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(54) MICRO-CHANNEL REFRIGERATING EVAPORATOR AND FREEZE-DRYING SYSTEM USING EVAPORATOR

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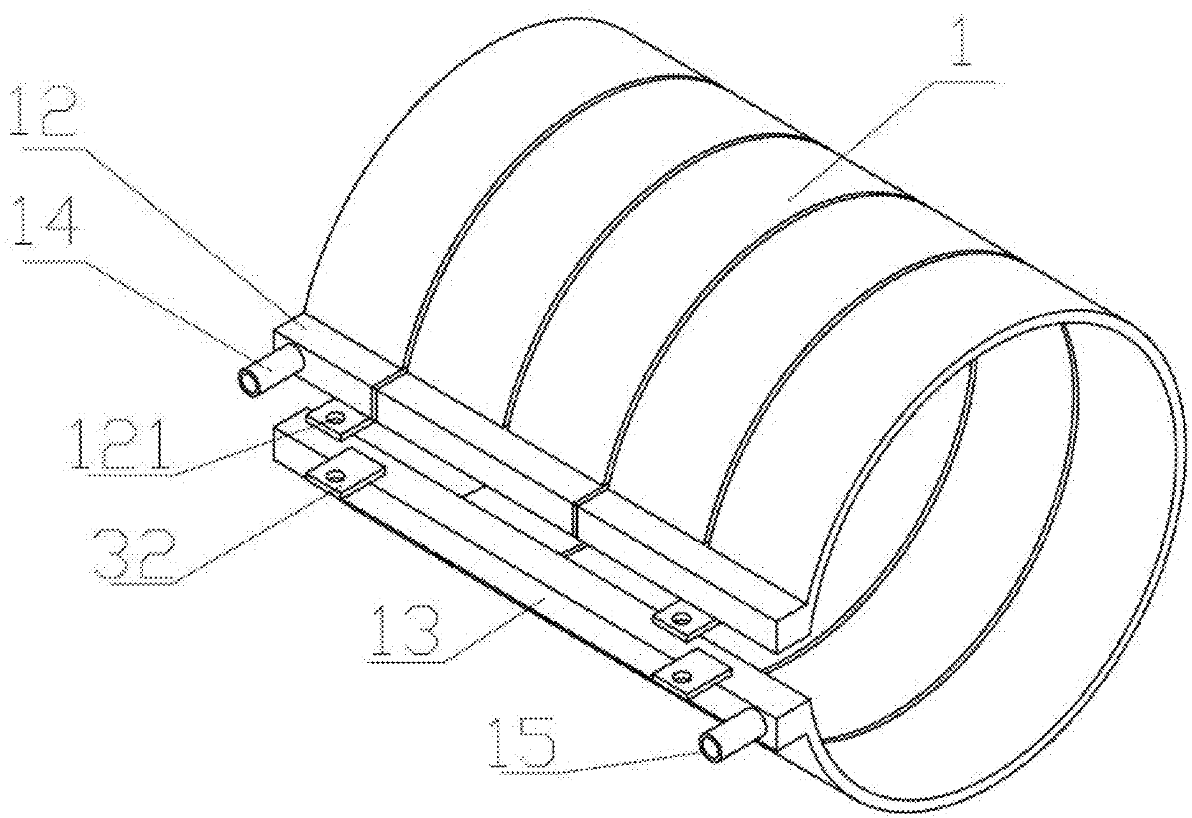
(57) **ABSTRACT**

A micro-channel refrigerating evaporator and a freeze-drying system using the evaporator. The micro-channel refrigerating evaporator comprises a rectangular flat tube structure, wherein the flat tube structure is arranged in a surrounding manner in the lengthwise direction thereof; first micro-channel structures, which are parallel to each other in a circumferential direction, are arranged in the flat tube structure. By means of using a rectangular metal flat tube structure and arrangement of the micro-channel structures in the middle thereof, the flat tube structure is completely attached to a surrounding drying box, such that no hollow structure is disposed in the middle, the coverage area is thus increased to the maximum extent and the heat exchange efficiency is improved.



