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(54) **COMPOUND HEAT EXCHANGE EVAPORATIVE CONDENSER OF BOARD PIPE**

(57) The present invention discloses a combined plate-and-tube heat exchange evaporative condenser, which comprises a fan, a water pump, a water sprayer, a reservoir and a combined plate-and-tube heat exchanger; the combined plate-and-tube heat exchanger consists of a plurality of combined plate-and-tube heat exchange pieces connected by inlet headers and outlet headers; the combined plate-and-tube heat exchange piece comprises a heat transfer plate and a serpentine tube machined by the heat exchange tube; the heat transfer plate is provided with a groove, and the shape of the groove matches with that of the serpentine tube; the serpentine tube is disposed in the groove, and a gap between the serpentine tube and the groove is filled with a thermally conductive adhesive layer. Compared with the existed technology, the thermally conductive adhesive layer makes the heat transfer plate fully contact with the serpentine tube, and subsequently enables the serpentine tube to have the fin effect and lead to improvement in the effective heat exchange area; the heat exchange plate can direct the cooling water to form a continuous water membrane, and lead to improvement in evaporation area of the cooling water; the improvement of the effective heat exchange area and the cooling water evaporation area increases the heat exchange effectiveness, as well as facilitates the reduction of the overall size of the condenser.

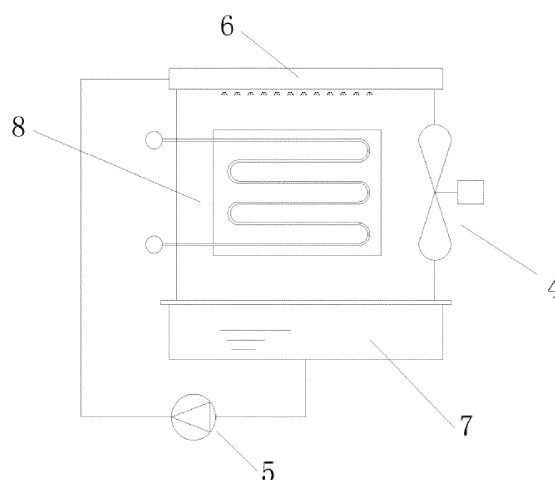


Fig. 1

Description

TECHNICAL FIELD

[0001] The present invention relates to technical field of heat exchange device, especially to a combined plate-and-tube heat exchange evaporative condenser.

BACKGROUND OF THE INVENTION

[0002] Currently, most of evaporative condensers in the market have a heat exchanger composed of bent tubes. Generally, a cooling procedure is performed on the outer surface of the heat exchanger using spray water, thus heat is dissipated by the evaporation of circulated spray water. However, in general, the outer surface of the bent tube (i.e., heat exchange tube) of the heat exchanger is smooth resulting in low heat exchange effectiveness of the heat exchanger. Moreover, due to evaporation of cooling water, heat exchange area of the bent tube is reduced during the cooling process, thus tube pitches of the bent tube have to be enlarged to increase the time of heat exchange between the cooling water and air. As a result, the whole heat exchanger becomes huge in size. On the other hand, as there is not any medium between upper and lower tubes in the bent tube to lead the flow of the cooling water, the cooling water would, when dripping down, flutter disorderly and get easy to fly about with the traction of an orthogonal wind. Consequently, the water would fail to be evenly sprayed over the bent tube, and result in the occurrence of dry points. This, as a result, decreases the heat exchange ability and increases the risk of fouling.

[0003] Applicant disclosed a heat exchange tubular plate used in a padding-and-serpentine tube coupled evaporative condenser in CN202836298U, wherein a padding plate are mounted between two tubular plates so as to lead the spray water to form a water-retaining layer by which the problem that the cooling water disorderly flies about can be solved. Although the padding-and-serpentine tube structure of said evaporative condenser exalts heat exchange effectiveness to a certain degree, it cannot largely improve the heat exchange effectiveness as it merely improves the utilization of the cooling water.

