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(54) **EVAPORATOR AND REFRIGERATION SYSTEM COMPRISING SAME**

(57) The present application provides an evaporator, comprising: a housing; and a falling film tube bundle disposed in an accommodating cavity and arranged in columns, the falling film tube bundle comprising a plurality of heat exchange tubes, the centers of the heat exchange tubes in each column being arranged along a height direction, and the centers of two adjacent heat exchange tubes in adjacent columns being staggered in a width direction of the accommodating cavity; wherein the falling film tube bundle is configured in a way that among four adjacent heat exchange tubes in two adjacent columns, a minimum distance between outer surfaces of at least two heat exchange tubes in different columns is greater than a minimum distance between outer surfaces of two heat exchange tubes in the same column. In the present application, a flow rate of gas flowing among the corresponding heat exchange tubes is reduced by increasing the flow space of a refrigerant in the width direction W , so that a ratio of the gas phase Reynolds number Re_v to the liquid film Reynolds number Re_{film} is reduced, and thus the heat exchange efficiency of the evaporator is improved.

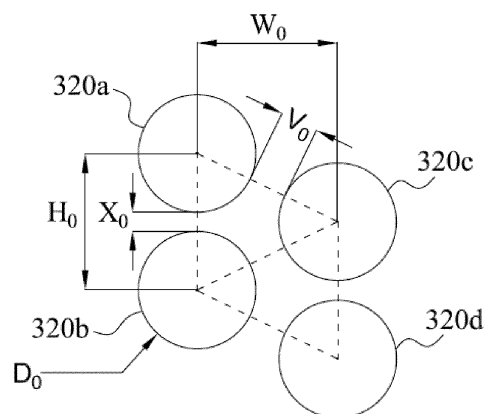


FIG. 3B

Description

Technical Field

[0001] The present application relates to an evaporator, and in particular, to an evaporator with a high heat exchange efficiency and a refrigeration system comprising the same.

Background Art

[0002] A traditional refrigeration system has an evaporator, a condenser, a throttling device, and a compressor. When passing through the evaporator, a low-temperature refrigerant liquid exchanges heat with an external working fluid and absorbs heat of the working fluid to reduce the temperature of the working fluid, thereby achieving cooling effect, wherein the working fluid may be air or cooling water. After the heat exchange, the refrigerant liquid is vaporized into gas refrigerant and enters the compressor. The heat transfer efficiency of the evaporator is affected by various factors.

Summary of the Invention

[0003] At least one objective of a first aspect of the present application is to provide an evaporator with a high heat exchange efficiency. The evaporator comprises: a housing, wherein the housing has an accommodating cavity, the accommodating cavity has a length direction, a width direction, and a height direction; and a falling film tube bundle, wherein the falling film tube bundle is disposed in the accommodating cavity and arranged in columns, the falling film tube bundle comprises a plurality of heat exchange tubes, each heat exchange tube extends along the length direction of the accommodating cavity, the centers of the heat exchange tubes in each column are arranged in the height direction, and the centers of two adjacent heat exchange tubes in adjacent columns are staggered in the width direction of the accommodating cavity; wherein the falling film tube bundle is configured in a way that among four adjacent heat exchange tubes in two adjacent columns, a minimum distance between outer surfaces of at least two heat exchange tubes in different columns is greater than a minimum distance between outer surfaces of two heat exchange tubes in the same column.

[0004] According to the first aspect, among the four adjacent heat exchange tubes in two adjacent columns, the distance between outer surfaces of at least two heat exchange tubes in different columns is set such as to reduce a flow rate of gas flowing through the two adjacent columns of heat exchange tubes, thereby improving heat exchange efficiency of the evaporator.

[0005] According to the first aspect, each heat exchange tube in the falling film tube bundle has the same tube diameter, and a ratio of a distance of the centers, in the width direction of the accommodating cavity, of two

adjacent heat exchange tubes in adjacent columns to a distance of the centers, in the height direction of the accommodating cavity, of two adjacent heat exchange tubes in the heat exchange tubes in each column meets

$$\cos 30^{\circ} < \frac{W_0}{H_0} 1.5 * \cos 30^{\circ}$$

a relationship:

[0006] According to the first aspect, the falling film tube bundle comprises a plurality of first heat exchange tubes with a larger tube diameter and a plurality of second heat exchange tubes with a smaller tube diameter; and the first heat exchange tubes and the second heat exchange tubes are staggered in the columns of the falling film tube bundle.

[0007] According to the first aspect, the falling film tube bundle comprises a plurality of first heat exchange tubes with a larger tube diameter and a plurality of second heat exchange tubes with a smaller tube diameter, wherein the plurality of first heat exchange tubes is arranged in columns, and the plurality of second heat exchange tubes is arranged in columns; and the columns of the first heat exchange tubes and the columns of the second heat exchange tubes are staggered.

[0008] According to the first aspect, a distance of the centers, in the width direction of the accommodating cavity, of the first heat exchange tubes and the second heat exchange tubes that are adjacent to each other in two adjacent columns of heat exchange tubes is not less than the larger tube diameter of the first heat exchange tube.

[0009] According to the first aspect, the larger tube diameter of the first heat exchange tube is 25.4 mm; and the smaller tube diameter of the second heat exchange tube is 19.05 mm.

[0010] According to the first aspect, the evaporator further comprises: a first baffle plate and a second baffle plate, wherein the first baffle plate and the second baffle plate are disposed on the outer side of the falling film tube bundle in the width direction of the accommodating cavity, respectively; wherein a plurality of windows is disposed on the first baffle plate and the second baffle plate, respectively, wherein the plurality of windows is arranged in the length direction of the accommodating cavity, and the plurality of windows is disposed on the outer side of the middle portion of the falling film tube bundle in the height direction of the accommodating cavity.

[0011] According to the first aspect, a liquid baffle plate extending along the length direction of the accommodating cavity is disposed on each outer side of the windows on the first baffle plate and the second baffle plate, wherein the top of the liquid baffle plate is connected to the corresponding first baffle plate and second baffle plate, and the liquid baffle plate and the window are spaced at a certain distance.

[0012] At least one objective of a second aspect of the present application is to provide a refrigeration system, comprising: a compressor, a condenser, a throttling device, and an evaporator that are disposed in a refrigerant loop, wherein the evaporator is as described in any one

item of the first aspect.

Brief Description of the Drawings

[0013]

FIG. 1 is a schematic block diagram of a refrigeration system;

FIG. 2 is a perspective view of the evaporator in FIG. 1;

FIG. 3A is a radial cross-sectional view of an embodiment of the evaporator in FIG. 2;

FIG. 3B is a partial enlarged view of four adjacent heat exchange tubes in a falling film tube bundle in FIG. 3A;

FIG. 3C is a comparison chart of theoretical values of heat transfer coefficients of a single heat exchange tube in the falling film tube bundle of the evaporator of the embodiment shown in FIG. 3A and an ideal-status falling film tube bundle;

FIG. 4A is a radial cross-sectional view of another embodiment of the evaporator in FIG. 2;

FIG. 4B is a partial enlarged view of four adjacent heat exchange tubes in a falling film tube bundle in FIG. 4A;

FIG. 4C is a comparison chart of theoretical values of heat transfer coefficients of a single heat exchange tube in the falling film tube bundle of the evaporator of the embodiment shown in FIG. 4A and an ideal-status falling film tube bundle;

FIG. 5A is a radial cross-sectional view of still another embodiment of the evaporator in FIG. 2;

FIG. 5B is a partial enlarged view of four adjacent heat exchange tubes in a falling film tube bundle in FIG. 5A;

FIG. 5C is a comparison chart of theoretical values of heat transfer coefficients of a single heat exchange tube in the falling film tube bundle of the evaporator of the embodiment shown in FIG. 5A and an ideal-status falling film tube bundle;

FIG. 6A is a radial cross-sectional view of still another embodiment of the evaporator in FIG. 2;

FIG. 6B is a schematic structural diagram of a first baffle plate in FIG. 6A; and

FIG. 6C is a comparison chart of theoretical values

of heat transfer coefficients of a single heat exchange tube in the falling film tube bundle of the evaporator of the embodiment shown in FIG. 6A and an ideal-status falling film tube bundle.

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Detailed Description of Embodiments

[0014] Various specific embodiments of the present application will be described below with reference to the accompanying drawings, which constitute a part of the specification. It should be understood that although terms, such as "front (前)", "rear", "upper", "lower", "left", "right", "inner", "outer", "top", "bottom", "front (正)", "back", "proximal", "distal", "horizontal direction", "longitudinal direction", that represent directions are used in the present application to describe various example structural parts and elements of the present application, these terms used herein are determined based on example orientations shown in the accompanying drawings for ease of illustration only. Since the embodiments disclosed in the present application may be disposed in different directions, these terms that represent directions are for illustration only and should not be regarded as limiting.

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[0015] Ordinal numbers such as "first" and "second" used in the present application are only used for distinction and identification and do not have any other meaning. Unless otherwise specified, they do not indicate a specific order or have a specific association. For example, the term "first component" does not indicate the existence of a "second component", and the term "second component" also does not indicate the existence of a "first component".

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[0016] FIG. 1 is a schematic block diagram of a refrigeration system 190. As shown in FIG. 1, the refrigeration system 190 comprises a compressor 193, a condenser 191, a throttling device 192, and an evaporator 100, which are connected by pipes to form a refrigerant circulation loop, and the loop is filled with a refrigerant. As shown by the arrow direction in FIG. 1, the refrigerant sequentially flows through the compressor 193, the condenser 191, the throttling device 192, and the evaporator 100, and then enters the compressor 193 again. During the refrigeration process, the throttling device 192 throttles a high-pressure liquid refrigerant from the condenser 191 for pressure reduction; a low-pressure refrigerant exchanges heat with a to-be-cooled object in the evaporator 100, and absorbs heat of the to-be-cooled object for being vaporized; refrigerant vapor generated by vaporization is sucked into the compressor 193, and is discharged as a high-pressure gas after compression; high-temperature and high-pressure gas refrigerant discharged from the compressor 193 exchanges heat with an ambient medium in the condenser 191, releases heat and condenses into a liquid refrigerant; and the high-pressure liquid refrigerant flows through the throttling device 192 again for pressure reduction. This process is

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performed circularly, producing a continuous refrigeration effect.

