US 20040134641A1

(19) United States

(12) Patent Application Publication (10) Pub. No.: US 2004/0134641 A1

Tanaka (43) Pub. Date: Jul. 15, 2004

(54) COOLING DEVICE BOILING AND CONDENSING REFRIGERANT

(76) Inventor: Hiroshi Tanaka, Toyoake-city (JP)

Correspondence Address:
HARNESS, DICKEY & PIERCE, P.L.C.
P.O. BOX 828
BLOOMFIELD HILLS, MI 48303 (US)

(21) Appl. No.: 10/744,642

(22) Filed: Dec. 22, 2003

(30) Foreign Application Priority Data

Dec. 26, 2002 (JP) 2002-377657

Publication Classification

(51) Int. Cl.[7] F28D 15/00

(52) U.S. Cl. 165/104.19; 165/104.33

(57) ABSTRACT

A cooling device includes a first refrigerant container having a side wall to which a heat-generating member is attached, a second refrigerant container, and plural tubes communicated with both of the containers. The first refrigerant container has therein a flow control unit for controlling a refrigerant flow in the first refrigerant container. The flow control unit is provided such that refrigerant introduced from the second refrigerant container into the first refrigerant container flows along an inner surface of the side wall of the first refrigerant container at least from a height position corresponding to a top end of the heat-generating member. Therefore, a height level of liquid refrigerant stored in the first refrigerant container can be decreased while heat radiation area can be widened. Thus, cooling performance is improved in the cooling device used in a side-heat condition.