SUMMARY OF THE INVENTION

[0004] Regarding to the defects in the above-mentioned technology, the present invention aims to solve those technical problems by changing the heat exchange structure of the serpentine tube, and therefore improve the heat exchange effectiveness to a much greater extent.

[0005] In order to solve the problems mentioned above, a technical solution of the present invention is a combined plate-and-tube heat exchange evaporative condenser, comprising a fan, a water pump, a water

sprayer, a reservoir; and a combined plate-and-tube heat exchanger; the combined plate-and-tube heat exchanger consists of a plurality of combined plate-and-tube heat exchange pieces connected by inlet headers and outlet headers; the combined plate-and-tube heat exchange piece comprises a heat transfer plate and a serpentine tube machined by the heat exchange tube; the heat transfer plate is provided with a groove, and the shape of the groove matches with that of the serpentine tube; the serpentine tube is disposed in the groove, and a gap between the serpentine tube and the groove is filled with a thermally conductive adhesive layer. The heat transfer plate can lead the sprayed cooling water to flow over the heat exchange tube from the top down, and increase the utilization of the cooling water; moreover, due to the fact that the gap between the serpentine tube and the heat transfer plate is filled with the thermally conductive adhesive layer making the serpentine tube fully contact with heat transfer plate, the heat transfer plate therefore becomes fins of the serpentine tube, and leads to increasing the effective heat exchange area.

[0006] Preferably, the thermally conductive adhesive layer is a metal filler layer. Such structure can be realized by recoiling the immersion liquid metal, whereby makes the thermally conductive adhesive layer fully fill up the gap. And the good thermal conductivity of the metal further improves fin effect of the heat transfer plate.

[0007] More preferably, the gap between the serpentine tube and the groove has a width smaller than 10mm. With such small gap, when performing the liquid metal immersion, due to the viscosity of the liquid metal, the capillary action may happen to the liquid metal. After the liquid metal permeates the interior of the contact surface between the heat transfer plate and the serpentine tube, a layer covered with uniform thin filler is formed in the contact surface. As a result, the heat transfer plate and the serpentine tube are joined together to be an integral, and the thermal contact resistance between the heat transfer plate and the serpentine tube is decreased as the filler layer is very thin.

[0008] More preferably, a plurality of limiting grooves and/or positioning solder joints are stamped on the heat transfer plate. Such structure ensures that the gap between the heat transfer plate and the serpentine tube is small enough when immersing the liquid metal.

[0009] Preferably, the metal filler layer comprises one or more metals selected from a group consisting of zinc, tin, aluminium, copper. These metals are low-melting and budget-friendly, with a pretty high quality-price ratio when being used in liquid metal immersion.

[0010] Preferably, the thermally conductive adhesive layer is a thermally conductive adhesive. A direct use of the thermally conductive adhesive can make the processing easier.

[0011] Preferably, the combined plate-and-tube heat exchange piece is longitudinally arranged, which means the cooling wind generated by the fan flows in the long direction of the serpentine tube. The flow direction of the

cooling wind is consistent with the long direction of the coiled tube and no leeside is existed reducing the dry points on the surface of the heat transfer coiled tube as well as the risk of fouling on the heat transfer coiled tube.

[0012] Preferably, the heat transfer tube is bent to form a plurality of straight sections; adjacent straight sections of the heat transfer tube are parallel with each other, and a tube pitch between the adjacent straight sections is uniform, or the tube pitch between the adjacent straight sections gets smaller gradually starting from the top and going down in the direction of the falling water. Such structure increases the heat exchange temperature difference between the cooling water and the lower coiled tube, and leads to improvement in effectiveness of the heat exchange and reduction in the consumption of the heat exchange tube.

[0013] Another preferable model can be: the heat exchange tube is bent to form several direct sections; the length of the straight sections get longer gradually starting from the top and going down in the direction of the falling water.

[0014] Preferably, one or more of water guiding pattern, water guiding opening, and flying-water prevention structure or reinforcing rib can be arranged on the heat transfer plate.

[0015] Compared with the existed technology, the present combined plate-and-tube heat exchange evaporative condenser has the following advantages.