[0017] FIG. 2 is a perspective view of the evaporator 100 in FIG. 1. As shown in FIG. 2, the evaporator 100 has a housing 203, wherein the housing 203 comprises a cylindrical main body 204 and a pair of tube sheets 205; the cylindrical main body 204 is in a cylindrical shape with openings at the two ends, and the pair of tube sheets 205 are arranged at the two ends of the cylindrical main body 204, respectively, to seal the openings at the two ends of the cylindrical main body 204. The cylindrical main body 204 and the pair of tube sheets 205 define an accommodating cavity 310 (referring to FIG. 3A), and the accommodating cavity 310 is used for accommodating heat exchange tubes. A water inlet tube 208 and a water outlet tube 207 are connected to the tube sheet 205. Referring to the location shown in FIG. 2, the evaporator 100 has a height direction H, a length direction L and a width direction W, wherein the height direction, length direction and width direction of the accommodating cavity 310 are consistent with the directions of the evaporator 100. A refrigerant inlet 101 and a refrigerant outlet 102 is disposed on the cylindrical main body 204, wherein the refrigerant inlet 101 and the refrigerant outlet 102 are both located at the upper portion of the evaporator 100 in the height direction H, and are staggered in the length direction and/or radial direction of the cylindrical main body 204. The liquid refrigerant or gas-liquid mixed refrigerant in the refrigeration system 190 enters the evaporator 130 from the refrigerant inlet 101, becomes the gas refrigerant after absorbing heat in the evaporator 130, and is discharged from the refrigerant outlet 102.

[0018] FIGs. 3A to 3C show a first embodiment of the evaporator of the present application. FIG. 3A is a schematic radial cross-sectional view of the first embodiment of the evaporator in FIG. 2; FIG. 3B is a partial enlarged view of four adjacent heat exchange tubes in a falling film tube bundle in FIG. 3A; and FIG. 3C is a comparison chart of theoretical values of heat transfer coefficients. As shown in FIGs. 3A and 3B, an accommodating cavity 310 is formed inside the housing 203, and a falling film tube bundle 315, a liquid-filled tube bundle 316, a distribution device 340 and a mist eliminator 341 are disposed in the accommodating cavity 310. As shown in FIGs. 2 and 3A, the refrigerant inlet 101 is located at the middle portion of the evaporator 100 in the length direction and the width direction to facilitate even refrigerant distribution. The refrigerant outlet 102 and the refrigerant inlet 101 are staggered in the length direction and/or the radial direction. The distribution device 340 is disposed above the falling film tube bundle 315 and is in communication with the refrigerant inlet 101 to evenly distribute, to the falling film tube bundle 315, the refrigerant received from the refrigerant inlet 101 from the throttling device 192. The mist eliminator 341 is connected below the refrigerant outlet 102, and an outlet for the evaporated gas of the falling film tube bundle 315 and the liquid-filled tube bundle 316 is disposed below the mist eliminator 341,

such that the mist eliminator 341 can prevent liquid droplets contained in the evaporated gas refrigerant from discharging from the refrigerant outlet 102.

[0019] The falling film tube bundle 315 is substantially disposed at the middle and upper portion of the accommodating cavity 310, the liquid-filled tube bundle 316 is disposed at the bottom of the accommodating cavity 310, and the liquid-filled tube bundle 316 and the bottom of the falling film tube bundle 315 are spaced at a certain distance. The falling film tube bundle 315 and the liquid-filled tube bundle 316 are separately heat exchange tube bundles formed by a plurality of heat exchange tubes 320 sequentially arranged. Each heat exchange tube 320 has the same tube diameter D_0 , and each heat exchange tube 320 extends along the length direction L of the accommodating cavity 305. As an example, the heat exchange tube 320 has a tube diameter D_0 of 1 inch, that is, 25.4 mm. A fluid channel is formed inside each heat exchange tube for communication with a water inlet tube 208 and a water outlet tube 207 to circulate water or another medium. A gap between each heat exchange tube 320 and an adjacent heat exchange tube 320 forms a refrigerant channel for circulating the refrigerant. The medium in the fluid channel and the refrigerant in the refrigerant channel exchanges heat through tube walls of the heat exchange tubes.

[0020] The heat exchange tubes 320 in the falling film tube bundle 315 are arranged in columns, and adjacent columns are spaced at the same distance. In addition, the centers of heat exchange tubes 320 in each column are evenly spaced at the same distance along the height direction H. However, in the width direction W, the centers of adjacent heat exchange tubes 320 in two adjacent columns of heat exchange tubes 320 are staggered, and spaced at the same distance. That is, in the width direction W, the centers of two adjacent heat exchange tubes 320 are not on the same horizontal line, that is, the centers are not at the same height.

[0021] In the height direction H, the centers of two adjacent heat exchange tubes 320 are on the same vertical line, that is, the centers are at the same width. The reason for arranging the heat exchange tubes in this way is that during the falling film evaporation process, the to-be-evaporated liquid refrigerant will flow from top to bottom, form a liquid film on the outer surface of the tube wall of each heat exchange tube 320, and exchange heat with the medium in the heat exchange tube 320. The heat exchange tubes 320 are arranged in columns, and the adjacent heat exchange tubes 320 are staggered in the width direction rather than arranged in a flush row, to avoid inconsistency between an extension direction of a refrigerant channel formed between two adjacent rows of heat exchange tubes 320 and a gravity direction of the liquid refrigerant, which makes it difficult to form liquid films on the lower row of heat exchange tubes. The tube layout method of the present application is conducive to the liquid refrigerant that is not completely evaporated continuing to flow to the outer surface of the lower heat

exchange tube 320 to form the liquid films, thereby improving evaporation efficiency of the heat exchange tubes.

[0022] The heat exchange tubes 320 in the liquid-filled tube bundle 316 are also arranged in columns and cover the bottom of the accommodating cavity 310. After the heat exchange on the falling film tube bundle 315, there is still a part of the liquid refrigerant that has not completely evaporated into gas refrigerant, and this part of the liquid refrigerant will form a liquid surface at the bottom of the accommodating cavity 310 whose height is greater than the height of the liquid-filled tube bundle 316. The heat exchange tubes 320 in the liquid-filled tube bundle 316 are used for being immersed in this part of the liquid refrigerant to further evaporate the liquid refrigerant into gas refrigerant.

[0023] The evaporator 100 further comprises a first baffle plate 331 and a second baffle plate 332, wherein the first baffle plate 331 and the second baffle plate 332 are disposed on the outer side of the falling film tube bundle 315 in the width direction W and extend along the length direction L, respectively. The first baffle plate 331 and the second baffle plate 332 are used for guiding the refrigerant to flow from top to bottom through each heat exchange tube in the falling film tube bundle 315, to prevent the liquid refrigerant from flowing to the outer side of the falling film tube bundle 315. The evaporated gas refrigerant flows along the first baffle plate 331 and the second baffle plate 332 and is discharged from the bottoms of the first baffle plate 331 and the second baffle plate 332. That is, an outlet of the evaporated gas refrigerant of the falling film tube bundle 315 is located approximately at the bottom edge of the first baffle plate 331 and the second baffle plate 332.

[0024] FIG. 3B shows an enlarged structure of four adjacent heat exchange tubes 320a, 320b, 320c, and 320d in two adjacent columns in the falling film tube bundle 315 in FIG. 3A. Those skilled in the art can understand that because the heat exchange tubes 320 in the falling film tube bundle 315 are evenly arranged, these four heat exchange tubes may be any four adjacent heat exchange tubes in two adjacent columns, which are adjacent to each other, and the centers of three adjacent heat exchange tubes form two acute-angled triangle shapes. As shown in FIG. 3B, the heat exchange tube 320a and the heat exchange tube 320b are in the same column, and the heat exchange tube 320c and the heat exchange tube 320d are in the same column. In addition, the heat exchange tube 320a, the heat exchange tube 320b, and the heat exchange tube 320c are adjacent to each other, and the centers thereof form an acute-angled triangle shape. The heat exchange tube 320b, the heat exchange tube 320c, and the heat exchange tube 320d are adjacent to each other, and the centers thereof form an acute-angled triangle shape. In the height direction H, the centers of the adjacent heat exchange tube 320a and heat exchange tube 320b in the same column have a distance

H_0 (hereinafter referred to as a vertical distance). In the width direction W, the centers of the adjacent heat exchange tube 320a and heat exchange tube 320c in different columns have a distance W_0 (hereinafter referred to as a horizontal distance). There is a minimum distance X_0 between the outer surfaces of the heat exchange tube 320a and the heat exchange tube 320b. There is a minimum distance V_0 between the outer surfaces of the heat exchange tube 320a and the heat exchange tube 320c. In this embodiment, V_0 is greater than X_0 . In addition, H_0 and W_0 meet a relationship:

$$\cos 30^\circ < \frac{W_0}{H_0} < 1.5 \cdot \cos 30^\circ$$

[0025] In some existing falling film tube bundles, the centers of three adjacent heat exchange tubes in heat exchange tubes arranged in columns are usually arranged in an equilateral triangle shape. These heat exchange tubes will have a horizontal distance approximately equal to D_0 and a vertical distance approximately

equal to $\frac{D_0}{\cos 30^\circ}$. That is, a ratio of the horizontal distance to the vertical distance of these heat exchange tubes is approximately $\cos 30^\circ$.

[0026] In the falling film evaporator, the gas-liquid two-phase refrigerant entering the evaporator from the refrigerant inlet is evenly distributed by the distribution device to the surfaces of the heat exchange tubes at the top of the falling film tube bundle to form liquid films for heat exchange. A part of the liquid refrigerant is converted into gas after the heat exchange and evaporation, and the other part of the liquid refrigerant that has not evaporated will drip onto the lower row of heat exchange tubes to continue evaporation; and a flow of the liquid refrigerant flowing through the falling film tube bundle gradually decreases from the top to the bottom of the falling film tube bundle, while a flow of the gas refrigerant gradually increases.

[0027] The applicant found through research that heat transfer coefficients " h_r " of the heat exchange tubes in the falling film tube bundle can be fitted to the Gaussian distribution equation (1):

$$h_r = y_0 + \frac{A \sqrt{\frac{2}{\pi}}}{w} \cdot e^{-2 \left(\frac{\frac{Re_v}{Re_{film}} - xc}{w} \right)^2}; \quad (1)$$

wherein y_0 , A , w , xc are fitting constants, Re_v is the gas phase Reynolds number, and Re_{film} is the liquid film Reynolds number. It can be seen from the Gaussian distribution equation (1) that the heat transfer coefficient " h_r " decreases as a ratio of the gas phase Reynolds number Re_v to the liquid film Reynolds number Re_{film} increases. The gas phase Reynolds number Re_v is directly proportional to the flow rate of the gas refrigerant between tubes, and the liquid film Reynolds number Re_{film} is also directly

proportional to the flow of the liquid refrigerant. When the flow rate of the gas refrigerant is smaller, the gas phase Reynolds number Re_v is smaller and the heat transfer coefficient " h_r " is larger. When the flow of the liquid refrigerant is greater, the liquid film Reynolds number Re_{film} is greater and the heat transfer coefficient " h_r " is also greater.