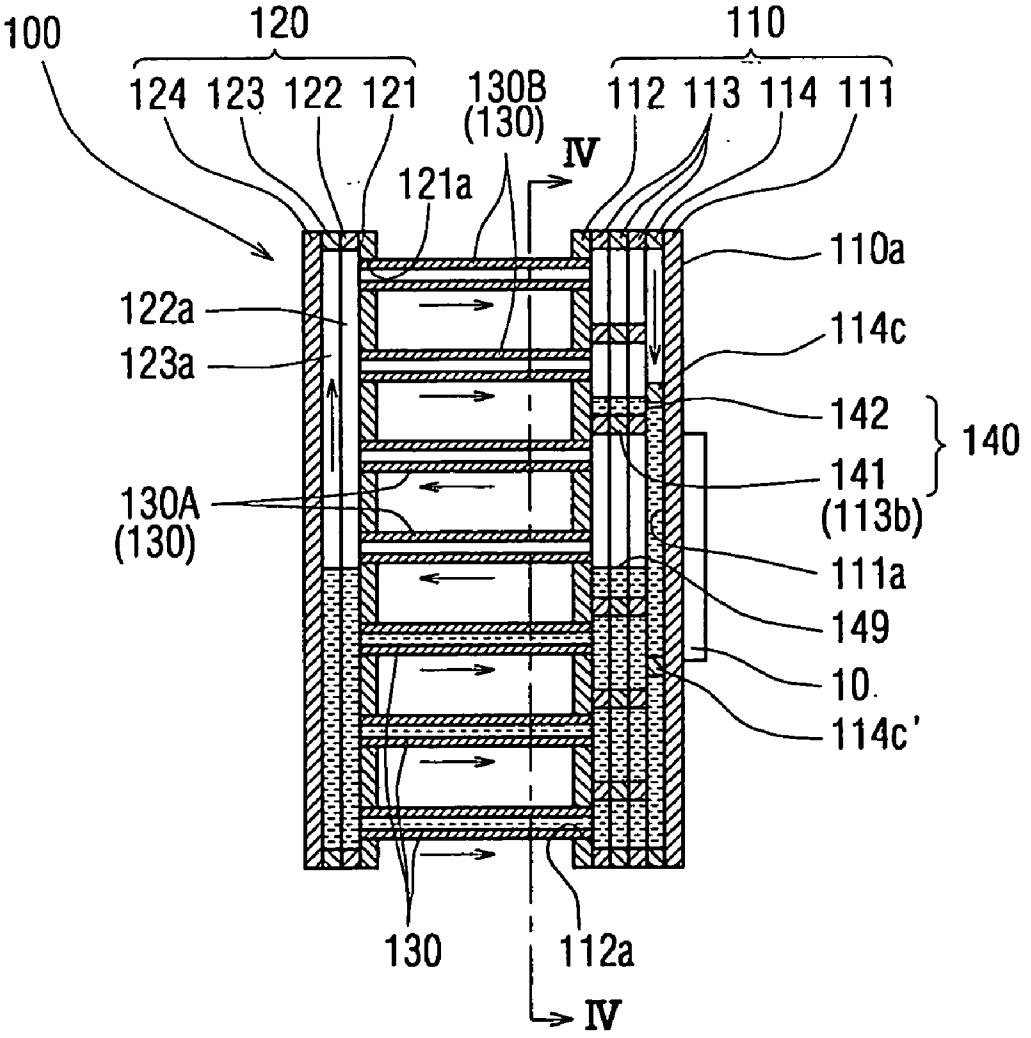


FIG. 1

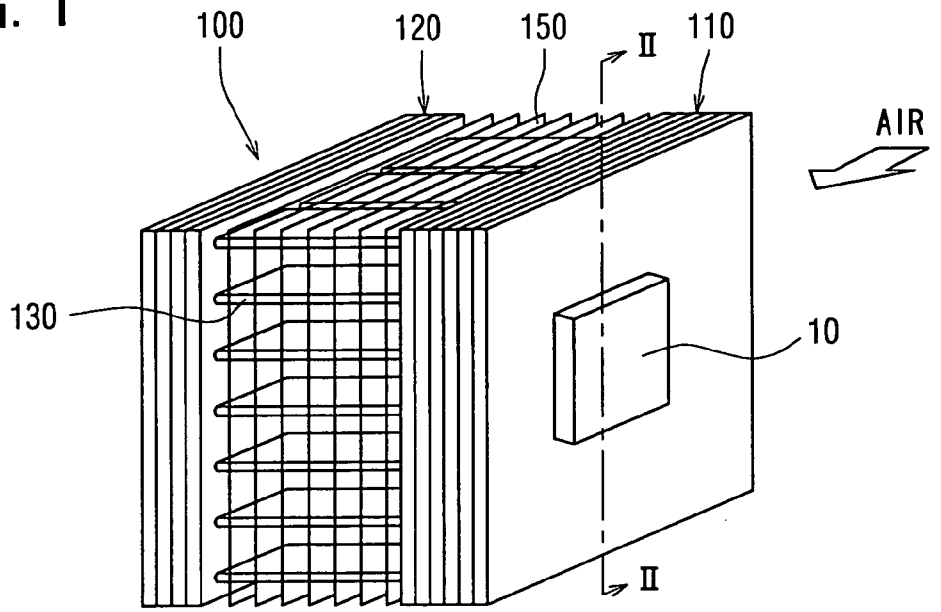

100
120
150
II
110
AIR
130
10
II

FIG. 2

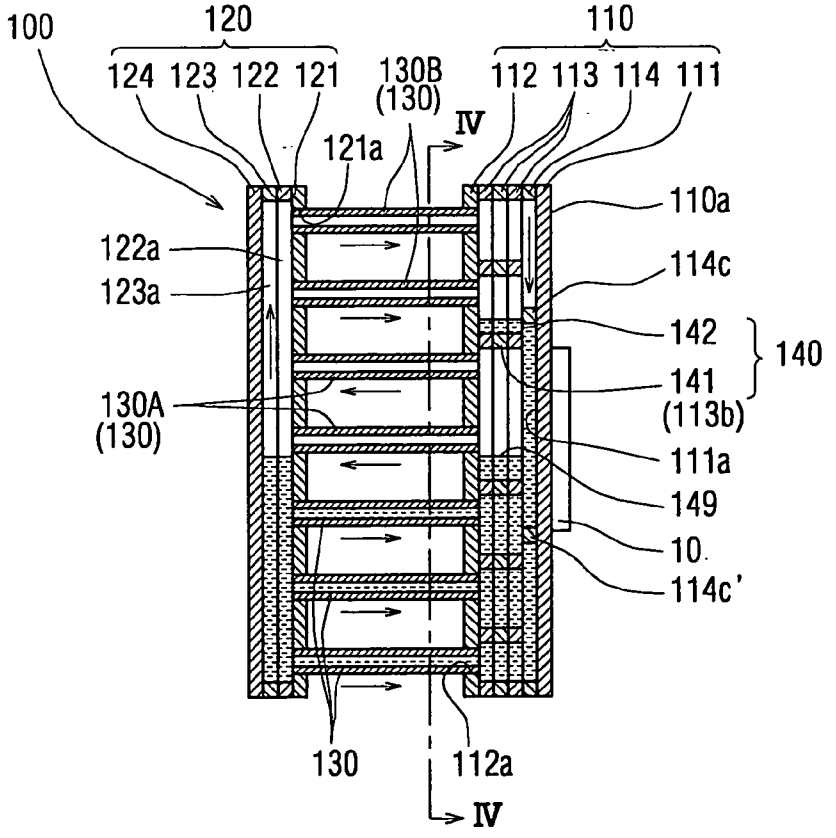

100
120
110
124 123 122 121
130B
(130)
112 113 114 111
IV
121a
110a
122a
114c
123a
142
140
141
(113b)
130A
(130)
111a
149
10
114c'
130
112a
IV

