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(54) DEHUMIDIFYING APPARATUS

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(57) **ABSTRACT**

A dehumidifying apparatus according to the present disclosure includes: a housing; an air inlet provided in the housing; an air outlet provided in the housing; a blower provided in the housing; and an evaporator provided on an air passage that connects the air inlet and the air outlet, and configured to cool and dehumidify air that is sent into the housing by the blower. The evaporator includes a plurality of flat tubes having flow passages through which refrigerant flows and extending in an up-down direction, a pair of headers connected to an upper end and a lower end of each of the flat tubes, and a first extension portion connected to a windward side of one of the flat tubes, and having long sides extending in the up-down direction along of the flat tube.

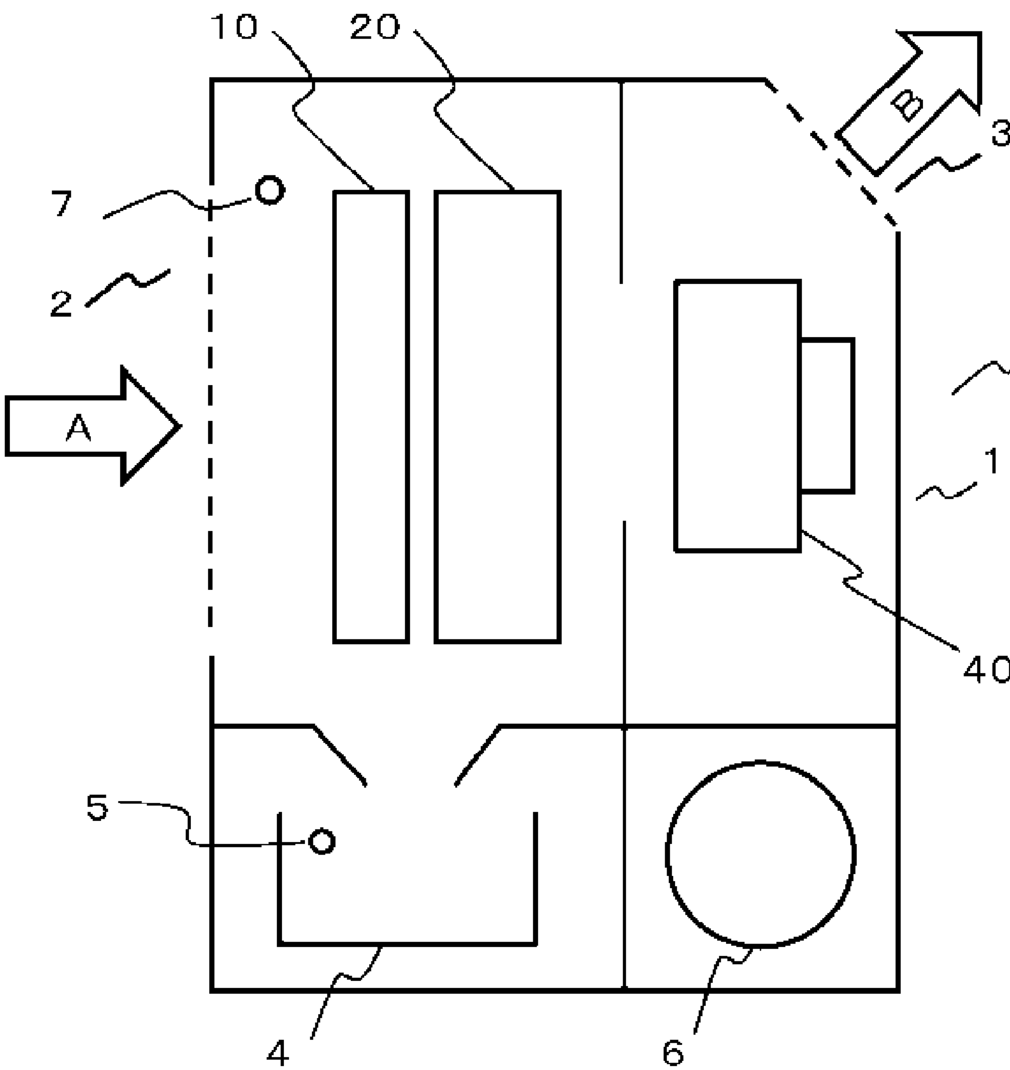


FIG. 1

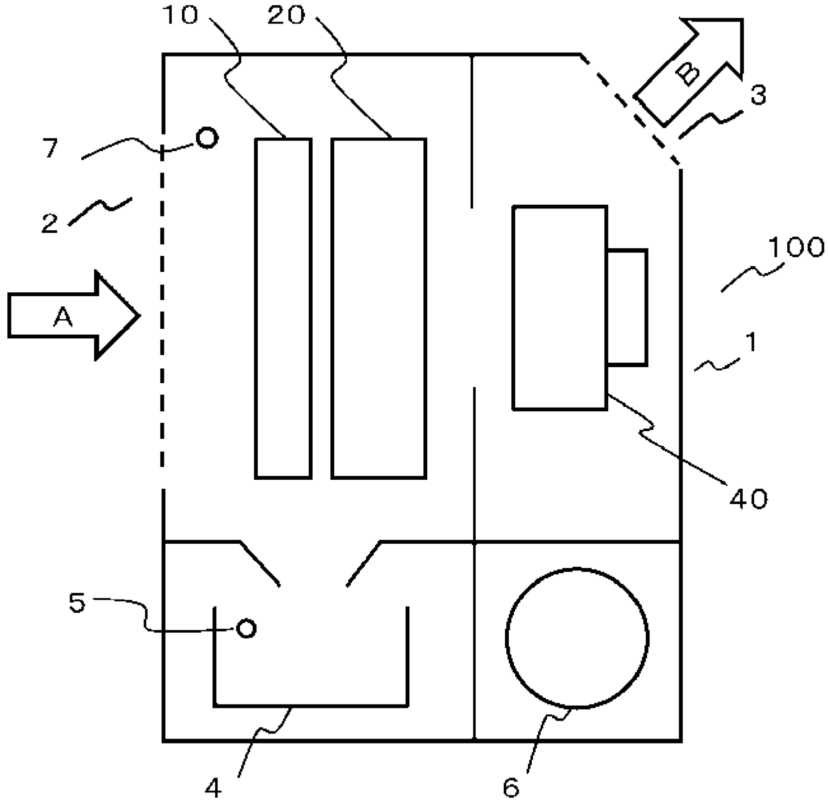


FIG. 2

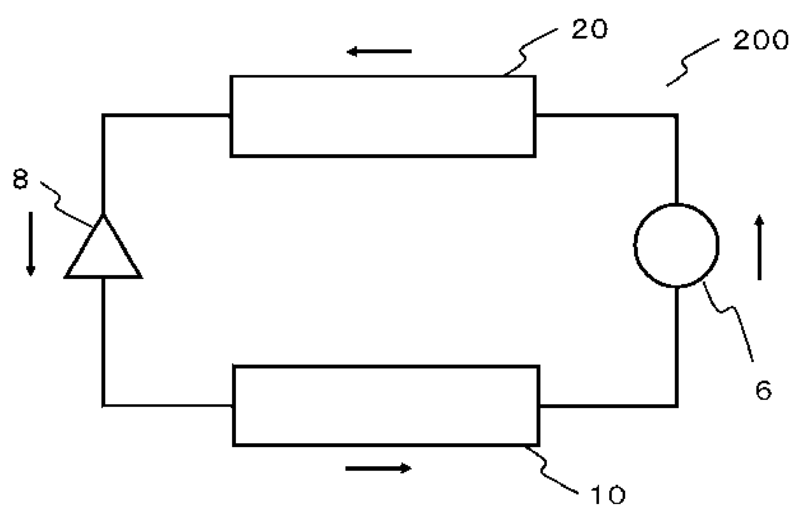


FIG. 3

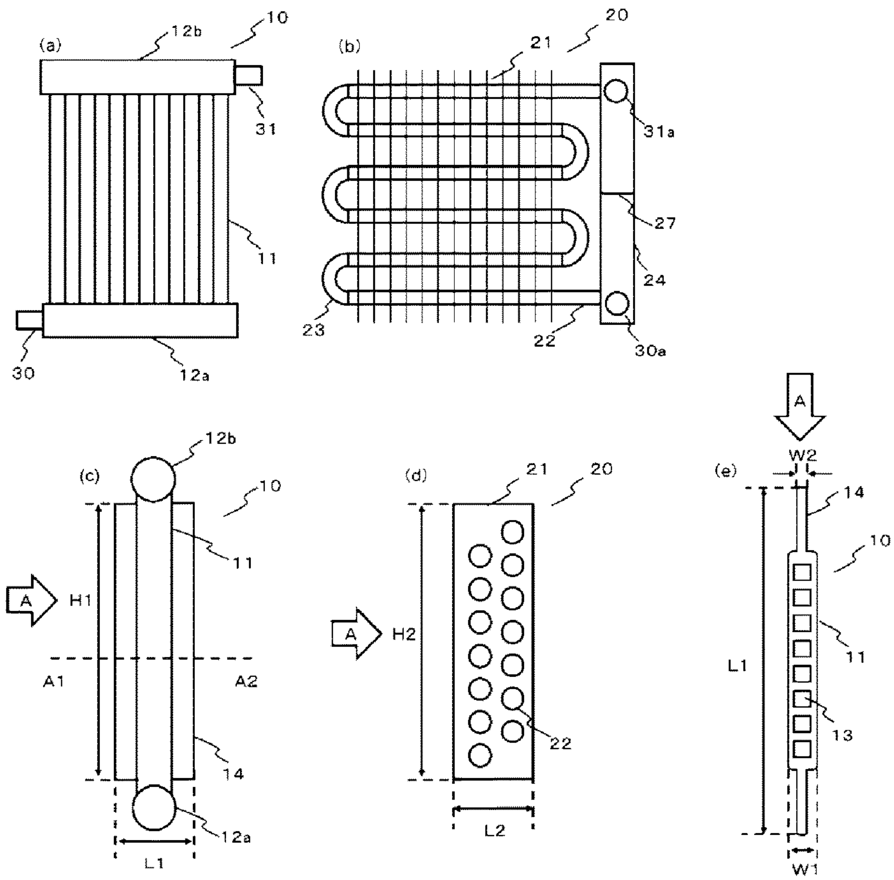


FIG. 4

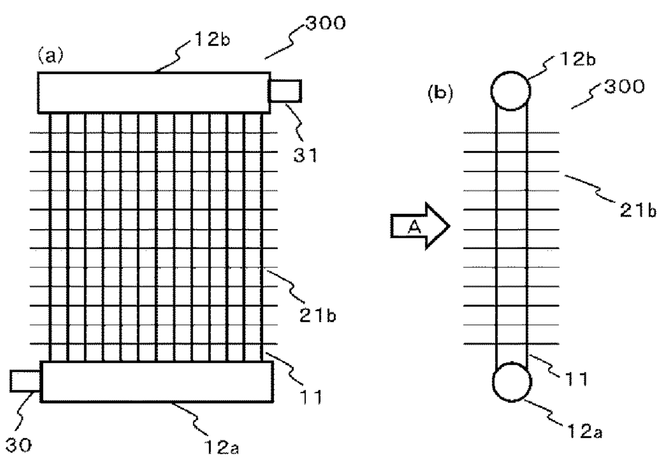


FIG. 5

	DRY-SURFACE HEAT TRANSFER PERFORMANCE	WET-SURFACE HEAT TRANSFER PERFORMANCE	DRY-SURFACE PRESSURE LOSS	WET-SURFACE PRESSURE LOSS
EXISTING HEAT EXCHANGER	1.00	1.00	1.00	1.00
FINLESS HEAT EXCHANGER	1.05	1.52	0.95	0.88