[0028] The flow rate of the gas refrigerant is related to the flow of the gas refrigerant and a flow area of the gas refrigerant. By increasing the minimum distance between the outer surfaces of tube walls of the heat exchange tubes in different columns of the falling film tube bundle, the space for the refrigerant channel in the width direction W can be increased, and at a certain flow of the gas refrigerant, the flow rate of the gas flowing among the corresponding heat exchange tubes is reduced, thereby increasing the heat transfer coefficient " h_r ". However, when the horizontal distance between heat exchange tubes increases, the quantity of the heat exchange tubes of the falling film tube bundle that can be arranged in a certain-sized accommodating cavity will be reduced, resulting in a decrease in the heat exchange capacity of the evaporator. Therefore, increasing the minimum distance between the outer surfaces of the tube walls of the heat exchange tubes of the falling film tube bundle within a certain range can improve the heat transfer efficiency of the evaporator, thereby increasing the heat exchange capacity of the evaporator. Alternatively, the quantity of the heat exchange tubes is reduced under the same heat exchange capacity of the evaporator.

[0029] In this embodiment, compared with the existing falling film tube bundle, the size of the evaporator is the same as that in the prior art, and the size of each heat exchange tube is also the same. In this embodiment, the minimum distance between the outer surfaces of the tube walls of the heat exchange tubes in different columns is increased by maintaining the vertical distance H_0 of the centers of the heat exchange tubes and increasing the horizontal distance W_0 of the centers of the heat exchange tubes. Specifically, the ratio of the horizontal distance W_0 to the vertical distance H_0 is increased to $(1-1.5) \cdot \cos 30^\circ$ in the falling film tube bundle 315 of the present application. That is, the centers of three adjacent heat exchange tubes of the falling film tube bundle 315 of the present application are not arranged in an equilateral triangle shape, but are arranged in an isosceles triangle shape with a vertex angle less than 60° . The increased ratio of the horizontal distance W_0 to the vertical distance H_0 will reduce the flow rate of the gas flowing through two adjacent columns of heat exchange tubes 320, thereby improving the heat exchange efficiency of the evaporator 100.

[0030] FIG. 3C shows a comparison chart of theoretical values of heat transfer coefficients of a single heat exchange tube in the falling film tube bundle 315 of this embodiment, the existing falling film tube bundle, the ideal-status falling film tube bundle, and the ideal-status liquid-filled tube bundle in a case of the same quantity of

heat exchange tubes, wherein the theoretical values are obtained through the Gaussian distribution equation (1). In FIG. 3C, the horizontal axis represents heat exchange tubes of different row numbers from top to bottom, and the vertical axis represents the heat transfer coefficients. The straight line 361 and the straight line 362 represent heat transfer coefficients of a single heat exchange tube in the ideal-status falling film tube bundle and liquid-filled tube bundle, respectively. The curve 360 and the curve 370 represent the heat transfer coefficients of the existing falling film tube bundle and the falling film tube bundle 315 of this embodiment, respectively.

[0031] It can be seen from FIG. 3C that in an ideal status, the heat transfer coefficients of the heat exchange tubes in both the falling film tube bundle and the liquid-filled tube bundle will not decrease as the row number increases. However, in the existing falling film tube bundle, the heat transfer coefficient decreases rapidly as the row number increases; even in the low-row heat exchange tubes at the bottom, the heat transfer efficiency will decrease below the heat transfer coefficient of the ideal-status liquid-filled tube bundle. In the falling film tube bundle of this embodiment, the heat transfer coefficient remains almost equal to the heat transfer coefficient of the ideal-status falling film tube bundle. Even if the heat transfer coefficient of the heat exchanger tube at the bottom decreases slightly, it is still much higher than that of the ideal-status liquid-filled tube bundle.

[0032] FIGs. 4A to 4C show a second embodiment of the evaporator of the present application. FIG. 4A shows a radial cross-sectional view of an evaporator 400 in the second embodiment of the evaporator in FIG. 2; FIG. 4B is a partial enlarged view of four adjacent heat exchange tubes in a falling film tube bundle in FIG. 4A; and FIG. 4C is a comparison chart of theoretical values of heat transfer coefficients. As shown in FIGs. 4A and 4B, the same as the first embodiment, a falling film tube bundle 415 and a liquid-filled tube bundle 416 are disposed in the evaporator 400 as well, wherein the falling film tube bundle 415 and the liquid-filled tube bundle 416 comprise a plurality of heat exchange tubes arranged in columns, respectively. Wherein, the heat exchange tubes in the liquid-filled tube bundle 416 and the arrangement of the heat exchange tubes are the same as those in the first embodiment. However, the falling film tube bundle 415 is different from that in the first embodiment, wherein the heat exchange tubes in the falling film tube bundle 415 does not have the same tube diameter, but comprise a plurality of first heat exchange tubes 421 with a larger tube diameter D_1 and a plurality of second heat exchange tubes 422 with a smaller tube diameter D_2 ; and in each column of the falling film tube bundle 415, the first heat exchange tubes 421 and the second heat exchange tubes 422 are staggered. That is, any four adjacent heat exchange tubes in two adjacent columns must comprise two first heat exchange tubes 421 with the larger tube diameter and two second heat exchange tubes 422 with the smaller tube diameter. For example, the larger tube

diameter D_1 of the first heat exchange tube 421 is equal to the tube diameter D_0 of the heat exchange tube 320 in the first embodiment. In this embodiment, the tube diameter D_1 of the first heat exchange tube 421 with the larger tube diameter is 1 inch, that is, 25.4 mm, and the tube diameter D_2 of the second heat exchange tube 422 with the smaller tube diameter is 3/4 inch, that is, 19.05 mm. In the falling film tube bundle 415, a quantity ratio of the first heat exchange tubes 421 and the second heat exchange tubes 422 is approximately 1:1.

[0033] FIG. 4B shows an enlarged structure of four adjacent heat exchange tubes 421a, 421b, 422a, and 422b in two adjacent columns, wherein these heat exchange tubes are adjacent to each other, and the centers of three adjacent heat exchange tubes form two equilateral triangles. As shown in FIG. 4B, the heat exchange tube 421a and the heat exchange tube 422a are in the same column, and the heat exchange tube 422b and the heat exchange tube 421b are in the same column. In addition, the heat exchange tube 421a, the heat exchange tube 422a, and the heat exchange tube 422b are adjacent to each other, and the heat exchange tube 421b, the heat exchange tube 422a, and the heat exchange tube 422b are adjacent to each other. In the height direction H , the centers of the adjacent heat exchange tube 421a and heat exchange tube 422a in the same column have a vertical distance H_1 . In the width direction W , the centers of the adjacent heat exchange tube 421a and heat exchange tube 422b in different columns have a horizontal distance W_1 . There is a minimum distance X_1 between the outer surfaces of the heat exchange tube 421a and the heat exchange tube 422a, and between the outer surfaces of the heat exchange tube 421a and the heat exchange tube 422b; and there is a minimum distance V_1 between the outer surfaces of the heat exchange tube 422a and the heat exchange tube 422b. In this embodiment, V_1 is greater than X_1 , and $W_1 \geq D_1$.

[0034] Generally, the second heat exchange tube 422 with the smaller tube diameter has a heat transfer coefficient greater than the heat transfer coefficient of the first heat exchange tube 421 with the larger tube diameter and has lower costs, but However, a smaller heat exchange area results in a poorer overall heat exchange capacity as compared to that of the first heat exchange tube 421. In this embodiment, a part of the first heat exchange tubes 421 with the larger tube diameter D_1 is replaced with the second heat exchange tubes 422 with the smaller tube diameter D_2 . On the one hand, the tube diameter of the part of the heat exchange tubes is reduced to increase the minimum distance V_1 between a part of the outer surfaces, so as to reduce a flow rate of gas flowing among the corresponding heat exchange tubes, thereby improving the heat exchange efficiency of the evaporator. On the other hand, in the same column, for the first heat exchange tubes 421 in the lower row of the second heat exchange tubes 422, because the heat exchange capacity of the second heat exchange tubes 422 is smaller than the heat exchange capacity of the

first heat exchange tubes 421, the flow of a liquid refrigerant on the first heat exchange tubes 421 in the lower row is increased, and in this way, the liquid film Reynolds number Re_{film} can also be increased by increasing the flow of the liquid refrigerant on the first heat exchange tubes 421 in the lower row, thereby further increasing the heat transfer coefficient " h_r ".

[0035] In this way, even if the horizontal distance W_0 between the centers of the heat exchange tubes is not increased, the space for the refrigerant channel can be increased in the width direction W , thereby reducing the flow rate of the gas flowing among the corresponding heat exchange tubes. In this embodiment, the center distance between the heat exchange tubes is not changed as compared to the existing technology in which all heat exchange tubes have the larger tube diameter, but both the space for the refrigerant channel between the heat exchange tubes 421a and 422b and the space for the refrigerant channel between the heat exchange tubes 422a and 422b are increased. Therefore, the overall heat exchange efficiency of the evaporator of this embodiment can still be improved, and the costs of the heat exchange tubes can be reduced in general.

[0036] It should be noted that, in some other embodiments, among the four adjacent heat exchange tubes 421a, 421b, 422a, and 422b in two adjacent columns, the centers of three adjacent heat exchange tubes may alternatively form two isosceles triangles, similar to the first embodiment, by increasing the horizontal distance between adjacent heat exchange tubes in different columns, instead of forming two equilateral triangles.

[0037] FIG. 4C shows a comparison chart of theoretical values of heat transfer coefficients of the first heat exchange tube in the falling film tube bundle 415 of this embodiment, the second heat exchange tube in the falling film tube bundle 415 of this embodiment, and a single heat exchange tube in the ideal-status falling film tube bundle comprising the first heat exchange tube, the ideal-status liquid-filled tube bundle comprising the first heat exchange tube, the ideal-status falling film tube bundle comprising the second heat exchange tube, and the ideal-status liquid-filled tube bundle comprising the second heat exchange tube in a case of the same quantity of heat exchange tubes, wherein the theoretical values are obtained through the Gaussian distribution equation (1). In FIG. 4C, the horizontal axis represents heat exchange tubes of different row numbers from top to bottom, and the vertical axis represents the heat transfer coefficients. The straight line 461, the straight line 462, the straight line 463, and the straight line 464 represent the heat transfer coefficients of a single heat exchange tube in the ideal-status falling film tube bundle comprising the first heat exchange tube, the ideal-status liquid-filled tube bundle comprising the first heat exchange tube, the ideal-status falling film tube bundle comprising the second heat exchange tube, and the ideal-status liquid-filled tube bundle comprising the second heat exchange tube, respectively. The curve 460 and the curve 470 represent the

heat transfer coefficients of the first heat exchange tubes and the second heat exchange tubes in the falling film tube bundle 415 of this embodiment, respectively.

