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(54) HEAT EXCHANGER AND REFRIGERATION CYCLE DEVICE USING THE SAME

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(57) **ABSTRACT**

An object is to improve a pressure resistance and a thermal performance of a heat exchanger and to provide the heat exchanger suitable for use in a refrigeration cycle device in which carbon dioxide is used as a refrigerant. The evaporator (the heat exchanger) includes a pair of plate materials, the whole periphery of a peripheral portion of an outer plate as at least one of the plate materials is secured to the other plate material constituting a bottom surface of an inner tank to constitute a sealed refrigerant passage space between the plate materials, a portion of the outer plate other than the peripheral portion is provided with a plurality of secured inner portions which are secured at predetermined intervals to the bottom surface, and a plurality of refrigerant inlet tubes and refrigerant outlet tubes are attached so as to communicate with the refrigerant passage space.

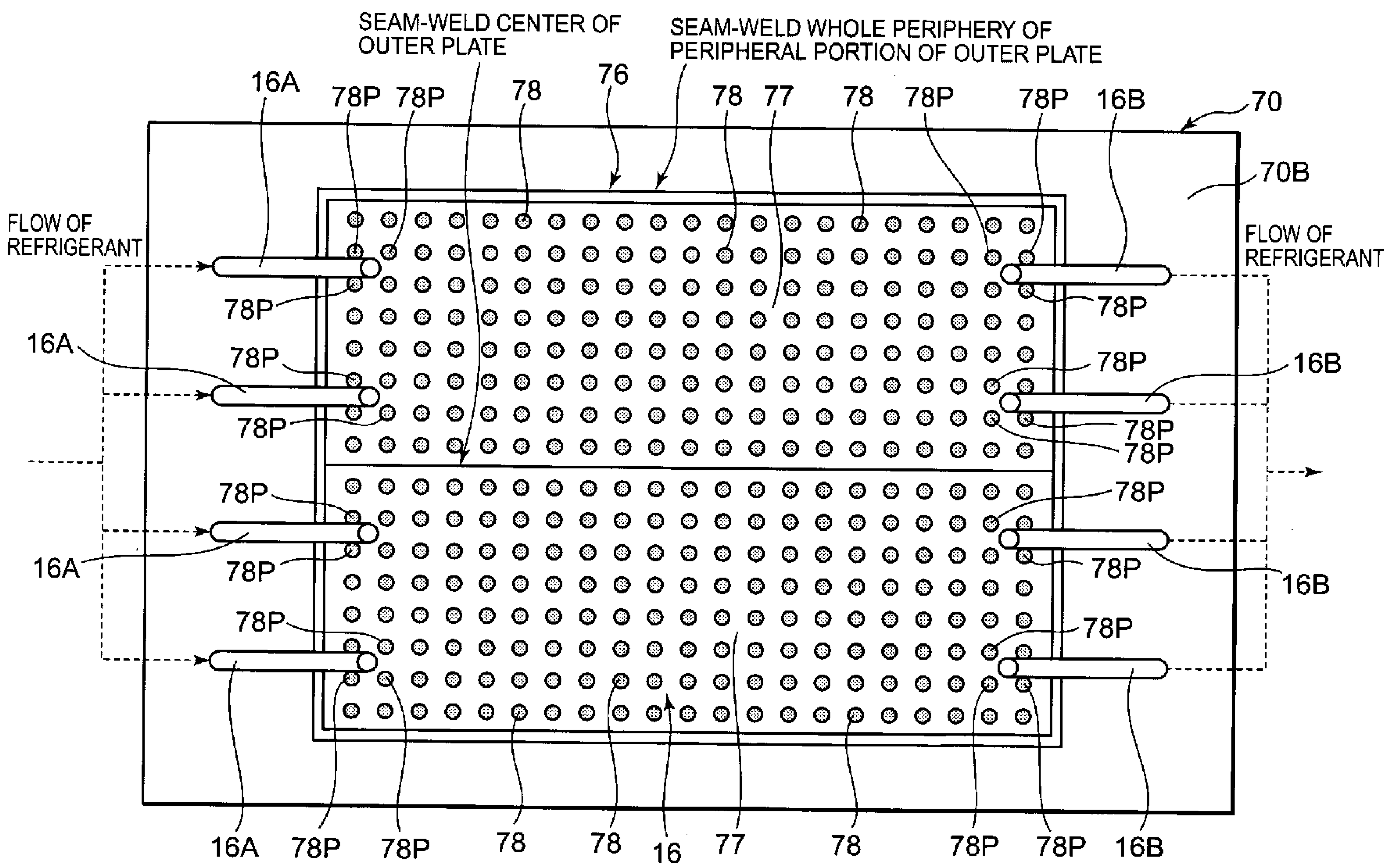


FIG. 1

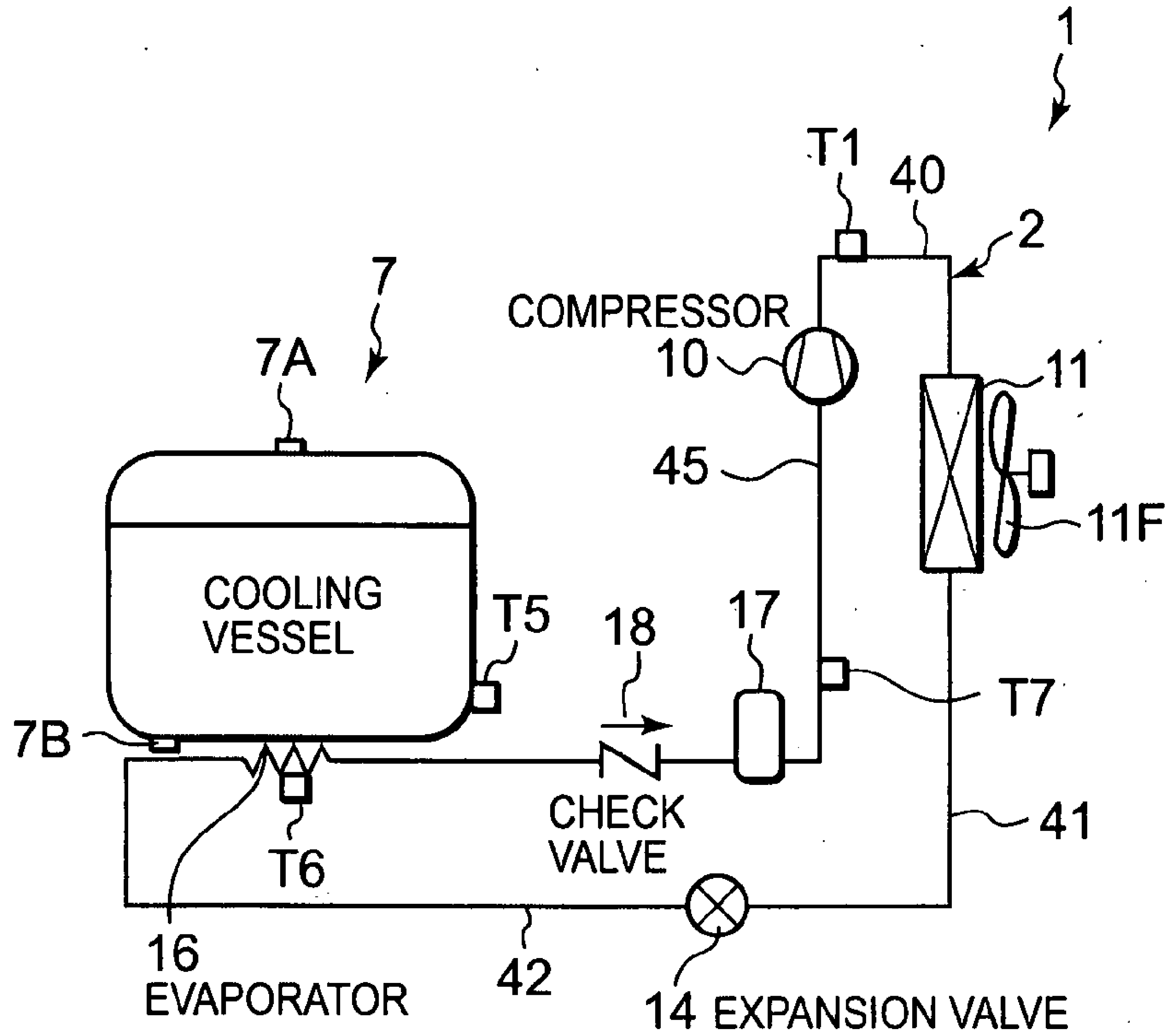

1
T1
40
2
7
COMPRESSOR
10
11
7A
45
11F
COOLING
VESSEL
T5
18
17
T7
7B
CHECK
VALVE
41
T6
16
EVAPORATOR
42
14 EXPANSION VALVE

FIG. 2

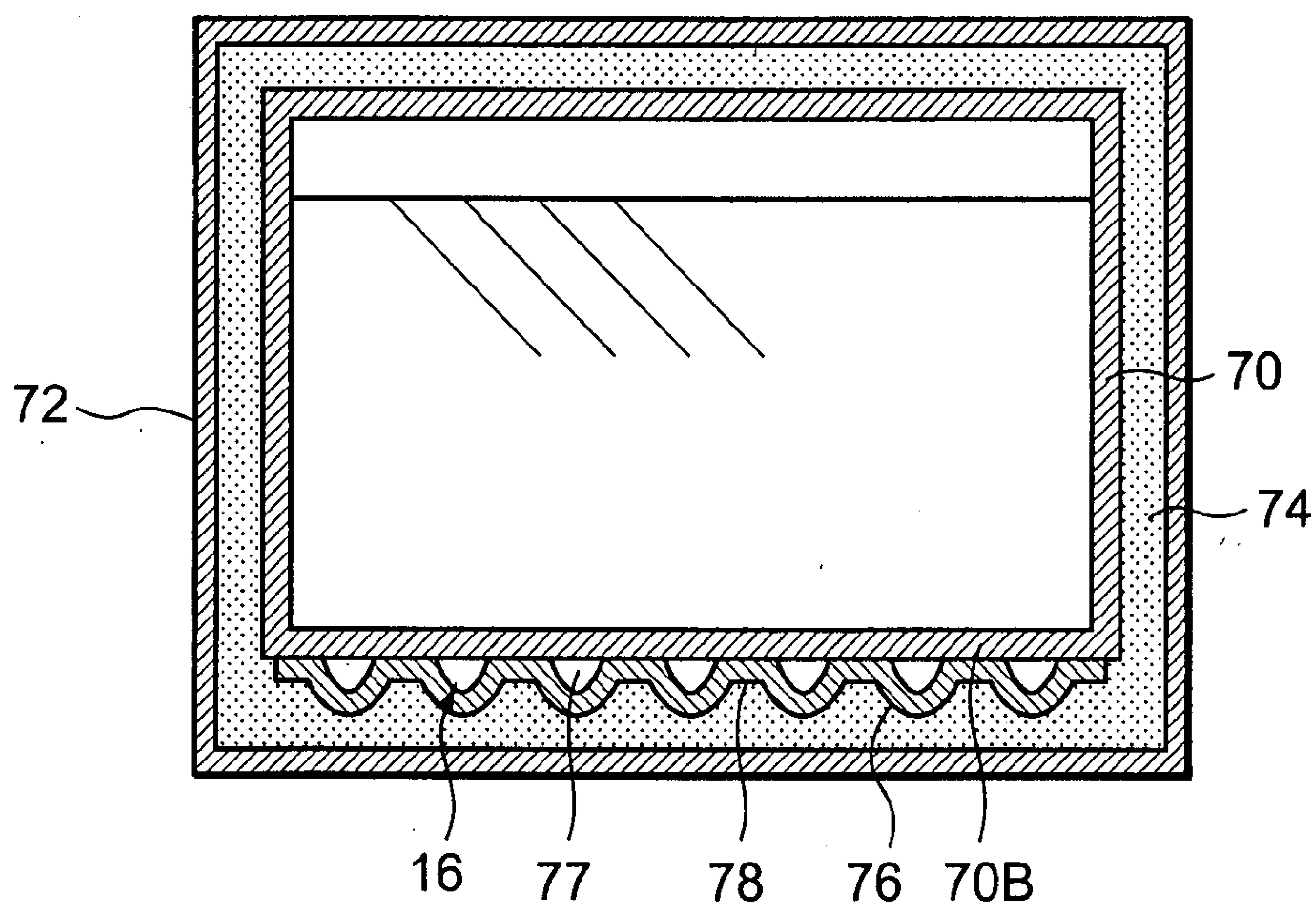

72
70
74
16
77
78
76
70B

FIG. 3

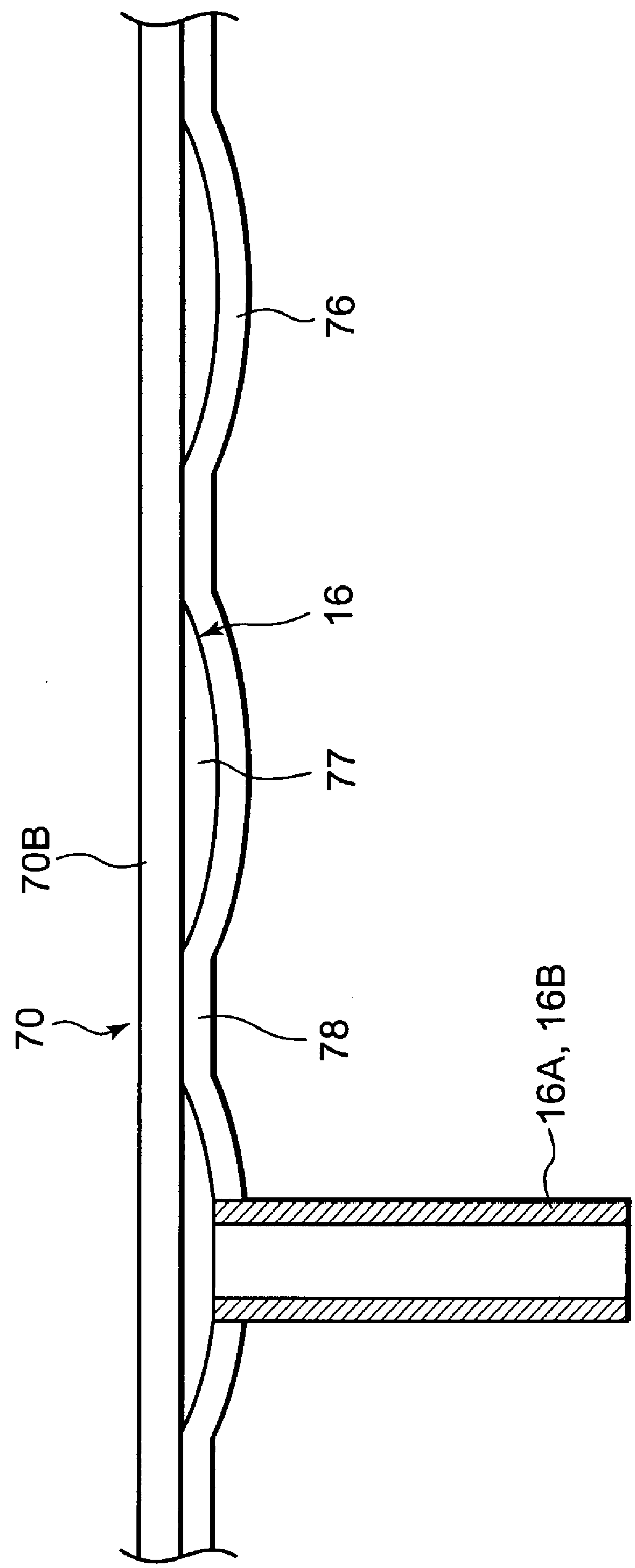
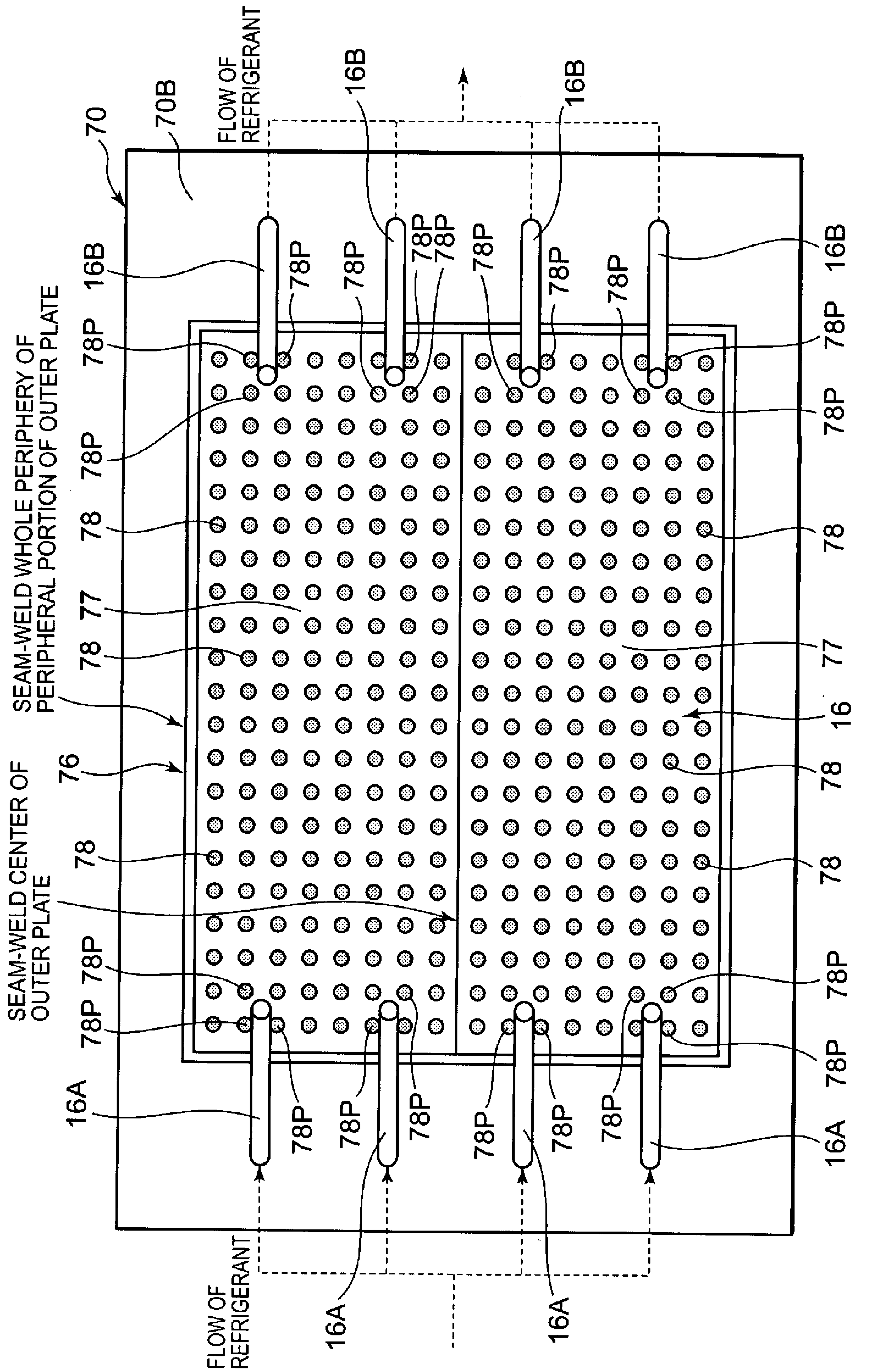
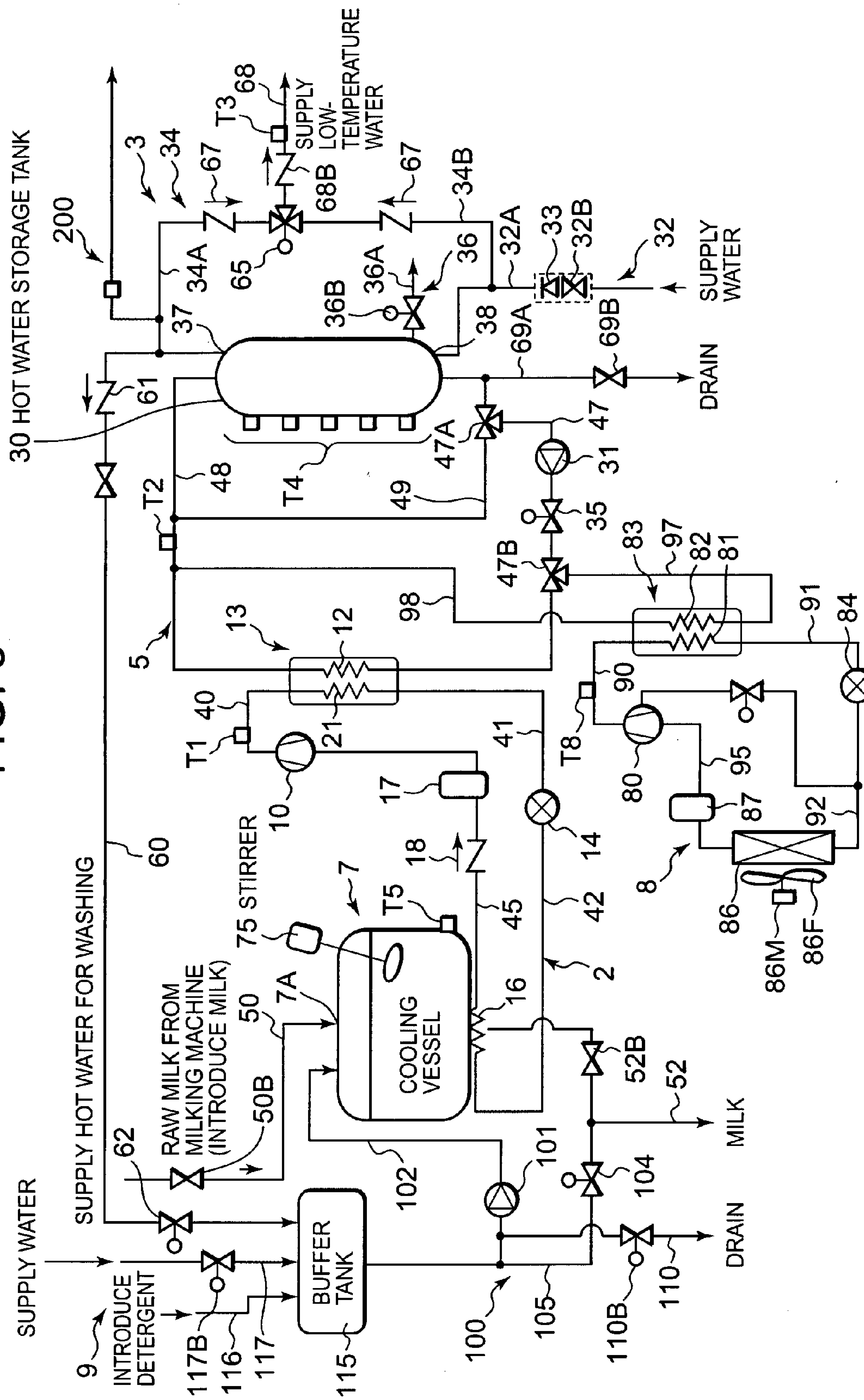


