

REFRIGERATION APPARATUS

TECHNICAL FIELD

[0001] The present invention relates to a refrigeration apparatus having high and low stage side refrigerant circuits which are connected together through a cascade heat exchanger to thereby perform a two-stage cascade refrigeration cycle.

Refrigeration apparatuses, intended to be installed, for example, in convenience stores et cetera for the purpose of providing indoor space air conditioning (cooling/heating) simultaneously with cold/freezing storage compartment cooling, have been known in the conventional technology. As such a refrigeration apparatus, there is a refrigeration apparatus having a high stage side refrigerant circuit and a low stage side refrigerant circuit which are connected together through a cascade heat exchanger to thereby perform a two-stage cascade refrigeration cycle.

[0002] For example, JP-A-2002-181406 discloses a refrigeration apparatus which incorporates therein an air conditioning heat exchanger for providing air conditioning of an indoor space and cooling heat exchangers for providing cooling of storage compartments. In addition, the cooling heat exchangers are composed of cold storage heat exchangers for providing cooling of cold storage compartments and a freezing storage heat exchanger for providing cooling of a freezing storage compartment.

[0003] Connected in parallel with the high stage side refrigerant circuit of the refrigeration apparatus are an air conditioning circuit and cold storage circuits. The air conditioning heat exchanger for selectively providing cooling or heating of the indoor space is disposed in the air conditioning circuit. On the other hand, the cold storage heat exchangers for providing cooling of the cold storage compartments are disposed in the cold storage circuits. In addition, a high stage side compressor, an outdoor heat exchanger, a first heat exchange section of the cascade heat exchanger, and an expansion valve are connected to the

high stage side refrigerant circuit. On the other hand, connected to the low stage side refrigerant circuit are the freeze storage heat exchanger for providing cooling of the freeze storage compartment, a low stage side compressor, a second heat exchange section of the cascade heat exchanger, and an expansion valve.

[0004] In the above-described refrigeration apparatus, for example, during an indoor space heating operation mode, the air conditioning heat exchanger functions as a condenser and heats indoor air while on the other hand the cold and freeze storage heat exchangers function as evaporators and cool air in the cold and freeze storage compartments. In the refrigeration apparatus, heat absorbed by the freeze storage heat exchanger is transferred through the cascade heat exchanger to the high stage side refrigerant circuit, and the transferred heat is used by the air conditioning heat exchanger for heating of the indoor space. To sum up, in the refrigeration apparatus, heat on the side of the low stage side refrigerant circuit is recovered by the cascade heat exchanger on the side of the high stage side refrigerant circuit and the recovered heat is utilized in the heating operation mode.

DISCLOSURE OF THE INVENTION

PROBLEMS THAT THE INVENTION INTENDS TO SOLVE

[0005] As described above, the refrigeration apparatus disclosed in the patent document (JP-A-2002-181406) is configured such that it can provide air conditioning of the indoor space simultaneously with cooling of the storage compartments (cold/freezing storage compartments) wherein the air conditioning heat exchanger, the cold storage heat exchangers, and the freeze storage heat exchanger are provided on the utilization side. Incidentally, the temperature of cooling of the indoor space by the air conditioning heat exchanger in the cooling operation mode ranges, for example, from about 20 degrees Centigrade to about 30 degrees Centigrade while on the other hand the temperature of storage compartment cooling by the cold storage heat exchanger ranges, for example, from 0 degrees Centigrade to 10 degrees Centigrade, in other words the air conditioning heat exchanger and the cold storage

heat exchanger differ much from each other in utilization temperature range. The air conditioning and cold storage heat exchangers of much different utilization temperature ranges are connected to the high stage side refrigerant circuit which is a closed circuit, so that the same refrigerant flows therethrough. Consequently, it is required that the same refrigerant be evaporated at different temperatures in different heat exchangers, i.e., the air conditioning heat exchanger and the cold storage heat exchanger. This accordingly produces the problem in that control of the refrigerant temperature in each heat exchanger becomes complicated.

[0006] The above-described problem becomes more serious when the air conditioning heat exchanger and the freeze storage heat exchanger, which differ very much from each other in utilization temperature range, are connected to the high stage side refrigerant circuit. Accordingly, there have been demands for refrigeration apparatuses capable of facilitating temperature control in the air conditioning heat exchanger and the cold/freeze storage heat exchanger (cooling heat exchanger) which differ from each other in utilization temperature range.

[0007] With the above problem in mind, the present invention was devised. Accordingly, an object of the present invention is to provide a two-stage cascade refrigeration cycle refrigeration apparatus capable of facilitating temperature control in the air conditioning heat exchanger for providing indoor space air conditioning and the cooling heat exchanger for providing storage compartment cooling.

MEANS FOR SOLVING THE PROBLEM

[0008] According to the present invention, the air conditioning heat exchanger is disposed only in the high stage side refrigerant circuit while on the other hand the cooling heat exchangers are disposed only in the low stage side refrigerant circuit.

[0009] More specifically, the present invention provides, as a first aspect, a refrigeration apparatus in which a high stage side refrigerant circuit (8) and a low stage side refrigerant

circuit (9) are connected together through a cascade heat exchanger to thereby perform a two-stage cascade refrigeration cycle, the refrigeration apparatus comprising an air conditioning heat exchanger (45) for selectively providing cooling or heating of an indoor space and a cooling heat exchanger (47a, 47b, 49) for providing cooling of a storage compartment. In the refrigeration apparatus of the first aspect of the present invention, the air conditioning heat exchanger (45) is disposed only in the high stage side refrigerant circuit (8) while on the other hand the cooling heat exchanger (47a, 47b, 49) is disposed only in the low stage side refrigerant circuit (9).

[0010] In the first aspect of the present invention, a refrigeration cycle is performed in the high stage side refrigerant circuit (8) which is a closed circuit while simultaneously another refrigeration cycle is performed in the low stage side refrigerant circuit (9) which is a closed circuit, in other words a so-called two-stage cascade refrigeration cycle is performed.

[0011] More specifically, in the cooling heat exchanger (47a, 47b, 49), refrigerant absorbs heat from air in the storage compartment and is evaporated. Stated another way, the cold storage heat exchanger (47a, 47b, 49) functions as an evaporator. On the other hand, in the air conditioning heat exchanger (45) during the indoor space cooling operation mode, refrigerant absorbs heat from indoor air and is evaporated. That is, during the indoor space cooling operation mode, the air conditioning heat exchanger (45) functions as an evaporator. In addition, in the air conditioning heat exchanger (45) during the indoor space heating operation mode, refrigerant dissipates heat to indoor air and is condensed. Stated another way, during the indoor space heating operation mode, the air conditioning heat exchanger (45) functions as a condenser. In the cascade heat exchanger (40) during the indoor space heating operation mode, the heat of the refrigerant in the low stage side refrigerant circuit (9), absorbed from air in the storage compartment, is recovered to the refrigerant in the high stage side refrigerant circuit (8). And, in the high stage side refrigerant circuit (8), the heat thus recovered is utilized to heat the indoor space.

[0012] In the present invention, the air conditioning heat exchanger (45) for providing indoor space cooling/heating is disposed only in the high stage side refrigerant circuit (8) while on the other hand the cooling heat exchanger (47a, 47b, 49) for providing cold/freezing storage compartment cooling is disposed only in the low stage side refrigerant circuit (9). To sum up, the air conditioning heat exchanger (45) and the cooling heat exchanger (47a, 47b, 49) are disposed in different closed circuits.

[0013] As described above, the air conditioning heat exchanger (45) and the cooling heat exchanger (47a, 47b, 49) are disposed in different closed circuits, whereby different refrigerants can be made to flow, respectively, through the air conditioning heat exchanger (45) and through the cooling heat exchanger (47a, 47b, 49). Therefore, a first refrigerant suited to indoor space air conditioning by the air conditioning heat exchanger (45) can be circulated in the high stage side refrigerant circuit (8) to thereby perform a first refrigeration cycle while simultaneously a second refrigerant different from the first refrigerant and suited to storage compartment cooling by the cooling heat exchanger (47a, 47b, 49) can be circulated in the low stage side refrigerant circuit (9) to thereby perform a second refrigeration cycle. To sum up, it is possible for the air conditioning and cooling heat exchangers (45) and (47a, 47b, 49) having different utilization temperature ranges to employ different refrigerants suited, respectively, to the utilization temperature range of the air conditioning heat exchanger (45) and to the utilization temperature range of the cooling heat exchanger (47a, 47b, 49). This therefore makes it possible to facilitate control of the refrigerant temperature in each heat exchanger.

[0014] The present invention provides, as a second aspect according to the first aspect, a refrigeration apparatus in which the cooling heat exchanger (47a, 47b, 49) comprises a cold storage heat exchanger (47a, 47b) for providing cooling of a cold storage compartment and a freezing storage heat exchanger (49) for providing cooling of a freezing storage compartment and a cold storage circuit (3, 4) including the cold storage heat exchanger (47a, 47b) and a freezing

storage circuit (7) including the freeze storage heat exchanger (49) are connected in parallel in the low stage side refrigerant circuit.

[0015] In the second aspect of the present invention, as the cooling heat exchanger (47a, 47b, 49) disposed only in the low stage side refrigerant circuit (9), the cold storage heat exchanger (47a, 47b) for providing cooling of the cold storage compartment and the freeze storage heat exchanger (49) for providing cooling of the freeze storage compartment are provided. This therefore allows the refrigeration apparatus to provide at the same time both air conditioning of the indoor space and cooling of the cold/freezing storage compartment.

[0016] The present invention provides, as a third aspect according to the second aspect, a refrigeration apparatus in which the freeze storage circuit (7) includes an auxiliary compressor (50) for compressing refrigerant drawn from the freeze storage heat exchanger (49) and discharging the compressed refrigerant to the suction side of a low stage side compressor (39) disposed in the low stage side refrigerant circuit (9).

[0017] In the third aspect of the present invention, the low stage side compressor (39) and the auxiliary compressor (50) are disposed in the low stage side refrigerant circuit (9). And, in the low stage side refrigerant circuit (9), refrigerant evaporated in the freeze storage heat exchanger (49) is compressed by the auxiliary compressor (50). The refrigerant is further compressed in the low stage side compressor (39). In other words, a so-called two-stage compression refrigeration cycle is performed in the low stage side refrigerant circuit (9).

[0018] The present invention provides, as a fourth aspect according to the third aspect, a refrigeration apparatus in which the low stage side refrigerant circuit (9) includes a first bypass pipeline (67) for enabling the suction and discharge sides of the low stage side compressor (39) to fluidly communicate with each other.

[0019] In the fourth aspect of the present invention, refrigerant on the suction side of the low stage side compressor (39) can be bypassed to the discharge side of the low stage side compressor (39) by way of the first bypass pipeline (67). As a result of such arrangement,

for example, even when the low stage side compressor (39) breaks down and becomes unable to operate, refrigerant can be circulated in the low stage side refrigerant circuit (9) by placing the auxiliary compressor (50) in operation, whereby refrigerant is caused to be evaporated in each cooling heat exchanger (47a, 47b, 49).

[0020] The present invention provides, as a fifth aspect according to the fourth aspect, a refrigeration apparatus in which the low stage side refrigerant circuit (9) includes a second bypass pipeline (68) for enabling the outlet side of the cold storage heat exchanger (47b) and the suction side of the auxiliary compressor (50) to fluidly communicate with each other.