[0038] It can be seen from FIG. 4C that, in the ideal status, the heat transfer coefficients of the falling film tube bundle and the liquid-filled tube bundle comprising the second heat exchange tubes with the smaller tube diameter are greater than those of the falling film tube bundle and the liquid-filled tube bundle comprising the first heat exchange tubes with the larger tube diameter, respectively, which indicates that the heat exchange tubes with the smaller tube diameter have a better heat transfer coefficient. In addition, the falling film tube bundle comprising the second heat exchange tubes with the smaller tube diameter can almost maintain the heat transfer coefficient equivalent to that in the ideal status, and the heat transfer coefficient does not decrease significantly as the row number decreases. The heat transfer coefficient of the falling film tube bundle comprising the first heat exchange tubes with the larger tube diameter is also always greater than the heat transfer coefficient of the ideal-status liquid-filled tube bundle with the same tube diameter.

[0039] FIGs. 5A to 5C show a third embodiment of the evaporator of the present application. FIG. 5A shows a radial cross-sectional view of an evaporator 500 in the third embodiment of the evaporator in FIG. 2; FIG. 5B is a partial enlarged view of four adjacent heat exchange tubes in a falling film tube bundle in FIG. 4A; and FIG. 5C is a comparison chart of theoretical values of heat transfer coefficients. As shown in FIGs. 5A and 5B, a falling film tube bundle 515 and a liquid-filled tube bundle 516 are disposed in the evaporator 500 as well, wherein the falling film tube bundle 515 and the liquid-filled tube bundle 516 comprise a plurality of heat exchange tubes arranged in columns, respectively, wherein the heat exchange tubes in the liquid-filled tube bundle 516 and the arrangement of the heat exchange tubes are the same as those in the first embodiment and the second embodiment. In addition, the heat exchange tubes in the falling film tube bundle 515 comprise a plurality of first heat exchange tubes 521 with a larger tube diameter D_1 and a plurality of second heat exchange tubes 522 with a smaller tube diameter D_2 . Different from the second embodiment, the plurality of first heat exchange tubes 521 is arranged in columns, the plurality of second heat exchange tubes 522 is arranged in columns, and the columns of the first heat exchange tubes 521 and the columns of the second heat exchange tubes 522 are staggered. For example, the larger tube diameter D_1 of the first heat exchange tube 521 is equal to the tube diameter D_0 of the heat exchange tube 320 in the first embodiment. In this embodiment, the tube diameter D_1 of the first heat exchange tube 521 with the larger tube diameter is 1 inch, that is, 25.4 mm, and the tube diameter D_2 of the second heat exchange tube 522 with the smaller tube diameter is 3/4 inch, that is, 19.05 mm. In the falling film tube bundle 515, a quantity ratio of the first heat exchange tubes 521 and the second heat exchange tubes 522 is

approximately 1:1.

[0040] FIG. 5B shows an enlarged structure of four adjacent heat exchange tubes 521a, 521b, 522a, and 522b in two adjacent columns, wherein these heat exchange tubes are adjacent to each other, and the centers of three adjacent heat exchange tubes form two equilateral triangles. As shown in FIG. 5B, the heat exchange tube 521a and the heat exchange tube 521b are in the same column, and the heat exchange tube 522a and the heat exchange tube 522b are in the same column. In addition, the heat exchange tube 521a, the heat exchange tube 522a, and the heat exchange tube 521b are adjacent to each other, and the heat exchange tube 521b, the heat exchange tube 522a, and the heat exchange tube 522b are adjacent to each other. In the height direction H, the centers of the adjacent heat exchange tube 521a and heat exchange tube 522a in the same column have a vertical distance H_2 . In the width direction W, the centers of the adjacent heat exchange tube 521a and heat exchange tube 522a in different columns have a horizontal distance W_2 . There is a minimum distance X_2 between the outer surfaces of the heat exchange tube 521a and the heat exchange tube 521b. There is a minimum distance V_2 between the outer surfaces of the heat exchange tube 522a and the heat exchange tube 521b, and between the outer surfaces of the heat exchange tube 522a and the heat exchange tube 521a. In this embodiment, V_2 is greater than X_2 , and $W_2 \geq D_1$.

[0041] Similar to the second embodiment, a part of the first heat exchange tubes 521 with the larger tube diameter D_1 in this embodiment is also replaced with the second heat exchange tubes 522 with the smaller tube diameter D_2 . The tube diameter of the part of the heat exchange tubes is reduced to increase the minimum distance V_1 between the outer surfaces, so as to reduce a flow rate of gas flowing among the corresponding heat exchange tubes, thereby improving the heat exchange efficiency of the evaporator. Compared with the second embodiment, although $V_2 < V_1$, in each row of heat exchange tubes in the falling film tube bundle 515, the minimum distance between the outer surfaces of heat exchange tubes in adjacent columns is increased.

[0042] It should be noted that, in some other embodiments, among the four adjacent heat exchange tubes 521a, 521b, 522a, and 522b in two adjacent columns, the centers of three adjacent heat exchange tubes may alternatively form two isosceles triangles, similar to the first embodiment, by increasing the horizontal distance between adjacent heat exchange tubes in different columns, instead of forming two equilateral triangles.

[0043] FIG. 5C shows a comparison chart of theoretical values of heat transfer coefficients of the first heat exchange tube in the falling film tube bundle 515 of this embodiment, the second heat exchange tube in the falling film tube bundle 515 of this embodiment, and a single heat exchange tube in the ideal-status falling film tube bundle comprising the first heat exchange tube, the ideal-status liquid-filled tube bundle comprising the first heat

exchange tube, the ideal-status falling film tube bundle comprising the second heat exchange tube, and the ideal-status liquid-filled tube bundle comprising the second heat exchange tube in a case of the same quantity of heat exchange tubes, wherein the theoretical values are obtained through the Gaussian distribution equation (1). In FIG. 5C, the horizontal axis represents heat exchange tubes of different row numbers from top to bottom, and the vertical axis represents the heat transfer coefficients. The straight line 561, the straight line 562, the straight line 563, and the straight line 564 represent the heat transfer coefficients of a single heat exchange tube in the ideal-status falling film tube bundle comprising the first heat exchange tube, the ideal-status liquid-filled tube bundle comprising the first heat exchange tube, the ideal-status falling film tube bundle comprising the second heat exchange tube, and the ideal-status liquid-filled tube bundle comprising the second heat exchange tube, respectively. The curve 560 and the curve 570 represent the heat transfer coefficients of the first heat exchange tubes and the second heat exchange tubes in the falling film tube bundle 515 of this embodiment, respectively.

[0044] It can be seen from FIG. 5C that, although the heat transfer coefficients of the falling film tube bundle comprising the first heat exchange tubes 521 and the second heat exchange tubes 522 decrease as the row number increases, the heat transfer coefficients do not decrease significantly as the row number decreases, and are all greater than the heat transfer coefficients of respective liquid-filled tube bundle.

[0045] FIGs. 6A to 6C show a fourth embodiment of the evaporator of the present application. FIG. 6A shows a radial cross-sectional view of an evaporator 600 in the fourth embodiment of the evaporator in FIG. 2; FIG. 6B is a schematic structural diagram of a baffle plate 631 in FIG. 6A, and FIG. 6C is a comparison chart of theoretical values of heat transfer coefficients. As shown in FIGs. 6A and 6B, a falling film tube bundle 615 and a liquid-filled tube bundle 616 are disposed in the evaporator 600 as well, wherein the falling film tube bundle 615 and the liquid-filled tube bundle 616 comprise a plurality of heat exchange tubes arranged in columns, respectively. In this embodiment, the heat exchange tubes in the liquid-filled tube bundle 616 and the arrangement of the heat exchange tubes are the same as those in the first embodiment. In addition, the heat exchange tubes in the falling film tube bundle 615 and the arrangement of the heat exchange tubes are substantially the same as those in the first embodiment. Details are not described herein again. The only difference is that in this embodiment, the heat exchange tubes in the middle portion of the falling film tube bundle 615 are spaced apart to form a fluid channel 638 substantially extending in the width direction W.

[0046] The evaporator 600 further comprises a first baffle plate 631 and a second baffle plate 632, wherein the first baffle plate 631 and the second baffle plate 632 are disposed on the left side and the right side of the

falling film tube bundle 615 in the width direction W, respectively. The first baffle plate 631 and the second baffle plate 632 are provided with a plurality of windows 635, respectively, wherein these windows 635 are arranged in the length direction L and are disposed at the corresponding positions of the fluid channel 638. The fluid channel 638 and the windows 635 allow the evaporated gas refrigerant obtained by the upper heat exchange tubes to flow out through the windows 635 instead of continuing to flow through the lower heat exchange tubes. In this way, a flow of gas refrigerant flowing through the lower heat exchange tubes is reduced.

[0047] In this embodiment, even though the quantity of the heat exchange tubes is the same as that in the first embodiment, because a part of gas refrigerant can be discharged through the fluid channel 638 and the windows 635, a flow rate of the gas refrigerant in the lower falling film heat exchange tube bundle is reduced, thereby further improving the heat exchange efficiency of the evaporator as compared to the first embodiment.

[0048] FIG. 6C shows a comparison chart of theoretical values of heat transfer coefficients of a single heat exchange tube in the falling film tube bundle 615 of this embodiment, the falling film tube bundle 315 of the first embodiment, the ideal-status falling film tube bundle, and the ideal-status liquid-filled tube bundle in a case of the same quantity of heat exchange tubes, wherein the theoretical values are obtained through the Gaussian distribution equation (1). In FIG. 6C, the horizontal axis represents heat exchange tubes of different row numbers from top to bottom, and the vertical axis represents the heat transfer coefficients. The straight line 661 and the straight line 662 represent heat transfer coefficients of a single heat exchange tube in the ideal-status falling film tube bundle and liquid-filled tube bundle, respectively. The curve 668 and the curve 670 represent the heat transfer coefficients of the falling film tube bundle 615 of this embodiment and the falling film tube bundle 315 of the first embodiment, respectively.

[0049] It can be seen from FIG. 6C that, in the falling film tube bundle 615 of this embodiment, by discharging a part of gas refrigerant through the middle portion, the heat transfer coefficient of each row of heat exchange tubes can be maintained at a high level.

[0050] Those skilled in the art can understand that, although in this embodiment, the heat exchange tubes in the falling film tube bundle are disposed in a way substantially the same as that in the first embodiment, the heat exchange tubes may alternatively be disposed in a way substantially the same as that in the second embodiment or the third embodiment, provided that a fluid channel is disposed in the falling film tube bundle in the second embodiment or the third embodiment, and windows for discharging the gas refrigerant are disposed on baffle plates corresponding to the fluid channel.

[0051] In the evaporators of the foregoing embodiments, for the falling film tube bundle in the evaporator of the first embodiment, the distance between the heat

exchange tubes in the width direction, that is, the distance between the heat exchange tubes in the individual columns, is increased, thereby increasing the space for the refrigerant channel in the width direction W. For the falling film tube bundles in the evaporators of the second embodiment and the third embodiment, a part of the heat exchange tubes are replaced with the heat exchange tubes with the smaller tube diameter to increase the minimum distance between the outer surfaces of the tube walls of the heat exchange tubes, thereby increasing at least a part of space for the refrigerant channel in the width direction W.