FIG. 4



FLOW OF REFRIGERANT
70
70B
16B
78P
SEAM-WELD WHOLE PERIPHERY OF PERIPHERAL PORTION OF OUTER PLATE
78
77
76
16
SEAM-WELD CENTER OF OUTER PLATE
16A
FLOW OF REFRIGERANT

FIG. 5



HOT WATER STORAGE TANK
SUPPLY LOW-TEMPERATURE WATER
SUPPLY WATER
DRAIN
SUPPLY HOT WATER FOR WASHING
RAW MILK FROM MILKING MACHINE (INTRODUCE MILK)
STIRRER
COOLING VESSEL
MILK
BUFFER TANK
INTRODUCE DETERGENT
SUPPLY WATER
DRAIN

FIG. 6

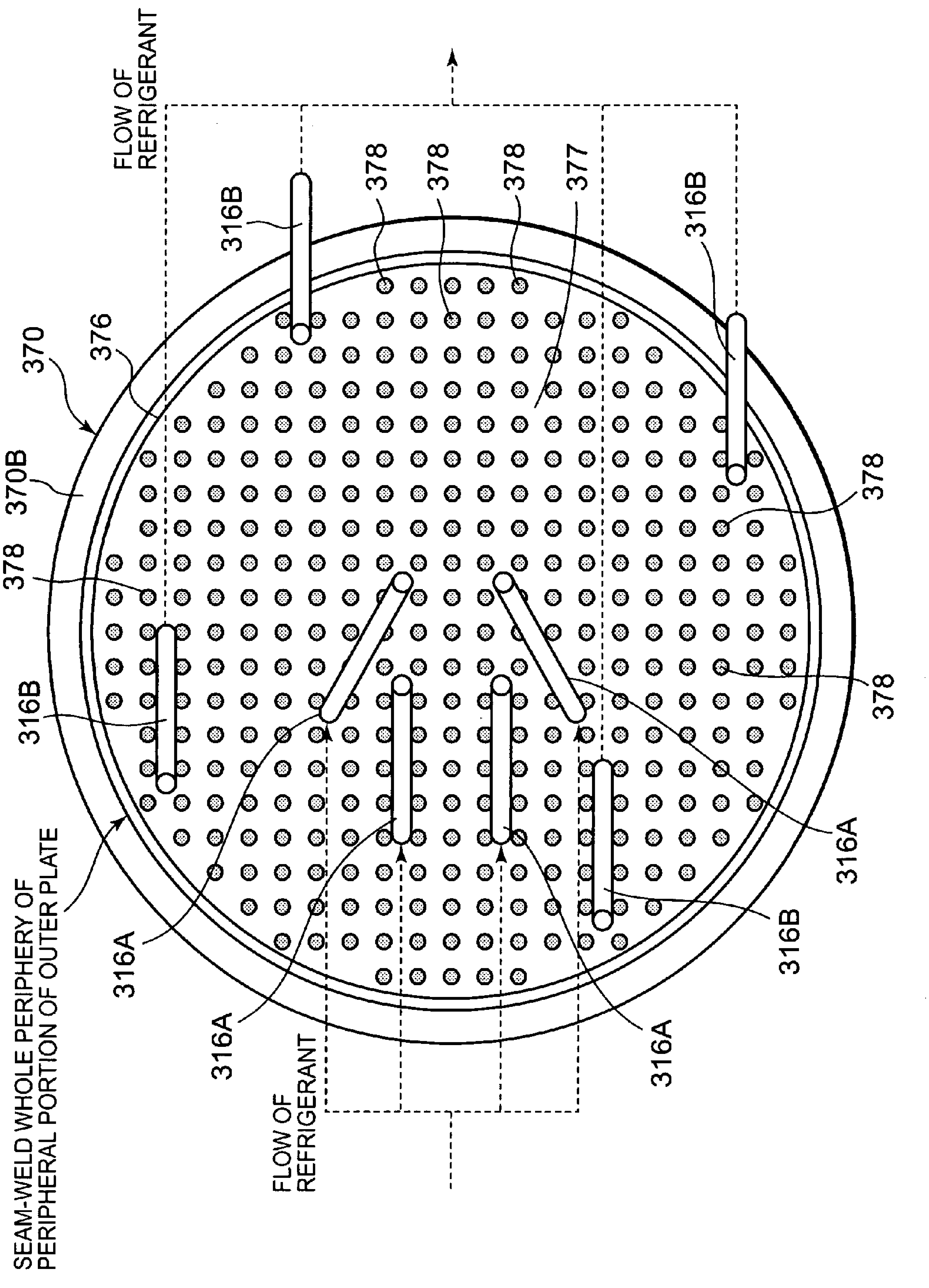
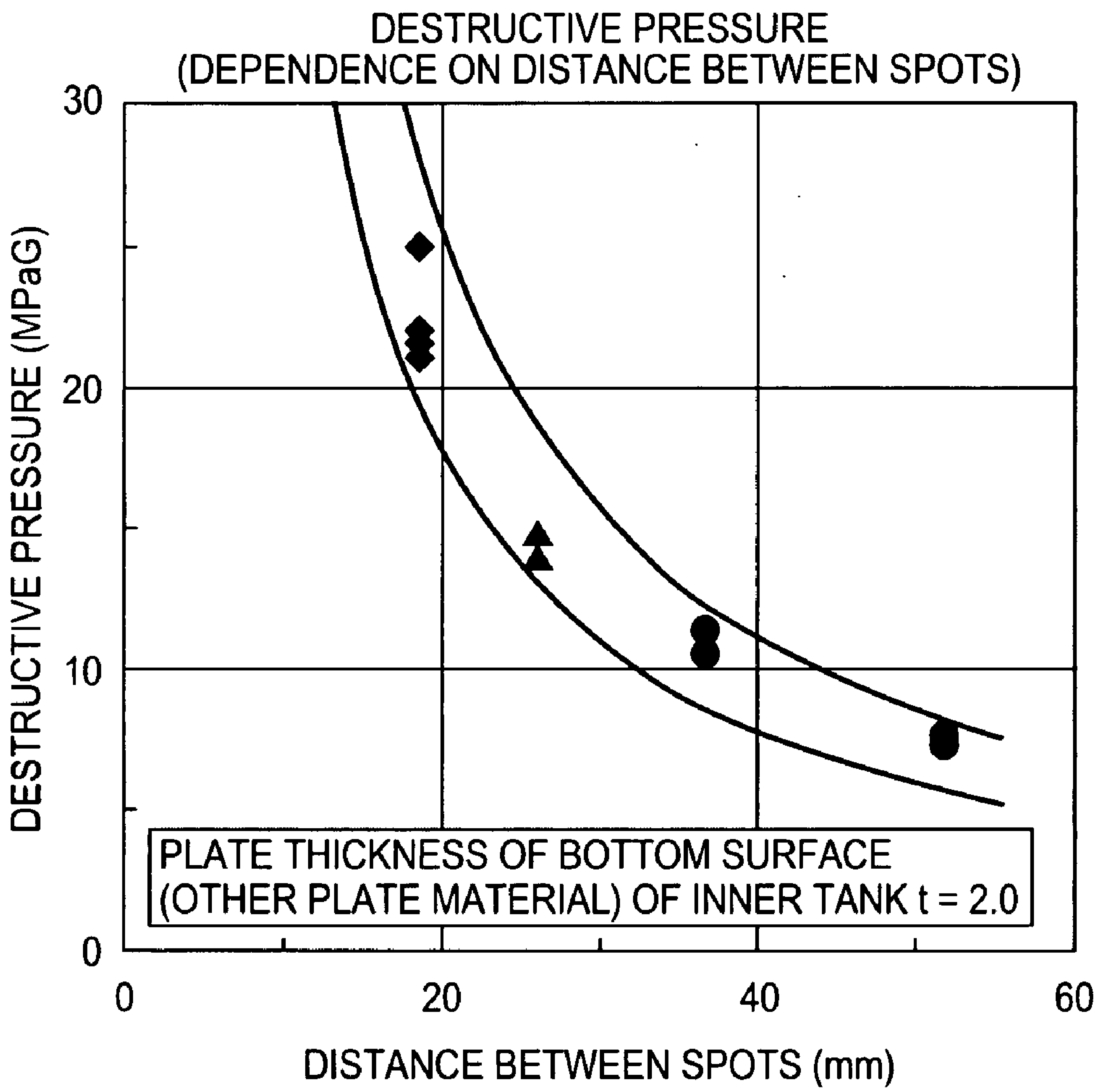

FLOW OF REFRIGERANT
316B
378
378
378
377
316B
370
376
370B
378
378
316B
378
316A
SEAM-WELD WHOLE PERIPHERY OF PERIPHERAL PORTION OF OUTER PLATE
316A
316A
316A
316B
FLOW OF REFRIGERANT

FIG. 7


DESTRUCTIVE PRESSURE
(DEPENDENCE ON DISTANCE BETWEEN SPOTS)
DESTRUCTIVE PRESSURE (MPaG)
30
20
10
0
0
20
40
60
DISTANCE BETWEEN SPOTS (mm)
PLATE THICKNESS OF BOTTOM SURFACE
(OTHER PLATE MATERIAL) OF INNER TANK t = 2.0

HEAT EXCHANGER AND REFRIGERATION CYCLE DEVICE USING THE SAME

BACKGROUND OF THE INVENTION

[0001] The present invention relates to a heat exchanger. The present invention more particularly relates to a heat exchanger for use in a refrigeration cycle (vapor-compression refrigeration cycle) device in which a refrigerant circuit including a compressor, a condenser (or gas cooler or condensing heat exchanger or gas cooling heat exchanger), a throttling means and an evaporator is constituted and in which carbon dioxide is introduced as a refrigerant, and a refrigeration cycle device using the heat exchanger.

[0002] Heretofore, in a refrigeration cycle device in which a refrigerant circuit including a compressor, a condenser, a throttling means and an evaporator is constituted, a fluorocarbon-based refrigerant has broadly been used. However, in recent years, this type of refrigerant cannot be used owing to global environment problems such as prevention of ozone layer destruction and prevention of global warming, and attempts to use carbon dioxide as the refrigerant instead of the fluorocarbon-based refrigerant have been made.

[0003] In a refrigeration cycle device in which a carbon dioxide refrigerant is used, a pressure of the refrigerant circuit remarkably increases as compared with a case where the conventional fluorocarbon-based refrigerant is used. Therefore, as each unit (the compressor, the condenser, the throttling means, the evaporator and the like) constituting the refrigerant circuit, a unit capable of bearing such a high pressure needs to be used. On the other hand, a theoretical coefficient of performance of the carbon dioxide refrigerant in the refrigerant circuit is remarkably lower than that of the conventional fluorocarbon-based refrigerant. Therefore, a heat exchanger having a high thermal performance is demanded (see, e.g., Japanese Patent Application Laid-Open No. **2005-37054**).

[0004] However, to bear such a high pressure of the carbon dioxide refrigerant, a thickness of each member constituting the heat exchanger needs to be increased, but this causes a problem of an increasing thermal conduction loss. Especially, in a case where the heat exchanger is constituted of an evaporator to cool an object to be cooled stored in a cooling vessel from the outside of the cooling vessel, it has been difficult for such a structure of the heat exchanger to bear the high pressure of the carbon dioxide refrigerant and secure the high thermal performance. That is, when the member constituting the evaporator is thickened so as to bear the high pressure of the carbon dioxide refrigerant, the thermal conduction loss further increases. As a result, a problem occurs that the thermal performance remarkably deteriorates as compared with the evaporator in which the conventional refrigerant is used.

[0005] Moreover, as another method of securing a high pressure resistance, it is considered that a round tube formed so as to have an excellent strength is used as a refrigerant passage of the evaporator. However, in a portion where the round tube comes into contact with the cooling vessel in which the object to be cooled is stored, a contact heat resistance increases. Therefore, such remarkable deterioration of the thermal performance cannot be avoided.

SUMMARY OF THE INVENTION

[0006] Therefore, the present invention has been developed to solve a problem of such a conventional technology, and an object thereof is to improve a pressure resistance and a thermal performance of a heat exchanger and to provide the heat exchanger suitable for use in a refrigeration cycle device in which carbon dioxide is used as a refrigerant.

[0007] A heat exchanger of a first invention is characterized by comprising: a pair of plate materials, the whole periphery of a peripheral portion of at least one of the plate materials is secured to the other plate material to constitute a sealed refrigerant passage space between the plate materials, a portion of the one plate material other than the peripheral portion is provided with a plurality of secured inner portions which are secured at predetermined intervals to the other plate material, and a plurality of refrigerant inlet tubes and refrigerant outlet tubes are attached so as to communicate with the refrigerant passage space.

[0008] Moreover, the heat exchanger of a second invention is characterized in that in the above invention, the secured inner portions are arranged at the predetermined intervals in a checkered form or a zigzag form.

[0009] The heat exchanger of a third invention is characterized in that in the above inventions, the refrigerant inlet tubes communicate with the refrigerant passage space in the center of the refrigerant passage space, and the refrigerant outlet tubes communicate with the refrigerant passage space in a peripheral portion of the refrigerant passage space.