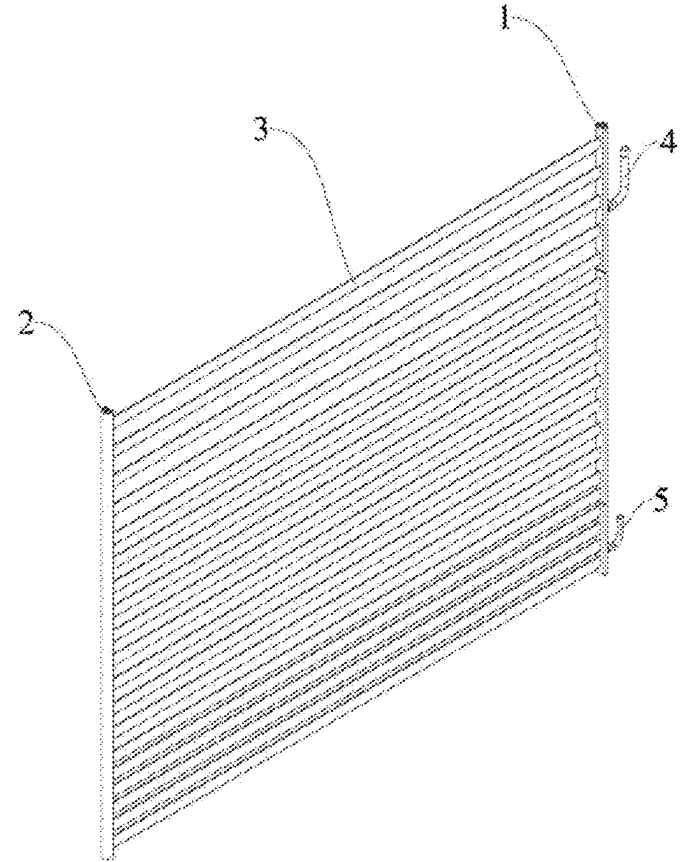


Figure 1

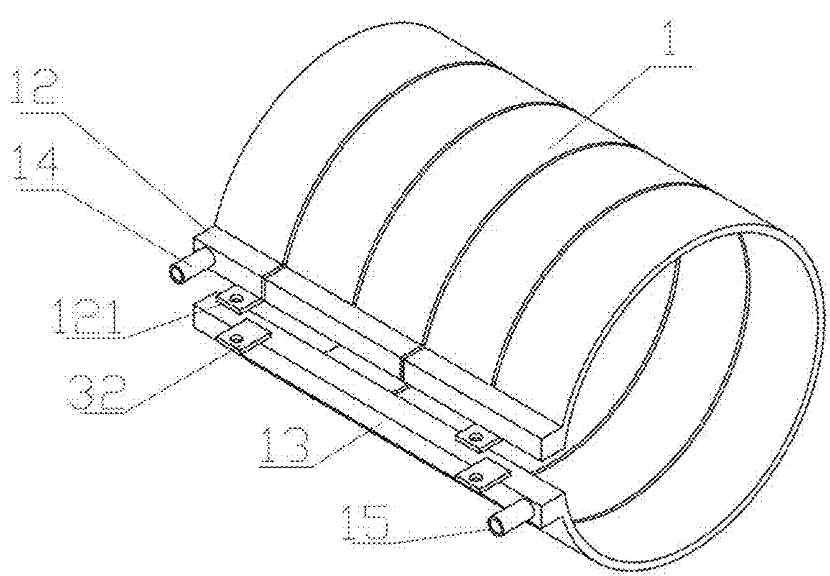


Figure 2

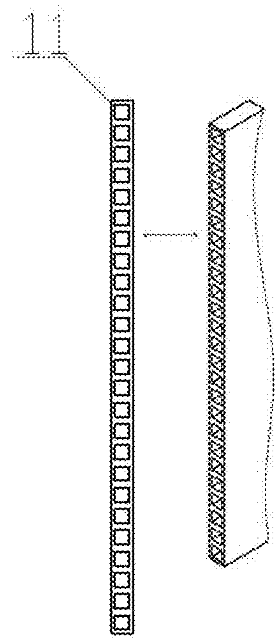


Figure 3

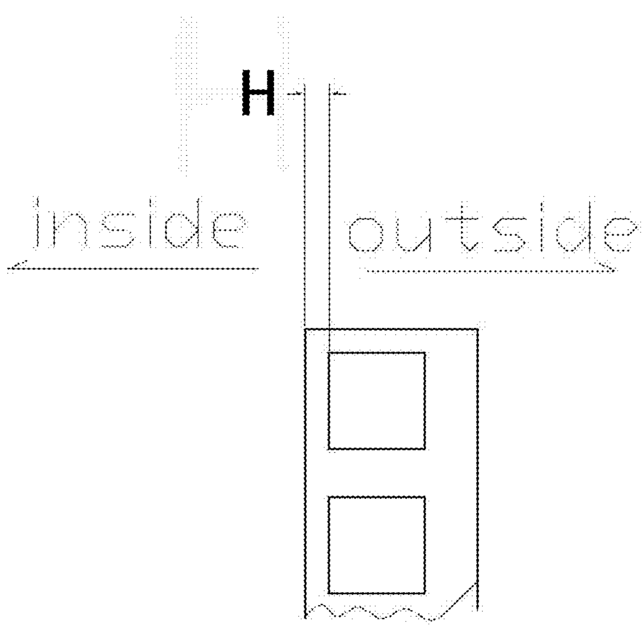


Figure 4

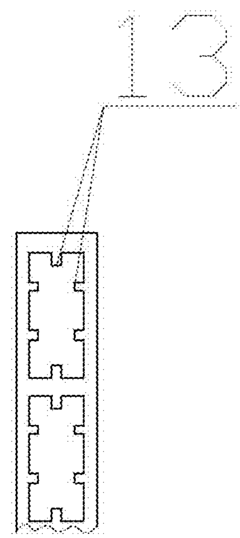


Figure 5

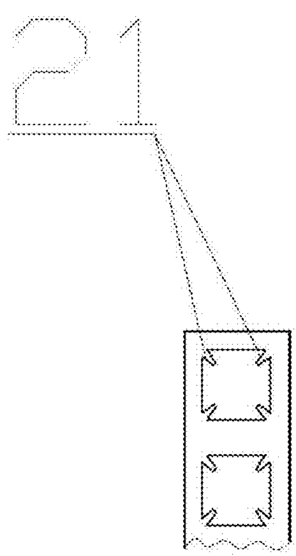


Figure 6

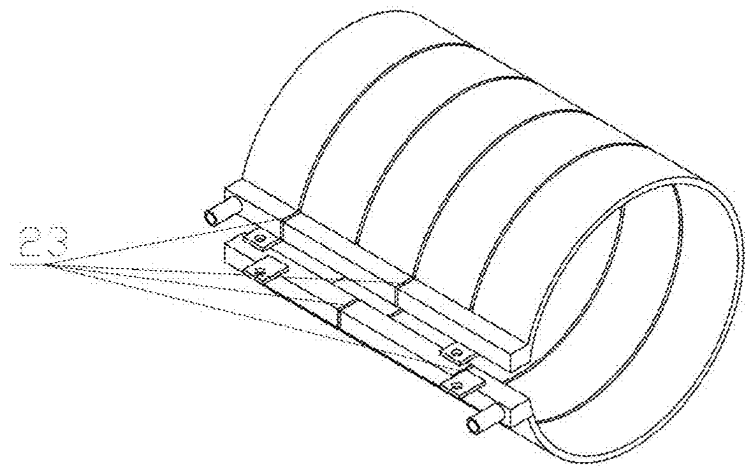


Figure 7

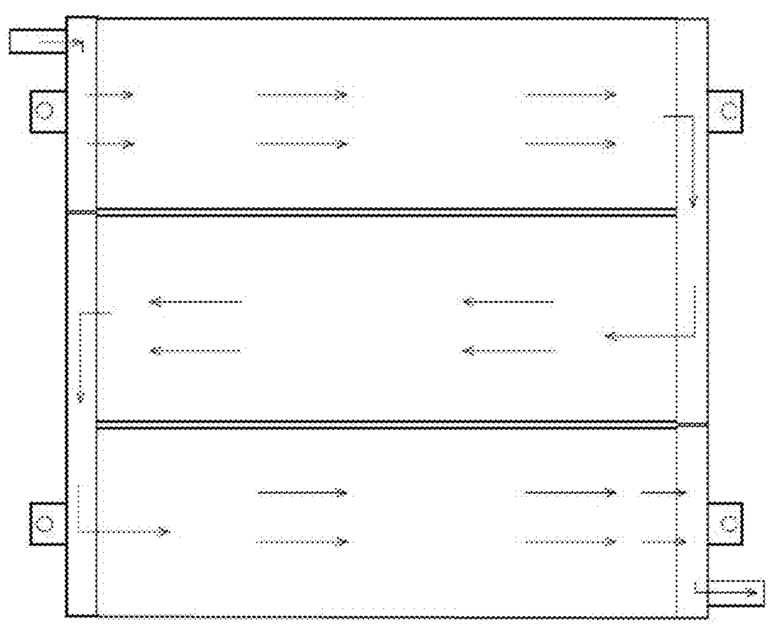