FIG. 6

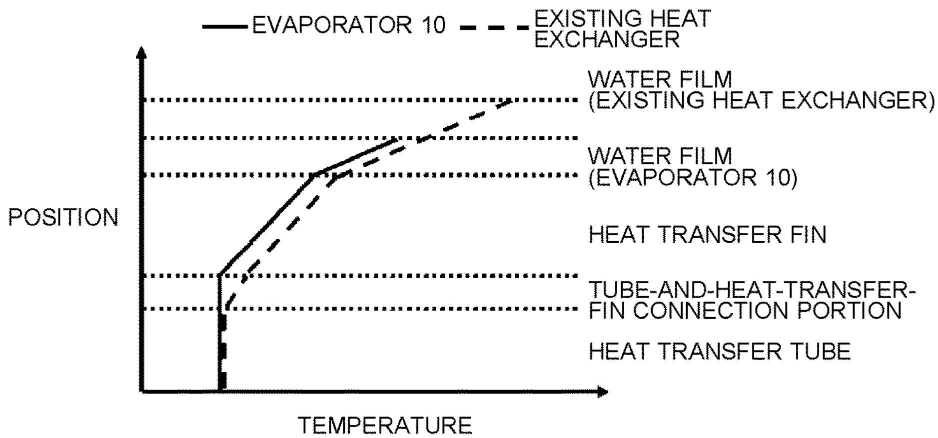


FIG. 7

	PITCH 4.0[mm]	3.0[mm]	2.8[mm]	2.2[mm]	2.0[mm]
WET-SURFACE HEAT TRANSFER PERFORMANCE OF FINLESS HEAT EXCHANGER AGAINST THAT OF EXISTING HEAT EXCHANGER	0.50	0.82	1.00	1.52	1.80