[0010] A refrigeration cycle device of a fourth invention is characterized in that a refrigerant circuit including a compressor, a condenser, a throttling means and an evaporator is constituted, the heat exchanger according to any one of the first to third inventions is used as the evaporator, carbon dioxide is introduced as a refrigerant, and a supercritical pressure is obtained on a high-pressure side.

[0011] The refrigeration cycle device of a fifth invention is characterized in that in the fourth invention, the surface of the other plate material opposite to the one plate material constitutes a wall surface of a predetermined space to be cooled, and the surface of the one plate material opposite to the other plate material is provided with a predetermined insulation structure.

[0012] According to the present invention, the heat exchanger comprises a pair of plate materials. The whole periphery of the peripheral portion of at least one of the plate materials is secured to the other plate material to constitute the sealed refrigerant passage space between the plate materials. Moreover, the portion of the one plate material other than the peripheral portion is provided with the plurality of secured inner portions which are secured at the predetermined intervals to the other plate material. Therefore, for example, after the whole periphery of the peripheral portion of the one plate material is secured to the other plate material, a pressure is applied between the plate materials. In consequence, the refrigerant passage space is swelled and formed between the plate materials. Therefore, where a pressure resistance of the heat exchanger is secured, a thermal performance of the refrigerant can be improved.

[0013] Moreover, since the plurality of refrigerant inlet tubes and refrigerant outlet tubes are attached so as to communicate with the refrigerant passage space, pressure losses of the refrigerant at an inlet and an outlet of the heat exchanger can be reduced while securing the pressure resistance of portions of the heat exchanger bonded to the refrigerant inlet tubes and the refrigerant outlet tubes.

[0014] Furthermore, when the secured inner portions are arranged at the predetermined intervals in the checkered form or the zigzag form, the pressure resistance of the heat exchanger can be improved without increasing thicknesses of the one plate material and the other plate material.

[0015] In addition, according to the present invention, the refrigerant inlet tubes communicate with the refrigerant passage space in the center of the refrigerant passage space, and the refrigerant outlet tubes communicate with the refrigerant passage space in the peripheral portion of the refrigerant passage space. Therefore, since the refrigerant entering the refrigerant passage space from the center flows so as to spread to the peripheral portion, the refrigerant obtains a satisfactory diversion property. Stagnation of the refrigerant in the heat exchanger can be prevented or eliminated as much as possible.

[0016] Since the heat exchanger of the present invention has an excellent pressure resistance, the heat exchanger can be used as the evaporator of the refrigeration cycle device in which carbon dioxide is introduced as the refrigerant. In consequence, it is possible to improve a performance of the refrigeration cycle device in which the carbon dioxide refrigerant is used.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] FIG. **1** is a schematic constitution diagram of a refrigeration cycle device of one embodiment to which the present invention is applied;

[0018] FIG. **2** is a sectional view showing a schematic structure of a cooling vessel;

[0019] FIG. **3** is a sectional view showing a schematic structure of an evaporator formed integrally with the cooling vessel;

[0020] FIG. **4** is a schematic constitution diagram of the evaporator;

[0021] FIG. **5** is a schematic constitution diagram of a refrigeration cycle device according to another embodiment of the present invention;

[0022] FIG. **6** is a schematic constitution diagram of an evaporator according to another embodiment of the present invention; and

[0023] FIG. **7** is a diagram showing one example of a result of a destructive pressure test.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0024] Embodiments of a heat exchanger of the present invention and a refrigeration cycle device including the heat exchanger will hereinafter be described in detail with reference to the drawings.

Embodiment 1

[0025] A refrigeration cycle device of the present embodiment is one example applied to a device which cools and insulates milk immediately after drawn until the milk is shipped. FIG. **1** is a schematic constitution diagram of the refrigeration cycle device of one embodiment to which the present invention is applied. A refrigeration cycle device **1** of the present embodiment is provided with a refrigerant circuit **2** constituted by connecting a compressor **10**, a condenser (condensing heat exchanger or gas cooler or gas cooling heat exchanger) **11**, an expansion valve **14** as a throttling means and an evaporator **16** in an annular form via pipes so as to form a closed circuit. That is, a high-pressure refrigerant pipe **40** connected to the compressor **10** on a discharge side is connected to an inlet of the condenser **11**. The condenser **11** is a heat exchanger which performs heat exchange between a refrigerant and a heat medium to release heat of the refrigerant to the heat medium. It is assumed in the present embodiment that air is used as the heat medium and that the heat exchange between air blown by a fan **11**F and the refrigerant is performed.

[0026] Moreover, a refrigerant pipe **41** connected to an outlet of the condenser **11** is connected to an inlet of the expansion valve **14**. The expansion valve **14** is the throttling means to reduce a pressure of the refrigerant which has rejected (transferred) the heat in the condenser **11**, and a refrigerant pipe **42** connected to an outlet of the expansion valve **14** is connected to an inlet of the evaporator **16**. Moreover, an outlet of the evaporator **16** is connected to one end of a suction pipe **45**, and the other end of the suction pipe **45** is connected to the compressor **10** on a low-pressure side (a suction portion). Along the suction pipe **45** which connects the evaporator **16** to the compressor **10** on the low-pressure side, an accumulator **17** is interposed which protects the compressor from a disadvantage that a liquid refrigerant is sucked into the compressor **10** to damage the compressor or the like. Furthermore, between the evaporator **16** of the suction pipe **45** and the accumulator **17**, a check valve **18** is disposed in which a compressor **10** side (an accumulator **17** side) is a forward direction in order to prevent a disadvantage that the refrigerant flows back to the evaporator **16** from the refrigerant circuit **2** on a high-pressure side.

[0027] Furthermore, a discharge temperature sensor T**1** which detects a temperature of the high-temperature high-pressure refrigerant discharged from the compressor **10** is disposed at the high-pressure refrigerant pipe **40**. An evaporation temperature sensor T**5** which detects an evaporation temperature of the refrigerant in the evaporator **16** is disposed at the evaporator **16** or the refrigerant pipe **42**. Furthermore, a sucked refrigerant temperature sensor T**7** which detects a temperature of the refrigerant entering the compressor **10** from the evaporator **16** is disposed at the suction pipe **45**.

[0028] In addition, carbon dioxide which is a natural refrigerant is introduced as the refrigerant in the refrigerant circuit **2**. Since the pressure of the refrigerant circuit **2** on the high-pressure side rises in excess of a critical pressure, the refrigerant cycle is a trans-critical cycle. As a lubricant of the compressor **10**, for example, mineral oil, alkyl benzene oil, ether oil, ester oil, polyalkylene glycol (PAG), polyol ether (POE) or the like is used.

[0029] On the other hand, the evaporator **16** is a heat exchanger which cools an object to be cooled (milk in the present embodiment) stored in an inner tank **70** of a cooling vessel **7**, and is formed integrally with this cooling vessel **7**. Here, the cooling vessel **7** of the present embodiment will be described in detail with reference to FIGS. **2** to **4**. FIG. **2** is a sectional view showing a schematic structure of the cooling vessel **7**; FIG. **3** is a sectional view showing a schematic structure of the evaporator **16** formed integrally with the cooling vessel **7**; and FIG. **4** is a schematic constitution diagram of the evaporator **16**, respectively. The cooling vessel **7** is provided with the inner tank **70** having a predetermined space to be cooled in which the object to be cooled (the milk) is stored in an outer tank **72** constituting an outer shell of the cooling vessel **7**. An outer plate (one plate material) **76** constituted of a plate material having a high thermal conductivity is disposed on an outer surface (a bottom surface **70**B in the present embodiment) of the inner tank **70**. The whole periphery of a peripheral portion of the outer plate **76** is secured to the other plate material constituting the bottom surface **70**B, and a sealed refrigerant passage space **77** is constituted between the plate materials (the bottom surface **70**B of the inner tank **70** and the outer plate **76**). It is assumed that this space is a refrigerant channel of the evaporator **16** (FIG. **3**).

[**0030**] In this case, the surface of the other plate material (the bottom surface) **70**B opposite to the outer plate (the one plate material) **76** constitutes a wall surface of the predetermined space to be cooled in which the object to be cooled (the milk) is stored, and the surface of the outer plate **76** opposite to the bottom surface **70**B as the other plate material is provided with a predetermined insulation structure. That is, in cooling vessel **7** of the present embodiment, a space between the inner tank **70** including the surface opposite to the bottom surface **70**B of the outer plate **76** and the outer tank **72** is filled with the an insulation material **74** constituted of a foaming material such as urethane. After securing the outer plate **76** to the inner tank **70** and further assembling the outer tank **72** on an outer side of the outer plate, the insulation material **74** is injected into the space between the inner tank **70** and the outer tank **72**.

[**0031**] Moreover, a portion of the outer plate **76** other than the peripheral portion is provided with a plurality of secured inner portions **78** which are secured at predetermined intervals to the bottom surface **70**B (FIGS. **3** and **4**). Specifically, the whole periphery of the peripheral portion of the outer plate **76** is secured to the bottom surface of the inner tank **70** by seam welding, and the portion other than the peripheral portion is secured at predetermined intervals in a checkered form or a zigzag form by spot welding (the portions secured by the spot welding are the secured inner portions **78**).

[**0032**] Here, the refrigerant channel (the refrigerant passage space **77**) of the evaporator **16** is processed by pressurizing. Specifically, after the whole periphery of the peripheral portion of the outer plate **76** and the secured inner portions **78** are secured to a bottom portion of the inner tank **70** as described above, a pressure is applied between the inner tank **70** and the outer plate **76**. In consequence, the refrigerant passage space **77** is expanded and formed between the inner tank **70** and the outer plate **76**. Therefore, portions other than the secured inner portions **78** of the outer plate **76** swell outwards substantially into circular sections (downwards in FIGS. **2** and **3**), and a large number of swelled portions are continuously formed in the checkered form or the zigzag form.

[**0033**] The bottom surface **70**B of the inner tank **70** secured to the outer plate **76** is constituted of a material having a high thermal conductivity in the same manner as in the outer plate **76** so that heat exchange between the refrigerant flowing through the refrigerant channel (the refrigerant passage space **77**) of the evaporator **16** and the object to be cooled (the milk) stored in the inner tank **70** is easily performed. It is preferable that a material of the inner tank **70**, the outer plate **76** and the outer tank **72** is selected in consideration of corrosion, durability and the like. For example, as the material of the inner tank **70**, the outer plate **76** and the outer tank **72**, a stainless steel may be used.

[**0034**] Moreover, as a shape of the cooling vessel **7**, various shapes such as a columnar shape, a horizontally disposed elliptic columnar shape and a rectangular parallelepiped shape are considered, but it is assumed in the present embodiment that the cooling vessel has the horizontally disposed elliptic columnar shape. It has been described in the present embodiment that the outer plate **76** is disposed on the bottom surface **70**B of the inner tank **70** to form the refrigerant channel (the refrigerant passage space **77**) of the evaporator **16** so that the object to be cooled (the milk) can efficiently be cooled, but the outer plate may further be formed on a side surface of the inner tank **70** if necessary. It is to be noted that as not shown in FIG. **2** for the sake of simplicity of the drawing, the cooling vessel **7** is provided with an introduction port **7**A for introducing the object to be cooled (the milk) and a takeout port **7**B for taking out the object to be cooled (the milk) (FIG. **1**).

[**0035**] Furthermore, a plurality of refrigerant inlet tubes **16**A and refrigerant outlet tubes **16**B are attached to the refrigerant passage space **77** (the refrigerant channel of the evaporator **16**) formed between the bottom surface **70**B of the inner tank **70** and the outer plate **76** so that the tubes communicate with the refrigerant passage space **77**. The refrigerant inlet tubes **16**A allow the refrigerant to enter the evaporator **16** (the refrigerant passage space **77**), and one end of each refrigerant inlet tube is connected to the refrigerant passage space **577**. The other end of the refrigerant inlet tube **16**A is connected to the refrigerant pipe **42** so that the refrigerant is branched from the refrigerant pipe **42** to the refrigerant passage space **77**. The refrigerant outlet tubes **16**B discharge the refrigerant from the evaporator **16** (the refrigerant passage space **77**), and one end of each refrigerant outlet tube is connected to the refrigerant passage space **77**. The other end of the refrigerant outlet tubes **16**B is connected to the suction pipe **45** so as to combine the refrigerant from the refrigerant outlet tubes **16**B.

[**0036**] In the cooling vessel **7** of the present embodiment, the inner tank **70** has a plate thickness of 2 mm, and the outer plate **76** has a plate thickness of 1 mm. Each of the spot-welded portions (secured inner portions **78**) has a diameter of 6 mm, and it is preferable to set a spot pitch (an interval from the center of a certain secured inner portion **78** to the center of another secured inner portion **78** adjacent to the certain secured inner portion **78**) to 20 mm or less so as to bear use of the carbon dioxide refrigerant. A specific method of determining the spot pitch will be described later. In the present embodiment, the spot pitch is set to 18.5 mm. It is preferable that an outer diameter of each of the refrigerant inlet tube **16**A and the refrigerant outlet tube **16**B is ½ or less of the spot pitch in order to prevent deterioration of strength of a tube bonding portion. In the present embodiment, the outer diameter is set to ϕ6.35 mm (¼ inch), and the plate thickness is set to 1.0 mm.

[0037] Moreover, in the present embodiment, as shown in FIG. **4**, the refrigerant passage space **77** is constituted of two parallel refrigerant channels obtained by dividing a region into two regions at the center by seam welding. That is, the vicinity of the center of the outer plate **76** is secured to the bottom surface **70**B of the inner tank **70** by the seam welding so that the refrigerant passage space **77** formed by securing the whole periphery of the peripheral portion of the outer plate **76** to the bottom surface **70**B of the inner tank **70** by the seam welding as described above is divided into two independent regions (two upper and lower regions in FIG. **4**). In consequence, the refrigerant passage space **77** is formed into two parallel refrigerant passages, and the refrigerant from the refrigerant pipe **42** is branched via the refrigerant inlet tubes **16**A to enter the refrigerant passages.

[0038] It is to be noted that the refrigerant passage space **77** constituting the refrigerant channels of the evaporator **16** is divided by the seam welding and can arbitrarily be constituted. In the present embodiment, the region is divided in the vicinity of the center to form the refrigerant passage space into two paths (two refrigerant passages). However, the region may constitute one path without being divided as in the present embodiment. As another method, the region may finely be divided to constitute three, four or more paths. Furthermore, the refrigerant passage may be formed into a meandering form or a spiral form by the seam welding.

[0039] Next, a processing method of the evaporator **16** will be described in detail. First, a flat plate material as a material of the inner tank **70** is pressed and cut into a predetermined size. Similarly, a flat plate material as a material of the outer plate **76** is pressed and cut into a predetermined size.

[0040] Next, a plurality of holes are processed beforehand in the outer plate **76**, the holes constituting refrigerant inlets to be connected to the refrigerant inlet tubes **16**A and refrigerant outlets to be connected to the refrigerant outlet tubes **16**B. The outer plates **76** are superimposed upon a position where the bottom surface **70**B of the plate material of the inner tank is to be formed. The outer plate **76** is secured by the spot welding with spots made at the predetermined intervals in the checkered form and zigzag form. In consequence, the outer plate **76** is provided with the plurality of secured inner portions **78** secured at the predetermined intervals to the plate material constituting a bottom portion of the inner tank **70**. Subsequently, the whole periphery of the peripheral portion of the outer plate **76** is secured to the bottom portion of the inner tank **70** by the seam welding, and further secured by the seam welding so as to form predetermined refrigerant passages as needed. In the present embodiment, as described above, the vicinity of the center of the outer plate **76** is secured to the plate material constituting the bottom surface **70**B of the inner tank **70** by the seam welding to form two parallel refrigerant passages.

[0041] Next, the plate material of the inner tank **70** to which the outer plate **76** is attached is formed into such a predetermined shape to form the inner tank **70** by roll processing or press processing. In the present embodiment, since the inner tank has a horizontally disposed elliptic columnar shape as described above, the flat plate material is rolled and bent by the roll processing. Subsequently, the material is welded and bonded to another member processed into a predetermined shape to form the inner tank **70**.

[0042] One end of each of the refrigerant inlet tubes **16**A and refrigerant outlet tubes **16**B is welded and bonded to each of the plurality of refrigerant inlet and outlet holes made beforehand in the outer plate **76** attached to the inner tank **70** processed into a predetermined tank shape as described above. Secured inner portions **78**P closest to bonded portions of these refrigerant inlet tubes **16**A and refrigerant outlet tubes **16**B are again welded from an outer plate **76** side to reinforce the tank.

[0043] It is to be noted that the refrigerant inlet tubes **16**A or the refrigerant outlet tubes **16**B are substantially bonded between the spots welded at the predetermined intervals in the checkered form or the zigzag form. Therefore, four secured inner portions **78**P for reinforcing the tank as described above are disposed for each of the refrigerant inlet tubes **16**A or the refrigerant outlet tubes **16**B (FIG. **4**).

[0044] Subsequently, a pressurizing fluid is injected from the refrigerant inlet tubes **16**A or the refrigerant outlet tubes **16**B to apply a pressure to a space formed between the inner tank **70** and the outer plate **76**. In consequence, the portion of the outer plate **76** other than the secured inner portions **78** is deformed outwards into a substantially circular sectional shape to form the refrigerant passage space **77**. Here, in a case where a plurality of (two paths in the present embodiment) refrigerant passages of the evaporator **16** are formed as in the present embodiment, it is preferable to simultaneously apply the pressures to all of the refrigerant passages in order to prevent deviating deformation.

[0045] It is to be noted that it has been described in the present embodiment that the inner tank **70** is secured to the outer plate **76** by the spot welding and the seam welding, but a securing method is not limited to this example. The securing can be performed by another method such as laser welding.

