



(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
19.02.2014 Bulletin 2014/08

(51) Int Cl.:
F28F 13/02 (2006.01) F28D 15/02 (2006.01)

(21) Application number: **12770839.4**

(86) International application number:
PCT/JP2012/060197

(22) Date of filing: **10.04.2012**

(87) International publication number:
WO 2012/141320 (18.10.2012 Gazette 2012/42)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

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(30) Priority: **13.04.2011 JP 2011089347**

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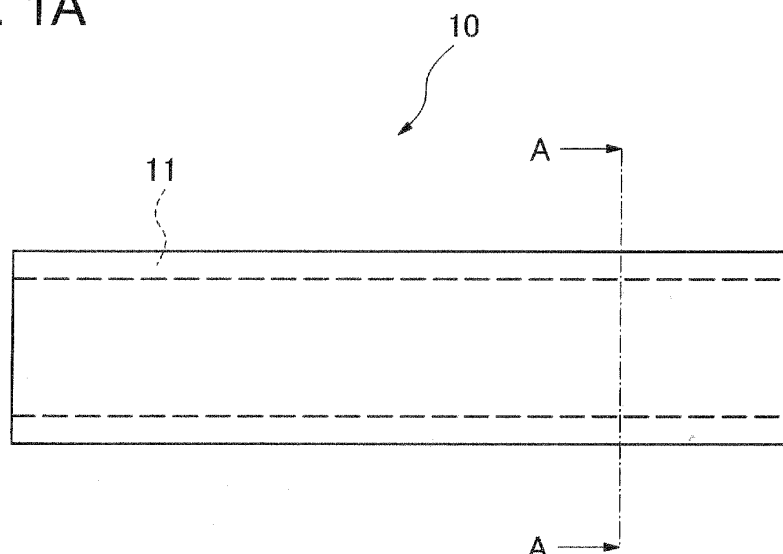
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(54) **PIPING STRUCTURE OF COOLING DEVICE, MANUFACTURING METHOD THEREOF, AND PIPE COUPLING METHOD.**

(57) In a piping structure of a cooling device using an ebullient cooling system, the cooling performance of the cooling device is degraded if the pipe is provided with flexibility, therefore, a piping structure of a cooling device according to an exemplary aspect of the invention in-

cludes a first tubular part with a hollow portion through which a refrigerant used in the cooling device flows; wherein the first tubular part is made of metal materials; and the surface roughness of the inner surface of the first tubular part is less than or equal to the size of a condensation nucleus for the refrigerant.

FIG. 1A



Description

TECHNICAL FIELD

[0001] The present invention relates to piping structures of cooling devices for semiconductor devices and electronic devices and the like, in particular, to a piping structure of a cooling device using an ebullient cooling system in which the heat transportation and heat radiation are performed by a cycle of vaporization and condensation of a refrigerant, a method for making the same, and a method for connecting pipes.

BACKGROUND ART

[0002] In recent years, with the progress of high performance and high functionality in semiconductor devices and electronic devices, the amount of heat generation from them has been increasing. On the other hand, the miniaturization of semiconductor devices and electronic devices has been advancing due to the popularization of portable devices. Because of such background, a cooling device with high efficiency and a small size is highly required. The cooling device using an ebullient cooling system in which the heat transportation and heat radiation are performed by a cycle of vaporization and condensation of a refrigerant, is expected as a cooling device for the semiconductor devices and the electronic devices because it does not require any driving unit such as a pump.

[0003] An example of the cooling device using an ebullient cooling system (hereinafter, also referred to as an ebullient cooling device) is described in patent literature 1. The ebullient cooling device described in patent literature 1 includes an evaporator absorbing the heat from a heating element by the evaporation action of working fluids such as pure water and ethanol, and a condenser releasing heat by the condensation action of working fluids. The ebullient cooling device includes flow conduits circulating the working fluids between the evaporator and the condenser, and is configured so that the flow conduits can be bent at a number of points. It is said that the configuration enables the flow conduits to act as a spring and to absorb the force applied to the evaporator and the condenser.

[0004] In the ebullient cooling device described in patent literature 1, however, a metal pipe made of rigid metal with a spring function is used as the flow conduit, and consequently, there has been a problem that the degree of freedom to dispose the flow conduits with a bent form is limited. There has also been a problem that the mechanical strength cannot be maintained, for example, a buckling occurs in the process of bending, if the thickness of the metal pipe is reduced to a thickness in which it can be bent freely. Furthermore, there has been a problem that the corrosion (electrical corrosion) based on an electrochemical action occurs due to the electrical potential difference between the metal composing the flow conduit

and the metal composing a connection of the evaporator or the condenser if an electrically-conductive refrigerant is used.

[0005] On the other hand, a low-boiling organic refrigerant is often used as the refrigerant in the ebullient cooling device in order to improve the cooling performance within a range of the operation temperature for a semiconductor device and an electronic device. It is possible to obtain a flexible pipe by using an organic material such as resin and rubber. If a pipe made of an organic material is used, however, there has been a problem that the internal pressure increases due to a chemical reaction with the organic refrigerant, and consequently, the cooling performance is degraded owing to the boiling point elevation of the refrigerant.

[0006] Patent literature 2 describes a technology to solve such problems. An ebullient cooling device described in patent literature 2 includes an evaporator container accommodating a refrigerant liquid, a condenser condensing the vaporized refrigerant, and a single pipe connecting the evaporator container to the condenser, through which a gas-liquid flows in a mixed phase. The pipe has a structure in which a thin film of a corrosion-resistant and permeation-resistant material such as aluminum and stainless steel is evaporated onto the inner wall of the pipe made of a resin. It is said that the structure enables the pipe to have enough rigidity to maintain its shape against the atmospheric pressure and thus the installation location of the evaporator container and the condenser can be freely decided.

