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(54) **MULTI-PROCESS DETACHABLE HEAT EXCHANGER AND DEDICATED HEAT EXCHANGE PLATE THEREOF**

(57) The disclosure relates to a multi-pass remova-ble plate heat exchanger without a need of arranging interfaces or connections on a mobile pressure plate, and a specific heat transfer plate therefor. The heat transfer plate has a plurality of lateral regions, where a plurality of mutually communicative lateral-pass partitions or mutually isolated pass partitions are formed with specially shaped gaskets. With such kind of heat transfer plates, a multi-pass removable plate heat exchanger without a need of arranging interfaces or nozzles on the mobile pressure plate may be constructed. The disclosure further relates to a specially shaped gasket to allow construction of a multi-pass removable plate heat exchanger without a need of arranging interfaces or nozzles on the mobile pressure plate. The multi-pass removable plate heat exchanger comprises a fixed pressure plate, a mobile pressure plate, and a plate pack where a plurality of the heat transfer plates configured with corresponding gaskets are assembled to form alternating cold and hot fluid flow channels.

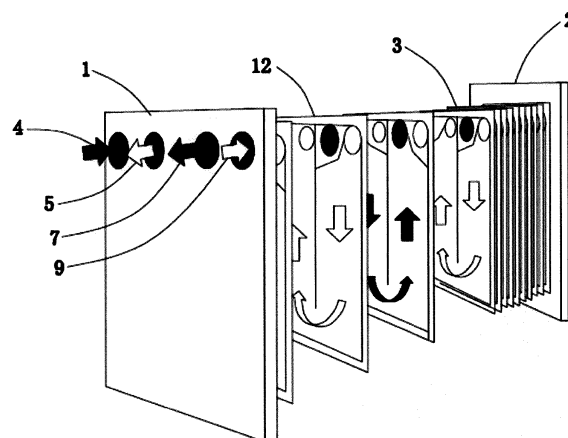


FIG. 4

Description

FIELD OF THE INVENTION

[0001] The present disclosure relates to a removable plate heat exchanger, and more specifically relates to a multi-pass removable plate heat exchanger without a need of installing connections to a mobile pressure plate side, and a dedicated heat transfer plate therefor.

BACKGROUND

[0002] A plate and frame heat exchanger is generally referred to as a plate heat exchanger (PHE), which was originated from the European food industry over 60 years ago, when there was a demand for a heat exchanger that was efficient, energy-saving, structurally compact, easy to clean, and adaptable to change of design conditions. PHEs could satisfy such initial requirements. Currently, those basic requirements are still present, and the PHEs have been widely used in various industrial fields throughout the world, e.g., refrigerating, heating and ventilation, air-conditioning, and oil cooling. Due to its characteristics such as high heat transfer efficiency, low heat loss, light-weighted and compact structure, less space demand, ease of assembly and cleaning, wide range of operating parameters, and long service life, etc., the plate heat exchanger is an ideal device for liquid-to-liquid and liquid-to-gas heat exchange. Under a same pressure loss, the plate heat exchanger has a heat transfer coefficient 3 to 5 times higher than that of a tubular heat exchanger, but with only a fraction of space requirement; besides, the heat recovery rate of the plate heat exchanger may amount to 90% above. Common plate heat exchangers available in the market are formed by stacking a series of metal sheets with certain corrugated patterns.

[0003] Variations of plate heat exchangers mainly include removable (frame) types and brazed/welded types. Profiles of heat transfer plate mainly include herringbone corrugated patterns, horizontally corrugated patterns, and dimpled patterns. The removable plate heat exchanger is the most commonly used compact heat exchanger type for heating, cooling or heat recovery in various industrial fields. The popularity of this type of exchanger is attributed to its various unique and advantageous properties, including a high heat transfer efficiency, a modular structure, ease of assembly and disassembly, convenience for cleaning and maintenance, and a high degree of flexibility in its sizing and configuration to match a particular application duty. A plate pack of a typical removable plate heat exchanger comprises a series of sequentially assembled metal sheets, where an elastic sealing gasket is installed between every two metal sheets to thereby form a hot fluid flow channel and a cold fluid flow channel that are mutually alternating and isolated. Sealing gaskets are mounted to seal corner ports and the periphery of heat transfer plates to prevent mixing of the cold and hot fluids as well as leakage of any fluid

through the periphery to the ambient. The plate pack is tightly compressed by a frame system to provide pressure bearing and sealing capabilities. The frame system comprises mainly: a front fixed pressure plate, a rear mobile pressure plate, a top carrying beam, and clamp bolts distributed around. During the assembly process, the clamp bolts are tightened to an appropriate pressure degree to secure all flow channels free from leakage, without crushing the heat transfer plates. Connections of different types and shapes are provided on the fixed pressure plate and/or the mobile pressure plate to allow the cold and hot fluid mediums to enter and exit the heat exchanger.

[0004] As shown in Fig. 1A, a conventional removable plate heat exchanger generally comprises: 1) a plate pack including a leading plate 5', an end plate 4', and a plurality of regular heat transfer plates 3'; 2) a frame system which comprise a fixed pressure plate 1', a mobile pressure plate 2', a top guide bar 6', a bottom guide bar 7', a back post 8', and a clamp bolt 9'; 3) ancillary components which comprise a lock washer 10', a fastening nut 11', a support foot 13', a roller assembly 14', and a protection board 15', etc.; and 4) four connections 16' attached to the fixed pressure plate to allow the cold and hot fluid media to enter and exit the heat exchanger. Further, as shown in Fig. 1B, the leading plate 5', the end plate 4' and the regular heat transfer plate 3' all comprise two components: a metal sheet and a sealing gasket, wherein the metal sheet is a thin metal sheet impressed with a corrugated surface, a sealing groove, and ports. The corrugated profile is the most important feature of the heat transfer plate, as the profile not only helps to intensify the heat transfer by enhancing turbulence, but also improves the rigidity of the thin sheet, thereby enhancing the pressure bearing capacity of the plate heat exchanger. The enhanced turbulence also helps to reduce formation of sediments or fouling, which creates a "self-cleaning" effect; the sealing gasket is installed in the sealing groove along the periphery of the metal sheet so as to seal the periphery between the metal sheets, thereby preventing the fluids from leaking to the external; all or some of the corner ports are sealed according to flow configurations such that the cold and hot fluids flow along their alternate channels. Additionally, the sealing gasket in port areas can be designed into a two-channel sealing structure with a draining hole leading to the ambient. The media may flow out from the draining hole in case of a leakage from the first line of sealing, thus reducing the chance of mixing of the cold and hot media. The draining hole can also serve as an early leakage warning and detection mechanism. Additionally, different glue types may be applied to the sealing gasket depending on different working media and operating temperatures.

[0005] As an important component of the plate heat exchanger, the plate pack significantly influences the overall performance and working condition of the plate heat exchanger. Therefore, the heat transfer and the cir-

culation characteristic of the removable plate heat exchanger may be adjusted and optimized by changing the following parameters: 1) geometric profiles of the heat transfer plate; 2) dimension (width and length) of the heat transfer plate; 3) dimension of the corner ports; 4) number of plates; and 5) respective numbers of flow passes for the cold and hot flow channels. It needs to be particularly noted that the flow pass and the flow channel in the art are two technical terms associated with each other but having different meanings. The flow pass refers to a group of parallel channels where any given medium flows in the same direction, while the flow channel refers to a medium flow channel formed by two adjacent sheets inside the plate heat exchanger. Generally, a plurality of flow channels are connected in parallel or in series to form different combinations of cold and hot medium channels. Based on the definitions above, it is seen that Fig. 1A shows a single pass design of the removable plate heat exchanger, and Fig. 1B represents, by arrows, the flow directions of respective cold and hot fluids, wherein in the single pass design, the cold and hot fluids flow in opposite directions, thereby generating more favorable temperature profiles for heat transfer. Because the connections for a "U"-shaped single pass are all attached to the fixed pressure plate and meanwhile the inlet and outlet piping for a same fluid are configured in parallel, engineering installation is simplified, which facilitates easy disassembly and assembly. It needs to be particularly noted that the rear end plate 4' and the leading plate 5' are not only different from the heat transfer plate 3' in terms of quantity, but also different from the heat transfer plate 3' in terms of the shape of sealing gasket. For example, due to the structural requirement, the sealing gasket s of the leading plate 5' as shown in Fig. 1B need to seal all of the four corner ports, while the sealing gasket of a common heat transfer plate 3' only seals some of the corner ports; in addition, the four corner ports of the rear end plate 4' do not penetrate through the metal thin sheet, while the corner ports of the common heat transfer plate 3' have to penetrate through the metal thin sheet. To simplify illustration and to highlight the technical contributions of the present disclosure, the rear end plate, the leading plate, and the heat transfer plate will not be specifically distinguished unless confusion is otherwise caused, but are generally referred to as a heat transfer plate.

