phase for R1234yf or gets cooled while still remaining in gas phase (for R744). Thereafter, the high pressure, treated refrigerant passes through an expansion valve, which further cools the liquid refrigerant / cooled gas due to lowering of the refrigerant pressure. For R1234yf - the low pressure refrigerant liquid and flash gas leaving the expansion valve flows at proper rate through the evaporator and the compressor to complete the air conditioning cycle. The operating pressure of the refrigerant circuit depends on the refrigerant flowing through the refrigerant circuit in both liquid and gaseous state. For example, in case, the refrigerant flowing through the refrigerant circuit is R1234yf, the condenser operates at an operating pressure of up to 25 bars. For example, in case, the refrigerant flowing through the refrigerant circuit is a high pressure refrigerant, is particularly, R744, the refrigerant circuit operates as the gas cooler (instead of the condenser) and operates at a substantially higher operating pressure as high as up to 170 bars.

[0005] Referring to **FIGURE 1** of the accompanying drawings, a conventional multi-circuit heat exchanger **10** is depicted. The conventional multi-circuit heat exchanger **10** is generally formed of plurality of corrugated plates **12a** and **12b** that are stacked over each other in a predefined configuration as illustrated in **FIGURE 1**, to define a refrigerant circuit **20a** and coolant circuits **20b** and **20c**. More specifically, the refrigerant flows though passages configured between the first and second corrugated plates **12a** and **12b** by joining the first and second corrugated plates **12a** and **12b** at specific points to define the refrigerant circuit **20a**. In case the multi-circuit heat exchanger **10** is operating as the condenser (R1234yf) / gas cooler (R744), as the refrigerant flows through the refrigerant circuit **20a**, the refrigerant loses heat energy by heat exchange with the first and second coolants flowing above and below the corrugated plates **12a** and **12b** respectively defining the coolant circuits **20b** and **20c**, and as such the refrigerant gets condensed to liquid phase (R1234yf) or gets cooled while still remaining in gas state (R744). In case the multi-circuit heat exchanger **10** is operating as the water chiller, the first and the second coolants flowing over and below the first and second corrugated plates **12a** and **12b** respectively are cooled by the refrigerant flowing between the first and the second corrugated plates **12a** and **12b**. Although such configuration of the conventional multi-circuit heat exchanger 10 configures circulation paths for the first and second coolants and the refrigerant for facilitating heat exchange between the coolants and the refrigerant. However, the heat exchange between the refrigerant and the coolants for condensation / cooling of the refrigerant or cooling of the coolant is not effective. Also, as the refrigerant flowing through the passages configured by joining the first and second corrugated plates **12a** and **12b** at specific points is high pressure refrigerant, particularly, in case the refrigerant is R744 (CO_2) having operating pressures as high as up to 170 bars there are chances of bursting and separation of the first and second corrugated plates **12a** and **12b**. Such bursting may cause pressure drop in the condenser / gas cooler circuit **20a** and may render the conventional multi-circuit heat exchanger **10** in-effective. Also, such bursting may cause irreversible damage to the multi-circuit heat exchanger **10** and render the same useless. Such bursting may also cause mixing of the refrigerant with the coolant, thereby rendering both the coolants and the refrigerant useless. Such bursting may also be cause of accidents and may render the multi-circuit heat exchanger **10** unsafe, requiring frequent maintenance and unreliable.

[0006] Accordingly, there is a need for a multi-circuit heat exchanger system that configures separate and independent one refrigerant circuit and two coolant circuits for facilitating effective heat exchange between the refrigerant and the coolant. Specifically, there is a need for a multi-circuit heat exchanger system that configures separate and independent circulation paths for flow of a first coolant, a second coolant and a high pressure refrigerant there through such that elements of the multi-circuit heat exchanger configuring a refrigerant circuit sandwiched between independent coolant circuits are able to withstand high operating pressures of the high pressure refrigerant flowing there through. Further, there is a need for a multi-circuit heat exchanger system that achieves effective direct heat exchange between the high pressure refrigerant flowing through a refrigerant circuit and a first and a second coolant flowing through respective separate coolant circuits for achieving cooling of the first and second coolants. Also, there is a need for a multi-circuit heat exchanger system that configures separate and independent refrigerant circuit sandwiched between independent coolant circuits so that mixing of high pressure refrigerant flowing through the refrigerant circuit with a first and a second coolant flowing through the respective coolant circuits is eliminated. Also there is a need for a multi-circuit heat exchanger system that is safe, requires less maintenance and exhibits extended service life and reliability.

[0007] An object of the present invention is to provide a multi-circuit heat exchanger system that configures separate and independent one refrigerant circuit and two coolant circuits for facilitating effective heat exchange between the refrigerant and the coolants for functioning either as Water Cooled Gas Cooler or Gas Cooled Water Chiller.

[0008] Another object of the present invention is to provide a multi-circuit heat exchanger system that obviates the drawbacks associated with conventional multi-circuit heat exchanger that use only corrugated plates for configuring heat exchange passages irrespective of whether heat exchange medium is high pressure medium.

[0009] Still another object of the present invention is to provide such a multi-circuit heat exchanger system that elements of the multi-circuit heat exchanger system configuring a refrigerant circuit are sandwiched between and in contact with plates configuring the separate coolant or chiller-circuits and are able to withstand high operating pressures of the high pressure refrigerant flowing there through.

[0010] Yet another object of the present invention is to provide a multi-circuit heat exchanger system that configures separate and independent circulation paths for a first coolant, a second coolant and a refrigerant so that mixing of high pressure refrigerant flowing through a refrigerant circuit with a first and a second coolant flowing through the respective coolant circuits is eliminated.

[0011] Another object of the present invention is to provide a multi-circuit heat exchanger system that configures heat exchange between refrigerant and first coolant, refrigerant and second coolant and between the first coolant and the second coolant.

[0012] Yet another object of the present invention is to provide a multi-circuit heat exchanger system that exhibits enhanced heat exchange efficiency and performance.

[0013] Still another object of the present invention is to provide a multi-circuit heat exchanger system that is robust in construction, reliable and ensures safe operation.

[0014] Another object of the present invention is to provide a multi-circuit heat exchanger system that is less prone to failures and requires less maintenance.

[0015] Yet another object of the present invention is to provide a multi-circuit heat exchanger system that exhibits better flow control of heat exchange fluids flowing there-through.

[0016] In the present description, some elements or parameters may be indexed, such as a first element and a second element. In this case, unless stated otherwise, this indexation is only meant to differentiate and name elements which are similar but not identical. No idea of priority should be inferred from such indexation, as these terms may be switched without betraying the invention. Additionally, this indexation does not imply any order in mounting or use of the elements of the invention.

[0017] A multi-circuit heat exchanger system, hereinafter referred to as a "system" is disclosed in accordance with an embodiment of the present invention. The "system" includes a plurality of sets of tubular elements to configure fluid flow passages for a refrigerant and a plurality of first cooling panels and second cooling panels to configure independent fluid flow passages for a first coolant and a second coolant respectively, wherein the first cooling panels and the second cooling panels are so arranged with respect to the sets of tubular elements that at least one set of tubular elements is sandwiched between each of the adjacent first cooling panels and second cooling panels.

[0018] Further, the multi-circuit heat exchanger system includes an inlet manifold and an outlet manifold of a first manifold that are connected by at least one set of tubular elements configuring fluid flow passages for the refrigerant.

[0019] In accordance with an embodiment of the present invention, the tubular elements of each set of tubular elements are divided into inlet tubular elements and the corresponding outlet tubular elements that are interconnected to each other by an intermediate manifold.

[0020] Generally, each tubular element of the set of tubular elements withstands high operating pressures of a high pressure refrigerant flowing there through.

[0021] Specifically, each tubular element of the set of tubular elements receives R744 as refrigerant and withstands operating pressures in range of 150 to 190 bars.

[0022] Further, the multi-circuit heat exchanger system includes a first pair of inlet and outlet columns connected by at least one fluid flow passage configured by at least one of the first cooling panels.

[0023] Still further, the multi-circuit heat exchanger system includes a second pair of inlet and outlet columns connected by at least one fluid flow passage configured by at least one of the second cooling panels, the fluid flow passages configured by the second cooling panels are independent from fluid flow passages configured by the first cooling panels.

[0024] Generally, the inlet and outlet columns of the first pair of inlet and outlet columns are configured at opposite front corners of the multi-circuit heat exchanger system near the first manifold and interconnect all of the first cooling panels configuring the multi-circuit heat exchanger system.

[0025] Similarly, the inlet and outlet columns of the second pair of inlet and outlet columns are configured at opposite rear corners of the multi-circuit heat exchanger system near the intermediate manifold and interconnect all of the second cooling panels configuring the multi-circuit heat exchanger system.

[0026] In accordance with an embodiment of the present invention, the inlet manifold further includes at least one inlet and the outlet manifold further includes at least one outlet, the at least one inlet receives refrigerant to be treated to facilitate distribution of the refrigerant to the inlet tubular elements via the inlet manifold, whereas the at least one outlet delivers out the treated refrigerant received by the outlet manifold from the outlet tubular elements.

[0027] Specifically, the first manifold includes at least one plate with a first set of slots and a second set of slots configured thereon, at least one distribution column and at least one collection column. The first set of slots in conjunction with the at least one distribution column facilitates distribution of refrigerant received by the inlet manifold to the inlet tubular elements and the second set of slots in conjunction with the at least one collection column facilitates collection of refrigerant from the outlet tubular elements into the outlet manifold.

[0028] Specifically, the intermediate manifold includes a cover, at least one plate with a first set of slots and a second set of slots configured thereon. The first set of slots facilitates receiving refrigerant from the inlet tubular elements and the second set of slots facilitates delivering the refrigerant received from said first set of slots to the outlet tubular elements.

[0029] Generally, each of the first and second cooling panels respectively withstands low operating pressures (0.5 to 3 bars) of the first and second coolants flowing there-through.

[0030] Specifically, each of the first and second cooling panels receives water glycol mixture as the first coolant and the second coolant respectively and withstands operating pressures in range of 0.5 to 3 bars.

[0031] In accordance with an embodiment of the present invention, each of the first cooling panels is formed by joining preferably identical half plates with an array of flow restrictors disposed between the half plates.

[0032] Similarly, each of the second cooling panels is formed by joining preferably identical half plates with the flow restrictors disposed between the half plates.

[0033] In accordance with an embodiment of the present invention, each column of the first pair of inlet and outlet columns is configured by assembling and joining connector elements configured on adjacent first cooling panels by brazing. Each connector element includes a male collar and a female collar, wherein the male collar is received in a female collar of a first adjacent connector element and the female collar receives a male collar of a second adjacent connector element.

[0034] Similarly, each column of the second pair of inlet and outlet columns is configured by assembling and joining connector elements configured on adjacent second cooling panels by brazing. Each connector element includes a male collar and a female collar, wherein the female collar receives a male collar of a first adjacent connector element and the male collar is received in a female collar of a second adjacent connector element.