FIG. 3A

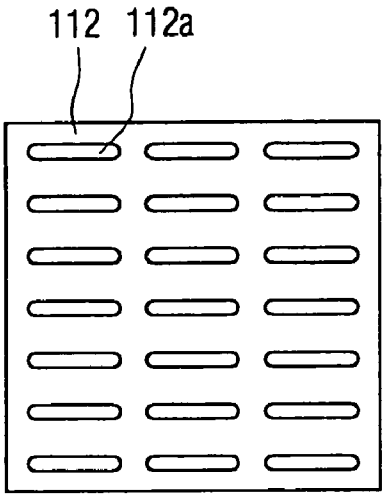


FIG. 3B

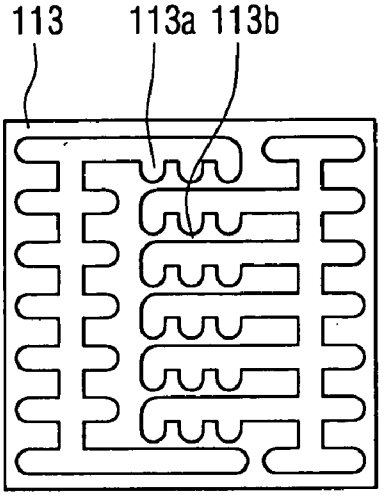


FIG. 3C

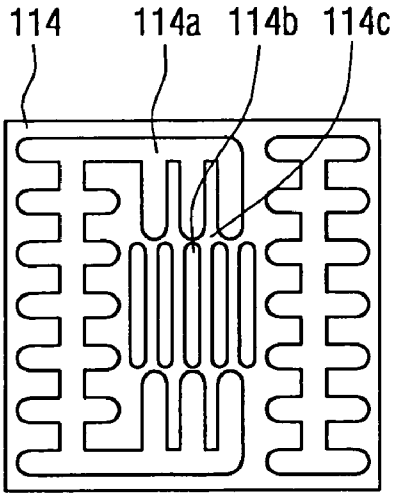


FIG. 3D

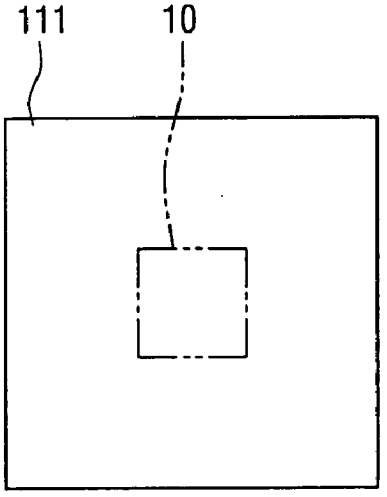


FIG. 4

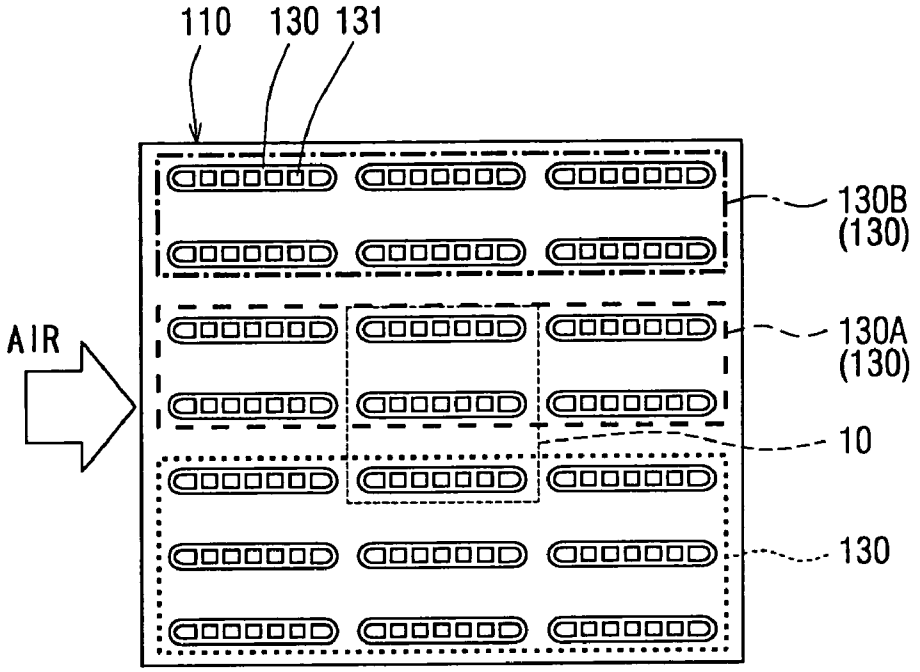

110
130
131
130B
(130)
AIR
130A
(130)
10
130

FIG. 5

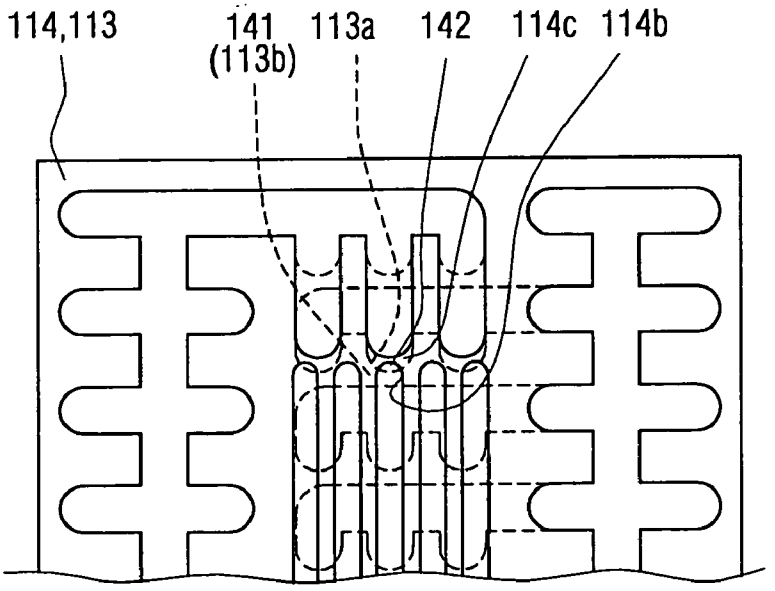

114,113
141
(113b)
113a
142
114c
114b

FIG. 6

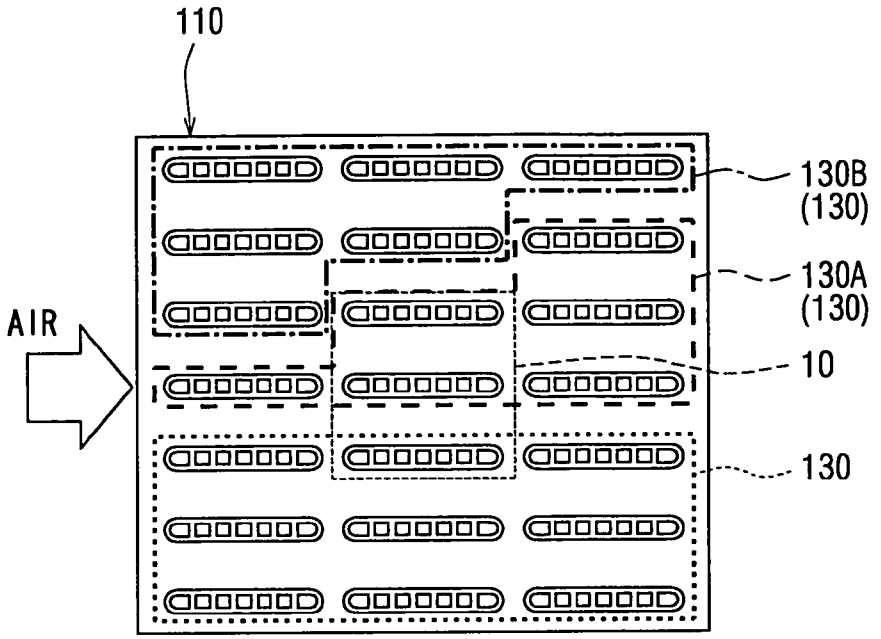

110
130B
(130)
130A
(130)
AIR
10
130

FIG. 7

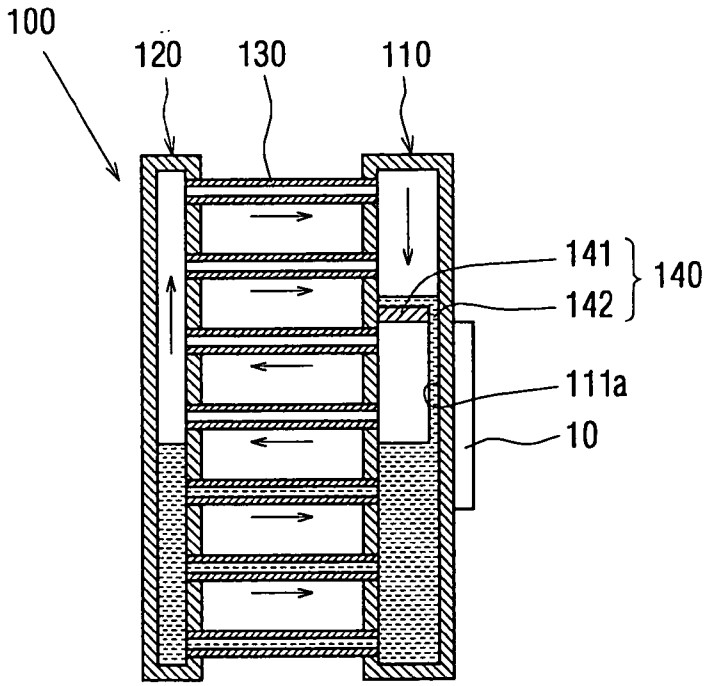

100
120
130
110
141
142
140
111a
10

FIG. 8A

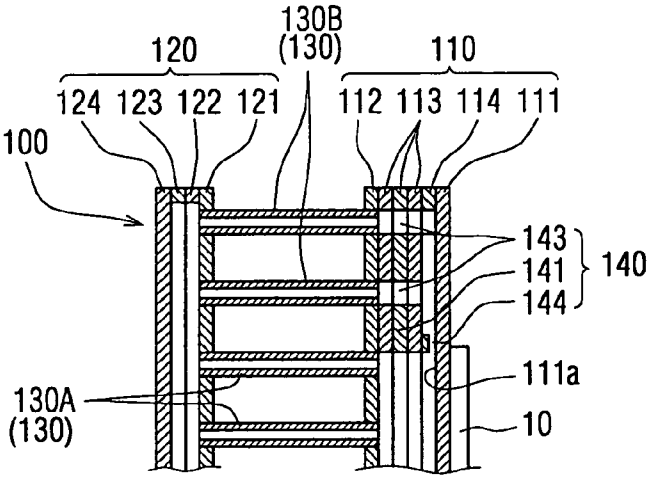


FIG. 8B

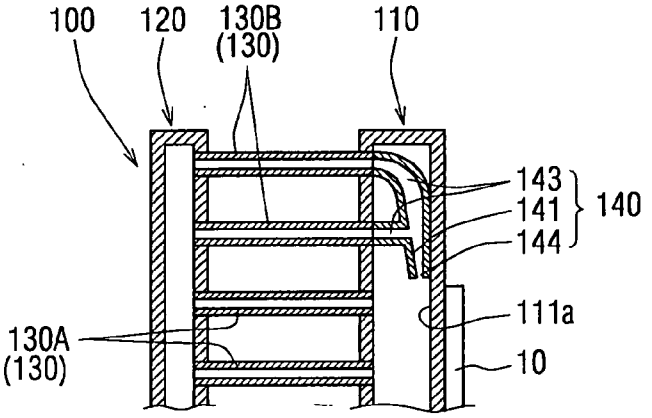