[0021] In the fifth aspect of the present invention, refrigerant on the outlet side of the cold storage heat exchanger (47b) can be bypassed through the second bypass pipeline (68) to the suction side of the auxiliary compressor (50). As a result of such arrangement, for example, when the auxiliary compressor (50) is placed in operation in order to cause refrigerant to be circulated due to failure of the low stage side compressor (39), refrigerant after flow through the cold storage heat exchanger (47b) can be directed to the suction side of the auxiliary compressor (50) through the second bypass pipeline (68). This therefore makes it possible to provide cooling of the cooling storage compartment by causing refrigerant to be circulated in the cold storage heat exchanger (47b) only by the operation of the auxiliary compressor (50).

[0022] The present invention provides, as a sixth aspect according to the fifth aspect, a refrigeration apparatus wherein a pressure control mechanism (48) for controlling the evaporating pressure of refrigerant in the cold storage heat exchanger (47b) is disposed between a downstream end of the cold storage heat exchanger (47b) and a downstream end of the second bypass pipeline (68).

[0023] In the sixth aspect of the present invention, the pressure control mechanism (48) is provided which prevents the evaporating pressure of refrigerant in the cold storage heat exchanger (47b) from falling to the evaporating pressure of refrigerant in the freeze storage

heat exchanger (49) when refrigerant on the outlet side of the cold storage heat exchanger (47b) is introduced through the second bypass pipeline (68) to the suction side of the auxiliary compressor (50), for example, in the event of failure of the low stage side compressor (39).

[0024] The above is explained more concretely. For example, as described in regard to the fifth aspect of the present invention, when the low stage side compressor (39) stops due to failure or the like, refrigerant is circulated in the low stage side refrigerant circuit (9) by placing only the auxiliary compressor (50) in operation. When the auxiliary compressor (50) is operated, refrigerant is circulated in the freeze storage heat exchanger (49) in connection with the suction side of the auxiliary compressor (50) as well as in the cold storage heat exchanger (47b) in connection with the suction side of the auxiliary compressor (50) through the second bypass pipeline (68), whereby each heat exchanger (47b) is made to function as an evaporator. In the case where both the heat exchangers (47b, 49) operate as evaporators, it is required that the evaporating pressure of refrigerant in the cold storage heat exchanger (47b) be higher than the evaporating pressure of refrigerant in the freeze storage heat exchanger (49) because of the difference in utilization temperature. However, when the cold storage heat exchanger (47b) and the freeze storage heat exchanger (49) become fluidly communicative with each other through the second bypass pipeline (68), there is the possibility that the evaporating pressure of refrigerant in the cold storage heat exchanger (47b) will fall down to the evaporating pressure of refrigerant in the freeze storage heat exchanger (49).

[0025] In the sixth aspect of the present invention, however, the pressure control mechanism (48) is disposed between the downstream end of the cold storage heat exchanger (47b) and the downstream end of the second bypass pipeline (68). As a result of such arrangement, it becomes possible to prevent the evaporating pressure of refrigerant in the cold storage heat exchanger (47b) from falling to the evaporating pressure of refrigerant in the freeze storage heat exchanger (49) by reducing the opening of the pressure control mechanism

(48) to a given extent.

[0026] The present invention provides, as a seventh aspect according to any one of the third to sixth aspects, a refrigeration apparatus in which the low stage side refrigerant circuit (9) includes a third bypass pipeline (69) for enabling the suction and discharge sides of the auxiliary compressor (50) to fluidly communicate with each other.

[0027] In the seventh aspect of the present invention, refrigerant on the suction side of the auxiliary compressor (50) can be bypassed through the third bypass pipeline (69) to the discharge side of the auxiliary compressor (50). As a result of such arrangement, by placing the low stage side compressor (39) in operation when the auxiliary compressor (50) stops due to failure or the like, refrigerant can be circulated in the low stage side refrigerant circuit (9) without causing refrigerant to flow through the auxiliary compressor (50).

[0028] The present invention provides, as an eighth aspect according to any one of the first to seventh aspects, a refrigeration apparatus in which a low stage side outdoor heat exchanger (60) for effectuating heat dissipation from refrigerant to outdoor air is connected in series with the cascade heat exchanger (40) in the low stage side refrigerant circuit (9).

[0029] In the eighth aspect of the present invention, the low stage side outdoor heat exchanger (60) is disposed in the low stage side refrigerant circuit (9). Therefore, when the amount of heat absorbed by the refrigerant in the cooling heat exchanger (47a, 47b, 49) exceeds a predetermined level, the heat can be released outdoors through the low stage side outdoor heat exchanger (60).

[0030] The present invention provides, as a ninth aspect according to the eighth aspect, a refrigeration apparatus wherein the cascade heat exchanger (40) is disposed downstream of the low stage side outdoor heat exchanger (60) in the low stage side refrigerant circuit (9).

[0031] In the ninth aspect of the present invention, refrigerant condensed after heat dissipation in the low stage side outdoor heat exchanger (60) flows into the cascade heat exchanger (40). In the cascade heat exchanger (40), the heat of the refrigerant condensed in

the low stage side outdoor heat exchanger (60) is recovered by refrigerant in the high stage side refrigerant circuit (8), whereby refrigerant on the side of the low stage side refrigerant circuit (9) is cooled. Therefore, the refrigerant on the side of the low stage side refrigerant circuit (9) is supercooled.

ADVANTAGEOUS EFFECTS OF THE INVENTION

[0032] According to the first aspect of the present invention, the high stage side refrigerant circuit (8) and the low stage side refrigerant circuit (9) are connected together through the cascade heat exchanger (40) to thereby perform a two-stage cascade refrigeration cycle, and the air conditioning heat exchanger (45) in the high stage side refrigerant circuit (8) utilizes the heat of the low stage side refrigerant circuit (9) to provide heating.

[0033] In the first aspect of the present invention, the air conditioning heat exchanger (45) is provided only in the high stage side refrigerant circuit (8) and the cooling heat exchanger (47a, 47b, 49) is provided only in the low stage side refrigerant circuit (9). This therefore allows the air conditioning heat exchanger (45) and the cooling heat exchanger (47a, 47b, 49) to use different refrigerants. Each heat exchanger performs a respective refrigeration cycle by use of a respective refrigerant suited to its utilization temperature range, whereby it becomes possible to facilitate temperature control in each heat exchanger.

[0034] According to the second aspect of the present invention, as the cooling heat exchanger (47a, 47b, 49), the cold storage heat exchanger (47a, 47b) for providing cooling of the cold storage compartment and the freeze storage heat exchanger (49) for providing cooling of the freeze storage compartment are provided. This arrangement therefore makes it possible to provide, at the same time, indoor space air conditioning, cold storage compartment cooling, and freeze storage compartment cooling.

[0035] According to the third aspect of the present invention, a two-stage compression refrigeration cycle is performed in the low stage side refrigerant circuit (9). This therefore ensures that the refrigerant evaporating pressure of the freeze storage heat exchanger (49) can

be made to fall below the refrigerant evaporating pressure of the cold storage heat exchanger (47a, 47b) without fail, whereby the freeze storage compartment is assuredly cooled by the freeze storage heat exchanger (49).

[0036] According to the fourth aspect of the present invention, the first bypass pipeline (67) is provided which makes it possible for refrigerant on the suction side of the low stage side compressor (39) to be bypassed to the discharge side of the low stage side compressor (39). This arrangement therefore makes it possible to cause the refrigerant of the low stage side refrigerant circuit (9) to be circulated by placing the auxiliary compressor (50) in operation even when the low stage side compressor (39) breaks down, whereby the cooling heat exchanger (47b, 49) can be functioned as an evaporator.

[0037] According to the fifth aspect of the present invention, the second bypass pipeline (68) is provided which makes it possible for refrigerant on the outlet side of the cold storage heat exchanger (47b) to be bypassed to the suction side of the auxiliary compressor (50). This arrangement therefore makes it possible to cause refrigerant to be circulated in the cold storage heat exchanger (47b) by placing the auxiliary compressor (50) in operation even when the low stage side compressor (39) breaks down, whereby the cooling heat exchanger (47b) can be functioned as an evaporator.

[0038] According to the sixth aspect of the present invention, when refrigerant on the outlet side of the cold storage heat exchanger (47b) is introduced through the second bypass pipeline (68) to the suction side of the auxiliary compressor (50), for example, in the event of failure of the low stage side compressor (39), it becomes possible to prevent the refrigerant evaporating pressure of the cold storage heat exchanger (47b) from falling to the refrigerant evaporating pressure of the freeze storage heat exchanger (49) by reducing the opening of the pressure control mechanism (48) to a given extent. Accordingly, even when the low stage side compressor (39) breaks down, the refrigerant evaporating temperature of the cold storage heat exchanger (47b) and the refrigerant evaporating temperature of the freeze storage heat

exchanger (49) can be set at different values.

[0039] According to the seventh aspect of the present invention, the third bypass pipeline (69) is provided which makes it possible for refrigerant on the suction side of the auxiliary compressor (50) to be bypassed to the discharge side of the auxiliary compressor (50). This arrangement therefore makes it possible to cause the refrigerant of the low stage side refrigerant circuit (9) to be circulated by placing the low stage side compressor (39) in operation even when the auxiliary compressor (50) breaks down, whereby the cooling heat exchanger (47b, 47b, 49) can be functioned as an evaporator.

[0040] According to the eighth aspect of the present invention, the low stage side outdoor heat exchanger (60) is disposed in the low stage side refrigerant circuit (9). Therefore, when in the low stage side refrigerant circuit (9) the amount of heat absorbed from the cooling heat exchanger (47a, 47b, 49) exceeds a predetermined level, the heat can be released outdoors through the low stage side outdoor heat exchanger (60). This therefore improves the cooling capacity of the cooling heat exchanger (47a, 47b, 49).

[0041] According to the ninth aspect of the present invention, refrigerant condensed in the low stage heat exchanger (60) is cooled by refrigerant in the cascade heat exchanger (40) on the side of the high stage side refrigerant circuit (8), whereby supercooling is performed in the low stage side refrigerant circuit (9). This therefore makes it possible to improve the cooling capacity of the cooling heat exchanger (47a, 47b, 49) to a further extent.

BRIEF DESCRIPTION OF THE DRAWINGS

[0042] In the drawings:

Figure 1 is a schematic block diagram of a refrigeration apparatus according to a first embodiment of the present invention;

Figure 2 is a schematic block diagram which shows the flow of refrigerant in a cooling operation mode of the refrigeration apparatus of the first embodiment;

Figure 3 is a schematic block diagram which shows the flow of refrigerant in a first

heating operation mode of the refrigeration apparatus of the first embodiment;

Figure 4 is a schematic block diagram which shows the flow of refrigerant in a second heating operation mode of the refrigeration apparatus of the first embodiment;

Figure 5 is a schematic block diagram which shows the flow of refrigerant in a third heating operation mode of the refrigeration apparatus of the first embodiment;

Figure 6 is a schematic block diagram which shows the flow of refrigerant when a low stage side compressor of the refrigeration apparatus of the first embodiment breaks down;

Figure 7 is a schematic block diagram of a refrigeration apparatus according to a second embodiment of the present invention;

Figure 8 is a schematic block diagram which shows the flow of refrigerant in a cooling operation mode of the refrigeration apparatus of the second embodiment;

Figure 9 is a schematic block diagram which shows the flow of refrigerant in a first heating operation mode of the refrigeration apparatus of the second embodiment;

Figure 10 is a schematic block diagram which shows the flow of refrigerant in a second heating operation mode of the refrigeration apparatus of the second embodiment;

Figure 11 is a schematic block diagram of a refrigeration apparatus according to a third embodiment of the present invention;

Figure 12 is a schematic block diagram which shows the flow of refrigerant in a cooling operation mode of the refrigeration apparatus of the third embodiment; and

Figure 13 is a schematic block diagram which shows the flow of refrigerant in a heating operation mode of the refrigeration apparatus of the third embodiment.