[0035] Other characteristics, details and advantages of the invention can be inferred from the description of the invention hereunder. A more complete appreciation of the invention and many of the attendant advantages thereof will be readily obtained as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying figures, wherein:

FIGURE 1 illustrates a schematic representation depicting a multi-circuit heat exchanger system in accordance with a prior art, wherein the multi-circuit heat exchanger is configured by arranging and joining corrugated plates in a pre-defined configuration;

FIGURE 2 illustrates an isometric view of a multi-circuit heat exchanger system in accordance with an embodiment of the present invention;

FIGURE 3 illustrates an isometric view of the multi-circuit heat exchanger system of **FIGURE 2** without a first manifold and an intermediate manifold for depicting arrangement of inlet and outlet tubular elements with respect to cooling panels;

FIGURE 4a illustrates an assembled view depicting arrangement of adjacent sets of tubular elements with respect to the adjacent first and second cooling panels in accordance with an embodiment of the present invention;

FIGURE 4b illustrates an exploded view depicting the arrangement of **FIGURE 4a**, wherein one set of tubular elements including inlet and outlet tubular elements is depicted sandwiched between adjacent first and second cooling panels;

FIGURE 5a illustrates an isometric view of the inlet and outlet tubular elements of **FIGURE 4b**;

FIGURE 5b illustrates an isometric sectional view of the first and second cooling panels of **FIGURE 4a** and **FIGURE 4b** depicting internal details thereof, wherein an array of flow restrictors is disposed within each one of the first and second cooling panels;

FIGURE 6 illustrates a sectional view of the multi-circuit heat exchanger system along a sectional plane passing through centre of each column of a first pair of inlet and outlet columns of **Figure 2** and **Figure 3**, also is depicted an enlarged view depicting connection between connector elements of adjacent first cooling panels for configuring the first pair of inlet and outlet columns;

FIGURE 7 illustrates a sectional view of the multi-circuit heat exchanger system along a sectional plane passing through centre of each column of a second pair of inlet and outlet columns of **Figure 2** and **Figure 3**, also is depicted an enlarged view depicting connection between connector elements of adjacent second cooling panels for configuring the second pair of inlet and outlet columns;

FIGURE 8a illustrates an isometric view of a first manifold in accordance with an embodiment of the present invention, wherein the first manifold is configured with at least one inlet for receiving refrigerant, particularly high pressure refrigerant to be treated and at least one outlet for delivering the treated high pressure refrigerant;

FIGURE 8b illustrates an isometric view of the first manifold of **FIGURE 8a** with a distribution arrangement for distributing high pressure refrigerant to be treated to inlet tubular elements and a collection arrangement for collecting treated high pressure refrigerant from corresponding outlet tubular elements;

FIGURE 9a illustrates an isometric view of an intermediate manifold in accordance with an embodiment of the present invention configured with a first and a second set of slots to facilitate receiving and delivering of high pressure refrigerant from and to the inlet tubular elements and the outlet tubular elements respectively;

FIGURE 9b illustrates another isometric view of the intermediate manifold of **FIGURE 9a**; and

FIGURE 10a and **FIGURE 10b** illustrate isometric views of an adaptor element connected to the first manifold of **FIGURE 8a** and **FIGURE 8b** for facilitating receiving of high pressure refrigerant in the multi-circuit heat exchanger system and delivering of treated high pressure refrigerant out of the multi-circuit heat exchanger.

[0036] It must be noted that the figures disclose the invention in a detailed enough way to be implemented, the figures helping to better define the invention if needs be. The invention should however not be limited to the embodiment disclosed in the description.

[0037] Although, as per the disclosures made in the present specification, a multi-circuit heat exchanger system that configures separate and independent coolant circuits and a refrigerant circuit for operating either as a water chiller for a battery cooling system or as a water cooled gas cooler for a Heating Ventilation and Air Conditioning (HVAC) system of a vehicle respectively is disclosed. More specifically, as per the disclosure made in the current specification, the multi-circuit heat exchanger system configures separate independent heat exchange circuits for facilitating efficient heat exchange between a refrigerant, particularly a high pressure refrigerant and two coolants. However, the multi-circuit heat exchanger system of the present invention is also applicable for use in other systems and applications not limited for use in vehicle only. Particularly, such multi-circuit heat exchanger system are also applicable in any other systems or applications in which the multi-circuit heat exchanger system is required to configure separate independent heat exchange circuits for facilitating efficient heat exchange between different media, and wherein one of the heat exchange media is a high pressure medium and the heat exchange element configuring heat exchange circuit for such high pressure medium is required to withstand high operating pressures.

[0038] Referring to **FIGURE 2** of the accompanying drawings, a multi-circuit heat exchanger system **100** also simply referred to as "system" in accordance with an embodiment of the present invention is illustrated. The "system" **100** includes a plurality of sets of tubular elements **102a**, **102b**, first and second cooling panels **104** and **106** respectively, a first manifold **130**, an intermediate manifold **140** and an adaptor element **150**.

[0039] The plurality of sets of tubular elements **102a**, **102b** configure fluid flow passages for a refrigerant, particularly, a high pressure refrigerant to facilitate heat exchange and also connect an inlet manifold **130a** and an outlet manifold **130b** of the first manifold **130** that in turn facilitate ingress and egress of high pressure refrigerant in and out of the "system" **100**. The inlet manifold **130a** and the outlet manifold **130b** of the first manifold **130** are connected by at least one set of tubular elements **102a**, **102b** configuring fluid flow passages for the high pressure refrigerant. Particularly, the tubular elements of each set of tubular elements are divided into the inlet tubular elements **102a** and the corresponding outlet tubular elements **102b** that are interconnected to each other either directly or indirectly by the intermediate manifold **140**. The inlet tubular elements **102a** receive high pressure refrigerant-from the inlet manifold **130a** and the outlet tubular elements **102b** deliver high pressure refrigerant to the outlet manifold **130b.** Further, in one example, the inlet tubular elements **102a** configure a portion of fluid flow passage for high pressure refrigerant from the inlet manifold **130a** to the intermediate manifold **140** and the outlet tubular elements **102b** configure a reverse flow passage for high pressure refrigerant from the intermediate manifold **140** to the outlet manifold **130b**. Such configuration of the inlet and outlet tubular elements **102a** and **102b** of each set of tubular elements configure a fluid flow path connecting the inlet manifold **130a** to the outlet manifold **130b.** Similar sets of tubular elements configure numerous fluid flow paths connecting the inlet manifold **130a** to the outlet manifold **130b**. In accordance with an embodiment of the present invention, the inlet manifold **130a** and the outlet manifold **130b** are connected by at least one tubular element configuring a continuous fluid flow path connecting the inlet manifold **130a** and the outlet manifold **130b.** More specifically, instead of the separate inlet tubular elements **102a** and the outlet tubular elements **102b** connected by the intermediate manifold **140** forming connection between the inlet manifold **130a** to the outlet manifold **130b**, a plurality of continuous tubular elements configures continuous fluid flow paths connecting the inlet manifold **130a** to the outlet manifold **130b**.

[0040] **FIGURE 3** illustrates an isometric view of the "system" **100** without the first manifold **130** and the intermediate manifold **140** for the purpose of clearly depicting the arrangement of inlet and outlet tubular elements **102a** and **102b** with respect to the first and the second cooling panels **104** and **106** respectively.

[0041] Specifically, **FIGURE 4a** of the accompanying drawings depicts arrangement of adjacent sets of tubular elements **102a**, **102b**, for example in form of multi-port panels with respect to the adjacent first and second cooling panels **104** and **106**. Generally, the tubular elements **102a, 102b** are multi-port panels formed by either one of extrusion and folding. The adjacent sets of tubular elements **102a, 102b** in the form of multi port panels are depicted converging at both the extreme ends thereof while one of the adjacent sets of the of tubular elements **102a**, **102b** is depicted sandwiched between adjacent first and second cooling panels **104** and **106**. In the sandwiched configuration of one of the adjacent sets of the of tubular elements **102a**, **102b** between adjacent first and second cooling panels **104** and **106**, the tubular elements **102a**, **102b** of the set are in contact with the first and second cooling panels **104** and **106**. Such arrangement of the tubular elements **102a** and **102b** with respect to the adjacent first and second cooling panels **104** and **106** facilitates better heat exchange between the high pressure refrigerant flowing through the tubular elements **102a**, **102b** and the first and second coolants flowing through the first and second cooling panels **104** and **106** respectively. The converging extreme ends of the adjacent sets of tubular elements **102a**, **102b** are received in slots configured on at least one plate **134** of the first manifold **130**. Such arrangement facilitates in packaging of the various elements of the "system" **100** in limited space, thereby achieving a compact configuration of the "system" **100**.

[0042] **FIGURE 4b** of the accompanying drawings illustrate an exploded view depicting the arrangement, wherein one set of tubular elements including inlet and outlet tubular elements **102a**, **102b** is depicted sandwiched between the adjacent first and the second cooling panels **104** and **106** respectively. However, more than one set of the tubular elements **102a**, **102b** can also be disposed between or sandwiched between each of the adjacent first and second cooling panels **104** and **106**, such that the tubular elements **102a**, **102b** are in direct contact with the adjacent first and second cooling panels **104** and **106** for facilitating direct heat exchange between a first coolant flowing in the first cooling panels **104** and high pressure refrigerant flowing through the tubular elements **102a**, **102b**, separate direct heat exchange between a second coolant flowing in the second cooling panels **106** and high pressure refrigerant flowing through the tubular elements **102a**, **102b** and indirect heat exchange between the first coolant and the second coolant flowing in the adjacent first and second cooling panels **104** and **106** respectively via the high pressure refrigerant flowing through the tubular elements **102a**, **102b** disposed between adjacent first and second cooling panels **104** and **106**. The flow of the high pressure refrigerant through the inlet tubular elements **102a** and flow of first coolant flowing in the first cooling panels **104** is either parallel flow or counter flow. The flow of the high pressure refrigerant through the inlet tubular elements **102a** and flow of second coolant flowing in the second cooling panels **106** is either parallel flow or counter flow. Such configuration results in cooling of the first and second coolants when the multi-circuit heat exchanger system **100** is operating as chiller and condensation (R1234yf) / cooling (R744) of the high pressure refrigerant when the multi-circuit heat exchanger system **100** is operating as condenser / gas cooler. More specifically, depending upon whether the refrigerant flowing through the refrigerant circuit is R744 or R1234yf, the refrigerant is either cooled without phase change or condensed with phase change respectively. For, example, in case R744 refrigerant is flowing through the refrigerant circuit, the R744 refrigerant is cooled without undergoing phase change, i.e. the R744 refrigerant remains in gas phase and the refrigerant circuit acts as a gas cooler, whereas in case the R1234yf is flowing through the refrigerant circuit, the R1234yf undergoes condensation and the refrigerant circuit acts as the condenser of the air conditioning system. However, counter flow between high pressure refrigerant with respect to the first coolant and the second coolant is preferred for better performance and efficiency. Further, the present invention is not limited to the configuration of the flow between the refrigerant and the two coolants as far as there is efficient heat transfer between the refrigerant and the two coolants.