FIG. 9

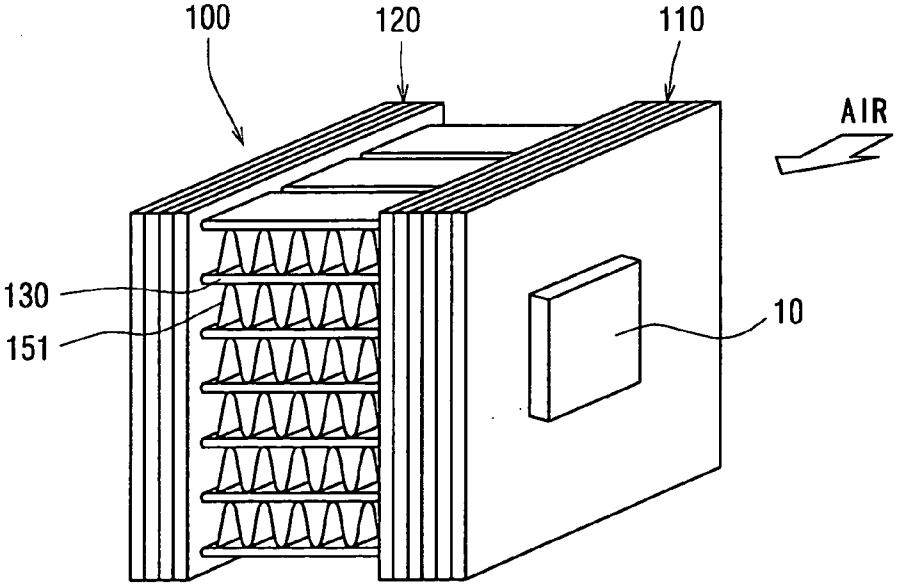


FIG. 10
RELATED ART

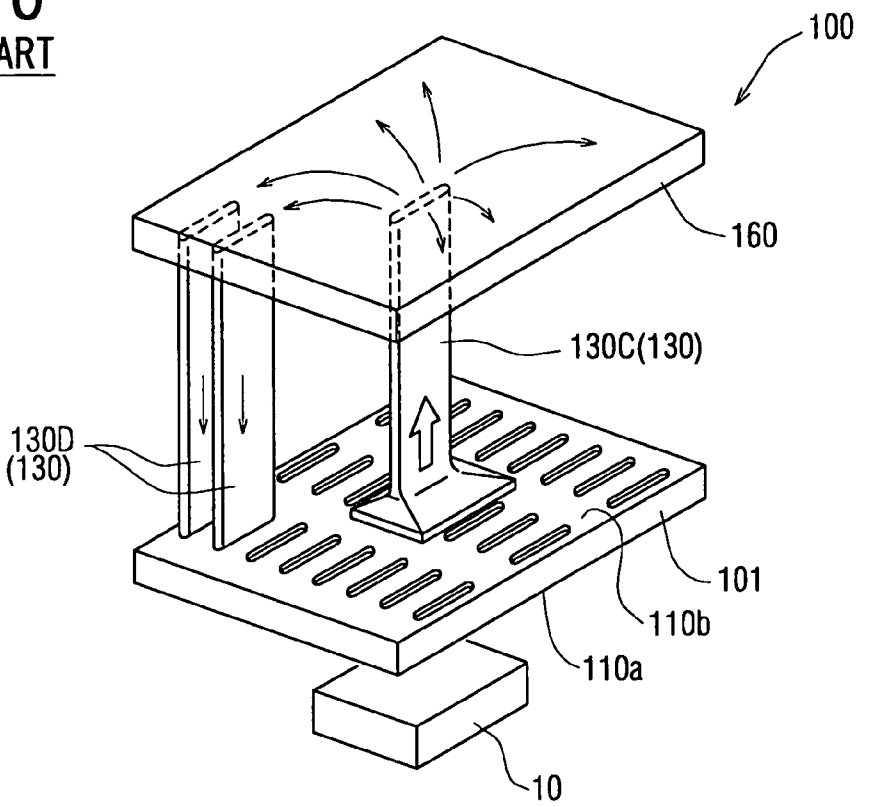
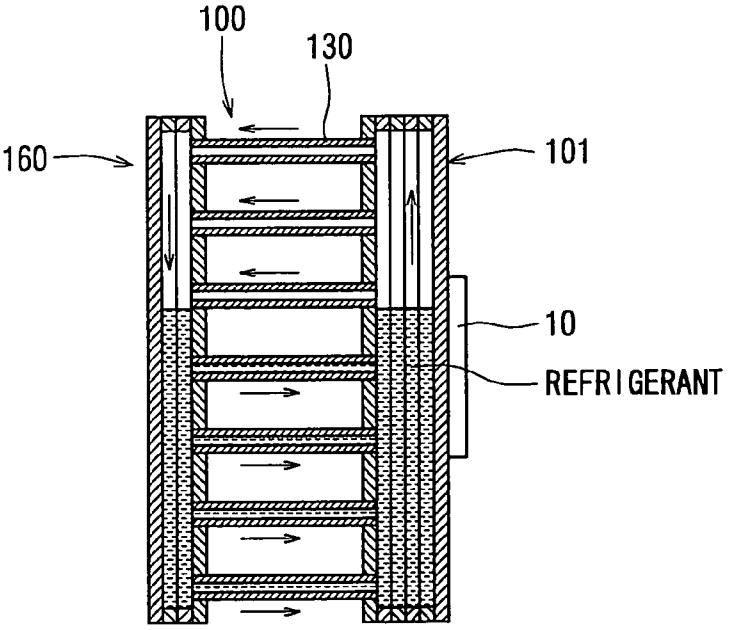


FIG. 11
RELATED ART



COOLING DEVICE BOILING AND CONDENSING REFRIGERANT

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application is based on Japanese Patent Application No. 2002-377657 filed on Dec. 26, 2002, the disclosure of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention is related to a cooling device for cooling a heat-generating member such as a semiconductor or the like, by movement of latent heat due to boiling and condensation of the refrigerant.