REFERENCE NUMERALS IN THE DRAWINGS

[0043]

(2) air conditioning circuit

(3,4) cold storage circuit

(7) freeze storage circuit (freeze storage compartment circuit (5), booster circuit (6))

- (8) high stage side refrigerant circuit
- (9) low stage side refrigerant circuit
- (10) refrigeration apparatus
- (11) outdoor unit
- (12) air conditioning unit
- (13, 14) cold storage unit
- (15) freeze storage unit
- (16) booster unit
- (31, 32) high stage side compressor
- (39) low stage side compressor
- (40) cascade heat exchanger
- (45) air conditioning heat exchanger
- (47a, 47b) cold storage heat exchanger
- (48) pressure control valve
- (49) freeze storage heat exchanger
- (50) auxiliary compressor (booster compressor)
- (67) first bypass pipeline
- (68) second bypass pipeline
- (69) third bypass pipeline

BEST EMBODIMENT MODE FOR CARRYING OUT THE INVENTION

[0044] In the following, preferred embodiments of the present invention are described in detail with reference to the accompanying drawings.

FIRST EMBODIMENT OF THE INVENTION

[0045] A refrigeration apparatus (10) according to a first embodiment of the present invention is a refrigeration apparatus of the type that may be installed, for example, in a convenience store or the like. The refrigeration apparatus (10) provides, at the same time,

air conditioning of the store and cooling of showcases. The refrigeration apparatus (10) is provided with a high stage side refrigerant circuit (8) and a low stage side refrigerant circuit (9) and performs a two-stage cascade refrigeration cycle.

[0046] Referring to Figure 1, the refrigeration apparatus (10) includes an outdoor unit (11), an air conditioning unit (12), first and second cold storage units (13, 14), a freeze storage unit (15), and a booster unit (16). The outdoor unit (11) is installed outside the store while on the other hand the other units (12, 13, ...) are all installed inside the store.

[0047] The outdoor unit (11) has a high stage side outdoor circuit (1a) and a low stage side outdoor circuit (1b). The air conditioning unit (12) has an air conditioning circuit (2). The first cold storage unit (13) has a first cold storage circuit (3). The second cold storage unit (14) has a second cold storage circuit (4). The freeze storage unit (15) has a freeze storage compartment circuit (5). The booster unit (16) has a booster circuit (6). The freeze storage compartment circuit (5) and the booster circuit (6) are connected together in series to form a freeze storage circuit (7).

[0048] In the refrigeration apparatus (10), the high stage side outdoor circuit (1a) of the outdoor unit (11) is connected by a pipeline to the air conditioning circuit (2) to form the high stage side refrigerant circuit (8) which is a closed circuit while on the other hand the low stage side outdoor circuit (1b) of the outdoor unit (11) is connected by a pipeline to the first and second cold storage circuits (3, 4) and the freeze storage circuit (7) to form the low stage side refrigerant circuit (9) which is a closed circuit. The high stage side refrigerant circuit (8) and the low stage side refrigerant circuit (9) are connected together through a cascade heat exchanger (40) (described later in detail).

[0049] In the high stage side refrigerant circuit (8), the high stage side outdoor circuit (1a) and the air conditioning circuit (2) are connected together through two interunit pipelines (first and second interunit pipelines) (21, 22). The air conditioning circuit (2) is connected in series to the high stage side outdoor circuit (1a).

[0050] In the low stage side refrigerant circuit (9), the low stage side outdoor circuit (1b) is connected through two interunit pipelines (third and fourth interunit pipelines) (23, 24) to the first and second cold storage circuits (3, 4) and the freeze storage circuit (7). The cold storage circuits (3, 4) and the freeze storage circuit (7) are each connected in parallel with the low stage side outdoor circuit (1b).

CONFIGURATION OF THE OUTDOOR UNIT

[0051] As described above, the outdoor unit (11) has the high stage side outdoor circuit (1a) which is connected to the air conditioning circuit (2) to form the high stage side refrigerant circuit (8), and the low stage side outdoor circuit (1b) which is connected to the first and second cold storage circuits (3, 4) and the freeze storage circuit (7) to form the low stage side refrigerant circuit (9). The cascade heat exchanger (40) has a first heat exchange section (41) and a second heat exchange section (42), wherein the first heat exchange section (41) is connected to the high stage side outdoor circuit (1a) while on the other hand the second heat exchange section (42) is connected to the low stage side outdoor circuit (1b).

CONFIGURATION OF THE HIGH STAGE SIDE OUTDOOR CIRCUIT

[0052] The high stage side outdoor circuit (1a) includes first and second high stage side compressors (31, 32), an outdoor heat exchanger (33), first and second high stage side expansion valves (34, 35), a high stage side receiver (36), and the first heat exchange section (41) of the cascade heat exchanger (40). The high stage side outdoor circuit (1a) further includes first and second four-way switch valves (37, 38) each having first to fourth ports, and first to third shut-off valves (51, 52, 53).

[0053] Both the first high stage side compressor (31) and the second high stage side compressor (32) are high pressure dome scroll compressors of the hermetical type. Electric power is supplied through an inverter to the first high stage side compressor (31). The first high stage side compressor (31) is implemented by a so-called variable capacity compressor whose capacity can be varied by changing the output frequency of the inverter to thereby

change the rotating speed of an associated compressor motor. On the other hand, the second high stage side compressor (32) is implemented by a so-called fixed capacity compressor which is operated by an associated compressor motor whose rotating speed is constant.

[0054] The suction side of the first high stage side compressor (31) is connected to one end of a first suction pipe (31a). On the other hand, the suction side of the second high stage side compressor (32) is connected to one end of a second suction pipe (32a). The other end of the first suction pipe (31a) and the other end of the second suction pipe (32a) are connected to a main suction pipe (61). The main suction pipe (61) is branched off into two branch pipelines. One of the branch pipelines diverged from the main suction pipe (61) is connected to the first heat exchange section (41) of the cascade heat exchanger (40) and the other branch pipeline is connected to the second port of the second four-way switch valve (38).

[0055] The discharge side of the first high stage side compressor (31) is connected to one end of a first discharge pipe (31b). On the other hand, the discharge side of the second high stage side compressor (32) is connected to one end of a second discharge pipe (32b). The other end of the first discharge pipe (31b) and the other end of the second discharge pipe (32b) are connected to a main discharge pipe (62). The second discharge pipe (32b) is provided with a first check valve (71) which permits only refrigerant flow towards the main discharge pipe (62) from the second high stage side compressor (32). In addition, the main discharge pipe (62) is branched off into two branch pipelines. One of the branch pipelines diverged from the main discharge pipe (62) is connected to the first port of the first four-way switch valve (37) and the other branch pipeline is connected to the first port of the second four-way switch valve (38).

[0056] In the first four-way switch valve (37), the second port is connected to the third port of the second four-way switch valve (38), the third port is connected through the first shut-off valve (51) to the first interunit pipeline (21), and the fourth port is connected through

the fifth shut-off valve (55) to one end of the outdoor heat exchanger (33). The first four-way switch valve (37) is configured to be selectively switchable between a first state (as indicated by a solid line of Figure 1) in which the first and fourth ports are in fluid communication with each other while simultaneously the second and third ports are in fluid communication with each other and a second state (as indicated by a broken line of Figure 1) in which the first and third ports are in fluid communication with each other while simultaneously the second and fourth ports are in fluid communication with each other.

[0057] The fourth port of the second four-way switch valve (38) is closed, in other words no pipeline is connected thereto. The second four-way switch valve (38) is configured to be selectively switchable between a first state (as indicated by a solid line of Figure 1) in which the first and fourth ports are in fluid communication with each other while simultaneously the second and third ports are in fluid communication with each other and a second state (as indicated by a broken line of Figure 1) in which the first and third ports are in fluid communication with each other while simultaneously the second and fourth ports are in fluid communication with each other.

[0058] The outdoor heat exchanger (33) is a fin and tube heat exchanger of the cross fin type and constitutes a heat source side heat exchanger in the high stage side refrigerant circuit (8). In the outdoor heat exchanger (33), heat exchange is effectuated between the refrigerant and the outdoor air. The other end of the outdoor heat exchanger (33) is connected to one end of a first high stage side pipeline (63) and to one end of a second high stage side pipeline (64).

[0059] The other end of the first high stage side pipeline (63) is connected, through a second check valve (72), then through a third check valve (73), and then through the second shut-off valve (52), to the second interunit pipeline (22). On the other hand, the other end of the second high stage side pipeline (64) is connected, through the first high stage side expansion valve (34), then through a fourth check valve (74), and then through the second

high stage side expansion valve (35), to the first heat exchange section (41) of the cascade heat exchanger (40). The first and second high stage side expansion valves (34, 35) are formed by electronic expansion valves.

[0060] One end of a first liquid pipe (65) having the high stage side receiver (36) is connected to a part of the first high stage side pipeline (63) that is located between the second check valve (72) and the third check valve (73). The other end of the first liquid pipe (65) is connected to the second high stage side pipeline (64) in the vicinity of the fourth check valve (74). One end of a second liquid pipe (66) having a fifth check valve (75) is connected to a part of the first high stage side pipeline (63) that is located between the third check valve (73) and the second shut-off valve (52). The other end of the second liquid pipe (66) is connected to the second high stage side pipeline (64) in the vicinity of the second high stage side expansion valve (35).

[0061] The second check valve (72) permits only refrigerant flow towards the high stage side receiver (36) from the outdoor heat exchanger (33) and the first high stage side expansion valve (34) in the high stage side pipeline (63). In the high stage side pipeline (63), the third check valve (73) permits only refrigerant flow towards the junction of the first liquid pipe (65) with the high stage side pipeline (63) from the junction of the second liquid pipe (66) with the high stage side pipeline (63). In the second high stage side pipeline (64), the fourth check valve (74) permits only refrigerant flow towards the first high stage side expansion valve (34) from the junction of the first liquid pipe (65) with the second high stage side pipeline (64). In the second liquid pipe (66), the fifth check valve (75) permits only refrigerant flow towards the first high stage side pipeline (63) from the second high stage side pipeline (64).

[0062] The high stage side outdoor circuit (1a) includes various functional components such as sensors, pressure switches, filters et cetera. More specifically, a first suction pressure sensor (81), a first suction temperature sensor (82), and a first filter (83) are provided

in an interflow part of the main suction pipe (61). On the other hand, a first discharge temperature sensor (84) and an oil separator (85) are provided in an interflow part of the main discharge pipe (62). The oil separator (85) separates refrigerating machine oil from gases discharged from both the compressors (31, 32). The refrigerating machine oil separated by the oil separator (85) is returned back to the suction side of the compressors (31, 32) by way of an oil return pipe (not shown).

[0063] The first discharge pipe (31b) is provided with a first high pressure switch (86) and a first discharge pressure sensor (87). On the other hand, the second discharge pipe (32b) is provide with a second high pressure switch (88). The first liquid pipe (65) is provided with a dryer filter (89). The outdoor heat exchanger (33) is provided with an outside air temperature sensor (90) and an outdoor fan (91). The outdoor fan (91) supplies outdoor air to the outdoor heat exchanger (33).

CONFIGURATION OF THE LOW STAGE SIDE OUTDOOR CIRCUIT

[0064] The low stage side outdoor circuit (1b) includes a low stage side compressor (39), the second heat exchange section (42) of the cascade heat exchanger (40), and a low stage side receiver (43). The low stage side outdoor circuit (1b) further includes fourth and fifth shut-off valves (54, 55).

[0065] The low stage side compressor (39) is supplied through an inverter with electric power. The low stage side compressor (39) is implemented by a so-called variable capacity compressor whose capacity can be varied by changing the output frequency of the inverter to thereby change the rotating speed of an associated compressor motor.