[0043] The inlet tubular elements **102a** and the outlet tubular elements **102b** are receives and facilitates fluid flow there through of a high pressure refrigerant such as for example, R744 (CO2) refrigerant that has an operating pressure up to 170 bars. Accordingly, the inlet tubular elements **102a** and the outlet tubular elements **102b** should be capable of withstanding such high pressures and as such the inlet tubular elements **102a** and the outlet tubular elements **102b** are for example configured of micro multiport panels or extruded tubes as depicted in **FIGURE 5a** of the accompanying drawings that in turn are configured by either one of extrusion and folding. Also, with such configuration, the inlet and outlet tubular elements **102a** and **102b** respectively are able to withstand high operating pressures of the high pressure refrigerant such as for example, R744 (CO_2) flowing there through without any danger of bursting. Specifically, the inlet and outlet tubular elements **102a** and **102b** configured of micro multiport panels that are capable of receiving R744 as refrigerant and withstanding high operating pressures in range of 150 to 190 bars. Such a configuration of the inlet and outlet tubular elements **102a** and **102b** configured of micro multiport panels, renders the inlet and outlet tubular elements **102a** and **102b** lighter in weight, safe and compact. Further, the inlet and outlet tubular elements **102a** and **102b** of such configuration exhibits enhanced heat transfer efficiency, energy and material saving potential and service life over regular tube counterparts. As the inlet and outlet tubular elements **102a** and **102b** configured of micro multiport panels are compact, these can be conveniently packaged in limited space between adjacent first and second cooling panels **104** and **106**. However, the operating pressure of the tubular elements **102a** and **102b** defining the refrigerant circuit is based on the refrigerant selected. For example, in case the refrigerant is R134a / R1234yf, the operating pressure of the tubular elements **102a** and **102b** defining the refrigerant circuit is in the range of 3-25 bars (absolute), whereas in case the refrigerant is R744 - CO_2, the operating pressure of the tubular elements **102a** and **102b** defining the refrigerant circuit is up to 170 bars (absolute). However, present invention is not limited to use of any particular refrigerant in the tubular elements **102a** and **102b** of the multi-circuit heat exchanger system **100** of the present invention and any high pressure refrigerant can be used.

[0044] The first and second cooling panels **104** and **106** configure independent fluid flow passages for first and second coolants respectively, wherein the first and the second cooling panels **104** and **106** are so arranged with respect to the sets of tubular elements **102a** and **102b** that at least one set of the inlet and the outlet tubular elements **102a**, **102b** is sandwiched between each of the adjacent first and second cooling panels **104** and **106** as illustrated in the **FIGURE 4b.** In accordance with an embodiment, the first and second coolants are water glycol mixtures of same or different concentrations or composition, for example water-glycol mixture having different percentage of water and glycol. With use of water glycol mixture, the operating pressure of the first and the second cooling panels **104** and **106** is up to 3 bars (absolute). However, present invention is not limited to use of any particular coolants. With such configuration, cold refrigerant flowing through the refrigerant circuit can be used for cooling the different coolants flowing through the two different coolant circuits either one at a time or simultaneously. The cooled coolants received from the two different coolant circuits can be used differently, for example, one coolant can be used for battery cooling while the other coolant can be used for other applications such as at least one of battery cooling, facilitating cooling the air supplied to vehicle cabin and cooling power electronics based elements such as controllers. Further, the coolants in the first and second cooling panels **104** and **106** can be of same or different compositions.

[0045] Each of the first cooling panels **104** is formed by joining identical half plates **104a** and **104b** with an array of flow restrictors **120** disposed between the half plates **104a** and **104b**. **FIGURE 5b** of the accompanying drawings depicts an isometric sectional view of the first cooling panel **104**, wherein internal details thereof with the array of flow restrictors **120** disposed within the first cooling panel **104** are also depicted. Further, each one of the first cooling panels **104** is configured with at least one fluid flow passage to facilitate flow of the first coolant there through and heat exchange between the first coolant flowing there through and high pressure refrigerant flowing through the tubular elements **102a**, **102b** disposed adjacent thereto. Further, the first cooling panels **104** also connect a first pair of inlet and outlet columns **108a** and **108b** that facilitate ingress and egress of first coolant in and out of the "system" **100**. As illustrated in **FIGURE 3**, as an example, the first coolant enters inside the "system" **100** from the first inlet column **108a**, the first coolant's entry inside the "system" is referred to by arrow $C1_{in}$ and leaves the "system" **100** from the outlet column **108b**, referred to arrow $C1_{out}$. In between the first set of inlet and outlet columns **108a** and **108b**, the first coolant is distributed among and flows through the heat exchange passages configured by the first cooling panels **104** connecting the first pair of inlet and outlet columns **108a** and **108b**. The flow restrictors **120** retard fluid flow through the at least one fluid flow passage configured within each of the first cooling panels **104** to enhance heat transfer.

[0046] Similarly, each of the second cooling panels **106** is formed by joining identical half plates **106a** and **106b** with the flow restrictors **120** disposed between the half plates **106a** and **106b. FIGURE 5b** of the accompanying drawings also depicts an isometric sectional view of the second cooling panel **106**, wherein internal details thereof with the array of flow restrictors **120** disposed within the second cooling panel **106** are also depicted. Further, each of the second cooling panels **106** is configured with at least one fluid flow passage independent from fluid flow passages associated with and configured by the first cooling panels **104**. The fluid flow passages associated with the second cooling panels **106** facilitate heat exchange between the second coolant flowing there through and high pressure refrigerant flowing through the tubular elements **102a, 102b** disposed adjacent to the second cooling panels **106.** The second cooling panels **106** also connect a second pair of inlet and outlet columns **110a** and **110b** that facilitate ingress and egress of the second coolant in and out of the "system" **100**. As illustrated in **FIGURE 3**, as an example, the second coolant enters inside the "system" **100** from the second inlet column **110a**, the second coolant's entry in the "system" **100** is referred to by arrow $C2_{in}$ and leaves the "system" **100** from the outlet column **110b**, referred to by arrow $C2_{out}$. In between the second set of inlet and outlet columns **110a** and **110b**, the second coolant is distributed among and flows through the heat exchange passages configured by the second cooling panels **106** connecting the second pair of inlet and outlet columns **110a** and **110b**. The flow restrictors **120** retard fluid flow through the at least one fluid flow passage configured within each of the second cooling panels **106** and enhance heat transfer. Each of the first and second cooling panels **104** and **106** is capable of withstanding low pressures in range of 0.5 to 3 bars.

[0047] **FIGURE 6** of the accompanying drawings illustrates a sectional view of the "system" **100** along a sectional plane passing through center of each column of the first pair of inlet and outlet columns **108a** and **108b**. Also, is depicted first set of fluid flow passages configured by the first cooling panels **104** for facilitating flow of first coolant there-through. Further is depicted the first pair of inlet and outlet columns **108a** and **108b** connected with the first set of fluid flow passages configured by at least one of the first cooling panels **104** for facilitating ingress and egress of first coolant in and out of the first cooling panels **104** of the "system" **100**. As depicted in **FIGURE 2** and **FIGURE 3**, the inlet and outlet columns **108a** and **108b** of the first pair of inlet and outlet columns are configured at opposite front corners of the multi-circuit heat exchanger system **100** near the first manifold **130** and interconnect all of the first cooling panels **104** configuring the multi-circuit heat exchanger system **100**. Again referring to the **FIGURE 6**, connection between adjacent connector elements **105**, **105a** and **105b** configured on adjacent first cooling panels **104** for configuring the first pair of inlet and outlet columns **108a** and **108b** is depicted in an enlarged view. More specifically, each column of the first pair of inlet and outlet columns **108a** and **108b** is configured by assembling and joining connector elements configured on adjacent first cooling panels of all of the first cooling panels **104** by brazing. More specifically, each connector element **105** includes a male collar **105m** and a female collar **105f**, wherein the male collar **105m** is received in a female collar **105fa** of a first connector element **105a** configured on an adjacent first cooling panel **104** and the female collar **105f** receives male collar **105mb** of a second connector element **105b** configured on another adjacent first cooling panel **104**. Similarly, the connector elements configured on the subsequent adjacent first cooling panels are also assembled to facilitate configuring of the first pair of inlet and outlet columns **108a** and **108b**. Once all the adjacent connector elements configured on all of the first cooling panels **104** are assembled together, the connector elements can be joined by a single step brazing process to configure the first pair of inlet and outlet columns **108a** and **108b**, thereby making the manufacturing of the "system" **100** both convenient and quick.

[0048] **FIGURE 7** of the accompanying drawings illustrates a sectional view of the "system" **100** along a sectional plane passing through centre of each column of the second pair of inlet and outlet columns **110a** and **110b**. Also is depicted a second set of fluid flow passages configured by at least one of the second cooling panels **106** for facilitating flow of second coolant there through. Further, is depicted the second pair of inlet and outlet columns **110a** and **110b** connected with the second set of fluid flow passages configured by at least one of the second cooling panels **106** to facilitate ingress and egress of second coolant in and out of the second cooling panels **106**. As depicted in **FIGURE 2** and **FIGURE 3**, the second pair of inlet and outlet columns **110a** and **110b** are configured at opposite rear corners of the multi-circuit heat exchanger system **100** near the intermediate manifold **140** and interconnects all of the second cooling panels **106** configuring the multi-circuit heat exchanger system **100**. Again referring to the **FIGURE 7**, connection between connector elements of adjacent second cooling panels **106** for configuring the second pair of inlet and outlet columns **110a** and **110b** is depicted in an enlarged view. More specifically, each column of the second pair of inlet and outlet columns **110a** and **110b** is configured by assembling and joining connector elements configured on all of the second cooling panels **106** by brazing. More specifically, each connector element **111** includes a male collar **111m** and a female collar **111f**. The female collar **111f** receives a male collar **111ma** of a first connector element **111a** configured on an adjacent second cooling panel **106** and the male collar **111m** is received in a female collar **111fb** of a second connector element **111b** configured on another adjacent second cooling panel **106**. Similarly, the connector elements configured on the subsequent adjacent second cooling panels are also assembled to facilitate configuring of the second pair of inlet and outlet columns **110a** and **110b**. Once all the adjacent connector elements configured on all of the second cooling panels **106** are assembled together, the connector elements can be joined by a single step brazing process to configure the second pair of inlet and outlet columns **110a** and **110b**, thereby making the manufacturing of the "system" **100** both convenient and quick.