[0046] On the other hand, an introduction pipe (not shown) is detachably connected to the introduction port **7**A of the cooling vessel **7** into which the object to be cooled (the milk) is introduced via an introduction port valve. Similarly, a takeout pipe for taking out the milk is detachably connected to the takeout port **7**B via a takeout valve. Moreover, the introduction pipe is attached to the introduction port **7**A in an only case where the object to be cooled (the milk) is introduced into the inner tank **70** of the cooling vessel **7**. In another case, the pipe is detached from the introduction port **7**A, and the introduction port **7**A is hermetically closed. Similarly, the takeout pipe is attached to the takeout port **7**B in an only case where the object to be cooled (the milk) is taken out of the inner tank **70** of the cooling vessel **7**. In another case, the pipe is detached from the takeout port **7**B, and the takeout port **7**B is hermetically closed.

[0047] Moreover, the cooled object temperature sensor T**5** for detecting the temperature of the object to be cooled (the milk) is attached to the outer peripheral surface of the inner tank **70** of the cooling vessel **7**. Furthermore, the cooling vessel **7** is provided with a stirrer (not shown) which stirs the object to be cooled (the milk) in order to promote heat conduction during cooling, reduce temperature unevenness of the object to be cooled (the milk) stored in the inner tank **70** and perform correct temperature measurement.

[0048] Next, an operation of the refrigeration cycle device **1** of the present embodiment constituted as described above will be described.

[0049] (1) Operation During Cooling Operation

[0050] First, an operation to cool the milk as the object to be cooled during a cooling operation will be described. A milking pipeline connected to a milking machine (not shown) is connected to the introduction port 7A of the cooling vessel 7 via an introduction pipe (not shown), the introduction port valve is opened, and the milk immediately after drawn is introduced into the cooling vessel 7. At this time, the takeout valve is completely closed, and the takeout port 7B is also hermetically closed. A temperature of the milk immediately after drawn is substantially equal to or slightly lower than a body temperature of a cow, and is specifically in a range of about 35° C. to 38° C. Then, the refrigerant circuit 2 is operated to cool and insulate the milk for the purpose of preventing generation of bacteria and maintaining a quality of the milk.

[0051] After starting the milking (after starting the introduction of the milk), the compressor 10 of the refrigerant circuit 2 is driven, and the stirrer (not shown) is simultaneously driven. Usually, it is assumed that after a predetermined amount of milk is stored in the cooling vessel 7, the compressor 10 is driven to start the cooling operation. However, the cooling operation may be started simultaneously with the start of the introduction of the milk or before the introduction of the milk as long as careful consideration is given so as to prevent freezing and idling of the stirrer is prevented.

[0052] When the compressor 10 is driven, a low-temperature low-pressure refrigerant gas is sucked and compressed on the low-pressure side (the suction portion) of the compressor 10 from the suction pipe 45. In consequence, the refrigerant gas which has obtained a high temperature and a high pressure enters the high-pressure refrigerant pipe 40 from the discharge side, and is discharged from the compressor 10. At this time, the refrigerant is compressed under an appropriate supercritical pressure.

[0053] The high-temperature high-pressure refrigerant discharged from the compressor 10 enters the condenser 11 via the high-pressure refrigerant pipe 40. Here, the refrigerant releases the heat to air, and is cooled at a low temperature by ventilation of the fan 11F. At this time, since the pressure of the refrigerant is not less than a supercritical pressure in the condenser 11, the refrigerant is not condensed. Therefore, the temperature of the refrigerant gradually lowers from the inlet toward the outlet of the condenser 11 as the heat is rejected to the air. Moreover, at the outlet of the condenser 11, the refrigerant is brought into a liquid-phase state usually having the pressure which is not less than the critical pressure (or above the critical pressure).

[0054] Moreover, the low-temperature high-pressure refrigerant discharged from the condenser 11 passes through the refrigerant pipe 41. The pressure of the refrigerant is reduced by the expansion valve 14. The refrigerant expands to obtain a low pressure, is then branched to flow through the refrigerant inlet tubes 16A via the refrigerant pipe 42, and reaches the evaporator 16. It is to be noted that the refrigerant at the inlet of the evaporator 16 has a two-phase mixed state in which the liquid refrigerant is mixed with a vapor refrigerant. Moreover, when the liquid-phase refrigerant absorbs the heat from the milk as the object to be cooled in the evaporator 16, the refrigerant evaporates to form the vapor refrigerant. At this time, the milk is cooled by the heat absorption.

[0055] Furthermore, the refrigerant evaporated in the evaporator 16 repeats a cycle of exiting from the evaporator 16 via the refrigerant outlet tubes 16B to combine and enter the suction pipe 45 and being again sucked from the low-pressure side to the compressor 10 via the check valve 18 and the accumulator 17. When the above cycle is repeated, the milk is cooled by the heat absorption of the refrigerant in the evaporator 16.

[0056] When the milking is completed, the introduction of the milk into the cooling vessel 7 is completed. However, the above cooling operation is continued until the milk reaches a predetermined temperature. Here, the temperature of the milk is detected by the cooled object temperature sensor T5 attached to the outer peripheral surface of the inner tank 70. The predetermined temperature at which the cooling operation ends is set from a viewpoint that the generation of the bacteria in the milk be inhibited and the quality be maintained, and is specifically about 4° C.

[0057] Furthermore, during the cooling operation, an open degree of the expansion valve 14 is adjusted so that a difference between the temperature of the refrigerant entering the compressor 10 from the evaporator 16 detected by the sucked refrigerant temperature sensor T7 disposed at the suction pipe 45 of the refrigerant circuit 2 and the evaporation temperature of the refrigerant detected by the evaporation temperature sensor T6 disposed at the evaporator 16 or the refrigerant pipe 42, that is, a so-called superheat degree indicates a predetermined value. That is, when the superheat degree is larger than the predetermined value, the open degree of the expansion valve 14 is enlarged. Conversely, when the superheat degree is smaller than the predetermined value, the open degree of the expansion valve 14 is reduced.

[0058] It is to be noted that the compressor 10 during the cooling operation may have the constant number of rotations. Alternatively, a frequency may be adjusted by an inverter or the like. In the present embodiment, a required cooling capacity is calculated from a change of the temperature of the milk with time, the temperature being detected by the cooled object temperature sensor T5 attached to the outer peripheral surface of the inner tank 70, and the number of the rotations of the compressor 10 is controlled so as to obtain the operation frequency according to the calculation result. In consequence, a cooling efficiency can be improved.

[0059] Here, the above control will be described in detail. As described above, the predetermined temperature at which the milk is cooled in the cooling vessel 7 is determined from a viewpoint of the maintenance of the quality of the milk as the object to be cooled. For a similar reason, a required time for cooling the milk at the predetermined temperature is determined. Since a cow farming scale differs with a farm, a device to cool the milk is selected in accordance with each farming scale so as to complete the cooling at the predetermined temperature within a predetermined time. However, since a milking amount fluctuates even in the same farm daily, milk quality control is usually prioritized, and the refrigeration cycle device having a sufficiently large cooling capacity is used. Therefore, when the number of the rotations of the device during the cooling operation is set to be constant, an excessively large cooling capacity is required during an actual cooling operation, and the operation cannot necessarily be said to be efficient.

[0060] To solve the problem, in the present embodiment, a cooling speed is calculated from the change of the temperature of the milk with time, detected by the cooled object temperature sensor T5 attached to the outer portion of the inner tank **70** as described above. The number of the rotations of the compressor **10** is adjusted so as to complete the cooling operation within a preset required cooling time, and the cooling capacity is controlled. That is, according to a calculation result, in a case where it is judged that a small amount of the milk is to be cooled and that the cooling at the predetermined temperature is completed within a time which is shorter than the predetermined required time, control is executed so as to reduce the number of the rotations of the compressor **10**. In consequence, the evaporation temperature can be raised, and the efficiency can be improved. Therefore, while a predetermined cooling capacity is satisfied and the quality of the milk is secured, energy consumption during the cooling operation can be reduced.

[0061] It is to be noted that the operation at a frequency at which the highest efficiency is obtained may be prioritized in consideration of the operation efficiency of the compressor **10**, a conversion efficiency of the inverter and the like. In this case, the cooling operation is sometimes completed within the time shorter than the predetermined required time on conditions that the amount of the milk is sufficiently small.

[0062] As described above, during the cooling operation of the refrigeration cycle device **1** of the present embodiment, when the milk immediately after drawn is introduced into the cooling vessel **7**, the milk can be cooled at the predetermined temperature in order to maintain the quality of the milk.

[0063] (2) Operation During Cold Insulating Operation

[0064] When the temperature of the milk reaches the predetermined value during the above cooling operation, the compressor **10** is stopped, the expansion valve **14** is completely closed and the stirrer (not shown) is stopped to end the cooling operation, and a cold insulating operation of the milk stored in the cooling vessel **7** is performed. In this case, the cooling vessel **7** is insulated by the insulation material **74** as described above, but the temperature of the milk rises owing to the heat entering from the outside during storage for a long time.

[0065] To solve the problem, even when the compressor **10** and the like are stopped during the cold insulating operation, the milk temperature sensor T5 continuously detects the temperature of the milk stored in the cooling vessel **7** (this state will hereinafter be referred to as a standby state). When the milk temperature reaches the predetermined value or more, the cooling operation is started again to cool the milk. Moreover, when the milk is cooled at the predetermined temperature by the cooling operation during the cold insulating operation, the cooling operation is stopped, and the device is brought into the standby state again. The predetermined temperature at which the cooling operation is started during the cold insulating operation is specifically about 4.5° C., and the predetermined temperature at which the cooling operation is stopped is about 4° C.

[0066] Moreover, the expansion valve **14** is completely closed in the standby state in order to prevent a refrigerant backflow from the high-pressure side of the refrigerant circuit **2** to the evaporator **16** and suppress the incoming heat into the milk as the object to be cooled in combination with the function of the check valve **18** disposed between the evaporator **16** and the accumulator **17** along the suction pipe **45**. It is to be noted that even in a case where a block valve or the like is disposed at the suction pipe **45** instead of the check valve **18** or at the refrigerant pipe **42** or **41** instead of the expansion valve **14** and the block valve is closed in the standby state during the cold insulating operation, a similar effect can be obtained.

[0067] Here, it is assumed that the stirrer is driven intermittently at a constant interval in the standby state during the cold insulating operation. It is assumed that a stirring operation is performed for, for example, two minutes at an interval of 30 minutes. The stirrer is intermittently driven in this manner in order to prevent a disadvantage that a temperature distribution is stratificationally generated in the cooling vessel **7** owing to a temperature difference of the milk during cold storage for a long time and that correct temperature measurement cannot be performed.

[0068] Since an operation of the refrigerant circuit **2** is similar to the above cooling operation during the milking, detailed description is omitted here. It is assumed that during the cold insulating operation, the compressor **10** is controlled to operate with the number of the rotations with the best efficiency irrespective of the amount of the milk.

[0069] (3) Operation Patterns of Cooling Operation and Cold Insulating Operation in General Farm

[0070] The cooling operation and the cold insulating operation of the introduced milk during the milking have been described above. Next, operation patterns of the cooling operation and the cold insulating operation in a general farm will be described.

[0071] In the general farm, the milking is performed about twice or three times a day. During and after the second milking, the milk immediately after drawn is additionally introduced into the cooling vessel **7** in which the cooled and insulated milk is stored. As a result, since the milk temperature in the cooling vessel **7** rises, the cooling operation is started. When the temperature reaches the predetermined temperature, the cooling operation is stopped to perform the cold insulating operation as described above.

[0072] Moreover, there is a case where the milk is taken out of the cooling vessel **7** (milk cargo collection) every day or every other day. Therefore, from the first milking till the milk cargo collection, the cooling operation and the cold insulating operation of the introduced milk are repeatedly performed twice to six times.

[0073] (4) Regarding Refrigerant Inlet Tubes **16**A and Refrigerant Outlet Tubes **16**B

[0074] Next, a relation between sizes and spot pitches of the refrigerant inlet tubes **16**A and refrigerant outlet tubes **16**B, and a relation between the number of the refrigerant inlet tubes **16**A and the refrigerant outlet tubes **16**B and the capacity of the cooling vessel **7** will be described in more detail.

[0075] Since carbon dioxide is used as the refrigerant in the refrigerant circuit **2** of the present embodiment, the refrigerant pressure in the evaporator **16** during the cooling operation is as high as about 3 MPa to 5 MPa as compared with a conventional fluorocarbon-based refrigerant. Therefore, a pressure resistance in excess of at least 20 MPa is considered to be necessary in consideration of safety during the operation of the compressor **10**. Furthermore, it is preferable to secure a pressure resistance of about 25 MPa or more in consideration of a pressure rise during stopping of the compressor **10**.

[0076] Especially, the pressure resistances of the bonded portions of the refrigerant inlet tubes **16**A and the refrigerant outlet tubes **16**B of the evaporator **16** differ with outer dimensions and the spot pitches of the refrigerant inlet tubes **16**A and the refrigerant outlet tubes **16**B. Therefore, the dimensions and the spot pitches need to be set so that the pressure resistance suitable for the use of carbon dioxide can be secured.

[0077] To solve the pressure, a destructive pressure test was conducted using the evaporator having variously changed spot pitches. FIG. **7** shows one example of a result of the destructive pressure test, the abscissa indicates the spot pitch of each spot welding (an interval between the center of the certain secured inner portion **78** and the center of the secured inner portion **78** adjacent to the certain secured inner portion **78**, i.e., a distance between spots), and the ordinate shows a destructive pressure. According to the test result shown in FIG. **7**, it has been found that the destructive pressure depends on the spot pitch and that, if the spot pitch exceeds 20 mm, it is difficult to secure the pressure resistance of 25 MPa or more. Therefore, it is preferable to set the spot pitch to 20 mm or less. In the present embodiment, the spot pitch is set to 18.5 mm as described above.

[0078] However, here, it has been found that, when a tube having a dimension (especially, an outer diameter) substantially equal to that of the refrigerant pipe **42** or the suction pipe **45** is used as the refrigerant inlet tubes **16**A and the refrigerant outlet tubes **16**B as in a conventional example, the pressure resistances of the bonded portions of the refrigerant inlet tubes **16**A and the refrigerant outlet tubes **16**B remarkably deteriorate owing to the heat during the welding. Then, the destructive pressure test was performed on conditions that shapes and tube dimensions of the refrigerant inlet tubes **16**A and the refrigerant outlet tubes **16**B were changed. It has been found that, when the outer diameter of each of the refrigerant inlet tubes **16**A and the refrigerant outlet tubes **16**B is set to be ½ or less of the spot pitch, deterioration of strength of each bonded portion of the tubes **16**A, **16**B can be prevented. Therefore, it is assumed in the present embodiment that as the refrigerant inlet tubes **16**A and the refrigerant outlet tubes **16**B, the pipe having an outer diameter of ϕ6.35 mm (¼ inch) and a plate thickness of 1.0 mm is used.

[0079] Furthermore, even in a case where the refrigerant inlet tubes **16**A and the refrigerant outlet tubes **16**B each having an outer diameter smaller than that of the refrigerant pipe **42** or the suction pipe **45** are used, when one refrigerant inlet tube **16**A and one refrigerant outlet tube **16**B are connected to one refrigerant passage of the evaporator as in a conventional case, pressure losses of the refrigerant at the refrigerant inlet and outlet of the evaporator **16** increase. This has incurred the deterioration of the efficiently of the refrigeration cycle device **1**.

[0080] To solve the problem, as a result of investigation of the number of the refrigerant inlet tubes **16**A, the number of the refrigerant outlet tubes **16**B and the capacity of the cooling vessel **7**, it has been concluded that it is possible to secure the numbers of the refrigerant inlet tubes **16**A and the refrigerant outlet tubes **16**B, which are not less than at least a value obtained by the following equation (1):

$$NT=6.5\times10^{-3}\times V/N \qquad \text{Equation (1),}$$

in which NT is the number (tubes) of the refrigerant inlet tubes **16**A or the refrigerant outlet tubes **16**B of the evaporator **16**, V is a rated capacity (L) of the cooling vessel **7** and N is the number of times of milking every cargo collection.

[0081] Since the evaporator **16** of the present invention performs heat exchange between the object to be cooled (the milk) and the refrigerant via the only inner tank **70**, a thermal performance of the refrigerant improves, and a temperature difference between the object to be cooled (the milk) and the refrigerant can remarkably be reduced. As a result, it is possible to obtain an effect that the evaporation temperature and an evaporation pressure increase and that the efficiency of the refrigeration cycle device **1** improves. However, if the number of the refrigerant inlet tubes **16**A or the refrigerant outlet tubes **16**B is smaller than that obtained by Equation (1), the pressure losses of the refrigerant at the inlet and the outlet of the evaporator **16** increases, and the efficiency deteriorates. Therefore, the above excellent effect of the thermal performance is offset.

[0082] That is, when the pressure losses of the refrigerant in the evaporator **16** increase, a suction pressure of the compressor **10** drops, and an amount (a refrigerant circulation amount) of the refrigerant to be circulated through the refrigerant circuit **2** decreases. Therefore, a disadvantage occurs that the cooling capacity of the evaporator **16** deteriorates, a pressure difference of the compressor **10** further increases, and the efficiency of the refrigeration cycle device **1** deteriorates.

[0083] In the present embodiment, the cooling vessel **7** having a rated capacity of 1150 liters is used, and the number of the milking times per cargo collection is twice. Therefore, NT (the number of the refrigerant inlet tubes **16**A or the refrigerant outlet tubes **16**B) calculated from Equation (1) is 3.7, and four refrigerant inlet tubes **16**A and four refrigerant outlet tubes **16**B of the evaporator **16** are used. It is to be noted that in the present embodiment, the evaporator **16** has two paths of the refrigerant passages as described above. Therefore, the refrigerant from the refrigerant pipe **42** is branched through the four refrigerant inlet tubes **16**A, and the refrigerant enters either of two refrigerant passages of the evaporator **16** from each refrigerant inlet tube **16**A. In consequence, two refrigerant inlet tubes **16**A are connected to one refrigerant passage, and two refrigerant outlet tubes **16**B are similarly connected to the passage.