[0004] 2. Description of Related Art

[0005] JP-A-2003-130561 proposes a cooling device **100** that is constructed with a refrigerant container **101** for storing refrigerant, plural tubes **130** and a header tank **160**, as shown in **FIG. 10**. A heat-generating member **10** is attached to a heat reception surface **110***a* placed under the refrigerant container **101**.

[0006] The tubes **130** are substantially vertically arranged with respect to a heat radiation surface **110***b* of the refrigerant container **101**, so that the refrigerant container **101** and the header tank **101** are communicated with each other. A boiling area is defined in a place where the surface area of the heat-generating member **10** is projected to the heat radiation surface **110***b*. Tubes **130** (i.e., tubes **130**C) arranged in the boiling area and the tubes **130** (i.e., tubes **130**D) arranged away from the boiling area respectively have refrigerant passages. The refrigerant passage area of each tube **130**C is set larger than the refrigerant passage area of each tube **130**D, at the lower end opening connected to the refrigerant container **101**.

[0007] Refrigerant is boiled and evaporated by the heat received from the heat-generating member **10**, and is preferentially introduced into the tubes **130**C comparing with the tubes **130**D. As a result, refrigerant from the tubes **130**C is introduced into the header tank **160**, and is diffused in the header tank **160**. The refrigerant introduced into the tubes **130**D is cooled so as to be condensed, and the condensed refrigerant is returned to the refrigerant container **101**.

[0008] Recently, heat radiation amount of such the heat-generating member **10** tends to be increased, so cooling performance of the cooling device **100** strongly needs to be improved. Furthermore, as shown in **FIG. 11**, the cooling device **100** is apt to be used in a side-heat condition for improving packing density of the heat-generating member **10**. The heat-generating member **10** is positioned in the side surface of the refrigerant container **101** in the side-heat condition. Generally, the heat-generating member **10** is mounted in the substantially center of the refrigerant container **101** for convenience of various wiring. Therefore, the refrigerant needs to be filled in the refrigerant container **101** up to the vicinity of the top end of the heat-generating member **10**, in this side-heat condition. As a result, a heat radiation section, where the evaporated refrigerant is condensed, is narrowed. That is, because the number of the tubes **130**, where the evaporated refrigerant passes, is decreased, sufficient cooling performance cannot be obtained.

SUMMARY OF THE INVENTION

[0009] In view of the foregoing problems, it is an object of the present invention to provide a cooling device that improves cooling performance by widening heat radiation section. The heat radiation section can be effectively widened by lowering a liquid refrigerant level stored in the cooling device when the cooling device is used in the side-heat condition.

[0010] According to the present invention, a cooling device for cooling a heat-generating member includes a first refrigerant container having a side wall to which the heat-generating member is attached, a second refrigerant container that is disposed on an opposite side of the heat-generating member with respect to the first refrigerant container, a plurality of tubes through which refrigerant evaporated in the first refrigerant container by heat from the heat-generating member flows into the second refrigerant container and refrigerant in the second refrigerant container returns to the first refrigerant container while being cooled and condensed, and a refrigerant flow control unit provided in the first refrigerant container for controlling a refrigerant flow. In the cooling device, the refrigerant flow control unit is provided in such a manner that the refrigerant introduced into the first refrigerant container from the second refrigerant container flows along an inner wall surface of the side wall of the first refrigerant container at least from a position corresponding to a top end of the heat-generating member. Thus, the liquid refrigerant flowing on the inner wall surface of the side wall of the first refrigerant container can be directly boiled and evaporated by the heat of the heat-generating member in the first refrigerant container. Accordingly, the height level of the liquid refrigerant stored in the first refrigerant container can be set lower, and heat radiation area of the tubes can be relatively increased. Therefore, the first refrigerant container can be effectively downsized. As a result, cooling performance of the cooling device can be improved in the side-heat condition.

[0011] Preferably, the refrigerant flow control unit includes a partition section that is placed in the vicinity of the top end of the heat-generating member so as to partition the inner section of the first refrigerant container into an upper section and a lower section, and a passage section that is provided adjacent to the partition section for communicating the upper section and the lower section on a side of the inner wall surface of the side wall. Therefore, the refrigerant flow control unit can be readily constructed in the first refrigerant container.

[0012] More preferably, the passage section has an opening area that is smaller than a total passage sectional area of the tubes in which refrigerant flows from the first refrigerant container toward the second refrigerant container. Therefore, a refrigerant circulation in the cooling device can be facilitated, and the cooling capacity of the cooling device can be further improved.

[0013] The tubes are horizontally arranged in addition to the vertically stacked arrangement, to which an external fluid is generally horizontally supplied. In this case, the tubes, through which the refrigerant passes from the first

refrigerant container to the second refrigerant container, have a refrigerant flow area that increases in a flow direction of the external fluid from an upstream position toward a downstream position. Further, the tubes, through which the refrigerant passes from the second refrigerant container to the first refrigerant container; have a refrigerant flow area that increases in a flow direction of the external fluid from the downstream position toward the upstream position. Accordingly, the refrigerant circulation in the cooling device can be further facilitated.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] The above and other objects, features and advantages of the present invention will become more apparent from the following detailed description made with reference to the accompanying drawings. In the drawings:

[0015] **FIG. 1** is a schematic perspective view showing a cooling device according to a first embodiment of the present invention;

[0016] **FIG. 2** is a cross-sectional view of the cooling device taken along line II-II in **FIG. 1**;

[0017] **FIG. 3A** is a schematic plan view showing a heat radiation plate for constructing a first refrigerant container of the cooling device, **FIGS. 3B and 3C** are schematic plan views showing intermediate plates for constructing the first refrigerant container of the cooling device, and **FIG. 3D** is a schematic plan view showing a heat reception plate for constructing the first refrigerant container of the cooling device, according to the first embodiment;

