(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 233 861 A1

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

(43) Date of publication:
29.09.2010 Bulletin 2010/39

(21) Application number: **08862712.0**

(22) Date of filing: **21.10.2008**

(51) Int Cl.:
F25B 1/00 *(2006.01)* ***F25D 16/00*** *(2006.01)*
F25D 17/00 *(2006.01)* ***F28D 15/02*** *(2006.01)*

(86) International application number:
PCT/JP2008/069049

(87) International publication number:
WO 2009/078218 (25.06.2009 Gazette 2009/26)

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

(30) Priority: **19.12.2007 JP 2007327771**

(71) Applicant: **Hoshizaki Denki Kabushiki Kaisha**
Toyoake-shi
Aichi 470-1194 (JP)

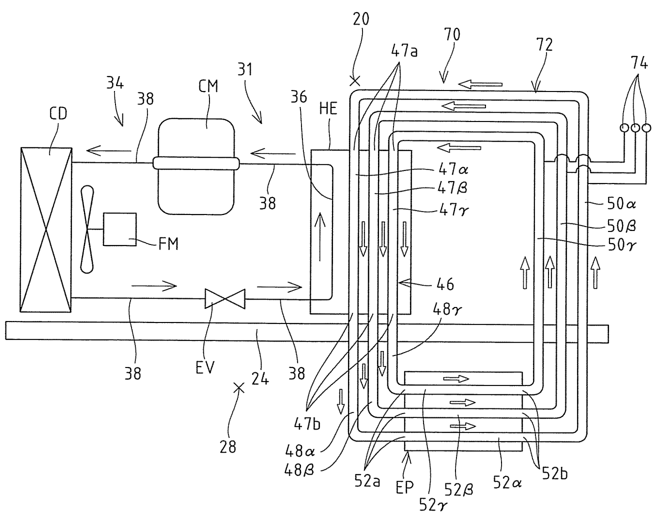
(72) Inventor: **SEKI, Kazuyoshi**
Toyoake-shi
Aichi 470-1194 (JP)

(74) Representative: **Prüfer & Partner GbR**
European Patent Attorneys
Sohnckestraße 12
81479 München (DE)

(54) COOLING DEVICE

(57) A cooling device is made compact without impairing the desired cooling efficiency. A secondary cooling device (70) has a heat exchanging part (46) for condensing a vaporized coolant flowing in a condensation path (47) into a liquid coolant, and an evaporator (EP) arranged under the heat exchanging part (46) to vaporize the liquid coolant flowing in an evaporation pipe (52) into the vaporized coolant. The secondary cooling device (70) has a plurality of natural circulation circuits (72) independent of one another. In each natural circulation circuit (72), the liquid coolant flows down from the condensation path (47) of the heat exchanging part (46) to the evaporation pipe (52) of the evaporator (EP) through a liquid piping (48), and the vaporized coolant flows from the evaporation pipe (52) of the evaporator (EP) to the condensation path (47) of the heat exchanging part (46) through a gas piping (50).

Fig.2



EP 2 233 861 A1

Description

Technical Field

[0001] The present invention relates to a cooling device provided with a natural circulation circuit which causes natural convection of a coolant using the temperature gradient between a heat exchanging part and an evaporator.

Background Art

[0002] A cooling device using a thermo-siphon to cause natural convection of a coolant is used in a storage system, such as a refrigerator, or an air conditioner. As shown in Fig. 9, a cooling device according to a first prior art using a thermo-siphon has a condenser 102 which condenses a vaporized coolant into a liquid coolant, and an evaporator 104 arranged under the condenser 102 to vaporize the liquid coolant into the vaporized coolant, with a natural circulation circuit 100 configured to permit the liquid coolant to flow down from the condenser 102 to the evaporator 104 through a liquid piping 106, and permit the vaporized coolant to flow from the evaporator 104 to the condenser 102 through a gas piping 108.

[0003] In the condenser 102 and the evaporator 104, the coolant that flows through coolant paths 102a, 104a provided therein exchanges heat with another medium, such as the outside air or water, to be condensed or vaporized. Namely, since the cooling efficiency of the cooling device depends on the quantity of heat exchanged between the coolant and another medium, the cooling device of the first prior art shown in Fig. 9 has the meandered coolant paths 102a, 104a provided in the condenser 102 and the evaporator 104 to increase the contact area of the coolant path 102a, 104a with another medium (hereinafter called "heat exchange area"). There has been proposed the configuration, like a cooling device according to a second prior art shown in Fig. 10, where two coolant paths 104a and 104a branched in parallel from a single liquid piping 106 are provided in an evaporator 104, and are joined into a single gas piping 108 which is connected to a condenser 102 (for example, Patent Literature 1).

[0004] As shown in Fig. 11, there has also been proposed a cooling device according to a third prior art that is configured to have three evaporators 104 provided for one condenser 102, so that a plurality of subjects are cooled by a plurality of evaporators 104 (for example, refer to Patent Literature 2). In the cooling device of the third prior art, liquid branch pipes 106a corresponding to the respective evaporators 104 are branched from a liquid piping 106 connected to the condenser 102, a liquid coolant is supplied to coolant paths 104a of the evaporators 104 via the liquid branch pipes 106a, gas branch pipes 108a connected to the outflow ends of the coolant paths 104a of the individual evaporators 104 are jointed together to a gas piping 108, so that the vaporized coolant gathered into the gas piping 108 flows back to the condenser 102.

Patent Literature 1: Japanese Unexamined Patent Publication No. 2005-283022
Patent Literature 2: Japanese Unexamined Patent Publication No. 2004-60956

Disclosure of the Invention

Problems to be Solved by the Invention

[0005] According to the cooling device of the first prior art, however, if the pipe length needed to secure the heat exchange area that provides the desired cooling efficiency is obtained is set, the coolant paths 102a, 104a become long, increasing the flow resistance of the coolant in the coolant paths 102a, 104a. In addition, the coolant paths 102a, 104a would have a greater number of bent portions in order to make the elongated coolant paths 102a, 104a compact, further increasing the flow resistance of the coolant. Since the system using a thermo-siphon like the cooling device of the first prior art is configured to permit the coolant to have natural convection using the temperature gradient between the condenser 102 and the evaporator 104, the circulation power of the coolant is weaker, as compared with the system that forcibly circulate the coolant with a pump or the like, so that a slight pressure loss or the flow resistance against the coolant would greatly interfere with the smooth flow of the coolant. When the coolant does not flow smoothly in the coolant paths 102a, 104a, the circulation of the coolant in the natural circulation circuit 100 including the evaporator 104 is impaired, or the coolant flows reversely, lowering the cold carrying performance, so that the target cannot be cooled efficiently. To avoid reduction in the cooling efficiency, therefore, the cooling device of the first prior art should have the cross-sectional areas of the coolant paths 102a, 104a set large according to the amount of circulation of the coolant, thereby decreasing the flow resistance of the coolant to stabilize the flow state of the coolant which is greatly influenced by a slight pressure loss. However, the increase in the diameter of the pipings constituting the coolant paths 102a and 104a increases the restrictions on the formation of the coolant paths, and enlarges the condenser 102 and the evaporator 104, which leads to cost increase.

[0006] Although pressure loss can be made small by reducing the bent part of the coolant path 104a like the cooling device of the second prior art as configuration in which the coolant paths 104a and 104a branch in the evaporator 104, it is difficult to make a coolant shunt toward each branched coolant paths 104a and 104a with sufficient balance. Similarly, even if it is a case where a plurality of evaporators 104 are formed in the cooling device of the third prior art in parallel like, it is difficult to make a coolant shunt with sufficient balance to the coolant path 104a of each evaporator 104. And when the coolant of the quantity which inclined toward the coolant path 104a circulates, not only cooling efficiency falls by the coolant path 104a whose amount of supply of the coolant decreased, but it will influence the circulation balance of the whole natural circulation circuit greatly, and cooling efficiency will fall as a whole. Then, the control valve 110 which opens and closes a pipeline in the cooling device of the third prior art is inserted in the liquid branch pipe 106a connected to the evaporator 104, and the coolant amount supplied to the coolant path 104a of each evaporator 104 is adjusted by carrying out opening and closing control of each control valve 110 by the control means C based on the coolant temperature of the entrance side of the evaporator 104, and the coolant temperature of the outlet side of the evaporator 104. However, in the cooling device of the third prior art, an apparatus such as the control valve 110, the sensor which measures the coolant temperature, and the control means C, is needed, the configuration of a cooling device becomes complicated and there is inconvenience which causes the rise of cost. Thus, in the cooling device using a thermo-siphon, even if it shunts the coolant paths 102a, 104a in order to decrease the flow resistance of the coolant in the coolant paths 102a, 104a, it is dramatically difficult to collateralize circulation of the equivalent coolant between the coolant paths used as indispensable conditions in order to attain this purpose, and reducing the flow resistance of the coolant in each coolant paths 102a, 104a by carrying out the diversion of the coolant paths 102a, 104a is technically accompanied by extraordinary difficulty.

[0007] Namely, the invention is proposed in view of the problem which is inherent in the cooling device according to a related art so that it may solve these suitably, and in the natural circulation circuit in which a coolant carries out a natural convection using a thermo-siphon, it aims at providing a cheap and compact cooling device, without causing the increase in the flow resistance of the coolant, the coolant fill ration in this circuit, and the cross-section area of each path, with desired cooling efficiency maintained.

Effect of the Invention

[0008] The cooling device according to the invention can be made inexpensive and compact without increasing the flow resistance of the coolant, the amount of the coolant to be filled in this circuit, and the cross-sectional area of each path while keeping the desired cooling efficiency.

Brief Description of the Drawings

[0009]

[Fig. 1] A side cross-sectional view showing a refrigerator provided with a cooling device according to a preferred first embodiment of the invention as a secondary circuit of a cooling system.
[Fig. 2] A schematic circuit diagram showing the essential parts of the cooling system provided with the cooling device of the first embodiment as a secondary circuit.
[Fig. 3] A schematic circuit diagram showing the essential parts of the cooling system provided with a cooling device of a second embodiment as a secondary circuit.
[Fig. 4] A schematic circuit diagram showing a cooling device according to a first modification.
[Fig. 5] A schematic circuit diagram showing a cooling device according to a second modification.
[Fig. 6] A schematic circuit diagram showing a cooling device according to a third modification.
[Fig. 7] A schematic circuit diagram showing a cooling device according to a fourth modification.
[Fig. 8] A schematic circuit diagram showing a cooling device according to a fifth modification.
[Fig. 9] A schematic circuit diagram showing the cooling device of the first prior art.
[Fig. 10] A schematic circuit diagram showing the cooling device of the second prior art.
[Fig. 11] A schematic circuit diagram showing the cooling device of the third prior art.

Best Mode of Carrying Out the Invention

[0010] In these days, the use of the chlorofluorocarbon as a coolant in systems provided with cooling devices, such as a refrigerator and a freezer, is restricted from a viewpoint of global warming prevention. In particular, since large-sized systems, such as business-use freezer machines, use a large amount of chlorofluorocarbon, there are considerable demands to reduce the amount used or not to use chlorofluorocarbon. In this respect, a secondary loop type refrigeration circuit whose circuit configuration is advantageous in promoting a non-chlorofluorocarbon operation, is attracting attention. The secondary loop type refrigeration circuit is configured in such a way that two independent circuits, namely a primary-side circuit of a mechanical compression type which forcibly circulates the coolant and a secondary-side circuit which causes natural convection of the coolant using a thermo-siphon are connected together via a heat exchanger, and can use a heating medium other than chlorofluorocarbon as the coolant that is circulated in each circuit. However, the conventional secondary loop type refrigeration circuit has shortcomings of making the whole device larger, thereby requiring a large installation area, and increasing the cost, as compared with the refrigeration circuit of the mechanical compression type which uses chlorofluorocarbon as the coolant, and cannot compete the conventional system using chlorofluorocarbon in terms of the size and price. This stands in the way of promoting the non-chlorofluorocarbon operation. In this respect, the present inventor has invented a compact and inexpensive cooling device according to the invention without spoiling the desired cooling efficiency. For example, application of the cooling device according to the invention to a secondary loop type refrigeration circuit makes it possible to design a system provided with the secondary loop type refrigeration circuit with a size and cost equivalent to those of the conventional system using chlorofluorocarbon, and can overcome the foregoing shortcomings, providing the competitive strength in the market. That is, the cooling device according to the invention is technically effective in promoting the spread of the non-chlorofluorocarbon technique achieved by the secondary loop type refrigeration circuit which is considered important from the viewpoint of prevention of global warming. Apparently, the cooling device according to the invention, when adapted to the secondary loop type refrigeration circuit, is a very significant invention which can overcome the shortcomings of the conventional secondary loop type refrigeration circuit of being large in size and expensive, and can provide the technique which can become generally popular.