[0084] Next, a flow of the refrigerant in one refrigerant passage of the evaporator **16** will be described. The refrigerant entering one refrigerant passage of the evaporator **16** from two refrigerant inlet tubes **16**A is combined in the one refrigerant passage, absorbs the heat by the heat exchange between the refrigerant and the object to be cooled (the milk), evaporates, is then branched into two flows to enter the refrigerant outlet tubes **16**B, exits from the evaporator **16**, and is then combined to flow through the suction pipe **45**.

[0085] Next, an area of the outer plate **76** will be described. Since the refrigerant passage space **77** constituted between the inner tank **70** and the outer plate **76** is the refrigerant passage of the evaporator **16** as described above, it is considered that the area of the outer plate **76** is substantially equal to a heat conduction area of the evaporator **16**. Therefore, the area of the outer plate **76** should be determined in consideration of a required cooling capacity in accordance with the capacity of the cooling vessel **7** (the inner tank **70**). Specifically, it is preferable to set the area to be not less than an area obtained by Equation (2):

$$A=2\times10^{-3}\times V/N \qquad \text{Equation (2),}$$

in which A is an area (m^2) of the outer plate, V is a rated capacity (L) of the cooling vessel **7**, and N is the number of the milking times every cargo collection.

[0086] When the area of the outer plate **76** is set to be smaller than the value calculated by Equation (2), a temperature difference between the object to be cooled and the refrigerant in the evaporator **16**, and the evaporation pressure drops. As a result, the cooling capacity and the efficiency deteriorate, and an highly efficient cooling operation cannot be performed.

[0087] It is to be noted that, needless to say, the area of the outer plate, that is, the heat conduction area can easily be secured, depending on the shape of the cooling vessel (the inner tank). In this case, the outer plate having an area larger than the value obtained by Equation (2) may be used. In the present embodiment, as described above, the cooling vessel **7** having a rated capacity of 1150 liters is used, and the number of the milking times per cargo collection is twice. Therefore, A (the area of the outer plate **76**) calculated from Equation (2) is 1.15. However, the area can further be enlarged in consideration of the shape of the inner tank **70** of the present embodiment. Therefore, the area of the outer plate **76** is set to 1.6 m^2.

[0088] As described above in detail, in the present embodiment, the portions of the refrigerant passage space **77** between the inner tank **70** and the outer plate **76** constituting the evaporator **16** are bonded at an interval of 20 mm or less in the checkered form or the zigzag form. Therefore, the pressure resistance of the evaporator **16** can be improved without increasing the plate thicknesses of the inner tank **70** and the outer plate **76**. The outer diameter of the refrigerant inlet tube **16**A which allows the refrigerant to enter the evaporator **16** is set to be smaller than that of the refrigerant pipe **42**, and ½ or less of the spot pitch. The plurality of refrigerant inlet tubes **16**A are connected to the refrigerant passage (the refrigerant passage space **77**) of the evaporator **16**. In consequence, when the refrigerant inlet tubes **16**A are connected to the evaporator **16**, the deterioration of the strength of the bonded portion of the refrigerant inlet tube **16**A due to the welding can be prevented to the utmost. Moreover, the pressure losses of the refrigerant can be reduced.

[0089] Similarly, the outer diameter of the refrigerant outlet tube **16**B which allows the refrigerant to exit from the evaporator **16** is set to be smaller than that of the suction pipe **45**, and ½ or less of the spot pitch. Moreover, the plurality of refrigerant outlet tubes **16**B are connected to the refrigerant passage (the refrigerant passage space **77**) of the evaporator **16**. In consequence, when the refrigerant outlet tubes **16**B are connected to the evaporator **16**, the deterioration of the strength of the bonded portion of the refrigerant outlet tube **16**B due to the welding can be prevented to the utmost. Moreover, the pressure losses of the refrigerant can be reduced.

[0090] Furthermore, since the pressure resistance of the evaporator **16** can be secured without increasing the plate thicknesses of the inner tank **70** and the outer plate **76** constituting the evaporator **16** as described above, the heat exchange between the object to be cooled and the refrigerant flowing through the evaporator **16** is performed via the only inner tank **70**. Therefore, the thermal performance of the evaporator **16** can be improved.

[0091] As a result, the temperature difference between the object to be cooled and the refrigerant during the cooling operation can further be reduced. In consequence, since the evaporation temperature and the evaporation pressure rise and the refrigerant circulation amount of the refrigerant circuit **2** increases, the pressure difference can be reduced. As described above, while the pressure resistance of the heat exchanger (the evaporator **16**) is secured in the refrigeration cycle device using carbon dioxide, the cooling capacity and the efficiency can be improved.

[0092] Embodiment 2

[0093] Next, a refrigeration cycle device of another embodiment to which the present invention is applied will be described. FIG. **5** is a schematic constitution diagram of the refrigeration cycle device of the embodiment to which the present invention is applied. The refrigeration cycle device of the present embodiment cools and insulates milk (an object to be cooled) immediately after drawn in a cooling vessel. Moreover, the device generates hot water by heat obtained by cooling the milk, and uses the hot water in automatic washing of the cooling vessel. It is to be noted that in the following drawing, components denoted with the same reference numerals as those of FIGS. **1** to **4** produce the same or similar function and effect, and detailed description thereof is therefore omitted. A refrigeration cycle device **200** shown in FIG. **5** is provided with a refrigerant circuit **2** including a compressor **10**, a condenser **21**, an expansion valve **14** as a throttling means and an evaporator **16**; a second refrigerant circuit **8** including a second compressor **80**, a second condenser **81**, an expansion valve **84** as a throttling means and an evaporator **86**; a hot water supply circuit **3** including a hot water storage tank **30**; and an automatic washing unit **9** described later.

[0094] The refrigerant circuit **2** is constituted so that the compressor **10**, the condenser **21**, the expansion valve **14** and the evaporator **16** are successively connected to one another in an annular form via pipes to form a closed circuit. Specifically, a high-pressure refrigerant pipe **40** connected to the compressor **10** on a discharge side is connected to an inlet of the condenser **21**. The condenser **21** is a refrigerant passage constituting a part of a heat exchanger **13**, and disposed so that heat exchange between the condenser and a water passage **12** of the hot water supply circuit **3** can be performed. This heat exchanger **13** is a heat exchanger of heat exchange between water and a refrigerant, which performs the heat exchange between the condenser **21** and the water stored in the hot water storage tank **30** of the hot water supply circuit **3**. The heat exchanger is constituted of the refrigerant passage as the condenser **21** and the water passage **12** of the hot water supply circuit **3**. One end of the heat exchanger **13** is provided with an inlet of the refrigerant passage of the condenser **21** and an outlet of the water passage **12**, and the other end of the heat exchanger is provided with an outlet of the refrigerant passage of the condenser **21** and an inlet of the water passage **12**. Therefore, in the heat exchanger **13**, a high-temperature high-pressure refrigerant discharged from the compressor **10** and flowing through the condenser **21** and the water flowing through the water passage **12** form a counterflow.

[**0095**] On the other hand, a refrigerant pipe **41** connected to the outlet of the condenser **21** is connected to an inlet of the expansion valve **14**. A refrigerant pipe **42** connected to an outlet of the expansion valve **14** is connected to an inlet of the evaporator **16**. Moreover, an outlet of the evaporator **16** is connected to one end of a suction pipe **45**, and the other end of the suction pipe **45** is connected to the compressor **10** on a low-pressure side (a suction portion). Along the suction pipe **45** which connects the evaporator **16** to the compressor **10** on the low-pressure side, an accumulator **17** is interposed which protects the compressor **10** from a disadvantage that a liquid refrigerant is sucked into the compressor **10** to damage the compressor or the like. Furthermore, at the suction pipe **45** between the evaporator **16** and the accumulator **17**, a check valve **18** is disposed in which a compressor **10** side (an accumulator **17** side) is a forward direction in order to prevent backflow of the refrigerant from a high-pressure side of the refrigerant circuit **2** to the evaporator **16**.

[**0096**] Moreover, a discharge temperature sensor T**1** which detects a temperature of the high-temperature high-pressure refrigerant discharged from the compressor **10** is disposed at the high-pressure refrigerant pipe **40** of the refrigerant circuit **2**.

[**0097**] Furthermore, carbon dioxide which is a natural refrigerant is introduced as the refrigerant in the refrigerant circuit **2** in the same manner as in the refrigerant circuit **2** of Embodiment 1. Moreover, since the pressure of the refrigerant circuit **2** on the high-pressure side rises in excess of a critical pressure, the refrigerant circuit **2** constitutes a transcritical cycle. As a lubricant of the compressor **10**, for example, mineral oil, alkyl benzene oil, ether oil, ester oil, polyalkylene glycol (PAG), polyol ether (POE) or the like is used.

[**0098**] On the other hand, the evaporator **16** is a heat exchanger which cools the object to be cooled (the milk in the present embodiment) stored in an inner tank **70** of a cooling vessel **7**, and is formed integrally with this cooling vessel **7**. Since a basic constitution of the cooling vessel **7** is similar to that of the cooling vessel **7** of Embodiment 1 shown in FIGS. **2** to **4**, detailed description thereof is omitted.

[**0099**] As shown in FIG. **5**, the cooling vessel **7** is provided with an introduction port **7**A for introducing the object to be cooled (the milk) and a takeout port (not shown) for taking out the object to be cooled (the milk). An introduction pipe **50** is detachably connected to the introduction port **7**A via an introduction port valve **50**B. Furthermore, a takeout pipe **52** for taking out the milk is detachably connected to the milk takeout port via a takeout valve **52**B. Moreover, the milk introduction pipe **50** is attached to the milk introduction port **7**A in an only case where the milk is introduced into the inner tank **70** of the cooling vessel **7**. In another case, the pipe is detached from the milk introduction port **7**A, and the milk introduction port **7**A is hermetically closed. Similarly, the milk takeout pipe **52** is attached to the milk takeout port in an only case where the milk is taken out of the inner tank **70** of the cooling vessel **7**. In another case, the pipe is detached from the milk takeout port, and the milk takeout port is hermetically closed.

[**0100**] Moreover, a milk temperature sensor T**5** for detecting a temperature of the milk as the object to be cooled is attached to an outer peripheral surface of the inner tank **70** of the cooling vessel **7**. Furthermore, the cooling vessel **7** is provided with a stirrer **75** which stirs the milk in order to promote heat conduction during the cooling and correctly measure the temperature with reduced temperature unevenness. The stirrer **75** is constituted of a stirring blade, a stirring motor and a shaft which connects the blade to the motor.

[**0101**] On the other hand, the second refrigerant circuit **8** is constituted so that the compressor **80**, the condenser **81**, the expansion valve **84** and the evaporator **86** are successively connected to one another in an annular form via pipes to form a closed circuit. Specifically, a high-pressure refrigerant pipe **90** connected to the compressor **80** on the discharge side is connected to an inlet of the condenser **81**. The condenser **81** is a refrigerant passage constituting a part of a heat exchanger **83**, and disposed so that heat exchange between the condenser and a second water passage **82** of the hot water supply circuit **3** can be performed. This heat exchanger **83** is a heat exchanger of heat exchange between water and a refrigerant, which performs the heat exchange between the condenser **81** and the water stored in the hot water storage tank **30** of the hot water supply circuit **3**. The heat exchanger is constituted of the refrigerant passage as the condenser **81** and the water passage **82** of the hot water supply circuit **3**. One end of the heat exchanger **83** is provided with an inlet of the refrigerant passage of the condenser **81** and an outlet of the water passage **82**, and the other end of the heat exchanger is provided with an outlet of the refrigerant passage of the condenser **81** and an inlet of the water passage **82**. Therefore, in the heat exchanger **83**, a high-temperature high-pressure refrigerant discharged from the compressor **80** and flowing through the condenser **81** and the water flowing through the water passage **82** form a counterflow.

[**0102**] On the other hand, a refrigerant pipe **91** connected to the outlet of the condenser **81** is connected to an inlet of the expansion valve **84**. The expansion valve **84** is a throttling means to reduce the pressure of the refrigerant which has rejected the heat in the condenser **81**, and a refrigerant pipe **92** connected to an outlet of the expansion valve **84** is connected to an inlet of the evaporator **86**. The evaporator **86** is, for example, a tube and fin type heat exchanger, and constituted of a copper tube and a thermal conduction promoting aluminum fin disposed at this copper tube. Moreover, in the copper tube, a channel is constituted through which the refrigerant from the expansion valve **84** flows. In the vicinity of the evaporator **86**, a fan **86**F and a fan motor **86**M which drives the fan **86**F are installed. The fan supplies, to the evaporator **86**, atmospheric air (air) as a heat source to be subjected to heat exchange between the air and the refrigerant flowing through the copper tube. It is to be noted that the heat source of the evaporator **86** is not limited to the atmospheric air, and another heat source such as water, drain, solar heat or underground water may be used.

[0103] Moreover, an outlet of the evaporator **86** is connected to one end of a suction pipe **95**, and the other end of the suction pipe **95** is connected to the compressor **80** on the low-pressure side (the suction portion). Along the suction pipe **95** which connects the evaporator **86** to the compressor **80** on the low-pressure side, an accumulator **87** is interposed which protects the compressor **80** from a disadvantage that a liquid refrigerant is sucked into the compressor **80** to damage the compressor or the like.

[0104] Furthermore, the high-pressure refrigerant pipe **90** of the second refrigerant circuit **8** is provided with a discharge temperature sensor T**8** which detects a temperature the high-temperature high-pressure refrigerant discharged from the compressor **80**.

[0105] It is to be noted that carbon dioxide which is a natural refrigerant is introduced as the refrigerant in the second refrigerant circuit **8** in the same manner as in the refrigerant circuit **2**. Moreover, since the pressure of the second refrigerant circuit **8** on the high-pressure side rises in excess of the critical pressure, the second refrigerant circuit **8** constitutes a trans-critical cycle.

[0106] On the other hand, the hot water supply circuit **3** is constituted of a hot water storage circuit **5** which receives the heat from the refrigerant flowing through the condenser **21** of the refrigerant circuit **2** or the refrigerant flowing through the condenser **81** of the second refrigerant circuit **8** to heat the water and generate the high-temperature water and which stores the hot water in the hot water storage tank **30**; a water supply unit **32** which supplies water into the hot water storage tank **30**; a hot water supply unit **34** which supplies the hot water stored in the hot water storage tank **30** to the automatic washing unit **9** and another hot water supply load facility; and a discharge unit **36** described later.

[0107] The hot water storage tank **30** is a tank in which the high-temperature water generated by the heat rejected from the condenser **21** in the heat exchanger **13** or the condenser **81** in the heat exchanger **83** is stored. The whole outer peripheral surface of the tank is covered with an insulation material, and the tank is structured so that the stored hot water does not easily cool.

[0108] Moreover, a lower portion of the hot water storage tank **30** is connected to a low-temperature pipe **47** which takes out low-temperature water (the water) stored in the hot water storage tank **30** from below the hot water storage tank **30**. The low-temperature pipe **47** is connected to the inlet of the water passage **12** formed at the other end of the heat exchanger **13** via a circulation pump **31** and a flow rate adjustment valve **35**. The circulation pump **31** circulates the water through the hot water storage circuit **5**. The circulation pump **31** of the present embodiment discharges the water taken from the lower portion of the hot water storage tank **30** on a heat exchanger **13** side or a heat exchanger **83** side, and circulates the water through the hot water storage circuit **5** so that a water flow in the water passage **12** or **82** of the heat exchanger **13** or **83** forms a counterflow against a refrigerant flow in the condenser **21** or **81** as described above (circulates the water in a clockwise direction in FIG. **5**). The flow rate adjustment valve **35** is a valve unit which adjusts a flow rate of the warm water circulated through the hot water storage circuit **5** by the circulation pump **31**.

[0109] Furthermore, a three-way valve **47**A is disposed on an upstream side of the circulation pump **31** of the low-temperature pipe **47**, and connected to one end of a bypass pipe **49** so that the pipe is branched from the low-temperature pipe **47** via the three-way valve **47**A. The other end of the bypass pipe **49** is connected to a middle portion of a high-temperature pipe **48**. Moreover, the three-way valve **47**A can be switched to thereby selectively switch whether the water is passed through the circulation pump **31** from below the hot water storage tank **30**, or the hot water (the water) passed through the heat exchanger **13** or the hot water (the water) passed through the heat exchanger **83** is passed through the circulation pump **31**.

[0110] In addition, a three-way valve **47**B is disposed on a downstream side of the flow rate adjustment valve **35** of the low-temperature pipe **47**, and connected to a low-temperature pipe **97** so that the pipe is branched from the low-temperature pipe **47** via the three-way valve **47**B. The low-temperature pipe **97** is connected to an inlet of the water passage **82** formed at the other end of the heat exchanger **83**. The three-way valve **47**B can selectively switch whether the water passed through the flow rate adjustment valve **35** is passed through the heat exchanger **13** or **83**.

[0111] Moreover, one end of a high-temperature pipe **98** is connected to an outlet of the water passage **82** formed at one end of the heat exchanger **83**, and the other end of the high-temperature pipe **98** is connected to a middle portion of the high-temperature pipe **48**.

[0112] On the other hand, an outlet of the water passage **12** formed at one end of the heat exchanger **13** is connected to one end of the high-temperature pipe **48**, and the other end of the high-temperature pipe **48** is connected to an upper portion (an upper end in the present embodiment) of the hot water storage tank **30**. On a downstream side of a connection point of this high-temperature pipe **48** to the high-temperature pipe **98**, a hot water temperature sensor T**2** is disposed which detects a temperature of the high-temperature water generated by the heat rejected from the condenser **21** in the heat exchanger **13** or the heat rejected from the condenser **81** in the heat exchanger **83** and entering the hot water storage tank **30**.

[0113] Moreover, the upper portion of the hot water storage tank **30** is connected to the high-temperature pipe **48**, and provided with a high-temperature water takeout port **37** which takes the high-temperature water out of the hot water storage tank **30**. The high-temperature water takeout port **37** is connected to a high-temperature water takeout pipe **34**A of the hot water supply unit **34**. The lower portion of the hot water storage tank **30** is connected to the low-temperature pipe **47**, and provided with a low-temperature water takeout port **38** which takes the low-temperature water out of the hot water storage tank **30**. This low-temperature water takeout port **38** is connected to a low-temperature water takeout pipe **34**B of the hot water supply unit **34**.