[0018] **FIG. 4** is a cross-sectional view of the cooling device taken along line IV-IV in **FIG. 2**;

[0019] **FIG. 5** is a partial plan view showing stacked intermediate plates according to the first embodiment;

[0020] **FIG. 6** is a cross-sectional view showing tubes of a cooling device according to a second embodiment of the present invention;

[0021] **FIG. 7** is a cross-sectional view showing a cooling device according to a third embodiment of the present invention;

[0022] **FIGS. 8A and 8B** are schematic sectional views showing cooling devices according to a fourth embodiment of the present invention;

[0023] **FIG. 9** is a schematic perspective view showing a cooling device according to a fifth embodiment of the present invention;

[0024] **FIG. 10** is a perspective view showing a cooling device according to a related art; and

[0025] **FIG. 11** is a schematic sectional view showing a cooling device in a side-heat condition in a related art.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

First Embodiment

[0026] The first embodiment of the present invention will be now described with reference to FIGS. **1-5**. As shown in **FIG. 1, a** cooling device **100** according to the first embodiment is constructed with a first refrigerant container **110**, a second refrigerant container **120**, plural tubes **130** and heat radiation fins **150**. The cooling device **100** is used for cooling a heat-generating member **10** such as a semiconductor device or the like. Members of the cooling device **100** described as follows are made of aluminum or an aluminum alloy. The members of the cooling device **100** are joined with each other, and are integrally brazed by using brazing material at joining sections between the members.

[0027] The first refrigerant container **110** is constructed with a heat reception plate **111**, a heat radiation plate **112** and plural intermediate plates **113**, **114**. The heat reception plate **111** is used as a sidewall of the cooling device **100**. The intermediate plates **113**, **114** are stacked between the heat reception plate **111** and the heat radiation plate **112**. The heat radiation plate **112** is arranged on the opposite side of the heat reception plate **111** with respect to the intermediate plates **113**, **114**. The whole structure of the first refrigerant container is integrally brazed.

[0028] As shown in **FIG. 3**D, the heat reception plate **111** is a substantially square plate-shaped member. The heat-generating member **10** is attached onto the heat reception plate **111**. As shown in **FIG. 3A** the heat radiation plate **112** is a substantially square plate-shaped member as well as the heat reception plate **111** as described above. Plural tube insertion holes **112***a* are formed in the heat radiation plate **112**, so that one side ends of the tubes **130** are respectively inserted into the tube insertion holes **112***a*.

[0029] As shown in **FIG. 3**B, each intermediate plate **113** is a substantially square plate-shaped member. The intermediate plate **113** has plural openings **113***a* extending vertically and horizontally. Thick wall sections **113***b* are formed between adjacent openings **113***a*. For example, three intermediate plates **113** are used in the cooling device **100** of the first embodiment. As shown in **FIG. 3**C, the intermediate plate **114** has openings **114***a*, similarly to the intermediate plate **113** as described above. Each intermediate plate **114** has slit-shaped plural openings **114***b* that vertically extends in a place corresponding to the heat-generating area of the heat-generating member **10**. Thick wall sections **114***c* are formed between the openings **114***a* and the openings **114***b*. The openings **113***a*, **114***a* and **114***b* of the intermediate plates **113**, **114** are formed by cutting, pressing, etching or the like.

[0030] As shown in **FIG. 2**, the intermediate plates **113** and **114** are stacked and inserted between the heat reception plate **111** and the heat radiation plate **112**, so that the first refrigerant container **110** is constructed. The openings **113***a*, **114***a* and **114***b* are overlapped with each other so as to communicate each other, so that inner sections are formed in the first refrigerant container **110**. Predetermined amount of refrigerant is sealed in the inner sections of the first refrigerant container **110**. Freon (HFC134a) is used as the refrigerant in this invention. However, other fluid such as water, alcohol, fluorocarbon can be used as the refrigerant.

[0031] The openings **113***a*, **114***a*, **114***b* and the thick wall sections **113***b*, **114***c* are suitably combined, so that a refrigerant flow control unit **140** is formed in the first refrigerant container **110**. The refrigerant flow control unit **140** is a characterizing portion in this invention.

[0032] The heat reception plate **111** of the first refrigerant container **110** has a heat reception surface **110***a* on its outer side. The heat-generating member **10** is attached to the

central section of the heat reception surface **110***a* and is fixed using bolts or the like (not shown). Thermal conductive grease can be inserted between the heat reception surface **110**a and the heat-generating member **10** for reducing thermal resistance on the contact surfaces. The heat-generating member **10** is mounted on the heat reception plate (side wall) **111** of the first refrigerant container **110**, so that the cooling device **100** is used in a side-heat condition.

[**0033**] Plural plates **121**-**124** are stacked, so that the second refrigerant container **120** is constructed similarly to the first refrigerant container **110** as described above. The second refrigerant container **120** is arranged on the opposite side of the heat-generating member **10** with respect to the first refrigerant container **110**. Intermediate plates **122**, **123** are inserted in the second refrigerant container **120**. The intermediate plate **122** has an opening **122***a*, and the intermediate plate **123** has an opening **123***a* respectively. The opening **122***a* and the opening **123***a* are overlapped with each other, so that an inner section is formed in the second refrigerant container **120**. Besides, tube insertion holes **121***a* are formed in the plate **121**.

[**0034**] As shown in **FIG. 4**, each tube **130** has a flat cross-sectional shape, and plural flow passages **131** are formed in each tube **130**. The plural tubes **130** are arranged in the vertical direction (e.g., seven levels in this embodiment), and are arranged in the horizontal direction (e.g., three rows in this embodiment). The tubes **130** are formed by extrusion.

[**0035**] The tubes **130** are inserted into the tube insertion holes **112***a* of the heat radiation plate **112** at one ends, and brazed. The tubes **130** are inserted into the tube insertion holes **121***a* of the plate **121** at the other ends, and brazed. Thus, the tubes **130** communicate with the inner section (inner space) of the first refrigerant container **110** and the inner section (inner space) of the second refrigerant container **120**.

[**0036**] The ends of the tubes **130** are positioned so as not to protrude to the inner spaces of both of the refrigerant containers **110**, **120**. Thus, both of the refrigerant containers **110**, **120** are downsized, and refrigerant flow is not disturbed around the ends of the tubes **130** in the refrigerant containers **110**, **120**.

[**0037**] Plural heat radiation fins **150** are provided to be connected to the tubes **130**. The tubes **130** penetrate through the heat radiation fins **150**, so that the heat radiation fins **150** are attached to the tubes **130**. The heat radiation fins **150** are generally classified in a plate fin type.