[0011] Next, the cooling device according to the invention will be described below by way of preferred embodiments with reference to the accompanying drawings. The description of the embodiments will be given of a case where a large-sized refrigerator which is used for business use in a store or the like and can store a large quantity of goods, such as vegetables and meat, is illustrated by way of example, and a so-called secondary loop refrigeration circuit that uses the cooling device according to the invention in the secondary-side circuit as the cooling system of this refrigerator is adopted.

First Embodiment

[0012] As shown in Fig. 1, a refrigerator 10 has a box 12 with a heat insulated structure which has a storage room 14 defined therein, a cabinet 16 which is provided above the box 12 and has an outer wall formed by a metal panel 18. An opening 12a which is open frontward to serve as a goods inlet/outlet opening is formed in the box 12 to communicate with the storage room 14. This opening 12a is closed by a heat insulated door 22 supported at the front portion of the box 12 in an openable/closable manner with an unillustrated hinge.

[0013] Defined inside the cabinet 16 is a machinery room 20 in which a part of a cooling system 31 for cooling the storage room 14 and an electric control box (not shown) which controls the cooling system 31 are disposed. A base plate 24 which is mounted on a top plate 12b of the box 12 to serve as a common base plate for devices to be disposed in the machinery room 20 is installed at the bottom portion of the machinery room 20. An air flow hole (not shown) which communicates with the machinery room 20 is formed at an adequate position in the metal panel 18 which serves as the outer wall of the cabinet 16, so that the atmosphere in the machinery room 20 and the outside air are interchanged via this air circulation hole.

[0014] A cooling duct 26 is disposed at the upper portion of the storage room 14 apart from the bottom side of the top plate 12b of the box 12 by a predetermined distance, and a cooling room 28 is defined between the cooling duct 26 and the base plate 24 which faces the storage room 14 via a notched port 12c formed in the top plate 12b of the box 12. This cooling room 28 communicates with the storage room 14 via a suction opening 26a formed in the front bottom portion of the cooling duct 26 and a cold outlet 26b formed in the rear side thereof. A blower fan 30 is disposed at the suction opening 26a. When the blower fan 30 is driven, the air in the storage room 14 is fed into the cooling room 28 from the suction opening 26a, and the cold in the cooling room 28 is sent out to the storage room 14 from the cold outlet 26b. The notched port 12c of the top plate 12b is closed airtight by the base plate 24, so that the storage room 14 (cooling room 28) and the machinery room 20 are separated by the base plate 24 to be independent spaces (see Fig. 1).

[0015] Fig. 2 is a schematic circuit diagram showing the cooling system 31 provided with a secondary cooling device (cooling device) 70 according to the first embodiment as a secondary-side circuit. As shown in Fig. 2, the cooling system 31 adopts the secondary loop refrigeration circuit in which a primary cooling device (primary-side circuit) 34 of a mechanical compression type which forcibly circulates the coolant and the secondary cooling device 70 comprised of a thermo-siphon which causes the natural convection the coolant are thermally connected (cascade connected) in such a way as to exchange heat through a heat exchanger HE. The heat exchanger HE is installed in the machinery room 20, and has a primary heat exchanging part 36 which constitutes the primary cooling device 34, and a secondary heat exchanging part (heat exchanging part) 46 which is formed separate from the primary heat exchanging part 36 and constitutes the secondary cooling device 70. That is, circuits through which independent coolants circulate are formed in the primary cooling device 34 and the secondary cooling device 70, respectively, and carbon dioxide with high safety which is intoxic, inflammable, and non-corrosive is adopted as a secondary coolant (coolant) which circulates through the secondary cooling device 70. On the other hand, a HC-based coolant, such as butane or propane, or ammonia, which has an excellent characteristic as a coolant, such as heat of evaporation or saturation pressure, is adopted as a primary coolant which circulates through the primary cooling device 34; propane is used in the first embodiment. That is, the cooling system 31 need not use chlorofluorocarbon as a coolant. For example, a plate type, a double tube type, developed types thereof, or equivalents thereto are used as the heat exchanger HE.

[0016] The primary cooling device 34 is configured by connecting a compressor CM which compresses a gaseous-phase primary coolant, a condenser CD which liquefies the compressed primary coolant, an expansion valve EV which lowers the pressure of a liquid-phase primary coolant, and the primary heat exchanging part 36 of the heat exchanger HE which vaporizes the liquid-phase primary coolant by a coolant piping 38 (see Fig. 2). The compressor CM and the condenser CD are commonly disposed on the base plate 24 in the machinery room 20, and a condenser cooling fan FM which forcibly cools the condenser CD is also disposed facing the condenser CD on the base plate 24. In the primary cooling device 34, the compression of the primary coolant by compressor CM forces the primary coolant to circulate in the order of the compressor CM, the condenser CD, the expansion valve EV, the primary heat exchanging part 36 of the heat exchanger HE, and the compressor CM to carry out the desired cooling in the primary heat exchanging part 36 with the individual components in operation (see Fig. 2).

[0017] The secondary cooling device 70 has a secondary heat exchanging part 46 of the heat exchanger HE which liquefies a gaseous-phase secondary coolant (vaporized coolant), and an evaporator EP which vaporizes a liquid-phase secondary coolant (liquid coolant). The secondary heat exchanging part 46 and evaporator EP correspond to each other in a 1 to 1 relation (see Fig. 2). The secondary cooling device 70 has a liquid piping 48 and a gas piping 50 which connect the secondary heat exchanging part 46 and evaporator EP together, and is provided with a natural circulation circuit 72 which supplies the liquid-phase secondary coolant from the secondary heat exchanging part 46 through the liquid piping 48 to the evaporator EP under the gravity, and permits the gaseous-phase secondary coolant to flow from the evaporator EP to the secondary heat exchanging part 46 through the gas piping 50. A plurality of natural circulation circuits 72 (three circuits in the illustrated example) independent of one another are formed in parallel in the secondary cooling device 70 of the first embodiment. The secondary heat exchanging part 46 is disposed in the machinery room 20 while the evaporator EP is disposed in the cooling room 28 located under the machinery room 20, at a position lower than the secondary heat exchanging part 46 with the base plate 24 in between.

[0018] A plurality of (three in the first embodiment) condensation paths 47 (α, β, γ,... are added to the numeral 47 in case of particularly distinguishing them) are provided in parallel in the secondary heat exchanging part 46. A plurality of evaporation pipes (evaporation paths) 52 (three in the first embodiment; α, β, γ, ... are added to the numeral 52 in case of particularly distinguishing them) are provided in parallel in the evaporator EP. Although the condensation path 47 is expressed as a linear path from an inflow end 47a connected to the gas piping 50 to an outflow end 47b connected to the liquid piping 48, and the evaporation pipe 52 is expressed as a linear path from an inflow end 52a connected to the liquid piping 48 to an outflow end 52b connected to the gas piping 50 in Fig. 2, the condensation path 47 and the evaporation pipe 52 may be formed meandering or linearly. In the secondary cooling device 70, a plurality of condensation paths 47, a plurality of evaporation pipes 52, a plurality of liquid pipings 48 (α, β, γ, ... are added to the numeral 48 in case of particularly distinguishing them), and a plurality of gas pipings 50 (α, β, γ, ... are added to the numeral 50 in case of particularly distinguishing them) are equal in number. In each natural circulation circuit 72, the liquid piping 48 has an upper end (start end) connected to the outflow end 47b of the condensation path 47 in the secondary heat exchanging part 46, is laid out through the base plate 24, and has a lower end (termination end) located on the cooling room 28 side and connected to the inflow end 52a of the evaporation pipe 52 in the evaporator EP. In each natural circulation circuit 72, the gas piping 50 has a lower end (start end) located on the cooling room 28 side and connected to the outflow end 52b of the evaporation pipe 52 in the evaporator EP, is laid out through the base plate 24, and has an upper end (termination end) located on the machinery room 20 side and connected to the inflow end 47a of the condensation path 47 in the secondary heat exchanging part 46. Numeral 74 denotes a coolant charge port provided to fill each natural circulation circuit 72 with a coolant.

[0019] A temperature gradient is formed between the evaporator EP and the secondary heat exchanging part 46 which is cooled by heat exchange with the primary heat exchanging part 36, which is forcibly cooled, in each natural circulation circuit 72 in the secondary cooling device 70, and the coolant circulation cycle in which the secondary coolant naturally circulates in the secondary heat exchanging part 46, the liquid piping 48, the evaporator EP, and the gas piping 50, and returns to the secondary heat exchanging part 46 again is formed. Although a plurality of evaporation pipes 52 are laid out one above another in Fig. 2, they may be laid out in parallel horizontally.

[Operation of First Embodiment]

[0020] Next, the operation of the cooling system 31 provided with the secondary cooling device 70 according to the first embodiment will be described. In the cooling system 31, when the cooling operation starts, circulation of the coolant in each of the primary cooling device 34 and the secondary cooling device 70 starts. First, if the primary cooling device 34 is described. The compressor CM and condenser cooling fan FM are driven to compress the gaseous-phase primary coolant in the compressor CM. This primary coolant is supplied to the condenser CD via the coolant piping 38 to be condensed and liquefied with forced cooling by the condenser cooling fan FM to become a liquid phase. The liquid-phase primary coolant is decompressed by the expansion means EV, takes (absorbs) heat from the secondary coolant which circulates in the secondary heat exchanging part 46 in the primary heat exchanging part 36 of the heat exchanger HE to be expanded and vaporized at once. Thus, the primary cooling device 34 is functioning to forcibly cool the secondary heat exchanging part 46 by means of the primary heat exchanging part 36 in the heat exchanger HE. The gaseous-phase primary coolant vaporized in the primary heat exchanging part 36 repeats the forced circulation cycle in which the gaseous-phase primary coolant returns to the compressor CM through the coolant piping 38.

[0021] In the secondary cooling device 70, since the secondary heat exchanging part 46 is cooled by the primary heat exchanging part 36, the gaseous-phase secondary coolant discharges heat to be condensed during the circulation in each condensation path 47 of the secondary heat exchanging part 46 in each natural circulation circuit 72, so that the phase of the secondary coolant changes from the gaseous phase to the liquid phase, increasing its specific gravity. This causes the liquid-phase secondary coolant to flow down along each condensation path 47 of the secondary heat exchanging part 46 under the gravity. In the secondary cooling device 70, the secondary heat exchanging part 46 is disposed in the machinery room 20, and the evaporator EP is disposed in the cooling room 28 located under the machinery room 20, thereby providing a fall between the secondary heat exchanging part 46 and the evaporator EP. That is, in each natural circulation circuit 72, the liquid-phase secondary coolant can be caused to naturally flow, under the gravity, toward the evaporator EP through the liquid piping 48 connected to the lower part of the secondary heat exchanging part 46. During the circulation in each evaporation pipe 52 of the evaporator EP, the liquid-phase secondary coolant takes heat from the ambient atmosphere of the evaporator EP to be vaporized to change the phase to the gaseous phase. The gaseous-phase secondary coolant flows back from the evaporator EP to the secondary heat exchanging part 46 through the gas piping 50, and in the secondary cooling device 70, the cycle in which the secondary coolant is caused to circulate naturally with a simple configuration is repeated in each natural circulation circuit 72, without using power, such as a pump or a motor.