[0114] Furthermore, the high-temperature water takeout pipe **34**A is connected to a washing hot water supply pipe **60**, and the high-temperature water taken out of the hot water storage tank **30** via the high-temperature water takeout port **37** is supplied to the automatic washing unit **9** via the washing hot water supply pipe **60**. The automatic washing unit **9** is a unit for washing the cooling vessel **7**, and the high-temperature water stored in the hot water storage tank **30** is taken from the washing hot water supply pipe **60** for use as water for washing the cooling vessel **7**. The washing hot water supply pipe **60** is provided with a check valve **61** for preventing a disadvantage that the hot water flowing through the washing hot water supply pipe **60** flows back to the hot water storage tank **30**; and a water supply valve (a hot water supply valve) **62** for supplying the hot water as the washing water. It is to be noted that although not shown in FIG. **5**, the washing hot water supply pipe **60** may be provided with a temperature sensor which detects a temperature of the hot water flowing through the washing hot water supply pipe **60**; a flow rate sensor which detects an amount of the hot water; a flow switch or the like if necessary.

[**0115**] In addition, it is assumed in the present embodiment that the high-temperature water supplied from the washing hot water supply pipe **60** is used in washing the cooling vessel **7**. However, the washing hot water supply pipe **60** may be connected to, for example, a washing unit for washing a unit such as a milking machine or a milking pipeline other than the cooling vessel **7** (not shown: with the proviso that a part of the machine or the pipeline is connected to the milk introduction pipe **50**) to use the hot water in washing the machine or the pipeline.

[**0116**] Moreover, in FIG. **5**, a mixture valve **65** mixes the high-temperature water taken out of the hot water storage tank **30** via the high-temperature water takeout pipe **34**A with the low-temperature water taken out of the hot water storage tank **30** via the low-temperature water takeout pipe **34**B or the water supplied from the water supply unit **32** via the low-temperature water takeout pipe **34**B, adjusts a temperature of the mixed water into an optimum temperature and supplies the water to the hot water supply load facility for use in an application other than the washing application. The mixture valve **65** is connected to each hot water supply load facility for use in an application other than the washing application. Moreover, the hot water is supplied to the hot water supply load facility for the application other than the washing application by operating a hot water supply valve (not shown). The high-temperature water takeout pipe **34**A and the low-temperature water takeout pipe **34**B connected to the mixture valve **65** are provided with check valves **67** for preventing a disadvantage that the hot water taken out of the hot water storage tank **30** from the high-temperature water takeout pipe **34**A or the low-temperature water takeout pipe **34**B flows back to the hot water storage tank **30**, respectively.

[**0117**] Furthermore, a hot water supply pipe **68** leading from the mixture valve **65** to the hot water supply valve of each hot water supply load facility is provided with a check valve **68**B for preventing the backflow to the hot water storage tank **30**; and a temperature sensor T**3** for use in hot water supply control. Moreover, a temperature of the hot water to be supplied to the hot water supply load facility is detected by the temperature sensor T**3**. It is to be noted that the hot water supply valve is, for example, a faucet for hot water supply or the like, and the number of the valves is not limited to one. A plurality of hot water supply valves may be disposed. The hot water supply pipe **68** may be provided with a flow rate sensor and a flow switch (both are not shown) if necessary.

[**0118**] In addition, the lower portion of the hot water storage tank **30** is connected to a water supply pipe **32**A of the water supply unit **32** via a pressure reduction valve **32**B. The water supply unit **32** supplies water into the hot water storage tank **30**. Water such as city water having an amount corresponding to an amount of the hot water of the hot water storage tank **30** to be used is supplied into the hot water storage tank **30** via the water supply pipe **32**A. A water supply valve (not shown) is interposed along this water supply pipe **32**A, and the water supply valve is usually constantly brought into an open state.

[**0119**] Moreover, the lower portion of the hot water storage tank **30** is connected to a discharge pipe **69**A via a discharge valve **69**B. The discharge pipe discharges the hot water from the hot water storage tank **30**, when the hot water storage tank **30** is unused.

[**0120**] Here, the discharge unit **36** discharges the water (the hot water) from the hot water storage tank **30**, and is disposed below the high-temperature water takeout port **37** and above the low-temperature water takeout port **38**. In the present embodiment, a hot water discharge pipe **36**A of the discharge unit **36** is connected to a portion of the hot water storage tank **30** below the high-temperature water takeout port **37** and above the low-temperature water takeout port **38** via a hot water discharge valve **36**B. Since the discharge unit **36** is disposed below the high-temperature water takeout port **37** and above the low-temperature water takeout port **38** in this manner, the hot water taken out of the hot water storage tank **30** by the discharge unit **36** is medium-temperature water having a temperature which is lower than that of the hot water taken from the high-temperature water takeout port **37** and higher than the water taken from the low-temperature water takeout port **38**. Therefore, when the hot water discharge valve **36**B is opened as needed, the medium-temperature water can be discharged from the hot water storage tank **30**.

[**0121**] On the other hand, an outer surface of the hot water storage tank **30** is provided with a plurality of stored hot water sensors T**4** arranged at appropriate intervals from the upper portion to the lower portion. The stored hot water sensors T**4** are sensors which detect temperatures of portions of the hot water stored in the hot water storage tank **30** and which detect whether or not there is hot water. Since the plurality of stored hot water sensors T**4** are arranged at varied heights to detect the temperatures of the portions in this manner, it is possible to detect the amount of the hot water stored in the hot water storage tank **30** while grasping a temperature distribution from the upper portion to the lower portion of the hot water storage tank **30**.

[**0122**] It is to be noted that a capacity of the hot water storage tank **30** needs to be determined in due consideration of an amount of the milk as the object to be cooled, introduced into the cooling vessel **7**; and an assumed hot water supply load. That is, during a cooling operation, if the high-temperature water is taken from the lower portion of the hot water storage tank **530** instead of the low-temperature water and the water enters the water passage **12** of the heat exchanger **13**, an amount of the heat to be rejected from the condenser **21** remarkably decreases. As a result, a cooling capacity and COP of the refrigerant circuit **2** deteriorate. Therefore, when the capacity of the hot water storage tank **30** is considered, the tank should have a sufficient volume so that the low-temperature water can constantly be taken from the lower portion of the hot water storage tank **30**, and passed through the water passage **12** of the heat exchanger **13**.

[0123] Specifically, each capacity needs to be investigated individually in accordance with use conditions. For example, in a case where the hot water is not used simultaneously with the cooling operation, it is preferable to use the hot water storage tank having a capacity which equals or exceeds the maximum amount of the milk as the object to be cooled, supposed to be introduced into the cooling vessel **7** during one cooling operation. For example, in a case where 500 liters of the object to be cooled (the milk) is introduced into the cooling vessel **7**, it is preferable that the capacity of the hot water storage tank **30** equals or exceeds about 500 liters. In a case where it is assumed that the hot water is used during the cooling operation, the capacity of the hot water storage tank **30** can be set to be smaller than the above capacity.

[0124] Moreover, the automatic washing unit **9** is constituted of a circulation washing circuit **100** constituted by successively connecting a washing circulation pump **101**, a washing pipe **102**, the cooling vessel **7**, the takeout valve **52**B, a circulation changeover valve **104** and a washing return pipe **105**; a washing water discharge passage **110** connected to the washing return pipe **105** of the circulation washing circuit **100** via a washing discharge valve **110**B; and a washing buffer tank **115** connected to the washing return pipe **105** of the circulation washing circuit **100**.

[0125] The washing buffer tank **115** is connected to at least one or more detergent supply pipes **116** for supplying a detergent or a germicide; a water supply pipe **117** for supplying the washing water (the city water in the present embodiment); and the washing hot water supply pipe **60** for supplying the hot water for washing from the hot water supply circuit **3**. The water supply pipe **117** is provided with a water supply valve **117**B, and the water supply to the buffer tank **115** for washing is controlled by the water supply valve **117**B. The detergent supply pipe **116** is provided with a detergent supply pump (not shown) for supplying the detergent, and the other end of the detergent supply pipe **116** is connected to a detergent vessel (not shown).

[0126] An operation of the refrigeration cycle device **200** of the present embodiment constituted as described above will be described.

[0127] (1) Cooling Operation of Object (Milk) to be Cooled

[0128] First, an operation to cool the milk as the object to be cooled during the cooling operation will be described. The milking pipeline connected to the milking machine (not shown) is connected to the cooling vessel **7** via the milk introduction pipe **50**, the introduction port valve **50**B is opened, and the milk immediately after drawn is introduced into the cooling vessel **7**. At this time, the milk takeout valve **52**B is closed. A temperature of the milk immediately after drawn is substantially equal to or slightly lower than a body temperature of a cow, and is specifically in a range of about 35° C. to 38° C. Then, the refrigerant circuit **2** is operated to cool and insulate the milk for the purpose of preventing generation of bacteria and maintaining a quality of the milk.

[0129] After starting the milking (after starting the introduction of the milk), the compressor **10** of the refrigerant circuit **2** is driven, and the stirrer **75** is simultaneously driven. Usually, it is assumed that after a predetermined amount of milk is stored in the cooling vessel **7**, the compressor **10** is driven to start the cooling operation. However, the cooling operation may be started simultaneously with the start of the introduction of the milk or before the introduction of the milk as long as careful consideration is given so as to prevent freezing and idling of the stirrer **75** is prevented.

[0130] When the compressor **10** is driven, a low-temperature low-pressure refrigerant gas is sucked and compressed on the low-pressure side (the suction portion) of the compressor **10** from the suction pipe **45**. In consequence, the refrigerant gas which has obtained a high temperature and a high pressure enters the high-pressure refrigerant pipe **40** from the discharge side, and is discharged from the compressor **10**. At this time, the refrigerant is compressed under an appropriate supercritical pressure.

[0131] The high-temperature high-pressure refrigerant discharged from the compressor **10** enters the heat exchanger **13** from the inlet of the condenser **21** via the high-pressure refrigerant pipe **40**. Moreover, while passing through the condenser **21** of the heat exchanger **13**, the high-temperature high-pressure refrigerant gas releases the heat to the water of the hot water storage circuit **5** flowing through the water passage **12** disposed so as to perform the heat exchange between the water and the condenser **21**. In consequence, the gas obtains a low temperature. On the other hand, the water flowing through the water passage **12** is heated by a heat radiation function of this condenser **21**, and the high-temperature water is generated.

[0132] In the present embodiment, carbon dioxide is used as the refrigerant, and the refrigerant pressure in the condenser **21** is not less than a critical pressure. Therefore, since condensation of the refrigerant does not occur in the condenser **21**, the temperature of the refrigerant gradually drops from the inlet toward the outlet of the condenser **21** as the heat is rejected to the water flowing through the water passage **12**. On the other hand, from the inlet to the outlet of the water passage **12** of the heat exchanger **13**, the temperature of the water gradually rises as the heat is absorbed from the refrigerant. Since the refrigerant pressure of the condenser **21** is set to be not less than the critical pressure by use of the carbon dioxide refrigerant in this manner, the heat exchange can highly efficiently be performed and the high-temperature water can be generated as compared with condensation heat radiation of a conventional refrigerant such as an HFC-based refrigerant at a constant temperature. In the heat exchanger **13**, the refrigerant passage and the water passage **12** constituting the condenser **21** are arranged so as to form the counterflow as described above. Therefore, the heat exchange between the water and the refrigerant can further efficiently be performed.

[0133] The low-temperature high-pressure refrigerant cooled by the condenser **21** exits from the heat exchanger **13** via the outlet of the condenser **21**, passes through the refrigerant pipe **41**, expands at the expansion valve **14** to obtain a low pressure and reaches the evaporator **16** via the refrigerant pipe **42**. It is to be noted that the refrigerant at the inlet of the evaporator **16** has a two-phase mixed state in which the liquid refrigerant is mixed with a vapor refrigerant. Moreover, when the liquid-phase refrigerant absorbs the heat from the milk as the object to be cooled in the evaporator **16**, the refrigerant evaporates to form the vapor refrigerant. At this time, the milk is cooled by the heat absorption.

[0134] Moreover, the refrigerant evaporated in the evaporator **16** repeats a cycle of exiting from the evaporator **16** to enter the suction pipe **45** and being again sucked from the low-pressure side (the suction portion) to the compressor **10** via the check valve **18** and the accumulator **17**. When the above cycle is repeated, the milk is cooled by the heat absorption of the evaporator **16**. Moreover, the hot water is generated by the heat rejected from the condenser **21**.

[0135] When the milking is completed, the introduction of the milk into the cooling vessel **7** is completed. However, the above cooling operation is continued until the milk reaches a predetermined temperature. Here, the temperature of the milk is detected by the milk temperature sensor T**5** attached to the outer peripheral surface of the inner tank **70**. The predetermined temperature at which the cooling operation ends is set from a viewpoint that the generation of the bacteria in the milk be inhibited and the quality be maintained, and is specifically about 4° C.

[0136] Furthermore, an open degree of the expansion valve **14** is adjusted so that the temperature of the discharged refrigerant detected by the discharge temperature sensor T**1** disposed at the high-pressure refrigerant pipe **40** of the refrigerant circuit **2** is a predetermined temperature during the cooling operation. Specifically, when the refrigerant temperature detected by the discharge temperature sensor T**1** rises above the predetermined value, the open degree of the expansion valve **14** is enlarged. Conversely, when the refrigerant temperature detected by the discharge temperature sensor T**1** drops below the predetermined value, the open degree of the expansion valve **14** is reduced. In consequence, a highly efficient operation can be performed on conditions preferable for an operation of generating the high-temperature water suitable for the washing application.

[0137] It is to be noted that the compressor **10** during the cooling operation may have the constant number of rotations. Alternatively, a frequency may be adjusted by an inverter or the like. Since the number of the rotations is controlled in the same manner as in Embodiment 1 described above, detailed description is omitted.

[0138] (2) Operation of Hot Water Supply Circuit **3** During Cooling Operation

[0139] Next, the operation of the hot water supply circuit **3** during the cooling operation will be described. First, the three-way valve **47**A is switched so that the water flows through the circulation pump **31** from the lower portion of the hot water storage tank **30**, and the three-way valve **47**B is switched so that the water passed through the flow rate adjustment valve **35** flows through the heat exchanger **13** of the refrigerant circuit **2** (the refrigerant circuit **2** for cooling the milk).

[0140] Moreover, when the above cooling operation is started, the circulation pump **31** of the hot water supply circuit **3** is started. The low-temperature water or the water (hereinafter referred to simply as the water) is sucked from the lower portion of the hot water storage tank **30** to the circulation pump **31** via the low-temperature pipe **47**, and pushed out to the low-temperature pipe **47** connected to the outlet of the circulation pump **31** on the heat exchanger **13** side. In consequence, the water pushed out of the circulation pump **31** enters the heat exchanger **13** from the inlet of the water passage **12** via the flow rate adjustment valve **35**. In the heat exchanger **13**, as described above, the water flowing through the water passage **12** receives the heat from the condenser **21** by the heat exchange between the water and the refrigerant flowing through the condenser **21**, and is heated. In consequence, the high-temperature water is generated. Moreover, the high-temperature water discharged from the heat exchanger **13** via the outlet of the water passage **12** passes through the high-temperature pipe **48** of the hot water storage circuit **5**, and is injected into the hot water storage tank **30** from the upper portion (the upper end) of the hot water storage tank **30**. The high-temperature water generated by the heat exchanger **13** is injected into the upper portion of the hot water storage tank **30**, and the water is taken from the lower portion of the tank. Therefore, the high-temperature water is stored in an upper part of the tank and the low-temperature water is stored in a lower part of the tank by use of a density difference due to a water temperature difference.

[0141] Furthermore, the flow rate adjustment valve **35** adjusts the flow rate of the water so that the temperature of the hot water at the outlet of the water passage **12** of the heat exchanger **13** indicates a predetermined value. In the present embodiment, the flow rate adjustment valve **35** is controlled based on the temperature of the hot water at the outlet of the water passage **12** of the heat exchanger **13** detected by the hot water temperature sensor T**2**. That is, when the temperature of the hot water at the outlet of the water passage **12** detected by the hot water temperature sensor T**2** is higher than the predetermined temperature, the open degree of the flow rate adjustment valve **35** is enlarged. In consequence, an amount (the flow rate) of the water to be circulated through the hot water storage circuit **5** can be increased.

[0142] On the other hand, when the temperature of the hot water at the outlet of the water passage **12** detected by the hot water temperature sensor T**2** is lower than the predetermined temperature, the open degree of the flow rate adjustment valve **35** is reduced. In consequence, the amount (the flow rate) of the water to be circulated through the hot water storage circuit **5** can be reduced. It is to be noted that in the present embodiment, the temperature of the hot water at the outlet of the water passage **12** is detected by the hot water temperature sensor T**2** installed at the middle portion of the high-temperature pipe **48**. However, the present invention is not limited to this example. Needless to say, the temperature of the hot water at the outlet of the water passage **12** may be detected by a temperature sensor disposed at the outlet of the water passage **12** of the heat exchanger **13**. It is preferable to set the predetermined temperature to a temperature suitable for an application of hot water supply (including a washing application), specifically in a range of about 50° C. to 85° C. in accordance with a use application.

[0143] As described above, during the cooling operation of the refrigeration cycle device **200** of the present embodiment, when the milk immediately after drawn is introduced into the cooling vessel **7**, the milk is cooled at the predetermined temperature in order to maintain the quality of the milk. Moreover, the high-temperature water is generated by the heat rejected from the refrigerant circuit **2** on the high-pressure side, and the hot water can be stored in the hot water storage tank **30**.

[0144] (3) Operation During Cold Insulating Operation

[0145] In the refrigeration cycle device **200**, when the temperature of the milk reaches the predetermined value during the above cooling operation, a cold insulating operation to insulate the milk is executed in the same manner as in the refrigeration cycle device **1** of Embodiment 1. Since operation conditions, an operation method and the like during the cold insulating operation are similar to those of Embodiment 1, detailed description thereof is omitted. A function of the refrigerant circuit **2**, an operation of the hot water supply circuit **3** and the like during the cold insulating operation are similar to those during the above cooling operation. It is to be noted that in the refrigeration cycle device **200** of the present embodiment, even in the cooling operation during the cold insulating operation, simultaneously with the cooling of the milk, the hot water can be stored by effectively using discharged heat during the cooling.