[0066] The suction side of the low stage side compressor (39) is connected through the fifth shut-off valve (55) to the fourth interunit pipeline (24). On the other hand, the discharge side of the low stage side compressor (39) is connected through a sixth check valve (76) to one end of the second heat exchange section (42). The sixth check valve (76) permits only refrigerant flow towards the second heat exchange section (42) from the low stage side

compressor (39). In addition, the other end of the second heat exchange section (42) is connected to one end of the low stage side receiver (43). The other end of the low stage side receiver (43) is connected through the fourth shut-off valve (54) to the third interunit pipeline (23).

[0067] The low stage side refrigerant circuit (9) includes a first bypass pipeline (67) for enabling the suction and discharge sides of the low stage side compressor (39) to fluidly communicate with each other. More specifically, one end of the first bypass pipeline (67), i.e., the inflow end, is connected to a pipeline between the fifth shut-off valve (55) and the low stage side compressor (39) while on the other hand the other end of the first bypass pipeline (67), i.e., the outflow end, is connected to a pipeline between the low stage side compressor (39) and the cascade heat exchanger (40). The first bypass pipeline (67) is provided with a seventh check valve (77). The seventh check valve (77) permits only refrigerant flow towards the outflow end from the inflow end of the first bypass pipeline (67).

[0068] As described above, the first bypass pipeline (67) is configured such that, for example when the low stage side compressor (39) breaks down, refrigerant on the suction side of the low stage side compressor (39) is bypassed to the discharge side of the low stage side compressor (39).

[0069] The low stage side outdoor circuit (1b) includes various functional components such as sensors, pressure switches, filters et cetera. More specifically, a second filter (92) and a second suction temperature sensor (93) are provided in a pipeline extending from the fifth shut-off valve (55) to the low stage side compressor (39). In addition, provided in a pipeline extending from the low stage side compressor (39) to the second heat exchange section (42) are a third high pressure switch (94), a second discharge temperature sensor (95), and a second discharge pressure sensor (96). Furthermore, the first bypass pipeline (67) is provided with a bypass pressure sensor (97).

CONFIGURATION OF THE AIR CONDITIONING UNIT

[0070] As described previously, the air conditioning unit (12) includes the air conditioning circuit (2) which is connected to the high stage side outdoor circuit (1a) of the outdoor unit (11) to constitute the high stage side refrigerant circuit (8). The air conditioning circuit (2) includes a third filter (98), an air conditioning side expansion valve (44), and an air conditioning heat exchanger (45), in that order from the junction with the second interunit pipeline (22).

[0071] The air conditioning side expansion valve (44) is implemented by an electronic expansion valve. The air conditioning heat exchanger (45) is implemented by a fin and tube heat exchanger of the cross fin type. In the air conditioning heat exchanger (45), heat exchange is effectuated between the refrigerant and the indoor air.

[0072] The air conditioning heat exchanger (45) is provided with a first air conditioning temperature sensor (99). Furthermore, in the air conditioning circuit (2), a second air condition temperature sensor (100) is provided in a pipeline between the junction with the first interunit pipeline (21) and the air conditioning heat exchanger (45).

[0073] The air condition heat exchanger (45) further includes an inside air temperature sensor (101) and an indoor fan (102). The indoor fan (102) supplies indoor air to the air conditioning heat exchanger (45).

[0074] In the configuration of the air conditioning unit (12) as described above, the air conditioning heat exchanger (45) is configured such that it selectively provides cooling or heating of the store.

CONFIGURATION OF THE COLD STORAGE UNIT

[0075] As described previously, the cold storage unit (13, 14) includes the cold storage circuit (3, 4) which is connected to the low stage side outdoor circuit (1b) and the freeze storage circuit (7) (the freeze storage compartment circuit (5) and the booster circuit (6)) to constitute the low stage side refrigerant circuit (9).

[0076] One end of the first cold storage circuit (3) is connected to the third interunit

pipeline (23) while the other end thereof is connected to the fourth interunit pipeline (24). The first cold storage circuit (3) includes a fourth filter (103), a first solenoid switch valve (56a), a first cold storage side expansion valve (46a), a first cold storage heat exchanger (47a), and a first cold storage side pressure sensor (57a), in that order from the junction with the third interunit pipeline (23) (in that order relative to the refrigerant flow direction).

[0077] The first cold storage side expansion valve (46a) is implemented by an electronic expansion valve. The opening of the first cold storage side expansion valve (46a) is controllable in response to a pressure detected by the first cold storage side pressure sensor (57a). The first cold storage heat exchanger (47a) is implemented by a fin and tube heat exchanger of the cross fin type. In the first cold storage heat exchanger (47a), heat exchange is effectuated between the refrigerant and the air in the cold storage compartment. In addition, the first cold storage heat exchanger (47a) is provided with a first cold storage compartment temperature sensor (104) and a first cold storage compartment fan (105). The first cold storage compartment fan (105) supplies air in the cold storage compartment to the first cold storage heat exchanger (47a).

[0078] One end of the second cold storage circuit (4) is connected to a first branch pipeline (25) diverged from the third interunit pipeline (23). On the other hand, the other end of the second cold storage circuit (4) is connected to a second branch pipeline (26) diverged from the fourth interunit pipeline (24). The second cold storage circuit (4) includes a fifth filter (106), a second solenoid switch valve (56b), a second cold storage side expansion valve (46b), a second cold storage heat exchanger (47b), a second cold storage side pressure sensor (57b), a pressure control valve (48) whose details will be described later, and an eighth check valve (78), in that order from from the junction with the first branch pipeline (25) (in that order relative to the refrigerant flow direction).

[0079] The second cold storage side expansion valve (46b) is implemented by an electronic expansion valve. The opening of the second cold storage side expansion valve

(46b) is controllable in response to a pressure detected by the second cold storage side pressure sensor (57b). The second cold storage heat exchanger (47b) is implemented by a fin and tube heat exchanger of the cross fin type. In the second cold storage heat exchanger (47b), heat exchange is effectuated between the refrigerant and the air in the cold storage compartment. In addition, the second cold storage heat exchanger (47b) is provided with a second cold storage compartment temperature sensor (107) and a second cold storage compartment fan (108). The second cold storage compartment fan (108) supplies air in the cold storage compartment to the second cold storage heat exchanger (47b). In addition, the eighth check valve (78) permits only refrigerant flow towards the second branch pipeline (26) from the second cold storage heat exchanger (47b). Furthermore, one end of a second bypass pipeline (68) whose details will be described later is connected to the second cold storage circuit (4).

[0080] In the above-described configuration of the cold storage unit (13, 14), the cold storage heat exchanger (47a, 47b) is configured so as to function as a cooling heat exchanger for providing cooling of the showcase cold storage compartment.

CONFIGURATION OF THE FREEZE STORAGE UNIT

[0081] As described previously, the freeze storage unit (15) includes the freeze storage compartment circuit (5). One end of the freeze storage compartment circuit (5) is connected to a third branch pipeline (27) diverged from the first branch pipeline (25) while the other end thereof is connected to one end of the booster circuit (6). The freeze storage compartment circuit (5) includes a sixth filter (109), a third solenoid switch valve (56c), a freeze storage side expansion valve (46c), a freeze storage heat exchanger (49), and a freeze storage side pressure sensor (57c), in that order from the junction with the first branch pipeline (25) (in that order relative to the refrigerant flow direction).

[0082] The freeze storage side expansion valve (46c) is implemented by an electronic expansion valve. The opening of the freeze storage side expansion valve (46c) is

controllable in response to a pressure detected by the freeze storage side pressure sensor (57c). The freeze storage heat exchanger (49) is implemented by a fin and tube heat exchanger of the cross fin type. In the freeze storage heat exchanger (49), heat exchange is effectuated between the refrigerant and the air in the freeze storage compartment. In addition, the freeze storage heat exchanger (49) is provided with a freeze storage compartment temperature sensor (110) and a freeze storage compartment fan (111). The freeze storage compartment fan (111) supplies air in the freeze storage compartment to the freeze storage heat exchanger (49). In addition, the other end of the second bypass pipeline (68) whose details will be described later is connected to the freeze storage heat exchanger (49).

[0083] In the above-described configuration of the freeze storage unit (15), the freeze storage heat exchanger (49) is configured so as to function as a cooling heat exchanger for providing cooling of the showcase freeze storage compartment.

CONFIGURATION OF THE BOOSTER UNIT

[0084] As described previously, the booster unit (16) includes the booster circuit (6). One end of the booster circuit (6) is connected to the freeze storage compartment circuit (5) while the other end thereof is connected to the second branch pipeline (26). The booster circuit (6) includes a seventh filter (112), a booster compressor (50) as an auxiliary compressor, and a ninth check valve (79), in that order from the junction with the freeze storage compartment circuit (5) (in that order relative to the refrigerant flow direction).

[0085] The booster compressor (50) is supplied through an inverter with electric power. The booster compressor (50) is implemented by a so-called variable capacity compressor whose capacity can be varied by changing the output frequency of the inverter to thereby change the rotating speed of an associated compressor motor. The booster compressor (50) is configured such that it performs, along with the low stage side compressor (39), a two-stage compression by subjecting refrigerant drawn from the freeze storage

compartment circuit (5) to compression and then discharging the compressed refrigerant to the suction side of the low stage side compressor (39).

[0086] The ninth check valve (79) permits only refrigerant flow towards the second branch pipeline (26) from the discharge side of the booster compressor (50). A fourth high pressure switch (113) is provided in a pipeline between the booster compressor (50) and the ninth check valve (79).

[0087] The booster circuit (6) includes a third bypass pipeline (69) for enabling the suction and discharge sides of the booster compressor (50) to fluidly communicate with each other. More specifically, one end of the third bypass pipeline (69), i.e., the inflow end, is connected to a pipeline between the seventh filter (112) and the booster compressor (50) while the other end thereof, i.e., the outflow end, is connected to a pipeline between the fourth high pressure switch (113) and the junction with the second branch pipeline (26). The third bypass pipeline (69) is provided with a tenth check valve (80). The tenth check valve (80) permits only refrigerant flow towards the outflow end from the inflow end of the third bypass pipeline (69).

[0088] As described above, the third bypass pipeline (69) is configured such that, for example, when the booster compressor (50) breaks down, refrigerant on the suction side of the booster compressor (50) is bypassed to the discharge side of the booster compressor (50).

CONFIGURATION OF THE SECOND BYPASS PIPELINE

[0089] As described previously, one end of the second bypass pipeline (68) is connected to the second cold storage circuit (4) while the other end thereof is connected to the freeze storage compartment circuit (5). More specifically, one end of the second bypass pipeline (68) is connected to a pipeline between the pressure control valve (48) and the eighth check valve (78) in the second cold storage circuit (4). On the other hand, the other end of the second bypass pipeline (68) is connected to a pipeline between the freeze storage side pressure sensor (57c) and the junction with the booster circuit (6) in the freeze storage

compartment circuit (5). In this way, the second bypass pipeline (68) enables the discharge side of the second cold storage heat exchanger (47b) and the suction side of the booster compressor (auxiliary compressor) (50) to fluidly communicate with each other.

[0090] The second bypass pipeline (68) is provided with a bypass solenoid switch valve (56d). The bypass solenoid switch valve (56d) is configured such that it enters the open state when the low stage side compressor (39) breaks down while on the other hand it enters the closed state when the low stage side compressor (39) operates normally. Therefore, when the low stage side compressor (39) breaks down, only the booster compressor (50) is operated, whereby refrigerant is circulated in the second cold storage heat exchanger (47b), leaves the second cold storage heat exchanger (47b), and is returned back to the suction side of the booster compressor (50) via the second bypass pipeline (68). The pressure control valve (48) disposed in the second cold storage circuit (4) is configured such that it adjusts the refrigerant evaporating pressure of the second cold storage heat exchanger (47) to a predetermined pressure level, the detail of which is described later.