[0016] Firstly, the thermally conductive adhesive layer makes the heat transfer plate fully contact with the serpentine tube, and subsequently enables the serpentine tube to have a fin effect via the heat transfer plate and lead to an enlargement of the effective heat exchange area;

[0017] Secondly, the heat exchange plate can direct the cooling water to form a continuous water-retaining layer, and lead to an enlargement of the evaporation area of the cooling water;

[0018] Thirdly, the enlargement of the effective heat exchange area and the cooling water evaporation area increases the heat exchange effectiveness, as well as facilitates the reduction of the overall size of the condenser.

[0019] Above-mentioned is merely an overview of the present invention. In order to clarify the technical solution of the present invention to make it implementable in accordance with the specification, and specify the objectives, characteristic, and advantages mentioned above or others, several specific preferable embodiments, in conjunction with drawings, are described in detail as follows.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020]

Fig. 1 is a schematic diagram of a combined plate-and-tube heat exchange evaporative condenser in

the present invention.

Fig. 2 is a schematic diagram of a combined plate-and-tube heat exchange plate of the combined plate-and-tube heat exchange evaporative condenser in the present invention.

Fig. 3 is a schematic diagram of a heat transfer plate of the combined plate-and-tube heat exchange plate of the combined plate-and-tube heat exchange evaporative condenser in the present invention.

Fig. 4 is a sectional view along the line A-A of Fig. 2.

DETAILED DESCRIPTION OF THE INVENTION

[0021] The present invention is further specified in conjunction with the drawings and the detailed embodiments.

[0022] As shown in Fig. 1, a combined plate-and-tube heat exchange evaporative condenser of the present invention includes a fan 4, a water pump 5, a water sprayer 6, a reservoir 7 and a combined plate-and-tube heat exchanger 8; wherein the combined plate-and-tube heat exchanger 8 is disposed between the water sprayer 6 and the reservoir 7, and the water sprayer 6 is connected with the reservoir 7 via the water pump 5; the fan 4 is disposed at one end of the combined plate-and-tube heat exchanger 8. The combined plate-and-tube heat exchanger 8 consists of a plurality of combined plate-and-tube heat exchange pieces connected by inlet headers and outlet headers. As shown in Fig. 2 and Fig. 3, the combined plate-and-tube heat exchange piece includes a serpentine tube 1 machined by a heat exchange tube (the machining can be a process bending a long heat exchange tube to form the serpentine tube, or the machining also can be a process welding bent heat exchange tubes and straight heat exchange tubes together to form the serpentine tube), and a heat transfer plate 2. In this embodiment, the serpentine tube 1 is formed by bending the heat exchange tube in a continuous S direction, wherein straight sections of the heat exchange tube are substantially parallel with each other; in another embodiment, the straight sections also could be placed in non-parallel. The serpentine tube 1 also could be any shape which suits for the evaporative condenser. The heat exchange tube of the serpentine tube 1 can be a copper tube, stainless steel tube or galvanized steel tube, etc., and the cross-sectional shape of an inner flow pathway of the serpentine tube 1 can be round, oval, spiral, corrugation or olive-shaped or other shapes. It could be understood by one of ordinary skill in the art that the inner and outer surface of the serpentine tube 1 can be smooth, but preferably strengthened heat transfer surfaces with inner and outer thread respectively. Simultaneously, a hydrophilic or anticorrosion coating can be disposed on the outer surface of the serpentine tube 1. The serpentine tube 1 has an inlet and an outlet for the flow pathway, the inlet and the outlet respectively connecting with an

inlet header and an outlet header. In this embodiment, the heat exchange tube is bent to have a plurality of straight sections; adjacent straight sections in the heat exchange tube are parallel with each other, and a tube pitch between the adjacent straight sections is uniform, or the tube pitch between the adjacent straight sections gets smaller gradually starting from the top and going down in the direction of falling water; it also could be one that the length of the straight section gets longer gradually starting from the top and going down in the direction of the falling water. The material of the heat transfer plate 2 can be carbon steel plate, stainless steel plate, aluminium plate, copper plate and etc. The combined plate-and-tube heat exchange piece is longitudinally arranged, whereby cooling wind generated by the fan 4 flows substantially in the long direction of the serpentine tube 1.