[0022] As the air in the storage room 14 which is sucked into the cooling room 28 from the suction opening 26a is sprayed to the evaporator EP by the blower fan 30, the air which has exchanged heat with the cooled evaporator EP is turned into cold. The storage room 14 is cooled by feeding the cold to the storage room 14 from the cooling room 28 via the cold outlet 26b. The cold repeats the cycle of circulating inside the storage room 14 and returning into the cooling room 28 again via the suction opening 26a.

[0023] In the secondary cooling device 70, the condensation path 47 and the evaporation pipe 52 are connected by the liquid piping 48 and the gas piping 50 so that the individual natural circulation circuits 72 are independent of one another to constitute one circuit without involving branching of a path and piping. Since the individual natural circulation circuits 72 are independent of one another, it is possible to suppress maldistribution of the secondary coolant between the condensation paths 47, 47, between the evaporation pipes 52, 52 or between the condensation path 47 and the evaporation pipe 52, so that the amounts of the secondary coolant which circulates in each condensation path 47 and in each evaporation pipe 52 can be matched with each other.

[0024] There is a case where the secondary coolant which circulates through each natural circulation circuit 72 may be maldistributed in any of the condensation paths 47 and the evaporation pipes 52 due to an external factor, such as a change in the temperature of the outside air which acts on the secondary cooling device 70. Since each natural circulation circuit 72 has an independent thermo-siphon formed, however, the balance of the secondary coolant is naturally adjusted so that the amount of the secondary coolant in each condensation path 47 coincides with the amount of the secondary coolant in each evaporation pipe 52. Therefore, maldistribution of the secondary coolant in each condensation path 47 and each evaporation pipe 52 does not occur easily. Even if maldistribution of the secondary coolant occurs, regulation is applied in such a way that the amounts of the secondary coolant which circulates in the condensation path 47 and the evaporation pipe 52 are matched with each other, eliminating the need for providing regulation means, such as a valve, for adjusting the balance of the secondary coolant, and making it possible to simplify the configuration of the secondary cooling device 70. In addition, since smooth natural circulation of the secondary coolant takes place in the natural circulation circuit 72, the cooling efficiency in the evaporator EP can be improved. Providing the cooling device 70 with the natural circulation circuits 72 whose quantity accords to the heat exchange area required in the heat exchanging part 46 and the evaporator EP can allow the required condensation paths 47 and evaporation pipes 52 to be disposed in the heat exchanging part 46 and the evaporator EP, thereby securing the heat exchange area needed by the whole device.

[0025] In the secondary cooling device 70, a plurality of condensation paths 47 and a plurality of evaporation pipes 52 can be disposed in each of the heat exchanger 46 and evaporator EP. That is, the heat exchange area required of a single condensation path 47 and a single evaporation pipe 52 becomes smaller, making it possible to shorten the pipe lengths of each condensation path 47 and each evaporation pipe 52. This can reduce the number of times each condensation path 47 and each evaporation pipe 52 is meandered to attain the pipe length needed, thus reducing the bent portions which serve as the flow resistance. It is therefore possible to reduce the pressure loss of the secondary coolant which circulates in the condensation path 47 and the evaporation pipe 52. In addition, since each natural circulation circuit 72 is formed by a single coolant path without branching the liquid piping 48, the gas piping 50, the condensation path 47, and the evaporation pipe 52, the pressure loss originating from the branched portion of a pipe or the like does not occur. Further, since the head difference of the secondary coolant needed for the natural convection between the condensation path 47 and the evaporation pipe 52 can be made small in each natural circulation circuit 72, the fall needed between the condensation path 47 and the evaporation pipe 52 becomes small. This makes it possible to narrow the vertical layout intervals of the secondary heat exchanging part 46 and the evaporator EP, so that the secondary cooling device 70 can be made compact. The pressure loss of the secondary coolant in each natural circulation circuit 72 is small, so that even if a small tube diameter is selected for the liquid piping 48 and the gas piping 50 as compared with the prior arts, the same amount of the secondary coolant can be circulated in the circuit, and the amount of the secondary coolant which is filled in the whole circuit can be reduced.

[0026] Since it is possible to reduce the lengths and cross-sectional areas of each condensation path 47 and each evaporation pipe 52, the secondary heat exchanging part 46 and the evaporator EP can be made compact, and reducing the amount of the coolant which circulates reduces the supplementary facilities, such as capacity of the expansion tank (not shown) which eases the pressure rise in the natural circulation circuit 72. This can make the secondary cooling device 70 compact as a whole, and achieve cost reduction. Further, the thicknesses of the pipings, such as the liquid piping 48, the gas piping 50, and the evaporation pipe 52, which are needed to secure the pressure resistance therein can be reduced by narrowing those pipings. That is, the synergistic effect of narrowing the pipings 48, 50, 52 and reducing the thicknesses of the pipings 48, 50, 52 can reduce the weights of the pipings further, and reducing the cost further.

[0027] A specific description will be given of cost reduction which is achieved by narrowing the pipings, such as the liquid piping 48, the gas piping 50, and the evaporation pipe 52.

For example, the thickness t of the piping which has a pressure resistance P is obtained by the following equation where σ is allowable stress of the material and D is the outside diameter of the piping.

$$t=PD/2\ (\sigma+P)\ ...\ (I)$$

A pipe weight M with a length L is obtained by the following equation where C is the specific gravity of the material and D_i is the inside diameter of the piping.

$$M=\pi LC(D^2-D_i^2)\ /4\ ...\ (II)$$

Since it is possible to express D_i=D-2t, substituting it in the equation (II) yields the following equation.

$$M=\pi LC\ (Dt-t^2)\ ...\ (III)$$

Substituting the equation I into the equation (III) yields the following equation.

$$M=(1-P/2(\sigma+P))x\pi LCPD^2/2(\sigma+P)\ ...\ (IV)$$

The equation (IV) shows the weight of the piping which has the pressure resistance P. If conditions other than D are unchanged in the equation (IV), the conditions of π, L, C, P, and σ can be treated as constants. Therefore, the weight of the piping (the outside diameter D of the piping) which has the pressure resistance P can be expressed by the following equation.

$$M=((1-P/2(\sigma+P))x\ \pi LCP/2(\sigma+P)\}xD^2\ ...\ (V)$$

Inside {} in the equation (V) is a constant as mentioned above, it is possible to express $M=AD^2$.
The pipe weight MD_1 of the piping with the outside diameter D_1 which has the pressure resistance P is AD_1^2, and the pipe weight MD_2 of the piping with the outside diameter D_2 which has the pressure resistance P is AD_2^2.
Further, the ratio of the pipe weight MD_1 to the pipe weight MD_2 is expressed as follows.

$$MD_2/MD_1=D_2^2/D_1^2 \ldots \text{(VI)}$$

[0028] Specific numbers are applied in the equation (VI) in the description. In the general cooling device, the outside diameter of an evaporation pipe is often set to 9.52 mm. According to the cooling device of the first embodiment, an evaporation pipe with the outside diameter of 6.35 mm can be used, which depends on the conditions. Applying these conditions to the equation (VI) yields the following.

$$MD_{\phi 6.35}/MD_{\phi 9.52}=(6.35)^2/(9.52)^2=0.44$$

When an evaporation pipe with the outside diameter of 4.76 mm is used in the cooling device of the first embodiment, the equation becomes as follows.

$$MD_{\phi 4.76}/MD_{\phi 9.52}=(4.76)^2/(9.52)^2=0.25$$

That is, since the weight ratio of the pipings can be said as the ratio of the prices of the materials of the pipings, it is apparent that the secondary cooling device 70 of the first embodiment can achieve a significant cost reduction by narrowing the pipings as compared with the conventional cooling devices.

[0029] The cooling system 31 connects the primary cooling device 34 and the secondary cooling device 70 by the heat exchanger HE, which performs heat exchange of the primary coolant of the primary cooling device 34 and the secondary coolant of the secondary cooling device 70 under evaporation and condensation. That is, since the heat transfer coefficient is very high as compared with the heat exchange that is carried out by sensible heat alone, the heat transfer area between the primary cooling device 34 and the secondary cooling device 70 can be made smaller. Since both of the primary coolant and the secondary coolant transport heat based on the latent heat, comparatively small amounts of the coolants can transfer a large quantity of heat, so that the internal volumes of the primary cooling device 34 and the secondary cooling device 70 can be made smaller without reducing the quantity of heat exchanged by the heat exchanger HE. Therefore, it is possible to reduce both of the amount of the primary coolant in the primary cooling device 34 and the amount of the secondary coolant in the secondary cooling device 70, leading to cost reduction and reduction in the space of the cooling system 31 as a result of making the primary cooling device 34 and the secondary cooling device 70 compact.

[0030] Since there is a small amount of the primary coolant needed in the primary cooling device 34, the amount can be set equal to or less than the upper limit of the usable amount of the coolant that is defined by the law or the like, thus widening the range of choices for the kind of the coolant used as the primary coolant. To cool the condenser CD and compressor CM with air, the machinery room 20 is set as the open space where air is refreshed. Since the primary cooling device 34 is disposed in such a machinery room 20, even if the primary coolant should leak out, it would not stay in the machinery room 20. Since the machinery room 20 is separated airtightly from the storage room 14 which is closed space with the base plate 24, the leaked primary coolant does not flow into the storage room 14, and the corrosive gas, such as ammonia or hydrogen sulfide, originating from some goods stored in the storage room 14 does not flow into the machinery room 20. In addition, as the cooling system 31 is formed by the secondary loop type refrigeration circuit including the primary cooling device 34 and the secondary cooling device 70, it is possible to choose carbon dioxide or the like excellent in safety as the secondary coolant. That is, in the secondary cooling device 70, although the evaporator EP faces the storage room 14 (cooling room 28), even if a secondary coolant leaks out to the storage room 14, for example, the safety to the user can be guaranteed.

[0031] The primary cooling device 34 and the secondary cooling device 70, which are thermally connected by the primary heat exchanging part 36 and the secondary heat exchanging part 46 of the heat exchanger HE, are independent of each other as the coolant circulation paths. When the cooling system 31 is stopped (compressor CM: stopped), a hot liquid-phase primary coolant flows into the primary heat exchanging part 36 from the condenser CD in the primary cooling device 34. Although that raises the temperature of the heat exchanger HE, the temperature of the evaporator EP does not rise since the secondary cooling device 70 is independent, thus making the temperature rise in the storage room 14 gentle at the time of stopping the cooling system 31. That is, by cooling the storage room 14 to the desired set temperature with the cooling system 31, the time for the cooling system 31 to be driven again after being stopped can be made longer. Accordingly, the operating ratio of the cooling system 31 drops, leading to reduction in the amount of power consumption.

[0032] With the secondary cooling device 70 of the first embodiment applied to the cooling system 31 which is comprised of the secondary loop type refrigeration circuit, the cooling system 31 can be designed to be equal in size and cost to the conventional cooling system using chlorofluorocarbon, and to overcome the shortcomings of the refrigeration circuit of the mechanical compression type using chlorofluorocarbon as the coolant, such as enlargement of the whole device, a large installation area required, and cost increase, providing the competitive strength in the market. That is, the secondary cooling device 70 according to the first embodiment is technically effective in promoting the spread of the non-chlorofluorocarbon technique achieved by the secondary loop type refrigeration circuit which is considered important from the viewpoint of prevention of global warming.