[0006] To satisfy a heat transfer duty that requires an extremely high heat recovery efficiency at a very small temperature difference, a heat transfer plate with a relatively high aspect ratio is needed. However, a maximum length of the heat transfer plate is limited to a feasible aspect ratio, because if the heat transfer plate has too high an aspect ratio, the heat exchanger becomes unstable in structure and spatially less optimized for installation; therefore, the height of the heat transfer plate is more frequently limited by the available height for installing the device. This limitation may be alleviated by designing a multi-pass heat exchanger, such that the cold

and hot fluids are turned into opposite directions by a stopper plate in each flow channel. Theoretically, varying the number of flow passes may satisfy the need of any efficient heat transfer duty; multi-pass design is required particularly for industrial applications with a low flow rate or a close approach temperature. Fig. 2 shows a schematic structure and the working principle of a conventional three-pass removable plate heat exchanger. The heat exchanger comprises a plate pack 3, a fixed pressure plate 1, and a mobile pressure plate 2. The cold fluid enters the heat exchanger from a cold fluid inlet connection 4 attached to the fixed pressure plate 1, flows upwards in the first flow pass, flows downwards in the second flow pass, and flows upwards again in the third flow pass, and finally flows out of the heat exchanger from a cold fluid outlet connection 7 on the mobile pressure plate 2. Likewise, the hot fluid flows in from a hot fluid inlet connection 9 attached to the mobile pressure plate 2, flows reversely through the three passes, and then flows out of the heat exchanger via a hot fluid outlet connection 5 attached to the fixed pressure plate 1.

[0007] In a conventional multi-pass heat exchanger, the plate pack is divided into a plurality of sections between the fixed pressure plate and the mobile pressure plate. A stopper plate 6 is mounted between two adjacent sections to force a fluid to change its flow direction between passes. The stopper plate 6 differs from a regular heat transfer plate 3 in that two corner ports of the stopper plate 6 are blocked. Despite of the many advantages, conventional multi-pass designs have a number of problems and inconveniences in practical applications. As shown in Fig. 2, a conventional multi-pass design always needs to install a cold fluid outlet connection 7 and a hot fluid inlet connection 9 on the mobile pressure plate 2. In other words, the inlet and outlet connections for the cold and hot fluid, respectively, have to be attached to the opposite ends of a multi-pass heat exchanger. Therefore, for maintenance and cleaning, it is needed to loosen the mobile pressure plate 2 to open the plate pack in order to gain access to each heat transfer plate. However, because one end of the mobile pressure plate 2 is physically attached to the connections for the cool/hot fluids, it is required to first disconnect the fluid piping 8 and 10 connected to the mobile pressure plate 2. This makes the installation and maintenance cumbersome, time-consuming, and costly. This is why a multi-pass configuration design scheme is often excluded from actual applications, despite of the obvious advantages in thermal performance.

[0008] Further, as shown in Fig. 2, due to the working principle of the conventional multi-pass design, the flow directions of the cold and hot fluid flow channels at the opposite sides of each stopper plate 6 are in co-current flows (local co-currency) 11. Such local co-current flows 11 deteriorate to a certain extent the overall heat transfer efficiency of the heat exchanger. In additional, the conventional multi-pass design needs a series of flow reversal, compression, expansion, and re-distribution in

the port area of each stopper plate, which causes an additional flow pressure drop. Although there are increasing demands on efficient heat exchangers in industrial applications geared towards environment protection, energy saving, and energy recovery, their wider applications are hindered by the above drawbacks of the conventional multi-pass plate heat exchangers, particularly by the inconveniences in the installation and maintenance process due to the existence of piping and connections on the mobile pressure plate.

SUMMARY OF THE PRESENT INVENTION

[0009] To solve various problems existing in the prior art, and particularly to overcome the technical limitations in the prior art that connections need to be arranged at two opposite ends of a heat exchanger with a multi-pass design, the present disclosure provides a novel structure and design of a multi-pass heat transfer plate, which allows for more efficient and easier maintenance process, by allowing multi-pass removable plate heat exchanger without the need of arranging connections on a mobile pressure plate.

[0010] To address some performance drawbacks and operational inconvenience in use of a conventional multi-pass plate heat exchanger described above, the present disclosure further provides a novel heat transfer plate construction, which has an equivalent or better heat transfer performance compared with a traditional multi-pass plate, but without key drawbacks of the traditional multi-pass plate heat exchanger.

[0011] Specifically, the present disclosure provides a heat transfer plate for a multi-pass removable plate heat exchanger. The heat transfer plate has a plurality of lateral partitions, where a plurality of mutually communicative lateral-pass partitions or mutually isolated longitudinal pass partitions may be formed by specially shaped gaskets. With this novel type of heat transfer plates, a multi-pass removable plate heat exchanger without a need of arranging connections at the mobile pressure plate may be constructed. The present disclosure further provides a specially shaped and constructed gasket to implement a multi-pass removable plate heat exchanger without a need of arranging connections at the mobile pressure plate.

[0012] According to one of the technical solutions of the present disclosure, a multi-pass removable plate heat exchanger can be implemented, which comprises: a fixed pressure plate, a mobile pressure plate, and a plate pack sandwiched between the fixed pressure plate and the mobile pressure plate via clamp bolts. The plate pack further comprises a plurality of lateral-pass plates configured with specially shaped sealing gaskets to form two or more successively communicating lateral partitions. The lateral-pass plates are assembled to form the plate pack with mutually alternating cold and heat fluid flow channels, the number of passes on the multi-pass removable plate heat exchanger being equal to the number

of lateral partitions on each lateral-pass plate.

[0013] Preferably, in the multi-pass removable plate heat exchanger according to the technical solution above, connections are only arranged on the fixed pressure plate, without a need of arranging connections on the mobile pressure plate.

[0014] Preferably, in the multi-pass removable plate heat exchanger according to the technical solution above, the lateral-pass plate may typically have two, three, or four lateral partitions.

[0015] According to another technical solution of the present disclosure, a multi-pass removable plate heat exchanger can be implemented, which comprises: a fixed pressure plate, a mobile pressure plate, and a plate pack sandwiched between the fixed pressure plate and the mobile pressure plate via clamp bolts. The plate pack further comprises one section of two-zone lateral-pass plates, and (N-1) sections of two-zone lateral-partition plates. Each two-zone lateral-pass plate is configured with specially shaped sealing gaskets to form two mutually communicating lateral partitions. Each two-zone lateral-partition plate is configured with specially shaped sealing gasket to form two mutually isolated lateral partitions. The section of two-zone lateral-pass plates is allocated immediately adjacent to the mobile pressure plate to force both hot fluid and cold fluids to make a U-turn, while (N-1) sections of two-zone lateral-partition plates are arranged adjacent to the fixed pressure plate. The thus assembled plate pack creates mutually alternating cold and heat fluid flow channels, where each fluid enters the heat exchanger via the fixed pressure plate, flows towards the mobile pressure plate along one side of the partition, makes a U-turn upon reaching the mobile pressure plate, and then flows back along the other side of the partition, and lastly exits the heat exchanger via the fixed pressure plate. The total number of passes achieved in this novel type of the multi-pass removable plate heat exchanger is equal to 2N, where N is a natural number greater than or equal to 2.

[0016] Preferably, in the multi-pass removable plate heat exchanger according to the technical solution above, connections are only arranged on the fixed pressure plate, without a need of arranging connections on the mobile pressure plate.

[0017] Preferably, in the multi-pass removable plate heat exchanger according to the technical solution above, the sections with lateral-pass plates are allocated immediately adjacent to the mobile pressure plate, and while the remaining sections of lateral-partition plates are allocated adjacent to fixed pressure plate to achieve the remaining flow passes.

[0018] According to a further technical solution of the present disclosure, a lateral-pass plate specific for the novel type of multi-pass removable plate heat exchanger is provided, wherein the heat transfer plate is a lateral-pass plate, wherein flat groove patterns are provided at the periphery and in the interior of the lateral-pass plate for configuring sealing gaskets to thereby form two or

more successively communicative lateral partitions.

[0019] According to a further technical solution of the present disclosure, a lateral-partition plate specific for the novel type of multi-pass removable plate heat exchanger is provided, wherein the heat transfer plate is a lateral-partition plate, wherein flat groove patterns are provided at the periphery and in the interior of the lateral-partition plate for configuring sealing gaskets to thereby form two or more mutually isolated lateral partitions

[0020] Preferably, in the heat transfer plate specific for the novel type of multi-pass removable plate heat exchanger according to the technical solution above, the heat transfer plate may possess different thermal-hydraulic performance characteristics through variations in geometrical profiles, wherein heat transfer plates with different geometrical profiles may also be arranged in a hybrid fashion within the same plate pack to form a mixed plate pack.

[0021] Preferably, in the heat transfer plate specific for the novel type of multi-pass removable plate heat exchanger according to the technical solution above, the geometrical profile variations may include, but not limited to chevron corrugation angles, circular or irregular dimples, studs, or other structures with the effect of enhancing heat transfer efficiency.