[0023] As shown in Fig. 3 and Fig. 4, the heat transfer plate 2 is provided with a groove 21. In this embodiment, the groove 21 is formed by stamping the heat transfer plate 2, the groove 21 also could be directly formed during the molding of the heat transfer plate 2; the shape of the groove 21 matches with that of the serpentine tube 1; the serpentine tube 1 is disposed in the groove 21, and a gap between the serpentine tube 1 and the groove 21 is filled with a thermally conductive adhesive layer 3. In this embodiment, the thermally conductive adhesive layer 3 is a metal filler layer made of zinc. A detailed preparation method of the zinc layer can be as follows: the heat transfer plate 2 and the serpentine tube 1 are immersed in high-temperature liquid zinc, the liquid zinc flows into the gap between the serpentine tube 1 and the groove 21 to fill up the gap; the viscosity of the fluid metal makes the serpentine tube 1 and the groove 21 join together tightly; when the fluid metal is cooled down and solidified into solid state, it becomes the thermally conductive adhesive layer 3 which is filled between the serpentine tube 1 and the groove 21 to fix both of them. Besides the zinc, other metal, such as tin and aluminum, or a metal combination thereof can be used as well. All of these metals are low-melting and budget-friendly that shows high quality-price ratio.

[0024] Furthermore, in this embodiment, the gap between the serpentine tube 1 and the groove 21 has a width smaller than 10 mm. When performing the liquid metal immersion, due to the viscosity of the liquid metal, a capillary action may occur between the liquid metal and a contact surface of the heat transfer plate 2 and the serpentine tube 1 after the liquid metal has permeated into the interior of the contact surface, as a result an uniform and thin thermally conductive adhesive layer 3 is formed in the gap of the contact surface. This not only makes the heat transfer plate 2 and the serpentine tube 1 join together to be an integral, but also reduces the thermal contact resistance between the heat transfer plate 2 and the serpentine tube 1 as the thermally conductive adhesive layer 3 is very thin. The smaller the gap between the serpentine tube 1 and the groove 21 is, the more obvious the capillary action of the liquid metal per-

meation is, and the more uniform the formed thermally conductive adhesive layer 3 is, and correspondingly, the more the expense and manufacturing complexity will be; the cost-optimal choice is when the width of the gap is about 10 mm; meanwhile, the optimal quality-price ratio is when the width of the gap is about 5 mm; the optimal choice concerning the uniform effect is when the width of the gap is no more than 3 mm. Furthermore, in order to ensure that the gap between the serpentine tube 1 and the heat transfer plate 2 is small enough when being immersed into the high-temperature liquid metal, several limiting grooves and/or positioning solder joints (not shown) can be stamped on the heat transfer plate 2. Before the immersion, the serpentine tube 1 is mounted in the limiting groove or is partly soldered on the positioning soldered joint to make it prefixed. In another embodiment, the serpentine tube 1 and the heat transfer plate 2 can be prefixed by using fixtures which needs more complicate operations.

[0025] The heat of the serpentine tube 1 is transmitted to the heat transfer plate 2 via the thermally conductive adhesive layer 3; the heat transfer plate 2 becomes fins of the serpentine tube 1 that greatly increases the heat exchange area and directly enhances the heat exchange effect of the serpentine tube 1; meanwhile, the heat transfer plate 2 also can direct the cooling water to form a continuous water flow, whereby the problem of disorder flying-water is avoided and the utilization of the cooling water is increased. In addition, because the heat transfer plate 2 is an integral, it can avoid the crossflow of the cooling water at joint positions between the heat transfer plate 2 and the serpentine tube 1, and consequently guarantee the water spray rate.

