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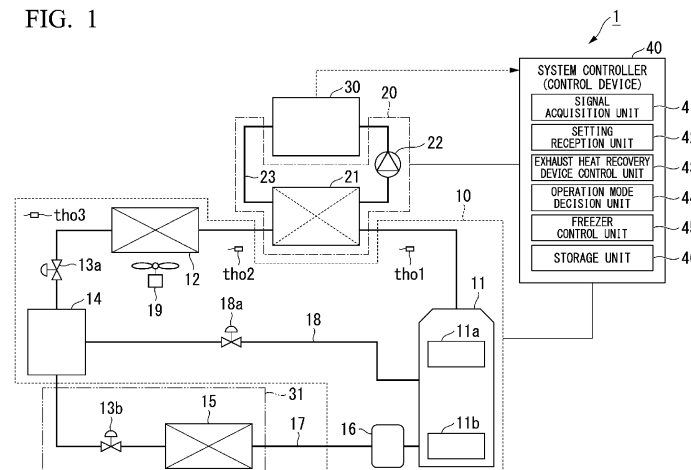
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(54) **CONTROL DEVICE, EXHAUST HEAT RECOVERY FREEZER SYSTEM, CONTROL METHOD, AND PROGRAM**

(57) A control device (40) includes an operation mode decision unit (44) that decides, in accordance with necessity of heat recovery from a refrigerant circulating in a refrigerant circuit, which operation of a supercritical operation in which a high pressure in the refrigerant circuit is in a supercritical state and a subcritical operation in

which the high pressure is in a subcritical state is to be performed; and a freezer control unit (45) that controls the refrigerant circuit to be operated in either the supercritical operation or the critical operation on the basis of decision of the operation mode decision unit (44).

FIG. 1



Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a control device, an exhaust heat recovery freezer system, a control method, and a program. Priority is claimed on Japanese Patent Application No. 2022-040662, filed March 15, 2022, the content of which is incorporated herein by reference and to which the person of the art can refer to when considering the present disclosure.

Description of Related Art

[0002] Patent Document 1 discloses control in which heat discharged from a freezer using a CO₂ refrigerant when a show case in a store is cooled using the freezer is utilized for hot water or heating. Specifically, Patent Document 1 discloses control in which a part of a refrigerant emitted by a compressor is supplied to a radiator unit and utilized for heating and water which has been heat-exchanged in a condenser is utilized as hot water. In addition, Patent Document 2 discloses an air conditioner using a CO₂ refrigerant with a freezing cycle in which a high pressure is in a supercritical state when a cooling operation is performed in normal environmental conditions and the high pressure is in a subcritical state in a state in which the outside air temperature is low.

[Patent Documents]

[0003]

[Patent Document 1] Japanese Unexamined Patent Application, First Publication No. 2020-118354

[Patent Document 2] Japanese Unexamined Patent Application, First Publication No. 2014-89042

SUMMARY OF THE INVENTION

[0004] There is a demand for a method for improving combined efficiency of both a load-side device (an air conditioner, a water heater, or the like), which utilizes exhaust heat from a freezer, and the freezer.

[0005] Hence, an object of this invention is to provide a control device, an exhaust heat recovery freezer system, a control method, and a program capable of resolving the problems described above.

[0006] According to an aspect of the present disclosure, a control device includes an operation mode decision unit that decides, in accordance with necessity of heat recovery from a refrigerant circulating in a refrigerant circuit, which operation of a supercritical operation in which a high pressure in the refrigerant circuit is in a supercritical state and a subcritical operation in which the high pressure is in a subcritical state is to be per-

formed; and a freezer control unit that controls the refrigerant circuit to be operated in either the supercritical operation or the subcritical operation on the basis of decision of the operation mode decision unit.

[0007] According to another aspect of the present disclosure, an exhaust heat recovery freezer system includes a freezer that has a refrigerant circuit including a compressor, a gas cooler, an expansion valve, and an evaporator; an exhaust heat recovery device that recovers heat through heat exchange with a refrigerant circulating in the refrigerant circuit between the compressor and the gas cooler in the refrigerant circuit and supplies the recovered heat to a load device; and the foregoing control device.

[0008] According to another aspect of the present disclosure, a control method includes a step of deciding, in accordance with necessity of heat recovery from a refrigerant circulating in a refrigerant circuit, which operation of a supercritical operation in which a high pressure in the refrigerant circuit is in a supercritical state and a subcritical operation in which the high pressure is in a subcritical state is to be performed; and a step of controlling the refrigerant circuit to be operated in either the supercritical operation or the subcritical operation on the basis of decision in the step of deciding an operation.