[0022] Preferably, in the heat transfer plates specific for the novel type of multi-pass removable plate heat exchanger according to the technical solution above, sealing and/or partitioning functionalities of the sealing gaskets may be partially or completely replaced by other seal structures or mechanisms.

[0023] Preferably, in the heat transfer plate specific for the novel type of multi-pass removable plate heat exchanger according to the technical solution above, the other seal structures or mechanisms may include, but not limited to brazing, welding, diffusion bonding or mechanical contact sealing.

[0024] According to a further technical solution of the present disclosure, a sealing gasket specific for the lateral-pass plate is provided, wherein the sealing gasket is situated inside flat grooves provided at the periphery and in the interior of the lateral-pass plate, such that the lateral-pass plate is formed with two or more lateral partitions that are successively in communication.

[0025] According to a further technical solution of the present disclosure, a sealing gasket specific for the lateral-partition plate is provided, wherein the sealing gasket is situated within flat grooves provided at the periphery and in the interior of the lateral-partition plate, such that the lateral-partition plate is formed with two or more lateral partitions that are mutually isolated.

[0026] Compared with conventional single-pass designs and conventional multi-pass designs, the multi-pass removable plate heat exchanger (PHE) constructed according to the present disclosure has the following advantages:

[0027] Improved maintainability: because no connections are arranged at the mobile pressure plate side, the

multi-pass heat exchanger according to the present disclosure may be easily disassembled for cleaning and repair like a conventional single-pass heat exchanger;

[0028] Increased effective heat transfer area: because i) with fewer corner ports in lateral-pass plate, the percentage of non-heat transfer area is reduced; ii) with decreased peripheral length of the heat transfer plates, heat loss through the external area in direct contact with the ambient is reduced; iii) internal gasket grooves can be made very narrow, which reduces loss in effective heat exchange areas;

[0029] Improved overall heat transfer efficiency: With lateral-pass plates, multiple pass heat exchanger can be formed without occurrence of local co-currency between each neighboring pass as present in conventional multi-pass designs, and the overall heat transfer efficiency of the heat exchanger is improved;

[0030] Reduced flow pressure drop: because the turn of flow direction on a lateral-pass plate is relatively gentle and the fluid velocities are substantially constant during each lateral turn, there is no apparent compression and expansion in distribution areas, and the additional pressure drop due to directional turn associated with multiple passes is smaller;

[0031] Reduced heat loss from the ambience: because the interface area with the ambient for the same heat transfer area is reduced, the heat loss of the entire heat exchanger is reduced;

[0032] More compact structure: due to the small aspect ratio of each heat transfer plate, the overall shape of the heat exchanger tends to be cubic, such that the space requirement for the same amount of total heat transfer area can be substantially reduced;

[0033] Overall more efficient heat exchanger: due to various advantages above, a multi-pass heat exchanger that is thermally more efficient and easier-to-maintain may be constructed according to the present disclosure, thereby satisfying the demand of more efficient and more easy-to-service heat exchangers in a wide range of applications such as energy recovery, process isolation, and pressure breaker, etc.

[0034] The features, working principles, and other advantages of the present disclosure will become apparent through further illustration in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0035] Hereinafter, the present disclosure will be described through examples with reference to the accompanying drawings, wherein:

Fig. 1A is a structural exploded view of a single-pass removable plate heat exchanger according to the prior art;

Fig. 1B is a structural schematic diagram of various kinds of heat transfer plates formed by metal sheets and sealing gaskets in Fig. 1A;

Fig 2 is a schematic diagram of the working principle of a conventional three-pass removable plate heat exchanger that requires connections on the mobile pressure plate;

Fig. 3A is a schematic diagram of the working principle of a lateral-pass plate having two lateral partitions using a hot side flow channel as an example according to an embodiment of the present disclosure;

Fig. 3B is a schematic diagram of the working principle of a lateral-pass plate having two lateral partitions using a cold side flow channel as an example according to an embodiment of the present disclosure;

Fig. 4 is a simplified structural exploded view of a two-pass removable plate heat exchanger without a need of arranging connections on mobile pressure plate according to an embodiment of the present disclosure;

Fig. 5A is a schematic diagram of the working principle of a lateral-pass plate having three lateral partitions using a hot side flow channel as an example according to an embodiment of the present disclosure;

Fig. 5B is a schematic diagram of the working principle of a lateral-pass plate having three lateral partitions using a cold side flow channel as an example according to an embodiment of the present disclosure;

Fig. 6A is a schematic diagram of the working principle of a lateral-partition plate having two lateral partitions using a hot side flow channel as an example according to an alternative embodiment of the present disclosure;

Fig. 6B is a schematic diagram of the working principle of a lateral-partition plate having two lateral partitions using a cold side flow channel as an example according to an alternative embodiment of the present disclosure; and

Fig. 7 is an exploded view of a simplified structure of a six-pass removable plate heat exchanger without a need of arranging connections at a mobile pressure plate side according to an alternative embodiment of the present disclosure.

DETAILED DESCRIPTION

[0036] Hereinafter, the technical contents, structural features, and achieved technical objects and effects of the preferred embodiments of the present disclosure will be illustrated in detail with reference to the accompanying drawings.

[0037] The present disclosure overcomes the following technical bias regarding a multi-pass plate heat exchanger: the multi-pass plate heat exchanger needs to arrange inlet and outlet interfaces for cold and hot fluids, as well as the connections therefor, at two opposite sides of the fixed pressure plate and mobile pressure plate of a heat

exchanger. This technical bias is extensively seen in prior technical literatures describing multi-pass heat exchangers, but the Inventor of the present disclosure fundamentally overthrows this technical bias through innovative technical solutions. A heat transfer plate for a multi-pass removable plate heat exchanger according to the present disclosure has a plurality of lateral partitions, which, in combination with specially shaped gaskets, may form a plurality of communicative flow channels or mutually isolated flow channels. In contrast with the dedicated heat transfer plate of the present disclosure, the heat transfer plate in the prior art does not have a plurality of mutually communicative or isolated lateral partitions, which is an integral zone for circulating cold and hot fluids.

[0038] According to a preferred embodiment of the present disclosure, a key component for solving the technical problem of a conventional multi-pass plate heat exchanger is a heat transfer plate having a plurality of lateral partitions. These lateral partitions are further fitted with specially shaped sealing gaskets, such that a plurality of mutually communicative lateral-pass flow channels may be implemented between two adjacent plates, and such a special heat transfer plate may be referred to as a lateral-pass plate. Further, with the lateral-pass plate of the present disclosure, a multi-pass plate heat exchanger without a need of arranging connections on the mobile pressure plate may be built, the number of its passes corresponding to the number of lateral partitions on each lateral-pass plate. The working principle of the lateral-pass plate of the present disclosure is described below.

[0039] Fig. 3A shows a lateral-pass plate having two lateral partitions using a hot side flow channel as an example; Fig. 3B shows a lateral-pass plate with two lateral partitions using a cold side flow channel as an example. Different from Fig. 1B where four corner ports of a conventional heat transfer plate are fixedly disposed at the upper and lower two ends of the plate, the positions of the four corner ports of the lateral-pass plate 12 of the present disclosure varying with different numbers of passes. As shown in Fig. 3A, a hot fluid 15 flows into a right-side partition of the heat transfer plate 12 from a hot side inlet corner port 14 at the upper right corner. Elastic sealing gaskets 16 are mounted in a gasket groove at a periphery of a metal sheet of the lateral-pass plate 12 to seal the periphery between metal sheets for preventing leakage of the fluid to the external, and to seal relevant corner ports according to flow configurations such that the cold and hot fluids flow along respective flow channels, thereby preventing the hot fluid 15 from contacting with the cold side fluid flowing through an adjacent cold side corner port 13. The sealing gaskets 16 and inner partition gaskets 17 guide the hot fluid 15 to flow towards a bottom portion of the sheet. Inner partition gaskets 17 and an opening 18 between peripheral gaskets let the hot fluid 15 to laterally flow towards the left partition of the heat transfer plate. Next, the hot fluid 15 further flows upwards from here and finally flows out of the hot side outlet corner port 19; likewise, the elastic sealing gasket

16 may prevent the hot fluid 15 from contacting with the cold side fluid flowing through a neighboring cold side corner port. It needs to be noted that compared with the stopper plate 6 shown in Fig. 2 as the prior art, the opening 18 that changes the pass direction has a relatively gentle turn of flow direction; and the fluid velocity is substantially constant during direction turn, wherein there is no apparent compression and expansion of fluids through the distribution area; therefore, the increase in pressure drop due to direction turn of multiple passes is relatively small.

[0040] The pass for the cold side fluid as shown in Fig. 3B is just opposite to the pass for the hot side fluid as shown in Fig. 3A. As shown in Fig. 3B, the cold fluid 20 flows into the left side partition of the heat transfer plate from the cold side inlet corner port 21 at the upper left corner. Likewise, the elastic sealing gaskets 16 are configured for preventing the cold fluid 20 from contacting with the hot side fluid flowing through a neighboring hot side corner port. The sealing gaskets 16 and inner partition gaskets 17 guide the cold fluid 20 to flow towards a bottom portion of the sheet. The inner partition gaskets 17 and the opening 18 between peripheral gaskets let the cold fluid 15 to laterally flow towards a right-side partition of the sheet. Next, the cold fluid 20 flows upwards from here and finally flows out of the cold side outlet corner port 22. According to the present disclosure, because the circulating areas of the cold and hot fluids are identical but have completely opposite flow directions, a complete counter-current flow configuration is achieved, which in turn leads to a maximal heat transfer potential.