CONFIGURATION OF THE CONTROLLER

[0091] The refrigeration apparatus (10) of the first embodiment is provided with a controller (200). Based on values detected by the temperature sensors, the pressure sensors et cetera, the controller (200) controls the opening of each expansion valve and changes the capacity of each capacity variable compressor. In addition, the first and second four-way switch valves (37, 38) are each switched, by the controller (200), to the state indicated by solid line in Figure 1 or to the state indicated by broken line in Figure 1 according to the operating condition of the refrigeration apparatus (10). Furthermore, the controller (200) places each solenoid valve in the open or closed state according to the operating condition.

[0092] As described above, in the refrigeration apparatus (10) of the first embodiment, the air conditioning heat exchanger (45) for selectively providing indoor space cooling or heating is disposed only in the high stage side refrigerant circuit (8), while on the other hand

the cold storage heat exchanger (47a, 47b) for providing cold storage compartment cooling and the freeze storage heat exchanger (49) for providing freeze storage compartment cooling are disposed, as cooling heat exchangers, only in the low stage side refrigerant circuit (9). The high stage side refrigerant circuit (8) and the low stage side refrigerant circuit (9) are charged with different types of refrigerants.

RUNNING OPERATION

[0093] Next, the running operation of the refrigeration apparatus (10) of the first embodiment is described. The refrigeration apparatus (10) is configured such that it selectively performs a cooling operation mode or a heating operation mode.

COOLING OPERATION MODE

[0094] The cooling operation mode is an operation mode in which the air conditioning unit (12) provides cooling of the store space while simultaneously the cold storage units (13, 14) and the freeze storage unit (15) provide cooling of the storage compartments.

[0095] As shown in Figure 2, in the high stage side refrigerant circuit (8), both the first four-way switch valve (37) and the second four-way switch valve (38) are set to the first state. In addition, the first high stage side expansion valve (34) is fully closed while on the other hand the opening of each of the second high stage side expansion valve (35) and the air conditioning side expansion valve (44) is controlled properly.

[0096] The first and second high stage side compressors (31, 32) are operated and refrigerant discharged out of each high stage side compressor (31, 32) passes through the first four-way switch valve (37) and then flows into the outdoor heat exchanger (33). In the outdoor heat exchanger (33), the inflow refrigerant dissipates heat to outdoor air and is condensed. The refrigerant condensed in the outdoor heat exchanger (33) passes through the high stage side receiver (36) and flows through the second high stage side pipeline (64). Then, a portion of the refrigerant continues to flow through the second high stage side pipeline (64) while the other refrigerant portion is diverged to the second liquid pipe (66).

[0097] The refrigerant flowing through the second high stage side pipeline (64) is decompressed during passage through the second high stage side expansion valve (35) and then flows into the first heat exchange section (41) of the cascade heat exchanger (40). In the cascade heat exchanger (40), the refrigerant flowing through the first heat exchange section (41) absorbs heat from refrigerant flowing through the second heat exchange section (42) (described later) and is evaporated. The refrigerant evaporated in the cascade heat exchanger (40) passes through the main suction pipe (61) and is drawn into the first and second high stage side compressors (31, 32).

[0098] On the other hand, the refrigerant diverged to the second liquid pipe (66) passes through the second interunit pipeline (22) and is introduced into the air conditioning circuit (2). The refrigerant introduced into the air conditioning circuit (2) is decompressed during passage through the air conditioning side expansion valve (44) and then flows into the air conditioning heat exchanger (45). In the air conditioning heat exchanger (45), the inflow refrigerant absorbs heat from indoor air and is evaporated. Therefore, air cooled in the air conditioning heat exchanger (45) of the air conditioning unit (12) is supplied into the store.

[0099] The refrigerant evaporated in the air conditioning heat exchanger (45) passes through the first interunit pipeline (21) and is returned back to the high stage side outdoor circuit (1a). The returned refrigerant passes through the first four-way switch valve (37), then through the second four-way switch valve (38), and then through the main suction pipe (61) and is drawn into the first and second high stage side compressors (31, 32).

[0100] On the other hand, in the low stage side refrigerant circuit (9), the first, second, and third solenoid switch valves (56a, 56b, 56c) enter the open state and the bypass solenoid switch valve (56d) enters the closed state. In addition, the opening of each of the first and second cold storage side expansion valves (46a, 46b) and the freeze storage side expansion valve (46c) is controlled properly.

[0101] The low stage side compressor (39) and the booster compressor (50) are operated

and refrigerant discharged out of the low stage side compressor (39) flows into the second heat exchange section (42) of the cascade heat exchanger (40). In the cascade heat exchanger (40), the refrigerant flowing through the second heat exchange section (42) dissipates heat to refrigerant flowing through the first heat exchange section (41) and is condensed. The refrigerant condensed in the second heat exchange section (42) of the cascade heat exchanger (40) passes through the low stage side receiver (43). Then, the refrigerant passes through the third interunit pipeline (23) and is diverged to the first cold storage circuit (3), to the second cold storage circuit (4), and to the freeze storage compartment circuit (5).

[0102] Refrigerant diverged to the first cold storage circuit (3) is decompressed during passage through the first cold storage side expansion valve (46a) and then flows into the first cold storage heat exchanger (47a). In the first cold storage heat exchanger (47a), the inflow refrigerant absorbs heat from air in the cold storage compartment and is evaporated. Therefore, in the first cold storage unit (13), air cooled in the first cold storage heat exchanger (47a) is supplied into the cold storage compartment. The refrigerant evaporated in the first cold storage heat exchanger (47a) flows into the fourth interunit pipeline (24).

[0103] Refrigerant diverged to the second cold storage circuit (4) is decompressed during passage through the second cold storage side expansion valve (46b) and then flows into the second cold storage heat exchanger (47b). In the second cold storage heat exchanger (47b), the inflow refrigerant absorbs heat from air in the cold storage compartment and is evaporated. Therefore, in the second cold storage unit (14), air cooled in the second cold storage heat exchanger (47b) is supplied into the cold storage compartment. The refrigerant evaporated in the second cold storage heat exchanger (47b) passes through the second branch pipeline (26) and then flows into the fourth interunit pipeline (24).

[0104] Refrigerant diverged to the freeze storage compartment circuit (5) is decompressed during passage through the freeze storage side expansion valve (46c) and then

flows into the freeze storage heat exchanger (49). In the freeze storage heat exchanger (49), the inflow refrigerant absorbs heat from air in the freeze storage compartment and is evaporated. Therefore, in the freeze storage unit (15), air cooled in the freeze storage heat exchanger (49) is supplied into the freeze storage compartment. The refrigerant evaporated in the freeze storage heat exchanger (49) flows into the booster circuit (6).

[0105] The inflow refrigerant into the booster circuit (6) is drawn into the booster compressor (50) where it is compressed. The refrigerant compressed in the booster compressor (50) passes through the second branch pipeline (26) and then flows into the fourth interunit pipeline (24). In the way as described above, the refrigerants, after having been circulated, respectively, through the first cold storage circuit (3), through the second cold storage circuit (4), and through the freeze storage circuit (7), join together in the fourth interunit pipeline (24) and the merged flow of the refrigerants is drawn into the low stage side compressor (39).

HEATING OPERATION MODE

[0106] The heating operation mode is an operation mode in which the air conditioning unit (12) provides heating of the store while simultaneously the cold storage units (13, 14) and the freeze storage unit (15) provide cooling of the storage compartments. In the heating operation mode, in the cascade heat exchanger (40), refrigerant flowing through the first heat exchange section (41) recovers heat from refrigerant flowing through the second heat exchange section (42), whereby the air conditioning heat exchanger (45) utilizes the heat of the refrigerant in the low stage side refrigerant circuit (9) for providing heating. In addition, the refrigeration apparatus (10) performs the following three different heating operation modes depending on the heating load of the store and on the efficiency of heat recovery by the cascade heat exchanger (40).

FIRST HEATING OPERATION MODE

[0107] The first heating operation mode is a heating operation mode in which the air

conditioning heat exchanger (45) provides heating just by making utilization of heat recovered in the cascade heat exchanger (40). The flow of refrigerant in the low stage side refrigerant circuit (9) in the first heating operation mode is the same as the flow of refrigerant in the aforesaid cooling operation mode.

[0108] As shown in Figure 3, in the high stage side refrigerant circuit (8), the first four-way switch valve (37) is set to the second state while on the other hand the second four-way switch valve (38) is set to the first state. In addition, the first high stage side expansion valve (34) is fully closed while on the other hand the opening of the second high stage side expansion valve (35) is controlled properly and the air conditioning side expansion valve (44) enters the fully open state. In the first heating operation mode, no refrigerant flows through the outdoor heat exchanger (33), in other words the outdoor heat exchanger (33) enters the stopped state.

[0109] The first and second high stage side compressors (31, 32) are operated and refrigerant discharged out of each of the first and second high stage side compressors (31, 32) passes through the first four-way switch valve (37) and then through the first interunit pipeline (21) and is introduced into the air conditioning circuit (2). The refrigerant introduced into the air conditioning circuit (2) flows into the air conditioning heat exchanger (45). In the air conditioning heat exchanger (45), the inflow refrigerant dissipates heat to indoor air and is condensed. The air conditioning unit (12) supplies air heated in the air conditioning heat exchanger (45) into the store.

[0110] The refrigerant condensed in the air conditioning heat exchanger (45) passes through the second interunit pipeline (22) and is returned back to the high stage side outdoor circuit (1a). The returned refrigerant flows into the first liquid pipe (65) by way of the first high stage side pipeline (63) and passes through the high stage side receiver (36). Subsequently, the refrigerant is decompressed during passage through the second high stage side expansion valve (35) and then flows into the first heat exchange section (41) of the

cascade heat exchanger (40). In the cascade heat exchanger (40), the refrigerant flowing through the first heat exchange section (41) absorbs heat from refrigerant flowing through the second heat exchange section (42), whereby the recovery of heat from the low stage side refrigerant circuit (9) to the high stage side refrigerant circuit (8) is effectuated and the refrigerant is evaporated. The refrigerant evaporated as a result of the recovery of heat in the cascade heat exchanger (40) passes through the main suction pipe (61) and is drawn into the first and second high stage side compressors (31, 32).

SECOND HEATING OPERATION MODE

[0111] The second heating operation mode is a heating operation mode that is carried out when the heating capacity becomes excessive in the first heating operation mode. The flow of refrigerant in the low stage side refrigerant circuit (9) in the second heating operation mode is the same as the flow of refrigerant in the first heating operation mode.

[0112] As shown in Figure 4, in the high stage side refrigerant circuit (8), both the first four-way switch valve (37) and the second four-way switch valve (38) are set to the second state. In addition, the first high stage side expansion valve (34) is fully closed while on the other hand the opening of the second high stage side expansion valve (35) is controlled properly, and the air conditioning side expansion valve (44) enters the fully open state.

[0113] The first and second high stage side compressors (31, 32) are operated and refrigerant discharged out of each of the first and second high stage side compressors (31, 32) is diverged from the main discharge pipe (62) to the first four-way switch valve (37) and the second four-way switch valve (38).

[0114] Refrigerant diverged to the first four-way switch valve (37) passes through the first interunit pipeline (21) and is introduced into the air conditioning circuit (2). The refrigerant introduced into the air conditioning circuit (2) flows into the air conditioning heat exchanger (45). In the air conditioning heat exchanger (45), the inflow refrigerant dissipates heat to indoor air and is condensed. The air conditioning unit (12) supplies air heated in the

air conditioning heat exchanger (45) into the store. The refrigerant condensed in the air conditioning heat exchanger (45) passes through the second interunit pipeline (22) and then flows into the first high stage side pipeline (63) of the high stage side outdoor circuit (1a).