Patent literature 1: Japanese Patent Application Laid-Open Publication No. 2006-125718 (paragraphs [0025] to [0044])

Patent literature 2: Japanese Patent Application Laid-Open Publication No. 1994-224337 (paragraphs [004] to [009])

DISCLOSURE OF INVENTION

PROBLEM TO BE SOLVED BY THE INVENTION

[0007] As mentioned above, the pipe in the related ebullient cooling device has a structure in which a metal film is evaporated onto the inner surface of the pipe. The vapor of the refrigerant, however, is condensed again and liquefies in the middle of the pipe due to the surface roughness of the metal film evaporated on the resin. The related ebullient cooling device using such pipes, therefore, has a problem that the amount of heat transports by the refrigerant decreases.

[0008] Thus, in the piping structure of the related ebullient cooling device, there is a problem that the cooling performance of the cooling device is degraded if the pipe is provided with flexibility.

[0009] The objective of the present invention is to provide a piping structure of a cooling device, a method for making the same, and a method for connecting pipes

which solve the problem mentioned above that in a piping structure of a cooling device using an ebullient cooling system, the cooling performance of the cooling device is degraded if the pipe is provided with flexibility.

MEANS FOR SOLVING A PROBLEM

[0010] A piping structure of a cooling device according to an exemplary aspect of the invention includes a first tubular part with a hollow portion through which a refrigerant used in the cooling device flows; wherein the first tubular part is made of metal materials; and the surface roughness of the inner surface of the first tubular part is less than or equal to the size of a condensation nucleus for the refrigerant.

[0011] A method for making a piping structure of cooling device according to an exemplary aspect of the invention includes the steps of: applying a rolling process to a metal material composing a hollow portion through which a refrigerant used in a cooling device flows; forming a plate-like metal plate material with a surface roughness less than or equal to the size of a condensation nucleus for the refrigerant by the rolling process; and bending the metal plate material into a tube and joining both ends.

[0012] A method for connecting pipes according to an exemplary aspect of the invention includes the steps of: fitting, in a connective projection, a pipe including a first tubular part, the first tubular part having a hollow portion through which a refrigerant used in a cooling device flowing, made of a metal material, and a surface roughness of its inner surface being less than or equal to the size of a condensation nucleus for the refrigerant; applying a pressure from the outer periphery of the pipe toward the center; and deforming the metal material composing the first tubular part by the pressure and attaching firmly the metal material to the connective projection.

EFFECT OF THE INVENTION

[0013] According to the piping structure of the cooling device of the present invention, it is possible to obtain a piping structure of a cooling device which does not cause deterioration in the cooling performance of the cooling device even if the pipe is provided with flexibility.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014]

FIG. 1A is a plan view showing a configuration of a piping structure of a cooling device in accordance with the first exemplary embodiment of the present invention.

FIG. 1B is a cross-sectional view showing a configuration of a piping structure of a cooling device in accordance with the first exemplary embodiment of the present invention.

FIG. 2A is a plan view showing a configuration of a

piping structure of a cooling device in accordance with the second exemplary embodiment of the present invention.

FIG. 2B is a cross-sectional view showing a configuration of a piping structure of a cooling device in accordance with the second exemplary embodiment of the present invention.

FIGS. 3A is a cross-sectional view to illustrate a method for making the piping structure of cooling device in accordance with the second exemplary embodiment of the present invention.

FIGS. 3B is a cross-sectional view to illustrate a method for making the piping structure of cooling device in accordance with the second exemplary embodiment of the present invention.

FIG. 4 is a cross-sectional view showing a configuration of an ebullient cooling device in accordance with the third exemplary embodiment of the present invention.

FIG. 5A is a cross-sectional view to illustrate a method for connecting pipes in the cooling device in accordance with the third exemplary embodiment of the present invention.

FIG. 5B is a cross-sectional view to illustrate a method for connecting pipes in the cooling device in accordance with the third exemplary embodiment of the present invention.

DESCRIPTION OF EMBODIMENTS

[0015] The exemplary embodiments of the present invention will be described with reference to drawings below.

[The first exemplary embodiment]

[0016] FIGS. 1A and 1B show configurations of a piping structure of cooling device 10 in accordance with the first exemplary embodiment of the present invention. FIG. 1A is a plan view and FIG. 1B is a cross-sectional view in a plane perpendicular to the axial direction of the piping structure (a cross-sectional view taken along the line A-A of FIG. 1A). The piping structure of cooling device 10 in accordance with the present exemplary embodiment includes a first tubular part 11 with a hollow portion through which a refrigerant used in the cooling device flows.

[0017] The first tubular part 11 is made of metal materials, and the surface roughness of the inner surface of the first tubular part 11 is less than or equal to the size of a condensation nucleus for the refrigerant. Here, the condensation nucleus means a spot which acts as a base point when a vapor liquefies. If the vapor touches the base points, the liquefaction is accelerated there. It is possible to use aluminum materials and the like as the first tubular part 11, for example. By setting the center line average roughness of a surface equal to or more than 0.1 micrometers and less than or equal to 10 mi-

chrometers, preferably less than or equal to 1 micrometer, it is possible to prevent the inner surface of the first tubular part 11 from acting as a condensation nucleus of the refrigerant.

[0018] It is possible to use a material formed through an annealing process for the first tubular part. By means of the annealing process, it is possible to adjust a strain arising at a processing treatment, and it becomes possible to maintain the strength of the first tubular part with maintenance of its flexibility.