Figure 8

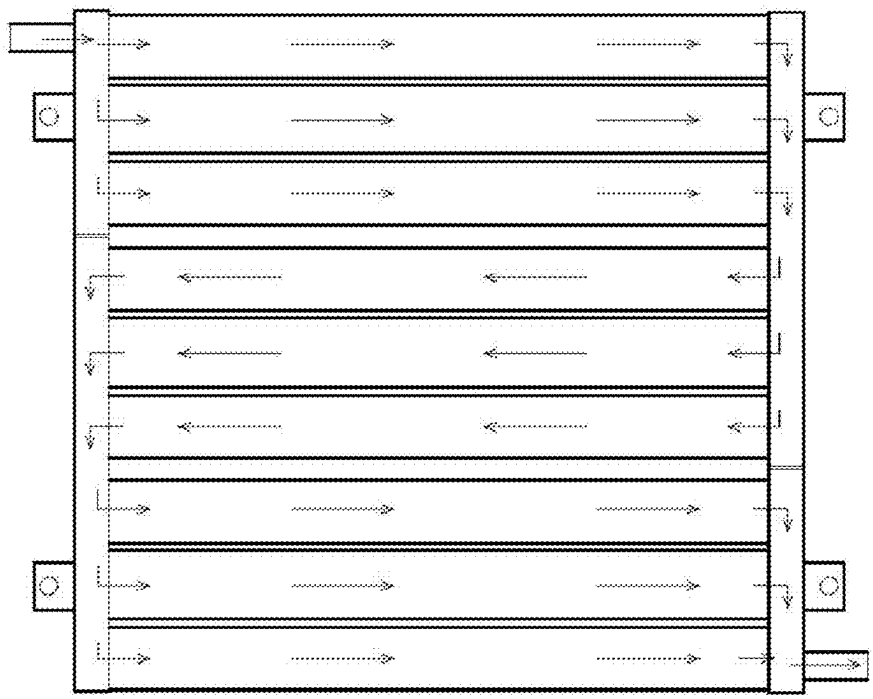


Figure 9

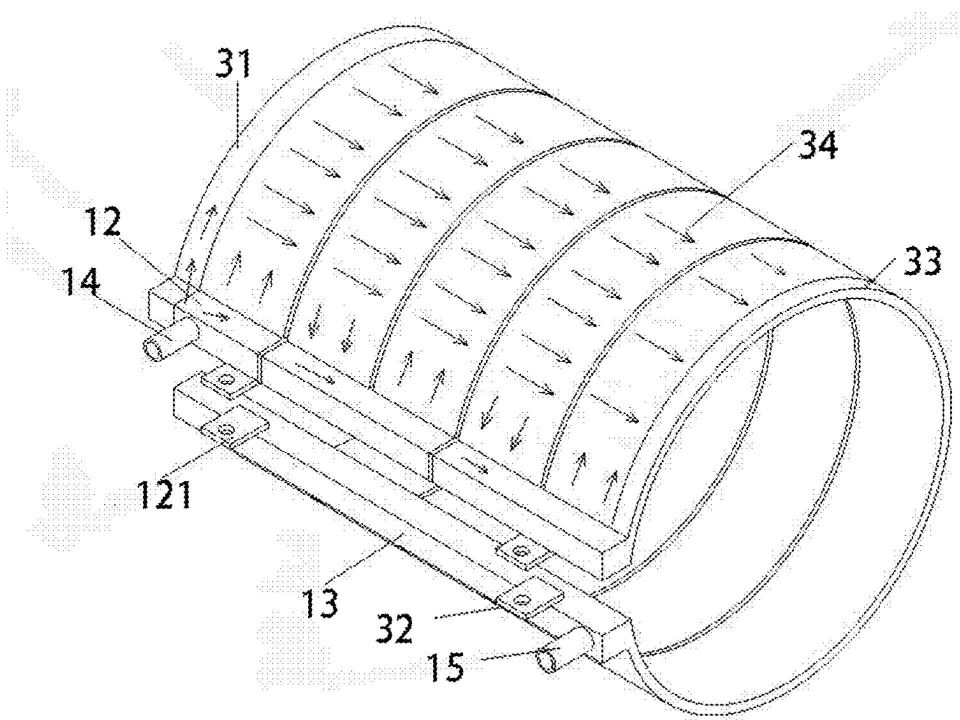


Figure 10

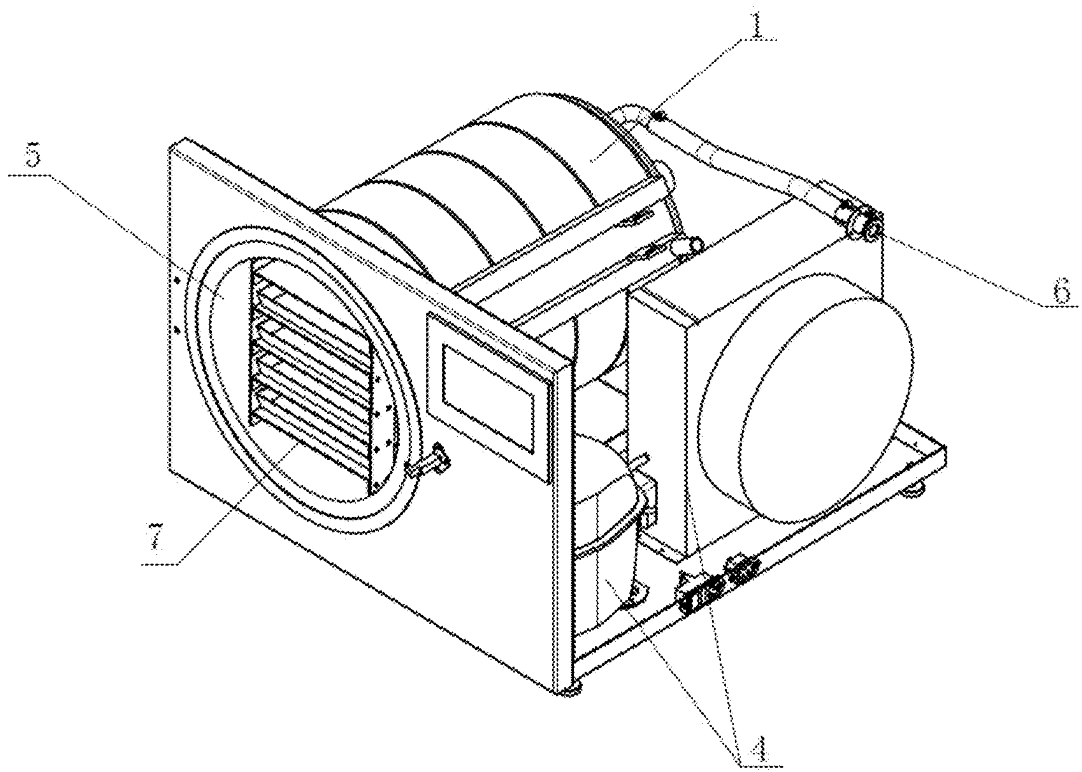


Figure 11

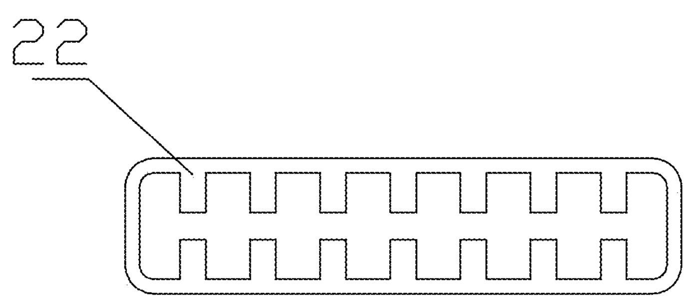


Figure 12

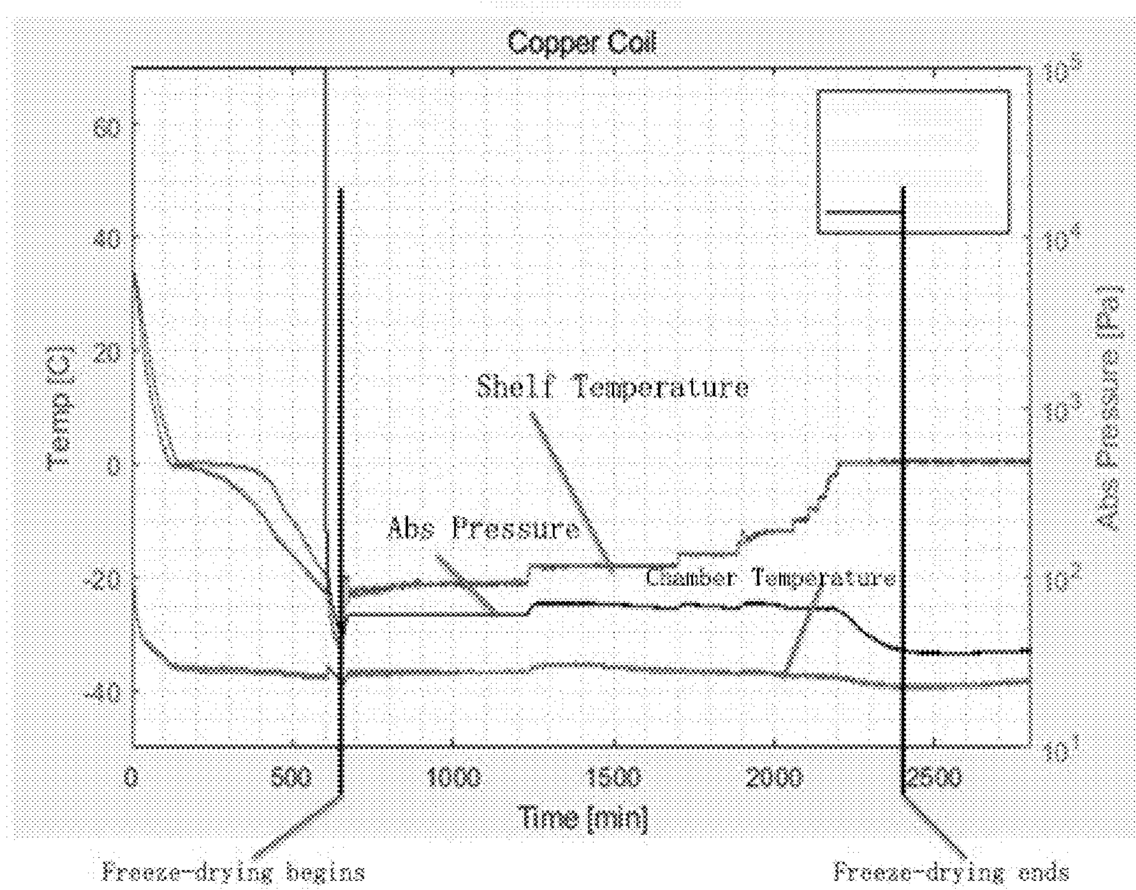

Copper Coil
Temp [C]
Abs Pressure [Pa]
Time [min]
Shelf Temperature
Abs Pressure
Chamber Temperature
Freeze-drying begins
Freeze-drying ends