[0041] Fig. 4 shows an exploded view of a simplified structure of a two-pass heat exchanger using the lateral-pass plate having two lateral partitions as shown in Fig. 3. As shown in Fig. 4, the heat exchanger comprises a fixed pressure plate 1, a mobile pressure plate 2, and a plate pack sandwiched between the fixed pressure plate 1 and the mobile pressure plate 2 via clamp bolts, the plate pack being further assembled by a series of lateral-pass plates 12 having two lateral partitions. Additionally, those skilled in the art may understand that the heat transfer plates as the rear end plate and the leading plate may be regarded as specially shaped lateral-pass plates 12, and their sealing gaskets and corner port structures may be configured correspondingly as shown in Fig. 1 according to needs. As shown in Fig. 4, each lateral-pass plate 12 itself is used for implementing a lateral U-turn of the flow direction, thereby allowing the hot side and cold side fluid inlet and outlet connections 4, 5, 7, and 9 to be solely arranged at the fixed pressure plate 1 side, such that it is unnecessary to arrange any connections at the mobile pressure plate 2 side; in this way, the multi-pass removable plate heat exchanger according to the present disclosure is as convenient as the conventional single-pass heat exchanger in terms of mounting, piping, assembling, disassembling and maintenance.

[0042] The lateral-pass plate having two lateral partitions according to the present disclosure may be easily

extended to other multi-pass arrangements, e.g., theoretically, the number of lateral partitions of each lateral-pass plate may be increased to 3 or 4 or higher dependent on operating duties. In actual industrial applications, a lateral-pass plate having two to four lateral partitions is possibly the most practical and most economical. Fig. 5A shows a structure and the working principle of a lateral-pass plate having three lateral partitions using a hot flow channel as an example according to an embodiment of the present disclosure; Fig. 5B shows a structure and the working principle of a lateral-pass plate having three lateral partitions using a cold flow channel as an example according to an embodiment of the present disclosure. To those skilled in the art, the structure and the working principle of the lateral-pass plate with three lateral partitions may be easily understood based on the above detailed depiction of the lateral-pass plate with two lateral partitions with reference to Fig. 5A and Fig. 5B, which are thus not detailed herein. Further, those skilled in the art can easily understand that a three-pass heat exchanger using a lateral-pass plate with 3 lateral partitions as shown in Fig. 5 likewise allows the hot side and cold side fluid inlet and outlet connections to be all arranged at the fixed pressure plate side, such that it is unnecessary to arrange any connections to the mobile pressure plate side.

[0043] As mentioned above, because the number of passes of the multi-pass heat exchanger that only uses lateral-pass plates corresponds to exactly the number of lateral partitions on each lateral-pass plate, it may be understood that the number of passes of the plate heat exchanger manufactured according to the above embodiments of the present disclosure increases in a lateral direction. Although the number of passes may arbitrarily increase to any number in the lateral direction theoretically, the lateral-pass plate with 2, 3, or 4 lateral-pass partitions is likely most practical and economical due to unfavorable dimension increase in horizontal direction at higher pass numbers; in other words, the number of passes of the plate heat exchanger employing lateral-pass plates is preferably 2 to 4. In view of the above, the Inventor of the present disclosure further provides an alternative embodiment based on a combined implementation of lateral-pass plates and lateral-partition plates, such that the number of passes of the multi-pass plate heat exchanger manufactured by the present disclosure may increase without limitation. Hereinafter, this alternative embodiment of the present disclosure will be specifically described.

[0044] Fig. 6A and Fig. 6B show a construction structure and a working principle of the heat transfer plate in this alternative embodiment, wherein Fig. 6A shows a heat transfer plate having two lateral partitions using a hot flow channel as an example according to an alternative embodiment of the present disclosure; Fig. 6B shows a heat transfer plate having two lateral partitions using a cold flow channel as an example according to an embodiment of the present disclosure. As shown in the figures,

this alternative embodiment uses a same heat transfer plate, but arrangements of corner ports and the shapes of sealing gaskets are slightly different; particularly, the internal partition gasket 17 extends through the entire length of the pass, such that the lateral flow of the fluid is completely blocked. This alternation is referred to in the present disclosure as a lateral-partition plate, which has two mutually isolated longitudinal pass partitions. From this point of view, it is prominently different from the lateral-pass plate, which has two or more mutually communicative lateral partitions. Additionally, the cold and hot flow channels in each longitudinal pass partition of the lateral-partition plate as shown in Fig. 6A and Fig. 6B are identical to the two conventional heat transfer plates 3' shown in Fig. 1B, which are thus not detailed here.

[0045] By using the two-zone lateral-pass plate shown in Fig. 3 and the lateral-partition plate shown in Fig. 6 in combination, a higher number of passes meeting demanding thermal duty requirements can be implemented, e.g., 4, 6, 8, 10 or any even number of passes. It needs to be noted that because each heat transfer plate has two partition passes, the number of passes achievable for the entire heat exchanger can be viewed as any number, without being limited to even number only, if each heat transfer plate is used as the reference. In a heat exchanger with such a high number of passes, the lateral-pass plates shown in Fig. 3 are to be situated adjacent to the mobile pressure plate side, while the remaining passes using the lateral-partition plates shown in Fig. 6 are to be situated adjacent to the fixed pressure plate. Actually, the lateral-pass plate in this multi-pass construction allows the cold and hot fluids to make a 180° U-turn upon reaching the mobile pressure plate so as to avoid the need of having any connections on the mobile pressure plate.

[0046] Fig. 7 shows a structure and the working principle of a six-pass removable plate heat exchanger according to an alternative embodiment of the present disclosure. As illustrated in Fig. 7, the heat exchanger comprises a fixed pressure plate 1, a mobile pressure plate 2, and a plate pack 3 sandwiched between the fixed pressure plate 1 and the mobile pressure plate 2 via clamp bolts, wherein the plate pack 3 further comprises one section of two-zone lateral-pass plates for the two passes (third and fourth passes) directly adjacent to the mobile pressure plate, and two sections of lateral-partition plates for the remaining other passes (first and sixth passes, and second and fifth passes). Hot side and cold side fluid inlet and outlet connections 4, 5, 7, and 9 are all arranged on the fixed pressure plate 1, such that it is unnecessary to arrange any connections on the mobile pressure plate 2. Hereinafter, the working principle of the six-pass removable plate heat exchanger is illustrated using a hot side flow channel as an example, where the hot fluid enters the heat exchanger from the hot fluid inlet connection 9 on the fixed pressure plate 1, and the first pass and the second pass are implemented via lateral-partition plates,

where the first pass flows upwardly and the second pass flows downwardly; next, the third pass and the fourth pass are implemented via the two-zone lateral-pass plate, where the third pass flows upwardly, and the fourth pass flows downwardly; finally, the fifth pass and the sixth pass are implemented via the lateral-partition plates shared with the second pass and the first pass, respectively, wherein the fifth pass flows upwardly and the sixth pass flows downwardly; and finally, the hot fluid flows out of the heat exchanger from a hot fluid outlet connection 5 on the fixed pressure plate 1. The cold side fluid flow channel is reverse to the hot side fluid flow channel.

[0047] As shown in Fig. 7, the lateral-pass plates are only used in the third and fourth passes immediately adjacent to mobile pressure plate side, while the lateral-partition plates are used in other passes; in this alternative multi-pass design, the lateral-pass plate is for facilitating a longitude U-turn of the flow direction, to allow the hot side and cold side fluid inlet and outlet connections 4, 5, 7, and 9 to be all arranged on the fixed pressure plate 1, such that it is unnecessary to arrange any connections on the mobile pressure plate 2; in this way, the multi-pass removable plate heat exchanger according to this alternative multi-pass construction is as convenient as the conventional single-pass heat exchanger in terms of mounting, piping, assembling, disassembling and maintenance.

[0048] Based on operating parameters and the required number of passes, the heat transfer plate described by the present disclosure has the following two typical application examples. The heat transfer plate required by the two application examples may be provided by a same plate pressing die, except for the number of corner ports needed to be cut, and the shapes and configurations of sealing gaskets.

First Application Example

[0049] In the first application example, there are only lateral passes without longitudinal passes. In other words, only lateral-pass heat transfer plates are used, while partition heat transfer plate is not used. Although the number of lateral passes is not limited theoretically according to the principle of the present disclosure, the present application example is more suitable for implementing a multi-pass removable plate heat exchanger with 2, 3, or 4 passes in actual applications due to consideration of unfavorable dimension increase in horizontal direction.