[0009] According to another aspect of the present disclosure, a program causes a computer to execute a step of deciding, in accordance with necessity of heat recovery from a refrigerant circulating in a refrigerant circuit, which operation of a supercritical operation in which a high pressure in the refrigerant circuit is in a supercritical state and a subcritical operation in which the high pressure is in a subcritical state is to be performed; and a step of controlling the refrigerant circuit to be operated in either the supercritical operation or the subcritical operation on the basis of decision in the step of deciding an operation.

[0010] According to the control device, the exhaust heat recovery freezer system, the control method, and the program of the present disclosure, it is possible to improve overall efficiency of both a load device, which utilizes exhaust heat of a freezer, and the freezer.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011]

FIG. 1 is a diagram illustrating an example of an exhaust heat recovery freezer system according to an embodiment.

FIG. 2 is a diagram illustrating characteristics of a high-pressure supercritical operation and a high-pressure subcritical operation according to the embodiment.

FIG. 3 is a diagram illustrating an example of conditions for switching according to the embodiment.

FIG. 4 is a flowchart illustrating an example of switching control according to the embodiment.

FIG. 5 is a diagram illustrating an example of a hardware constitution of a system controller according to the embodiment.

DETAILED DESCRIPTION OF THE INVENTION

<Embodiment>

[0012] Hereinafter, an exhaust heat recovery freezer system according to an embodiment of the present disclosure will be described with reference to FIGS. 1 to 5.

(Constitution)

[0013] FIG. 1 is a diagram illustrating an example of an exhaust heat recovery freezer system according to the embodiment.

[0014] An exhaust heat recovery freezer system 1 is a system in which heat discharged by a freezer 10 performing a cooling operation is recovered by an exhaust heat recovery device 20 and the recovered heat is supplied to a warming cycle of a high-temperature load device 30. For example, the exhaust heat recovery freezer system 1 is used in supermarkets or the like, in which the freezer 10 refrigerates or freezes food and exhaust heat therefrom is recovered by the exhaust heat recovery device 20 and utilized for heating of the store or in a water heater. In the exhaust heat recovery freezer system 1, CO₂ is used as a refrigerant. A CO₂ refrigerant is in a supercritical state within an ordinary temperature range at approximately 31°C. From a viewpoint of efficiency of the exhaust heat recovery freezer system 1 in its entirety instead of efficiency of the freezer 10 alone, the exhaust heat recovery freezer system 1 determines necessity of heat recovery by the exhaust heat recovery device 20 and operates with a high pressure in the freezer 10 in a supercritical state or a subcritical state in accordance with the necessity thereof.

[0015] As shown in FIG. 1, the exhaust heat recovery freezer system 1 includes the freezer 10, the exhaust heat recovery device 20, the high-temperature load device 30, a low-temperature load device 31 (for example, a refrigerating show case or a freezing show case in a supermarket), and a system controller 40. The freezer 10 includes a two-stage compressor 11, a gas cooler 12, a first expansion valve 13a, a receiver 14, an accumulator 16, a main piping 17 connecting these to the low-temperature load device 31, a piping 18 connecting a gas-phase portion of the receiver 14 to an emission side of a low stage-side compressor 11b of a high stage-side compressor 11a and the low stage-side compressor 11b included in the two-stage compressor 11, a valve 18a controlling a flow rate of the refrigerant flowing in the piping 18, a fan 19 provided in the gas cooler 12, and temperature sensors tho1 to tho3. The temperature sensor tho1 is provided on the emission side of the two-stage compressor 11 and an entrance side of a heat exchanger 21, and the temperature sensor tho2 is provided on an exit

side of the heat exchanger 21 and the entrance side of the gas cooler 12. The exit side and the entrance side are an exit side and an entrance side in a flowing direction of the refrigerant. In addition, the temperature sensor tho3 is provided at a position where an outside air temperature can be measured. The low-temperature load device 31 is constituted of a second expansion valve 13b and an evaporator 15 and is connected to a low pressure side of the freezer 10.

[0016] The heat exchanger 21 of the exhaust heat recovery device 20 is connected (inserted) between the two-stage compressor 11 and the gas cooler 12, and the CO₂ refrigerant of the freezer 10 flows in the heat exchanger 21. The exhaust heat recovery device 20 includes the heat exchanger 21 for exhaust heat recovery, a pump 22, and a piping 23 connecting these to the high-temperature load device 30. For example, the high-temperature load device 30 is an air conditioner, a water heater, or the like in a store. In the heat exchanger 21, heat exchange is performed between the CO₂ refrigerant of the freezer 10 and the refrigerant (for example, water) of the exhaust heat recovery device 20. In the exhaust heat recovery device 20, warm water which has been warmed through heat exchange in the heat exchanger 21 circulates in the piping 23 by driving of the pump 22, and for example, exhaust heat from the freezer 10 is supplied to the high-temperature load device 30 via a heat exchanger (not shown) provided in the high-temperature load device 30. Since the refrigerant does not circulate in the piping 23 when the pump 22 is at a stop, exhaust heat is not recovered by the exhaust heat recovery device 20.