[**0146**] It is to be noted that since operation patterns of the cooling operation and the cold insulating operation in a general farm are the same as described above in Embodiment 1, detailed description thereof is omitted.

[**0147**] (4) Washing Operation

[**0148**] Next, a washing operation will be described. As described above, the milk cooled and insulated in the cooling vessel **7** as described above is taken from the takeout port during the milk cargo collection. Specifically, the milk takeout valve **52**B is connected to the milk takeout pipe **52**, the milk takeout valve **52**B is opened and the milk is taken out of the cooling vessel **7**. Moreover, after the milk is taken out, the washing operation is performed by the automatic washing unit **9** in order to keep the inside of the cooling vessel **7** to be clean, inhibit propagation of the bacteria and secure the quality of the milk.

[**0149**] Usually, the washing of the cooling vessel **7** is performed after taking the milk out of the cooling vessel **7**. Therefore, in a case where the cargo is collected every day, the washing is performed once a day. When the cargo is collected every other day, the washing is performed once every two days. In the present embodiment, the hot water for washing can be supplied even for the washing of the milking machine or the milking pipeline (not shown). However, since the milking machine and the milking pipeline are washed every time the milking is completed, the washing is performed twice or three times a day.

[**0150**] Washing steps in a case where the cooling vessel **7** is washed are basically the same as those in a case where the milking pipeline or the like is washed. That is, a rinsing step with the water, a rinsing step with the hot water, a washing step with a plurality of types of detergents such as an alkaline detergent and an acid detergent and a sterilization step with a germicide are performed. In each of such steps, the hot water or the water is supplied, predetermined amounts of predetermined types of detergent and germicide are supplied, then a washing liquid (a mixture liquid of the hot water or the water and the detergent and the like) is circulated through the device (through the circulation washing circuit **100** in a case where the cooling vessel **7** is washed) for a predetermined time if necessary, and the washing liquid is then discharged.

[**0151**] Moreover, the above steps are performed in a predetermined order the necessary number of times. For example, first the rinsing step with the water is performed. Subsequently, another rinsing step with the hot water, an alkali washing step with the hot water and the alkaline detergent, still another rinsing step with the hot water, an acid washing step with the hot water and the acid detergent and a further rinsing step with the water are performed. Subsequently, the sterilization step with the germicide is performed.

[**0152**] When the milk cargo collection is completed, prior to the washing, first the milk takeout pipe **52** is detached from the takeout valve **52**B so that the washing water flows through the washing return pipe **105** via the takeout valve **52**B, and the takeout valve **52**B is opened. In the rinsing step with the water, the discharge valve **110**B for washing and the circulation changeover valve **104** are closed, and the circulation pump **101** for washing is stopped. In this state, the water supply valve **117**B is opened, and the predetermined amount of the washing water is supplied to the buffer tank **115** for washing via the water supply pipe **117**. It is to be noted that it can be judged with, for example, a floating type level switch or the like whether or not an amount of the water in the buffer tank **115** for washing reaches a predetermined value.

[**0153**] Moreover, when the amount of the water in the buffer tank **115** for washing reaches the predetermined value, the water supply valve **117**B is closed, and the circulation pump **101** is brought into an operative state. In consequence, the water passes through the washing pipe **102** from the buffer tank **115** for washing, and is supplied into the cooling vessel **7**. To inject the water into the cooling vessel **7** from the washing pipe **102**, the water is jetted from nozzles and sprayed into each portion of the cooling vessel **7** without unevenness so that efficient washing can be performed. If necessary, the stirrer **75** may be operated.

[**0154**] If the water in the buffer tank **115** for washing is used up, the operation of the circulation pump **101** for washing is stopped, the circulation changeover valve **104** and the discharge valve **110**B for washing are opened, and the rinsing water is discharged from the washing water discharge passage **110**. One rinsing step with the water has been described above. The predetermined number of the steps are repeatedly performed as needed.

[**0155**] On the other hand, the rinsing step with the hot water is basically an operation similar to that of the above rinsing step with the water, and is different only in that the high-temperature water is supplied instead of the water. That is, in the rinsing step with the water, the water supply valve **117**B is opened to supply the water. However, in the rinsing step with the hot water, the hot water supply valve **62** is opened to thereby supply the high-temperature water stored in the hot water storage tank **30** to the buffer tank **115** for washing via the hot water supply pipe **60** for washing. Description of another similar operation is omitted.

[**0156**] In the washing step with the detergent, the discharge valve **110**B for washing and the circulation changeover valve **104** are closed, and the circulation pump **101** for washing is stopped. In this state, the water supply valve **62** is opened, and a predetermined amount of the hot water is supplied to the buffer tank **115** for washing via the hot water supply pipe **60** for washing. Moreover, a detergent supply pump (not shown) is driven to supply the predetermined amount of the predetermined type of detergent to the buffer tank **115** for washing via the detergent supply pipe **116**. The type and the amount of the supplied detergent are determined beforehand in accordance with the steps, and the amount of the detergent is adjusted in accordance with a driving time of the detergent supply pump (not shown).

[0157] Moreover, when the amount of the hot water (the mixture liquid of the hot water and the detergent) in the buffer tank **115** for washing reaches a predetermined value, the water supply valve **62** is closed, and the circulation pump **101** is brought into the operative state. In consequence, the detergent passes through the washing pipe **102** from the buffer tank **115** for washing, and is supplied into the cooling vessel **7**. To inject the washing liquid into the cooling vessel **7** from the washing pipe **102**, the washing liquid is jetted from nozzles and sprayed into each portion of the cooling vessel **7** without unevenness so that the efficient washing can be performed. If necessary, the stirrer **75** may be operated.

[0158] If the washing liquid in the buffer tank **115** for washing is used up, the operation of the circulation pump **101** for washing is stopped. The circulation changeover valve **104** and the discharge valve **110**B for washing remain to be closed until the predetermined amount of the washing liquid is stored in the cooling vessel **7**. The water supply valve **62** is opened again, and the predetermined amount of the hot water is supplied into the buffer tank **115** for washing. Subsequently, the water supply valve **62** is closed, the circulation pump **101** is driven, and the hot water is supplied into the cooling vessel **7**. This operation is repeated. Here, the amount of the hot water supplied and stored in the cooling vessel **7** can be known from the capacity of the buffer tank **115** and the number of the repeated operations. Therefore, in a case where the number of the times when the hot water is stored in the buffer tank **115** is determined beforehand, an appropriate amount can be controlled.

[0159] After the predetermined amount of the washing liquid (the mixture liquid of the hot water and the detergent) is stored in the cooling vessel **7**, the circulation changeover valve **104** is opened, and the circulation pump **101** for washing is driven for a predetermined time. The washing liquid from the cooling vessel **7** successively flows through the takeout valve **52**B, the circulation changeover valve **104**, the washing return pipe **105**, the washing circulation pump **101** and the washing pipe **102** to return to the cooling vessel **7**, and circulates through the circulation washing circuit **100**. In consequence, dirt of the milk in the cooling vessel **7** can be removed. It is to be noted that to inject the washing liquid into the cooling vessel **7** from the washing pipe **102**, the washing liquid is jetted from nozzles and sprayed into each portion of the cooling vessel **7** without unevenness so that efficient washing can be performed. If necessary, the stirrer **75** may be operated.

[0160] Moreover, after the washing liquid is circulated for a predetermined time, the circulation pump **101** for washing is stopped, the discharge valve **110**B for washing is opened, and the washing liquid is discharged from the circulation washing circuit **100** via the discharge passage **110** for washing.

[0161] An operation of the sterilization step is basically similar to that of the washing step with the detergent, and is different only in that the detergent to be injected is the germicide, the water is used instead of the hot water and a different time for circulation or the like is set. The sterilization step is performed in accordance with the next use time, and a germicide liquid (a mixture liquid of the germicide and the water) is held in systems of the cooling vessel **7** and the circulation washing circuit **100** and left to stand for a predetermined time to improve a sterilization effect. Detailed description of an operation common to that of the rinsing step or the washing step with the detergent is omitted.

[0162] It is to be noted that in the standby state of the cold insulating operation, the expansion valve **14** is completely closed in order to reduce thermal losses due to the entering refrigerant in the evaporator **16**. However, during the washing operation, especially when the washing with the hot water is performed, it is preferable to bring the expansion valve **14** into an open state in order to avoid an abnormally high pressure in the evaporator **16**.

[0163] Moreover, in a case where a large hot water supply load is required and the supply of the only amount of the hot water generated by cooling the milk is insufficient, the hot water may be generated by performing the cooling operation even during the washing operation. For example, in the sterilization step, while the germicide liquid is held in the cooling vessel **7**, the cooling operation is performed. In consequence, a hot water supply operation (a heat pump operation) can highly efficiently be performed using the germicide liquid as a heat source. Furthermore, if necessary, the water can additionally be introduced as the heat source into the cooling vessel **7** to perform the cooling operation (the hot water supply operation).

[0164] (5) Hot Water Supply Operation for Application Other than Washing Application

[0165] Next, an operation of supplying the hot water to an application other than the above washing application will be described. The hot water is supplied to a hot water supply load for the application other than the washing application by opening the hot water supply valve. When the hot water supply valve is opened, the high-temperature water stored in the hot water storage tank **30** flows through the mixture valve **65** from the upper portion of the hot water storage tank **30** via the high-temperature water takeout pipe **34**A. Moreover, the water from the water supply unit **32**, or the low-temperature water from the lower portion of the hot water storage tank **30** flows through the mixture valve **65** via the low-temperature water takeout pipe **34**B connected to the lower portion of the hot water storage tank **30**. Moreover, the mixture valve **65** mixes the high-temperature water and the water or the low-temperature water. After the temperature is adjusted into a predetermined temperature, the hot water is supplied to each hot water supply load facility via the hot water supply valve.

[0166] It is to be noted that the temperature of the hot water to be supplied is detected by the temperature sensor T**3** disposed at the pipe **68** which connects the mixture valve **65** to the hot water supply valve. It is to be noted that since the water supply valve (not shown) of the water supply unit **32** is usually constantly opened, the city water having an amount corresponding to the amount of the hot water supplied to another hot water supply load facility (the hot water supply load facility other than the automatic washing unit **9**) is supplied into the hot water storage tank **30** of the hot water supply circuit **3** from the water supply pipe **32**A of the water supply unit **32**.

[0167] As described above, according to the refrigeration cycle device **200** of the present embodiment, at the same time the milk as the object to be cooled is cooled, the hot water is generated by effectively using the heat of the high-temperature side of the refrigerant circuit **2** generated in the cooling process. Moreover, the high-temperature water can be supplied by using the trans-critical cycle by use of the carbon dioxide refrigerant. This hot water can be used in washing the cooling vessel **7** and the like. Therefore, as compared with a conventional case in which the water is boiled with a boiler or the like to supply the hot water for the washing application, energy to be consumed can largely be reduced. Since the heat released from the high-temperature side of the refrigerant circuit **2** to the atmospheric air can be reduced, a rise of an ambient temperature can be inhibited.

[0168] (6) Hot Water Supply Operation by Use of Second Refrigerant Circuit **8**

[0169] Next, an operation of the second refrigerant circuit **8** will be described. The second refrigerant circuit **8** is disposed so as to perform a hot water supply operation (the heat pump operation) of absorbing the heat from a heat source such as air other than the milk in a case where a large hot water supply load is required and the supply of the only hot water obtained by cooling the milk is insufficient.

[0170] Since the operation of the second refrigerant circuit **8** is substantially the same as that of the refrigerant circuit **2**, detailed description thereof is omitted. The operation is different from that of the refrigerant circuit **2** only in that the refrigerant in the evaporator **86** absorbs the heat from the atmospheric air. That is, in the evaporator **86**, the refrigerant absorbs the heat from the atmospheric air, and the heat is rejected to the water passage **82** disposed so that the heat exchange between the water and the condenser **81** is performed in the heat exchanger **83**. In consequence, the water flowing through the water passage **82** is heated, and the high-temperature water is generated.

[0171] During the hot water supply operation, the open degree of the expansion valve **84** is adjusted so that the temperature of the discharged refrigerant detected by the discharge temperature sensor T**8** disposed at the high-pressure refrigerant pipe **90** of the second refrigerant circuit **8** indicates a predetermined value. Specifically, when the refrigerant temperature detected by the discharge temperature sensor T**8** rises above the predetermined value, the open degree of the expansion valve **84** is enlarged. Conversely, when the refrigerant temperature detected by the discharge temperature sensor T**8** drops below the predetermined value, the open degree of the expansion valve **84** is reduced. In consequence, a highly efficient operation can be performed on conditions preferable for an operation of generating the high-temperature water suitable for the washing application.

[0172] Next, an operation of the hot water supply circuit **3** during the hot water supply operation will be described. In this case, the three-way valve **47**A is switched so that the water flows through the circulation pump **31** from the lower portion of the hot water storage tank **30**, and the three-way valve **47**B is switched so that the water passed through the flow rate adjustment valve **35** flows through the heat exchanger **83**. During the hot water supply operation, the circulation pump **31** of the hot water supply circuit **3** is operated, and the low-temperature water or the water from the lower portion of the hot water storage tank **30** flows through the low-temperature pipe **47**, the circulation pump **31**, the flow rate adjustment valve **35** and the low-temperature pipe **97** to enter the inlet of the water passage **82** of the heat exchanger **83**. In the heat exchanger **83**, as described above, the water flowing through the water passage **82** is heated by the heat exchange between the water and the refrigerant flowing through the condenser **81** to generate the high-temperature water. Moreover, the high-temperature water exiting from the water passage **82** of the heat exchanger **83** successively flows through the high-temperature pipes **98** and **48**, and is injected into the hot water storage tank **30** from the upper portion of the hot water storage tank **30**. The high-temperature water is injected from the upper portion of the hot water storage tank **30**, and the low-temperature water is taken from the lower portion of the tank. Therefore, the high-temperature water is stored in an upper part of the hot water storage tank **30** and the low-temperature water is stored in a lower part of the tank by use of a density difference due to a water temperature difference.

[0173] Moreover, the flow rate adjustment valve **35** adjusts the flow rate of the water so that the temperature of the hot water at the outlet of the water passage **82** of the heat exchanger **83** indicates a predetermined value. Specifically, when the temperature of the hot water at the outlet of the water passage **82** is higher than the predetermined temperature, the open degree of the flow rate adjustment valve **35** is enlarged to increase the flow rate of the water. Conversely, when the temperature of the hot water at the outlet of the water passage **82** is lower than the predetermined temperature, the open degree of the flow rate adjustment valve **35** is reduced to decrease the flow rate of the water. The temperature of the hot water at the outlet of the water passage **82** is detected by the hot water temperature sensor T**2** attached to the high-temperature pipe **48**. Moreover, the predetermined temperature is a temperature suitable for the washing application or another hot water supply application. Specifically, it is preferable to set the temperature in a range of about 50 to 85° C. in accordance with a use application.

[0174] As described above, the hot water supply operation of the second refrigerant circuit **8** is performed in a case where the amount of the hot water generated by the milk cooling operation falls short with respect to the required hot water supply load. A length of time when the hot water supply operation is performed, that is, the amount of the hot water to be generated is determined in accordance with the required amount of the hot water. However, when the hot water storage tank **30** is completely filled with the high-temperature water, the high-temperature water flows through the heat exchanger **13** from the lower portion of the hot water storage tank **30** during the cooling operation. The cooling capacity and efficiency remarkably deteriorate, and it is difficult to cool the milk. Therefore, during the hot water supply operation, the hot water storage tank **30** is not completely filled with the high-temperature water, and it is necessary to surely secure a cold water portion (a portion of water having a low temperature) having an amount corresponding to an amount for use during the cooling operation in the lower part of the hot water storage tank **30**.

[0175] The amount of the hot water to be stored in the hot water storage tank **30** during the hot water supply operation of the second refrigerant circuit **8** depends on conditions on which the refrigeration cycle device **200** is used, that is, the amount (a farming scale) of the milk, the amount of the hot water for use and the like. For example, when the amount of the hot water is ⅕ or less of that in the hot water storage tank **30**, the hot water supply operation is started by the second refrigerant circuit **8**. When the amount is ½ or more, the hot water supply operation of the second refrigerant circuit **8** is stopped. Such control is considered. It is to be noted that the amount of the hot water stored in the hot water storage tank **30** can be grasped by the stored hot water sensors T**4**.

[0176] As described above, the refrigeration cycle device **200** of the present embodiment includes the second refrigerant circuit **8**. Therefore, when the required hot water supply load cannot be covered only with the hot water generated during the cooling of the milk, the hot water supply operation is performed using the atmospheric air as the heat source. In consequence, the hot water can be generated to compensate for shortage. Therefore, an auxiliary boiler or the like for the additional hot water supply is not required. Moreover, heat pump hot water supply is highly efficiently performed. Therefore, energy consumption is further reduced.

[0177] (7) Changeover Operation of Three-Way Valve **47**A

[0178] Next, an operation of the three-way valve **47**A will be described. The three-way valve **47**A prevents the low-temperature water from being passed through the upper portion of the hot water storage tank **30** to disturb thermal stratification in the hot water storage tank **30** during the starting and stopping of the cooling operation and the hot water supply operation. For a predetermined time TL**1** after the start of the cooling operation or the hot water supply operation, the three-way valve **47**A is blocked on a hot water storage tank **30** side, and switched so as to pass the hot water (or the water) through the circulation pump **31** from the bypass pipe **49**. In consequence, for the predetermined time TL**1** from the start of the cooling operation or the hot water supply operation, the hot water passed through the water passage **12** of the heat exchanger **13** or the water passage **82** of the heat exchanger **83** of the second refrigerant circuit **8** does not enter the hot water storage tank **30**. The hot water flows through the closed circuit from the high-temperature pipe **48** via the bypass pipe **49**, the three-way valve **47**A and the circulation pump **31** to return to the water passage **12** of the heat exchanger **13** or the water passage **82** of the heat exchanger **83** of the second refrigerant circuit **8**.