- a heat transfer plate with 2, 3 or 4 lateral partitions is molded using a same pressing die;
- appropriately shaped sealing gaskets are mounted to each heat transfer plate to form the desired number of lateral partitions;
- a plurality of lateral-pass plates configured with corresponding sealing gaskets are assembled together to form a plate pack with alternating cold and hot

fluid flow channels;

- an integral multi-pass removable plate heat exchanger is implemented by sandwiching the plate pack between the front fixed and rear mobile pressure plates via clamp bolts;
- only four connections need to be attached to the fixed pressure plate irrespective of the number of passes of the heat exchanger.

Second Application Example

[0050] In the second application example, not only the lateral passes but also the longitudinal passes are employed; in other words, lateral-pass heat transfer plates and partition heat transfer plates are used in combination. A second application example of the present disclosure is suitable for circumstances requiring a higher number of passes, including 4, 6, 8, 10, ... 2N (any even number) passes (the number of passes achievable for the entire heat exchanger can be viewed as any number, without being limited to even number only, if each heat transfer plate is used as the reference.). In this application example, there is no structural limitation on the maximum number of passes.

- a heat transfer plate with 2 lateral partitions is molded using a same pressing die;
- Appropriately shaped sealing gaskets are mounted to each heat transfer plate to form the lateral-partition plate described above. The heat transfer plate of this type is used in all passes other than the two passes immediately adjacent to mobile pressure plate.
- appropriately shaped sealing gaskets are mounted to each lateral-pass heat transfer plate to form the lateral-pass plate described above. This type of heat transfer plate is suitable for the two passes immediately adjacent to mobile pressure plate.
- a plurality of heat transfer plates configured with corresponding sealing gaskets are assembled to form a plate pack with alternating cold and hot fluid flow channels, wherein the lateral-pass plates are used in the two passes immediately adjacent to mobile pressure plate.
- an integral multi-pass removable plate heat exchanger is implemented by sandwiching the plate pack between the front fixed and rear mobile pressure plates via clamp bolts;
- only four connections are provided on the fixed pressure plate irrespective of the number of passes of the heat exchanger.

[0051] In the first application example and the second application example, the lateral-pass plate for a multi-pass removable plate heat exchanger is provided with flat grooves at the periphery and in the interior to allow sealing gaskets to form mutually communicative two or more lateral partitions; while the lateral-partition plate for the multi-pass removable plate heat exchanger is pro-

vided with flat grooves at the periphery and in the interior to allow the sealing gaskets to form two mutually isolated partitions.

[0052] Besides, in the actual applications, the heat transfer plate pattern or corrugation may be customized and optimized according to actual needs of the heat exchange circumstances; for a scenario of large flow rates with small allowable pressure drops, a plate profile with a small pressure resistance should be selected; otherwise, a plate model with a large pressure resistance is selected. Additionally, when selecting suitable plates, those with too small a single-plate area should not be selected; otherwise, too many plates will be needed, and consequently the inter-plate fluid velocity would be too small, and the heat transfer coefficient would be too low; this issue should be particularly addressed for large heat exchangers. Specifically, the heat transfer plate for the multi-pass removable plate heat exchanger may possess different thermal performances through variations in geometrical profiles, wherein the heat transfer plates with different geometrical profiles may be combined within the same plate pack in a hybrid fashion. Variations in plate geometrical profiles may include employing different chevron corrugation angles, circular or irregular dimple, studs, or other structures for enhancing heat transfer coefficient. Additionally, for the heat transfer plate in the multi-pass removable plate heat exchanger according to the present disclosure, sealing and partitioning functionalities of the sealing gaskets may be partially or completely replaced by other seal structures or mechanisms, which may include, but not limited to, brazing, welding, diffusion bonding or mechanical contact sealing.

[0053] In the application examples of the present disclosure, illustration will be made with a single-wall PHE as an example. In heat exchange scenarios, which require absolute prevention of mixing of two media (e.g., household water application), a double-wall PHE is mostly adopted so as to effectively prevent leakage and mixing of fluids. To those skilled in the art, the pass structures and designs of the lateral-pass plate and lateral-partition plate as disclosed in the present disclosure may also be directly applied to the double-wall PHE.

[0054] What have been disclosed above are only preferred embodiments of the present disclosure, which, of course, cannot serve as a basis for limiting the scope of the present disclosure. Therefore, similar, extended or equivalent embodiments using the same principles still fall within the scope covered by the present disclosure. It should be understood that the descriptions given above are intended for illustration only, not for limitation. For example, the embodiments (and/or aspects thereof) may be combined in use; an ideal number of passes of the lateral-pass plate might be greater than 4 in some industrial applications. In addition, various alterations may be made based on the teachings of the present disclosure so as to be adapted to specific circumstances or materials without departing from the scope of the present disclosure. Through reading the descriptions above, many oth-

er embodiments and alternations within the scope and spirit of the claims are obvious to those skilled in the art.

Claims

1. A multi-pass removable plate heat exchanger, comprising:

a fixed pressure plate;
a mobile pressure plate; and
a plate pack sandwiched between the fixed pressure plate and the mobile pressure plate via clamp bolts, wherein
the plate pack comprises a plurality of lateral-pass plates configured with specially shaped sealing gaskets to form two or more successively communicating lateral partitions, and wherein the lateral-pass plates are assembled to form the plate pack with mutually alternating cold and heat fluid flow channels, the number of the multi-pass removable plate heat exchangers being equal to the number of lateral partitions of the lateral-pass plates.

2. The multi-pass removable plate heat exchanger according to claim 1, wherein connections are only arranged on the fixed pressure plate, without a need of arranging connections on the mobile pressure plate.
3. The multi-pass removable plate heat exchanger according to claim 2, wherein the lateral-pass plate has two, three, four or more lateral partitions.

4. A multi-pass removable plate heat exchanger, comprising:

a fixed pressure plate,
a mobile pressure plate, and
a plate pack sandwiched between the fixed pressure plate and the mobile pressure plate via clamp bolts, wherein
the plate pack comprises one section of lateral-pass plates configured with specially shaped sealing gaskets to form two successively communicating lateral partitions, and (N-1) sections of lateral-partition plates configured with specially shaped sealing gaskets to form two mutually isolated lateral partitions, the lateral-pass plates and the lateral-partition plates being assembled to form the plate pack with mutually alternating cold and heat fluid flow channels, the total number of passes of the multi-pass removable plate heat exchanger being $2N$, where N is a natural number greater than or equal to 2, and wherein a value of 1 for N corresponds to a special case, where only lateral-pass plates are

needed for form a 2-pass heat exchanger.

5. The multi-pass removable plate heat exchanger according to claim 4, wherein connections are only arranged on the fixed pressure plate, without a need of arranging connections on the mobile pressure plate.
6. The multi-pass removable plate heat exchanger according to claim 4, wherein the lateral-pass plates are applied to two passes immediately adjacent to the mobile pressure plate, and the lateral-partition plates are applied to all other passes.
7. A heat transfer plate dedicated for the multi-pass removable plate heat exchanger wherein the heat transfer plate is a lateral-pass plate, and wherein flat groove patterns are provided at the periphery and in the interior of the lateral-pass plate for configuring sealing gaskets to thereby form two or more successively communicative lateral partitions.
8. A heat transfer plate specific for the multi-pass removable plate heat exchanger, wherein the heat transfer plate is a lateral-partition plate, and wherein flat groove patterns are provided at the periphery and in the interior of the lateral-partition plate for configuring sealing gaskets to thereby form two mutually isolated lateral partitions.
9. The heat transfer plate specific for the multi-pass removable plate heat exchanger according to claim 7 or 8, wherein the heat transfer plate may obtain different thermodynamic performance through variations in plate geometrical profiles, and wherein the heat transfer plates with different geometrical profiles may be arranged within a same plate pack in a hybrid fashion.
10. The heat transfer plates specific for the multi-pass removable plate heat exchanger according to claim 9, wherein variations in geometrical profiles may include, but are not limited to, varying chevron corrugation angles, circular or irregular dimples, studs, or other structures for enhancing heat transfer efficiency.
11. The heat transfer plate specific for the multi-pass removable plate heat exchanger according to claim 7 or 8, wherein sealing and/or partitioning functionalities of the sealing gaskets may be partially or completely replaced by other sealing structures or mechanisms.
12. The heat transfer plate specific for the multi-pass removable plate heat exchanger according to claim 11, wherein the other sealing structures and mechanisms may include, but are not limited to, brazing,

welding, diffusion bounding or mechanical contact
sealing.