[0017] In the freezer 10, the two-stage compressor 11 emits a high-pressure refrigerant compressed by the high stage-side compressor 11a and the low stage-side compressor 11b. In more detail, a suction side of the low stage-side compressor 11b is connected to the accumulator 16, and the low stage-side compressor 11b suctions and compresses the refrigerant (gas) separated by the accumulator 16. The low stage-side compressor 11b emits the compressed refrigerant to the suction side of the high stage-side compressor 11a. The refrigerant is supplied from the gas-phase portion of the receiver 14 to the suction side of the high stage-side compressor 11a through the piping 18 (injection circuit). The high stage-side compressor 11a suctions and compresses these refrigerants. The compressed refrigerant is supplied to the heat exchanger 21 for exhaust heat recovery. As described above, in the heat exchanger 21, heat of the high-temperature/high-pressure CO₂ refrigerant is recovered by the refrigerant (water) of the exhaust heat recovery device 20 and is supplied to the high-temperature load device 30. The CO₂ refrigerant which has passed through the heat exchanger 21 is subjected to heat dissipation through heat exchange in the gas cooler 12 with air sent by the fan 19 and is condensed and liquefied. The condensed refrigerant is subjected to pressure reduction and expansion by the first expansion valve 13a and is sup-

plied to the receiver 14. In the receiver 14, a two-phase refrigerant of gas and liquid is present in a mixed manner. A part (gas-phase portion) of the refrigerant present in the receiver 14 branches to the piping 18 as described above and is supplied to the two-stage compressor 11. The liquid-phase refrigerant flows out from the receiver 14, is subjected to additional pressure reduction by the second expansion valve, and is then supplied to the evaporator 15. The CO₂ refrigerant supplied to the evaporator 15 absorbs heat of the low-temperature load device 31 (for example, a show case for refrigeration or a show case for freezing in a store), is gasified, and cools the low-temperature load device 31. The CO₂ refrigerant gasified by the evaporator 15 is supplied to the accumulator 16. The CO₂ refrigerant is separated into gas and liquid by the accumulator 16, and the gas refrigerant is suctioned into the low stage-side compressor 11b. The refrigerant is compressed by the low stage-side compressor 11b and the high stage-side compressor 11a and circulates through the foregoing path again.

[0018] The exhaust heat recovery freezer system 1 shown in FIG. 1 is a schematic basic constitution and may further include other constituent elements. In FIG. 1, the exhaust heat recovery device 20 has only one heat exchanger 21, but the exhaust heat recovery device 20 may include two or more heat exchangers 21. In this case, all or some of the plurality of heat exchangers 21 may be connected to (inserted into) a refrigerant circuit of the freezer 10. In addition, a plurality of exhaust heat recovery devices 20 may be present, and the heat exchanger 21 provided in each exhaust heat recovery device 20 may be connected to the refrigerant circuit of the freezer 10.

[0019] The system controller 40 controls the freezer 10 and the exhaust heat recovery device 20. The system controller 40 includes a signal acquisition unit 41, a setting reception unit 42, an exhaust heat recovery device control unit 43, an operation mode decision unit 44, a freezer control unit 45, and a storage unit 46. In addition, the system controller 40 has a timer, which can recognize the current date and time.

[0020] The signal acquisition unit 41 acquires the temperature detected by the temperature sensors tho1 to tho3, a signal indicating a working state of the exhaust heat recovery device 20, and a signal indicating an operation state (a working state or a load state) of the high-temperature load device 30. The signal acquisition unit 41 records various kinds of acquired signals in the storage unit 46.

[0021] The setting reception unit 42 receives an input of various kinds of settings made by a user. For example, the setting reception unit 42 receives a setting for working (ON) or stopping (OFF) of the exhaust heat recovery device 20 and outputs the setting to the exhaust heat recovery device control unit 43. In addition, regarding the operation of the freezer 10, the setting reception unit 42 receives a setting of conditions for switching between an operation in which the high pressure is in the supercritical

state (which may hereinafter be referred to as a supercritical operation) and an operation in which the high pressure is in the subcritical state (which may hereinafter be referred to as a subcritical operation) and records the received setting of the conditions for switching in the storage unit 46.