[0052] In the present application, the flow rate of the gas flowing among the corresponding heat exchange tubes is reduced by increasing the flow space of the refrigerant in the width direction W, so that the ratio of the gas phase Reynolds number Re_v to the liquid film Reynolds number Re_{film} is reduced, and thus the heat exchange efficiency of the evaporator is improved.

[0053] While only some of the features of the present application have been illustrated and described herein, various modifications and changes will occur to those skilled in the art. It is therefore to be understood that the appended claims are intended to cover all such modifications and changes that fall within the true spirit of the present application.

Claims

1. An evaporator, comprising:

- a housing (203), wherein the housing (203) has an accommodating cavity (310), the accommodating cavity (310) has a length direction (L), a width direction (W), and a height direction (H); and
- a falling film tube bundle (315), wherein the falling film tube bundle (315) is disposed in the accommodating cavity (310) and arranged in columns, the falling film tube bundle (315) comprises a plurality of heat exchange tubes (320), each heat exchange tube (320) extends along the length direction (L) of the accommodating cavity (310), the centers of the heat exchange tubes (320) in each column are arranged along the height direction (H), and the centers of two adjacent heat exchange tubes (320) in adjacent columns are staggered in the width direction (W) of the accommodating cavity (310);

wherein the falling film tube bundle (315) is configured in a way that among four adjacent heat exchange tubes (320) in two adjacent columns, a minimum distance (V_0, V_1, V_2) between outer surfaces of at least two heat exchange tubes (320) in different columns is greater than a minimum distance (X_0, X_1, X_2) between outer surfaces of two heat exchange

tubes (320) in the same column.

2. The evaporator of claim 1, wherein

- among the four adjacent heat exchange tubes (320) in two adjacent columns, the distance between outer surfaces of at least two heat exchange tubes (320) in different columns is set such as to reduce a flow rate of gas flowing through the two adjacent columns of heat exchange tubes (320), thereby improving heat exchange efficiency of the evaporator (100).

3. The evaporator of claim 2, wherein

- each heat exchange tube (320) in the falling film tube bundle (315) has the same tube diameter (D_0), and a ratio of a distance (W_0) of the centers, in the width direction (W) of the accommodating cavity (310), of two adjacent heat exchange tubes (320) in adjacent columns to a distance (H_0) of the centers, in the height direction (H) of the accommodating cavity (310), of two adjacent heat exchange tubes (320) in the heat exchange tubes (320) in each column meets a relationship:

$$\cos 30^\circ < \frac{W_0}{H_0} < 1.5 * \cos 30^\circ$$

4. The evaporator of claim 2, wherein

- the falling film tube bundle (415) comprises a plurality of first heat exchange tubes (421) with a larger tube diameter (D_1) and a plurality of second heat exchange tubes (422) with a smaller tube diameter (D_2); and
- the first heat exchange tubes (421) and the second heat exchange tubes (422) are staggered in the columns of the falling film tube bundle (415).

5. The evaporator of claim 2, wherein

- the falling film tube bundle (515) comprises a plurality of first heat exchange tubes (521) with a larger tube diameter (D_1) and a plurality of second heat exchange tubes (522) with a smaller tube diameter (D_2), wherein the plurality of first heat exchange tubes (521) is arranged in columns, and the plurality of second heat exchange tubes (522) is arranged in columns;

wherein the columns of the first heat exchange tubes (521) and the columns of the second heat exchange tubes (522) are staggered.

6. The evaporator of claim 4 or 5, wherein

- a distance (W1, W2) of the centers, in the width direction (W) of the accommodating cavity (310), of the first heat exchange tubes (421, 521) and the second heat exchange tubes (422, 522) that are adjacent to each other in two adjacent columns of heat exchange tubes (320) is not less than the larger tube diameter (D1) of the first heat exchange tube (421, 521). 5

7. The evaporator of claim 6, wherein 10

- the larger tube diameter (D1) of the first heat exchange tubes (421, 521) is 25.4 mm; and
- the smaller tube diameter (D2) of the second heat exchange tubes (422, 522) is 19.05 mm. 15

8. The evaporator of claim 1, wherein the evaporator further comprises:

- a first baffle plate (631) and a second baffle plate (632), wherein the first baffle plate (631) and the second baffle plate (632) are disposed on the outer side of the falling film tube bundle (615) in the width direction (W) of the accommodating cavity (310), respectively; 20
25

wherein a plurality of windows (635) is disposed on the first baffle plate (631) and the second baffle plate (632), respectively, wherein the plurality of windows (635) is arranged along the length direction (L) of the accommodating cavity (310), and the plurality of windows (635) is disposed on the outer side of the middle portion of the falling film tube bundle (615) in the height direction (H) of the accommodating cavity (310). 30
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9. The evaporator of claim 8, wherein

- a liquid baffle plate (638) extending along the length direction (L) of the accommodating cavity (310) is disposed on each outer side of the windows (635) on the first baffle plate (631) and the second baffle plate (632), wherein the top of the liquid baffle plate (638) is connected to the corresponding first baffle plate (631) and second baffle plate (632), and the liquid baffle plate (638) and the window (635) are spaced at a certain distance. 40
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10. A refrigeration system, comprising: 50

- a compressor (193), a condenser (191), a throttling device (192), and an evaporator (100) that are disposed in a refrigerant loop, wherein the evaporator (100) is as described in any one of claims 1 to 9. 55