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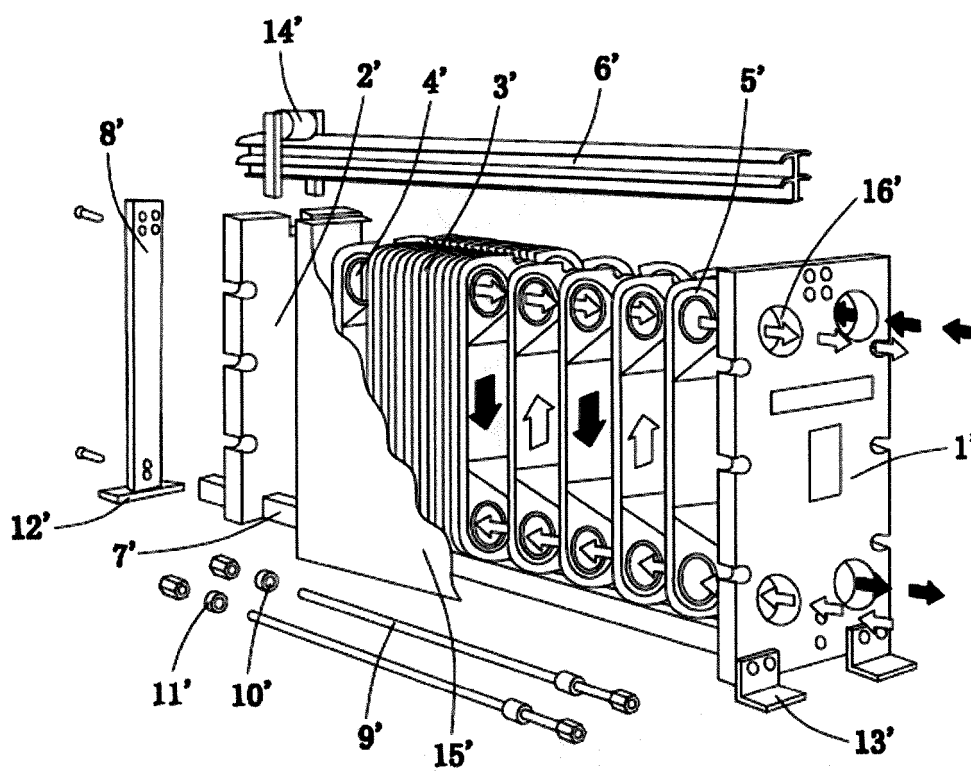