[0026] On the other hand, the thermally conductive adhesive layer 3 can be replaced by a thermally conductive adhesive; the bonding can be achieved simply by evenly applying the thermally conductive adhesive in the groove 21 of the thermally conductive plate 2, and then mounting the serpentine tube 1 into the groove 21 (for some thermally conductive adhesives that are used in combination with a matching thermally conductive adhesive, it may need to apply the matching thermally conductive adhesive on the serpentine tube 1). Such structure can be easily mounted and only simple procedure is needed. However, the currently existed thermally conductive adhesives, such as organosilicon thermally conductive adhesive, epoxy resin AB adhesive, polyurethane thermally conductive adhesive, etc., are inferior in thermal conduction as compared with metals like zinc, aluminum, and etc. Moreover, the unevenly applying of the adhesive results in occurrence of air space between the serpentine tube 1 and the groove 21, which adversely affects the heat exchange effectiveness.

[0027] Also, other structures, such as opening, corrugation, bend, water guiding groove, swallowtail groove, strengthen rib, etc., can be arranged on the heat transfer plate 2, so as to enhance the effect of water spraying, prevent flying-water, and enhance sturdiness. Further-

more, a plurality of through holes (not shown) with shapes like rectangular, round or others, can be opened in the groove 21. When the serpentine tube 1 is disposed in the groove 21, a part of the serpentine tube 1 may be exposed and not covered by the groove 21, this part of the serpentine tube 1 can directly contact with the cooling water. Such design can enlarge the direct contact surface between the serpentine tube and the water. Moreover, the through holes can induce turbulence of the water flow to enhance heat exchange of the copper tube, while weaken the fin effect of the heat transfer plate to a certain degree.

[0028] Above-mentioned embodiment is merely one of the preferable embodiments of the present invention, which cannot be used to limit the scope as claimed of the present invention. Any non-substantive modification or replacement on the basis of the present invention made by the person skilled in the art should be deemed falling within the scope as claimed of the present invention.

Claims

1. A combined plate-and-tube heat exchange evaporative condenser, comprising a fan, a water pump, a water sprayer and a reservoir; **characterized in that** the evaporative condenser further comprises a combined plate-and-tube heat exchanger; the combined plate-and-tube heat exchanger consists of a plurality of combined plate-and-tube heat exchange pieces connected by a plurality of inlet headers and a plurality of outlet headers; the combined plate-and-tube heat exchange piece comprises a heat transfer plate and a serpentine tube machined by a heat exchange tube; the heat transfer plate is provided with a groove, and the shape of the groove matches with that of the serpentine tube; the serpentine tube is disposed in the groove, and a gap between the serpentine tube and the groove is filled with a thermally conductive adhesive layer.
2. The combined plate-and-tube heat exchange evaporative condenser according to claim 1, **characterized in that** the thermally conductive adhesive layer is a metal filler layer.
3. The combined plate-and-tube heat exchange evaporative condenser according to claim 2, **characterized in that** the gap between the serpentine tube and the groove has a width smaller than 10mm.
4. The combined plate-and-tube heat exchange evaporative condenser according to claim 3, **characterized in that** a plurality of limiting grooves and/or positioning solder joints are stamped on the heat transfer plate.
5. The combined plate-and-tube heat exchange evaporative condenser according to claim 2, **characterized in that** the metal filler layer comprises one or more metals selected from a group consisting of zinc, tin, aluminium, and copper.
6. The combined plate-and-tube heat exchange evaporative condenser according to claim 1, **characterized in that** the thermally conductive adhesive layer is a thermally conductive adhesive.
7. The combined plate-and-tube heat exchange evaporative condenser according to claim 1, **characterized in that** the combined plate-and-tube heat exchange piece is longitudinally arranged, which means cooling wind generated by the fan flows past in a long direction of the serpentine tube.
8. The combined plate-and-tube heat exchange evaporative condenser according to claim 1, **characterized in that** the heat transfer tube is bent to form a plurality of straight sections; adjacent straight sections of the heat transfer tube are parallel with each other, and a tube pitch between the adjacent straight sections is uniform, or the tube pitch between the adjacent straight sections gets smaller gradually starting from the top and going down in the direction of the falling water.
9. The combined plate-and-tube heat exchange evaporative condenser according to claim 1, **characterized in that** the heat exchange tube is bent to form a plurality of straight sections; the length of the straight section gets longer gradually starting from the top and going down in the direction of the falling water.
10. The combined plate-and-tube heat exchange evaporative condenser according to claim 1, **characterized in that** the heat transfer plate further has a structure selected from a group consisting of a water-guiding pattern, a water-guiding hole, a flying-water prevention structure, a reinforcing rib and any combination thereof.