[0049] Referring to **FIGURE 8a** and **FIGURE 8b** of the accompanying drawings, isometric views of the first manifold **130** that in turn includes the inlet manifold **130a** and the outlet manifold **130a** is depicted. The inlet manifold **130a** of the first manifold **130** includes at least one inlet **132a** that receives high pressure refrigerant to be treated, particularly, high pressure refrigerant to be condensed and facilitates distribution of the high pressure refrigerant to be treated to the inlet tubular elements **102a** via the inlet manifold **130a** and a distribution arrangement. The outlet manifold **130b** includes at least one outlet **132b** that delivers out the treated high pressure refrigerant received by the outlet manifold **130b** from the outlet tubular elements **102b** via a collection arrangement. Specifically, the manifold **130** includes at least one plate **134** with a first set of slots **134a** and a second set of slots **134b** configured thereon, at least one distribution column **136a** and at least one collection column **136b**. The first set of slots **134a** in conjunction with the at least one distribution column **136a** facilitate distribution of high pressure refrigerant received by the inlet manifold **130a** to the inlet tubular elements **102a**. The second set of slots **134b** in conjunction with the at least one collection column **136b** facilitates collection of high pressure refrigerant received from the outlet tubular elements **102b** into the outlet manifold **130b.** More specifically, each of the first set of slots **134a** configured on the at least one plate **134** receives the inlet tubular elements **102a** in the form of multi port panels to facilitate fluid communication between the inlet manifold **130a** and the inlet tubular elements **102a** received in the first set of slots **134a**. In one example, converging ends of adjacent multi port panels configuring adjacent inlet tubular elements **102a** are received in one of the slots of the first set of slots **134a** configured on the at least one plate **134** of the first manifold **130**. Further, the remaining slots of the first set of slots **134a** also receive converging ends of adjacent multi port panels configuring adjacent inlet tubular elements **102a** to facilitate fluid communication between the inlet manifold **130a** and the remaining inlet tubular elements **102a**. Such configuration of the inlet manifold **130a** enables uniform distribution of the high pressure refrigerant received by the inlet manifold **130a** to all of the inlet tubular elements **102a**.

[0050] Similarly, each of the second set of slots **134b** configured on the at least one plate **134** receives the outlet tubular elements **102b** in the form of multi port panels to facilitate fluid communication between the outlet manifold **130b** and the outlet tubular elements **102b** received in the second set of slots **134b.** In one example, converging ends of adjacent multi port panels configuring adjacent outlet tubular elements **102b** are received in one of the slots of the second set of **134b** configured on the at least one plate **134** of the first manifold **130**. Further, the remaining slots of the second set of slots **134a** also receive converging ends of adjacent multi port panels configuring adjacent outlet tubular elements **102b** to facilitate fluid communication between the outlet manifold **130b** and the remaining outlet tubular elements **102b.** Such configuration of the outlet manifold **130b** enables the outlet manifold **130b** to effectively collect the high pressure refrigerant from the outlet tubular elements **102b.** With such configuration, the sets of inlet and outlet tubular elements **102a** and **102b** configure connection between the inlet manifold **130a** and the outlet manifold **130b**

[0051] Referring to **FIGURE 9a** and **FIGURE 9b** of the accompanying drawings, isometric views of the intermediate manifold **140** are depicted. The intermediate manifold **140** interconnects and facilitates fluid communication between the inlet tubular elements **102a** and corresponding outlet tubular elements **102b.** In an example, the intermediate manifold **140** includes a cover **142**, at least one plate **144** with a first set of slots **144a** and a second set of slots **144b** configured thereon. The plate **144** with the first set of slots **144a** and the second set of slots **144b** configured thereon is similar to the plate **134** with the first set of slots **134a** and the second set of slots **134b** configured thereon. The first set of slots **144a** facilitate receiving high pressure refrigerant from the inlet tubular elements **102a** and the second set of slots **144b** facilitate delivering the high pressure refrigerant to the outlet tubular elements **102b.** More specifically, each of the first set of slots **144a** configured on the at least one plate **144** receives the inlet tubular elements **102a** in the form of multi port panels to facilitate fluid communication between the inlet tubular elements **102a** received in the first set of slots **144a** and the intermediate manifold **140**. In one example, converging ends of adjacent multi port panels configuring adjacent inlet tubular elements **102a** are received in one of the slots of the first set of slots **144a** configured on the at least one plate **144** of the intermediate manifold **140**. Further, the remaining slots of the first set of slots **144a** also receive converging ends of adjacent multi port panels configuring adjacent inlet tubular elements **102a** to facilitate fluid communication between the remaining inlet tubular elements **102a** and the intermediate manifold **140a**. Similarly, each of the second set of slots **144b** configured on the at least one plate **144** receives the outlet tubular elements **102b** in the form of multi port panels to facilitate fluid communication between the intermediate manifold **140** and the outlet tubular elements **102b** received in the second set of slots **144b**. In one example, converging ends of adjacent multi port panels configuring adjacent outlet tubular elements **102b** are received in one of the slots **144b** configured on the at least one plate **144** of the intermediate manifold **140**. Further, the remaining slots of the second set of slots **144b** also receive converging ends of adjacent multi port panels configuring adjacent outlet tubular elements **102b** to facilitate fluid communication between the intermediate manifold **140** and the remaining outlet tubular elements **102b.** With such configuration, the intermediate manifold **140** configures fluid communication between the sets of inlet and outlet tubular elements **102a** and **102b**.

[0052] Referring to **FIGURE 10a** and **FIGURE 10b**, an adaptor element **150** connected to the first manifold **130** for facilitating receiving of high pressure refrigerant in the "system" **100** and delivering the condensed high pressure refrigerant out of the "system" **100** is illustrated. The adaptor element **150** is configured with snap fit engagement elements **154a** and **154b** for configuring snap fit engagement with the corresponding engagement elements **138a** and **138b** configured on the first manifold **130** that facilitate engagement between the adaptor element **150** over the first manifold **130** such that at least one inlet and outlet **152a** and **152b** configured on the adaptor element **150** are aligned with the corresponding inlet and outlet **132a** and **132b** configured on the first manifold **130**. Further, the inlet **152a** configured on the adaptor element **150** is connected to inlet hoses supplying high pressure refrigerant to the "system" **100** and the outlet **152b** is connected to the outlet hoses for receiving high pressure refrigerant from the "system" **100**.

[0053] Several modifications and improvement might be applied by the person skilled in the art to a multi-circuit heat exchanger system as defined above, as long as the multi-circuit heat exchanger system include sets of tubular elements that configure fluid flow passages for a refrigerant and plurality of first and second cooling panels to configure independent fluid flow passages for first and second coolants respectively, wherein the first and second cooling panels are so arranged with respect to the sets of tubular elements that at least one set of tubular elements is sandwiched between each of the adjacent first and second cooling panels.

[0054] Obviously, numerous modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that the invention may be practiced otherwise than as specifically described herein.

[0055] In any case, the invention cannot and should not be limited to the embodiments specifically described in this document, as other embodiments might exist. The invention shall spread to any equivalent means and any technically operating combination of means.

Claims

1. A multi-circuit heat exchanger system (100) comprising a plurality of sets of tubular elements (102a, 102b) adapted to configure fluid flow passages for a refrigerant and a plurality of first cooling panels (104) and second cooling panels (106) adapted to configure independent fluid flow passages for a first coolant and a second coolant respectively, wherein the first cooling panels (104) and the second cooling panels (106) are so arranged with respect to the sets of tubular elements (102a, 102b) that at least one set of tubular elements (102a, 102b) is sandwiched between each of the adjacent first cooling panels (104) and second cooling panels (106).

2. The multi-circuit heat exchanger system (100) according to any of the preceding claims, further comprising an inlet manifold (130a) and an outlet manifold (130b) of a first manifold (130) that are connected by at least one set of tubular elements (102a, 102b) configuring fluid flow passages for the refrigerant.

3. The multi-circuit heat exchanger system (100) according to any of the preceding claims, wherein the tubular elements of each set of tubular elements are divided into inlet tubular elements (102a) and the corresponding outlet tubular elements (102b) that are interconnected to each other by an intermediate manifold (140).

4. The multi-circuit heat exchanger system (100) according to any of the preceding claims, wherein each tubular element of the set of tubular elements (102a, 102b) is adapted to withstand high operating pressures of a high pressure refrigerant flowing there through.

5. The multi-circuit heat exchanger system (100) according to the previous claim, wherein each tubular element of the set of tubular elements (102a, 102b) is adapted to receive R744 as refrigerant and withstand operating pressures in range of 150 to 190 bars.

6. The multi-circuit heat exchanger system (100) according to any of the preceding claims, further comprising a first pair of inlet and outlet columns (108a) and (108b) adapted to be connected by at least one fluid flow passage configured by at least one of the first cooling panels (104).

7. The multi-circuit heat exchanger system (100) according to any of the preceding claims, further comprising a second pair of inlet and outlet columns (110a) and (110b) adapted to be connected by at least one fluid flow passage configured by at least one of the second cooling panels (106).

8. The multi-circuit heat exchanger system (100) according to any of the preceding claims, the inlet and outlet columns (108a) and (108b) of the first pair of inlet and outlet columns are configured at opposite front corners of the multi-circuit heat exchanger system (100) near the first manifold (130) and adapted to interconnect all of the first cooling panels (104) configuring the multi-circuit heat exchanger system (100).

9. The multi-circuit heat exchanger system (100) according to any of the preceding claims, the second pair of inlet and outlet columns (110a) and (110b) of the second pair of inlet and outlet columns are configured at opposite rear corners of the multi-circuit heat exchanger system (100) near the intermediate manifold (140) and adapted to interconnect all of the second cooling panels (106) configuring the multi-circuit heat exchanger system (100).

10. The multi-circuit heat exchanger system (100) according to any of the preceding claims, wherein the first manifold (130) comprises at least one plate (134) with a first set of slots (134a) and a second set of slots (134b) configured thereon, at least one distribution column (136a) and at least one collection column (136b), the first set of slots (134a) in conjunction with the at least one distribution column (136a) are adapted to facilitate distribution of refrigerant received by the inlet manifold (130a) to the inlet tubular elements (102a) and the second set of slots (134b) in conjunction with the at least one collection column (136b) is adapted to facilitate collection of refrigerant from the outlet tubular elements (102b) into the outlet manifold (130b).

11. The multi-circuit heat exchanger system (100) according to any of the preceding claims, wherein the intermediate manifold (140) comprises a cover (142), at least one plate (144) with a first set of slots (144a) in fluid communication with a second set of slots (144b) configured thereon, the first set of slots (144a) are adapted to facilitate receiving refrigerant from the inlet tubular elements (102a) and the second set of slots (144b) are adapted to facilitate delivering the refrigerant received from the first set of slots (144a) to the outlet tubular elements (102b).

12. The multi-circuit heat exchanger system (100) according to any of the preceding claims, wherein each of the first cooling panels (104) and second cooling panels (106) respectively is adapted to withstand low operating pressures of the first coolant and the second coolant.

13. The multi-circuit heat exchanger system (100) according to any of the preceding claims, wherein each of the first and second cooling panels is adapted to receive water glycol mixture as the first coolant and the second coolant respectively and withstand operating pressures in the range of 0.5 to 3 bars.