FIG. 1A

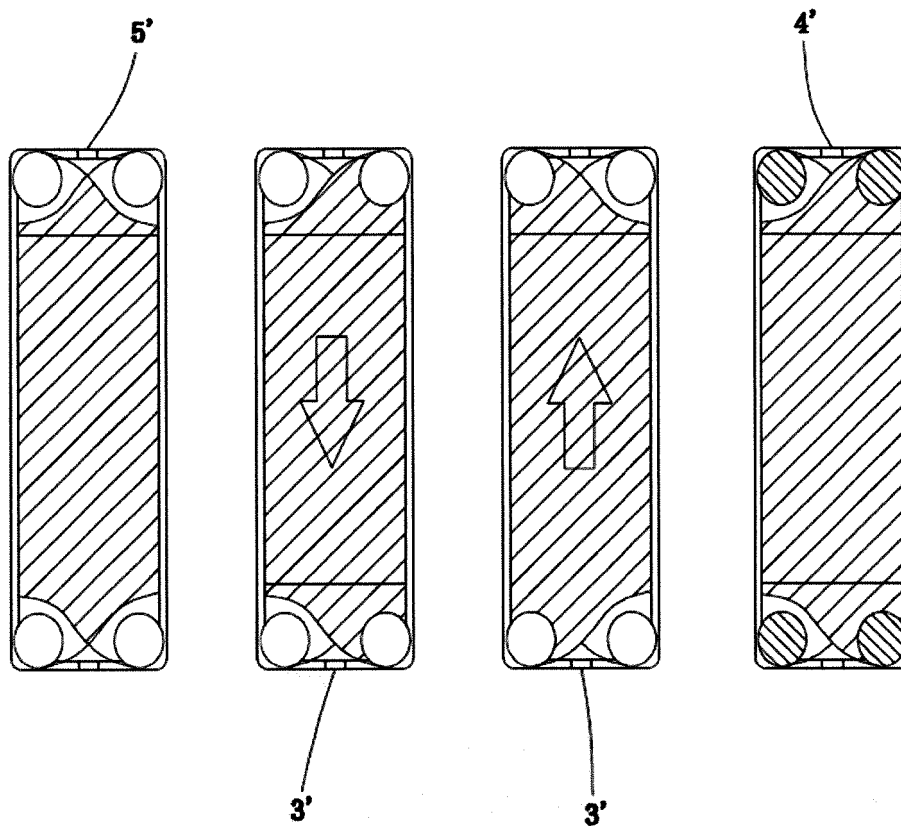


FIG. 1B

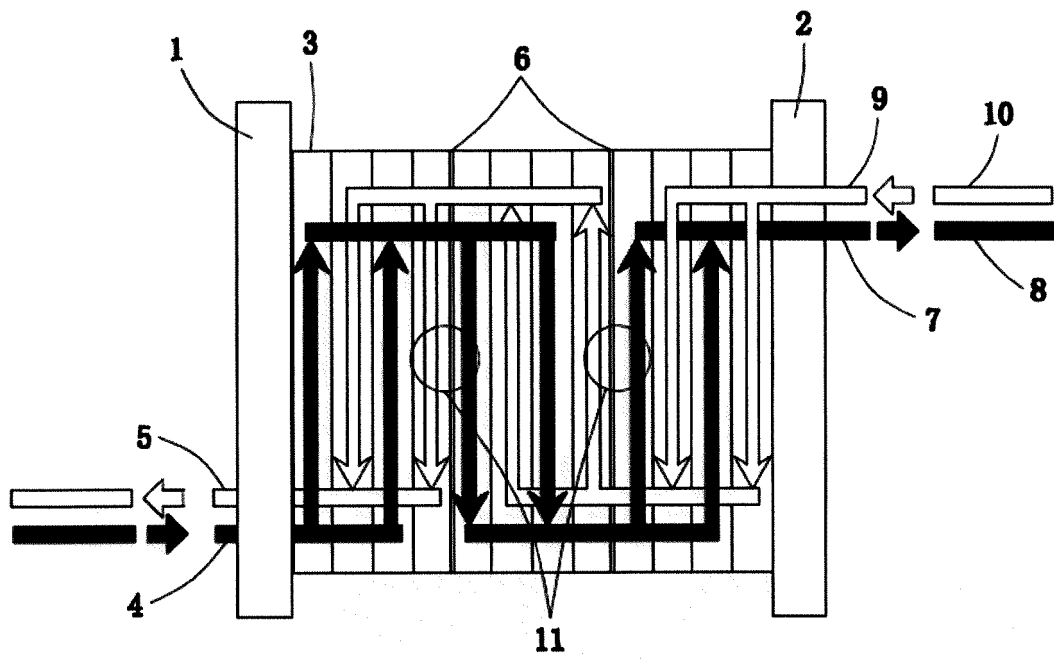


FIG. 2

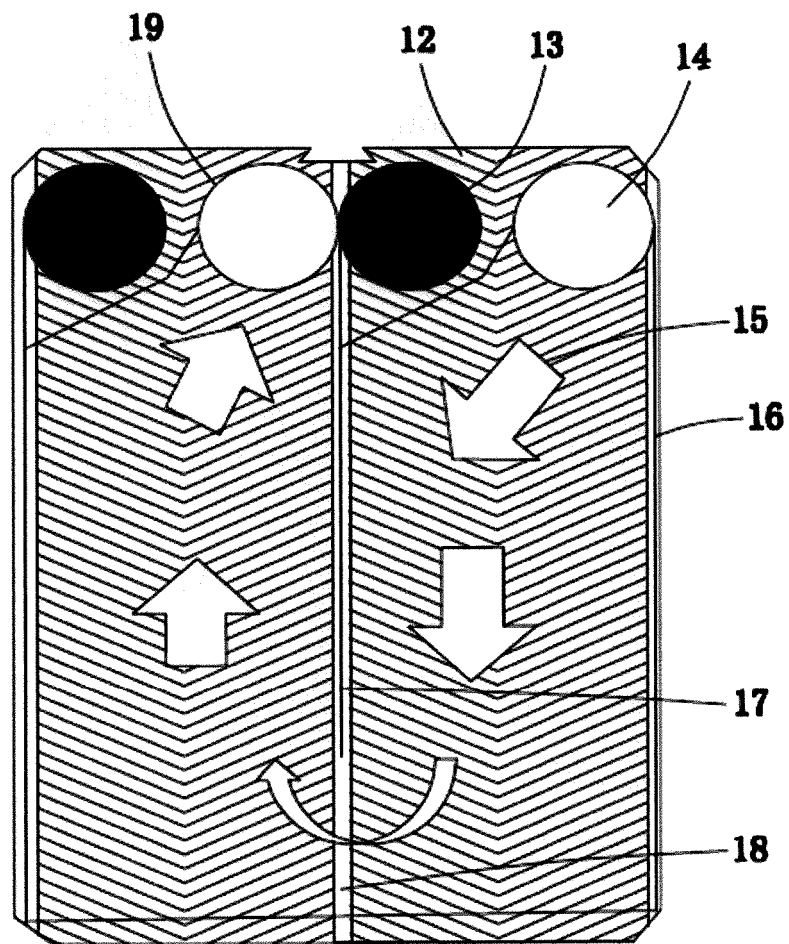


FIG. 3A

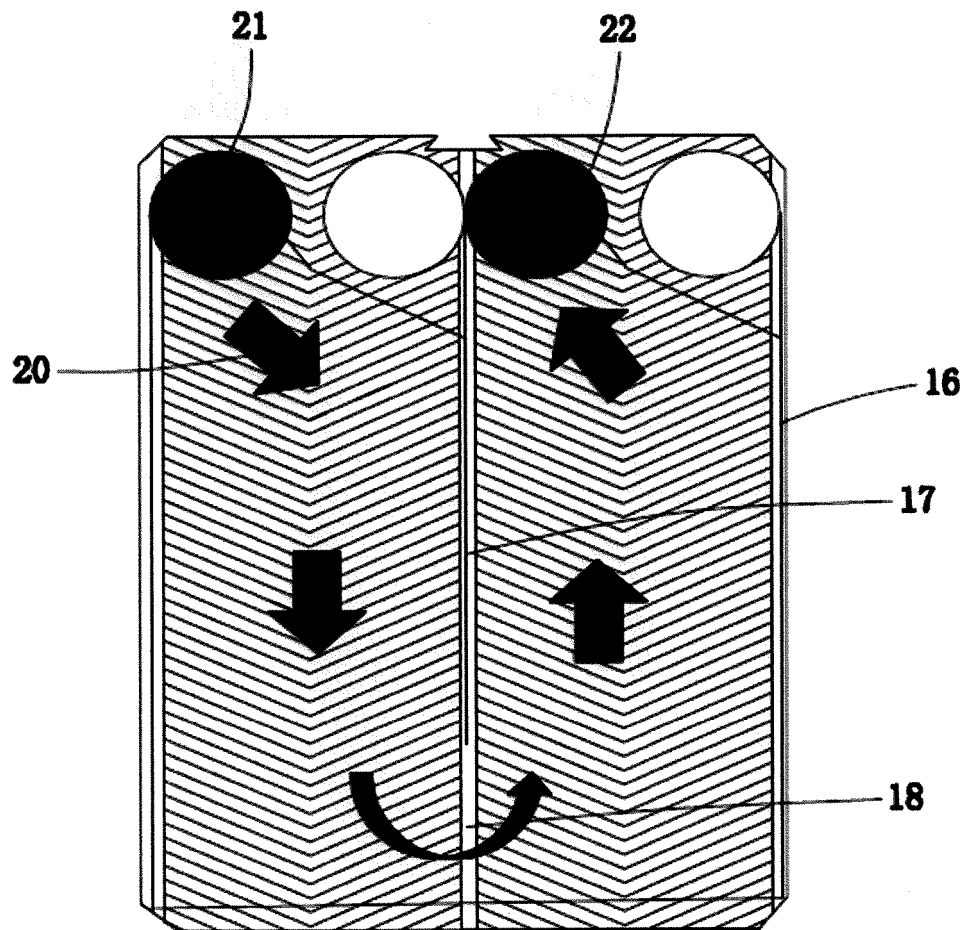


FIG. 3B

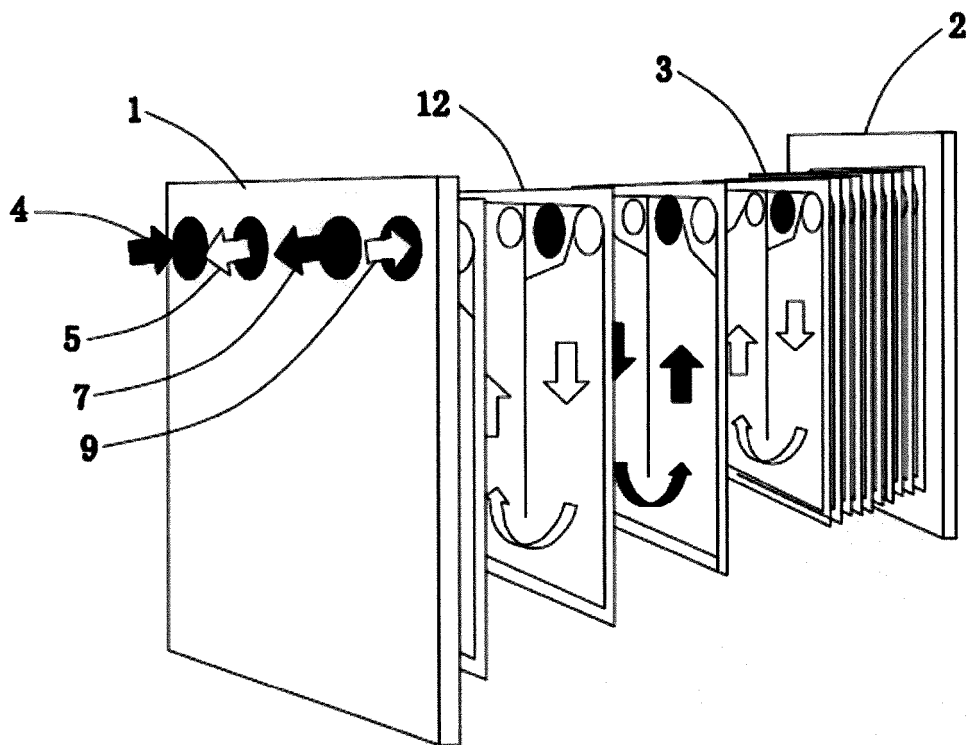


FIG. 4

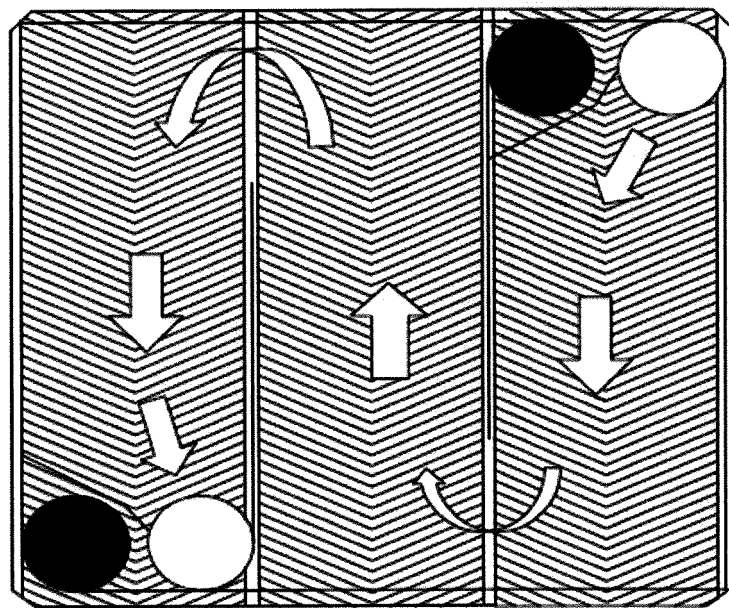


FIG. 5A

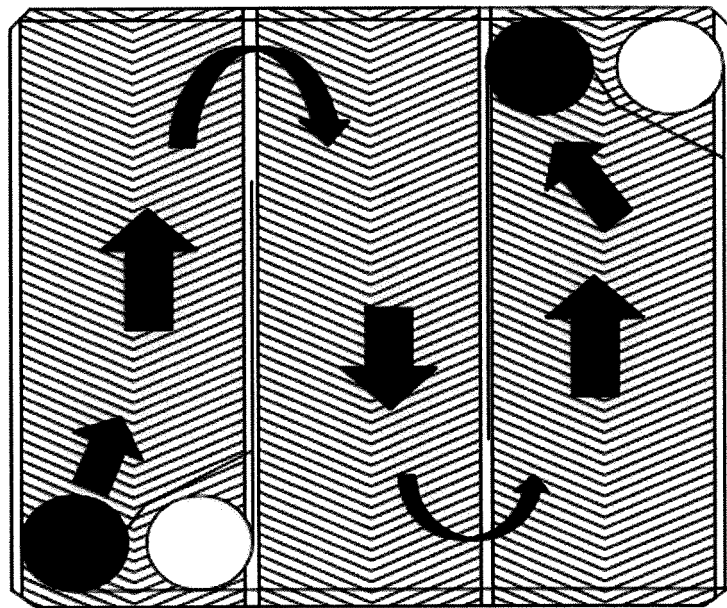


FIG. 5B

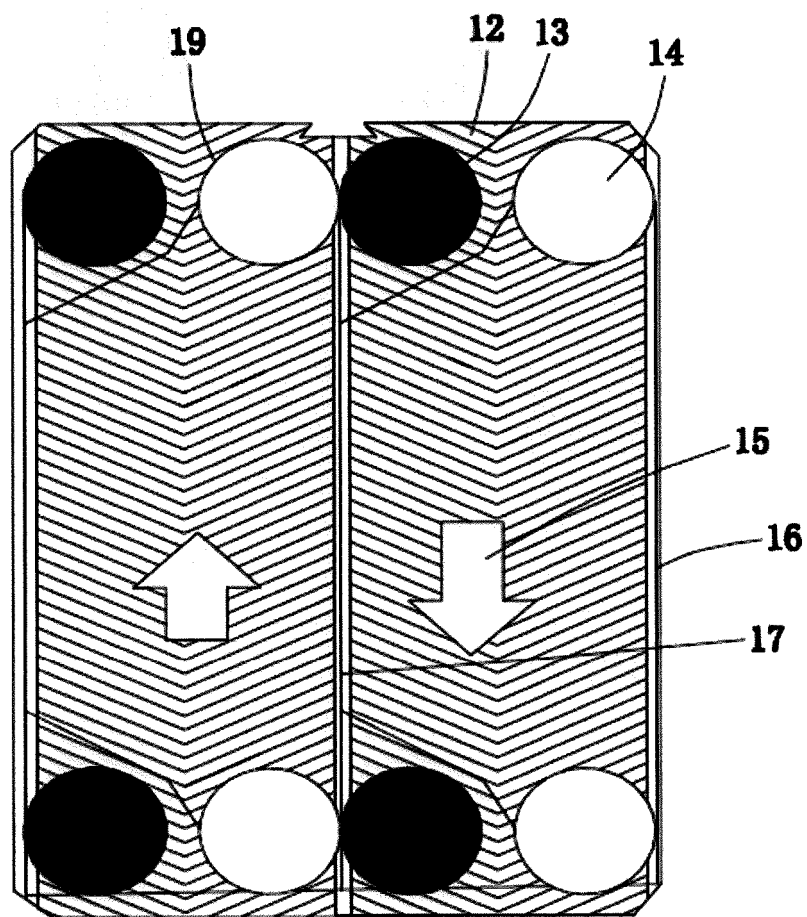


FIG. 6A

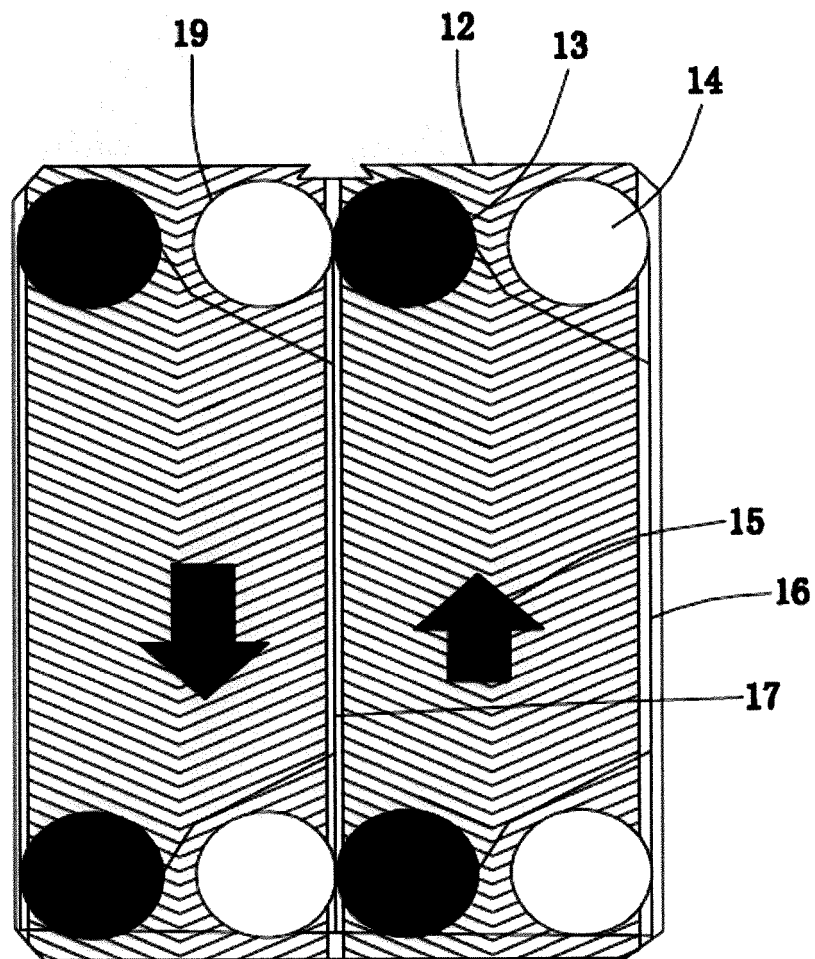


FIG. 6B

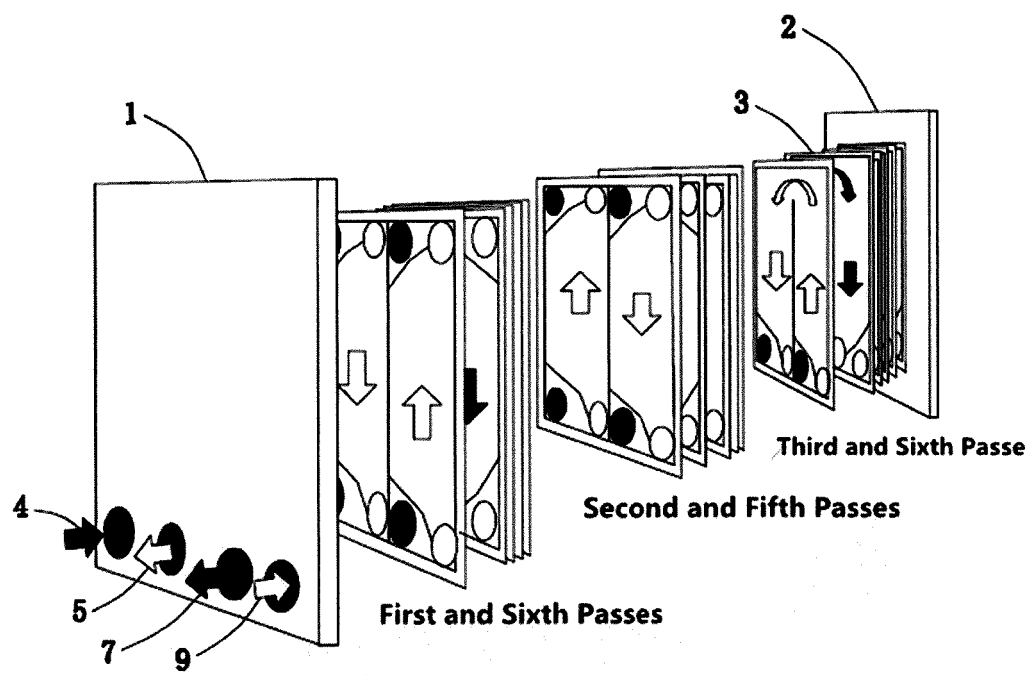


FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2017/093650

A. CLASSIFICATION OF SUBJECT MATTER

F28D 9/00 (2006.01) i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F28D 9, F28F 3

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNKI, CNABS, CNKI, VEN: baffling stream, isolate, plat+, heat+ w exchang+, U, flow, cool+, heat+

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
PX	CN 205980876 U (HENG FENG ENGINEERING (HONG KONG) LTD.), 22 February 2017 (22.02.2017), claims 1-12	1-12
X	CN 103217049 A (HANGZHOU SANHUA RESEARCH INSTITUTE CO., LTD.), 24 July 2013 (24.07.2013), description, paragraphs [0024]-[0041], and figures 2-8	1-3, 7, 9-12
Y	CN 103217049 A (HANGZHOU SANHUA RESEARCH INSTITUTE CO., LTD.), 24 July 2013 (24.07.2013), description, paragraphs [0024]-[0041], and figures 2-8	4-6, 8