Figure 13

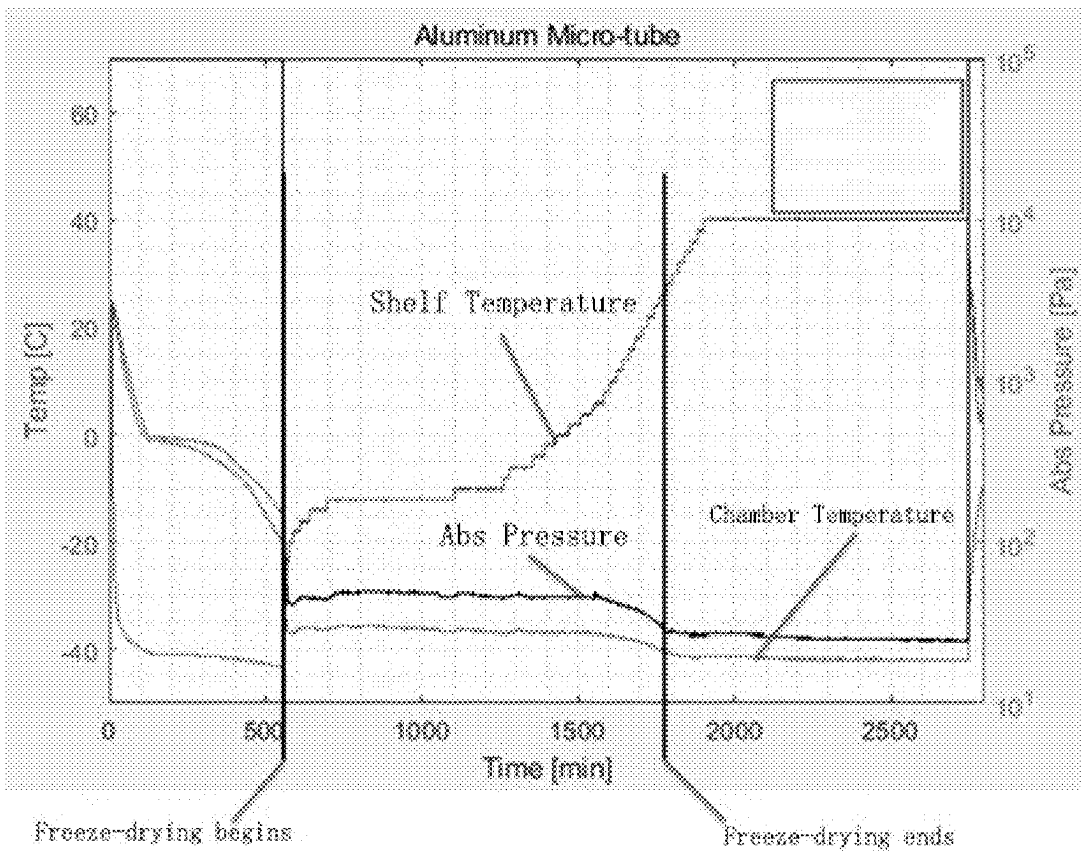

Aluminum Micro-tube
Temp [C]
Abs Pressure [Pa]
Time [min]
Shelf Temperature
Abs Pressure
Chamber Temperature
Freeze-drying begins
Freeze-drying ends
60
40
20
0
-20
-40
0
500
1000
1500
2000
2500

Figure 14

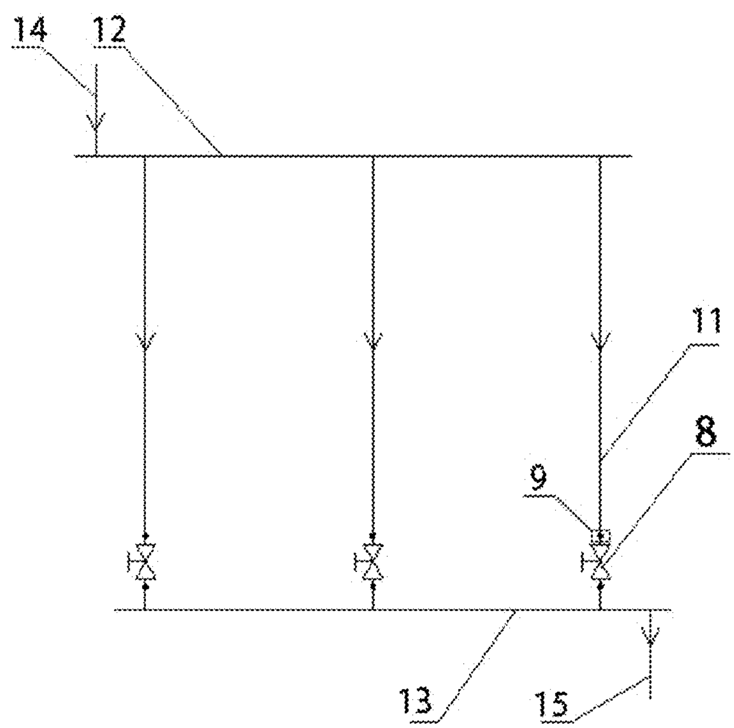


Figure 15

MICRO-CHANNEL REFRIGERATING EVAPORATOR AND FREEZE-DRYING SYSTEM USING EVAPORATOR

FIELD OF THE INVENTION

[0001] The present disclosure relates to an evaporator and a freeze-drying system, and in particular to a micro-channel refrigerating evaporator and a freeze-drying system using the evaporator.

BACKGROUND OF THE INVENTION

[0002] Vacuum freeze-dryer is suitable for drying materials such as high-grade raw material medicine, traditional Chinese medicine tablets, seafood, wild vegetables, dehydrated vegetables, foodstuffs, fruits, chemical drug intermediates and so on.

[0003] At present, vacuum freeze-dryer with freeze drying chamber and refrigerating evaporator are two separate components, freeze drying chamber is mainly used to withstand the pressure generated by the vacuum, refrigerating evaporator is mainly used for refrigerating. The refrigerating evaporator is installed on the outer wall of the freeze drying chamber, and it mainly relies on the contact heat transfer between the outer wall of the freeze drying chamber and the refrigerating evaporator, which has low heat transfer efficiency.

[0004] By physics, water has three phases, known as the three-phase common point, according to the principle of lower pressure lower boiling point, as long as the pressure in the three-phase point pressure (pressure of 611.657 below), the moisture in the material can sublimate directly from the solid phase to water vapor without passing through the liquid phase. According to this principle, the material can be frozen to below the freezing point, so that the moisture in the material into solid ice, and then in the appropriate vacuum environment, the ice will be directly heated sublimation of steam and remove, and then the water vapor condenser in the vacuum system will be water vapor condensation, so that the material to be dry. The vacuum freeze-dryer integrates the refrigerating system, vacuum system, thermal oil heating system, and moisture exhaust system into a single unit, and introduces a new type of chamber structure. This structure makes greater use of the space inside the drying chamber for the storage and freeze-drying of materials. At present, the vacuum freeze-dryer refrigerating system utilizes the evaporator to realize the refrigerating function, and the evaporator is made into spiral shape with the copper tube, and the copper tube will be coiled in the periphery of the vacuum freeze drying chamber by manual work during the processing, and the set will be on the outer wall of the vacuum freeze-dryer drying chamber, and the installation will be time-consuming and laborious.

[0005] For the improvement of heat transfer efficiency, prior art patent application No. CN201410332136.2, Patent Title: Heat Exchanger, provides a heat exchanger comprising: a plurality of pipes, horizontally disposed; a pair of vertical collector tubes, connected to said pipes; and at least one flow distribution baffle mounted to the collector tubes at one set of said plurality of pipes, such that the flow distribution baffle is arranged between the pipes of said set of pipes. Each of the at least one flow distribution baffle is provided with at least one distribution aperture to allow refrigerant to flow through. When the heat exchanger operates as an evaporator of the outdoor unit, the heat exchanger prevents unbalanced distribution of the refrigerant. It utilizes a flow distribution baffle in the collector tube to achieve series flow of refrigerant. However, it does not give sufficient consideration to the problems arising from the resistance to the flow of liquid, and in the process of upward flow there is a problem of refrigerant not being able to flow in some of the tubes.

[0006] Prior Art Patent Application No. CN201420324502.5, Patent Title: Heat exchanger for a heat pump water heater and a heat pump water heater, providing a heat exchanger comprising a plurality of flat tubes, a plurality of said flat tubes spaced apart from one another between said first collector tube and said second collector tube, and each end of each of said flat tubes being connected to said first collector tube and said second collector tube, respectively, with the inner cavities of said first collector tube, said second collector tube and said flat tubes constituting a refrigerant flow passage, wherein the spacing between adjacent flat tubes decreases in the direction from the refrigerant inlet along the refrigerant flow channel to the refrigerant outlet. The heat exchanger according to the utility model can increase the heat exchange area covered by the high-pressure gaseous refrigerant section, improve the efficiency of the heat exchanger and have a uniform water temperature. As shown in FIG. **1**, it improves the pipe into the shape of a flat pipe, but the flat pipe is still skeletonized between the design, which increases the coverage area of the heat exchanger pipe to a certain extent, and thus strengthens the efficiency of heat exchange. However, the structure still exists refrigerant upward reflux, the flow may be blocked, can not completely circulate the entire pipeline problem.

SUMMARY OF THE INVENTION

[0007] The present disclosure provides an evaporator for refrigerating with a larger heat exchange coverage area, a higher refrigerant circulation efficiency, and a more comprehensive circulation.

[0008] The specific solution is listed below:

[0009] A micro-channel refrigerating evaporator,

[0010] comprising a rectangular flat tube structure, the flat tube structure is encircled along its length, the flat tube structure is provided with a plurality of first micro-channel structures circumferentially parallel;

[0011] the flat tube structure is connected at one end to a width-extending first liquid inlet collector tube and at the other end to a width-extending first liquid outlet collector tube;

[0012] the first inlet collector, the first outlet collector and the first micro-channel structure are interconnected;

[0013] the first liquid inlet collector tube, the first liquid outlet collector tube are connected to a flow inlet and a flow outlet, respectively.