[0115] On the other hand, refrigerant diverged to the second four-way switch valve (38) flows into the outdoor heat exchanger (33). In the outdoor heat exchanger (33), the inflow refrigerant dissipates heat to outdoor air and is condensed. The refrigerant condensed in the outdoor heat exchanger (33) flows into the first high stage side pipeline (63).

[0116] The merged flow of the refrigerants in the first high stage side pipeline (63) enters the first liquid pipe (65), passes through the high stage side receiver (36), and flows through the second high stage side pipeline (64). The refrigerant is decompressed during passage through the second high stage side expansion valve (35) and then flows into the first heat exchange section (41) of the cascade heat exchanger (40). In the cascade heat exchanger (40), the refrigerant flowing through the first heat exchange section (41) absorbs heat from refrigerant flowing through the second heat exchange section (42), whereby the recovery of heat from the low stage side refrigerant circuit (9) to the high stage side refrigerant circuit (8) is effectuated and the refrigerant is evaporated. The refrigerant evaporated after heat recovery in the cascade heat exchanger (40) passes through the main suction pipe (61) and is drawn into the first and second high stage side compressors (31, 32).

THIRD HEATING OPERATION MODE

[0117] The third heating operation mode is a heating operation mode that is carried out when the heating capacity becomes insufficient in the first heating operation mode. The flow of refrigerant in the third heating operation mode is the same as the flow of refrigerant in the cooling operation mode.

[0118] As shown in Figure 5, in the high stage side refrigerant circuit (8), the first four-way switch valve (37) is set to the second state while on the other hand the second four-way switch valve (38) is set to the first state. In addition, the opening of each of the first and

second high stage side expansion valves (34, 35) is controlled properly, and the air conditioning side expansion valve (44) enters the fully open state.

[0119] The first and second high stage side compressors (31, 32) are operated and refrigerant discharged out of each of the first and second high stage side compressors (31, 32) passes through the first four-way switch valve (37) and then through the first interunit pipeline (21) and is introduced into the air conditioning circuit (2). The refrigerant introduced into the air conditioning circuit (2) flows into the air conditioning heat exchanger (45). In the air conditioning heat exchanger (45), the inflow refrigerant dissipates heat to indoor air and is condensed. The air conditioning unit (12) supplies air heated in the air conditioning heat exchanger (45) into the store.

[0120] The refrigerant condensed in the air conditioning heat exchanger (45) passes through the second interunit pipeline (22) and is returned back to the high stage side outdoor circuit (1a). The refrigerant flows into the first liquid pipe (65) from the first high stage side pipeline (63) and then passes through the high stage side receiver (36). The refrigerant after passage through the high stage side receiver (36) is diverged in the second high stage side pipeline (64) to the cascade heat exchanger (40) and the outdoor heat exchanger (33).

[0121] Refrigerant diverged to the cascade heat exchanger (40) is decompressed during passage through the second high stage side expansion valve (35) and then flows into the first heat exchange section (41) of the cascade heat exchanger (40). In the cascade heat exchanger (40), the refrigerant flowing through the first heat exchange section (41) absorbs heat from refrigerant flowing through the second heat exchange section (42), whereby the recovery of heat from the low stage side refrigerant circuit (9) to the high stage side refrigerant circuit (8) is effectuated and the refrigerant is evaporated. The refrigerant evaporated after heat recovery in the cascade heat exchanger (40) passes through the main suction pipe (61) and is drawn into the first and second high stage side compressors (31, 32).

[0122] On the other hand, refrigerant diverged to the outdoor heat exchanger (33) is

decompressed during passage through the first high stage side expansion valve (34) and then flows into the outdoor heat exchanger (33). In the outdoor heat exchanger (33), the inflow refrigerant absorbs heat from outdoor air and is evaporated. The refrigerant evaporated in the outdoor heat exchanger (33) flows through the first four-way switch valve (37), then through the second four-way switch valve (38), and then through the main suction pipe (61) and is drawn into the first and second high stage side compressors (31, 32).

RUNNING OPERATION AT FAILURE OF THE LOW STAGE SIDE COMPRESSOR

[0123] Next, the running operation of the refrigeration apparatus (10) in the event of failure of the low stage side compressor (39) of the low stage side refrigerant circuit (9) is described. In the description, the flow of refrigerant in the high stage side refrigerant circuit (8) is omitted.

[0124] As shown in Figure 6, when the low stage side compressor (39) of the low stage side refrigerant circuit (9) breaks down, the first solenoid switch valve (56a) enters the closed state while the second and third solenoid switch valves (56b, 56c) and the bypass solenoid switch valve (56d) enter the open state. In addition, the opening of each of the first and second cold storage side expansion valves (46a, 46b), the freeze storage side expansion valve (46c), and the pressure control valve (48) is controlled properly. In this running operation, no refrigerant flows through the first cold storage heat exchanger (47a), in other words, the first cold storage heat exchanger (47a) enters the stopped state.

[0125] The booster compressor (50) is operated and refrigerant discharged out of the booster compressor (50) passes through the second branch pipeline (26) and then through the fourth interunit pipeline (24) and then flows on the suction side of the low stage side compressor (39). Since the low stage side compressor (39) is stopped, the refrigerant flows through the first bypass pipeline (67) and then flows into the second heat exchange section (42) of the cascade heat exchanger (40). In the cascade heat exchanger (40), the refrigerant flowing through the second heat exchange section (42) dissipates heat to refrigerant flowing

through the first heat exchange section (41) and is condensed. The refrigerant condensed in the second heat exchange section (42) of the cascade heat exchanger (40) passes through the low stage side receiver (43). And, the refrigerant passes through the third interunit pipeline (23) and is diverged to the second cold storage circuit (4) and to the freeze storage compartment circuit (5).

[0126] Refrigerant diverged to the freeze storage compartment circuit (5) is decompressed during passage through the freeze storage side expansion valve (46c) and then flows into the freeze storage heat exchanger (49). In the freeze storage heat exchanger (49), the inflow refrigerant absorbs heat from air in the freeze storage compartment and is evaporated. The freeze storage unit (15) supplies air cooled in the freeze storage heat exchanger (49) into the freeze storage compartment.

[0127] On the other hand, refrigerant diverged to the second cold storage circuit (4) is decompressed during passage through the second cold storage side expansion valve (46b) and then flows into the second cold storage heat exchanger (47b). In the second cold storage heat exchanger (47b), the inflow refrigerant absorbs heat from air in the cold storage compartment and is evaporated. In the second cold storage unit (14), air cooled in the second cold storage heat exchanger (47b) is supplied into the cold storage compartment.

[0128] The refrigerant evaporated in the second cold storage heat exchanger (47b) passes through the second bypass pipeline (68) and then flows into the outlet side of the freeze storage heat exchanger (49) in the freeze storage compartment circuit (5).

[0129] Incidentally, in the case where the second cold storage heat exchanger (47b) and the freeze storage heat exchanger (49) are used as evaporators, it is required that the pressure at which refrigerant in the cold storage heat exchanger (47b) is evaporated be higher than the pressure at which refrigerant in the freeze storage heat exchanger (49) is evaporated, for each heat exchanger has a different utilization temperature from the other. However, in this running operation, the cold storage heat exchanger (47b) and the freeze storage heat

exchanger (49) are brought into fluid communication with each other through the second bypass pipeline (68), as a result of which the refrigerant evaporating pressure of the cold storage heat exchanger (47b) will fall down to the refrigerant evaporating pressure of the freeze storage heat exchanger (49) unless any adequate countermeasure is taken.

[0130] To cope with the above, during the running operation, the opening of the pressure control mechanism (48) disposed in the vicinity of the outlet side of the second cold storage heat exchanger (47b) is reduced to a predetermined extent, thereby preventing the refrigerant evaporating pressure of the cold storage heat exchanger (47b) from falling to the refrigerant evaporating pressure of the freeze storage heat exchanger (49).

[0131] The merged flow of the refrigerants in the freeze storage compartment circuit (5) enters the booster circuit (6) and is drawn into the booster compressor (50).

ADVANTAGEOUS EFFECTS OF THE FIRST EMBODIMENT

[0132] The first embodiment provides the following advantageous effects.

[0133] According to the first embodiment, the high stage side refrigerant circuit (8) and the low stage side refrigerant circuit (9) are connected together through the cascade heat exchanger (40) to thereby perform a two-stage cascade refrigeration cycle, whereby the air conditioning heat exchanger (45) of the high stage side refrigerant circuit (8) utilizes the heat of the low stage side refrigerant circuit (9) for providing heating.

[0134] Especially, according to the present invention, the air conditioning heat exchanger (45) is disposed only in the high stage side refrigerant circuit (8) while on the other hand the cooling heat exchangers (47a, 47b, 49) are disposed only in the low stage side refrigerant circuit (9). This therefore makes it possible to allow the air conditioning heat exchanger (45) and the cooling heat exchangers (47a, 47b, 49) to employ different types of refrigerants. Therefore, each heat exchanger is allowed to use a respective refrigerant suited to its utilization temperature and perform its own refrigeration cycle, thereby making it possible to facilitate temperature control in each heat exchanger.

[0135] In addition, according to the present embodiment, the first bypass pipeline (67) is provided, thereby making it possible for refrigerant on the suction side of the low stage side compressor (39) to be bypassed to the discharge side of the low stage side compressor (39). Therefore, even in the event of failure of the low stage side compressor (39), refrigerant in the low stage side refrigerant circuit (9) can be circulated by placing the booster compressor (50) in operation.

[0136] The second bypass pipeline (68) capable of fluid communication with the suction side of the booster compressor (50) is disposed on the outlet side of the second cold storage heat exchanger (47b). As a result of such arrangement, even when the low stage side compressor (39) breaks down, refrigerant can be circulated in the second cold storage heat exchanger (47b) by placing the booster compressor (50) in operation and the second cold storage heat exchanger (47b) functions as an evaporator.

[0137] Furthermore, the pressure control valve (48) is disposed on the outlet side of the second cold storage heat exchanger (47b). When refrigerant on the outlet side of the second cold storage heat exchanger (47b) is introduced through the second bypass pipeline (68) to the suction side of the booster compressor (50) in the event of failure of the low stage side compressor (39), the refrigerant evaporating pressure of the second cold storage heat exchanger (47b) is prevented from falling to the refrigerant evaporating pressure of the freeze storage heat exchanger (49) by reducing the opening of the pressure control valve (48) to a predetermined extent. Therefore, even when the low stage side compressor (39) breaks down, the cold and freeze storage compartments are cooled at specified temperatures by the second cold storage heat exchanger (47b) and the freeze storage heat exchanger (49).

SECOND EMBODIMENT OF THE INVENTION

[0138] A refrigeration apparatus (10) according to a second embodiment of the present invention differs from the refrigeration apparatus of the first embodiment in refrigerant circuit configuration. Hereinafter, only the difference from the first embodiment is described.

[0139] As shown in Figure 7, the high stage side outdoor circuit (1a) of the outdoor unit (11) has only a single four-way switch valve (37). In the four-way switch valve (37), the first port is connected to the main discharge pipe (62); the second port is connected to the main suction pipe (61); the third port is connected through the first shut-off valve (51) to the first interunit pipeline (21); and the fourth port is connected to one end of the first heat exchange section (41) of the cascade heat exchanger (40). The other end of the cascade heat exchanger (40) is connected to one end of the outdoor heat exchanger (33). The other end of the outdoor heat exchanger (33) is connected to one end of the high stage side expansion valve (34). The other end of the high stage side expansion valve (34) is connected through the second shut-off valve (52) to the second interunit pipeline (22).