[0019] Next, the method for making the piping structure of cooling device 10 according to the present exemplary embodiment will be described. In the method for making according to the present exemplary embodiment, first, a plate-like metal plate material made of a metal material such as aluminum is prepared. The metal plate material can be produced by a conventional rolling process. The metal plate material is bent into a tube by using a cylindrical jig such as a roll, for example, and both ends are joined by means of a weld process and the like. By this process, the first tubular part 11 made of a metal material is completed. It is also acceptable to perform the annealing process subsequently. The annealing process can be performed under conditions normally used for the metal material to be used. It is desirable to set the thickness of the first tubular part, which is determined by the plate thickness of the metal plate material, equal to or more than 0.4 mm and less than or equal to 1 mm. This is because it becomes difficult to weld the ends and to maintain the bending strength and the internal pressure capacity of the first tubular part if the plate thickness of the metal plate material becomes thinner than 0.4 mm. On the other hand, it is also because the flexibility of the piping structure of cooling device 10 decreases if the thickness of the first tubular part is more than 1 mm.

[0020] As mentioned above, according to the present exemplary embodiment, it is possible to obtain a piping structure of a cooling device which does not cause deterioration in the cooling performance of the cooling device even if the pipe is provided with flexibility.

[The second exemplary embodiment]

[0021] Next, the second exemplary embodiment of the present invention will be described. FIGS. 2A and 2B show configurations of a piping structure of cooling device 100 according to the second exemplary embodiment of the present invention. FIG. 2A is a plan view and FIG. 2B is a cross-sectional view in a plane perpendicular to the axial direction of the piping structure (a cross-sectional view taken along the line A-A of FIG. 2A). The piping structure of cooling device 100 in accordance with the present exemplary embodiment includes a first tubular part 110 with a hollow portion through which a refrigerant used in the cooling device flows, and a second tubular part 120 with which the first tubular part 110 is covered.

[0022] The first tubular part 110 is made of metal materials, and the surface roughness of the inner surface

of the first tubular part 110 is less than or equal to the size of a condensation nucleus for the refrigerant. Here, the condensation nucleus means a spot which acts as a base point when a vapor liquefies. If the vapor touches the base points, the liquefaction is accelerated there. It is possible to use aluminum materials and the like as the first tubular part 110, for example. By setting the center line average roughness of a surface equal to or more than 0.1 micrometers and less than or equal to 10 micrometers, preferably less than or equal to 1 micrometer, it is possible to prevent the inner surface of the first tubular part 110 from acting as a condensation nucleus of the refrigerant.

[0023] The second tubular part is made of organic materials such as resin and rubber, and it is possible to use polyethylene materials and butyl rubber materials, for example.

[0024] As mentioned above, the piping structure of cooling device 100 according to the present exemplary embodiment is configured in which the first tubular part 110 touching the refrigerant is made of metal materials and the surface roughness of the inner surface is less than or equal to the size of a condensation nucleus for the refrigerant. Accordingly, it is possible to prevent the piping structure of cooling device 100 from reacting chemically with the refrigerant, and prevent the vapor of the refrigerant from condensing again. Additionally, since the piping structure of cooling device 100 includes a multi-layered structure in which the first tubular part 110 is covered with the second tubular part 120 made of organic materials, it is possible to maintain the mechanical strength of the piping structure of cooling device 100 with maintenance of its flexibility. As a result, according to the present exemplary embodiment, it is possible to obtain a piping structure of a cooling device which does not cause deterioration in the cooling performance of the cooling device even if the pipe is provided with flexibility.

[0025] Next, the method for making the piping structure of cooling device 100 according to the present exemplary embodiment will be described. FIGS. 3A and 3B are cross-sectional views to illustrate a method for making the piping structure of cooling device 100 according to the present exemplary embodiment. In the method for making according to the present exemplary embodiment, first, a plate-like metal plate material 140 made of a metal material such as aluminum is prepared. As shown in FIG. 3A, the metal plate material 140 is bent into a tube by using a cylindrical jig 150 such as a roll, for example, and both ends 160 are joined by means of a weld process and the like. By this process, the first tubular part 110 made of a metal material is formed.

[0026] Subsequently, as shown in FIG. 3B, the outer periphery of the first tubular part 110 is covered by ejecting a resin material such as polyethylene from a nozzle 170 and the like, for example. By this process, the second tubular part made of the organic material is formed with which the first tubular part 110 is covered, and the piping structure of cooling device 100 is completed. Since the

method for making the piping structure of cooling device 100 according to the present exemplary embodiment is composed of the simple processes, it is possible to manufacture the piping structure of cooling device 100 massively and cheaply according to the present method for making.

[0027] Here, it is desirable to set the surface roughness of the inner surface of the first tubular part 110 made of the metal plate material 140 equal to or more than 0.1 micrometers and less than or equal to 10 micrometers, preferably less than or equal to 1 micrometer. This can be achieved by producing the metal plate material 140 by means of a conventional rolling process. By setting the surface roughness within the range, it is possible to prevent the inner surface of the first tubular part 110 from acting as a condensation nucleus of the refrigerant. It is desirable to set the thickness of the first tubular part, which is determined by the plate thickness of the metal plate material 140, equal to or more than 0.4 mm and less than or equal to 1 mm. This is because it becomes difficult to weld the ends 160 and to maintain the bending strength and the internal pressure capacity of the first tubular part if the plate thickness of the metal plate material 140 becomes thinner than 0.4 mm. On the other hand, it is also because the flexibility of the piping structure of cooling device 100 decreases if the thickness of the first tubular part is more than 1 mm.