FIG. 8

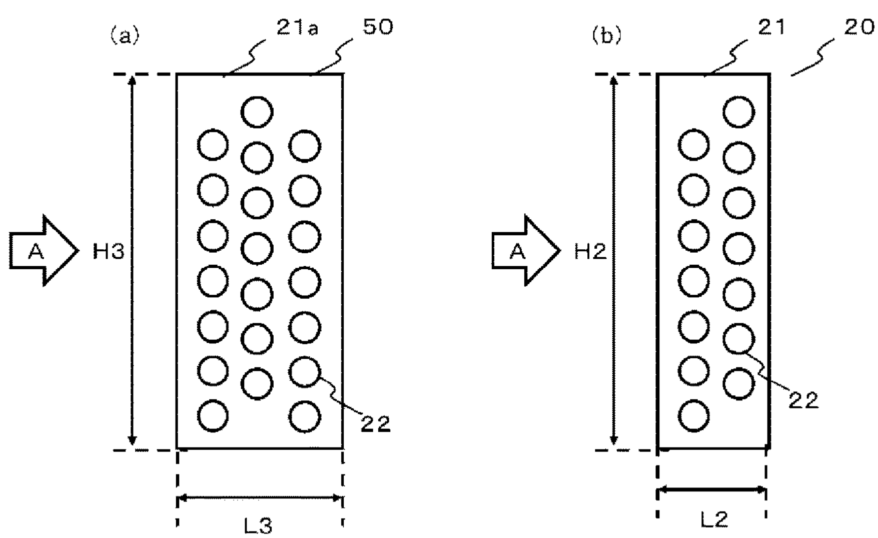


FIG. 9

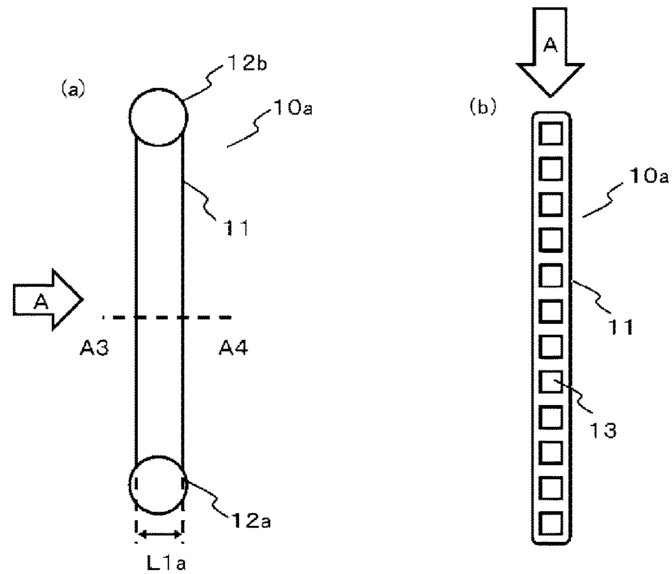


FIG. 10

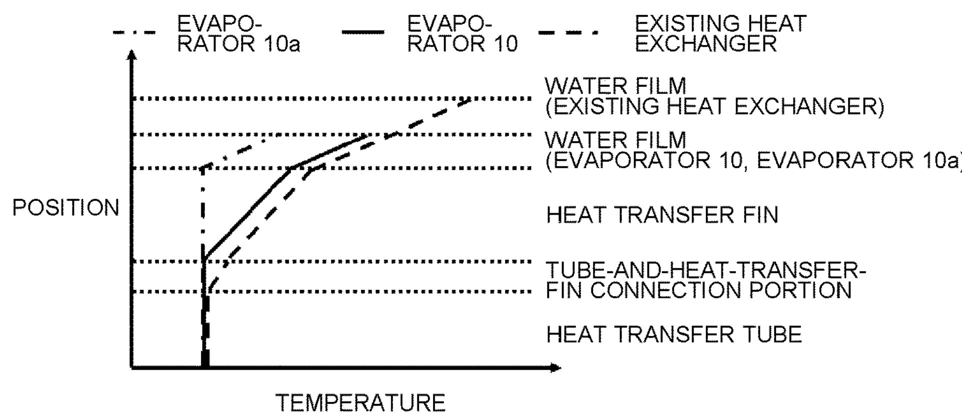


FIG. 11

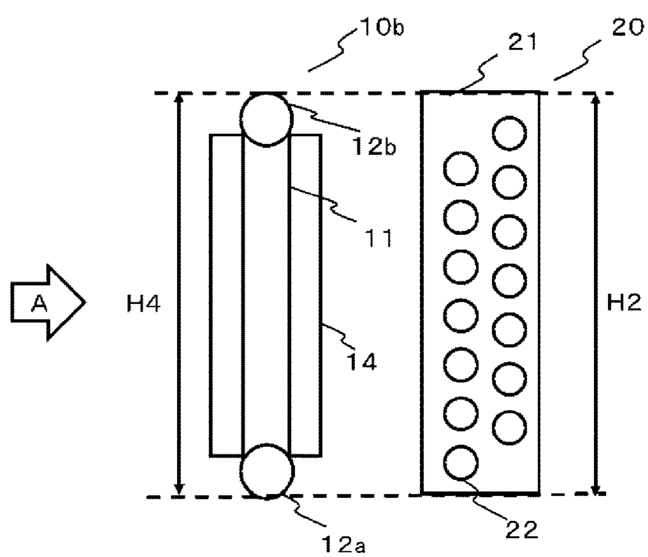


FIG. 12

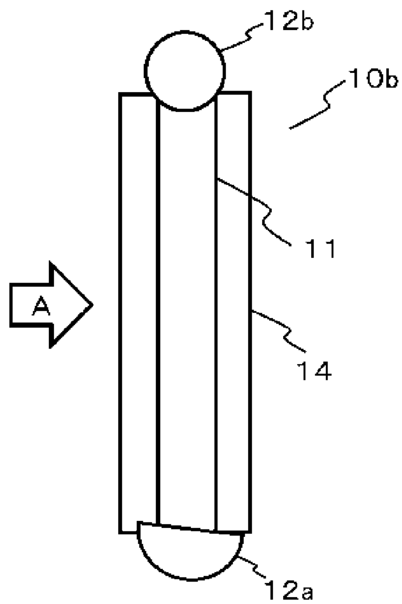


FIG. 13

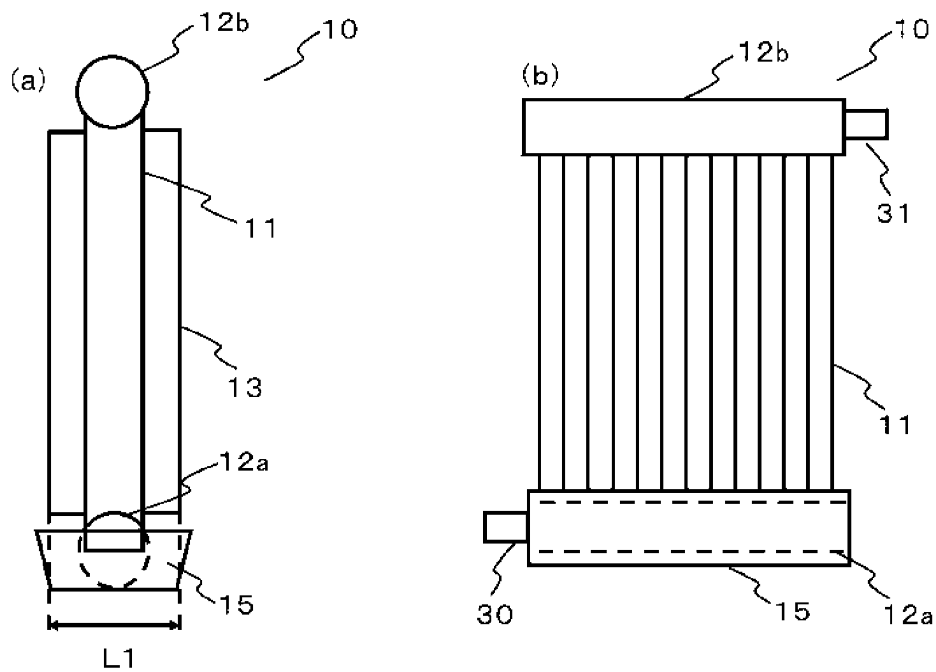


FIG. 14

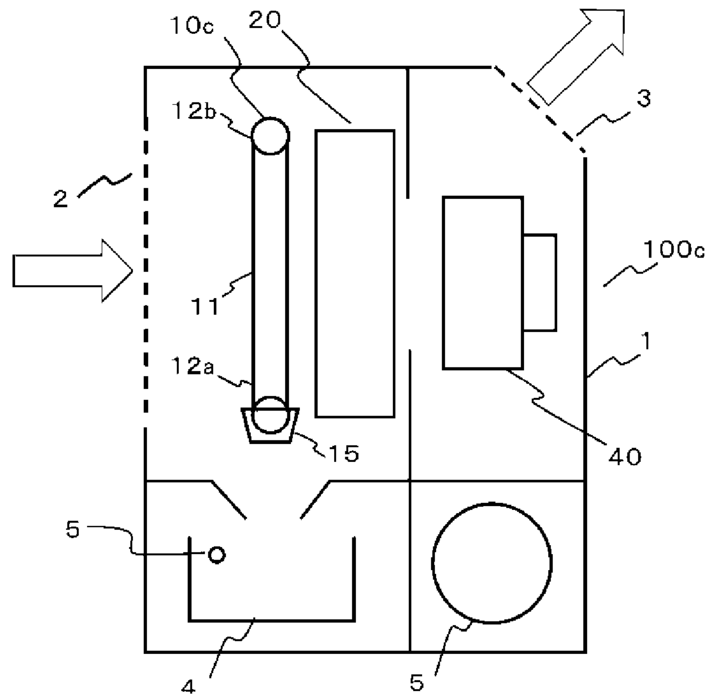
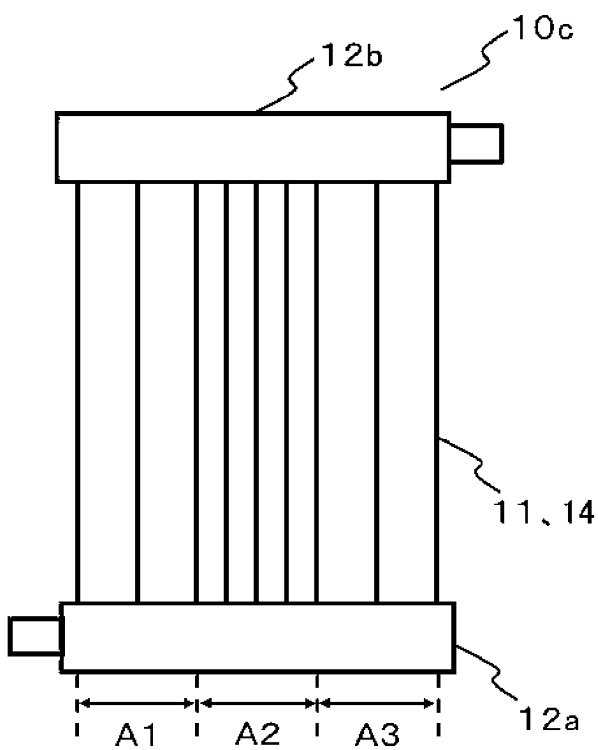


FIG. 15



DEHUMIDIFYING APPARATUS

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application is a U.S. national stage application of PCT/JP2021/045277 filed on Dec. 9, 2021, the contents of which are incorporated herein by reference.

TECHNICAL FIELD

[0002] The present disclosure relates to a dehumidifying apparatus.

BACKGROUND

[0003] In the past, dehumidifying apparatuses have been provided that include an evaporator configured to dehumidifies air having moisture by cooling the air and a condenser configured to reheat the air. The evaporator and the condenser are both fin-and-tube type circular heat exchangers.

PATENT LITERATURE

[0004] Patent Literature 1: Japanese Unexamined Patent Application Publication No. Hei 7-294179

[0005] When the humidity in a room rises, a resident may feel uncomfortable or a hygienic environment in the room may deteriorate, especially in the summer. However, in order to enhance a dehumidification performance, a dehumidifying apparatus disclosed in Patent Literature 1 needs an evaporator in which a larger number of tubes are arranged in a row, and as a result, the size and weight of the dehumidifying apparatus are increased, and noise is made due to an increase in a blowing pressure.

SUMMARY

[0006] The present disclosure is applied to solve the above problems, and relates to a dehumidifying apparatus that can be made to have a smaller size and a lower weight and also can reduce noise made from the dehumidifying apparatus, while having a dehumidification performance higher than or equivalent to that of an existing dehumidifying apparatus.

[0007] A dehumidifying apparatus according to an embodiment of the present disclosure includes: a housing; an air inlet provided in the housing; an air outlet provided in the housing; a blower provided in the housing; and an evaporator provided on an air passage that connects the air inlet and the air outlet, and configured to cool and dehumidify air that is sent into the housing by the blower. The evaporator includes a plurality of flat tubes having flow passages through which refrigerant flows and extending in an up-down direction, a pair of headers connected to an upper end and a lower end of each of the flat tubes, and a first extension portion connected to a windward side of one of the flat tubes, and having long sides extending in the up-down direction along of the flat tube.

[0008] By using, as the evaporator, a finless heat exchanger that is superior in drainage performance, it is possible to reduce the size and weight of the dehumidifying apparatus according to the embodiment of the present disclosure, and reduce noise to a low level, while keeping the dehumidification performance of the dehumidifying apparatus equivalent to that of an existing dehumidifying apparatus.

BRIEF DESCRIPTION OF DRAWINGS

[0009] FIG. **1** illustrates a configuration of a dehumidifying apparatus according to Embodiment 1.

[0010] FIG. **2** illustrates a refrigerant circuit according to Embodiment 1.

[0011] FIG. **3** illustrates configurations of heat exchangers in Embodiment 1.

[0012] FIG. **4** illustrates a configuration of an existing flat-tube heat exchanger.

[0013] FIG. **5** is a diagram indicating performances of a heat exchanger in Embodiment 1.

[0014] FIG. **6** is a diagram indicating a temperature distribution of the heat exchanger in Embodiment 1.

[0015] FIG. **7** is a diagram indicating another performance of the heat exchanger in Embodiment 1.

[0016] FIG. **8** illustrates configurations of heat exchangers in an existing dehumidifying apparatus.

[0017] FIG. **9** illustrates configurations of a heat exchanger in Embodiment 2.

[0018] FIG. **10** is a diagram indicating a temperature distribution of the heat exchanger in Embodiment 1.

[0019] FIG. **11** illustrates configurations of heat exchangers in Embodiment 3.

[0020] FIG. **12** illustrates a modification of the heat exchanger in Embodiment 3.

[0021] FIG. **13** illustrates configurations of a heat exchanger in Embodiment 4.

[0022] FIG. **14** illustrates a configuration of a dehumidifying apparatus according to Embodiment 4.

[0023] FIG. **15** illustrates a configuration of a heat exchanger in Embodiment 5.

DETAILED DESCRIPTION

[0024] The embodiments of the present disclosure will be described with reference to figures in the drawings. In each of the figures, components that are the same as those in a previous figure or previous figures are denoted by the same reference sings (**1***a*, **1***b*, . . .). Furthermore, in the following description, of the above components, components that do not need be distinguished from each other are denoted by reference signs not including suffixes.

[0025] The following description is made to explain the embodiments, and are not limiting. That is, a person with ordinary skill in the art can replace each or all of elements of a dehumidifying apparatus descried in the present disclosure with an equivalent or equivalents, and adopt the equivalents, and the equivalents are also encompassed in the scope of the present disclosure. That is, the present disclosure is not limited to the embodiments that will be described below but may be modified variously without departing from the gist of the present disclosure.

Embodiment 1

Configuration of Dehumidifying Apparatus

[0026] FIG. **1** illustrates a configuration of a dehumidifying apparatus **100** according to Embodiment 1 of the present disclosure. As illustrated in FIG. **1**, the dehumidifying apparatus **100** includes a housing **1** that is kept up with no support. The housing **1** has an air inlet **2** through which indoor air A (hereinafter referred to as "air A") flows into the housing **1** and an air outlet **3** through which dry air B (hereinafter referred to as "air B") flows out from the housing **1** into a room.

[0027] In the housing **1**, an evaporator **10** is provided downstream of the air inlet **2** and a condenser **20** is provided downstream of the evaporator **10**. Therefore, the air A sucked through the air inlet **2** flows into the condenser **20** after passing through the evaporator **10**.

[0028] Furthermore, in the housing **1**, a blower **40** is provided. The blower **40** sucks the air A into the housing **1** through the air inlet **2**, causes the air A to pass through the evaporator **10** and the condenser **20**, and then causes the air B to flow out into the room through the air outlet **3**. It should be noted that any type of blower such as a sirocco fan or a propeller fan can be used as the blower **40**.

[0029] In the housing **1**, a water storage tank **4** is provided in which moisture removed from the air A by the evaporator **10** is stored. The water storage tank **4** is, for example, a plastic cuboid having an open top. Furthermore, the water storage tank **4** can be removed from the housing **1** to the outside of the housing **1** through a slot (not illustrated) provided in the housing **1**. A user can remove the water storage tank **4** from the housing **1** and pour off the water stored in the water storage tank **4**, as occasion arises.

[0030] Furthermore, at the water storage tank **4**, a water level sensor **5** is provided as a water amount detector configured to detect the amount of water in the water storage tank **4**. As the water level sensor **5**, an optical water level sensor including a light-emitting element and a light-receiving element, an ultrasonic water level sensor including an ultrasonic emitting circuit and an ultrasonic receiving circuit, or other sensors can be used.

[0031] In addition, in the housing **1**, a compressor **6** is provided. It is preferable that a space in the housing **1** in which the compressor **6** is housed be partitioned by partition walls into a space in which the evaporator **10** and the condenser **20** are housed, a space in which the water storage tank **4** is housed, and a space in which the blower **40** is housed. This is intended to prevent exhaust heat from the compressor **6** from affecting the operation of other elements and deteriorating material of the other elements.

[0032] Furthermore, in the housing **1**, a temperature and humidity sensor **7** is provided to detect the temperature and humidity of the air A. The temperature and humidity sensor **7** is provided between the air inlet **2** and the evaporator **10**. However, preferably, the temperature and humidity sensor **7** should be provided close to the air inlet **2** in order to prevent the result of detection by the temperature and humidity sensor **7** from being affected by air cooled in the evaporator **10**.

[0033] The temperature and humidity sensor **7** is an integrated combination of a temperature sensor and a humidity sensor. However, the temperature sensor and the humidity sensor may be provided as separate members. Furthermore, in the dehumidifying apparatus **100**, a communication module may be provided to communicate with an air-conditioning apparatus that is installed in the same room as the dehumidifying apparatus **100**, receive the temperature and humidity of air that are measured by the air-conditioning apparatus, and regard the temperature and the humidity as the temperature and humidity of the air A.