[0140] On the other hand, unlike the first embodiment, the low stage side outdoor circuit (1b) of the outdoor unit (11) is provided with a low stage side outdoor heat exchanger (60). The low stage side outdoor heat exchanger (60) is connected in series to the second heat exchange section (42) of the cascade heat exchanger (40).

[0141] More specifically, one end of the low stage side outdoor heat exchanger (60) is connected, through the second heat exchange section (42), then through the low stage side compressor (39), and then through the fourth shut-off valve (54), to the fourth interunit pipeline (24). On the other hand, the other end of the low stage side outdoor heat exchanger (60) is connected, through the low stage side receiver (43) and then through the third shut-off valve (53), to the third interunit pipeline (23). In addition, the low stage side outdoor heat exchanger (60) is provided with a low stage outside air temperature (114) and a low stage side outdoor fan (115). The low stage side outdoor fan (115) supplies outdoor air to the low stage side outdoor heat exchanger (60). The low stage side outdoor heat exchanger (60) is configured such that it effectuates heat dissipation from the refrigerant to the outdoor air.

[0142] As described above, in the refrigeration apparatus (10) of the second embodiment, the air conditioning heat exchanger (45) for selectively providing indoor space

cooling or heating is disposed only in the high stage side refrigerant circuit (8) while on the other hand the cold storage heat exchangers (47a, 47b) for providing cooling of the cold storage compartments and the freeze storage heat exchanger (49) for providing cooling of the freeze storage compartment are disposed as cooling heat exchangers only in the low stage side refrigerant circuit (9), as in the first embodiment. The high stage side refrigerant circuit (8) and the low stage side refrigerant circuit (9) are charged with different types of refrigerants.

RUNNING OPERATION

[0143] Next, the running operation of the refrigeration apparatus (10) of the second embodiment is described. The refrigeration apparatus (10) is configured such that it selectively performs a cooling operation mode or a heating operation mode.

COOLING OPERATION MODE

[0144] The cooling operation mode is an operation mode in which the air conditioning unit (12) provides cooling of the store space while simultaneously the cold storage units (13, 14) and the freeze storage unit (15) provide cooling of the storage compartments.

[0145] As shown in Figure 8, in the high stage side refrigerant circuit (8), the first four-way switch valve (37) is set to the first state. In addition, the high stage side expansion valve (34) is fully opened while on the other hand the opening of the air conditioning side expansion valve (44) is controlled properly.

[0146] The first and second high stage side compressors (31, 32) are operated and refrigerant discharged out of each of the first and second high stage side compressors (31, 32) passes through the four-way switch valve (37) and then flows into the first heat exchange section (41). In the cascade heat exchanger (40), little heat exchange is effectuated between the refrigerant flowing through the first heat exchange section (41) and refrigerant flowing through the second heat exchange section (42).

[0147] The refrigerant after passage through the cascade heat exchanger (40) flows into the outdoor heat exchanger (33). In the outdoor heat exchanger (33), the inflow refrigerant

dissipates heat to outdoor air and is condensed. The refrigerant condensed in the outdoor heat exchanger (33) passes through the second interunit pipeline (22) and is introduced into the air conditioning circuit (2).

[0148] The refrigerant introduced into the air conditioning circuit (2) is decompressed during its passage through the air conditioning side expansion valve (44) and then flows into the air conditioning heat exchanger (45). In the air conditioning heat exchanger (45), the inflow refrigerant absorbs heat from indoor air and is evaporated. The air conditioning unit (12) supplies air cooled in the air conditioning heat exchanger (45) into the store.

[0149] The refrigerant evaporated in the air conditioning heat exchanger (45) passes through the first interunit pipeline (21) and is returned back to the high stage side outdoor circuit (1a). The returned refrigerant passes through the four-way switch valve (37) and then through the main suction pipe (61) and is drawn into the first and second compressors (31, 32).

[0150] On the other hand, the low stage side compressor (39) and the booster compressor (50) are operated and refrigerant discharged out of the low stage side compressor (39) flows into the second heat exchange section (42) of the cascade heat exchanger (40) in the low stage side refrigerant circuit (9). Since the temperature of refrigerant discharged out of the low stage side compressor (39) is almost equal to the temperature of refrigerant discharged out of each of the high stage side compressors (31, 32), this means that little heat exchange takes place between the refrigerant flowing through the second heat exchange section (42) and the refrigerant flowing through the first heat exchange section (41) in the cascade heat exchanger (40).

[0151] The refrigerant after passage through the cascade heat exchanger (40) flows into the low stage side outdoor heat exchanger (60). In the low stage side outdoor heat exchanger (60), the inflow refrigerant dissipates heat to outdoor air and is condensed. The refrigerant condensed in the second heat exchange section (42) passes through the low stage

side receiver (43) and then through the third interunit pipeline (23). Thereafter, the refrigerant dissipates heat to refrigerant flowing through the first heat exchange section (41) and is condensed. The refrigerant condensed in the second heat exchange section (42) of the cascade heat exchanger (40) passes through the low stage side receiver (43) and then through the third interunit pipeline (23) and is diverged to the first cold storage circuit (3), to the second cold storage circuit (4), and to the freeze storage compartment circuit (5). The subsequent flow of refrigerant in the low stage side refrigerant circuit (9) is the same as the cooling operation mode of the first embodiment.

HEATING OPERATION MODE

[0152] In the following, two examples of the heating operation mode of the second embodiment are described, one of which is a first heating operation mode in which the air conditioning unit (12) provides heating of the store space while simultaneously the cold storage units (13, 14) and the freeze storage unit (15) provide cooling of the air in the storage compartments and the other of which is a second heating operation mode in which the air conditioning unit (12) provides heating of the store space while on the other hand the cold storage units (13, 14) and the freeze storage unit (15) are placed in the stopped state.

FIRST HEATING OPERATION MODE

[0153] As shown in Figure 9, in the high stage side refrigerant circuit (8), the four-way switch valve (37) is set to the second state. In addition, the air conditioning side expansion valve (44) is fully opened and the opening of the high stage side expansion valve (34) is controlled properly. In the first heating operation mode, the outdoor fan (91) of the outdoor heat exchanger (33) and the low stage side outdoor fan (115) of the low stage side outdoor heat exchanger (60) are placed in the stopped state.

[0154] The first and second high stage side compressors (31, 32) are operated and refrigerant discharged out of each of the first and second high stage side compressors (31, 32) passes through the four-way switch valve (37) and then through the first interunit pipeline

(21) and is introduced to the air conditioning circuit (2). The refrigerant introduced to the air conditioning circuit (2) flows into the air conditioning heat exchanger (45). In the air conditioning heat exchanger (45), the inflow refrigerant dissipates heat to indoor air and is condensed. The air conditioning unit (12) supplies air heated in the air conditioning heat exchanger (45) into the store space.

[0155] The refrigerant condensed in the air conditioning heat exchanger (45) passes through the second interunit pipeline (22) and is returned back to the high stage side outdoor circuit (1a). The returned refrigerant is decompressed during its passage through the high stage side expansion valve (34) and then flows into the outdoor heat exchanger (33). Since the outdoor fan (91) of the outdoor heat exchanger (33) is placed in the stopped state, heat absorption (evaporation) of the refrigerant does not take place actively in the outdoor heat exchanger (33).

[0156] The refrigerant after passage through the outdoor heat exchanger (33) flows into the first heat exchange section (41) of the cascade heat exchanger (40). In the cascade heat exchanger (40), the refrigerant flowing through the first heat exchange section (41) absorbs heat from refrigerant flowing through the second heat exchange section (42), whereby the recovery of heat from the low stage side refrigerant circuit (9) to the high stage side refrigerant circuit (8) is effectuated and the refrigerant in the first heat exchange section (41) is evaporated. The refrigerant evaporated after heat recovery in the cascade heat exchanger (40) passes through the four-way switch valve (37) and then through the main suction pipeline (61) and is drawn into the first and second high stage side compressors (31, 32).

[0157] On the other hand, the low stage side compressor (39) and the booster compressor (50) are operated in the low stage side refrigerant circuit (9) and refrigerant discharged out of the low stage side compressor (39) flows into the second heat exchange section (42) of the cascade heat exchanger (40). In the cascade heat exchanger (40), the refrigerant flowing through the second heat exchange section (42) dissipates heat to

refrigerant flowing through the first heat exchange section (41) and is condensed. The refrigerant after its passage through the cascade heat exchanger (40) flows into the low stage side outdoor heat exchanger (60). Since the low stage side outdoor fan (115) of the low stage side outdoor heat exchanger (60) is placed in the stopped state, heat dissipation of the refrigerant does not take place actively in the low stage side outdoor heat exchanger (60). The refrigerant after its passage through the second heat exchange section (42) passes through the low stage side receiver (43) and then through the third interunit pipeline (23) and is diverged to the first cold storage circuit (3), to the second cold storage circuit (4), and to the freeze storage compartment circuit (5). The subsequent flow of refrigerant in the low stage side refrigerant circuit (9) is the same as the cooling operation mode of the first embodiment.

SECOND HEATING OPERATION MODE

[0158] As shown in Figure 10, in the high stage side refrigerant circuit (8), the four-way switch valve (37) is set to the second state. In addition, the air conditioning side expansion valve (44) enters the fully open state while on the other hand the opening of the high stage side expansion valve (34) is controlled properly. Unlike the first heating operation mode of the second embodiment, the outdoor fan (91) and the low stage side outdoor fan (115) are operated in the second heating operation mode. In addition, the low stage side compressor (39) and the booster compressor (50) in the low stage side refrigerant circuit (9) are placed in the stopped state, and the refrigerant in the low stage side refrigerant circuit (9) is not circulated, and cooling of the storage compartments is not provided.

[0159] The first and second high stage side compressors (31, 32) are operated and refrigerant discharged out of each of the first and second high stage side compressors (31, 32) passes through the four-way switch valve (37) and then through the first interunit pipeline (21) and is introduced to the air conditioning circuit (2). The refrigerant introduced to the air conditioning circuit (2) flows into the air conditioning heat exchanger (45). In the air conditioning heat exchanger (45), the inflow refrigerant dissipates heat to indoor air and is

condensed. The air conditioning unit (12) supplies air heated in the air conditioning heat exchanger (45) into the store space.

[0160] The refrigerant condensed in the air conditioning heat exchanger (45) passes through the second interunit pipeline (22) and is returned back to the high stage side outdoor circuit (1a). The returned refrigerant is decompressed during its passage through the high stage side expansion valve (34) and then flows into the outdoor heat exchanger (33). In the outdoor heat exchanger (33), the inflow refrigerant dissipates heat to outdoor air and is condensed. The refrigerant condensed in the outdoor heat exchanger (33) flows into the first heat exchange section (41) of the cascade heat exchanger (40). In the cascade heat exchanger (40), no heat exchange takes place between the refrigerant flowing through the first heat exchange section (41) and refrigerant flowing through the second heat exchange section (42). The refrigerant after passage through the cascade heat exchanger (40) passes through the four-way switch valve (37) and then through the main suction pipe (61) and is drawn into the first and second high stage side compressors (31, 32).

ADVANTAGEOUS EFFECTS OF THE SECOND EMBODIMENT

[0161] According to the refrigeration apparatus (10) of the second embodiment, the air conditioning heat exchanger (45) is disposed only in the high stage side refrigerant circuit (8) and the cooling heat exchangers (47a, 47b, 49) are disposed only in the low stage side refrigerant circuit (9), as in the first embodiment. This therefore makes it possible to allow the air conditioning heat exchanger (45) and the cooling heat exchangers (47a, 47b, 49) to employ different types of refrigerants. Therefore, each heat exchanger is allowed to use a respective refrigerant suited to its utilization temperature and perform its own refrigeration cycle, thereby making it possible to facilitate temperature control in each heat exchanger.