Second Embodiment

[0033] Fig. 3 is a schematic circuit diagram showing a cooling system 32 provided with a secondary cooling device (cooling device) 44 according to the second embodiment as a secondary-side circuit. The cooling system 32 of the second embodiment is installed in the refrigerator 10 described in the description of the first embodiment.

[0034] As shown in Fig. 3, the cooling system 32 according to the second embodiment adopts the secondary loop refrigeration circuit in which a primary cooling device (primary-side circuit) 34 of a mechanical compression type which forcibly circulates the coolant and the secondary cooling device (cooling device) 44 comprised of a thermo-siphon which causes the natural convection of the coolant are thermally connected (cascade connected) in such a way as to exchange heat through a heat exchanger HE. The heat exchanger HE is installed in the machinery room 20, and has a primary heat exchanging part 36 which constitutes the primary cooling device 34, and a secondary heat exchanging part (heat exchanging part) 46 which is formed separate from the primary heat exchanging part 36 and constitutes the secondary cooling device 44. That is, circuits through which independent coolants circulate are formed in the primary cooling device 34 and the secondary cooling device 44, respectively, and carbon dioxide with high safety which is intoxic, inflammable, and non-corrosive is adopted as a secondary coolant (coolant) which circulates through the secondary cooling device 44. On the other hand, a HC-based coolant, such as butane or propane, or ammonia, which has an excellent characteristic as a coolant, such as heat of evaporation or saturation pressure, is adopted as a primary coolant which circulates through the primary cooling device 34; propane is used in the second embodiment. That is, the cooling system 32 need not use chlorofluorocarbon as a coolant. For example, a plate type, a double tube type, developed types thereof, or equivalents thereto are used as the heat exchanger HE.

[0035] The primary cooling device 34 is configured by connecting a compressor CM which compresses a gaseous-phase primary coolant, a condenser CD which liquefies the compressed primary coolant, an expansion valve EV which lowers the pressure of a liquid-phase primary coolant, and the primary heat exchanging part 36 of the heat exchanger HE which vaporizes the liquid-phase primary coolant by a coolant piping 38 (see Fig. 3). The compressor CM and the condenser CD are commonly disposed on the base plate 24 in the machinery room 20, and a condenser cooling fan FM which forcibly cools the condenser CD is also disposed facing the condenser CD on the base plate 24. In the primary cooling device 34, the compression of the primary coolant by compressor CM forces the primary coolant to circulate in the order of the compressor CM, the condenser CD, the expansion valve EV, the primary heat exchanging part 36 of the heat exchanger HE, and the compressor CM to carry out the desired cooling in the primary heat exchanging part 36 with the individual components in operation (see Fig. 3).

[0036] The secondary cooling device 44 has a secondary heat exchanging part 46 of the heat exchanger HE which liquefies a gaseous-phase secondary coolant (vaporized coolant), and an evaporator EP which vaporizes a liquid-phase secondary coolant (liquid coolant). The secondary heat exchanging part 46 and evaporator EP correspond to each other in a 1 to 1 relation (see Fig. 3). The secondary cooling device 44 has a liquid piping 48 and a gas piping 50 which connect the secondary heat exchanging part 46 and evaporator EP together, and is provided with a natural circulation circuit 45 which supplies the liquid-phase secondary coolant from the secondary heat exchanging part 46 through the liquid piping 48 to the evaporator EP under the gravity, and permits the gaseous-phase secondary coolant to flow from the evaporator EP to the secondary heat exchanging part 46 through the gas piping 50. As mentioned above, the secondary heat exchanging part 46 is disposed in the machinery room 20 while the evaporator EP is disposed in the cooling room 28 located under the machinery room 20, at a position lower than the secondary heat exchanging part 46 with the base plate 24 in between. Numeral 74 denotes a coolant charge port provided to fill the natural circulation circuit 45 with a coolant; since the secondary cooling device 44 of the second embodiment has a single natural circulation circuit 45, one set of supplementary facilities, such as the coolant charge port 74, a safety valve and an expansion tank (none shown), is sufficient.

[0037] A plurality of (three in the second embodiment) condensation paths 47 (α, β, γ, ... are added to the numeral 47 in case of particularly distinguishing them) are provided in parallel in the secondary heat exchanging part 46. A plurality of evaporation pipes (evaporation paths) 52 (three in the second embodiment; α, β, γ, ... are added to the numeral 52 in case of particularly distinguishing them) are provided in parallel in the evaporator EP. Although the condensation path 47 is expressed as a linear path from an inflow end 47a connected to the gas piping 50 to an outflow end 47b connected to the liquid piping 48, and the evaporation pipe 52 is expressed as a linear path from an inflow end 52a connected to the liquid piping 48 to an outflow end 52b connected to the gas piping 50 in Fig. 3, the condensation path 47 and the evaporation pipe 52 may be formed meandering or linearly. In the secondary cooling device 44, a plurality of condensation paths 47, a plurality of evaporation pipes 52, a plurality of liquid pipings 48 (α, β, γ,... are added to the numeral 48 in case of particularly distinguishing them), and a plurality of gas pipings 50 (α, β, γ, ... are added to the numeral 50 in case of particularly distinguishing them) are set equal in number. The liquid piping 48 has an upper end (start end) connected to the outflow end 47b of the condensation path 47 in the secondary heat exchanging part 46, is laid out through the base plate 24, and has a lower end (termination end) located on the cooling room 28 side and connected to the inflow end 52a of the evaporation pipe 52 in the evaporator EP. The gas piping 50 has a lower end (start end) located on the cooling room 28 side and connected to the outflow end 52b of the evaporation pipe 52 in the evaporator EP, is laid out through the base plate 24, and has an upper end (termination end) located on the machinery room 20 side and connected to the inflow end 47a of the condensation path 47 in the secondary heat exchanging part 46.

[0038] The secondary cooling device 44 is configured in such a way that the liquid piping 48 connected to the outflow end 47b of the condensation path 47 is connected to an evaporation pipe 52 different from the evaporation pipe 52 which is connected with the gas piping 50 coupled to the inflow end 47a of the condensation path 47. In the secondary cooling device 44, the gas piping 50 connected to the outflow end 52b of the evaporation pipe 52 is connected to a condensation path 47 different from the condensation path 47 which is connected with the liquid piping 48 coupled to the inflow end 52a of the evaporation pipe 52. A temperature gradient is formed between the evaporator EP and the secondary heat exchanging part 46 which is cooled by heat exchange with the primary heat exchanging part 36, which is forcibly cooled, in the secondary cooling device 44, and the coolant circulation cycle in which the secondary coolant naturally circulates in the secondary heat exchanging part 46, the liquid piping 48, the evaporator EP, and the gas piping 50, and returns to the secondary heat exchanging part 46 again is formed. Although a plurality of evaporation pipes 52 are laid out one above another in Fig. 3, they may be laid out in parallel horizontally.

[0039] The natural circulation circuit 45 which is formed in the secondary cooling device 44 will be described more specifically referring to Fig. 3. In the secondary cooling device 44 of the second embodiment, three condensation paths 47α, 47β, 47γ are provided as coolant paths in the secondary heat exchanging part 46, and three evaporation pipes 52α, 52β, 52γ are provided as coolant paths in the evaporator EP. The start end of a first liquid piping 48α is connected to the outflow end 47b of the first condensation path 47α, and the termination end of the first liquid piping 48α is connected to the inflow end 52a of the first evaporation pipe 52α, so that the secondary liquid coolant is supplied to the first evaporation pipe 52α from the first condensation path 47α through the first liquid piping 48α. The start end of a first gas piping 50α is connected to the outflow end 52b of the first evaporation pipe 52α, and the termination end of the first gas piping 50α is connected to the inflow end 47a of a second condensation path 47β, so that the secondary vaporized coolant is returned to the second condensation path 47β from the first evaporation pipe 52α through the first gas piping 50α. The start end of the second liquid piping 48β is connected to the outflow end 47b of the second condensation path 47β, and the termination end of the second liquid piping 48β is connected to the inflow end 52a of the second evaporation pipe 52β, so that the secondary liquid coolant is supplied to the second evaporation pipe 52β from the second condensation path 47β through the second liquid piping 48β. The start end of a second gas piping 50β is connected to the outflow end 52b of the second evaporation pipe 52β, and the termination end of the second gas piping 50β is connected to the inflow end 47a of a third condensation path 47γ, so that the secondary vaporized coolant is returned to the third condensation path 47γ from the second evaporation pipe 52β through the second gas piping 50β. The start end of a third liquid piping 48 γ is connected to the outflow end 47b of the third condensation path 47γ, and the termination end of the third liquid piping 48γ is connected to the inflow end 52a of the third evaporation pipe 52γ, so that the secondary liquid coolant is supplied to the third evaporation pipe 52γ from the third condensation path 47γ through the third liquid piping 48γ. The start end of a third gas piping 50γ is connected to the outflow end 52b of the third evaporation pipe 52γ, and the termination end of the third gas piping 50γ is connected to the inflow end 47a of the first condensation path 47α, so that the secondary vaporized coolant is returned to the first condensation path 47α from the third evaporation pipe 52γ through the third gas piping 50γ, and the secondary coolant makes one circulation in the natural circulation circuit 45.

[Operation of Second Embodiment]

[0040] Next, the operation of the cooling system 32 provided with the secondary cooling device 44 according to the second embodiment will be described. In the cooling system 32, when the cooling operation starts, circulation of the coolant in each of the primary cooling device 34 and the secondary cooling device 44 starts. Since the operation of the primary cooling device 34 has been described in the [Operation of First Embodiment], its description will be omitted.

[0041] In the secondary cooling device 44, since the secondary heat exchanging part 46 is cooled by the primary heat exchanging part 36, the gaseous-phase secondary coolant discharges heat to be condensed during the circulation in each condensation path 47 of the secondary heat exchanging part 46, so that the phase of the secondary coolant changes from the gaseous phase to the liquid phase, increasing its specific gravity. This causes the liquid-phase secondary coolant to flow down along each condensation path 47 of the secondary heat exchanging part 46 under the gravity. In the secondary cooling device 44, the secondary heat exchanging part 46 is disposed in the machinery room 20, and the evaporator EP is disposed in the cooling room 28 located under the machinery room 20, thereby providing a fall between the secondary heat exchanging part 46 and the evaporator EP. That is, the liquid-phase secondary coolant can be allowed to naturally flow down, under the gravity, toward the evaporator EP through the liquid piping 48 connected to the lower part of the secondary heat exchanging part 46. During the circulation in each evaporation pipe 52 of the evaporator EP, the liquid-phase secondary coolant takes heat from the ambient atmosphere of the evaporator EP to be vaporized to change the phase to the gaseous phase. The gaseous-phase secondary coolant flows back from the evaporator EP to the secondary heat exchanging part 46 through the gas piping 50, and in the secondary cooling device 44, the cycle in which the secondary coolant is caused to circulate naturally with a simple configuration is repeated, without using power, such as a pump or a motor.

[0042] A single thermo-siphon which allows the secondary coolant to alternately flow to a single condensation path 47 and a single evaporation pipe 52 in the natural circulation circuit 45, formed in the secondary cooling device 44, by connecting a plurality of condensation paths 47 and a plurality of evaporation pipes 52 equal in number to the condensation paths 47 in a staggered fashion. That is, the natural circulation circuit 45 can have a plurality of condensation paths 47 and a plurality of evaporation pipes 52 provided in one circuit without branching the liquid piping 48, the gas piping 50, the condensation path 47 and the evaporation pipe 52. Since the natural circulation circuit 45 is formed by a single coolant path as a whole, it is possible to suppress maldistribution of the secondary coolant between the condensation paths 47, 47 and between the evaporation pipes 52, 52 or between the condensation path 47 and the evaporation pipe 52, so that the amounts of the secondary coolants in each condensation path 47 and evaporation pipe 52 are made to coincide with each other.