14. The multi-circuit heat exchanger system (100) according to any of the preceding claims, wherein each of the first cooling panels (104) is formed by joining preferably identical half plates (104a) and (104b) with an array of flow restrictors (120) disposed between the half plates (104a) and (104b).

15. The multi-circuit heat exchanger system (100) according to any of the preceding claims, wherein each of the second cooling panels (106) is formed by joining preferably identical half plates (106a) and (106b) with the flow restrictors (120) disposed between the half plates (106a) and (106b).

16. The multi-circuit heat exchanger system (100) according to any of the preceding claims, wherein each column of the first pair of inlet columns (108a) and outlet columns (108b) is configured by assembling and joining connector elements (105, 105a, 105b) configured on adjacent cooling panels of all of the first cooling panels (104) by brazing, each connector element (105) comprising a male collar (105m) and a female collar (105f), wherein the male collar (105m) is adapted to be received in a female collar (105fa) of a first adjacent connector element (105a) and the female collar (105f) is adapted to receive a male collar (105mb) of a second adjacent connector element (105b).

17. The multi-circuit heat exchanger system (100) according to any of the preceding claims, wherein each column of the second pair of inlet columns (110a) and outlet columns (110b) is configured by assembling and joining connector elements (111, 111a, 111b) configured on adjacent cooling panels of all of the second cooling panels (106) by brazing, each connector element (111) comprising a male collar (111m) and a female collar (111f), the female collar (111f) is adapted to receive a male collar (111ma) of a first adjacent connector element (111a) and the male collar (111m) is adapted to be received in a female collar (111fb) of a second adjacent connector element (111b).

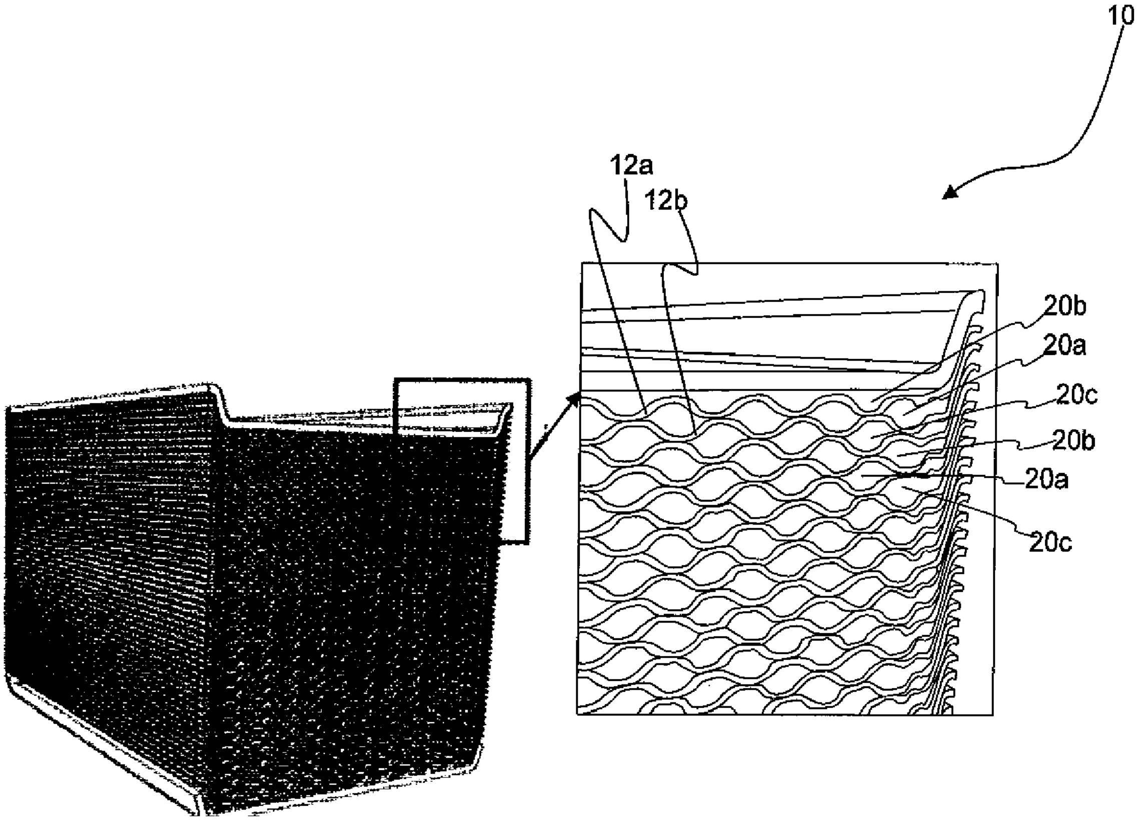
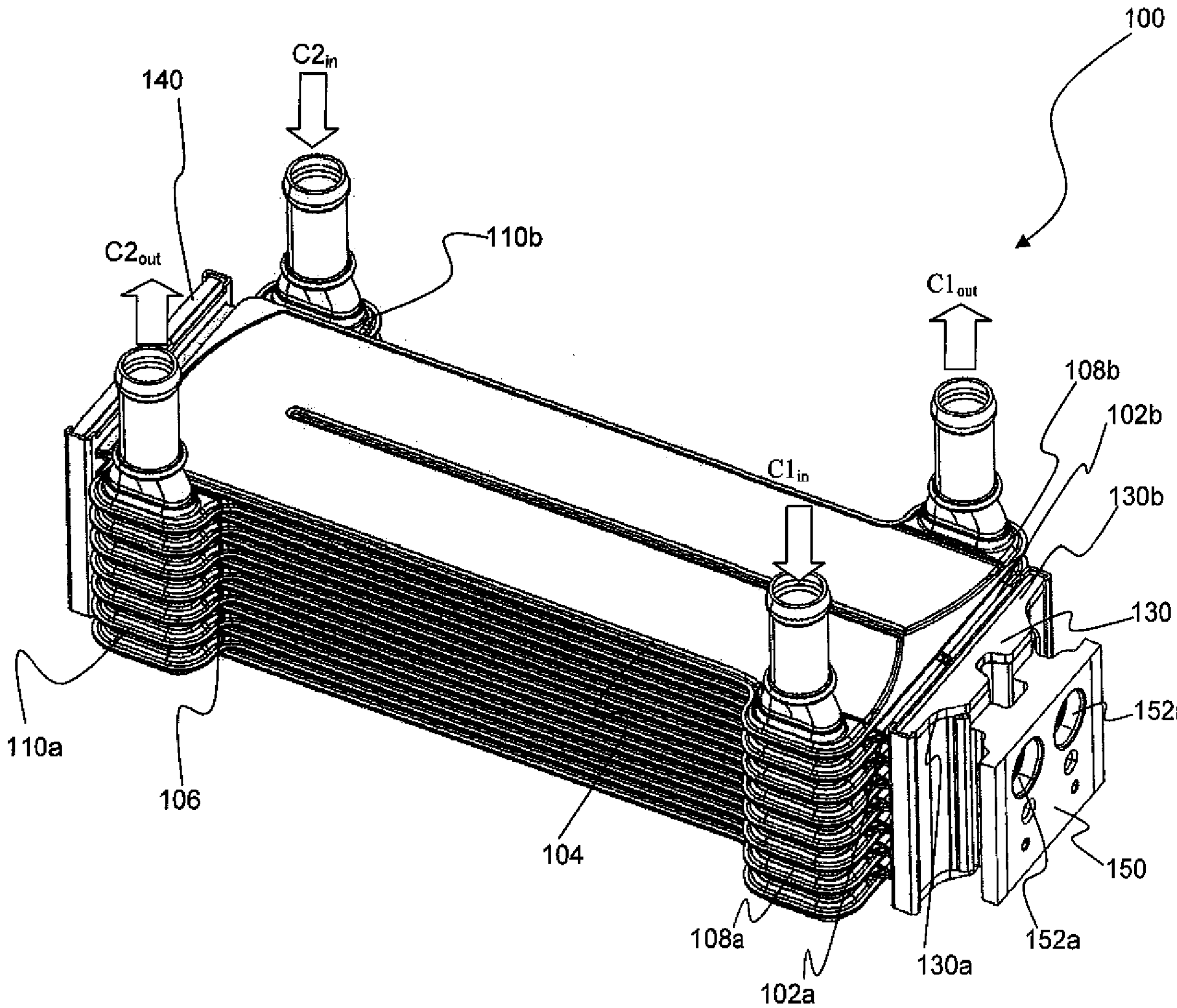


Fig. 1

(PRIOR ART)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140
$C2_{out}$
110b
$C1_{out}$
108b
102b
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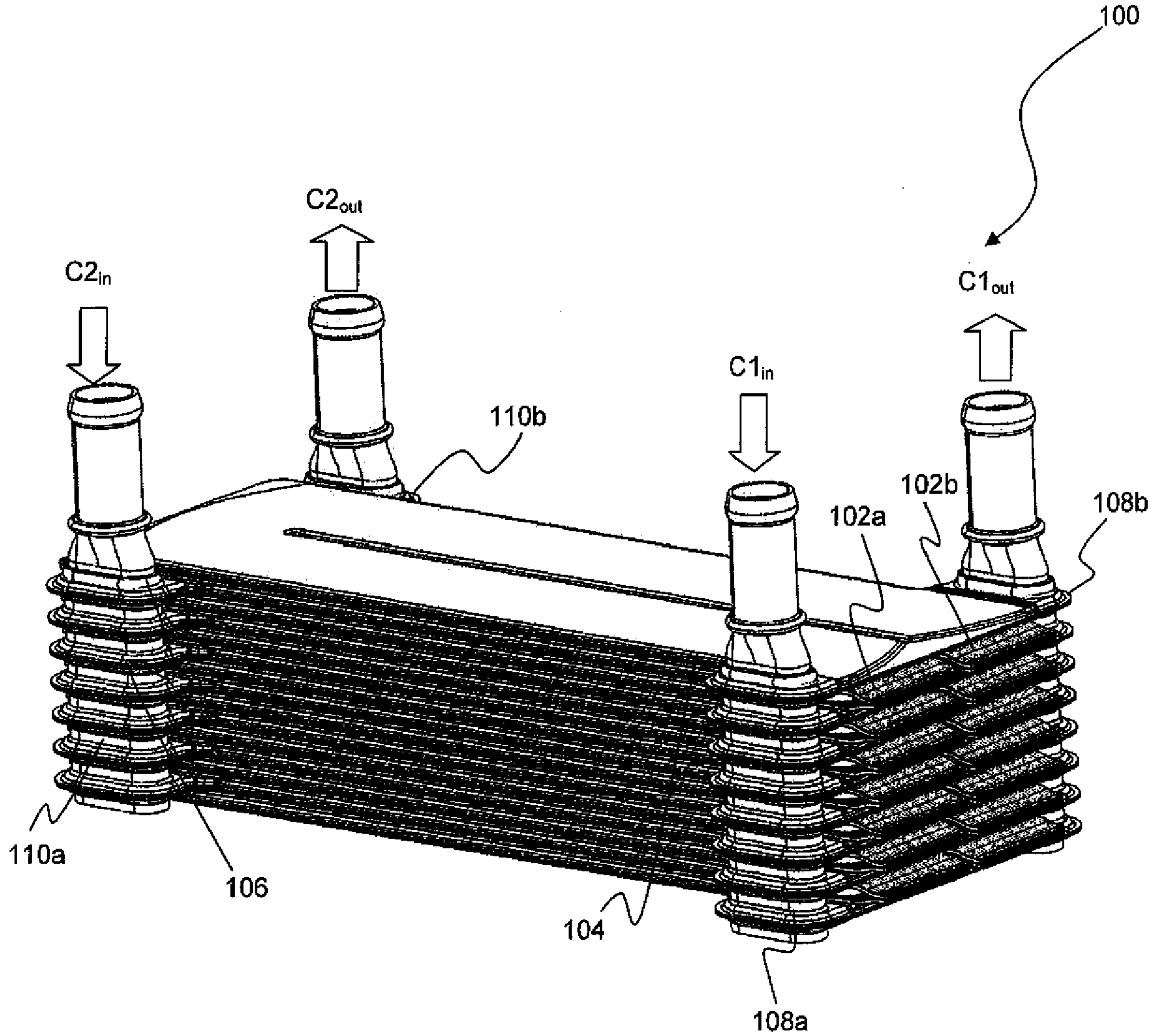
130
152b
110a
106
104
150
108a
102a
130a
152a