[The third exemplary embodiment]

[0028] Next, the third exemplary embodiment of the present invention will be described. In the present exemplary embodiment, a cooling device will be described which uses the piping structure of cooling device 100 according to the second exemplary embodiment, but it is also acceptable to use the piping structure of cooling device 10 according to the first exemplary embodiment. A case will be described below in which the piping structure is applied to a cooling device using an ebullient cooling system (hereinafter, referred to as an ebullient cooling device). FIG. 4 is a cross-sectional view showing a configuration of an ebullient cooling device 200 in accordance with the present exemplary embodiment. The ebullient cooling device 200 includes an evaporator 220 storing a refrigerant 210, and a condenser 230 condensing and liquefying a vapor-state refrigerant vaporized in the evaporator 220 and radiating heat. A heat-generating part 240 of an object to be cooled such as a semiconductor device is disposed so as to thermally contact with one surface of the evaporator 220.

[0029] The evaporator 220 is connected to the condenser 230 by using the piping structure of cooling device 100 according to the second exemplary embodiment. As shown in FIG. 2A, the piping structure of cooling device 100 includes a first connection 131 connected to the evaporator 210 and a second connection 132 connected to the condenser 230. FIG. 4 shows a case where the piping structure of cooling device 100 is used for a vapor-

phase pipe 251 through which a vapor-phase refrigerant flows from the evaporator 220 toward the condenser 230 and for a liquid-phase pipe 252 through which a liquid-phase refrigerant flows from the condenser 230 toward the evaporator 220. The bending strength of the vapor-phase pipe 251 and the liquid-phase pipe 252 (hereafter, referred to as "a pipe 250" simply) is maintained by means of the second tubular part 120 made of organic materials having the flexibility. In the ebullient cooling device 200, therefore, it is possible to decide freely the disposition of the evaporator 220 and the condenser 230 with maintenance of the mechanical strength of the pipe connecting the evaporator 220 to the condenser 230.

[0030] As mentioned above, the ebullient cooling device 200 of the present exemplary embodiment is configured in which the evaporator 220 is connected to the condenser 230 by using the pipe 250 including the first tubular part 110 made of metal materials as the inner layer and the second tubular part 120 made of organic materials having the flexibility as the outer layer. By adopting this configuration, it is possible to change the layout of the ebullient cooling device 200 easily even if the layout or the specifications of a device to be cooled are changed. Accordingly, it becomes unnecessary to design and produce the evaporator 220 and the condenser 230 with respect to each device to be cooled, and it becomes possible to standardize them. As a result, it is possible to reduce the costs of the evaporator 220 and the condenser 230.

[0031] It is also possible that the evaporator 220 is configured to include a first connective projection 221 connected to the first connection 131 of the piping structure of cooling device 100 and the condenser 230 is configured to include a second connective projection 231 connected to the second connection 132. It is also acceptable that at least one of the first connective projection 221 and the second connective projection 231 is made of the same material as the metal material of which the first tubular part 131 is made. In this case, since the electrical potential difference does not arise between the same type of metals, it is possible to prevent the corrosion based on the electrochemical action (electrical corrosion) even though a conductive refrigerant such as water is used.

[0032] In general, a semiconductor device, an electronic device and the like are designed so as to operate at temperature in the range from several tens of degrees Celsius to about 100 degrees Celsius. By using a material with small surface tension and a low boiling point as the refrigerant used in the ebullient cooling device, therefore, it is possible to activate the generation of bubbles in the evaporator and improve the cooling performance. For this reason, organic refrigerants such as hydrofluorocarbon and hydrofluoroether are used as the refrigerant. These organic refrigerants, however, react chemically with organic materials such as resin and rubber. Since the chemical reaction generates a reaction gas and the internal pressure in the related ebullient cooling device

increases, the boiling point of the refrigerant rises. As a result, the cooling performance in the related ebullient cooling device is degraded by the prolonged use.

[0033] In contrast, the ebullient cooling device 200 of the present exemplary embodiment uses the piping structure of cooling device 100 including the first tubular part 110 made of metal materials as the vapor-phase pipe 251 and the liquid-phase pipe 252. As a result, the reaction between the refrigerant and the pipe is suppressed, and accordingly, it is possible to prevent the cooling performance from degrading and ensure long-term reliability of the ebullient cooling device.

[0034] Next, the method for connecting pipes will be described in more detail using FIGS. 5A and 5B. FIGS. 5A and 5B are cross-sectional views to illustrate a method for connecting pipes in the cooling device according to the present exemplary embodiment.

[0035] In the method for connecting pipes according to the present exemplary embodiment, first, as shown in FIG. 5A, the pipe 250 is fitted in the first connective projection 221 or the second connective projection 231 (hereafter, referred to as "a connective projection 260" simply). Here, the pipe 250 includes the piping structure of cooling device 100 according to the second exemplary embodiment, as mentioned above. That is to say, the pipe 250 includes the first tubular part 110 made of metal materials with a hollow portion through which the refrigerant used in the cooling device flows, and the second tubular part 120 made of organic materials with which the first tubular part 110 is covered.

[0036] Next, a pressure is applied from the outer periphery of the second tubular part 120 toward the center. As shown in FIG. 5B, it is possible to use a clamping tool such as a clamp 270 in order to apply the pressure. The pressure enables the metal material composing the first tubular part 110 to deform and the metal material to be attached firmly to the connective projection 260 by a simple process.