[0043] There is a case where the secondary coolant which circulates through the natural circulation circuit 45 may be maldistributed in any of the condensation paths 47 and the evaporation pipes 52 due to an external factor, such as a change in the temperature of the outside air which acts on the secondary cooling device 44. Since the natural circulation circuit 45 is formed by a single thermo-siphon, however, the balance of the secondary coolant is naturally adjusted so that the amount of the secondary coolant in each condensation path 47 coincides with the amount of the secondary coolant in each evaporation pipe 52. Therefore, maldistribution of the secondary coolant in each condensation path 47 and each evaporation pipe 52 does not occur easily. Even if maldistribution of the secondary coolant occurs, regulation is applied in such a way that the amounts of the secondary coolant which circulates in the condensation path 47 and the evaporation pipe 52 are matched with each other, eliminating the need for providing regulation means, such as a valve, for adjusting the balance of the secondary coolant, and making it possible to simplify the configuration of the secondary cooling device 44. In addition, since smooth natural circulation of the secondary coolant takes place in the natural circulation circuit 45, the cooling efficiency in the evaporator EP can be improved. It is therefore possible to provide a plurality of condensation paths 47 and a plurality of evaporation pipes 52 in the secondary heat exchanging part 46 and the evaporator EP, thereby securing the heat exchange area without bending or branching the condensation path 47 and evaporation pipe 52.

[0044] In the secondary cooling device 44, a plurality of condensation paths 47 and a plurality of evaporation pipes 52 can be disposed in each of the heat exchanger 46 and evaporator EP. That is, the heat exchange area required for a single condensation path 47 and a single evaporation pipe 52 becomes smaller, making it possible to shorten the pipe lengths of each condensation path 47 and each evaporation pipe 52. This can reduce the number of times for meandering each condensation path 47 and each evaporation pipe 52 to attain the pipe length needed, thus reducing the bent portions which serve as the flow resistance. It is therefore possible to reduce the pressure loss of the secondary coolant which circulates in the condensation path 47 and the evaporation pipe 52. In addition, since the secondary cooling device 44 has the natural circulation circuit 45 formed by a single coolant path as a whole without branching the liquid piping 48, the gas piping 50, the condensation path 47, and the evaporation pipe 52, the pressure loss originating from the branched portion of a pipe or the like does not occur. Since the head difference of the secondary coolant needed for the natural convection between the condensation path 47 and the evaporation pipe 52 can be made small in the natural circulation circuit 45, the fall needed between the condensation path 47 and the evaporation pipe 52 becomes small. This makes it possible to narrow the vertical layout intervals of the secondary heat exchanging part 46 and the evaporator EP, so that the secondary cooling device 44 can be made compact. The pressure loss of the secondary coolant in the natural circulation circuit 45 is small, so that even if a small tube diameter is selected for the liquid piping 48 and the gas piping 50 as compared with the prior arts, the same amount of the secondary coolant can be circulated in the circuit, and the amount of the secondary coolant which is filled in the whole circuit can be reduced.

[0045] Since it is possible to reduce the lengths and cross-sectional areas of each condensation path 47 and each evaporation pipe 52, the secondary heat exchanging part 46 and the evaporator EP can be made compact, and reducing the amount of the coolant which circulates reduces the supplementary facilities, such as capacity of the expansion tank (not shown) which eases the pressure rise in the natural circulation circuit 45. This can make the secondary cooling device 44 compact as a whole, and achieve cost reduction. Further, the thicknesses of the pipings, such as the liquid piping 48, the gas piping 50, and the evaporation pipe 52, which are needed to secure the pressure resistance therein can be reduced by narrowing those pipings. That is, the synergistic effect of narrowing the pipings 48, 50, 52 and reducing the thicknesses of the pipings 48, 50, 52 can reduce the weights of the pipings further, and reducing the cost further. Further, the cooling system 32 of the second embodiment also demonstrate the functions and effects described in page 14, line 3 to page 17, line 23.

[0046] Since the secondary cooling device 44 of the second embodiment is formed by the single natural circulation circuit 45, it is sufficient to provide supplemental facilities, such as the coolant charge port 74, the safety valve which prevents an excessive rise in pressure, and the expansion tank (none shown), only in the quantity corresponding to the natural circulation circuit 45. That is, this configuration can make the supplemental facilities compact and reduce the cost while maintaining the merits, such as prevention of maldistribution of the secondary coolant, and reduction in the diameter of the piping, as compared with the configuration of the secondary cooling device 70 of the first embodiment which has a plurality of independent natural circulation circuits 72. In addition, the secondary cooling device 44 of the second embodiment simply performs a work of filling the coolant in the fabrication process or maintenance with respect to a single natural circulation circuit 45, so that the workability and maintenance performance can be improved.

[0047] The secondary cooling device of the second embodiment described above can also be modified as follows. It is to be noted that the configuration of the second embodiment is adopted for the configurations of modifications which are not particularly described.

[0048] (1) Fig. 4 is a schematic diagram of a cooling device 60 according to a first modification. The cooling device 60 of the first modification has a plurality of (three) secondary heat exchanging parts 46A, 46B, and 46C, and evaporators EP1, EP2, and EP3 equal in number (three) to the secondary heat exchanging parts 46A, 46B, 46C. Each second heat exchanging parts 46A, 46B, 46C is provided with one condensation path 47, and each evaporator EP1, EP2, EP3 is provided with one evaporation pipe 52. The natural circulation circuit of the first modification connects the liquid piping 48 connected to the outflow end 47b of the condensation path 47 to an evaporation pipe 52 different from the evaporation pipe 52 which is connected with the gas piping 50 coupled to the inflow end 47a of the condensation path 47, and connects the gas piping 50 connected to the outflow end 52b of the evaporation pipe 52 to a condensation path 47 different from the condensation path 47 which is connected with the liquid piping 48 coupled to the inflow end 52a of the evaporation pipe 52, and is formed as a single circuit as a whole. The cooling device 60 of the first modification is configured in such a way that the vaporized coolant flows from the evaporation pipe 52 of each evaporator EP back to the condensation path 47 of a secondary heat exchanging part 46 different from the secondary heat exchanging part 46 that has the condensation path 47 which has received the liquid coolant supplied. In the cooling device 60 of the first modification, the liquid coolant is supplied from the condensation path 47 of each second heat exchanging part 46 to the evaporation pipe 52 of an evaporator EP different from the evaporator EP that has the evaporation pipe 52 which has received the vaporized coolant supplied.

[0049] The cooling device 60 of the first modification demonstrates functions and effects similar to those explained in the description of the second embodiment. Even if a plurality of secondary heat exchanging parts 46 and a plurality of evaporators EP are provided, the condensation paths 47 are connected one to one to the evaporation pipes 52, making the sizes of each liquid piping 48 and each gas piping 50 with respect to the whole natural circulation circuit smaller, and reducing the flow resistance of the coolant in each liquid piping 48 and each gas piping 50, so that the pressure loss can be reduced.

[0050] (2) Fig. 5 is a schematic diagram of a cooling device 62 according to a second modification. The cooling device 62 of the second modification has a single secondary heat exchanging part 46, and a plurality of (three) evaporators EP1, EP2, and EP3. Each evaporator EP1, EP2, EP3 is provided with one evaporation pipe 52. The second heat exchanging part 46 is provided with condensation paths 47 whose quantity is equal to the total number of the evaporation pipes 52. The natural circulation circuit of the second modification connects the liquid piping 48 connected to the outflow end 47b of the condensation path 47 to an evaporation pipe 52 different from the evaporation pipe 52 which is connected with the gas piping 50 coupled to the inflow end 47a of the condensation path 47, and connects the gas piping 50 connected to the outflow end 52b of the evaporation pipe 52 to a condensation path 47 different from the condensation path 47 which is connected with the liquid piping 48 coupled to the inflow end 52a of the evaporation pipe 52, and is formed as a single circuit as a whole. In the cooling device 62 of the second modification, the liquid coolant is supplied from each condensation path 47 of the second heat exchanging part 46 to the evaporation pipe 52 of an evaporator EP different from the evaporator EP that has the evaporation pipe 52 which has received the vaporized coolant supplied.

[0051] The cooling device 62 of the second modification demonstrates functions and effects similar to those explained in the description of the second embodiment. Even if a plurality of evaporators EP are provided, the amounts of the liquid coolants to be supplied to the evaporation pipes 52 of the individual evaporators EP coincide with each other, so that the plurality of evaporators EP can perform well-balanced cooling of separate targets. The quantity of the evaporation pipes 52 provided at a plurality of evaporators EP is not limited to one, and two or more evaporation pipes 52 may be provided as in a cooling device 64 according to a third modification shown in Fig. 6, or the quantity of the evaporation pipes 52 may be made different for each evaporator EP.

[0052] (3) Fig. 7 is a schematic diagram of a cooling device 66 according to a fourth modification. The cooling device 66 of the fourth modification has a plurality of (three) secondary heat exchanging parts 46A, 46B, and 46C, and one evaporator EP. Each second heat exchanging parts 46A, 46B, 46C is provided with one condensation path 47, and the evaporator EP is provided with evaporation pipes 52 whose quantity (three) is equal to the total number of the condensation paths 47. The natural circulation circuit of the fourth modification connects the liquid piping 48 connected to the outflow end 47b of the condensation path 47 to an evaporation pipe 52 different from the evaporation pipe 52 which is connected with the gas piping 50 coupled to the inflow end 47a of the condensation path 47, and connects the gas piping 50 connected to the outflow end 52b of the evaporation pipe 52 to a condensation path 47 different from the condensation path 47 which is connected with the liquid piping 48 coupled to the inflow end 52a of the evaporation pipe 52, and is formed as a single circuit as a whole. The cooling device 66 of the fourth modification is configured in such a way that the vaporized coolant flows from each evaporation pipe 52 of the evaporator EP back to the condensation path 47 of a secondary heat exchanging part 46 different from the secondary heat exchanging part 46 that has the condensation path 47 which has received the liquid coolant supplied.

[0053] The cooling device 66 of the fourth modification demonstrates functions and effects similar to those explained in the description of the second embodiment. Even if a plurality of secondary heat exchanging parts 46 are provided, the amounts of the liquid coolants to circulate to the condensation paths 47 of the individual secondary heat exchanging parts 46 coincide with each other, so that maldistribution of the coolant can be avoided to efficiently cool targets with the evaporator EP. The quantity of the condensation paths 47 provided at a plurality of secondary heat exchanging parts 46 is not limited to one, and two or more condensation paths 47 may be provided as in a cooling device 68 according to a fifth modification shown in Fig. 8, or the quantity of the condensation paths 47 may be made different for each secondary heat exchanging part 46.

[0054] (4) Although the cooling device of the second embodiment and the modifications are configured to have a single natural circulation circuit, they may be configured to have a plurality of independent natural circulation circuits.

[0055]

(i) The cooling device according to the invention is also applicable to the cooling device of an air conditioner or the like.

(ii) The evaporator may be of the type which has the coolant path formed by partitioning the interior of a box with a wall.

(iii) The cooling device according to the invention can also be applied to so-called stockrooms, such as a freezer, a freezing/refrigerator, a showcase, and a prefabricated house.

(iv) An absorption type refrigeration circuit or refrigeration circuits of other types can also be used as the primary cooling device of a cooling system. The cooling device according to the invention may be of an air cooling type which cools the heat exchanging part with air fed by a fan or the like.

(v) A heat exchanger may be configured to have the primary heat exchanging part and the secondary heat exchanging part separate from each other, or may be of another type.

(vi) Although the expansion valve is used as means for decompressing the liquid coolant in the primary cooling device in the embodiments, it is not restricted and a capillary tube or other types of decompressing means can be adopted.