Fig. 2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C2in
C1out
C1in
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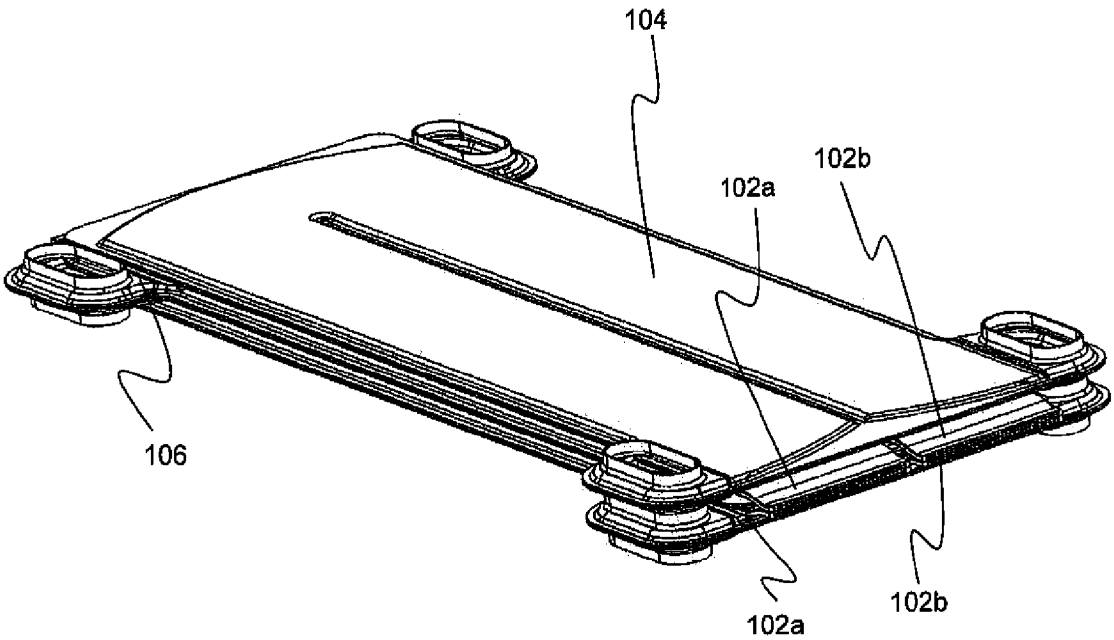
102a
102b
108b
110a
106
104
108a

Fig. 3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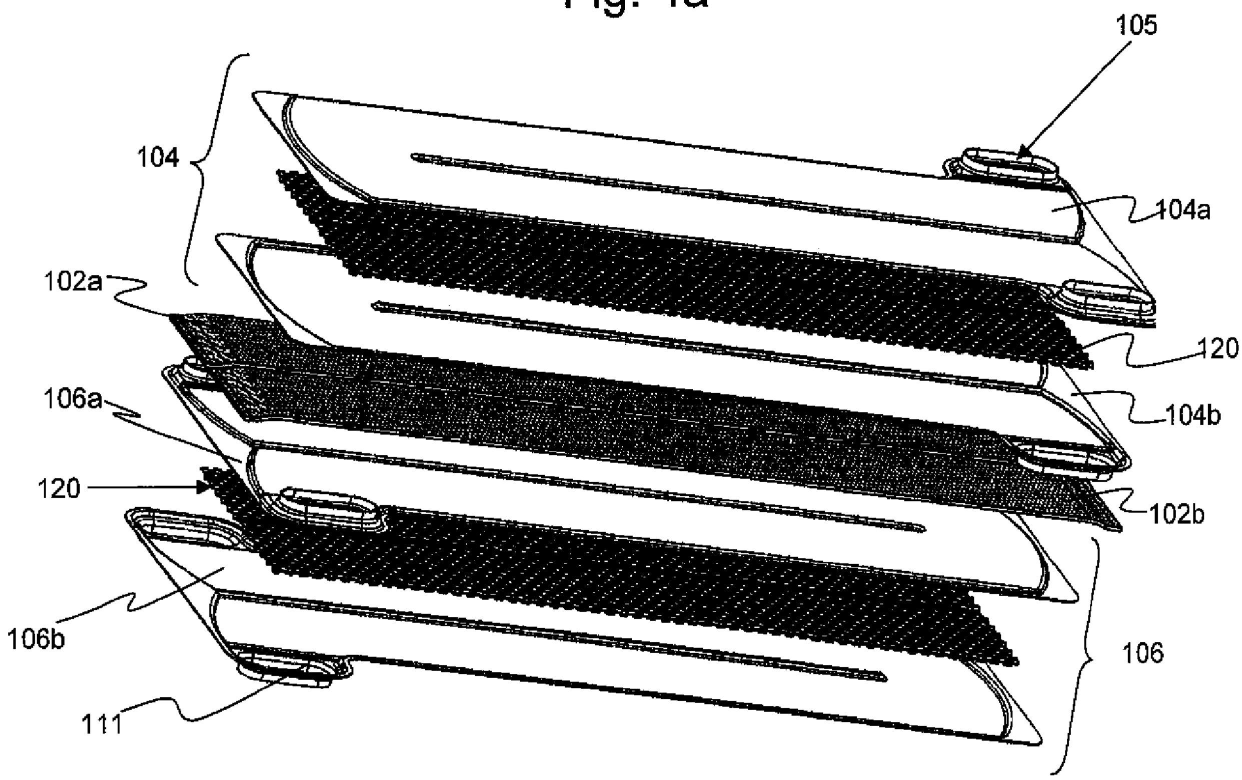
102b
102a
106
102a
102b

Fig. 4a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106a
104b
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102b
106b
106
111