[**0038**] Cooling air is supplied so as to pass through the tubes **130** and the heat radiation fins **150** using a blower or the like (not shown), when the cooling device **100** is activated. The cooling air is substantially horizontally (specifically, in the arrangement direction of the tubes **130**) supplied as an external fluid for enhancing heat exchange.

[**0039**] Next, the characterizing portion will be described. The refrigerant flow control unit **140** is provided in the first refrigerant container **110**. The intermediate plates **113**, **114** are constructed to form a partition section **141** and a gap section (passage section) **142**, so that the refrigerant flow control unit **140** is constructed.

[**0040**] The thick wall sections **113***b* of the intermediate plates **113** have stacking portions corresponding to the vicinity of the upper end section of the heat radiation member **10**. The stacking portions of the thick wall sections **113***b* are stacked so that the partition section **141** extending horizontally are formed. As shown in **FIG. 5**, the openings **113***a* of the intermediate plates **113** and the openings **114** of the intermediate plate **114** respectively have communication portions corresponding to the vicinity of the upper end section of the heat radiation member **10**. The communication portions of the openings **113***a*, **114***b* are slightly overlapped, so that the gap section **142** is formed.

[**0041**] The thick wall section **114***c* in the vicinity of the gap section **142** and the partition section **141** partition the inner section of the first refrigerant container **110** into the upper section and the lower section approximately at the vicinity of the upper end of the heat-generating member **10**. The upper section and the lower section of the first refrigerant container **110** are communicated with each other through the gap section **142** on a side of an inner wall surface **111***a* of the heat reception plate **111**.

[**0042**] Here, the tubes **130** positioned between a liquid surface **149** of the liquid refrigerant and the bottom surface of the partition section **141** are defined as tubes **130**A. Refrigerant is boiled and evaporated in the first refrigerant container **110** by the heat of the heat-generating member **10** as described below. The evaporated gas refrigerant passes through the tubes **130**A. Furthermore, the opening area of the gap section **142** is set smaller than the total opening area of the flow passages **131** of the tubes **130**A opened in the first refrigerant container **110**.

[**0043**] The refrigerant is boiled and evaporated by the heat of the heat-generating member **10** in the cooling device **100**. Most flow of the evaporated gas refrigerant is restricted by the partition section **141**, so that the evaporated refrigerant is introduced to the second refrigerant container **120** through the tubes **130**A. Subsequently, the refrigerant introduced into the second refrigerant container **120** flows into the tubes **130** (i.e., tubes **130**B) placed over the tubes **130**A, and returns to the first refrigerant container **110**. The evaporated refrigerant is cooled and condensed by the cooling air while passing through the tubes **130**A, **130**B, and is introduced into the upper section of the first refrigerant container **110**. Heat of the evaporated refrigerant is radiated as condensation latent heat to the cooling air, so that the heat-generating member **10** is cooled. The radiation of the condensation latent heat is enhanced by the heat radiation fins **150**. The refrigerant is cooled and condensed while passing through the tubes **130**A, and accumulated in the lower area of the second refrigerant container **120**.

[**0044**] Gas refrigerant in the second refrigerant container **120** is further condensed while passing through the tubes **130**B, and introduced into the upper section of the first refrigerant container **110**. The condensed refrigerant flows down through the gap **142** while forming thin liquid film along the inner wall surface **111***a*.

[**0045**] Because the refrigerant flow control unit **140** is provided in the first refrigerant container **110**, condensed liquid refrigerant is supplied in an arrangement area of the inner wall surface **111***a* corresponding to the heat-generating area of the heat-generating member **10** in the first refrigerant container **110**. Thus, the liquid refrigerant flowing along the inner wall surface **111***a* can be readily boiled and evaporated by the heat directly transmitted from the heat-generating

member **10**. Thus, refrigerant liquid level **149** contained in the first refrigerant container **110** can be set lower. Accordingly, heat radiation area of the tubes **130** can be enlarged due to the decreased refrigerant liquid level, and cooling performance can be enhanced in the cooling device **100** used in the side-heat condition.

[**0046**] Furthermore, the refrigerant flow control unit **140** is constructed with the partition section **141** and the gap section **142**. Therefore, the refrigerant flow control unit **140** can be formed easily.

[**0047**] The opening area of the gap section **142** is set smaller than the total opening area of the tubes **130**A opened into the first refrigerant container **110**, so that the evaporated refrigerant can readily flow into the tubes **130**A. Therefore, the refrigerant flowing into the tubes **130**A is readily recycled toward the gap section **142** through the second refrigerant container **120**. The recycle is enhanced and the cooling performance is improved, because the liquid refrigerant flow is restricted at the gap section **142**.

[**0048**] The plural plates **111-114**, **121-124** are stacked, so that the refrigerant containers **110**, **120** are constructed. Therefore, the refrigerant containers **110**, **120** can be manufactured easily. Especially, the refrigerant flow control unit **140** can be easily formed using the stack structure.

Second Embodiment

[**0049**] As shown in **FIG. 6**, in this second embodiment, the total flow areas of the tubes **130**A and the tubes **130**B are respectively varied with respect to the flow direction of the cooling air, comparing with the first embodiment. That is, the refrigerant flow control unit **140** is set at a middle height portion of the heat-generating member **10** in the vertical direction, at an upstream position of the cooling air in the cooling device **100**. The refrigerant flow control unit **140** is set at a position upper than the top end of the heat-generating member **10**, at a downstream position of the cooling air in the cooling device **100**. Therefore, the number of the tubes **130**A is increased from the upstream position of the cooling air toward the downstream position of the cooling air. That is, total flow area of the tubes **130**A increases downstream with respect to the cooling air flow direction. On the other hand, the total flow area of the tubes **130**B is increased from the downstream position of the cooling air toward the upstream position of the cooling air.

[**0050**] Temperature of the cooling air is increased in the cooling device **100** toward its downstream position while performing heat-exchange with the refrigerant. Here, the total flow area of the tubes **130**A is reduced in the cooling device in the upstream position of the cooling air comparing with the downstream position of the cooling air. Therefore, the heated evaporated refrigerant readily flows from the first refrigerant container **110** toward the second refrigerant container **120** through the tubes **130**A. Accordingly, the evaporated refrigerant does not stay in the upstream position of the cooling air in the cooling device **100**. Therefore, condensation of the evaporated refrigerant is restricted in the tubes **130**A, so that flow does not become stagnant in the tubes **130**A. On the contrary, the evaporated refrigerant in the tubes **130**B is largely condensed by the cooling air at the upstream air side. Therefore, the refrigerant flow from the second refrigerant container **120** toward the first refrigerant container **110** can be facilitated. Thus, the recycle of the refrigerant between the first refrigerant container **110** and the second refrigerant container **120** is enhanced, so that cooling performance can be improved. In the second embodiment, the other parts are similar to those of the above-described first embodiment.