(vii) The cooling device according to the invention is used on the secondary side of the cooling system provided with the secondary loop type refrigeration circuit as an example in the embodiments. Since the shortcomings of the cooling system provided with the secondary loop type refrigeration circuit can be overcome as mentioned above, it is very useful to apply the cooling device according to the invention to the secondary loop type refrigeration circuit. However, application of the cooling device according to the invention is not limited to a secondary loop type refrigeration circuit, but the cooling device can also be used alone as a cooling device.

(viii) In the cooling device of the first embodiment, a plurality of evaporators may be provided for one heat exchanging part. That is, the individual condensation paths of a plurality of coolant circulation circuits are provided at one heat exchanging part, and the evaporation paths of the coolant circulation circuits corresponding to the individual evaporators are provided. In the cooling device of the first embodiment, one evaporator may be provided at a plurality of heat exchanging parts. That is, the individual evaporation paths of a plurality of coolant circulation circuits are provided at one evaporator, and the condensation paths of the coolant circulation circuits corresponding to the individual heat exchanging parts are provided.

Claims

1. A cooling device including a heat exchanging part (46) for condensing a vaporized coolant flowing in a condensation path (47) into a liquid coolant, an evaporator (EP) arranged under the heat exchanging part (46) to vaporize the liquid coolant flowing in an evaporation path (52) into the vaporized coolant, and a natural circulation circuit (72) which permits the liquid coolant to flow down from the condensation path (47) of the heat exchanging part (46) to the evaporation path (52) of the evaporator (EP) through a liquid piping (48), and permits the vaporized coolant to flow from the evaporation path (52) of the evaporator (EP) to the condensation path (47) of the heat exchanging part (46) through a gas piping (50), **characterized by** including a plurality of natural circulation circuits (72) independent of one another.

2. A cooling device including a heat exchanging part (46) for condensing a vaporized coolant flowing in a condensation path (47) into a liquid coolant, an evaporator (EP) arranged under the heat exchanging part (46) to vaporize the liquid coolant flowing in an evaporation path (52) into the vaporized coolant, and a natural circulation circuit (45) which permits the liquid coolant to flow down from the condensation path (47) of the heat exchanging part (46) to the evaporation path (52) of the evaporator (EP) through a liquid piping (48), and permits the vaporized coolant to flow from the evaporation path (52) of the evaporator (EP) to the condensation path (47) of the heat exchanging part (46) through a gas piping (50), **characterized in that** the natural circulation circuit (45) includes a plurality of evaporation paths (52), and condensation paths (47) equal in number to the evaporation paths (52), and
a liquid piping (48) connected to an outflow end (47b) of the condensation path (47) is connected to an evaporation path (52) different from an evaporation path (52) to which the gas piping (50) coupled to an inflow end (47a) of the condensation path (47) is connected, and the gas piping (50) connected to an outflow end (52b) of an evaporation path (52) is connected to a condensation path (47) different from a condensation path (47) to which the liquid piping (48) coupled to an inflow end (52a) of the evaporation path (52) is connected, thereby forming a single natural circulation circuit (45) as a whole.

3. The cooling device according to claim 1 or 2, wherein one evaporator (EP) or a plurality of evaporators (EP) are provided for one heat exchanging part (46) or a plurality of heat exchanging parts (46).

4. The cooling device according to any one of claims 1 to 3, wherein the natural circulation circuit (45, 72) is thermally connected via the heat exchanging part (46) to a primary-side circuit (34) of a mechanical compression type which forcibly circulates a coolant.

Fig.1

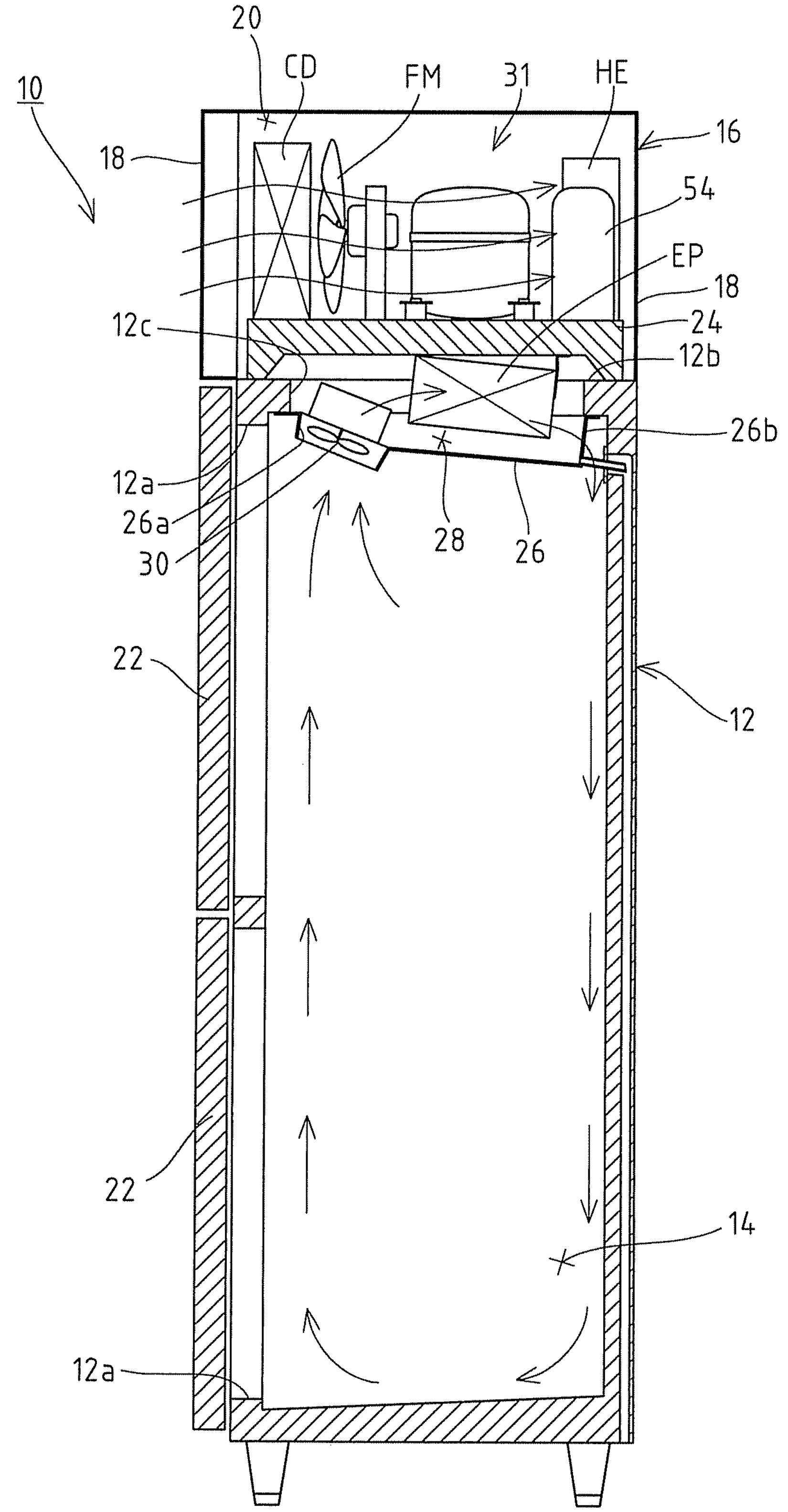

10
18
20
CD
FM
31
HE
16
54
EP
18
24
12c
12b
26b
12a
26a
30
28
26
22
12
22
14
12a

Fig.2

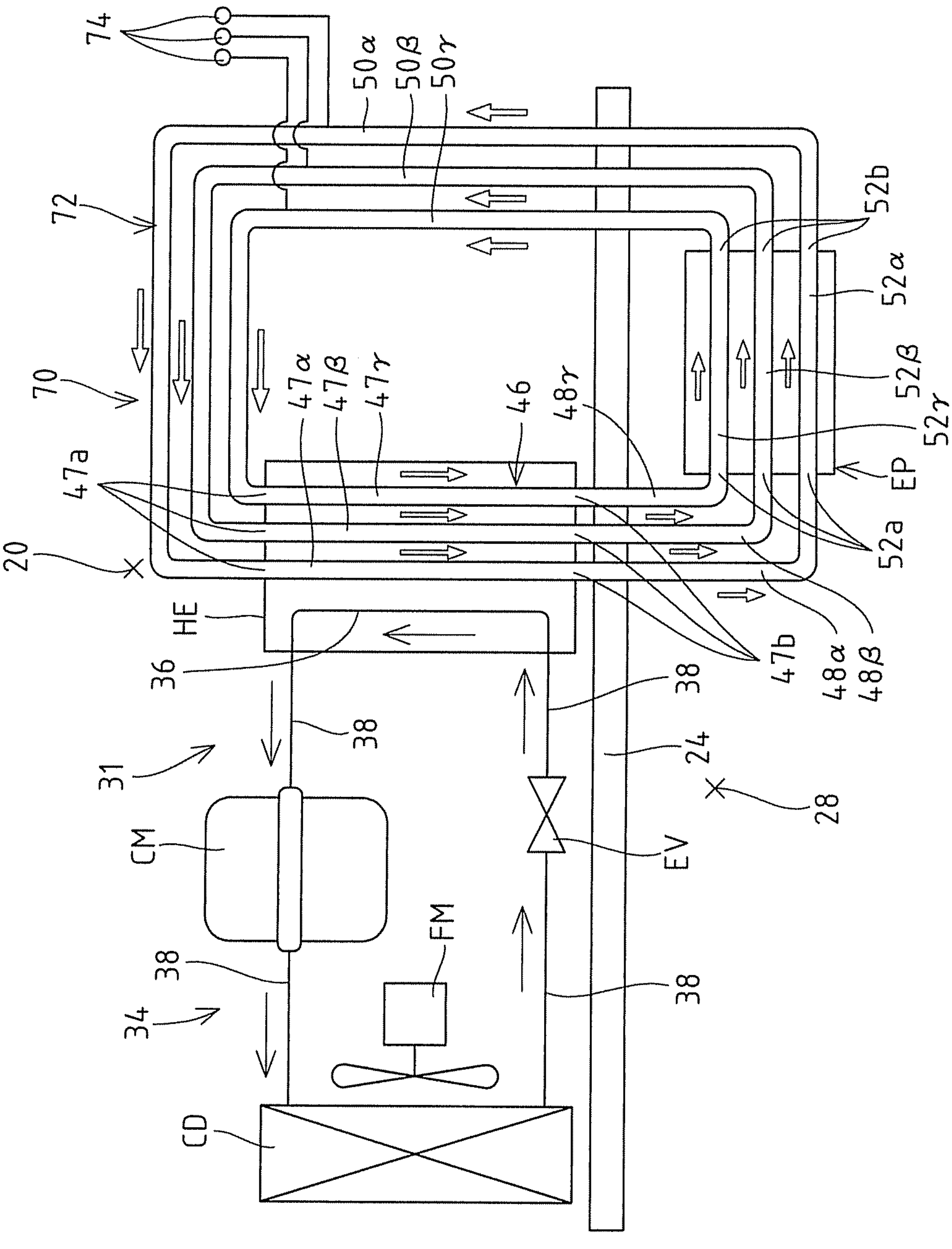

74
50α
50β
50γ
72
52b
52α
70
47α
47β
47γ
46
48γ
52β
52γ
47a
EP
20
52a
HE
47b
48α
48β
36
38
31
24
28
CM
EV
FM
34
CD