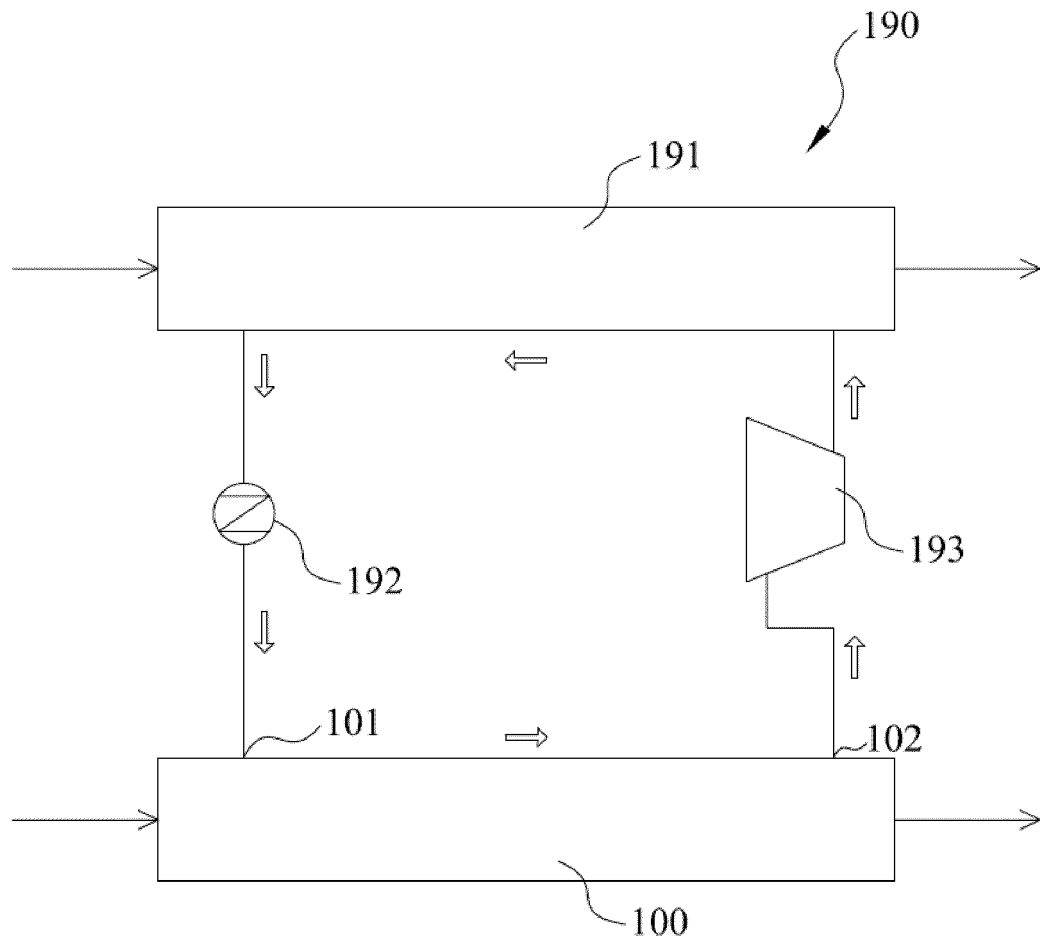


FIG. 1

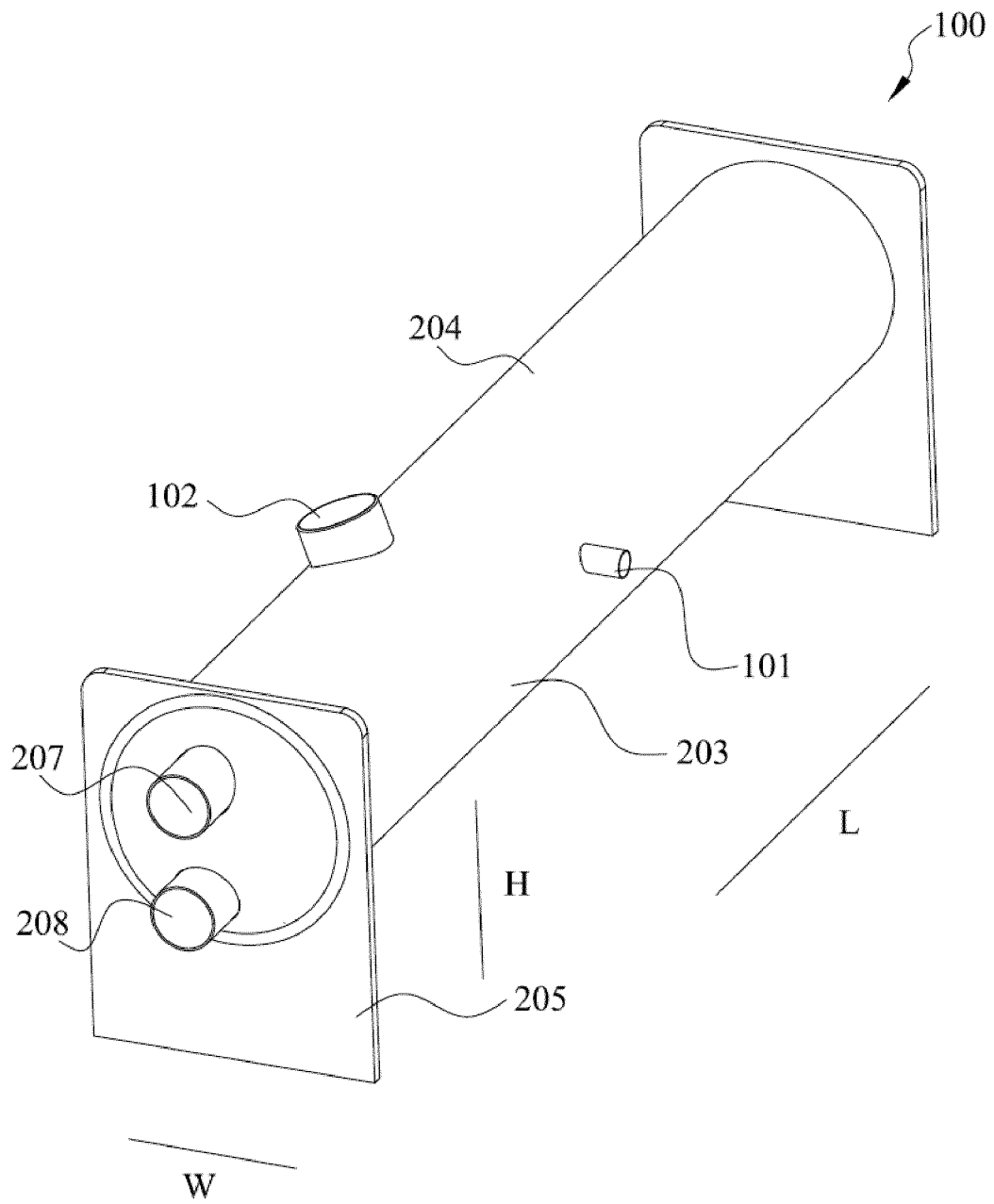


FIG. 2

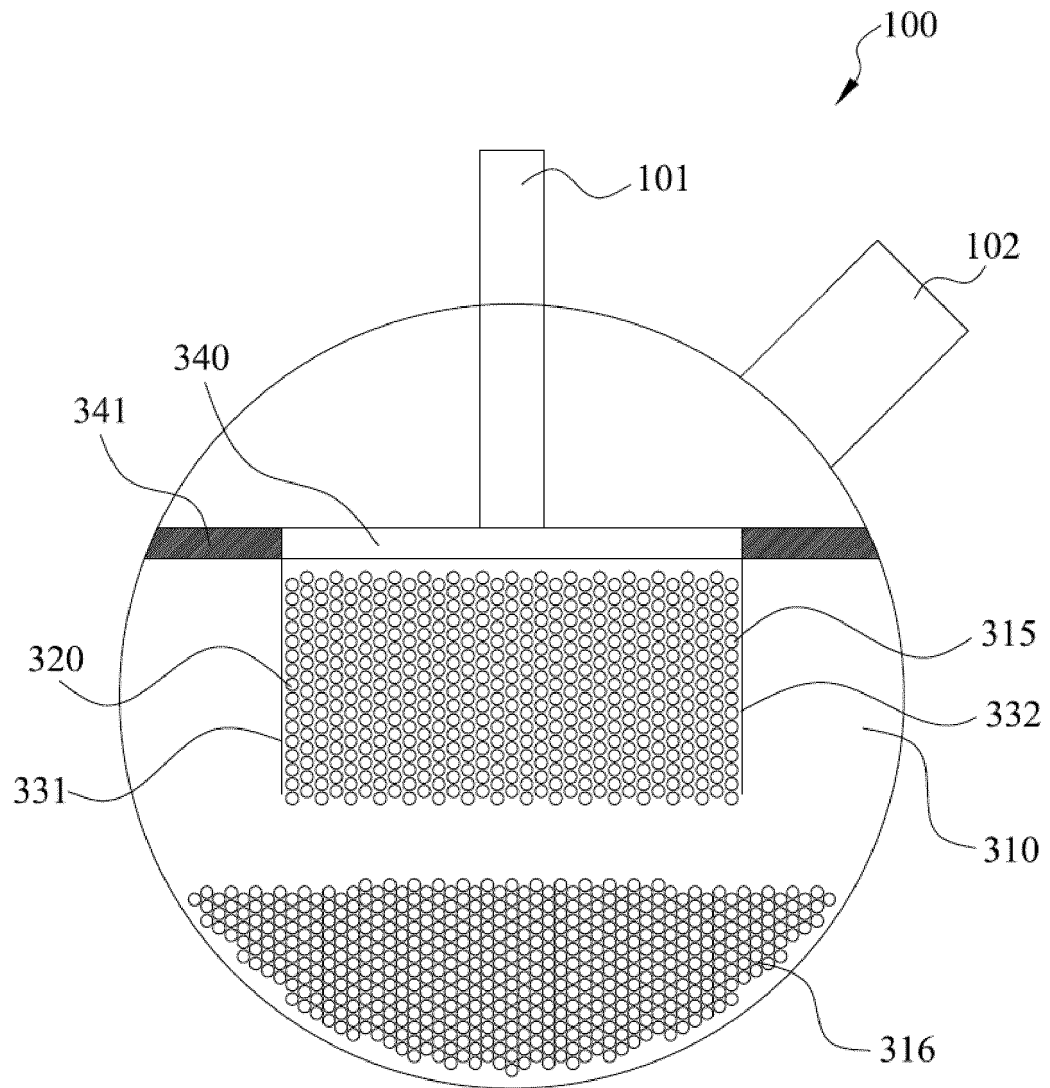


FIG. 3A

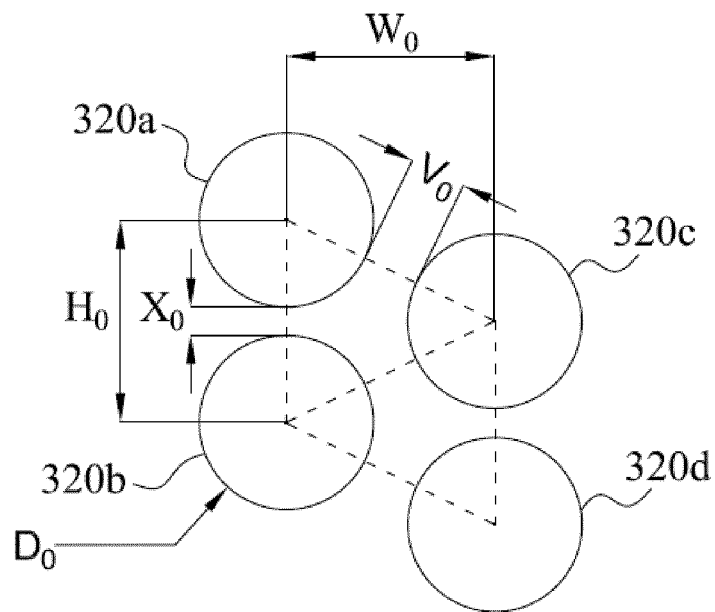


FIG. 3B

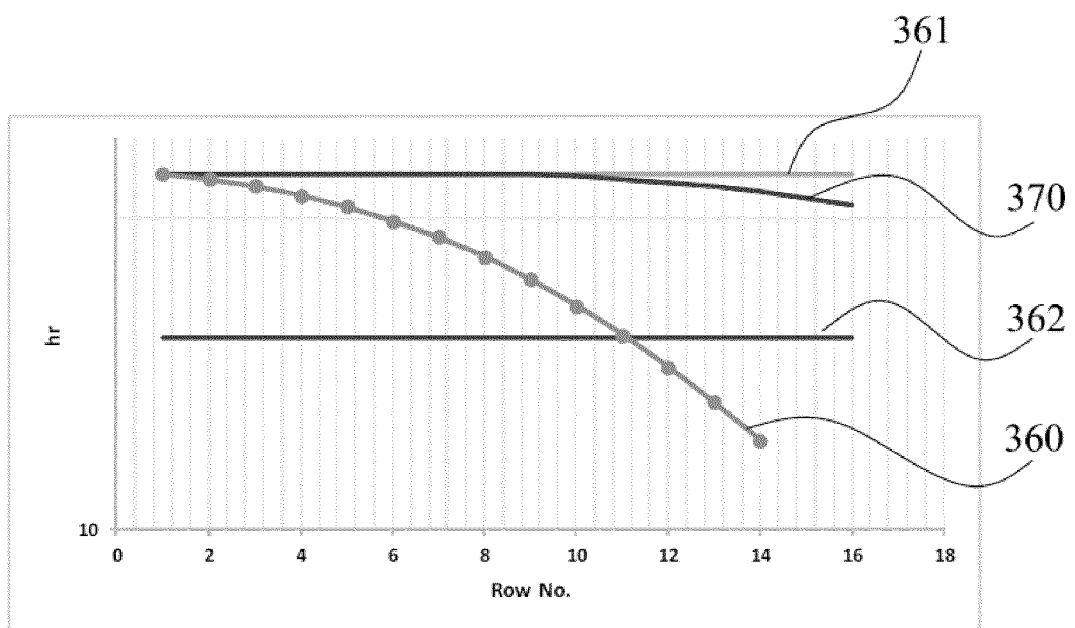


FIG. 3C

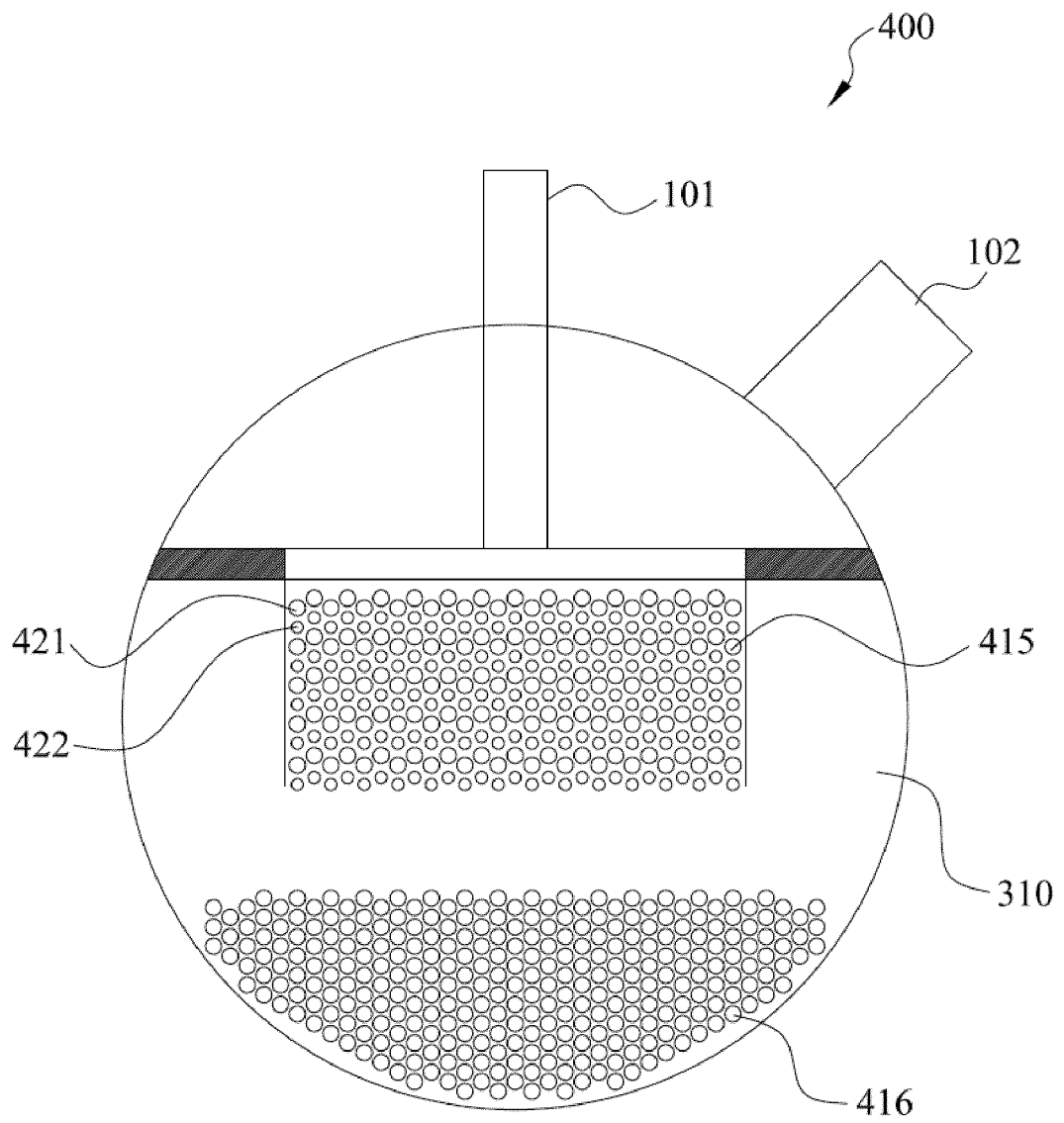


FIG. 4A

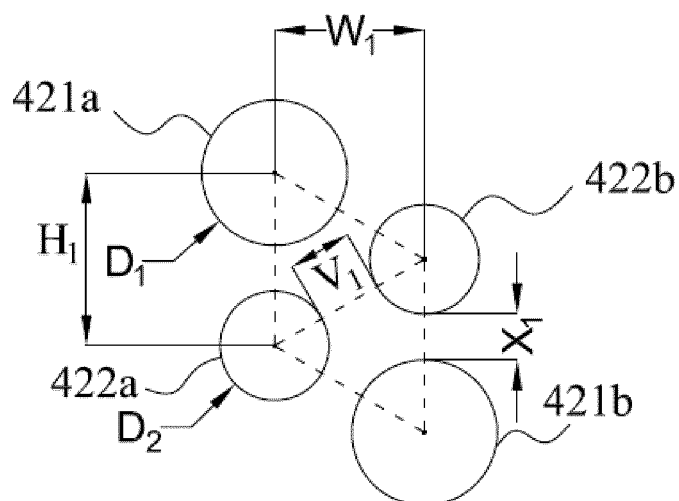


FIG. 4B

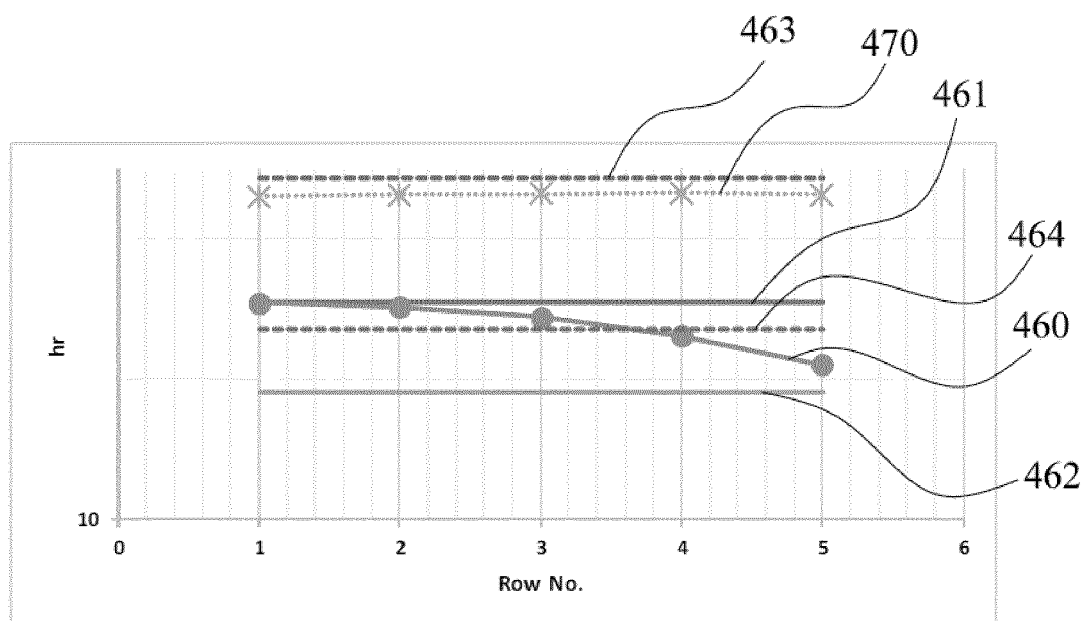


FIG. 4C

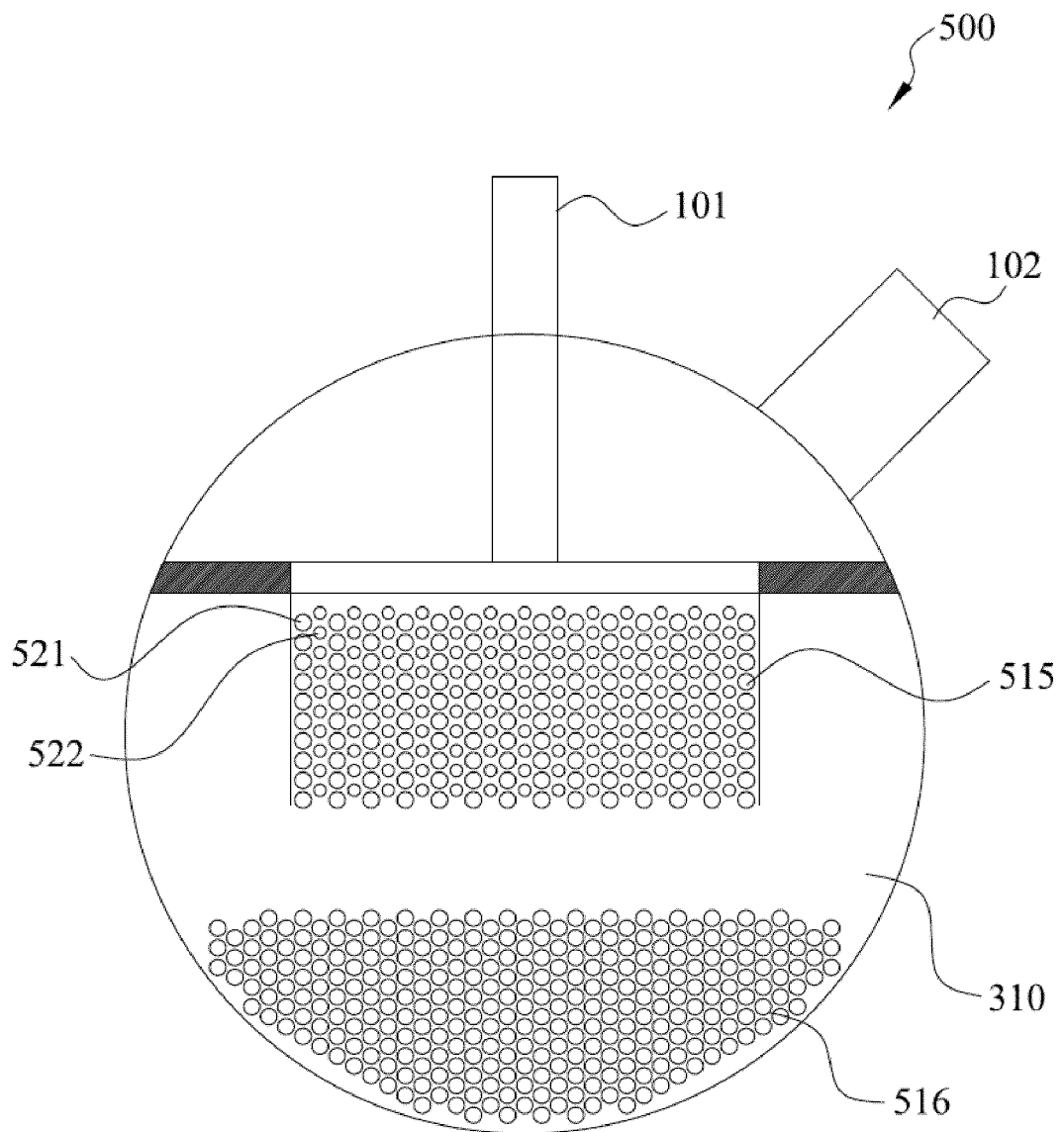


FIG. 5A

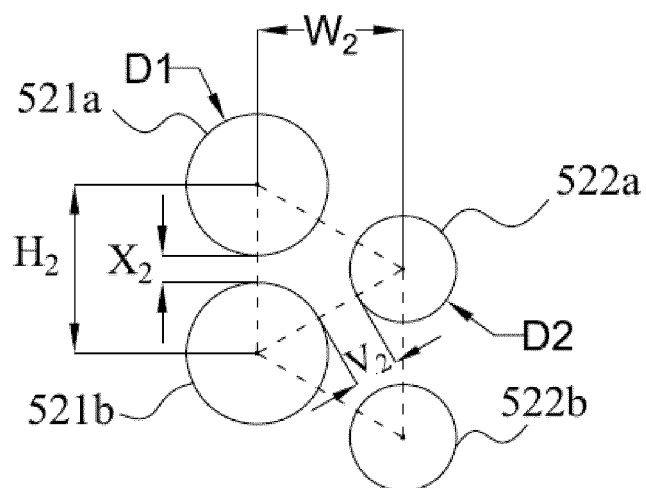


FIG. 5B

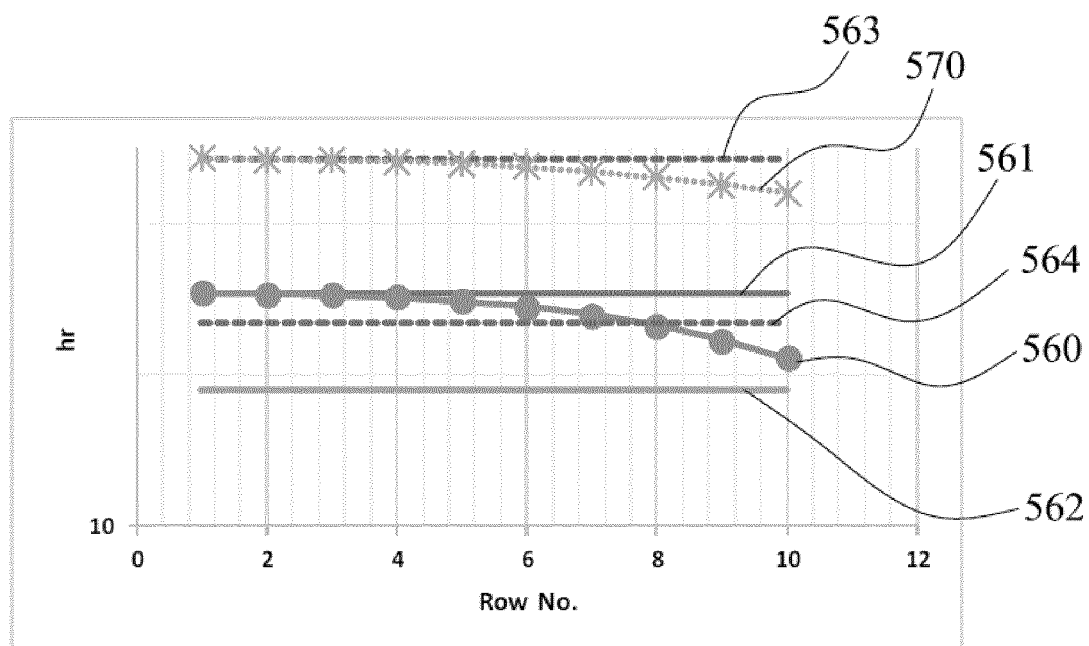


FIG. 5C

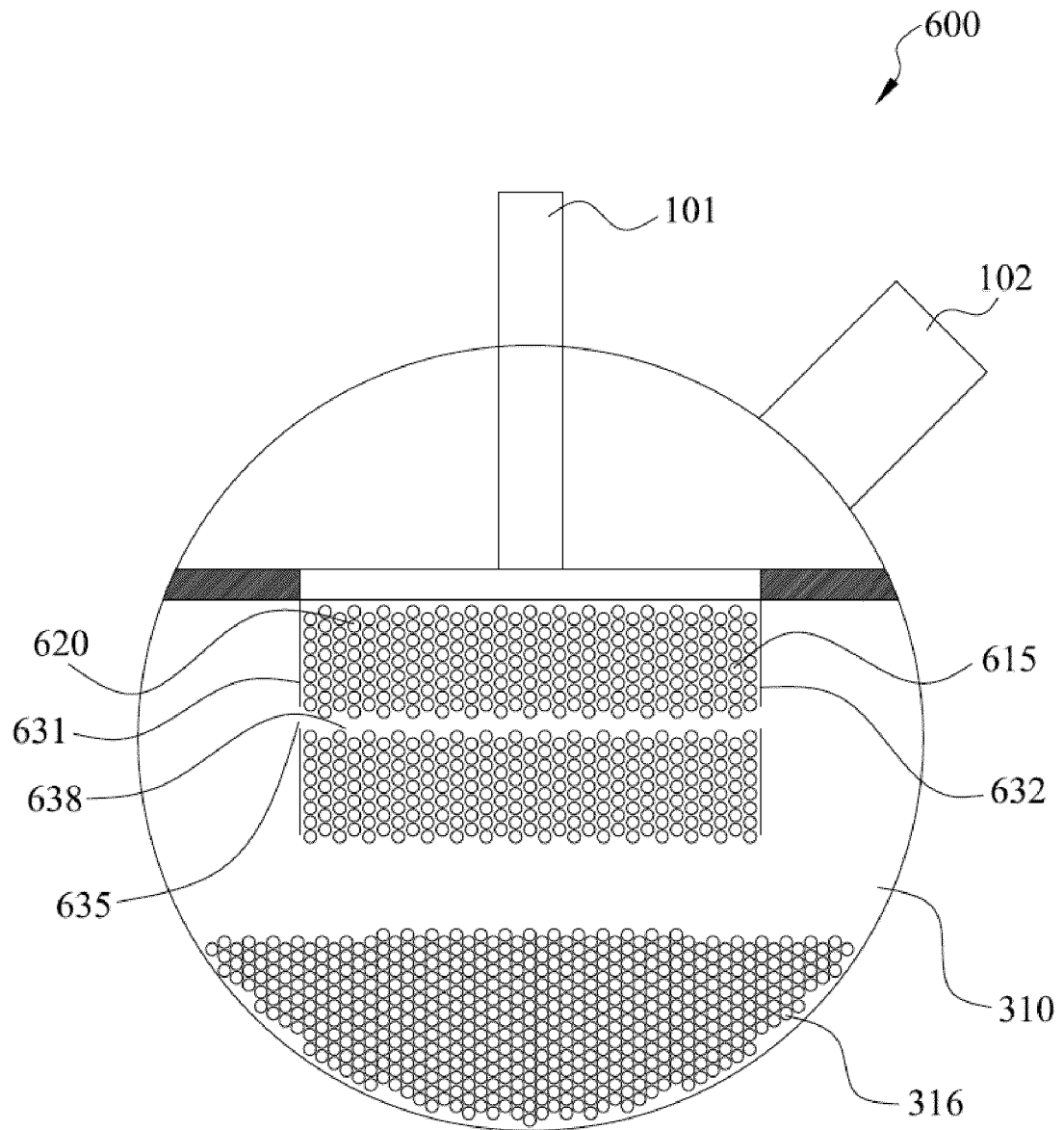


FIG. 6A

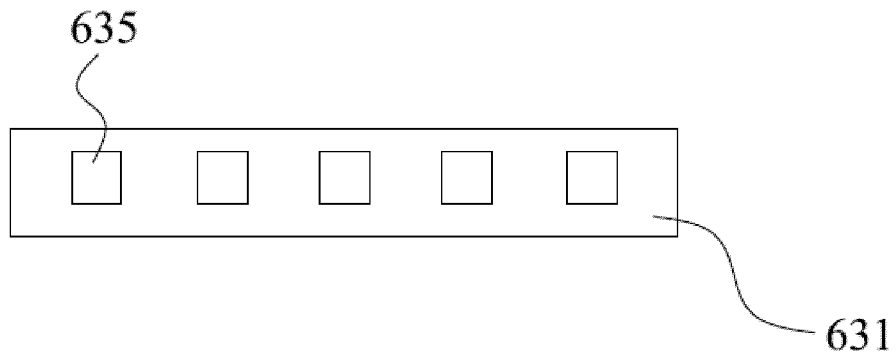


FIG. 6B

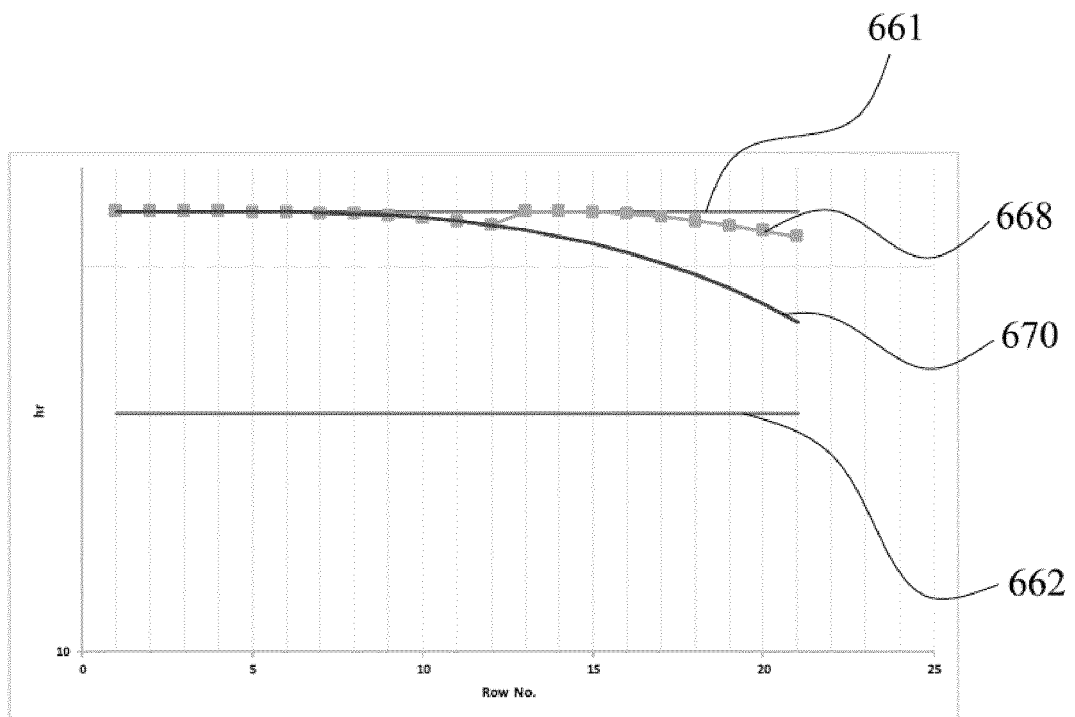


FIG. 6C

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2022/115500

A. CLASSIFICATION OF SUBJECT MATTER