[0162] In addition, in the second embodiment, the low stage side outdoor heat exchanger (60) is disposed in the low stage side refrigerant circuit (9). As a result of such arrangement, when in the low stage side refrigerant circuit (9) the amount of heat absorbed by

the cooling heat exchangers (47a, 47b, 49) exceeds a predetermined level, it is possible to discharge such heat outdoors from the low stage heat exchanger (60). This therefore makes it possible to accomplish improvement in the cooling capacity of each of the cooling heat exchangers (47a, 47b, 49).

THIRD EMBODIMENT OF THE INVENTION

[0163] A refrigeration apparatus (10) according to a third embodiment of the present invention differs from the refrigeration apparatus of the first embodiment in refrigerant circuit configuration. Hereinafter, only the difference from the first embodiment is described.

[0164] As shown in Figure 11, unlike the first embodiment, the low stage side outdoor heat exchanger (60) is disposed in the low stage side outdoor circuit (1b) of the outdoor unit (11). The low stage side outdoor heat exchanger (60) is connected in series to the second heat exchange section (42) of the cascade heat exchanger (40). In addition, unlike the second embodiment, the second heat exchange section (42) of the cascade heat exchanger (40) is positioned downstream of the low stage side outdoor heat exchanger (60).

[0165] More specifically, one end of the low stage side outdoor heat exchanger (60) is connected through the low stage side compressor (39) and then through the fifth shut-off valve (55) to the fourth interunit pipeline (24). On the other hand, the other end of the low stage side outdoor heat exchanger (60) is connected through the second heat exchange section (42), then through the low stage side receiver (43), and then through the fourth shut-off valve (54) to the third interunit pipeline (23). In addition, the low stage side outdoor heat exchanger (60) is provided with a low stage outside air temperature sensor (114) and a low stage side outdoor fan (115). The low stage side outdoor fan (115) supplies outdoor air to the low stage side outdoor heat exchanger (60). The low stage side outdoor heat exchanger (60) is configured such that it effectuates heat dissipation from the refrigerant to the outdoor air.

[0166] As described above, in the refrigeration apparatus (10) of the third embodiment,

the air conditioning heat exchanger (45) for selectively providing cooling or heating of the indoor space is disposed only in the high stage side refrigerant circuit (8) and the cold storage heat exchangers (47a, 47b) for providing cooling of the cold storage compartments and the freeze storage heat exchanger (49) for providing cooling of the freeze storage compartment are disposed as cooling heat exchangers only in the low stage side refrigerant circuit (9), as in the first embodiment. The high stage side refrigerant circuit (8) and the low stage side refrigerant circuit (9) are charged with different types of refrigerants.

RUNNING OPERATION

[0167] Next, the running operation of the refrigeration apparatus (10) of the present embodiment is described. The refrigeration apparatus (10) is configured such that it selectively performs a cooling operation mode or a heating operation mode. In the following, typical cooling and heating operation modes of the refrigeration apparatus (10) are described.

COOLING OPERATION MODE

[0168] As shown in Figure 12, the same operation mode as the cooling operation mode of the first embodiment is performed in the high stage side refrigerant circuit (8).

[0169] On the other hand, the low stage side compressor (39) and the booster compressor (50) are operated in the low stage side refrigerant circuit (9) and refrigerant discharged out of the low stage side compressor (39) flows into the low stage side outdoor heat exchanger (60). In the low stage side outdoor heat exchanger (60), the inflow refrigerant dissipates heat to outdoor air and is condensed.

[0170] The refrigerant condensed in the low stage side outdoor heat exchanger (60) flows into the second heat exchange section (42) of the cascade heat exchanger (40). In the cascade heat exchanger (40), the refrigerant flowing through the second heat exchange section (42) dissipates heat to refrigerant flowing through the first heat exchange section (41) and is further condensed. Stated another way, the refrigerant is supercooled in the cascade heat

exchanger (40).

[0171] The refrigerant supercooled in the second heat exchange section (42) passes through the low stage side receiver (43) and then through the third interunit pipeline (23) and is diverged to the first cold storage circuit (3), to the second cold storage circuit (4), and to the freeze storage compartment circuit (5). The subsequent flow of refrigerant in the low stage side refrigerant circuit (9) is the same as the cooling operation mode of the first embodiment.

HEATING OPERATION MODE

[0172] This heating operation mode is a heating operation mode in which the air conditioning heat exchanger (45) provides heating just by making utilization of heat recovered in the cascade heat exchanger (40).

[0173] As shown in Figure 13, the same operation mode as the first heating operation mode of the first embodiment is carried out in the high stage side refrigerant circuit (8). In addition, in this heating operation mode, the low stage side outdoor fan (115) of the low stage side outdoor heat exchanger (60) is placed in the stopped state.

[0174] The low stage side compressor (39) and the booster compressor (50) are operated in the low stage side refrigerant circuit (9) and refrigerant discharged out of the low stage side compressor (39) flows into the low stage side outdoor heat exchanger (60). Since the low stage side outdoor fan (115) of the low stage side outdoor heat exchanger (60) is placed in the stopped state, heat dissipation of the refrigerant does not take place actively in the low stage side outdoor heat exchanger (60).

[0175] The refrigerant after its passage through the low stage side outdoor heat exchanger (60) flows into the second heat exchange section (42) of the cascade heat exchanger (40). In the cascade heat exchanger (40), the refrigerant flowing through the second heat exchange section (42) dissipates heat to refrigerant flowing through the first heat exchange section (41) and is condensed.

[0176] The refrigerant condensed in the second heat exchange section (42) passes

through the low stage side receiver (43) and then through the third interunit pipeline (23) and is diverged to the first cold storage circuit (3), to the second cold storage circuit (4), and to the freeze storage compartment circuit (5). The subsequent flow of refrigerant in the low stage side refrigerant circuit (9) is the same as the cooling operation mode of the first embodiment.

ADVANTAGEOUS EFFECTS OF THE THIRD EMBODIMENT

[0177] According to the refrigeration apparatus (10) of the third embodiment, the air conditioning heat exchanger (45) is disposed only in the high stage side refrigerant circuit (8) and the cooling heat exchangers (47a, 47b, 49) are disposed only in the low stage side refrigerant circuit (9), as in the first embodiment. This therefore makes it possible to allow the air conditioning heat exchanger (45) and the cooling heat exchangers (47a, 47b, 49) to employ different types of refrigerants. Therefore, each heat exchanger is allowed to use a respective refrigerant suited to its utilization temperature and perform its own refrigeration cycle, thereby making it possible to facilitate temperature control in each heat exchanger.

[0178] In addition, in the third embodiment, the cascade heat exchanger (40) is disposed downstream of the low stage side outdoor heat exchanger (60). As a result of such arrangement, supercooling can be performed in the low stage side refrigerant circuit (9) by cooling the refrigerant condensed in the low stage side outdoor heat exchanger (60) with the refrigerant in the cascade heat exchanger (40) on the side of the high stage side refrigerant circuit (8). This therefore makes it possible to effectively accomplish improvements in the cooling capacity of each of the cooling heat exchangers (47a, 47b, 49).

OTHER EMBODIMENTS

[0179] In regard to the foregoing embodiments, the present invention may be arranged as follows.

[0180] In the foregoing first embodiment, only the running operation of the refrigeration apparatus (19) in the event of failure of the low stage side compressor (39) is described. On the other hand, in the event of failure of the booster compressor (50), it is possible to cause

refrigerant to be circulated in the low stage side refrigerant circuit (9) by way of the third bypass pipeline (69) just by placing only the low stage side compressor (39) (Figure 1) in operation. In this case, refrigerant can be circulated in each of the first and second cold storage heat exchangers (47a, 47b) and the freeze storage heat exchanger (49) and cooling of the cold and freeze storage compartments is provided by each heat exchanger (47a, 47b, 49) used as an evaporator.

[0181] In addition, the low stage side outdoor fan (115) of the low stage side outdoor heat exchanger (60) is placed in the stopped state in the first heating operation mode of the second embodiment; however, when the amount of heat absorbed in the cooling heat exchangers (47a, 47b, 49) exceeds a predetermined level, the low stage side outdoor fan (115) may be operated in order that heat dissipation may take place actively.

[0182] Furthermore, in the heating operation mode of the third embodiment, only the heating operation mode in which the air conditioning heat exchanger (45) provides heating just by making utilization of heat recovered in the cascade heat exchanger (40) is described; however, when the heating capacity becomes excessive, the same operation mode as the second heating operation mode of the first embodiment may be performed in the high stage side refrigerant circuit (8). On the other hand, when the heating capacity becomes insufficient, the same operation mode as the third heating operation mode of the first embodiment may be performed in the high stage side refrigerant circuit (8).

INDUSTRIAL APPLICABILITY

[0183] As has been described above, the present invention finds useful application in the field of refrigeration apparatuses in which a high stage side refrigerant circuit and a low stage side refrigerant circuit are connected together through a cascade heat exchanger to perform a two-stage cascade refrigeration cycle.

Claims:**What is claimed is:**

1. A refrigeration apparatus in which a high stage side refrigerant circuit and a low stage side refrigerant circuit are connected together through a cascade heat exchanger to thereby perform a two-stage cascade refrigeration cycle, the refrigeration apparatus comprising an air conditioning heat exchanger for selectively providing cooling or heating of an indoor space and a cooling heat exchanger for providing cooling of a storage compartment, wherein the air conditioning heat exchanger is disposed only in the high stage side refrigerant circuit, and wherein the cooling heat exchanger is disposed only in the low stage side refrigerant circuit.
2. The refrigeration apparatus of claim 1, wherein the cooling heat exchanger comprises a cold storage heat exchanger for providing cooling of a cold storage compartment and a freeze storage heat exchanger for providing cooling of a freeze storage compartment, and wherein a cold storage circuit including the cold storage heat exchanger and a freeze storage circuit including the freeze storage heat exchanger are connected in parallel in the low stage side refrigerant circuit.
3. The refrigeration apparatus of claim 2, wherein the freeze storage circuit includes an auxiliary compressor for compressing refrigerant drawn from the freeze storage heat exchanger and discharging the compressed refrigerant to the suction side of a low stage side compressor disposed in the low stage side refrigerant circuit.
4. The refrigeration apparatus of claim 3, wherein the low stage side refrigerant circuit includes a first bypass pipeline for enabling the suction and discharge sides of the low stage side compressor to fluidly communicate with each other.

5. The refrigeration apparatus of claim 4, wherein the low stage side refrigerant circuit includes a second bypass pipeline for enabling the outlet side of the cold storage heat exchanger and the suction side of the auxiliary compressor to fluidly communicate with each other.

6. The refrigeration apparatus of claim 5, wherein a pressure control mechanism for controlling the evaporating pressure of refrigerant in the cold storage heat exchanger is disposed between a downstream end of the cold storage heat exchanger and a downstream end of the second bypass pipeline.

7. The refrigeration apparatus of any one of claims 3-6, wherein the low stage side refrigerant circuit includes a third bypass pipeline for enabling the suction and discharge sides of the auxiliary heat exchanger to fluidly communicate with each other.

8. The refrigeration apparatus of any one of claims 1-7, wherein a low stage side outdoor heat exchanger for effectuating heat dissipation from refrigerant to outdoor air is connected in series with the cascade heat exchanger in the low stage side refrigerant circuit.

9. The refrigeration apparatus of claim 8, wherein the cascade heat exchanger is disposed downstream of the low stage side outdoor heat exchanger in the low stage side refrigerant circuit.

* * * * *