[0179] In addition, for a predetermined time TL**2** from the start of the cooling operation or the hot water supply operation, the open degree of the flow rate adjustment valve **35** is fixed to a predetermined open degree so as to secure a sufficient flow rate. After elapse of the predetermined time TL**2**, the open degree is gradually reduced to decrease the flow rate. Finally, the open degree is adjusted so that the hot water temperature sensor T**2** attached to the high-temperature pipe **48** indicates the predetermined value.

[0180] After elapse of the predetermined time TL**1**, the three-way valve **47**A is blocked on a bypass pipe **49** side, and switched so as to pass the water through the circulation pump **31** from the lower portion of the hot water storage tank **30**. As a result, the hot water generated by the water passage **12** of the heat exchanger **13** or the water passage **82** of the heat exchanger **83** of the second refrigerant circuit **8** enters the hot water storage tank **30**.

[0181] As the predetermined times TL**1** and TL**2**, a certain time may be determined beforehand. Alternatively, the operation may be performed based on the temperature of the hot water at the outlet of the heat exchanger **13** or the heat exchanger **83** of the second refrigerant circuit **8**, detected by the hot water temperature sensor T**2**. That is, at the start of the cooling operation, the flow rate adjustment valve **35** is fixed to the predetermined open degree. When the hot water temperature rises to a predetermined value or more, the open degree of the flow rate adjustment valve **35** is gradually reduced. Furthermore, when the hot water temperature rises to a second predetermined temperature, the three-way valve **47**A may be blocked on the bypass pipe **49** side, and switched so as to pass the water through the circulation pump **31** from the lower portion of the hot water storage tank **30**.

[0182] As described above, it is possible to avoid a problem that the thermal stratification of the hot water already stored in the hot water storage tank **30** is disturbed to lower the temperature of the stored hot water. As a result, the thermal loss of the stored hot water can be reduced, and the hot water can effectively be used.

[0183] Moreover, as described above, the flow rate adjustment valve **35** is fixed to the predetermined open degree so that the sufficient flow rate can be secured for the predetermined time TL**2** after the start of the cooling operation or the hot water supply operation. In consequence, it is possible to avoid an abnormal discharge temperature rise and an abnormally high pressure immediately after the compressor **10** (or the compressor **80**) is started.

[0184] On the other hand, even immediately after the stopping of the cooling operation or the hot water supply operation, when a predetermined time elapses after the stopping of the operation of the compressor **10** (or the compressor **80**) or the hot water indicates the predetermined value or less, the three-way valve **47**A is blocked on the hot water storage tank **30** side, and switched so as to pass the hot water (or the water) through the circulation pump **31** from the bypass pipe **49**. Subsequently, the circulation pump **31** is operated for a predetermined time. In consequence, the hot water passed through the water passage **12** of the heat exchanger **13** or the water passage **82** of the heat exchanger **83** of the second refrigerant circuit **8** does not enter the hot water storage tank **30**. The hot water flows through the closed circuit from the high-temperature pipe **48** via the bypass pipe **49**, the three-way valve **47**A and the circulation pump **31** to return to the water passage **12** of the heat exchanger **13** or the water passage **82** of the heat exchanger **83** of the second refrigerant circuit **8**.

[0185] Therefore, it is possible to prevent the low-temperature water from being passed from the upper portion of the hot water storage tank **30** into the hot water storage tank **30** to disturb the thermal stratification in the hot water storage tank **30**. Moreover, the heat exchanger **13** or the heat exchanger **83** of the second refrigerant circuit **8** can appropriately be cooled.

[0186] It is to be noted that, when the usual cooling operation or hot water supply operation is performed except during the starting and stopping, the three-way valve **47**A is blocked on the bypass pipe **49** side, and switched so as to pass the water through the circulation pump **31** from the lower portion of the hot water storage tank **30**. When the cooling operation or the hot water supply operation is not performed, the three-way valve **47**A is blocked on the hot water storage tank **30** side, and switched so as to communicate on the bypass pipe **49** side. When the cooling operation or the hot water supply operation is not performed, the valve is switched to the above state. In consequence, in a case where the high-temperature water is supplied to the washing application or the like, it is possible to avoid a problem that the cold water entering the lower portion of the hot water storage tank **30** from the water supply unit **32** flows through the hot water storage circuit **5** on the heat exchanger **13** side or the side of the heat exchanger **83** of the second refrigerant circuit **8** to enter the upper portion of the hot water storage tank **30** and lower the temperature of the hot water to be supplied.

[0187] (8) Operation of Discharge Unit **36**

[0188] In addition, in the refrigeration cycle device **200**, a disadvantage occurs that the excessively large amount of the high-temperature water is stored in the hot water storage tank **30** owing to increase of the cooling load during the cooling operation or decrease of a hot water supply load, then the temperature of the hot water taken from the lower portion of the hot water storage tank **30** also rises and consequently the high-temperature water enters the heat exchanger **13**.

[0189] When the high-temperature water enters the heat exchanger **13**, in the condenser **21** of the heat exchanger **13**, the amount of the heat to be rejected from the refrigerant flowing through the condenser **21** to the water flowing through the water passage **12** remarkably drops or falls short. In consequence, since the refrigerant cannot be cooled at a low temperature in the condenser **21**, a problem occurs that a specific enthalpy of the refrigerant flowing through the evaporator **16** rises, a cooling capacity of the evaporator **16** and the efficiency of the refrigeration cycle device **200** remarkably deteriorate and the cooling of the object to be cooled in the evaporator **16** is hindered.

[0190] To solve such a problem, according to the refrigeration cycle device **200** of the present embodiment, in a case where the temperature of the water stored in the hot water storage tank **30**, the temperature of the water to be circulated through the heat exchanger **13** for the heat exchange between the condenser **21** and the water stored in the hot water storage tank **30**, the temperature in the condenser **21** or the temperature of the refrigerant discharged from the condenser **21** rises to a predetermined value or more, the discharge unit **36** discharges the water from the hot water storage tank **30**.

[0191] Here, an operation of discharging the water from the hot water storage tank **30** by the discharge unit **36** will be described. It is assumed that in the refrigeration cycle device **200** of the present embodiment, when the temperature of the water to be circulated through the heat exchanger **13** for the heat exchange between the condenser **21** and the water stored in the hot water storage tank **30** rises to a predetermined value or more, for example, 25° C. to 30° C. or more, the water is discharged from the hot water storage tank **30** by the discharge unit **36**. It is to be noted that the temperature at which the water is discharged from the hot water storage tank **30** by the discharge unit **36** is not limited to the temperature of the water to be circulated through the heat exchanger **13** for the heat exchange between the condenser **21** and the water stored in the hot water storage tank **30** as in the present embodiment. The temperature may be the temperature of the water stored in the hot water storage tank **30**, detected by the stored hot water sensors T**4**, the temperature of the refrigerant in the condenser **21** of the heat exchanger **13** or the temperature of the refrigerant discharged from the condenser **21**.

[0192] Moreover, it is assumed that the hot water discharge valve **36**B disposed at the hot water discharge pipe **36**A of the discharge unit **36** is usually closed, and in this state the water is not discharged from the hot water storage tank **30** via the hot water discharge pipe **36**A.

[0193] Furthermore, during the cooling operation, when the temperature (the temperature of the water at the inlet of the water passage **12** of the heat exchanger **13**) of the water to be circulated through the heat exchanger **13** for the heat exchange between the condenser **21** and the water stored in the hot water storage tank **30** rises to the predetermined value or more, the hot water discharge valve **36**B of the hot water discharge pipe **36**A is opened. In consequence, the medium-temperature water having a temperature which is lower than that of the hot water taken from the high-temperature water takeout port **37** of the hot water storage tank **30** and higher than the water taken from the low-temperature water takeout port **38** is discharged from the hot water storage tank **30** via the hot water discharge pipe **36**A.

[0194] Simultaneously with the discharge of the hot water via the hot water discharge pipe **36**A, the amount of cold water corresponding the amount of the discharged hot water is supplied into the hot water storage tank **30** from the water supply pipe **32**A of the water supply unit **32**. It is to be noted that the hot water discharged from the hot water storage tank **30** via the hot water discharge pipe **36**A may be used for an appropriate application if any.

[0195] When the hot water is discharged from the hot water storage tank **30** via the hot water discharge pipe **36**A and the amount of the cold water corresponding to the amount of the discharged hot water is simultaneously supplied into the hot water storage tank **30** in this manner, the temperature of the hot water stored in the lower part of the hot water storage tank **30** can be lowered. The hot water stored in the lower part of the hot water storage tank **30** and having the lowered temperature, or the cold water supplied into the hot water storage tank **30** by the water supply unit **32** can be supplied to the heat exchanger **13**.

[0196] In consequence, in the heat exchanger **13**, it is possible to secure the amount of the heat rejected from the refrigerant, required for the evaporator **16** to maintain the cooling function. That is, in the heat exchanger **13**, the heat of the refrigerant flowing through the condenser **21** is sufficiently released to the water flowing through the water passage **12**, and the temperature of the refrigerant can be lowered. Therefore, the cooling capacity of the evaporator **16** can be maintained and the object to be cooled can securely be cooled.

[0197] Embodiment 3

[0198] It has been described in the above embodiments (Embodiments 1 and 2) that a cooling vessel **7** having a horizontally disposed elliptic columnar shape is used as a vessel to cool and insulate an object to be cooled. However, as described above, the shape of the cooling vessel may be another shape. Therefore, in the present embodiment, a case where a cooling vessel having a columnar shape is used will be described. It is to be noted that the present embodiment is different from the above embodiments only in the shape of the cooling vessel. Therefore, an only different constitution will be described. Since another constitution is the same as or similar to that of the above embodiments, description thereof is omitted.

[0199] FIG. 6 is a schematic constitution diagram of an evaporator 316 of the present embodiment as viewed from a bottom surface of an inner tank 370. A cooling vessel 307 of the present embodiment has a vertically disposed columnar shape, a bottom surface 370B (the other plate material) of the inner tank 370 substantially has a circular shape. An outer plate 376 (one plate material) secured to the bottom surface 370B substantially has a circular shape.

[0200] As shown in FIG. 6, the whole periphery of a peripheral portion of the outer plate 376 is secured to the bottom surface 370B of the inner tank 370 by seam welding, a sealed refrigerant passage space 377 is constituted between the plate materials (between the bottom surface 370B of the inner tank 370 and the outer plate 376), and this space is used as a refrigerant channel of the evaporator 316.

[0201] Moreover, a portion of the outer plate 376 other than the peripheral portion is provided with a plurality of secured inner portions 378 secured to the bottom surface 370B of the inner tank 370 at predetermined intervals. Specifically, the whole periphery of the peripheral portion of the outer plate 376 is secured to the bottom surface of the inner tank 370 by the seam welding, and the portion other than the peripheral portion is secured with spot at predetermined intervals in a checkered form or a zigzag form by spot welding (portions secured by the spot welding are the secured inner portions 378).

[0202] Furthermore, a plurality of refrigerant inlet tubes 316A and refrigerant outlet tubes 316B are attached to the refrigerant passage space 377 (a refrigerant channel of the evaporator 316) formed between the bottom surface 370B of the inner tank 370 and the outer plate 376. Moreover, as shown in FIG. 6, one end of each of the plurality of refrigerant inlet tubes 316A communicates with the refrigerant passage space 377 in the center of the refrigerant passage space 377, and one end of each refrigerant outlet tube 316B communicates with the refrigerant passage space 377 in the peripheral portion of the refrigerant passage space 377.

[0203] The refrigerant inlet tubes 316A have an arrangement concentric with the outer plate 376 substantially having a circular shape, and are connected to the center of the refrigerant passage space 377 at substantially equal intervals. The refrigerant outlet tubes 316B have an arrangement concentric with the outer plate 376 substantially having a circular shape, and are connected to the peripheral portion of the refrigerant passage space 377 at substantially equal intervals.

[0204] On the other hand, the other end of the refrigerant inlet tube 316A is connected to a refrigerant pipe 42 so that the refrigerant from the refrigerant pipe 42 is branched to flow through the refrigerant passage space 377. Moreover, the other end of the refrigerant outlet tube 316B is connected to a suction pipe 45 so that the refrigerants from the refrigerant outlet tubes 316B are combined.

[0205] Moreover, even in the present embodiment, in the same manner as in the above embodiments, the inner tank 370 has a plate thickness of 2 mm, and the outer plate 376 has a plate thickness of 1 mm. Spot-welded portions (the secured inner portion 78) have a diameter of 6 mm, and a spot pitch of 18.5 mm. The refrigerant inlet tubes 316A and the refrigerant outlet tubes 316B have an outer diameter of ϕ6.35 mm (¼ inch), and the refrigerant inlet tubes 316A and the refrigerant outlet tubes 316B have a plate thickness of 1.0 mm.

[0206] As described above in Embodiment 1, the number of the refrigerant inlet tubes 316A or the refrigerant outlet tubes 316B, and an area of the outer plate 376 can be calculated from Equations (1) and (2) described above. IN the present embodiment, the cooling vessel 307 having a rated capacity of 1000 liters is used, and the number of milking times per cargo collection is two. Therefore, NT (the number of the refrigerant inlet tubes 316A or the refrigerant outlet tubes 316B of the evaporator 316) calculated from Equation (1) is 3.25, and four refrigerant inlet tubes 316A and four refrigerant outlet tubes 316B are used. Since A (the area of the outer plate 376) calculated from Equation (2) is 1, an area of the outer plate 376 is set to 1.13 m^2 of the present embodiment.

[0207] In the present embodiment, the evaporator 316 has one path, four refrigerant inlet tubes 316A and four refrigerant outlet tubes 316B. Therefore, the refrigerant from the refrigerant pipe 42 is branched into four flows, flows through the refrigerant inlet tubes 316A, and enters the refrigerant passage (the center of the refrigerant passage space 77) of the evaporator 316 from each refrigerant inlet tube 316A. Moreover, the refrigerants entering the center of the evaporator 316 from the refrigerant inlet tubes 316A are once combined in the evaporator 316, and flows from the center in a circumferential direction. In this process, the refrigerant absorbs heat by heat exchange between the refrigerant and the object to be cooled and evaporates. The evaporated refrigerant is branched into four flows to enter the refrigerant outlet tubes 316B, flows out of the evaporator 316 via the refrigerant outlet tubes 316B, and is combined to flow through the suction pipe 45.

[0208] As described above in detail, in the evaporator 316 of the present embodiment, the refrigerant inlet tubes 316A communicate with the refrigerant passage space 377 in the center of the refrigerant passage space 377. Moreover, the refrigerant outlet tubes 316B communicate with the refrigerant passage space 377 in the peripheral portion of the refrigerant passage space 377. Therefore, the refrigerant entering the evaporator 316 from the vicinity of the center flows so as to spread in the circumferential direction. It is therefore possible to inhibit a disadvantage that pressure losses increase as the refrigerant evaporates.

[0209] That is, as the refrigerant evaporates, a specific volume increases. Therefore, in a case where the area of the refrigerant passage is set to be equal from a refrigerant inlet to an outlet of the evaporator 316, as the refrigerant evaporates, the pressure losses increase. However, as in the present embodiment, the refrigerant inlet tubes 316A are arranged in the center of the refrigerant passage space 377, and the refrigerant outlet tubes 316B are arranged in the peripheral portion of the refrigerant passage space 377. In consequence, a refrigerant passage area of the evaporator 316 is smallest at the inlet of the evaporator 316, gradually increases toward the outlet, and is maximized at the outlet of the evaporator **316**. Therefore, such pressure losses can further be reduced.

[**0210**] Furthermore, according to such a structure, a branching property of the refrigerant improves. Therefore, stagnation of the refrigerant in the evaporator **316** can be prevented, and improvement of a thermal performance can be expected.

[**0211**] It is to be noted that it is assumed in each embodiment that the heat exchanger of the present invention is used as the evaporator. However, the present invention is not limited to this example. The heat exchanger may be used as a condenser. When the heat exchanger of the present invention is used as the condenser, a heat exchange capability of the condenser can be enhanced.

[**0212**] Moreover, as the invention that can be grasped from the above description, in addition to the inventions described in claims, the following is considered. That is, the first invention is also directed to a heat exchanger characterized in that after the whole periphery of the peripheral portion of the one plate material is secured to the other plate material, a pressure is applied between the plate materials to thereby swell and form the refrigerant passage space between the plate materials.

[**0213**] The present invention is usable in not only the device which cools and insulates the milk immediately after drawn as in the above embodiments but also another industrial field such as a device related to processing of food and the like or an automatic dispenser in which cooling and cold storage are demanded.

What is claimed is:

1. A heat exchanger comprising:

a pair of plate materials,

wherein the whole periphery of a peripheral portion of at least one of the plate materials is secured to the other plate material to constitute a sealed refrigerant passage space between the plate materials;

a portion of the one plate material other than the peripheral portion is provided with a plurality of secured inner portions which are secured at predetermined intervals to the other plate material; and

a plurality of refrigerant inlet tubes and refrigerant outlet tubes are attached so as to communicate with the refrigerant passage space.

2. The heat exchanger according to claim 1, wherein the secured inner portions are arranged at the predetermined intervals in a checkered form or a zigzag form.

3. The heat exchanger according to claim 1 or 2, wherein the refrigerant inlet tubes communicate with the refrigerant passage space in the center of the refrigerant passage space; and

the refrigerant outlet tubes communicate with the refrigerant passage space in a peripheral portion of the refrigerant passage space.

4. A refrigeration cycle device comprising:

a refrigerant circuit including a compressor, a condenser, a throttling means and an evaporator,

wherein the heat exchanger according to any one of claims 1 to 3 is used as the evaporator;

carbon dioxide is introduced as a refrigerant; and

a supercritical pressure is obtained on a high-pressure side.

5. The refrigeration cycle device according to claim 4, wherein the surface of the other plate material opposite to the one plate material constitutes a wall surface of a predetermined space to be cooled; and

the surface of the one plate material opposite to the other plate material is provided with a predetermined insulation structure.

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