Fig.3

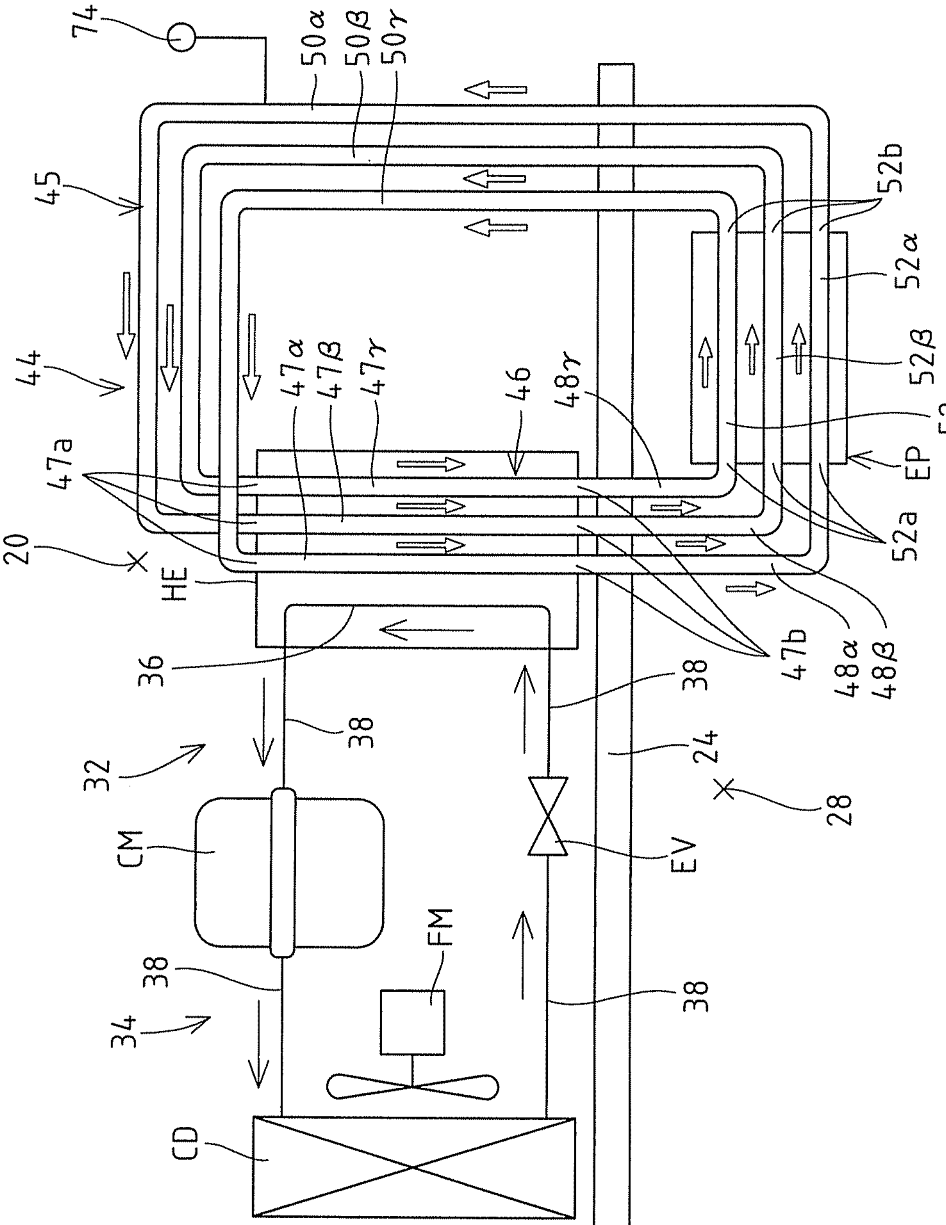

74
50α
50β
50γ
45
52b
52α
52β
52γ
44
47α
47β
47γ
46
48γ
EP
47a
52a
20
HE
47b
48α
48β
36
38
32
24
28
CM
EV
FM
34
CD

Fig.4

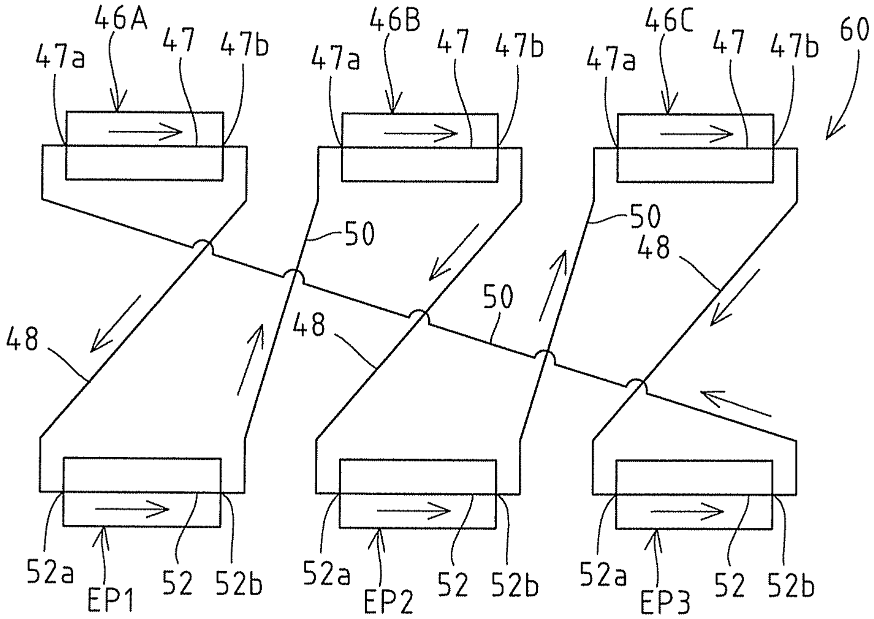

46A
47a
47
47b
46B
47a
47
47b
46C
47a
47
47b
60
50
50
48
50
48
48
52a
EP1
52
52b
52a
EP2
52
52b
52a
EP3
52
52b

Fig.5

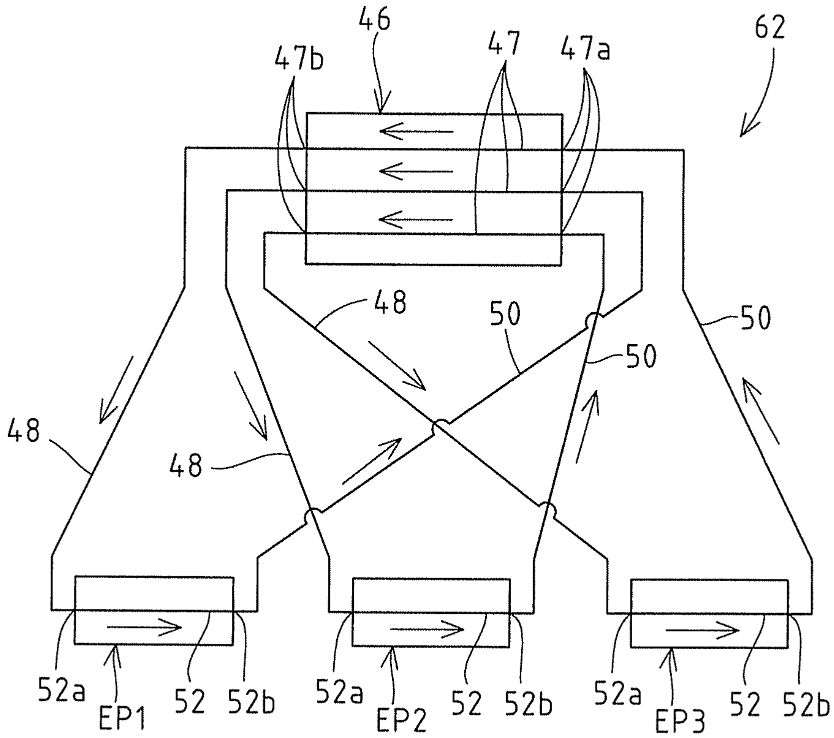

46
47b
47
47a
62
48
50
50
50
48
48
52a
EP1
52
52b
52a
EP2
52
52b
52a
EP3
52
52b

Fig.6

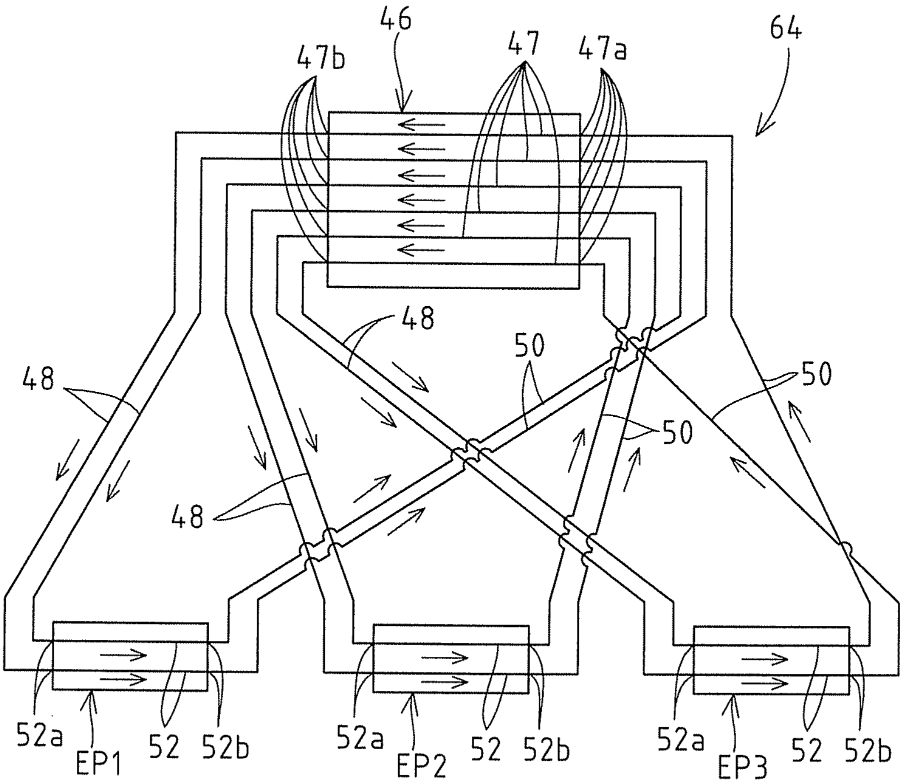

46
47b
47
47a
64
48
48
50
50
50
48
52a
EP1
52
52b
52a
EP2
52
52b
52a
EP3
52
52b

Fig.7

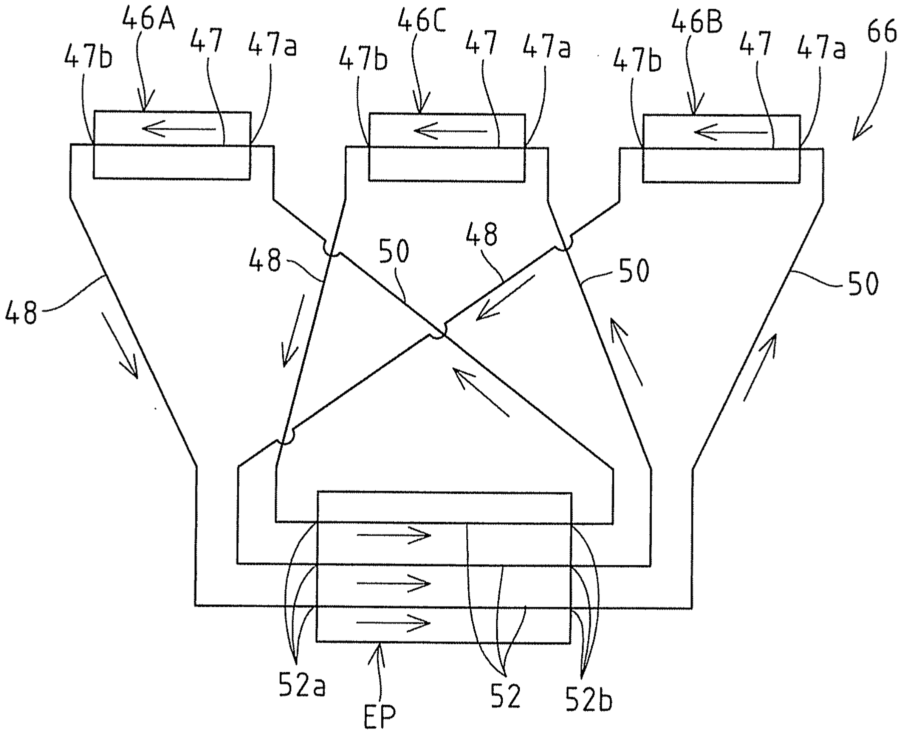

46A
47b
47
47a
46C
47b
47
47a
46B
47b
47
47a
66
48
48
50
48
50
48
50
52a
EP
52
52b