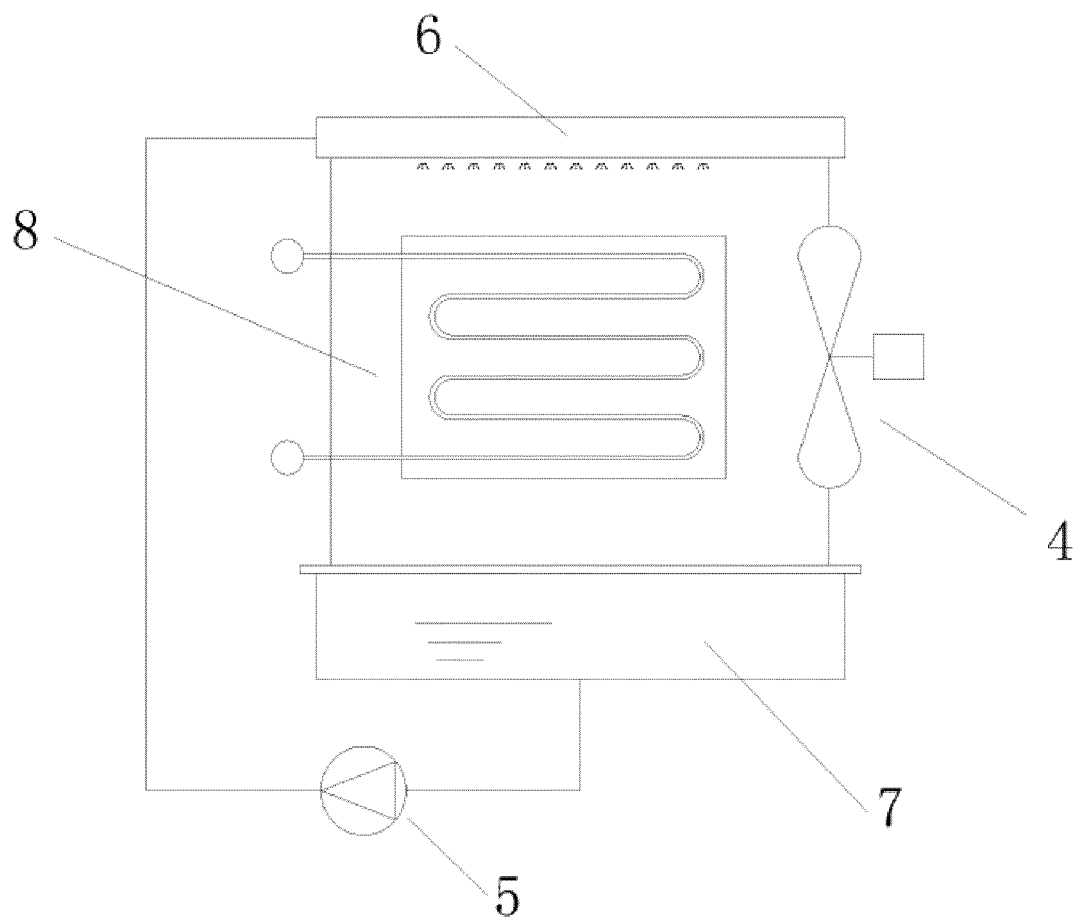


Fig. 1

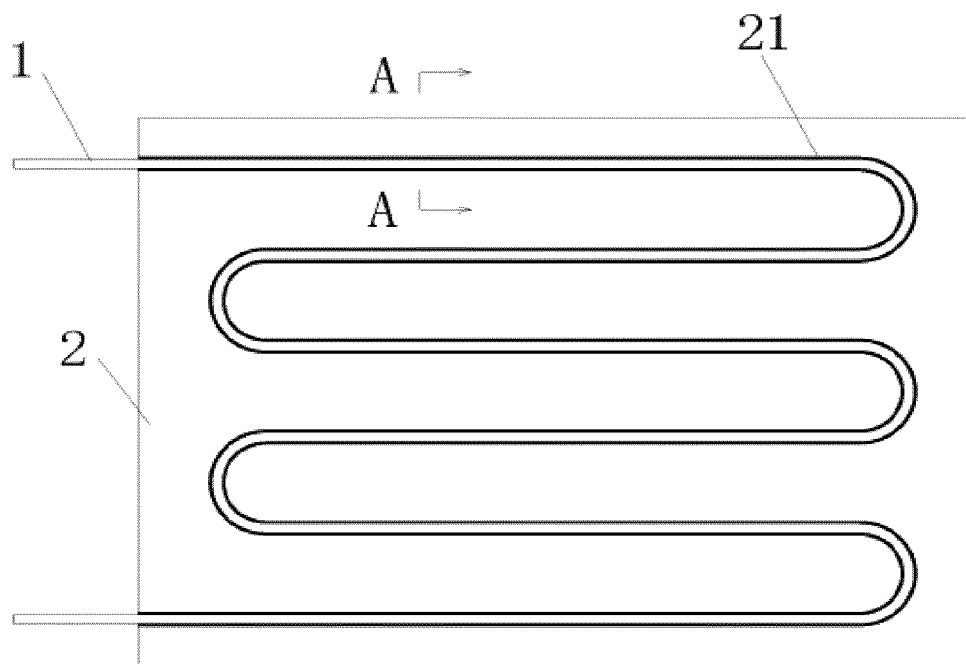


Fig. 2

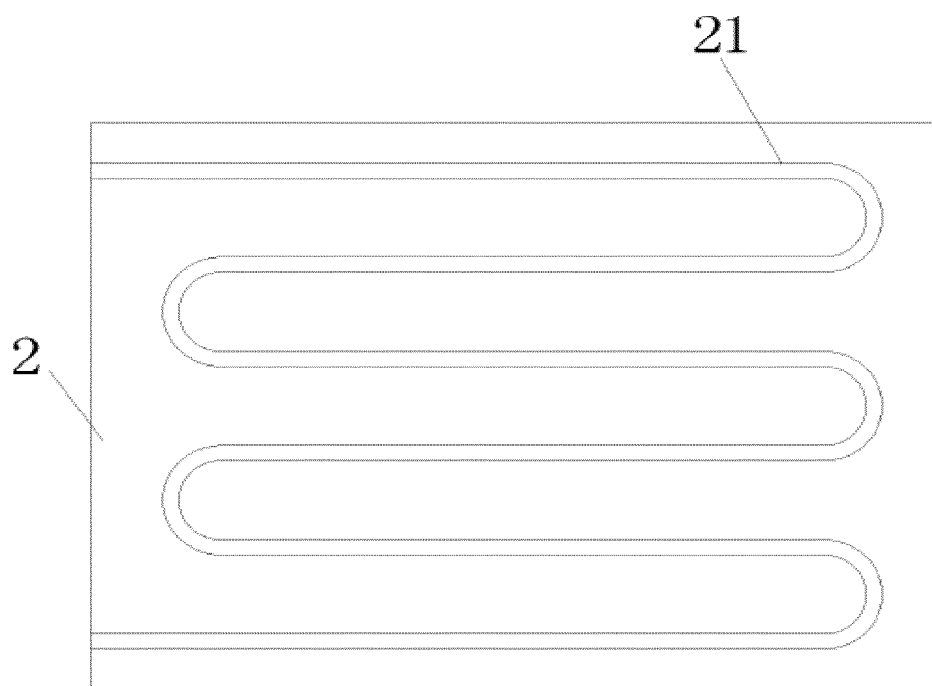


Fig. 3

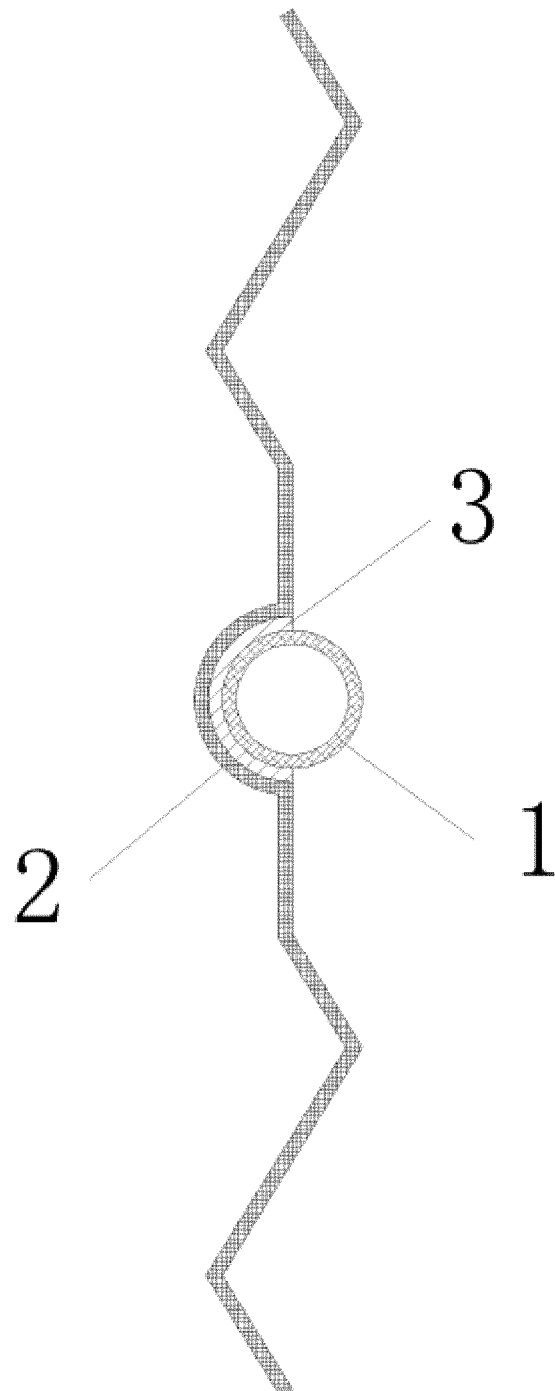


Fig. 4

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2015/081392

A. CLASSIFICATION OF SUBJECT MATTER

F28D 5/02 (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 5; F28F 1; F25B

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, CNPAT, WPI, EPODOC: water pump, sump, plate-type, mounting groove, placement groove, bond, heat exchang+, heat transfer+, plate?, pipe?, groove?, fan?, condenser

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	CN 103983072 A (CHEN, Dingbang), 13 August 2014 (13.08.2014), description, paragraphs 20-23, and figures 1-3	1, 6-10
Y	CN 202836267 U (GUANGZHOU WIDE INDUSTRIAL CO., LTD.), 27 March 2013 (27.03.2013), description, paragraphs 0042-0043, and figure 1	1, 6-10
A	CN 103983072 A (CHEN, Dingbang), 13 August 2014 (13.08.2014), description, paragraphs 20-23, and figures 1-3	2-5
A	CN 104001803 A (CHEN, Dingbang), 27 August 2014 (27.08.2014), the whole document	1-10
A	CN 102759229 A (SHUNDE POLYTECHNIC), 31 October 2012 (31.10.2012), the whole document	1-10
A	JP H11118381 A (DAIKIN IND LTD.), 30 April 1999 (30.04.1999), the whole document	1-10

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

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"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

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2015/081392

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
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Form PCT/ISA/210 (patent family annex) (July 2009)

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