[0014] Further, the center point of the micro-channel structure is closer to the inner wall side of the flat tube structure after it is surrounded.

[0015] Further, the distance of the inner wall side of the flat tube structure from the boundary of the micro-channel structure is set to be the micro-channel wall thickness, and the micro-channel wall thickness is valued at between 0.3 mm and 5 mm, preferably between 0.3 mm and 1 mm.

[0016] Further, the first micro-channel structure is provided with an enhanced-flow structure on the inner wall.

[0017] Further, the enhanced-flow structure comprises one or more protruding sheets distributed in the first micro-channel structure.

[0018] Further, the first micro-channel structure has a rectangular cross-section, with protruding sheets being provided at four vertices and extending towards the center of the rectangle.

[0019] Further, the enhanced-flow structure causes the inner wall of the first micro-channel structure to have a mesh-like recessed structure.

[0020] Further, each of the first micro-channel structures parallel to each other is provided with a control valve on the side near the first liquid outlet collector tube.

[0021] Further, there is a linkage function among the control valves; refrigerant flows sequentially from the first liquid inlet collector tube into the parallel first micro-channel structures, during which all control valves remain closed; a pressure sensor installed on the control valve at the end of the last first micro-channel structure, once the pressure sensor detects the flow of refrigerant, all control valves are opened to allow refrigerant circulation.

[0022] Further, the flat tube structure is divided into multiple uniform segments in the direction of its first liquid inlet collector tube and the first liquid outlet collector tube, and the first liquid inlet collector tube and the first liquid outlet collector tube are provided with collector partition plates which are spaced apart, and the collector partition plates are disposed at the same position as the segmentation of the flat tube structure is located, so that a series path is formed between the first liquid inlet collector tube, the first micro-channel structure and the first liquid outlet collector tube.

[0023] Further, three segments of the flat tube structure are connected in parallel as an integral channel and in series to the next set of three segmented channels, and so on.

[0024] Further, the flat tube structure is provided with a second liquid inlet collector tube on one side perpendicular to the first inlet collector, and the flat tube structure is provided with a second liquid outlet collector tube on the other side perpendicular to the first inlet collector;

[0025] the flat tube structure is provided with a plurality of second micro-channel structures longitudinally parallel to each other, the second micro-channel structure interconnects the second liquid inlet collector tube and the second liquid outlet collector tube;

[0026] the first inlet collector pipe and the second inlet collector pipe share the flow inlet;

[0027] the first outlet collector and the second outlet collector share the flow outlet;

[0028] the first micro-channel structure and the second micro-channel structure are staggered from each other.

[0029] Further, the first liquid inlet collector tube is provided with a first securing lug, and the first liquid outlet collector tube is provided with a matching second securing lug; and a hoop is internally threaded between the first securing lug and the second securing lug.

[0030] A freeze-drying system comprising a micro-channel refrigerating evaporator as described in any one of the foregoing, a compressor, a drying chamber, a vacuum device, a heating device; the micro-channel refrigerating evaporator is set up around the side wall of the drying chamber; the vacuum device and the bottom of the drying chamber are connected to each other; the heating device is set up in the interior of the drying chamber, and the compressor is connected to the micro-channel refrigerating evaporator.

[0031] Further, the compressor is selected as an air-cooled compressor and is connected to the other side of the micro-channel refrigerating evaporator away from the drying chamber, so that the whole freeze-drying system has a positive polygonal layout of the device.

[0032] Further, the drying chamber is in the form of a cylinder and the flat tube structure is made of aluminum.

[0033] The beneficial effects of this solution are as follows:

[0034] (1) By adopting a rectangular metal flat tube structure and setting a micro-channel structure in the middle, the flat tube structure is made to fully conform to the surrounding drying chamber. There is no hollow structure in the middle, which maximizes the coverage area and increases the heat exchange efficiency to the greatest extent.

[0035] (2) An enhanced-flow structure is provided within the micro-channel structure to increase the flow rate of the refrigerant in the micro-channel structure.

[0036] (3) Two sets of horizontal and vertical inlet and outlet manifold tubes are provided. This further increases the range of refrigerant flow, making up for the areas that cannot be reached in the traditional series structure, thereby enhancing the heat exchange efficiency.

BRIEF DESCRIPTION OF THE DRAWINGS

[0037] Other features, objects and advantages of the present disclosure will become more apparent by reading the detailed description of non-limiting embodiments made with reference to the following accompanying drawings:

[0038] FIG. **1** shows a schematic diagram of the structure of a flat tube in the prior art in the background art of the present disclosure;

[0039] FIG. **2** shows a schematic diagram of the structure of a micro-channel refrigerating evaporator in an embodiment of the present disclosure;

[0040] FIG. **3** shows a schematic structural diagram of a micro-channel structure in an embodiment of the present disclosure;

[0041] FIG. **4** shows a schematic diagram of the micro-channel wall thickness H in an embodiment of the present disclosure;

[0042] FIG. **5** shows a schematic structural diagram of a protruding piece of the first form of an embodiment of the present disclosure;

[0043] FIG. **6** shows a schematic structural diagram of a second form of protruding piece in an embodiment of the present disclosure;

[0044] FIG. **7** shows a schematic diagram of the structure of a flow-collecting partition in an embodiment of the present disclosure;

[0045] FIG. **8** shows a schematic diagram of liquid flow in a first form of the tandem structure of an embodiment of the present disclosure;

[0046] FIG. **9** shows a schematic diagram of liquid flow in a second form of tandem structure in an embodiment of the present disclosure;

[0047] FIG. **10** shows a schematic diagram of fluid flow in an embodiment of the present disclosure in which a series structure and a parallel structure coexist;

[0048] FIG. **11** shows a schematic diagram of the structure of a freeze-drying system in an embodiment of the present disclosure;

[0049] FIG. **12** shows a schematic structural diagram of a mesh recessed structure in an embodiment of the present disclosure;

[0050] FIG. **13** shows a graph of the results of the copper tube evaporator in the freeze-drying effectiveness test;

[0051] FIG. **14** shows a graph of the test results of the evaporator of the present disclosure H=0.3 mm in the freeze-drying effect test;

[0052] FIG. **15** shows a structural sketch of a parallel structure in an embodiment of the present disclosure;

ILLUSTRATED BY THE ACCOMPANYING MARKINGS

[0053] **1**. flat tube structure; **11**. first micro-channel structure; **12**. first liquid inlet collector tube; **121**. first securing lug; **13**. first liquid outlet collector tube; **14** flow inlet; **15**. flow outlet; **2**. enhanced-flow structure; **21**. protruding sheet; **22**. mesh-like recessed structure; **23**. collector partition plate; **31**. second liquid inlet collector tube; **32**. second securing lug; **33**. second liquid outlet collector tube; **34**. second micro-channel structure; **4**. compressor; **5**. drying chamber; **6**. vacuum device; **7**. heating device; **8**. control valve;

[0054] Micro-channel wall thickness: H.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0055] The disclosure is further described below in detail in conjunction with the accompanying drawings.

[0056] Other embodiments of the present disclosure will readily come to mind to those skilled in the art upon consideration of the specification and practice of the invention disclosed herein. This application is intended to cover any variations, uses, or adaptations of the present disclosure that follow the general principles of the invention and include common knowledge or customary technical means in the art not disclosed herein.

[0057] As shown in FIGS. **2** and **3**, a micro-channel refrigerating evaporator, comprising a rectangular flat tube structure **1**, which may also be in square shape; said flat tube structure **1** is in a wrap-around shape along the direction of its length, and one or more first micro-channel structures **11** is provided in said flat tube structure **1** in a circumferential direction parallel to each other; in the present embodiment, the flat tube structure **1** is made of rectangular metal plate, which leaves a certain thickness to form the micro-channel structure inside the flat tube structure **1**; the contact area between the metal plate and the drying chamber **5** is obviously larger than that of the pipeline structure which is parallel to each other and spaced apart in the middle, and even though the pipeline structure adopts the shape of a flat pipe, there are still many skeletonized areas between the pipes, and it is not possible to make use of the area in the middle to carry out heat exchange with the drying chamber **5**.

[0058] The equation for the summed heat transfer between the evaporator and the drying chamber **5**:

$$q\Delta T/R\_t,\text{total};$$

[0059] Wherein:

[0060] R_t,total: thermal resistance (k/w); q: heat (w); ΔT: temperature difference (k);

$$\text{Based on } R\_t,\ \text{total} = R\_t,\ cond + R\_t,\ conv;$$

[0061] R_t,cond: thermal conduction resistance (k/w) between drying chamber **5** and evaporator;

[0062] R_t,conv: thermal convection resistance (k/w) between refrigerant and evaporator copper tubes;

[0063] R_t,cond=L/(kA); L: thickness (m); K: thermal conductivity [w/(m-k)]; A: contact area (m^2).