[0037] Here, the connective projection 260 can be configured to be a nipple shape, as shown in FIGS. 5A and 5B. In this case, since the first tubular part 110 made of metal materials, which composes the inner layer of the pipe 250, has a small wall thickness, it undergoes plastic deformation due to the stress concentration at the convex portions of the nipple shape, and is attached firmly to the connective projection 260. As a result, it is possible to suppress the leakage of the refrigerant from the connective projection 260. Since the pipe 250 according to the present exemplary embodiment includes, as the outer layer, the second tubular part 120 made of organic materials such as resin and rubber, it is possible to maintain the mechanical strength as a pipe even if the metal material of the inner layer is deformed.

[0038] The present invention is not limited to the above-mentioned exemplary embodiments and can be variously modified within the scope of the invention described in the claims. It goes without saying that these modifications are also included in the scope of the

present invention.

[0039] This application is based upon and claims the benefit of priority from Japanese Patent Application No. 2011-089347, filed on April 13, 2011, the disclosure of which is incorporated herein in its entirety by reference.

DESCRIPTION OF THE CODES

[0040]

10	10, 100	piping structure of cooling device
	11, 110	first tubular part
15	120	second tubular part
	140	metal plate material
	150	cylindrical jig
20	160	end section
	170	nozzle
25	200	ebullient cooling device
	210	refrigerant
	220	evaporator
30	221	first connective projection
	230	condenser
35	231	second connective projection
	240	heat generating unit
	250	piping
40	251	vapor-phase pipe
	252	liquid-phase pipe
45	260	connective projection
	270	clamp

Claims

1. A piping structure of cooling device, comprising:

a first tubular part with a hollow portion through which a refrigerant used in the cooling device flows;
wherein the first tubular part is made of metal materials; and the surface roughness of the in-

- ner surface of the first tubular part is less than or equal to the size of a condensation nucleus for the refrigerant.
2. The piping structure of cooling device according to claim 1, wherein the first tubular part is formed through an annealing process. 5
 3. The piping structure of cooling device according to claim 1 or 2, wherein the surface roughness of an inner surface of the first tubular part is equal to or more than 0.1 micrometers and less than or equal to 10 micrometers. 10 15
 4. The piping structure of cooling device according to any one of claims 1, 2, and 3, wherein the thickness of the first tubular part is equal to or more than 0.4 mm and less than or equal to 1 mm. 20
 5. The piping structure of cooling device according to any one of claims 1, 2, 3, and 4, comprising: 25
 - the first tubular part; and
 - a second tubular part with which the first tubular part is covered,
 - wherein the second tubular part is made of organic materials. 30
 6. The piping structure of cooling device according to any one of claims 1, 2, 3, 4, and 5, further comprising: 35
 - a first connection connected to an evaporator storing a refrigerant; and
 - a second connection connected to a condenser condensing and liquefying a vapor-state refrigerant vaporized in the evaporator and radiating heat. 40
 7. A cooling device, comprising:
 - an evaporator storing a refrigerant;
 - a condenser condensing and liquefying a vapor-state refrigerant vaporized in the evaporator and radiating heat; and
 - a pipe connecting the evaporator to the condenser,
 - wherein the pipe comprises the piping structure of cooling device according to any one of claims 1, 2, 3, 4, 5, and 6. 50
 8. The cooling device according to claim 7, 55
 - wherein the evaporator comprises a first connective projection connected to the pipe;
 - the condenser comprises a second connective
- projection connected to the pipe; and
 at least one of the first connective projection and the second connective projection is made of the same material as a metal material of which the first tubular part is made.
9. A method for making a piping structure of cooling device, comprising the steps of:
 - applying a rolling process to a metal material composing a hollow portion through which a refrigerant used in a cooling device flows;
 - forming a plate-like metal plate material with a surface roughness less than or equal to the size of a condensation nucleus for the refrigerant by the rolling process; and
 - bending the metal plate material into a tube and joining both ends.
 10. The method for making a piping structure of cooling device according to claim 9, further comprising:
 - performing an annealing process subsequently to the joining process.
 11. The method for making a piping structure of cooling device according to claim 9, further comprising:
 - forming a first tubular part made of metal materials by the joining process; and
 - covering the outer periphery of the first tubular part by ejecting an organic material and forming a second tubular part made of the organic material.
 12. A method for connecting pipes, comprising the steps of:
 - fitting, in a connective projection, a pipe comprising a first tubular part, the first tubular part having a hollow portion through which a refrigerant used in a cooling device flowing, made of a metal material, and a surface roughness of its inner surface being less than or equal to the size of a condensation nucleus for the refrigerant;
 - applying a pressure from the outer periphery of the pipe toward the center; and
 - deforming the metal material composing the first tubular part by the pressure and attaching firmly the metal material to the connective projection.
 13. The method for connecting pipes according to claim 12, wherein the first tubular part is formed through an annealing process.
 14. The method for connecting pipes according to claim 12,

wherein the pipe comprises a second tubular part,
which is made of organic materials, with which the
first tubular part is covered; and
the pressure is applied from the outer periphery of
the second tubular part toward the center.