Fig.8

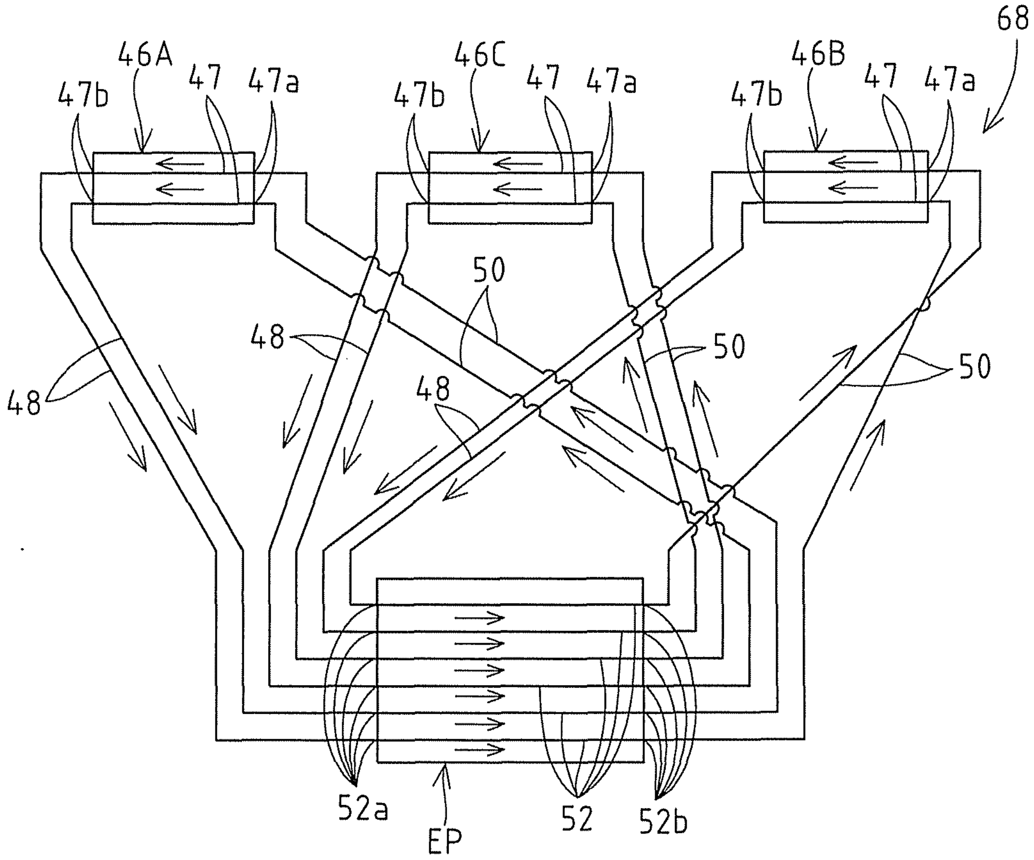

68
46A
47b
47
47a
46C
47b
47
47a
46B
47b
47
47a
50
48
50
50
48
48
52a
EP
52
52b

Fig.9
[Prior Art]

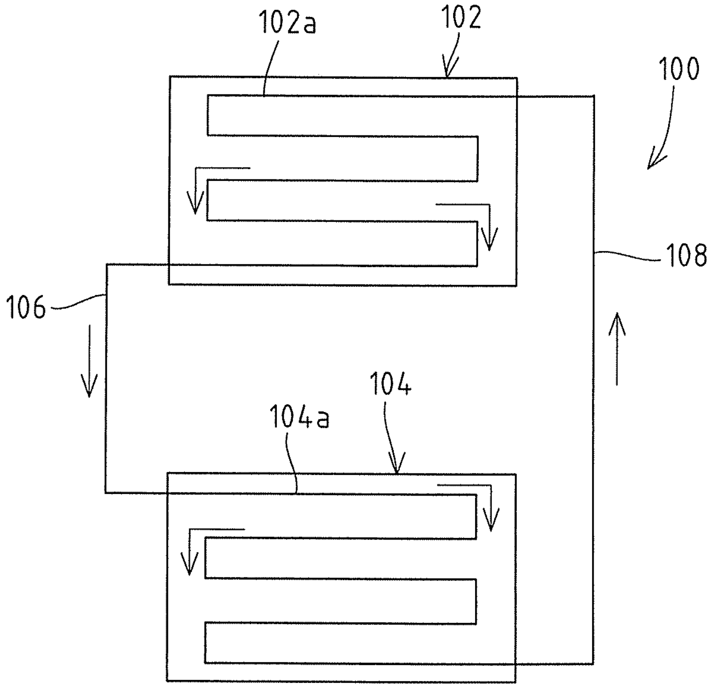


Fig.10
[Prior Art]

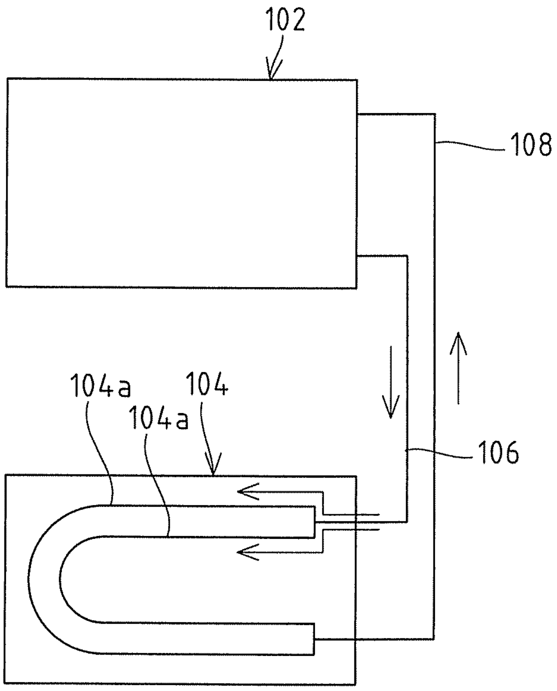
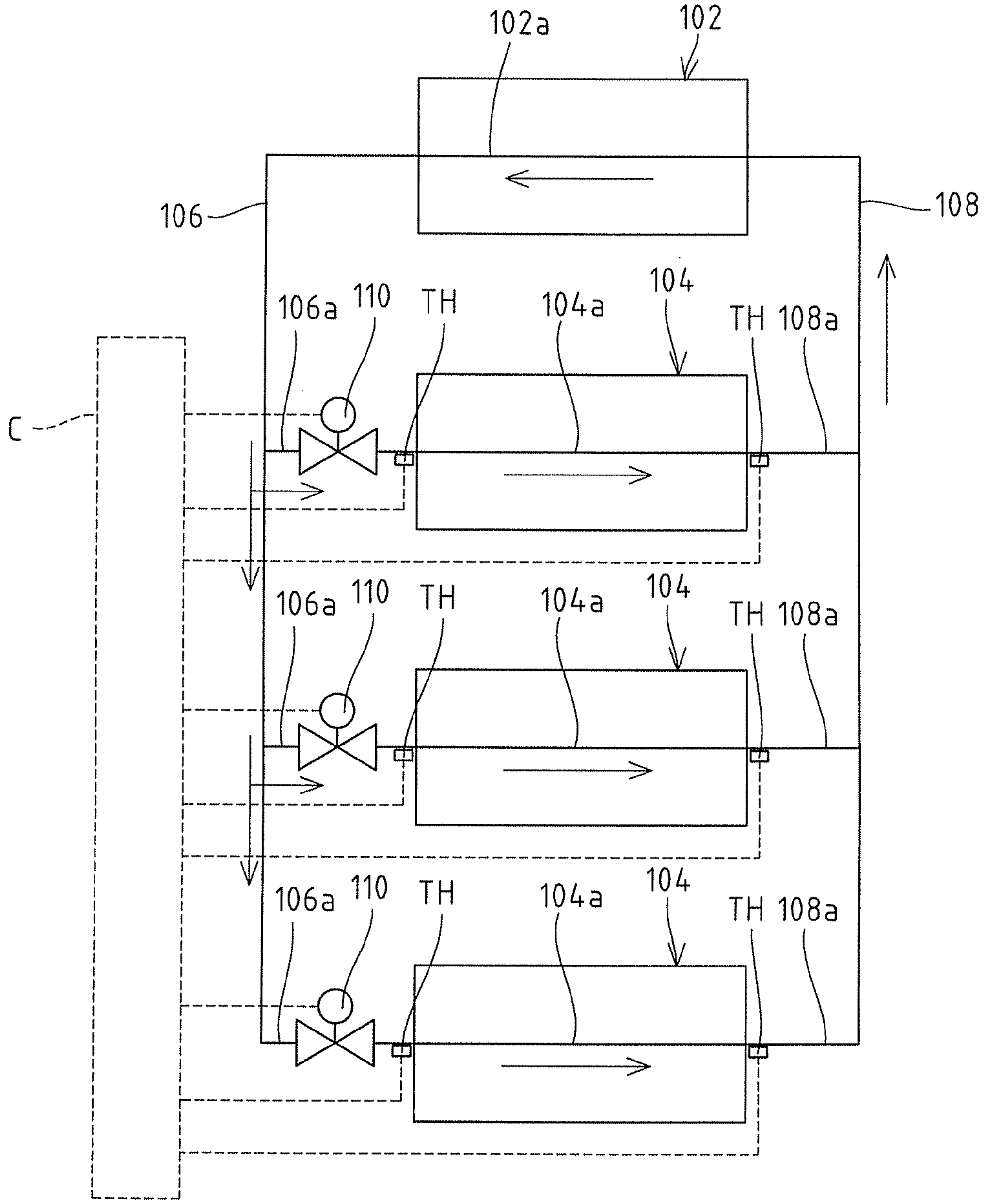


Fig.11
[Prior Art]



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2008/069049

A. CLASSIFICATION OF SUBJECT MATTER
F25B1/00(2006.01)i, *F25D16/00*(2006.01)i, *F25D17/00*(2006.01)i, *F28D15/02*(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F25B1/00, F25D16/00, F25D17/00, F28D15/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2008
Kokai Jitsuyo Shinan Koho	1971-2008	Toroku Jitsuyo Shinan Koho	1994-2008

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 11-257720 A (Takenaka Corp.), 24 September, 1999 (24.09.99), Par. Nos. [0018] to [0020]; Fig. 1 (Family: none)	1,3,4
X	JP 7-307226 A (Actronics Co., Ltd.), 21 November, 1995 (21.11.95), Par. Nos. [0001] to [0004]; Fig. 10 (Family: none)	2
Y	JP 3458310 B2 (Hachiyo Enjiniaringu Kabushiki Kaisha), 20 October, 2003 (20.10.03), Column 5, line 45 to column 6, line 31; Fig. 1 (Family: none)	4

☐ Further documents are listed in the continuation of Box C.　☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
03 December, 2008 (03.12.08)	16 December, 2008 (16.12.08)
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (April 2007)

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 2005283022 A **[0004]**
- JP 2004060956 A **[0004]**