[0064] According to the above formula, theoretically it is possible to test and calculate the thermal resistance value R_t,total of a material, but this formula is just an idealized formula, the condition it set is: the contact surface is completely smooth and flat, all the heat passes through the material by heat conduction and reaches the other end. In reality, this is an impossible condition, so the tested and calculated thermal resistance value is not exactly the thermal resistance value of the material itself, it should be the thermal resistance value of the material itself plus the so-called thermal resistance value of the contact surface. Because of the flatness, smoothness or roughness of the contact surface, as well as the different pressure of the mounting and fastening, there will be different thermal resistance values of the contact surface, which will also result in different total thermal resistance values. To summarize:

[0065] a. For the same material, thermal conductivity is a constant value, and the thermal resistance value R_t,total is subject to change with the thickness L.

[0066] b. For the same material, the greater the thickness L, the longer the distance that heat has to travel through the material. This can be simply understood as taking more time for the heat to be transferred, and thus the thermal performance is worse.

[0067] c. For thermal conductive materials, selecting the appropriate thermal conductivity K and thickness L is crucial for performance. Even if a material has a very high thermal conductivity K, a large thickness L can still result in suboptimal performance. The ideal choice is a material with high thermal conductivity K and a thin thickness L, combined with optimal contact pressure to ensure the best possible interface contact, i.e., a large contact area A.

[0068] As can be seen from the formula, the thermal conductivity K is an inherent performance parameter of the material itself, used to describe the thermal conductivity of the material. This characteristic has nothing to do with the size, shape, or thickness of the material itself, but only with the properties of the material itself, so the thermal conductivity of the same material is the same, and does not change because of the thickness. Under the same conditions, the larger the heat transfer contact area A is, the higher the heat transfer efficiency between the evaporator and the drying chamber **5** is.

[0069] As prior art often employs copper tubes, the contact between the copper tube and the drying chamber **5** is linear, which results in a small contact area. This leads to an increase in the system's thermal resistance, particularly the resistance for heat conduction from the copper tube to the stainless-steel shell. Therefore, using the flat tube structure **1** and micro-channel structure as described in the embodiment can greatly increase the contact area, thereby reducing the thermal resistance R_t, cond.

[0070] In this embodiment, the flat tube structure **1** is unfolded as a metal plate with a certain thickness, the lengthwise outer wall of the metal plate is a flat surface to ensure that the contact area A with the drying chamber **5** is as large as possible, micro-channels are distributed within the metal plate, and the wall thickness of the micro-channels is as thin as possible on the side of the contact with the freeze-dryer drying chamber **5** to ensure that the heat transfer thickness L is as small as possible, and a plurality of the flat tube structures **1** are connected to each other by two collector tubes.

[0071] According to the formula R_t,cond=L/(kA), if the contact area A between the drying chamber **5** and the evaporator increases, R_t,cond will decrease.

[0072] One end of the flat tube structure **1** is connected with a first liquid inlet collector tube **12** extending in the width direction, and the other end is connected with an liquid outlet collector tube extending in the width direction; the first liquid inlet collector tube **12**, the first liquid outlet collector tube **13**, and the first micro-channel structure **11** are connected to each other; the liquid inlet collector tube, the first liquid outlet collector tube **13** are connected with a flow inlet **14** and a flow outlet **15**, respectively; in the present embodiment, the first liquid inlet collector tube **12** is connected to one end of the flat tube structure **1**; the other end of the flat tube structure **1** is connected to the first liquid outlet collector tube **13**; the first liquid inlet collector tube **12** and the first liquid outlet collector tube **13** are connected to each other in series or in parallel through a plurality of flat tube structures **1**, and refrigerants can circulate through each other in the first liquid inlet collector tube **12**, the first liquid outlet collector tube **13**, and the micro-channel structure. The flow inlet **14** is connected to the front face of the first liquid inlet collector tube **12**, which can introduce refrigerant into the first liquid inlet collector tube **12**; the flow outlet **15** is connected to the front face of the first liquid outlet collector tube **13** which can lead refrigerant out of the first liquid outlet collector tube **13**.

[0073] As shown in FIG. **4**, further, the center point of the micro-channel structure is closer to the inner wall side of the flat tube structure **1** after it is wrapped. In this embodiment, the micro-channel structures distributed inside the flat tube structure **1** are positioned as close as possible to the inner wall side of the flat tube structure **1** after wrapping. This reduces the thermal conduction thickness L of the thermal resistance formula, thereby correspondingly reducing the thermal resistance, and achieving better heat transfer efficiency and cooling effect.

[0074] Further, the distance of the inner wall side of the flat tube structure **1** from the boundary of the micro-channel structure is set as the micro-channel wall thickness H. Said micro-channel wall thickness H is valued at 0.3 mm-5 mm, preferably between 0.3 mm-1 mm. In this embodiment, using the evaporator of the said first micro-channel structure **11** and the evaporator of the copper tube parallel to each other with a hollow in the middle as a comparison for the freeze-drying effect test, by taking 4 kg water replenishment in freeze-drying machine as the test subject; wherein the structure of the drying chamber **58** used is of the same dimensions; the thermal resistance K of the copper tube is 385 W/m-K, the thermal resistance K of the aluminum tube is 210 W/m-K; the size of the copper tube is φ9.5*0.7, the length is 22 meters, the thickness H of the micro-channel wall is 0.3 mm; the contact area A between the copper tube and the drying chamber **5** is about 220 cm^2, and the contact area A between the micro-channel flat tube and the drying chamber **5** is about 2246 cm^2; and the amount of refrigerant passing through the copper tube and the first micro-channel structure is the same.

[0075] During this freeze-drying test, the water is first frozen into ice, and the chamber is evacuated to a certain Abs pressure. The ice is then heated according to a specific pattern, causing it to sublimate into gas. When the gas encounters the cooled evaporator, it re-solidifies into ice and releases heat. This process realizes the transfer of water to the evaporator to achieve freeze-drying. The freeze-drying process is considered complete when the heating temperature reaches a certain value and the Abs pressure decreases to a specific level. After the test, the test results are shown in FIGS. **13** and **14**. Using the copper tube evaporator as the test object, the total freeze-drying time was approximately 1750 minutes. Freeze-drying began at the 650th minute and was completed at the 2400th minute when the Abs pressure no longer changed significantly. With the evaporator of the present invention, the total freeze-drying time was reduced to 1210 minutes. Freeze-drying started at the 570th minute and was completed at the 1780th minute when the pressure no longer changed significantly. The total freeze-drying time was shortened by 540 minutes, resulting in a 30% increase in efficiency.

[0076] Further, an enhanced-flow structure **2** is provided on the inner wall of the first micro-channel structure **11**. In this embodiment, the micro-channel structure is provided with an enhanced-flow structure **2**, and the function of said enhanced-flow structure **2** is not only to increase the heat exchange area of the refrigerant, but also to increase the fluid disturbance; the increase of the fluid disturbance increases the Reynolds number RE of the fluid, which in turn increases the Nusselt number, which describes the chaos constant of the fluid, and the convective heat transfer coefficient h of the fluid can be increased, thereby achieving the goal of improving heat transfer efficiency.

[0077] As shown in FIG. **5**, further, the enhanced-flow structure **2** is a protruding sheet **21** distributed in the first micro-channel. In this embodiment, the contact area of the refrigerant with the evaporator is increased by adding protruding sheets **21** in the first micro-channel structure **11**, i.e.

$$Nu = hL/K;$$

[0078] h: convective heat transfer coefficient;

[0079] K: Thermal conductivity.

[0080] According to R_t,conv=dT/q=1/(hS), when h becomes larger, R_t,conv will become smaller, the contact area between the refrigerant and the evaporator increases after increasing the protruding sheet, i.e. S increases and R_t,conv becomes smaller; as shown in FIGURE X, the protruding sheet **21**, which is set upwardly extended on the long side of a rectangle, is used in the present disclosure for increasing the heat transfer efficiency; in summary, after increasing the protruding sheet, R_t,conv becomes smaller and the heat transfer efficiency increases.

[0081] As shown in FIG. **6**, further, the first micro-channel structure **11** has a rectangular cross-section, and the protruding sheets **21** are provided at four vertices and extend toward the center of the rectangle. In another embodiment of the present disclosure, the protruding sheet **21** is provided at a corner of the rectangle and extends toward the center, and such a setup is able to reduce the resistance to the flow of the refrigerant as compared to the protruding sheet **21** provided at the long side of the rectangle extending upwardly and also increase the heat exchange area between the refrigerant and the evaporator, in order to increase the heat transfer efficiency.