Fig. 4b

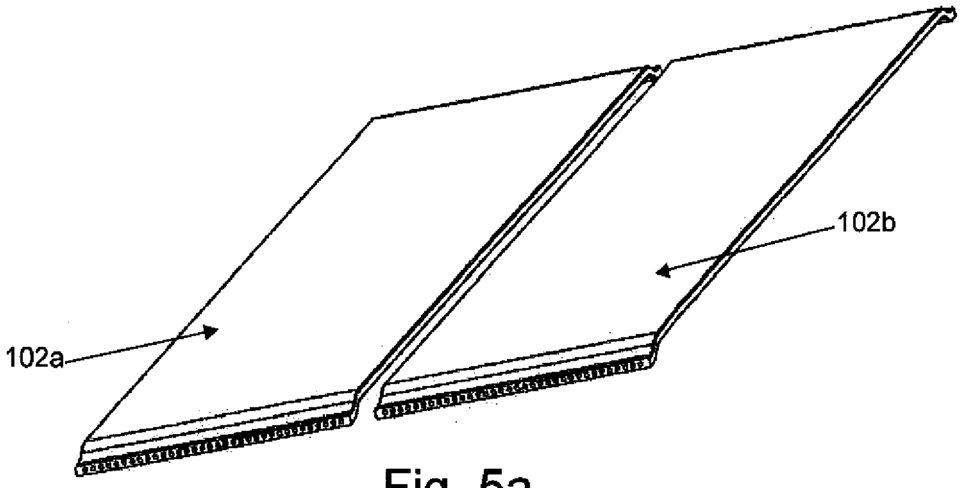


Fig. 5a

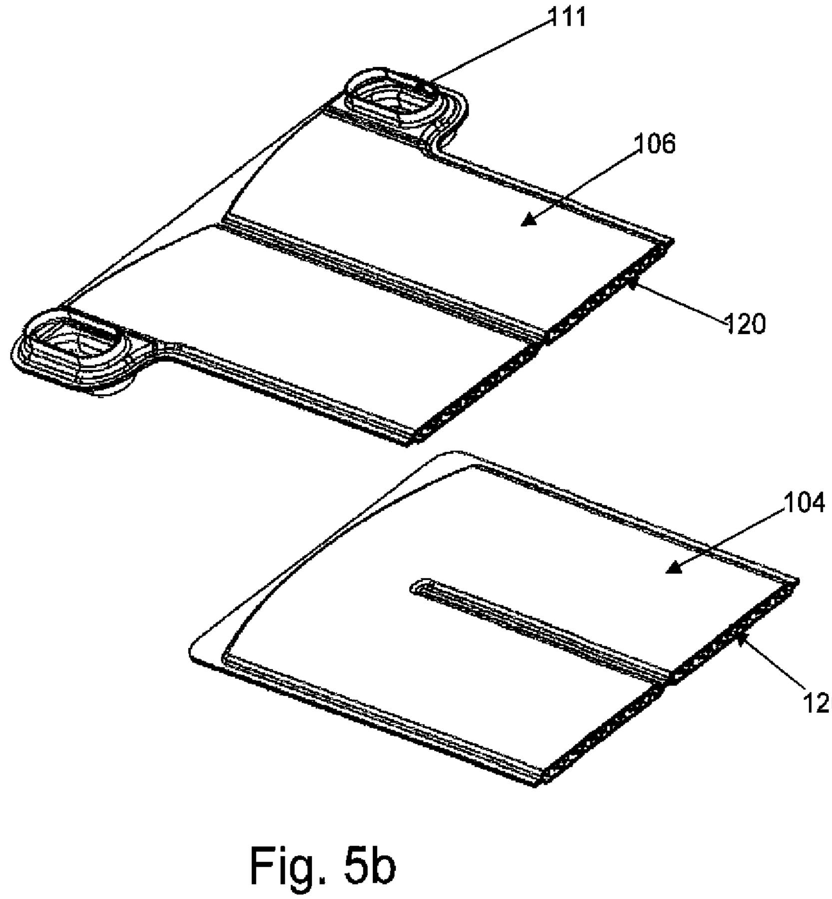
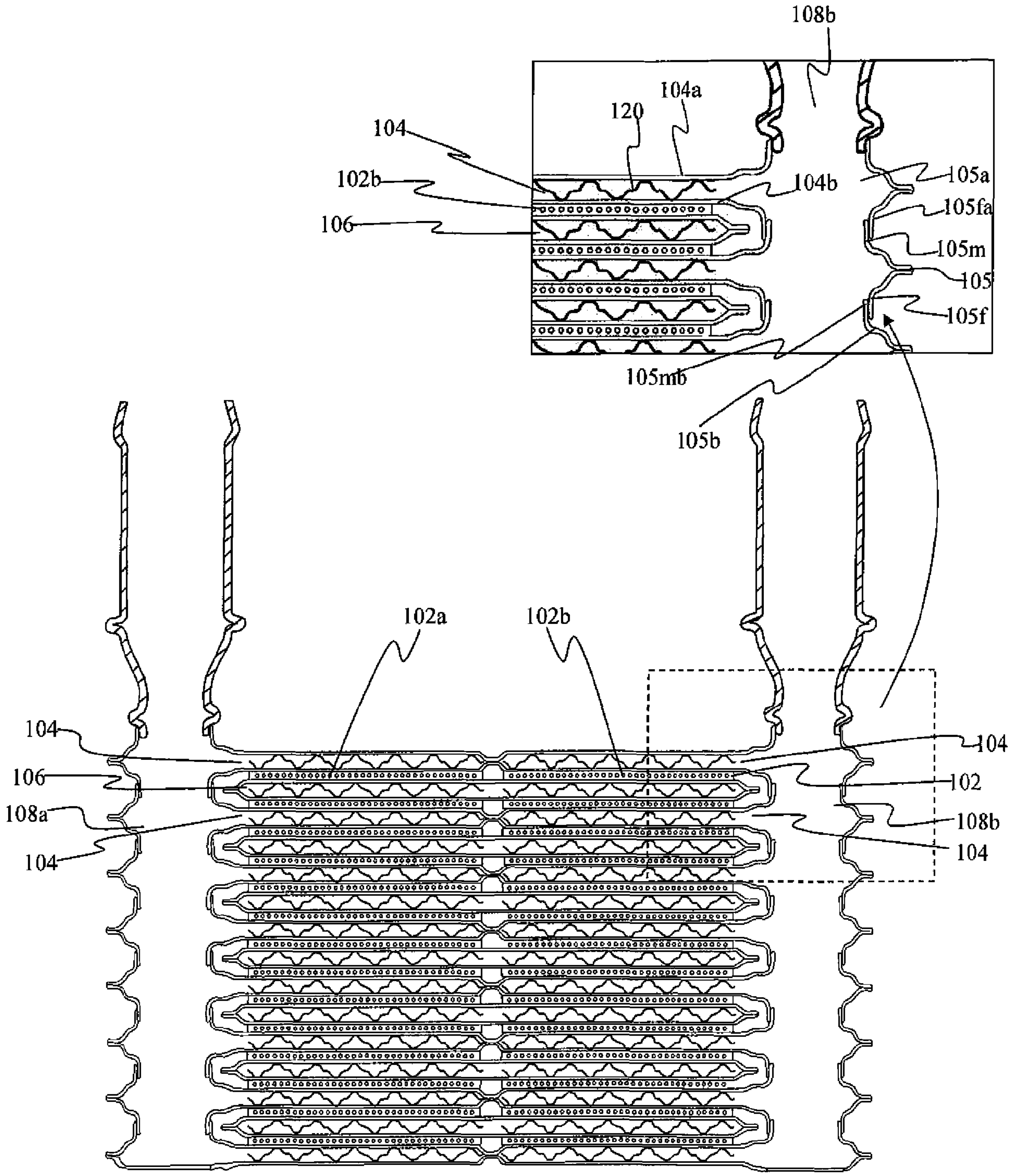


Fig. 5b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104
102b
104b
105a
105fa
106
105m
105
105f
105mb
105b
102a
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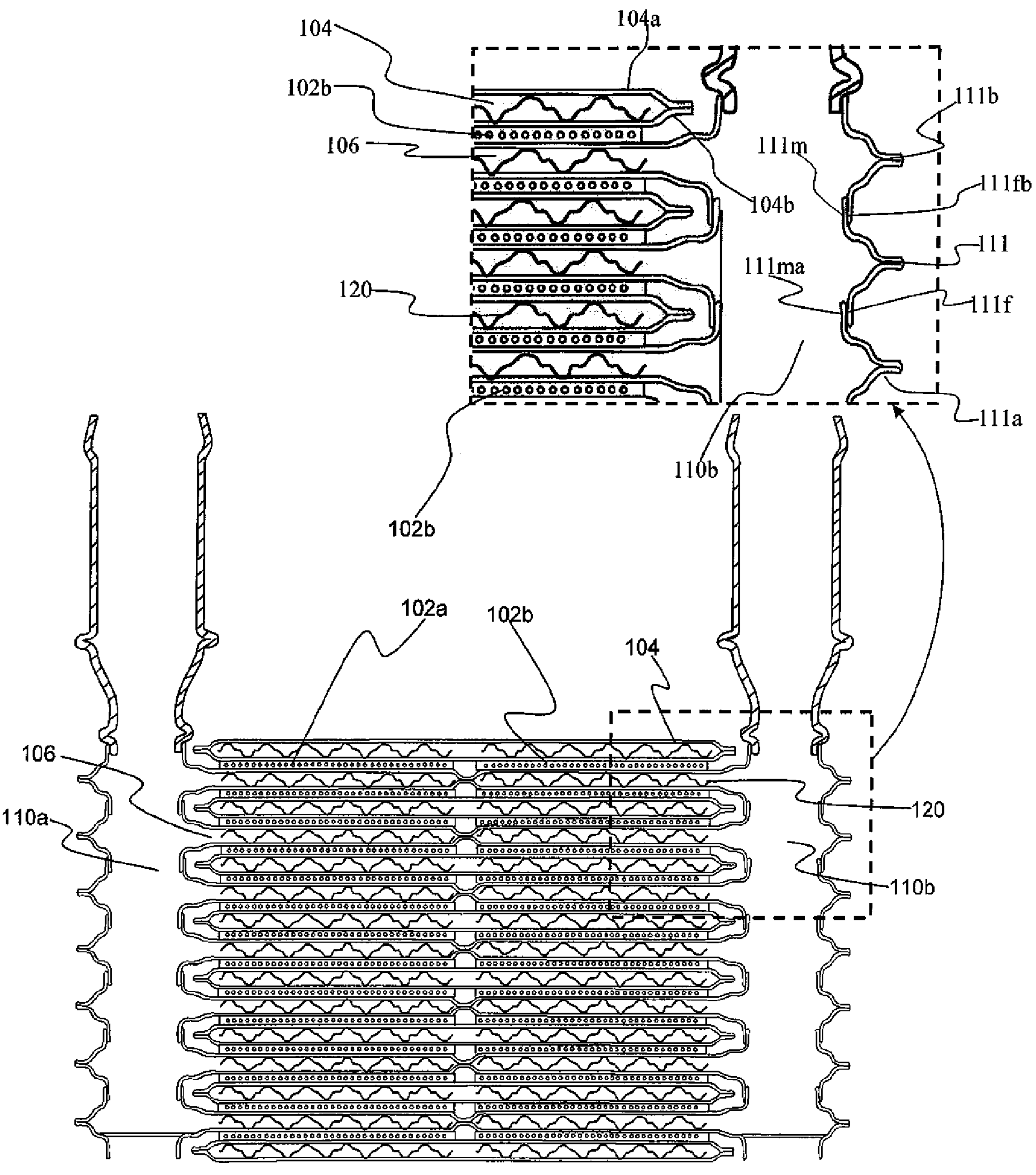
108b
104
104

Fig. 6


104
104a
102b
106
120
104b
111b
111m
111fb
111
111ma
111f
111a
110b
102b
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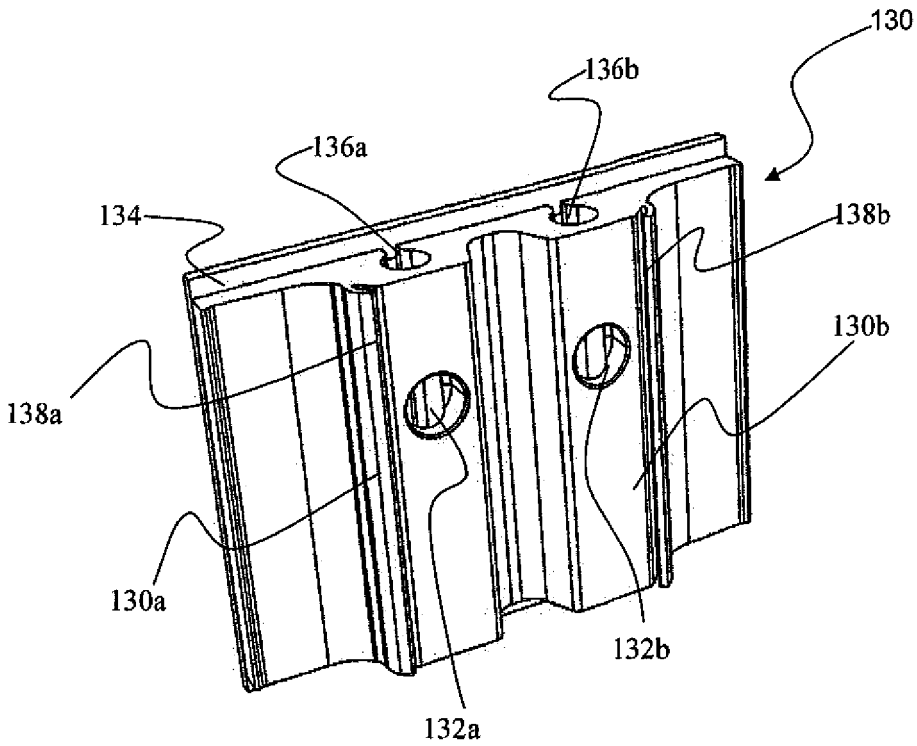
102b
104
106
110a
120
110b

Fig. 7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136a
134
138b
130b
138a
130a
132b
132a