Third Embodiment

[**0051**] The third embodiment of the present invention will be now described with reference to **FIG. 7**.

[**0052**] The refrigerant containers **110**, **120** are not limited to the stacked structure formed with plural plates, and can be formed with flat containers. In the third embodiment, as shown in **FIG. 7**, the partition section **141** is formed in the first container **110** to form a gap section **142** on the side of the inner wall surface **111***a*, so that the refrigerant flow control unit **140** can be constructed. That is, in the third embodiment, the partition section is formed in the first refrigerant container **110** to form the gap section **142**, so that condensed liquid refrigerant from the gap section **142** flows along the inner surface **111***a* at least from the top position of the heat generating member **10**.

Fourth Embodiment

[**0053**] The fourth embodiment of the present invention will be now described with reference to **FIGS. 8A and 8B**.

[**0054**] As shown in **FIG. 8A, a** first refrigerant container **110** of the fourth embodiment is constructed with plural plates **111-114**. The second refrigerant container **120** is constructed with the plural plates **121-124**. Intermediate plates **113**, **114** respectively have the plural openings **113***a*, **114***a*, and intermediate plates **122**, **123** respectively have the plural openings **122***a*, **123***a* in the same manner as the first embodiment. The refrigerant flow control unit, **140** is constructed with a communication passage **143** and an opening section (passage section) **144**. Refrigerant is introduced from the tubes **130**B toward the arrangement area of the inner wall surfaces **111***a* through the opening section **144** and the communication passages **143**. The opening section **144** is provided, so that the flow of the condensed liquid refrigerant is regulated. The arrangement area of the inner wall surfaces **111***a* corresponds to the heat radiation area of the heat-generating member **10**. The flow area of the opening section **144** can be set smaller than the total opening area of the tubes **130**A opened in the first header tank **110**.

[**0055**] **FIG. 8B** shows refrigerant containers **110**, **120** constructed with flat containers. The refrigerant flow control unit **140** is formed with a tube-shaped member. The tube-shaped member has a communication passage **143** communicated with the tubes **130**B, and an opening section **144**. The opening section **144** is substantially vertically opened, so that the condensed liquid refrigerant flows along the inner wall surface **111***a* downwardly at least from the top end portion of the heat-generating member **10**.

[**0056**] Accordingly, in the fourth embodiment, advantages described in the first embodiment can be obtained.

Fifth Embodiment

[**0057**] The heat radiation fins **150** are not limited to the plate fin type. As shown in **FIG. 9**, corrugated fins **151** or the like can be used for increasing heat radiation, for example. The corrugated fins **151** are formed in a wave-shape, and

provided (integrally brazed) between the tubes **130**. Other structures of the refrigerant containers **110**, **120** are substantially equivalent to the first embodiment. Accordingly, in the fourth embodiment, advantages described in the first embodiment can be obtained.

Other Embodiments

[**0058**] Although the present invention has been fully described in connection with the preferred embodiments thereof with reference to the accompanying drawings, it is to be noted that various changes and modifications will become apparent to those skilled in the art.

[**0059**] For Example, the number of each intermediate plate **114**, **122**, **123** is not limited to one, and the number of the intermediate plates **113** are not limited to three for the refrigerant containers **110**, **120**. Combinations of the intermediate plates **113**, **114**, **122**, **123** can be performed freely.

[**0060**] The cooling device described in the above-embodiments can be used in a bottom heat condition. In this case, the tubes **130** are arranged in the vertical direction, and the first refrigerant container **110** is placed below the tubes **130** in the bottom heat condition. Further, the heat-generating member **10** is placed below the first refrigerant container **110**.

[**0061**] Such changes and modifications are to be understood as being within the scope of the present invention as defined by the appended claims.

What is claimed is:

1. A cooling device for cooling a heat-generating member, comprising:

a first refrigerant container for storing therein at least liquid refrigerant, the first refrigerant container having a side wall to which the heat-generating member is attached;

a second refrigerant container that is disposed on an opposite side of the heat-generating member with respect to the first refrigerant container;

a plurality of tubes through which refrigerant evaporated in the first refrigerant container by heat from the heat-generating member flows into the second refrigerant container and refrigerant in the second refrigerant container returns to the first refrigerant container while being cooled and condensed, wherein the tubes are stacked substantially in a vertical direction and connected to the first refrigerant container and the second refrigerant container to be communicated with both of the first refrigerant container and the second refrigerant container; and

a refrigerant flow control unit provided in the first refrigerant container in such a manner that the refrigerant introduced into the first refrigerant container from the second refrigerant container flows along an inner wall surface of the side wall of the first refrigerant container at least from a position corresponding to a top end of the heat-generating member.

2. The cooling device according to claim 1, wherein the refrigerant flow control unit including:

a partition section that is placed in the vicinity of the top end of the heat-generating member so as to partition the inner section of the first refrigerant container into an upper section and a lower section; and

a passage section that is provided adjacent to the partition section, for communicating the upper section and the lower section on a side of the inner wall surface.

3. The cooling device according to claim 2, wherein the passage section has an opening area which is smaller than a total passage sectional area of the tubes in which refrigerant flows from the first refrigerant container toward the second refrigerant container.

4. The cooling device according to claim 1, wherein

the tubes are horizontally arranged in addition to the vertically stacked arrangement, to which an external fluid is generally horizontally supplied, wherein

the tubes, through which the refrigerant passes from the first refrigerant container to the second refrigerant container, have a refrigerant flow area that increases in a flow direction of the external fluid from an upstream position toward a downstream position, and

the tubes, through which the refrigerant passes from the second refrigerant container to the first refrigerant container, have a refrigerant flow area that increases in a flow direction of the external fluid from the downstream position toward the upstream position.

5. The cooling device according to claim 1, wherein

the first refrigerant container and the refrigerant flow control unit are constructed with a plurality of plates stacked with each other in a stacked direction,

the second refrigerant container is constructed with a plurality of plates stacked with each other in the stacked direction, and

at least one plate arranged in an intermediate section in the stacked direction has a plurality of openings.

6. The cooling device according to claim 1, wherein at least one of the first refrigerant container and the second refrigerant container is a flat container.

7. The cooling device according to claim 1, further comprising a plurality of fins disposed between the first and second container to contact the tubes.

* * * * *