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FIG. 1A

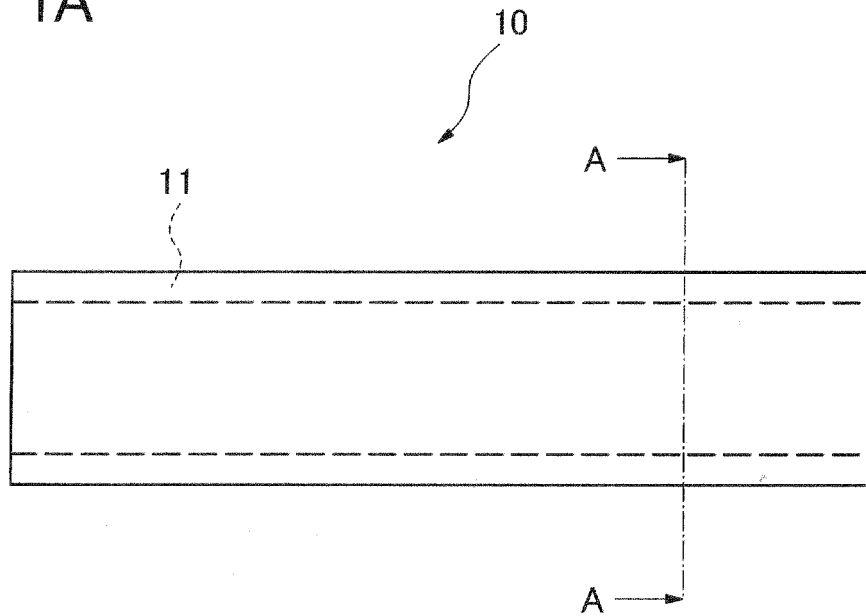


FIG. 1B

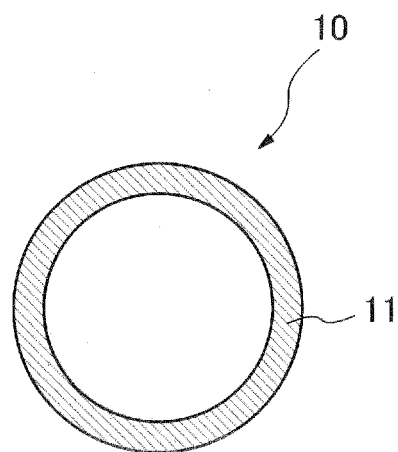


FIG. 2A

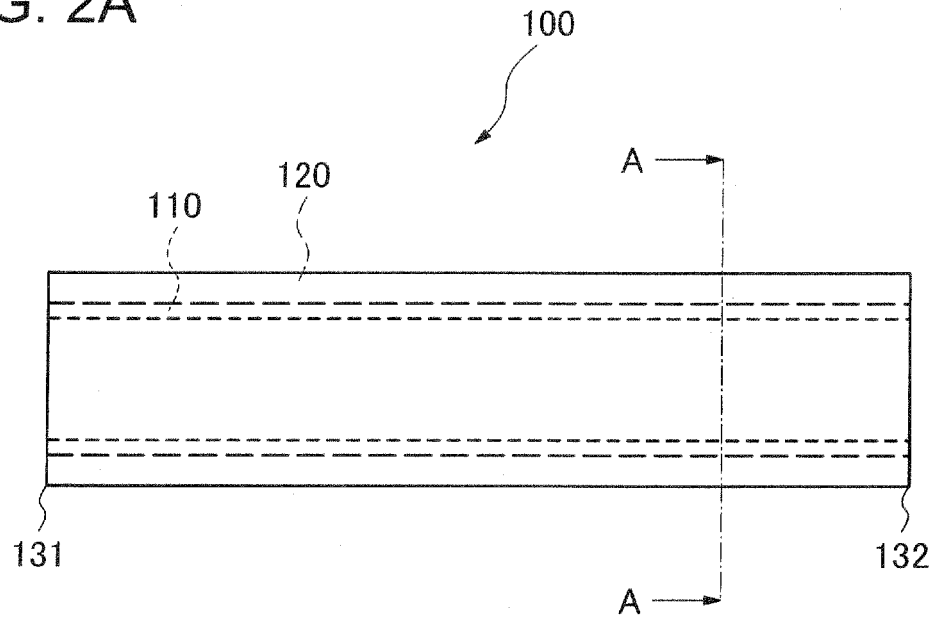


FIG. 2B

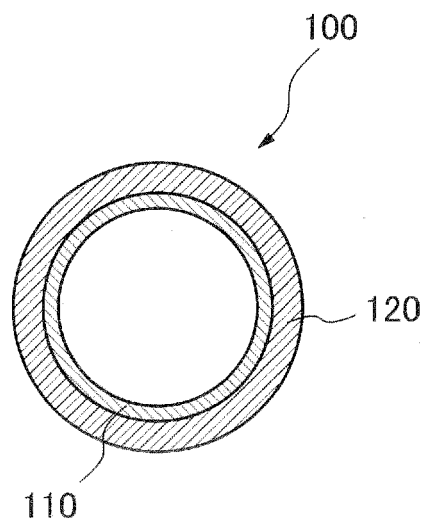