[0034] FIG. **2** illustrates a refrigerant circuit **200** mounted in the dehumidifying apparatus **100**. As illustrated in FIG. **2**, the refrigerant circuit **200** includes the compressor **6**, the condenser **20**, an expansion unit **8**, and the evaporator **10**. These components included in the refrigerant circuit **200** are connected to each other by copper pipes or other kinds of pipes. Refrigerant such as R134a, R410A, R290, R1234yf, or R1234ze flows in the refrigerant circuit **200**.

[0035] The compressor **6** is a certain type of compressor, such as a piston type compressor, a rotary type compressor, or a scroll type compressor. Furthermore, the expansion unit **8** is a certain kind of expansion module such as an expansion valve or a capillary tube.

[0036] The compressor **6**, the expansion unit **8**, the blower **40**, the water level sensor **5**, and the temperature and humidity sensor **7** are connected to a controller (not illustrated). The controller controls operations of the compressor **6**, the expansion unit **8**, and the blower **40**. Furthermore, the controller acquires, from the water level sensor **5** and the temperature and humidity sensor **7**, information necessary for control of the compressor **6**, the expansion unit **8**, and the blower **40**. In the case where the expansion unit **8** is a capillary tube, the controller does not exercise control.

[0037] It should be noted that the controller may include an inverter circuit configured to control the compressor **6**. The inverter circuit is a circuit configured to convert a DC voltage obtained by conversion by the inverter circuit into an AC voltage having a given voltage value, a given frequency, and a given phase. Because the inverter circuit is provided, the operating frequency [Hz] of the compressor **6** is adjusted to an optimum value depending on the state of the air A and a requisite amount of dehumidification. As a result, it is possible to increase the flow rate of refrigerant, especially in the case where the amount of dehumidification increases. Therefore, it is possible to achieve a desired amount of dehumidification even when the amount of refrigerant that is filled into the refrigerant circuit **200** is reduced.

[0038] It should be noted that the controller may be hardware such as a circuit device that fulfills the functions of the controller, or be made up of an arithmetic device, such as a microcomputer or a CPU, and software that is run on the arithmetic device.

[0039] In the housing **1**, a display panel (not illustrated) and control buttons (not illustrated) are provided. The user depresses control buttons to determine an operating condition of the dehumidifying apparatus **100**, and the display panel indicates an operating state of the dehumidifying apparatus **100**. Instead of the display panel and the control buttons provided in the housing **1**, for example, a display panel and control buttons that are displayed via a dedicated application on a smartphone possessed by the user may be used. In this case, the user can operate the dehumidifying apparatus **100** or check the operating state, based on content displayed on the smartphone.

Configuration of Heat Exchanger

[0040] FIG. **3** illustrates configurations of the evaporator **10** and the condenser **20**. To be more specific, FIG. **3**, (a), is a front view of the evaporator **10**. FIG. **3**, (b), is a front view of the condenser **20**. FIG. **3**, (c), is a side view of the evaporator **10**. FIG. **3**, (d), is a side view of the condenser **20**. FIG. **3**, (e), is a cross-sectional view of the evaporator **10** that is taken along line **A1**-**A2**. The "front view" is a view obtained as seen in the flow direction of air in FIG. **1**, and the "side view" is a view obtained as seen in a direction perpendicular to the flow direction of air.

[0041] As illustrated in FIG. **3**, (a) and (c), the evaporator **10** includes flat tubes **11** (elongated heat transfer tubes), headers **12***a* and **12***b* connected to both ends of each of the flat tubes **11**, and extension portions **14** connected to the flat tube **11**. Furthermore, to the header **12***a*, a first inlet tube **30** through which refrigerant is introduced into the header **12***a* is attached, and to the header **12***b*, a first outlet tube **31** through which the refrigerant is discharged from the header **12***b* is attached.

[0042] Each of the flat tubes **11** is an elongated tube extending in an up-down direction and includes a plurality of flow passages through which the refrigerant flows. In the example illustrated in FIG. **3**, (e), the flat tube **11** includes twelve rectangular flow passages **13** arranged in an equidistant manner. Furthermore, the flat tube **11** is made of an aluminum alloy or other material that has high heat conductivity.

[0043] As illustrated in FIG. **3**, (c) and (e), to a windward side and a leeward side of each of the flat tubes **11**, respective extension portions **14** are connected. As illustrated in FIG. **3**, (e), each of the extension portions **14** is a thin plate-shaped member, and unlike the flat tube **11**, the extension portion **14** includes no refrigerant flow passage. Furthermore, as illustrated in FIG. **3**, (c), the extension portion **14** has a long side connected to the flat tube **11** and short sides extending in the flow direction of air. The extension portion **14** is made of the same aluminum alloy or other material as the flat tube **11**.

[0044] It is preferable that the width W**2** of the extension portion **14** be smaller than the width W**1** of the flat tube **11**. This is because in the case where the width W**2** of the extension portion **14** located on a windward side relative to the flat tube **11** is greater than the width W**1** of the flat tube **11**, the velocity of air over a surface of the flat tube **11** decreases and the amount of heat exchange at the flat tube **11** decreases. In contrast, in the case where the width W**2** is smaller than the width W**1**, the velocity of air that flows over the surface of the flat tube **11** can be kept high, and the amount of heat exchange at the flat tube **11** can be kept large. For this reason, it is preferable that the width W**2** of the extension portion **14** be smaller than the width W**1** of the flat tube **11**.

[0045] The header **12***a* and the header **12***b* are hollow circular tubes. Both ends of the flat tube **11** are connected to the header **12***a* and the header **12***b*. Furthermore, the flow passages **13** formed in the flat tube **11** communicate with internal spaces of the header **12***a* and the header **12***b*.

[0046] It should be noted that the header **12***a* may have a function of distributing the refrigerant. For example, the header **12***a* may be configured such that a dispersion tube including a plurality of dispersing holes is provided inside the hollow circular tube. In such a manner, in the case where the header **12***a* is made to have the above distributing function, it is possible to equalize the amounts of refrigerant that flows into the passages **13** of the flat tube **11**, thereby increasing the amount of heat exchange at the evaporator **10**.

[0047] Furthermore, the first inlet tube **30** is connected to one end of the header **12***a*, and the first outlet tube **31** is connected to one end of the header **12***b*. The first inlet tube **30** and the first outlet tube **31** are hollow circular tubes. The first inlet tube **30** communicates with a space in the header **12***a*, and the first outlet tube **31** communicates with a space in the header **12***b*.

[0048] It will be described how an existing flat-tube heat exchanger and the evaporator **10** are different in configuration from each other. FIG. **4** illustrates a configuration of the existing flat-tube heat exchanger **300**. The heat exchanger **300** includes a plurality of flat tubes **11**, a plurality of heat transfer fins **21***b*, and headers **12***a* and **12***b* connected to both ends of each of the flat tubes **11**. In the exiting flat-tube heat exchanger **300**, the thin-plate-shaped heat transfer fins **21***b* are connected as heat-transfer enhancement portions to the flat tubes **11** and the heat transfer fins **21** are provided perpendicular to the flat tubes **11**, which extend in the up-down direction, and thus cross the flat tubes **11**. In contrast, in the evaporator **10**, the flat tube **11** is provided with the extension portions **14** that extend in the up-down direction as heat-transfer enhancement portions and no heat transfer fins are provided in a direction crossing an extending direction of the flat tubes **11**. In other words, the difference between the configuration of the existing flat-tube heat exchanger **300** and that of the evaporator **10** resides in whether a heat transfer enhancement portion is provided in such a manner as to cross the flat tube **11** or is provided along the extending direction of the flat tube **11**.

[0049] Next, a configuration of the condenser **20** will be described. As illustrated in FIG. **3**, (b) and (d), the condenser **20** includes the heat transfer fins **21** serving as heat transfer enhancement portions, circular tubes **22** through which the refrigerant flows, hairpin tubes **23** connecting the circular tubes **22**, and a header **24** connected to the circular tubes **22**. Furthermore, in the header **24**, a partition wall **27** is provided to divide the header **24** into upper and lower portions thereof. Furthermore, a second inlet tube **30***a* is connected to the lower portion of the header **24**, which is located below the partition wall **27**, and a second outlet tube **31***a* is connected to the upper portion of the header **24**, which is located above the partition wall **27**.

[0050] Each of the heat transfer fins **21** is formed of a highly thermally conductive metal such as an aluminum alloy and formed in the shape of a thin plate. The heat transfer fin **21** has a plurality of holes through which the circular tubes **22** pass. The heat transfer fins **21** are provided parallel to each other.

[0051] The circular tubes **22** are, for example, hollow circular tubes made of copper. The circular tubes **22** are provided to extend through holes provided in the heat transfer fin **21**, and the circular tubes **22** and the heat transfer fin **21** are fixed to each other by blazing. That is, the circular tubes **22** and the heat transfer fin **21** are thermally connected to each other. Furthermore, the circular tubes **22** are connected to each other by the hairpin tubes **23**. In the example as illustrated in FIG. **3**, (b), a single long tube including folded members penetrates the plurality of heat transfer fins **21**.

[0052] The header **24** is, for example, a hollow circular tube made of copper, and the inside of the header **24** is partitioned into upper and lower portions by the partition wall **27**. As illustrated in FIG. **3**, (b), an end of the lowermost one of the circular tubes **22** is connected to lower part of the header **24**, and an end of the uppermost one of the circular tubes **22** is connected to upper part of the header **24**. Furthermore, the second inlet tube **30***a* is connected to the lower part of the header **24**, and the second outlet tube **31***a* is connected to the upper part of the header **24**.

Operation of Dehumidifying Apparatus

[0053] An operation of the dehumidifying apparatus **100** will be described. The controller of the dehumidifying apparatus **100** controls the operations of the compressor **6**, the expansion unit **8**, and the blower **40** based on an operating condition that is determined when the user depresses the control buttons and the results of detection by the water level sensor **5** and the temperature and humidity sensor **7**.

[0054] First, when the water level sensor **5** detects that a predetermined or larger amount of water is stored in the water storage tank **4**, the controller does not cause any of the compressor **6**, the expansion unit **8**, and the blower **40** to operate. Furthermore, the controller causes the display panel to make a display indicating that the predetermined or larger amount of water is stored in the water storage tank **4**. In such a manner, the dehumidifying apparatus **100** prompts the user to pour off the water stored in the water storage tank **4**.

[0055] When the water level sensor **5** detects that the predetermined or larger amount of water is stored in the water storage tank **4** during operation of the dehumidifying apparatus **100**, the controller suspends the operations of the compressor **6**, the expansion unit **8**, and the blower **40** and causes the display panel to make the above display. As a result, there is no possibility that water will overflow from the water storage tank **4** during operation of the dehumidifying apparatus **100**.