[0082] As shown in FIG. **12**, further, the enhanced-flow structure **2** causes the inner wall of the first micro-channel structure **11** to be in the form of a mesh-like recessed structure **22**. In another embodiment of the present disclosure, the inner wall of the first micro-channel structure **11** is recessed downwardly and a mesh-like structure is provided further downwardly on the surface of the recessed structure, so as to increase the contact area between the first micro-channel structure **11** and the refrigerant by using the downwardly recessed structure, which can save material compared with protruding sheet **21** and also maintain the flow rate of the refrigerant in the micro-channel as well as increase the heat transfer efficiency.

[0083] As shown in FIG. **15**, further, the first micro-channel structures parallel to each other are provided with a control valve **8** on one side near the first liquid outlet collector tube. In the embodiment of the present disclosure, the first liquid inlet collector tube, the first micro-channel structure and the first liquid outlet collector tube adopt a direct flow mode, which are commonly known as a parallel path, which is a traditional parallel structure. When the refrigerant is flowing, due to the problem of liquid resistance, the refrigerant in the micro-channel structures far away from the inlet will have difficulty in flowing and the distribution of the cold volume will be uneven, which will affect the cooling efficiency of the overall evaporator, and also result in the phenomenon of uneven ice trapping. By installing control valves, the flow rate of the refrigerant within the micro-channel plates can be regulated through adjusting the opening degree of the valve. When the flow rates are consistent, the cooling capacity is maintained uniformly across each micro-channel plate. This regulation can be performed manually or automatically, with appropriate valve configurations. If a proportional control valve is used, a corresponding control system need to be incorporated. When the micro-channel structures far from the inlet have no refrigerant or only a small amount of refrigerant flowing through them, the control valve **8** in front is closed to prevent the refrigerant from flowing toward first liquid outlet collector tube. Meanwhile, the refrigerant will flow toward the rear micro-channel structures. Once the rear micro-channel structures are also fully supplied with refrigerant, the front control valve is opened. In this way, all the first micro-channel structures are fully supplied with refrigerant. By regulating the valves, the uniformity of the cooling capacity within the micro-channel plates is ensured, thereby improving the efficiency of refrigeration.

[0084] Further, the control valves **8** have a linkage function among them; the refrigerant will flow from the first liquid inlet collector tube into the first micro-channel structures parallel to each other in turn, at which time, all of the control valves **8** are in a closed state; a pressure sensor is provided on the control valve in the last first micro-channel structure, and when the pressure sensor senses the flow of the refrigerant, it opens all of the control valves and circulates the refrigerant. In this embodiment, a type of interlinked control valve is used, which can be an electromagnetic valve. A pressure sensor is installed on the last electromagnetic valve, and the pressure sensor is electrically connected to the valve, with a corresponding control system provided. Initially, all the electromagnetic valves are in a closed state. When the refrigerant flows into the last micro-channel structure, the pressure sensor on the electromagnetic valve will be triggered, which then opens all the valves simultaneously to allow the refrigerant to flow through. This structure fully considers the insufficient circulation of the refrigerant in the evaporator and the complexity of manual control. It provides a control valve interconnection device that can ensure the full circulation of the refrigerant and automatically complete the relevant adjustments, making it convenient and efficient.

[0085] As shown in FIG. **7**, further, the flat tube structure **1** is divided into multiple uniform sections along the direction of the first liquid inlet collector tube **12** and the first liquid outlet collector tube **13**. The first liquid inlet collector tube **12** and the first liquid outlet collector tube **13** are equipped with intermittently distributed collector partition plates **23**. The positions of the collector partition plates **23** correspond to the segmented locations of the flat tube structure **1**. This arrangement forms a series connection path between the first liquid inlet collector tube **12**, the first micro-channel structure **11**, and the first liquid outlet collector tube **13**. In this embodiment, the first liquid inlet collector tube **12** and the first liquid outlet collector tube **13** are regularly partitioned by the collector partition plates **23** to achieve the interconnection and series connection of the multiple sections of the flat tube structure **1**, as shown in FIG. **8**. When each segment of the micro-channel structure forms a single flow path, the refrigerant enters the first liquid inlet collector tube **12** through the flow inlet **14**. It encounters the obstruction of the collector partition plate, then changes direction and flows into the first micro-channel structure **11**. After reaching the end of the micro-channel, it enters the first liquid outlet collector tube **13**. In the first liquid outlet collector tube **13**, it encounters the obstruction of the collector partition plate again, and the refrigerant changes direction to flow into the next section of the micro-channel flat tube. After reaching the end of this micro-channel, it enters the first liquid inlet collector tube **12** again. This process is repeated multiple times until the refrigerant finally flows into the liquid outlet collector tube and is discharged through the flow outlet **15**. During this process, the refrigerant absorbs heat from the drying chamber **5**, reducing the temperature of the drying chamber **5** to achieve the purpose of freeze-drying the items inside the drying chamber **5**. The series flow can compensate for the issue of insufficient circulation within the collector tube that occurs in parallel flow, thereby achieving a better cooling effect.

[0086] As described in FIG. **9**, further, when the volume of the drying chamber **5** is large, three segments of said flat tube structure **1** can be connected in parallel as an integral channel, flowing in series to the next set of three segmented channels, and repeating in turn; and when the intermediate surrounding chamber is large in volume, it achieves better refrigerating effect.

[0087] As shown in FIG. 10, further, on the side of the flat tube structure perpendicular to the first liquid inlet collector tube, there is a second liquid inlet collector tube 31, and on the opposite side perpendicular to the first liquid inlet collector tube, there is a second liquid outlet collector tube 33. Inside the flat tube structure, there are longitudinally parallel second micro-channel structures 34, which interconnect the second liquid inlet collector tube and the second liquid outlet collector tube. The first liquid inlet collector tube and the second liquid inlet collector tube share the same flow inlet 14, and the first liquid outlet collector tube and the second liquid outlet collector tube share the same flow outlet 15. The first micro-channel structure and the second micro-channel structure are arranged alternately. In this embodiment, on the basis of the series flow structure, the second liquid inlet collector tube 31 and the second liquid outlet collector tube 33 are added in the vertical direction, along with the second micro-channel structure 34 that is connected in parallel. The first micro-channel structure 11 and the second micro-channel structure 34 are both set inside the flat tube structure 1 and do not interfere with each other. The parallel structure allows the flow to move from the inlet side to the other side, solving the problem of possible flow blockage in the first micro-channel that could lead to insufficient flow. This also compensates for the issue in the series structure where upward back-flow is prone to blockage and results in uneven flow. By using both series and parallel micro-channel structures simultaneously, the possible insufficient flow of the refrigerant in each other's structures is mutually compensated for. This is especially important when the volume of the drying chamber 5 is large, as the longer flow path of the refrigerant makes it more susceptible to insufficient flow. This structure can significantly improve the efficiency of refrigeration.

[0088] Further, the first liquid inlet collector tube 12 is provided with a first securing lug 121, and said first liquid outlet collector tube 13 is provided with a second securing lug 32 matching the first securing lug 121; said first securing lug 121 and said second securing lug 32 are internally pierced with a hoop. In this embodiment, since the refrigerating evaporator is surrounded by the outer side of the drying chamber 5, in order to better fit the outer wall of the drying chamber 5, the first liquid inlet collector tube 12 and the first liquid outlet collector tube 13 are provided with securing lugs and tightened with hooped bands, so that the evaporator is surrounded by the drying chamber 5 and tightened, and the shape of the evaporator is fixed, and will not be subjected to deformation due to external forces, which affects the heat transfer efficiency.

[0089] As described in FIG. 11, a freeze-drying system comprising a micro-channel refrigerating evaporator as described in any one of the foregoing, a compressor 4, a drying chamber 5, a vacuum device 6, and a heating device 7; said micro-channel refrigerating evaporator is set up around the side wall of the drying chamber 5; said vacuum device 6 is connected to each other and to the bottom of the drying chamber 5; said heating device is set up on the side of the inlet opening of the said drying chamber 5, and said compressor is connected to said micro-channel refrigerating evaporator. evaporator. In this embodiment, the freeze-drying drying chamber 5, the refrigerating device, the vacuum device 6, the heating device, the refrigerating system includes a micro-channel refrigerating evaporator and a compressor 4, said compressor is a kind of slave fluid machinery that raises a low-pressure gas to a high-pressure gas, and is the core of the refrigerating system. The micro-channel refrigerating evaporator is affixed to the outer wall of the drying chamber 5. The refrigerating device is used to reduce the temperature of the drying chamber 5 to freeze the substance into a solid; the vacuum device 6 is connected to the drying chamber 5 for evacuating the drying chamber 5; the heating device is used to heat the substance in the drying chamber 5; the heating method of the heating device can be hot air, heating blanket, microwave and other prior art.