Y	US 2003070797 A1 (CALSONIC KANSEI CORP.), 17 April 2003 (17.04.2003), description, paragraphs [0027]-[0047], and figures 1-5B	4-6, 8
A	CN 104315757 A (WUHAN WEI LENG SCIENCE AND TECHNOLOGY CO., LTD.), 28 January 2015 (28.01.2015), the whole document	1-12
A	EP 2187157 A3 (BEHR GMBH & CO KG), 16 October 2013 (16.10.2013), the whole document	1-12

☐ Further documents are listed in the continuation of Box C.
 ☒ See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"E" earlier application or patent but published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	"&" document member of the same patent family

Date of the actual completion of the international search 30 September 2017 (30.09.2017)	Date of mailing of the international search report 23 October 2017 (23.10.2017)
Name and mailing address of the ISA/CN: State Intellectual Property Office of the P. R. China No. 6, Xitucheng Road, Jimenqiao Haidian District, Beijing 100088, China Facsimile No.: (86-10) 62019451	Authorized officer LIU, Liyan Telephone No.: (86-10) 62084874

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2017/093650

5	Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
	CN 205980876 U	22 February 2017	None	
	CN 103217049 A	24 July 2013	CN 103217049 B	04 May 2016
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			US 6814135 B2	09 November 2004
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