FIG. 3A

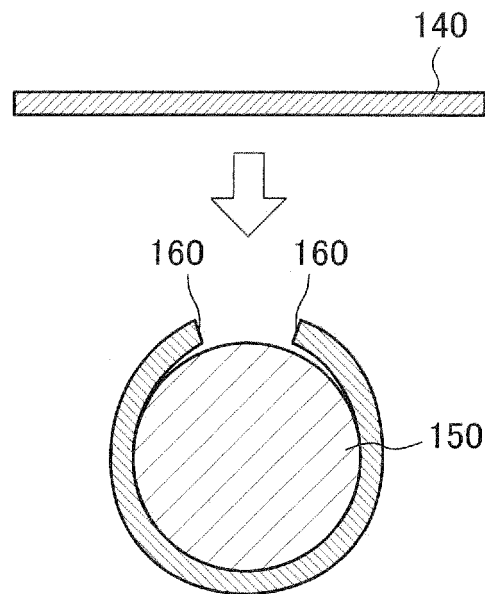


FIG. 3B

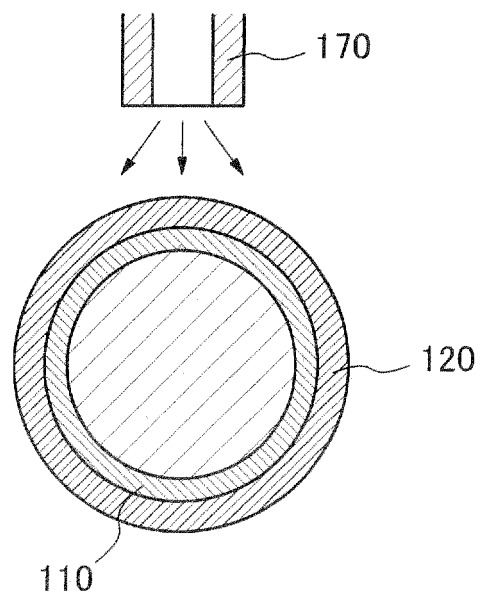


FIG. 4

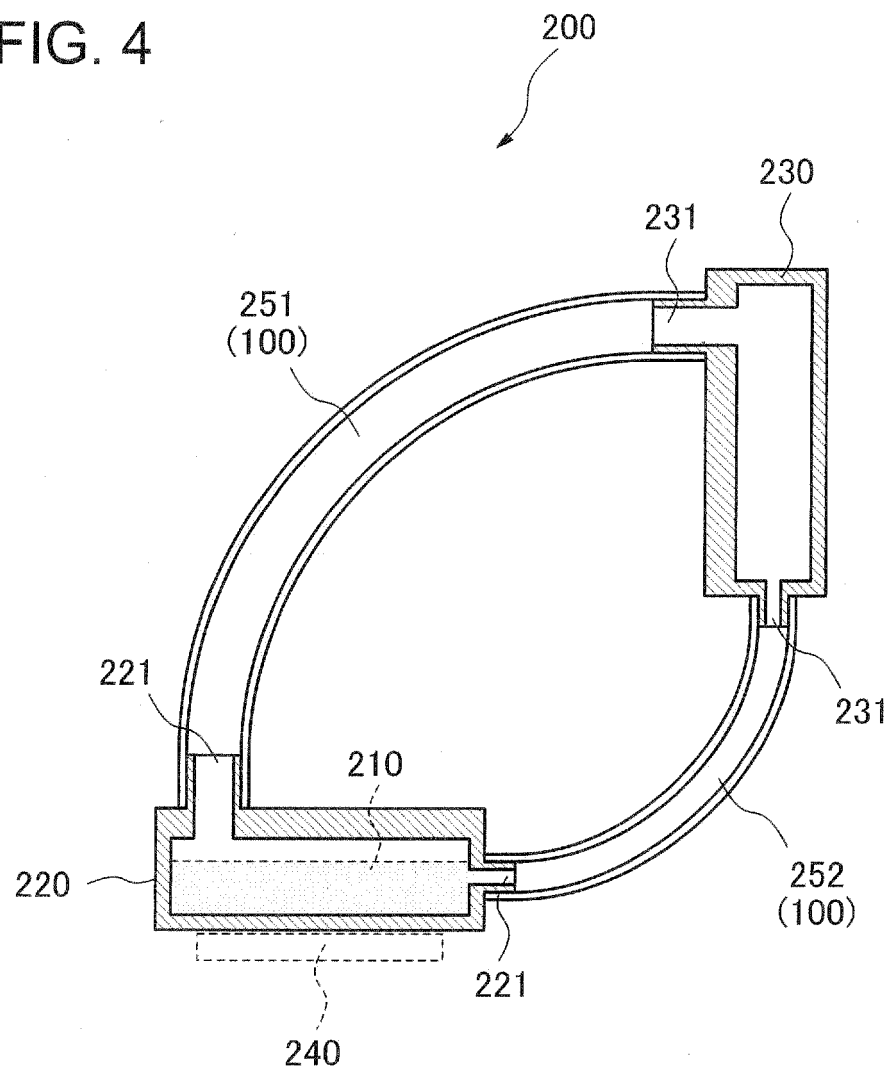


FIG. 5A

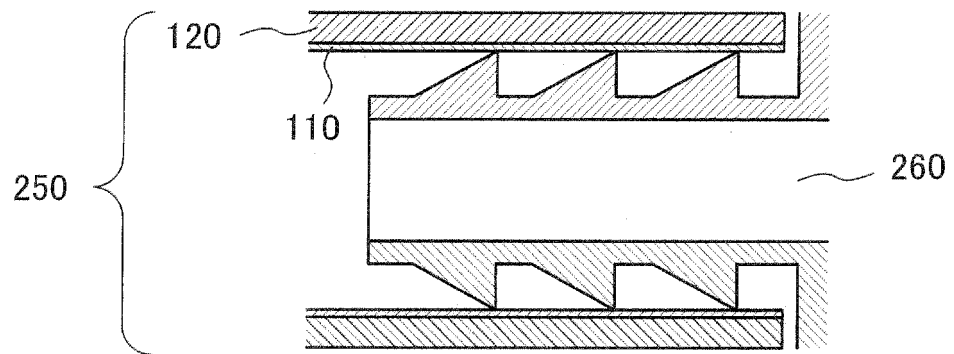
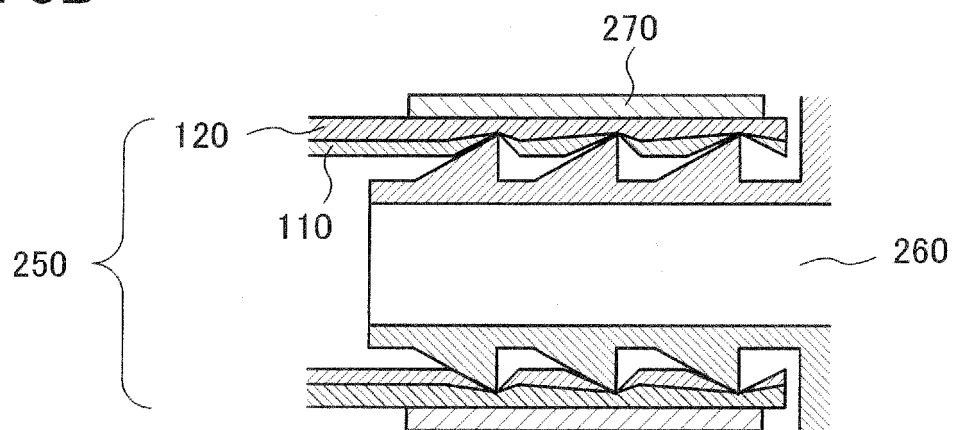