[0090] Further, said compressor 4 is selected as an air-cooled compressor and connected to the other side of said micro-channel refrigerating evaporator away from said drying chamber 5, so that the device layout of the whole freeze-drying system is in the form of a positive polygon. In this embodiment, the air-cooled compressor has an excellent refrigerating effect, and limiting its installation position can avoid said air-cooled compressor from inhaling the high temperature discharged from the drying chamber, which results in the exhaust gas temperature being too high and affects the normal operation of the entire freeze-drying system. In addition, designing the device layout of the entire freeze-drying system in the form of a positive polygon can reasonably save the occupying space of the freeze-drying system, so as to make the utilization scene of the whole set of system more extensive.

[0091] Further, said drying chamber 5 adopts a cylindrical shape, and said flat tube structure 1 adopts aluminum material. In this embodiment, according to the different shapes of the drying chamber 5, when the drying chamber 5 is cylindrical or rectangular, the shape of the flat tube and the flow collector tube will change, and the angle and position when bending is performed will change, and optimally, the drying chamber 5 is shaped as a cylinder, to ensure that the vaporizer can be better adhered to the outside of the drying chamber 5. The best evaporator is made of aluminum, has the micro-channel flat tube of the above structure, and the micro-channel is provided with the said enhanced-flow structure 2. The appropriate evaporator structure is selected according to the size of the cylinder of the drying chamber 5 through the design experience: the small drying chamber 5 is suitable to be equipped with a tandem structure of the micro-channel flat tube evaporator, so that the refrigerating unit refrigerating capacity meets the demand of the freeze-dryer, and the best refrigerating efficiency is achieved; if the parallel structure is used, the refrigerant flows through the evaporator rapidly, and the refrigerant flows out before it has time to exchange heat, but it is unfavorable to the refrigerating of the refrigerating device; the large drying chamber 5 is suitable for configuring the micro-channel flat-tube evaporator which is common to both the series and parallel structure to avoid the pipeline being too long and too much affected by the flow resistance, and the parallel structure ensures that the refrigerating capacity of the refrigerating device can meet the demand of the freeze-dryer, and the cooling efficiency is optimal; and it ensures that the flow resistance will not be too much to make the cooling efficiency optimal.

[0092] Working principle: The material to be frozen is placed on the shelves inside the freeze-drying chamber 5. When the freeze-dryer is activated, the refrigeration system begins to operate. Initially, the freeze-dryer lowers the temperature of the material, which contains a significant amount of moisture, to freeze it into a solid state. Subsequently, the vacuum system is activated, evacuating the drying chamber **5** to a vacuum condition. Under vacuum conditions, the heating device is turned on to directly sublime the solid-state water. The material itself remains within the ice framework formed during freezing, which completes the drying process. The volume of the material remains unchanged after drying. During sublimation, solid water absorbs heat, causing the temperature of the material to drop and slowing down the sublimation rate. To increase the sublimation rate and shorten the drying time, the product must be heated appropriately. Once the freezing and drying processes are complete, the material is removed from the drying chamber, completing the freeze-drying of the substance.

[0093] The refrigerating device transports refrigerant into the flat tube structure **1** with the help of a compressor and other tools, and the refrigerant enters the first liquid inlet collector tube from the inlet tube; the refrigerant then enters into a plurality of flat tubes and then flows into the liquid outlet collector tube, and when it is necessary to discharge the refrigerant, the refrigerant in the device is discharged from the outlet tube; and the freezing of the substance is completed.

[0094] It is to be understood that the present disclosure is not limited to the precise structure which has been described above and illustrated in the accompanying drawings, and that various modifications and alterations may be made without departing from its scope.

1. A micro-channel refrigerating evaporator, characterized in that,
- comprising a rectangular flat tube structure, the flat tube structure is encircled along its length, the flat tube structure is provided with a plurality of first micro-channel structures circumferentially parallel;
- the flat tube structure is connected at one end to a width-extending first liquid inlet collector tube and at the other end to a width-extending first liquid outlet collector tube;
- the first inlet collector, the first outlet collector and the first micro-channel structure are interconnected;
- the first liquid inlet collector tube, the first liquid outlet collector tube are connected to a flow inlet and a flow outlet, respectively.

2. The micro-channel refrigerating evaporator according to claim **1**, characterized in that the center point of the micro-channel structure is closer to the inner wall side of the flat tube structure after it is surrounded.

3. The micro-channel refrigerating evaporator according to claim **2**, characterized in that the distance of the inner wall side of the flat tube structure from the boundary of the micro-channel structure is set to be the micro-channel wall thickness, and the micro-channel wall thickness is valued at between 0.3 mm and 5 mm, preferably between 0.3 mm and 1 mm.

4. The micro-channel refrigerating evaporator according to claim **1**, characterized in that the first micro-channel structure is provided with an enhanced-flow structure on the inner wall.

5. The micro-channel refrigerating evaporator according to claim **4**, characterized in that the enhanced-flow structure comprises one or more protruding sheets distributed in the first micro-channel structure.

6. The micro-channel refrigerating evaporator according to claim **5**, characterized in that the first micro-channel structure has a rectangular cross-section, with protruding sheets being provided at four vertices and extending towards the center of the rectangle.

7. The micro-channel refrigerating evaporator according to claim **4**, characterized in that the enhanced-flow structure causes the inner wall of the first micro-channel structure to have a mesh-like recessed structure.

8. The micro-channel refrigerating evaporator according to claim **1**, characterized in that each of the first micro-channel structures parallel to each other is provided with a control valve on the side near the first liquid outlet collector tube.

9. The micro-channel refrigerating evaporator according to claim **8**, characterized in that there is a linkage function among the control valves; refrigerant flows sequentially from the first liquid inlet collector tube into the parallel first micro-channel structures, during which all control valves remain closed; a pressure sensor installed on the control valve at the end of the last first micro-channel structure, once the pressure sensor detects the flow of refrigerant, all control valves are opened to allow refrigerant circulation.

10. The micro-channel refrigerating evaporator according to claim **1**, characterized in that the flat tube structure is divided into multiple uniform segments in the direction of its first liquid inlet collector tube and the first liquid outlet collector tube, and the first liquid inlet collector tube and the first liquid outlet collector tube are provided with collector partition plates which are spaced apart, and the collector partition plates are disposed at the same position as the segmentation of the flat tube structure is located, so that a series path is formed between the first liquid inlet collector tube, the first micro-channel structure and the first liquid outlet collector tube.

11. The micro-channel refrigerating evaporator according to claim **10**, characterized in that three segments of the flat tube structure are connected in parallel as an integral channel and in series to the next set of three segmented channels, and so on.

12. The micro-channel refrigerating evaporator according to claim **10**, characterized in that,
- the flat tube structure is provided with a second liquid inlet collector tube on one side perpendicular to the first inlet collector, and the flat tube structure is provided with a second liquid outlet collector tube on the other side perpendicular to the first inlet collector;
- the flat tube structure is provided with a plurality of second micro-channel structures longitudinally parallel to each other, the second micro-channel structure interconnects the second liquid inlet collector tube and the second liquid outlet collector tube;
- the first inlet collector pipe and the second inlet collector pipe share the flow inlet;
- the first outlet collector and the second outlet collector share the flow outlet;
- the first micro-channel structure and the second micro-channel structure are staggered from each other.

13. The micro-channel refrigerating evaporator according to claim **1**, characterized in that the first liquid inlet collector tube is provided with a first securing lug, and the first liquid outlet collector tube is provided with a matching second securing lug; and a hoop is internally threaded between the first securing lug and the second securing lug.

14. A freeze-drying system, characterized in that, comprising a micro-channel refrigerating evaporator as described in claim **1**, a compressor, a drying chamber, a vacuum device, a heating device; the micro-channel refrigerating evaporator is set up around the side wall of the drying chamber; the vacuum device and the bottom of the drying chamber are connected to each other; the heating device is set up in the interior of the drying chamber, and the compressor is connected to the micro-channel refrigerating evaporator.

15. The freeze-drying system according to claim **14**, characterized in that the compressor is selected as an air-cooled compressor and is connected to the other side of the micro-channel refrigerating evaporator away from the drying chamber, so that the whole freeze-drying system has a positive polygonal layout of the device.

16. The freeze-drying system according to claim **14**, characterized in that the drying chamber is in the form of a cylinder and the flat tube structure is made of aluminum.

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