[0056] In contrast, in the case where the amount of water stored in the water storage tank **4** is less than the predetermined amount of water, the controller controls the frequency of the compressor **6**, the opening degree of the expansion unit **8**, and the rotation speed of the blower **40** to cause a humidity detected by the temperature and humidity sensor **7** to be lower than or equal to a humidity set by input using the control buttons.

[0057] More specifically, the controller determines a target dehumidification amount from the difference between the humidity first detected by the temperature and humidity sensor **7** and the set temperature. When the target dehumidification amount is less than a predetermined value (for example, 1 [g/kg (DA)]), the controller does not cause the compressor **6** to operate. In contrast, when the target dehumidification amount is larger than or equal to the predetermined value, the controller causes the compressor **6** to operate at a predetermined frequency.

[0058] Furthermore, in the case where the controller is provided with the inverter circuit and the frequency of the compressor **6** can be arbitrarily changed, the compressor **6** may be controlled in the following manner. When the target dehumidification amount is less than the predetermined value, the compressor **6** is operated at a frequency A Hz, and when the target dehumidification amount is larger than or equal to the predetermined value, the compressor **6** is operated at a frequency B Hz (B>A). The method of controlling the compressor **6** is not limited to the above method in which the compressor **6** is controlled at two frequencies, but the number of frequencies at which the compressor **6** is controlled may be larger than two.

[0059] Similarly, the controller controls the opening degree of the expansion unit **8**. Specifically, when the target dehumidification amount is smaller than the predetermined value, the opening degree (pressure drop) of the expansion unit **8** is decreased, and when the target dehumidification amount is larger than or equal to the predetermined value, the opening degree of the expansion unit **8** is increased. Similarly, the controller determines the rotation speed [rmp] of the blower **40** based on the target dehumidification amount. It is preferable that the opening degree of the expansion unit **8** and the rotation speed of the blower **40** be controlled in multiple stages based on the target dehumidification amount.

[0060] Once the compressor **6**, the expansion unit **8**, and the blower **40** start to operate as described above, the refrigerant starts to circulate in the refrigerant circuit **200**, and air also starts to be sucked into the housing **1**. In the following description, the circulation of the refrigerant in the refrigerant circuit **200** is first referred to, and the change of the state of air in the housing **1** is then referred to.

[0061] First, the refrigerant is compressed in the compressor **6**. High-temperature and high-pressure gas refrigerant obtained through compression by the compressor **6** flows into the condenser **20**. The refrigerant that has flowed into the condenser **20** transfers heat to surrounding air to liquefy. The refrigerant that has liquefied is decompressed by the expansion unit **8** to change into two-phase gas-liquid refrigerant and then flows into the evaporator **10**. The refrigerant that has flowed into the evaporator **10** receives heat from the surrounding air to change into gas refrigerant. Then, the gas refrigerant that has a low temperature and a low pressure flows out from the evaporator **10** and returns to the compressor **6**.

[0062] The flow of refrigerant in the evaporator **10** will be described in more detail. As illustrated in FIG. **3**, (a), (c), and (e), the evaporator **10** includes the header **12**_a_, the flat tubes **11**, and the header **12**_b_. The two-phase gas-liquid refrigerant obtained through decompression by the expansion unit **8** flows into the header **12**_a_ through the first inlet tube **30**. The refrigerant that has flowed into the header **12**_a_ branches into refrigerant streams to flow into the flow passages **13** of the flat tube **11**, and the refrigerant streams then join each other in the header **12**_b_. In the case where the header **12**_a_ has a function of distributing refrigerant, the header **12**_a_ can equalize the amounts of refrigerant streams that flow into the flow passage **13** of the flat tube **11**, whereby the amount of heat exchange at the evaporator **10** is increased.

[0063] The state of air in the housing **1** will then be described. When the blower **40** operates, the air A is sent to the evaporator **10** in the housing **1** through the air inlet **2**. It should be noted that the flat tubes **11** and the extension portions **14** are cooled by the refrigerant that flows through the flow passages **13**. Therefore, the air A sent to the evaporator **10** is cooled by the flat tubes **11** and the extension portion **14**, and moisture condenses on the flat tubes **11** and the extension portions **14**, and the air A is dehumidified. The moisture that has condensed moves downward along the flat tubes **11** and the extension portions **14**, drops from the evaporator **10**, and is stored in the water storage tank **4**.

[0064] In such a manner, indoor air is cooled, deceases in humidity, and is dehumidified. The dehumidified air is heated at the condenser **20** and flows out as humidity-controlled air B into the room through the air outlet **3**.

[0065] Dehumidification at the evaporator **10** will be described in more detail. In the evaporator **10**, moisture contained in the air A condenses on the flat tubes **11** and the extension portions **14**. That is, after being dehumidified, the moisture adheres to the flat tubes **11** and the extension portions **14**. It should be noted that in order to increase the dehumidification amount of the dehumidifying apparatus

100, it is necessary to enhance the heat exchange performance of the evaporator 10 and increase the amount of water that condenses per unit time.

[0066] FIG. 5 is a diagram indicating a dry-surface heat transfer performance, a wet-surface heat transfer performance, a dry-surface pressure loss, and a wet-surface pressure loss of a finless heat exchanger that is used as the evaporator 10, with reference to those of an existing heat exchanger. FIG. 5 illustrates relative values of the above items to values of the items of the existing heat exchanger that are each determined as 1.00. The existing heat exchanger is a fin and tube heat exchanger, such as the condenser 20 as illustrated in FIG. 3, (b) and (d), which includes circular tubes and heat transfer fins. More specifically, the heat transfer tubes are circular tubes each having a diameter of 7 mm, and are arranged in a row in the flow direction of air and arranged at a plurality of stages such that the stages are arranged at a stage pitch 21 mm, and the heat transfer fins each have a thickness of 0.1 mm and are arranged at a fin pitch of 1.5 mm. It should be noted that the heat transfer area ratio of the finless heat exchanger to the heat transfer area of the fin and tube heat exchanger for use in the measurement of the values indicated in FIG. 5 is 81%.

[0067] As indicated in FIG. 5, the finless heat exchanger exhibits a higher heat transfer performance than the existing heat exchanger on both a dry surface and a wet surface. Especially in the case where the surface is a wet surface, the finless heat exchanger exhibits a remarkably high performance as compared with the case where the surface is a dry surface. It will be described why the finless heat exchanger thus exhibits a high performance in the case where the surface is a wet surface.

[0068] During operation of the dehumidifying apparatus 100, condensed water adheres to a surface of the evaporator 10. The condensed water is discharged downward along the flat tubes 11 and the extension portions 14, since the flat tubes 11 and the extension portions 14 extend in the up-down direction. It should be noted that the condensed water is promptly discharged, because the evaporator 10 has no elements that hinder discharge of the condensed water, such as heat transfer fins provided to extend in the horizontal direction. In contrast, in the case where a fin and tube heat exchanger, such as the condenser 20, which includes heat transfer fins and circular tubes, is used as an evaporator, the circular tubes are elements that hinder discharge of dew condensation water. Accordingly, the evaporator 10 has a higher drainage performance than the fin and tube heat exchanger.

[0069] Therefore, the thickness of water films formed on surfaces of the flat tubes 11 and the extension portions 14 in the evaporator 10 is small. As a result, the temperature of a surface of each of the water films is reduced, as compared with an existing heat exchanger. FIG. 6 indicates a comparison between a temperature distribution of the evaporator 10 and that of the existing heat exchanger. It should be noted that the "temperature distribution" means a temperature distribution from the center of a heat transfer tube to a water film on the heat transfer fin through the heat transfer fin. Furthermore, in FIG. 6, it is assumed that the surface temperatures of the flat tube 11 and the circular tube 22 are equal to the temperature of refrigerant that flows in the flat tube 11 and the circular tube 22.

[0070] As illustrated in FIG. 6, in the existing heat exchanger, the temperature rises through a tube-and-heat-transfer-fin connection portion, the heat transfer fins, and a thick water film. In contrast, in the evaporator 10, the flat tube 11 and the extension portion 14 can be formed integral with each other, and the value by which the temperature is raised by a tube-extension portion connection is small. Furthermore, in the evaporator 10, since the thickness of the water film is small, the value by which the temperature at the water film rises is small.

[0071] For the above reason, in the existing heat exchanger, the difference in temperature between air and the water film on a surface of the evaporator is small and the amount of heat exchange is thus small. In contrast, in the evaporator 10, the difference in temperature between the water film and air is great, and the amount of heat exchange is thus great. In addition, in the evaporator 10, since it is ease to necessarily keep the temperature of the water film lower than or equal to the dew-point temperature of air, water necessarily continues to condense and the evaporator 10 thus exhibits a high dehumidification performance.

[0072] In addition, in the evaporator 10, since the thickness of the water film on the surface of the evaporator 10 can be reduced, the flow of air that passes through the evaporator 10 is rarely hindered by the water film. Accordingly, in the evaporator 10, an increase in ventilation resistance on the wet surface is small, and the efficiency of heat exchange between air and the refrigerant is improved.

[0073] For the above reasons, the finless heat exchanger that is used as the evaporator 10 is superior in both wet-surface heat transfer performance and pressure loss to the existing heat exchanger. Accordingly, even if the heat transfer area is reduced, a finless heat exchanger such as the evaporator 10 can exhibit a heat exchange performance higher than or equivalent to that of the existing heat exchanger, and the dehumidifying apparatus 100 can exhibit a dehumidification performance higher than or equivalent to that of an existing dehumidifying apparatus. As a result, it is possible to reduce the size of the housing 1 and thus also reduce the size the dehumidifying apparatus.

[0074] The dehumidifying apparatus 100 having the above configuration obtains the following advantages. First, since the size of the evaporator 10 can be reduced, the size of the entire dehumidifying apparatus 100 can also be reduced. As a result, the user can install the dehumidifying apparatus 100 in various places. At the same time, since the weight of the dehumidifying apparatus 100 is reduced, the user can easily move the dehumidifying apparatus 100.

[0075] Furthermore, the ventilation resistance of the evaporator 10 is lower than the ventilation resistance of the existing heat exchanger. It is therefore possible to reduce noise made by the dehumidifying apparatus 100, and also reduce the possibility that the user will feel annoyed.

[0076] In addition, the evaporator 10 has a high drainage performance for letting out condensed water therefrom. Thus, the dehumidifying apparatus 100 has a high dehumidification performance per unit time. Therefore, even if the room has a high humidity, it is possible to reduce the humidity in a short time.

[0077] Furthermore, the extension portions 14 of the evaporator 10 include no flow passage 13 for the flow of the refrigerant. Thus, the amount of refrigerant in the evaporator 10 is small, though the heat transfer area of the evaporator 10 is large. It is therefore possible to reduce the amount of refrigerant that is contained in the dehumidifying apparatus 100.