FIG. 5B



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/060197

A. CLASSIFICATION OF SUBJECT MATTER F28F13/02(2006.01)i, F28D15/02(2006.01)i		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols) F28F13/02, F28D15/02		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2012 Kokai Jitsuyo Shinan Koho 1971-2012 Toroku Jitsuyo Shinan Koho 1994-2012		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y A	JP 55-152181 A (Sueddeutsche Kuehlerfabrik Julius Fr. Behr GmbH & Co. KG.), 27 November 1980 (27.11.1980), claims 1, 2; page 1, lower right column, lines 6 to 12; page 2, upper right column, lines 6 to 14; page 3, upper left column, lines 3 to 5; page 3, upper left column, line 19 to upper right column, line 3 & US 4360058 A & GB 2049501 A & DE 2919188 A & FR 2456930 A	1 2-7, 9-14 8
Y	JP 2008-202880 A (Nomura Unison Kabushiki Kaisha), 04 September 2008 (04.09.2008), claim 6 (Family: none)	2-7, 10, 13
☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 03 July, 2012 (03.07.12)		Date of mailing of the international search report 17 July, 2012 (17.07.12)
Name and mailing address of the ISA/ Japanese Patent Office		Authorized officer
Facsimile No.		Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/060197

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 6-224337 A (Yaskawa Electric Corp.), 12 August 1994 (12.08.1994), paragraph [0006]; fig. 1, 2 (Family: none)	5-7, 12-14
Y	WO 2006/088138 A1 (Sumitomo Metal Industries, Ltd.), 24 August 2006 (24.08.2006), paragraphs [0074], [0077]; fig. 10, 11 & US 2009/0158799 A1 & EP 1857722 A1 & BRA PI0607951	9-11
Y	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 169687/1983 (Laid-open No. 76793/1985) (Showa Aluminum Corp.), 29 May 1985 (29.05.1985), drawings; claim 1; specification, page 7, lines 5 to 8 (Family: none)	11

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INTERNATIONAL SEARCH REPORT

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PCT/JP2012/060197

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:
See extra sheet.

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☒ No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet (2)) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/060197

Continuation of Box No.III of continuation of first sheet(2)

Document 1 (JP 55-152181 A (Sueddeutsche Kuehlerfabrik Julius Fr. Behr GmbH & Co. KG.), 27 November 1980 (27.11.1980), claims 1, 2; page 1, lower right column, lines 6 to 12; page 2, upper right column, lines 6 to 14; page 3, upper left column, lines 3 to 5; page 3, upper left column, line 19 to upper right column, line 3) discloses a piping structure of a cooling apparatus, which includes a first tube unit (1) having a hollow part allowing a refrigerant used for the cooling apparatus to flow, wherein the first tube unit is made of a metal material, and a surface roughness of the inner surface of the first tube unit is equal to or smaller than a size of the condensation nucleus of the refrigerant (approximately one to ten μm).

Therefore, the invention of claim 1 cannot be considered to be novel in the light of the invention disclosed in the document 1, and does not have a special technical feature.

Consequently, three inventions (invention groups) each having a special technical feature indicated below are involved in claims.

Meanwhile, the invention of claim 1 having no special technical feature is classified into invention 1.

(Invention 1) the inventions of claims 1-8

A piping structure of a cooling apparatus, which includes a first tube unit having a hollow part allowing a refrigerant used for the cooling apparatus to flow, wherein the first tube unit is made of a metal material, a surface roughness of the inner surface of the first tube unit is equal to or smaller than a size of the condensation nucleus of the refrigerant, and the first tube unit is formed through an anneal treatment step.

(Invention 2) the inventions of claims 9-11

A manufacturing method for a piping structure of a cooling apparatus, comprising: forming a plate-shaped metal plate member having a surface roughness equal to or smaller than a size of the condensation nucleus of the refrigerant by applying a rolling treatment to a metal material constituting a hollow part allowing a refrigerant used for a cooling apparatus to flow; bending the metal plate member into a cylindrical shape; and jointing both end portions thereof.

(Invention 3) the inventions of claims 12-14

A piping connecting method comprising: inserting a connecting protrusion part into a piping including a first tube unit made of a metal material, which has a hollow part allowing a refrigerant used for the cooling apparatus to flow, and the inner surface of which has a surface roughness equal to or smaller than a size of the condensation nucleus of the refrigerant; applying pressure in a direction from an outer circumferential portion of the piping toward the center thereof; deforming the metal material constituting the first tubular unit by the pressure; and bringing the metal material into close contact with the connecting protrusion part.

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 2006125718 A [0006]
- JP 6224337 A [0006]
- JP 2011089347 A [0039]