Fig. 8a

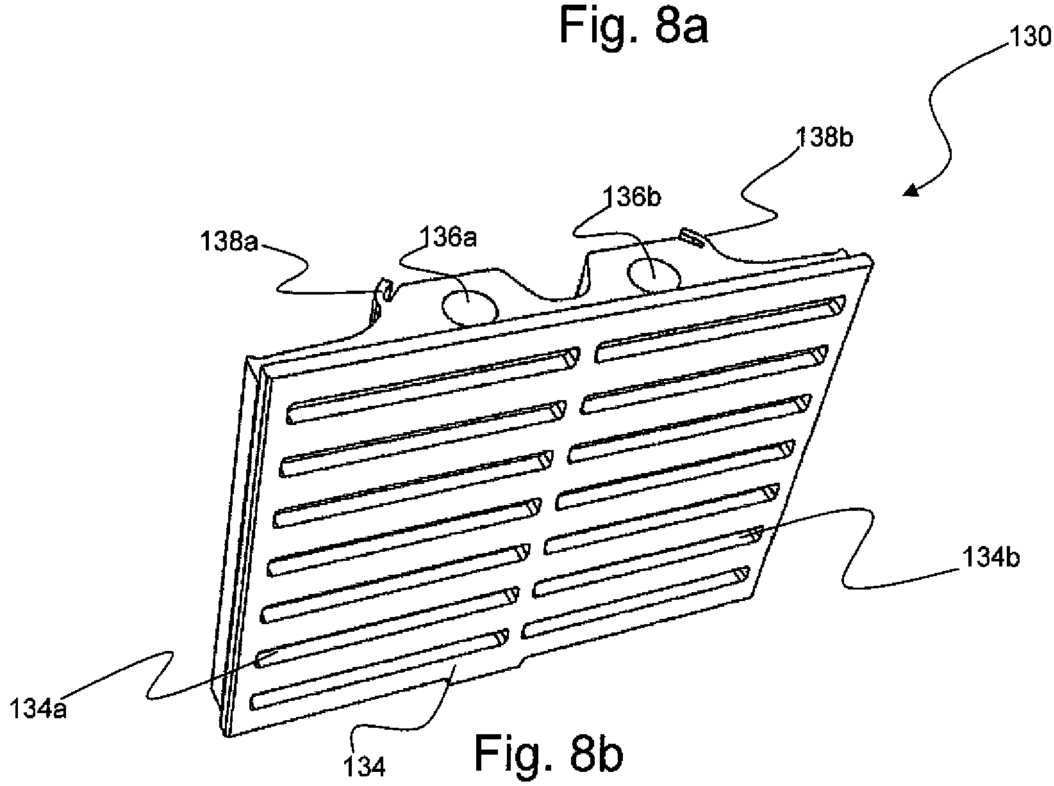
130
138b
136b
138a
136a
134b
134a
134

Fig. 8b

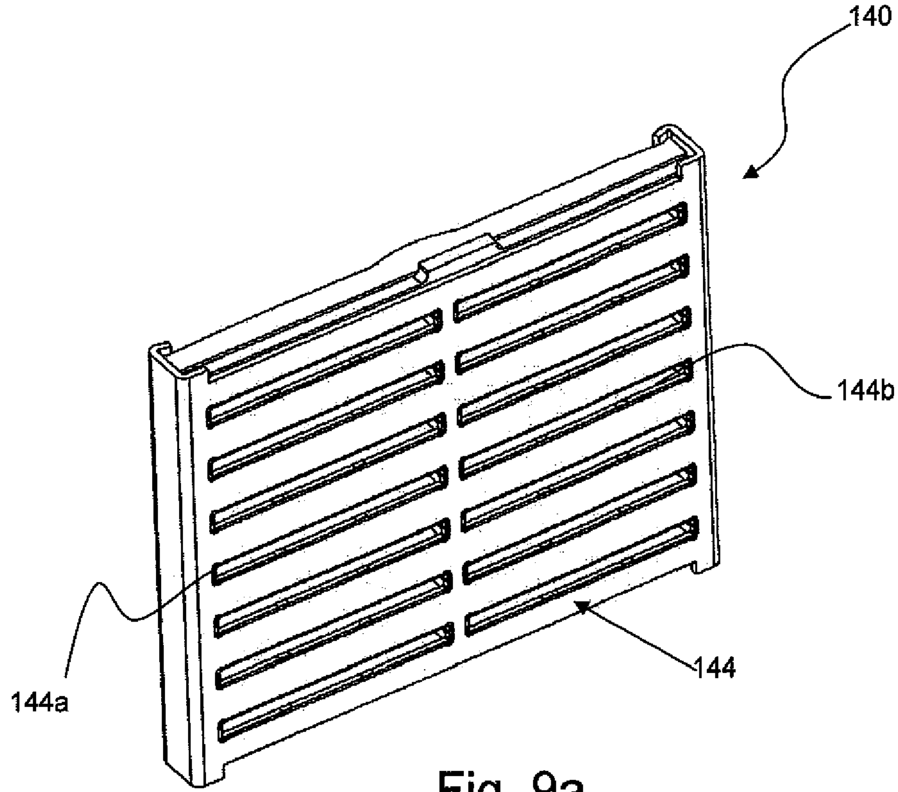

Fig. 9a

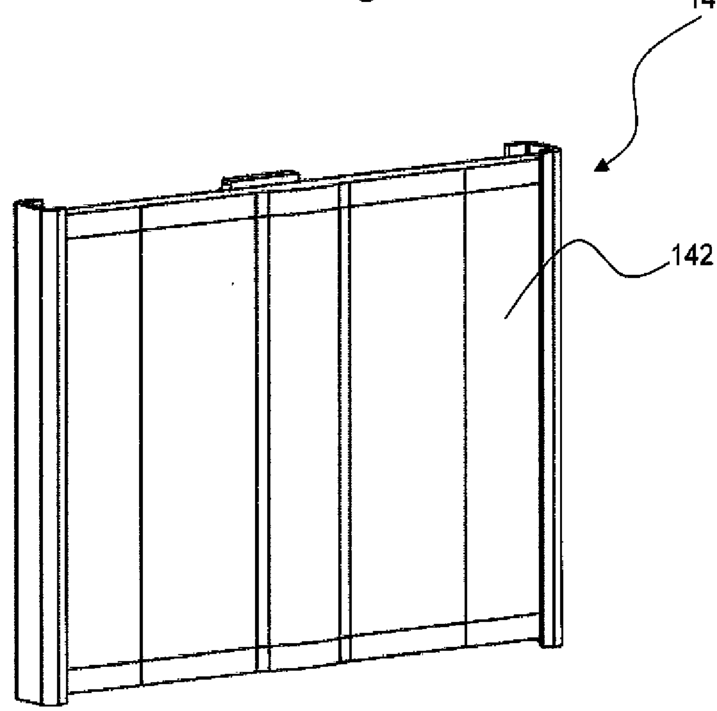

Fig. 9b

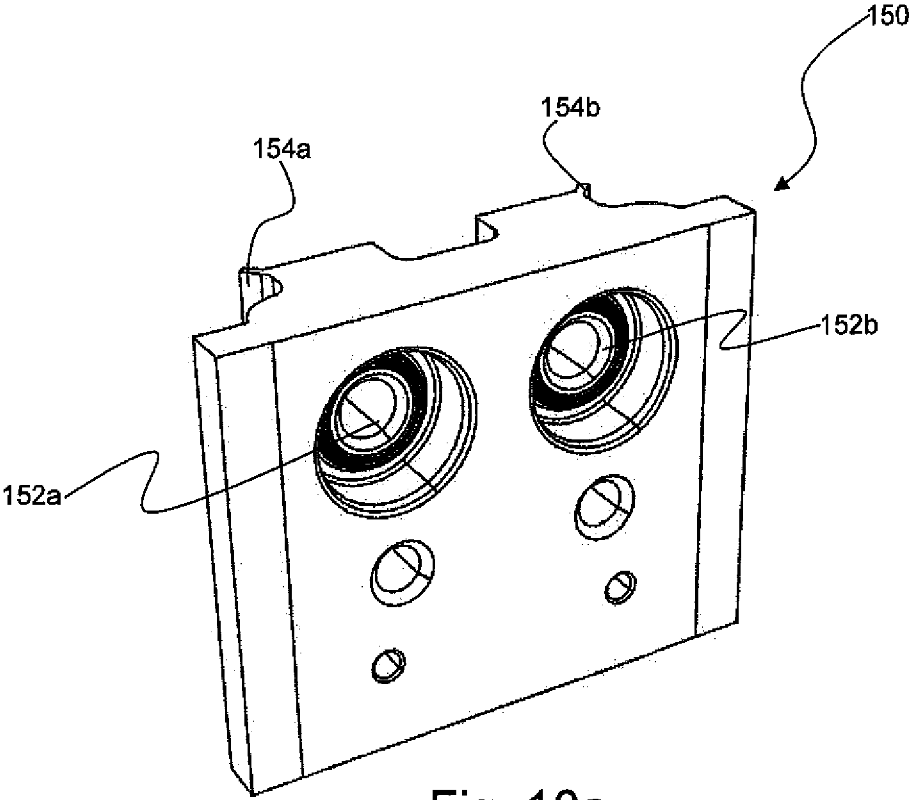

Fig. 10a

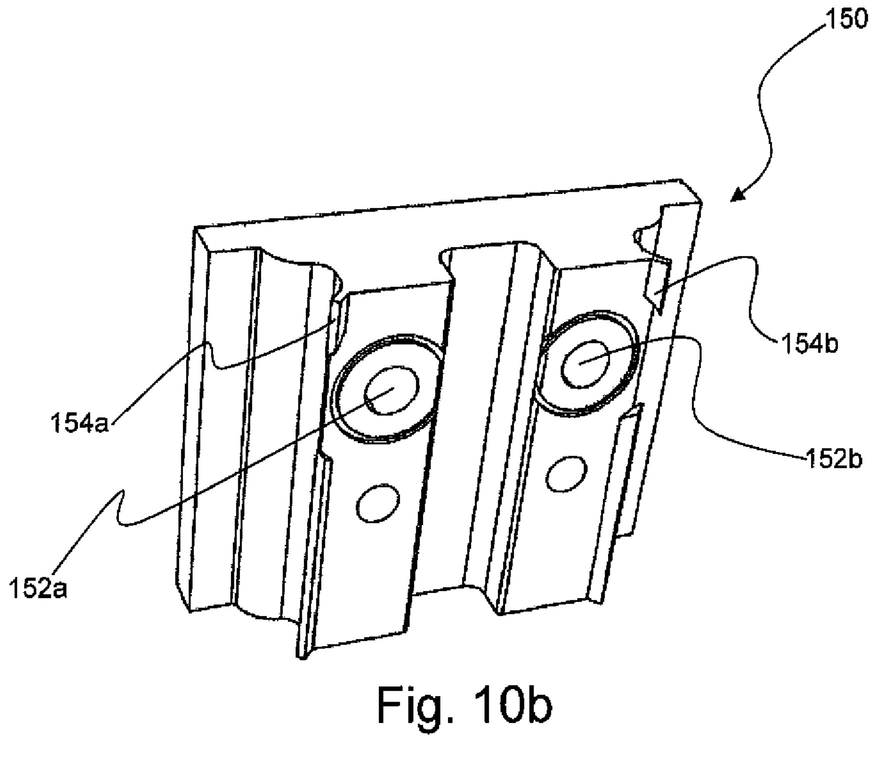

Fig. 10b

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EUROPEAN SEARCH REPORT

Application Number
EP 18 46 1648

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	7 June 2019	Bloch, Gregor

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