[0078] The width W**2** of the extension portion **14** is smaller than the width W**1** of the flat tube **11**. Therefore, the amount of metal material, for example, aluminum, of which the extension portion **14** is made is smaller than the amount of metal material of which a flat tube **11** having the same length as the extension portion **14** is made. It is therefore possible to reduce the cost of manufacturing the dehumidifying apparatus **100**, and also to reduce the weight of the dehumidifying apparatus **100**, since the amount of aluminum that is used is reduced.

[0079] The foregoing description refers to an example of the configuration of the dehumidifying apparatus **100**, and the dehumidifying apparatus **100** can be modified variously without departing from the gist of the present disclosure.

[0080] For example, in the present embodiment, the condenser **20** is a heat exchanger having one path (the number of times the refrigerant branches off is 1); however, the condenser **20** may be a heat exchanger having two or more paths. In addition, the condenser **20** may be a flat-tube heat exchanger that employs flat tubes as heat transfer tubes. In the case where the condenser **20** is a heat exchanger having two or more paths, it is preferable that the header in which the refrigerant flows into the circular tube be made to have a function of distributing the refrigerant.

[0081] Furthermore, although referring to FIG. **3**, (c) and (e), the extension portions **14** are provided both on the upstream side and downstream side of the flat tube **11**, an extension portion **14** may be provided only either upstream or downstream of the flat tube **11**. Furthermore, the length of the extension portion **14** located on the upstream side may be different from that of the extension portion **14** located on the downstream side. In the following description, the extension portion **14** located on the upstream side is referred to as a first extension portion **14***a* and the extension portion **14** located on the downstream side is referred to as a second extension portion **14***b*.

[0082] In the case where only either the first extension portion **14***a* or the second extension portion **14***b* is provided in the evaporator **10**, it is preferable that the first extension portion **14***a* be provided. Regarding the evaporator **10**, from a comparison between the temperature of the surrounding air, the temperatures of the first extension portion **14***a* and the second extension portion **14***b*, and the temperature of the flat tube **11**, it is found that the temperature of the air is the highest, the temperature of each of the first extension portion **14***a* and the second extension portion **14***b* is the second highest, and the temperature of the flat tube **11** is the lowest. Therefore, the difference between the temperature of the air and those of the first and second extension portions **14***a* and **14***b* is smaller than the difference between the temperature of the air and that of the flat tube **11**.

[0083] In such a case, even if air and the first extension portion **14***a* exchange heat with each other in a region located upstream of the flat tube **11** and the temperature of the air decreases, there is still a temperature difference between the air and the flat tube **11**. Therefore, both the first extension portion **14***a* and the flat tube **11** exchange heat with the air. In contrast, in the case where the second extension portion **14***b* is provided downstream of the flat tube **11**, the temperature difference between the second extension portion **14***b* and the air whose temperature is decreased by heat exchange between the air and the flat tube **11** decreases, and the heat exchange efficiency is reduced. Accordingly, in the case where only either the first extension portion **14***a* and the second extension portion **14***b* is provided, it is preferable that the first extension portion **14***a* be provided, since the dehumidification performance of the dehumidifying apparatus **100** is enhanced as compared with the case where the second extension portion **14***b* is provided. Similarly, in the case where the first extension portion **14***a* and the second extension portion **14***b* have different lengths, it is preferable that the first extension portion **14***a* be longer than the second extension portion **14***b*.

[0084] Furthermore, the evaporator **10** may be configured such that the flat tubes **11** are arranged in a depth direction. In that case, all of the flat tubes **11** may include extension portions **14**, or only one or more of the flat tubes **11** may include extension portions **14**. In this case, it is preferable that the extension portion **14** be provided upstream of the most upstream one of the flat tubes **11** in order to ensure the aforementioned temperature difference between the air and the extension portion **14**.

[0085] Furthermore, the flat tube **11** and the extension portion **14** may be formed integral with each other or may be joined to each boy by brazing. However, unless otherwise restricted, it is preferable that the flat tube **11** and the extension portion **14** may be formed integral with each other for the following reason. In the case where the flat tube **11** and the extension portion **14** are joined to each other by brazing, the joining portion between them may become an obstacle to the heat transfer, thereby degrading the heat transfer performance.

[0086] The tube diameter of the header **12***b* is not limited to a specific one, whereas preferably, the tube diameter of the header **12***a* should be nearly equal to the depth of the flat tube **11**. In this case, the tube diameter of the header **12***a* is smaller than the depth L1 of the evaporator **10** as illustrated in FIG. **3**, (c). By configuring the header **12***a* in such a manner, it is possible to reduce the amount of refrigerant in the header **12***a*, thereby reducing the possibility that water that drops from the extension portion **14** will adhere to the header **12***a*. This reduces the possibility that the user will feel annoyed by water dropping from the header **12***a* to a storage space of the water storage tank **4**, for example, while the user is pouring off water after taking out the water storage tank **4**.

[0087] In the evaporator **10**, it is preferable that the distances between the flat tubes **11** arranged parallel to each other, that is, the pitch between the flat tubes **11**, be less than or equal to 2.8 mm. FIG. **7** is a diagram indicating the wet-surface heat transfer performance of a finless heat exchanger with reference to the performance of the existing heat exchanger in the case where the performance of the existing heat exchanger is 1.00. FIG. **7** indicates the wet-surface heat transfer performance of the finless heat exchanger in the case where the pitch between flat tubes **11** varies from 4.0 mm to 2.0 mm.

[0088] As indicated in FIG. **7**, the wet-surface heat transfer performance of the finless heat exchanger is lower than in the existing heat exchanger in the case where the pitch is greater than 3.0 mm. This is because the number of flat tubes **11** is small, the heat transfer area thus decreases, and the distances between the flat tubes **11** are great, as a result of which the air A does not sufficiently come in contact with the flat tubes **11** or the extension portions **14**.

[0089] In contrast, referring to FIG. **7**, in the case where the pitch between flat tubes **11** is less than 3.0 mm, the wet-surface heat transfer performance of the finless heat exchanger is superior to that of the existing heat exchanger. From a linear interpolation (Formula 1) based on a wet-surface heat transfer performance of 0.82 in the case where the pitch is 3.0 mm and a wet-surface heat transfer performance of 1.52 in the case where the pitch is 2.2 mm, it can be assumed that the finless heat exchanger exhibits a performance that is substantially equivalent to that of the existing heat exchanger in the case where the pitch is less than or equal to 2.8 mm, although the inventors did not make a measurement in the case where the pitch is 2.8 mm. Therefore, in the present embodiment, it is preferable that the pitch between the flat tubes **11** be smaller than or equal to 2.8 mm.

$$0.82+(1.52-0.82)/(30-22)\times 2=1 \tag{1}$$

It should be noted that needless to say, even if the pitch is less than or equal to 2.8 mm, when the pitch is 0 mm, air does not flow between the flat tubes **11** and dehumidification is not performed.

[0090] Furthermore, it can be seen from FIG. **7** that since the wet-surface heat transfer performance of the evaporator **10** is high when the pitch between flat tubes **11** is small, the dehumidification performance of the dehumidifying apparatus can be maintained even when the heat transfer area of the evaporator **10** is decreased. As a result, it is possible to make the dehumidifying apparatus **100** smaller while maintaining the dehumidifying performance. This point will be described.

[0091] Referring to FIG. **3**, (c), L**1** is the depth of a combination of the extension portion **14** and the flat tube **11** of the evaporator **10**, H**1** is the height of the extension portion **14** and the flat tube **11**, L**2** is the depth of the heat transfer fin **21** of the condenser **20**, and H**2** is the height of the heat transfer fin **21**.

[0092] The heat transfer area of the evaporator **10** and the heat transfer area of the condenser **20** will be described. As illustrated in FIG. **3**, (c) and (e), the heat transfer area of the evaporator **10** is the sum of the surface area of the flat tube **11** and the surface area of the extension portion **14**. It should be noted that the depth L**1** of the extension portion **14** and the flat tube **11** is several times greater than the width W**1** of the flat tube **11** and the width W**2** of the extension portion **14**. Therefore, the heat transfer area of the evaporator **10** can be deemed as the size of a surface parallel to the flow direction of air, and is expressed by the product of H**1** and L**1**.

[0093] The heat transfer area of the condenser **20** is the sum of the surface area of the heat transfer fin **21** and the surface area of the circular tube **22**. In a fin and tube heat exchanger such as the condenser **20**, the surface area of a heat transfer fin is generally several to several tens of times greater than the surface area of the circular tube. Furthermore, the heat transfer fin is generally a metal plate whose thickness is less than 1 mm. Therefore, the heat transfer area of the condenser **20** can be deemed as the size of a surface parallel to the flow direction of air through the heat transfer fin **21**, and is expressed by the product of H**2** and L**2**.

[0094] Furthermore, the heat transfer area of the evaporator **10** and the heat transfer area of the condenser **20** will be described with reference to the structure of the existing dehumidifying apparatus. FIG. **8** illustrates configurations of an evaporator and a condenser in an existing dehumidifying apparatus. Since the condenser is also a fin and tube heat exchanger in the existing dehumidifying apparatus, referring to FIG. **8**, the condenser **20** according to the present embodiment is used.

[0095] As illustrated in FIG. **8**, in the existing dehumidifying apparatus, the evaporator **50** and the condenser **20** are both fin and tube heat exchangers. The evaporator **50** and the condenser **20** are the same as each other in the tube diameter and tube thickness of the circular tubes **22**, the number of stages at which the circular tubes **22** are provided, the row pitch, the stage pitch, the fin thickness and height of the heat transfer fins **21** and heat transfer fins **21***a*. Furthermore, the evaporator **50** and the condenser **20** are also the same as each other in stacking width. The evaporator **50** and the condenser **20** are different from each other as follows: the number of circular tubes **22** in each row in the evaporator **50** is 3 and that of circular tubes **22** in each row in the condenser **20** is 2, and as a result, the depth L**3** of the heat transfer fin **21***a* is approximately 1.5 times greater than the depth L**2** of the heat transfer fin **21**.

[0096] Referring to FIG. **7**, in the case where the pitch is less than or equal to 2.8 mm, the finless heat exchanger exhibits a higher wet-surface performance than the existing heat exchanger. Furthermore, in the case where the pitch is less than or equal to 2.2 mm, the finless heat exchanger exhibits a wet-surface performance that is 1.5 or more times higher than that of the existing heat exchanger.

[0097] Therefore, it is possible to reduce the heat transfer area to 1/1.5 by replacing the evaporator **50**, which is mounted in the existing dehumidifying apparatus, with a finless heat exchanger, such as the evaporator **10**, in which the pitch is less than or equal to 2.2 mm. It should be noted that since in the existing dehumidifying apparatus, the heat transfer area of the evaporator **50** is 1.5 times larger than that of the condenser **20**, and it is therefore possible to keep the dehumidifying performance at a value that is nearly equal to that of the existing dehumidifying apparatus, by replacing the evaporator **50** in the existing dehumidifying apparatus with the evaporator **10** and causing the heat transfer area of the evaporator **10** to be substantially equivalent to that of the condenser **20**.