F25B 39/02(2006.01)i; F25B 41/40(2021.01)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)

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)

CNABS; CNTXT; DWPI; WPABS; CNKI; USTXT; EPTXT; JPTXT; WOTXT; ISI Web of Knowledge; 万方, WANFANG; 超星读秀, CHAOXING DUXIU; 约克, 江森自控, 蒸发器, 降膜, 满液, 换热管, 间距, 距离, 挡板, 直径, 等腰, 三角形, YORK WUXI AIR, JOHNSON CONTROLS, evaporator, heat exchange tube, full liquid, distance, diameter, triangle, isoceles, falling film

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	CN 212390655 U (YORK (WUXI) AIR CONDITIONING AND REFRIGERATION EQUIPMENT CO., LTD. et al.) 22 January 2021 (2021-01-22) description, paragraphs 0025-0045, and figures 1-5	1-10
Y	CN 214095033 U (YORK (WUXI) AIR CONDITIONING AND REFRIGERATION EQUIPMENT CO., LTD. et al.) 31 August 2021 (2021-08-31) description, paragraphs 0021-0039, and figures 1 and 4	1-10
A	CN 105546881 A (SHANGHAI JIAO TONG UNIVERSITY et al.) 04 May 2016 (2016-05-04) entire document	1-10
A	CN 206156787 U (TIANJIN UNIVERSITY) 10 May 2017 (2017-05-10) entire document	1-10
A	US 2013055755 A1 (KOMPA, R. et al.) 07 March 2013 (2013-03-07) entire 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

“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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Date of the actual completion of the international search

31 October 2022

Date of mailing of the international search report

18 November 2022

Name and mailing address of the ISA/CN

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Facsimile No. (86-10)62019451

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2022/115500

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US	2013055755	A1	07 March 2013	None	