[0098] In the case of changing the heat transfer area of the evaporator **10**, it is more preferable to change the depth L**1**, not the height H**1** of the evaporator **10**. In the dehumidifying apparatus **100**, if the height H**1** of the evaporator **10** and the height H**2** of the condenser **20** greatly differ from each other, a wasted space is provided in the housing **1**. Therefore, it is preferable to change the depth L**1** to adjust the heat transfer area of the evaporator **10**. Furthermore, according to FIG. **7**, it is also possible to make the depth L**1** less than or equal to the depth L**2** of the condenser **20** if the pitch in the evaporator **10** is less than or equal to 2.2 mm.

[0099] In such a manner, by reducing the heat transfer area of the evaporator **10**, it is possible to further reduce the size of the housing **1** and thus also reduce the size of the dehumidifying apparatus **100**. In particular, it should be noted that by making the depth L**1** of the evaporator **10** less than the depth L**2** of the condenser **20**, it is possible to reduce the possibility that the performance of the condenser will fall below the performance of the evaporator, and thus reduce the possibility that the temperature in the room will be decreased during operation of the dehumidifying apparatus **100** and the comfort will be impaired.

Embodiment 2

Configuration of Dehumidifying Apparatus

[0100] Embodiment 2 of the present disclosure will be described with reference to FIGS. **9** and **10**. A dehumidifying apparatus **100***a* according to Embodiment 2 is substantially the same in configuration as the dehumidifying apparatus **100** of Embodiment 1, but is different in shape of the evaporator from the dehumidifying apparatus **100** of Embodiment 1. The following description concerning the dehumidifying apparatus **100***a* according to Embodiment 2 is made by referring mainly to the differences between Embodiments 1 and 2. Regarding Embodiment 2, components that will not be described are the same as those in Embodiment 1.

[0101] FIG. **9**, (a), is a side view of an evaporator **10***a* according to Embodiment 2, and FIG. **9**, (b), is a cross-sectional view taken along line A**3**-A**4**. The evaporator **10***a* of Embodiment 2 includes no extension portions **14**. In this regard, the evaporator **10***a* of Embodiment 2 is different from the evaporator **10** of Embodiment 1. To be more specific, the evaporator **10***a* includes the flat tubes **11**, the header **12***a*, and the header **12***b*. It should be noted that the condenser **20** of Embodiment 2 is the same in configuration as the configuration to the condenser **20** of Embodiment 1.

[0102] The heat transfer performance of the evaporator **10***a* will be described. FIG. **10** is a diagram indicating a temperature distribution of the evaporator **10***a*. The "temperature distribution" means a temperature distribution from the center of a heat transfer tube to a water film, as in FIG. **6**. Furthermore, FIG. **10** also indicates both a temperature distribution of the existing heat exchanger and a temperature distribution of the evaporator **10**.

[0103] The evaporator **10***a* includes no extension portion **14** and include the flat tubes **11** only. Thus, needless to say, the temperature does not rise at an extension portion **14**, and does not rise at a tube-extension portion connection. Therefore, in the evaporator **10***a*, the temperature rises at the water film only. Therefore, the temperature of the water film in the evaporator **10***a* is lower than in the existing heat exchanger and the evaporator **10**.

[0104] Therefore, the evaporator **10***a* is superior to the evaporator **10** in wet-surface heat transfer performance. In other words, in the evaporator **10***a*, since the temperature of air and that of the water film are greatly different from each other, the amount of heat exchange is large and the amount of water that condenses per unit time is large.

[0105] The dehumidifying apparatus **100***a* as described above obtains the following advantages, in addition to the advantages of the dehumidifying apparatus **100** of Embodiment 1.

[0106] The condenser **10***a* is superior in wet-surface heat transfer performance to the evaporator **10**, and can thus dehumidify the room in a shorter time.

Embodiment 3

Configuration of Dehumidifying Apparatus

[0107] Embodiment 3 of the present disclosure will be described with reference to FIG. **11**. A dehumidifying apparatus **100***b* of Embodiment 3 is substantially the same in configuration as the dehumidifying apparatus **100** of Embodiment 1, but includes an evaporator that is different in shape form the evaporator in the dehumidifying apparatus **100** of Embodiment 1. The following description concerning the dehumidifying apparatus **100***b* according to Embodiment 3 is made by referring mainly to the differences between Embodiments 1 and 3. Regarding Embodiment 3, components that will not be described are the same as those of Embodiment 1.

[0108] FIG. **11** illustrates configurations of an evaporator **10***b* and the condenser **20** according to Embodiment 3. In Embodiment 3, the configuration of the evaporator **10***b* is substantially the same as that of the evaporator **10** of Embodiment 1, and the evaporator **10***b* includes flat tubes **11**, a header **12***a*, a header **12***b*, and extension portions **14**.

[0109] In FIG. **11**, H**4** is the height of the evaporator **10***b*, and H**2** is the height of the condenser **20**. More specifically, H**4** is the length of the evaporator **10***b* from a lower end of the header **12***a* to an upper end of the header **12***b*, and H**2** is the length from a lower end of the heat transfer fin **21** to an upper end of the heat transfer fin **21**.

[0110] In Embodiment 3, the height H**4** of the evaporator **10***b* is less than or equal to the height H**2** of the condenser **20**. It should be noted that FIG. **11** illustrates the case where the height H**4** of the evaporator **10***b* is equal to the height H**2** of the condenser **20**. More specifically, the lower end of the header **12***a* of the evaporator **10***b* is located at the same level as the lower end of the heat transfer fin **21** of the condenser **20**, and the upper end of the header **12***b* is located at the same level as the upper end of the heat transfer fin **21**.

[0111] In the dehumidifying apparatus **100***b*, since the height of the evaporator **10***b* is restricted, the heat transfer area of the evaporator **10***b* is made smaller. However, the evaporator **10***b* is superior in wet-surface heat transfer performance to the existing heat exchanger for the same reason as described regarding Embodiment 1. In addition, in the evaporator **10***b*, the air A also collides with the headers **12***a* and **12***b* through which low-temperature refrigerant flows. Therefore, also, at surfaces of the headers **12***a* and **12***b*, the air A and the refrigerant exchange heat with each other. For the above two reasons, the dehumidifying apparatus **100***b* can exhibit a dehumidification performance that is higher than or equivalent to the existing dehumidifying apparatus, though even if the height of the evaporator **10***b* is restricted.

[0112] Furthermore, the positions of the headers **12***a* and **12***b* of the evaporator **10***b* and that of the header **24** of the condenser **20** will be described. The headers **12***a* and **12***b* of the evaporator **10***b* are attached to upper and lower ends of each of the flat tubes **11**, respectively. The header **24** of the condenser **20** is connected to one end of each of the circular tubes **22** in a lateral direction. That is, the evaporator **10***b* and the condenser **20** differ from each other in the direction in which the headers are attached.

[0113] The case where a region occupied by the flat tubes **11** (specifically, a region between upper and lower ends of flat tubes **11** in a region between the rightmost one of the flat tubes **11** and the leftmost one of the flat tubes **11** as illustrated in FIG. **3**, (a), and within the upper and lower ends of the flat tubes **11**) and a region occupied by the heat transfer fins **21** are the same as each other as seen in the flow direction of air will be referred to. In this case, portions that contribute to a heat exchanger are not present in a region located downstream of the headers **12***a* and **12***b* of the evaporator **10***b* and upstream of the header **24**. Thus, a wasted space is created in the housing **1**.

[0114] Therefore, it is preferable to eliminate the wasted space in order to reduce the size of the housing **1**. In Embodiment 3, since the height H**4** of the evaporator **10***b* is less than or equal to the height H**2** of the condenser **20**, the heat transfer fins **21** of the condenser **20** are located behind the headers **12***a* and **12***b*. In addition, since the evaporator **10***b* is a finless heat exchanger that is superior in wet-surface heat transfer performance, the size of the housing **1** of the dehumidifying apparatus **100***b* can be reduced and in addition, the dehumidifying performance is kept high.

[0115] The dehumidifying apparatus **100***b* as described above obtains the following advantages in addition to the advantages of the dehumidifying apparatus **100** of Embodiment 1. Since the height of the evaporator **10***b* is less than or equal to the height of the condenser **20**, a wasted space is not easily created in the housing **1**. It is therefore possible to reduce the size of the housing **1** and also reduce the size of the dehumidifying apparatus **100***b*.

[0116] The above description is made to explain an example of the configuration of the dehumidifying apparatus **100***b*, and the dehumidifying apparatus **100***b* may be variously modified without departing from the gist of the present disclosure.

[0117] It is preferable that the tube diameters of the headers **12***a* and **12***b* be nearly equal to the depth of the flat tube **11**, that is, the diameter of the flat tube **11**. This is because that when the tube diameters of the headers **12***a* and **12***b* are small, water does not easily collect in the headers **12***a* and **12***b* and the thickness of the water film decreases, whereby the heat exchange efficiency at the headers **12***a* and **12***b* thus increase.

[0118] The headers **12***a* and **12***b* may be changed in shape to enable drainage to be easily performed. FIG. **12** is a side view of the evaporator **10***b* in the case where the header **12***a* is changed in shape to enable drainage to be easily performed. In the present modification, as illustrated in FIG. **12**, the header **12***a* has a semicircular section.

[0119] In addition, since a linear portion of the header **12***a* having the semicircular cross section is located on an upper side of the header **12***a* and is inclined, condensed water stored in upper part of the header **12***a* is promptly let out along the inclination. In Embodiment 3, since heat exchange is also performed at the header **12***a*, it is possible to increase the heat exchange efficiency at the header **12***a* by promptly letting out water adhering to the header **12***a*. It is therefore also possible to efficiently perform dehumidification in the header **12***a*, thereby improving the dehumidification performance of the dehumidifying apparatus **100***b*. Although the above description refers to an example in which the shape of the header **12***a* is changed, the shape of the header **12***b* can also be changed in such a manner as described above.

Embodiment 4

Configuration of Dehumidifying Apparatus

[0120] Embodiment 4 of the present disclosure will be described with reference to FIGS. **13** and **14**. A dehumidifying apparatus **100***c* according to Embodiment 4 is substantially the same in configuration as the dehumidifying apparatus **100** of Embodiment 1, but includes an additional component not included in the dehumidifying apparatus **100** of Embodiment 1. The following description concerning the dehumidifying apparatus **100***c* of Embodiment 4 is made by referring mainly to the differences between Embodiments 1 and 4. Regarding Embodiment 4, components that will be not described are the same as those of Embodiment 1.

[0121] FIG. **13**, (a), is a side view of the evaporator **10** according to Embodiment 4, and FIG. **13**, (b), is a front view of the evaporator **10** according to Embodiment 4. In Embodiment 4, a water conduit **15** is provided in lower part of the evaporator **10**.

[0122] The water conduit **15** has a trapezoidal section. The length of the water conduit **15** is nearly equal to the length of the header **12***a* in the lateral direction. The water conduit **15** has openings in its upper and lower parts. Furthermore, the width of the opening in the upper part of the water conduit **15** is greater than the depth L**1** of the evaporator **10**. The water conduit **15** is provided such that at least part of the header **12***a* is accommodated in an internal space of the water conduit **15**.

[0123] The water conduit **15** has a function of receiving condensed water that drops from the evaporator **10** and of guiding the condensed water to the water storage tank **4**. FIG. **14** illustrates the configuration of the dehumidifying apparatus **100***c* of Embodiment 4. As illustrated in FIG. **14**, the water conduit **15** is located above the water storage tank **4**. Thus, the condensed water received by the water conduit **15** is let out from the water conduit **15** into the water storage tank **4** through the opening in the lower part of the water conduit **15**.

[0124] The dehumidifying apparatus **100***c* having the above configuration obtains the following advantages. Since the water conduit **15** is provided in lower part of the evaporator **10**, there is little likelihood that condensed water that drops from the evaporator **10** will fly off, and it is possible to keep the inside of the apparatus clean.

[0125] Furthermore, since the water conduit **15** accommodates part of the header **12***a*, space savings in the housing **1** is achieved. It is therefore possible to reduce the size of the dehumidifying apparatus **100***c*.

Embodiment 5

[0126] Embodiment 5 of the present disclosure will be described with reference to FIG. **15**. A dehumidifying apparatus **100***d* according to Embodiment 5 is substantially the same in configuration as each other, but the configuration of an evaporator of Embodiment 5 is different from the configuration of the evaporator in the dehumidifying apparatus **100** of Embodiment 1. The following description concerning the dehumidifying apparatus **100***d* according to Embodiment 5 is made by referring mainly to the differences between Embodiments 1 and 5. Regarding Embodiment 5, components that will not be described are the same as those of Embodiment 1.

[0127] FIG. **15** illustrates a configuration of an evaporator **10***c* according to Embodiment 5. In Embodiment 5, the evaporator **10***c* includes a region in which flat tubes **11** are arranged at a small pitch and at a high density and a region in which flat tubes **11** are sparsely arranged at a great pitch and at a low density. For example, referring to FIG. **15**, three regions A**1**, A**2**, and A**3** are provided. In the regions A**1** and A**3**, flat tubes **11** are arranged at a great pitch and a low density, and in the region A**2**, flat tubes **11** are arranged at a small pitch and a high density.

[0128] In a configuration in which holes formed in heat transfer fins formed in the shape of a thin plate and teat transfer tubes are made to extend thorough the holes as in an existing heat exchanger, the pitch cannot be easily locally changed. In contrast, in the finless heat exchanger, since it is not subject to the above restriction, it is possible to comparatively freely change the pitch as in the configuration as illustrated in FIG. **15**.

[0129] When the air A flows in the evaporator **10***c*, in the regions A**1** and A**3** in which the pitch between flat tubes **11** is great, the wet-surface heat transfer performance is degraded and the amount of heat exchange is thus decreased. In contrast, in the region A**2** in which flat tubes **11** are arranged at a small pitch and a high density, the wet-surface heat transfer performance is high and the amount of heat exchange is thus increased. In particular, when the pitch between flat tubes **11** is less than or equal to 2.2 mm, the evaporator **10** exhibits a wet-surface heat transfer performance that is 1.5 times or more higher than that of the existing heat exchanger. Thus, in some flat tubes, even when the pitch is increased, it is possible to maintain a heat exchange amount that is larger than or equal to that of the existing heat exchanger.

[0130] Furthermore, referring to FIG. **15**, flat tubes **11** are arranged at a high density at a central region of the evaporator **10***c* and in the vicinity of the central region for the following reason: generally, in the case where a heat exchanger and a blower are arranged side by side as illustrated in FIG. **2**, the volume of air in the vicinity of a central region of the heat exchanger is large and the volume of air on an outer side of the heat exchanger is small. By providing flat tubes **11** at the central region of the evaporator **10***c* and in the vicinity of the central region at a high density, the dehumidification efficiency at the central region and in the vicinity thereof is increased and it is therefore possible to increase the amount of dehumidification by the dehumidifying apparatus **100***d*.

[0131] It should be noted that the distribution of the volumes of air on the heat exchanger varies depending on the characteristics of the blower and the positional relationship between the heat exchanger and the blower. For example, contrary to the above example, in some cases, the volume of air on the outer side of the heat exchanger is large and the volume of air at the central region and in the vicinity thereof is small. In this case, in the evaporator **10***c*, flat tubes **11** on the outer side are arranged at a high density, and flat tubes **11** at the central region and in the vicinity thereof are arranged at a low density. Also, in cases other than the above case, it is preferable to change the density of the flat tubes **11** as appropriate depending on the distribution of the volumes of air on the heat exchanger.

[0132] The dehumidifying apparatus **100***d* as described above obtains the following advantages. Since the evaporator **10***c* is made to include a region in which flat tubes **11** are arranged at a low density, the weight of the evaporator **10***c* is decreased accordingly and the weight of the dehumidifying apparatus **100***d* is also decreased.

[0133] Furthermore, the ventilation resistance of the evaporator **10***c* is low, especially in a region in which flat tubes **11** are arranged at a low density. As a result, noise made in the dehumidifying apparatus **100***d* is reduced, thereby reducing the possibility that the user will feel annoyed.

[0134] The above description refers to an example of the configuration of the dehumidifying apparatus **100***d*, and the dehumidifying apparatus **100***d* can be variously modified without departing from the gist of the present disclosure.

[0135] For example, in Embodiment 5, the region A**2** in which flat tubes **11** are arranged at a high density, and the regions A**1** and A**3** in which flat tubes **11** are arranged at a low density, are provided. However, it is not indispensable that the region in which flat tubes **11** are arranged at a low density is provided. That is, it suffices that in part of the evaporator **10***c*, flat tubes **11** are arranged at a high density. It is allowable that in other parts of the evaporator **10***c*, flat tubes **11** are not provided. Even in such a configuration, dehumidification is performed intensively in the region in which flat tubes **11** are arranged at a high density, whereby the dehumidification performance of the dehumidifying apparatus **100***d* is maintained.

INDUSTRIAL APPLICABILITY

[0136] A dehumidifying apparatus of the present disclosure is applicable to dehumidification regardless of the dimensions of the room, the usage of the room, and other conditions.

1. A dehumidifying apparatus comprising:
a housing;
an air inlet provided in the housing;
an air outlet provided in the housing;
a blower provided in the housing; and
an evaporator provided on an air passage that connects the air inlet and the air outlet, and configured to cool and dehumidify air that is sent into the housing by the blower,
wherein the evaporator includes
a plurality of flat tubes having flow passages through which refrigerant flows and extending in an up-down direction,
a pair of headers connected to an upper end and a lower end of each of the flat tubes,
a first extension portion connected to a windward side of one of the flat tubes, and having long sides extending in the up-down direction along of the flat tube, and
a distance between any adjacent two of the flat tubes is less than or equal to 2.8 mm and greater than or equal to 2.0 mm.

2. The dehumidifying apparatus of claim **1**, further comprising a second extension portion connected to a leeward side of the flat tube, and extending in the up-down direction along the flat tube.

3. The dehumidifying apparatus of claim **2**, wherein a width of the first extension portion and a width of the second extension portion are smaller than a width of the flat tube.

4. The dehumidifying apparatus of claim **2**, wherein in a depth direction of the evaporator, the first extension portion is longer than the second extension portion.

5. The dehumidifying apparatus of claim **1**, wherein a diameter of the header connected to the lower end of the flat tube is smaller than a distance from a windward end of the first extension portion to a leeward end of the flat tube in a depth direction of the evaporator.

6. The dehumidifying apparatus of claim **2**, wherein a diameter of the header connected to the lower end of the flat tube is smaller than a distance from a windward end of the first extension portion to a leeward end of the second extension portion in a depth direction of the evaporator.

7. The dehumidifying apparatus of claim **1**, further comprising a condenser provided downstream of the evaporator on the air passage connecting the air inlet and the air outlet and configured to heat the air that is cooled and dehumidified by the evaporator,

wherein

the condenser includes

a refrigerant pipe through which the refrigerant flows, and

a heat-transfer accelerator connected to the refrigerant pipe and configured to accelerate heat exchange between a fluid passing through the condenser and a fluid flowing through the refrigerant pipe, and

a distance between an upper end of the header connected to the upper end of the flat tube and a lower end of the header connected to the lower end of the flat tube is less than or equal to a length of the heat-transfer accelerator of the condenser in the up-down direction.

8. The dehumidifying apparatus of claim **1**, further comprising:

a water storage tank provided below the evaporator; and

a water conduit configured to receive water that drops from the evaporator and guide the water to the water storage tank,

wherein at least part of the header connected to the lower end of the flat tube is provided inside the water conduit.

9. (canceled)

10. The dehumidifying apparatus of claim **1**,

wherein a distance between any adjacent two of the flat tubes is smaller than or equal to 2.2 mm,

the dehumidifying apparatus further comprising a condenser provided downstream of the evaporator on the air passage connecting the air inlet and the air outlet and configured to heat the air that is cooled and dehumidified by the evaporator,

wherein

the condenser includes

a refrigerant pipe through which the refrigerant flows, and

a heat-transfer accelerator connected to the refrigerant pipe and configured to accelerate heat exchange between a fluid passing through the condenser and a fluid flowing through the refrigerant pipe, and

a length of the evaporator in a depth direction is smaller than a length of the heat-transfer accelerator of the condenser in the depth direction.

11. The dehumidifying apparatus of claim **1**, wherein in the evaporator, a first region and a second region are provided in a lateral direction of the evaporator, the first region being a region in which a distance between any adjacent two of the flat tubes is small, the second region being a region in which a distance between any adjacent two of the flat tubes is greater than the distance between any adjacent two of the flat tubes in the first region.

12. (canceled)

13. A dehumidifying apparatus comprising:

a housing;

an air inlet provided in the housing;

an air outlet provided in the housing;

a blower provided in the housing; and

an evaporator provided on an air passage that connects the air inlet and the air outlet and configured to cool and dehumidify air that is sent into the housing by the blower,

wherein

the evaporator includes

a plurality of flat tubes having flow passages through which refrigerant flows and extending in an up-down direction, and

a pair of headers connected to an upper end and a lower end of each of the flat tubes, the evaporator has long sides extending in a direction crossing a direction in which the flat tubes extend,

the evaporator is not provided with a heat-transfer accelerator configured to accelerate heat exchange between a fluid passing through between the flat tubes and a fluid flowing through the flat tubes,

a distance between any adjacent two of the flat tubes is less than or equal to 2.8 mm and greater than or equal to 2.0 mm.

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