[0022] The exhaust heat recovery device control unit 43 controls working (ON) and stopping (OFF) of the exhaust heat recovery device 20. For example, when a user performs setting for causing the exhaust heat recovery device 20 to work, the exhaust heat recovery device control unit 43 acquires the setting through the setting reception unit 42 and causes the exhaust heat recovery device 20 to work by starting the pump 22, or the like. When a user performs setting for causing the exhaust heat recovery device 20 to stop, the exhaust heat recovery device control unit 43 acquires the setting through the setting reception unit 42 and causes the exhaust heat recovery device 20 to stop by stopping the pump 22, or the like. When the exhaust heat recovery device 20 is caused to work or stop, the exhaust heat recovery device control unit 43 records the time at which the control is performed and the executed operation of either working or stopping in the storage unit 46 as a working log.

[0023] The operation mode decision unit 44 determines necessity of exhaust heat recovery and decides the operation mode of the freezer 10 on the basis of the outside air temperature acquired by the signal acquisition unit 41, the working state of the exhaust heat recovery device 20, the load state of the high-temperature load device 30, and the setting of the conditions for switching recorded in the storage unit 46 by the setting reception unit 42. The operation mode is either the supercritical operation or the subcritical operation. For example, when the efficiency of the exhaust heat recovery freezer system 1 in its entirety is improved by intensifying exhaust heat recovery, the operation mode decision unit 44 determines that necessity of exhaust heat recovery is high. If not, it is determined that necessity of exhaust heat recovery is low. When necessity of exhaust heat recovery is high, the operation mode decision unit 44 decides that the supercritical operation is performed, and when necessity of exhaust heat recovery is not high, it is decided that the subcritical operation is performed.

[0024] The freezer control unit 45 causes the freezer 10 to operate in the operation mode decided by the operation mode decision unit 44. For example, the two-stage compressor 11 is constituted to operate with a rotation frequency in which the pressure on the high-pressure side is in the supercritical state when instructed to perform the supercritical operation and to operate with a rotation frequency in which the pressure on the high-pressure side is in the subcritical state when instructed to perform the subcritical operation. When the operation mode decision unit 44 decides that the supercritical operation is performed, the freezer control unit 45 instructs the two-stage compressor 11 to perform the supercritical operation. When the operation mode decision unit 44 de-

cides that the subcritical operation is performed, the freezer control unit 45 instructs the two-stage compressor 11 to perform the subcritical operation. Above this, the freezer control unit 45 performs various kinds of control related to the freezer 10, but description related to functions other than switching of the operation mode will be omitted. The storage unit 46 stores signals acquired by the signal acquisition unit 41 and the setting of the conditions for switching received by the setting reception unit 42.

[0025] FIG. 2 shows characteristics of the supercritical operation and the subcritical operation according to the embodiment. The applicant has found the characteristics shown in FIG. 2 after performing verification and desk calculation using the exhaust heat recovery freezer system 1 shown in FIG. 1 as an example. That is, when the freezer 10 is in the supercritical operation, the efficiency of the freezer 10 alone deteriorates, but the overall efficiency of the freezer 10 and the high-temperature load device 30 in their entirety rises. In contrast, when the freezer 10 is in the subcritical operation, the operation efficiency of the freezer 10 alone can be improved, but the overall efficiency of the exhaust heat recovery freezer system 1 (the freezer 10 and the high-temperature load device 30 in their entirety) deteriorates. Here, for example, efficiency indicates consumption energy consumed by the exhaust heat recovery freezer system 1. Through trial calculation, it has been confirmed that the total annual energy consumption of the freezer 10 and the high-temperature load device 30 can be reduced by several percent by performing the operation of the freezer 10 while switching between the supercritical operation and the subcritical operation under predetermined conditions.

(Conditions for switching between supercritical operation and subcritical operation)

[0026] The operation mode decision unit 44 may determine that necessity of heat recovery is high when at least one of the outside air temperature, the load state of the high-temperature load device 30 (whether the load is large or small), and the period or the timeslot satisfies the predetermined conditions. FIG. 3 shows an example of criteria for such determination. FIG. 3 is a diagram illustrating an example of conditions for switching between the supercritical operation and the subcritical operation according to the embodiment. In the table of FIG. 3, "-" denotes that the corresponding condition is not taken into consideration. In addition, the following (1) to (10) respectively correspond to the item numbers 1 to 10 in FIG. 3.

(1) When a show case for refrigeration or freezing in a store is cooled by the freezer 10, regardless of the working states of the exhaust heat recovery device 20 and the high-temperature load device 30, if operation is performed in an environment in which the

outside air temperature is $X1^{\circ}\text{C}$ (for example, 25°C) or higher, the high pressure is in the supercritical state. When the outside air temperature detected by the temperature sensor tho3 and acquired by the signal acquisition unit 41 becomes $X1^{\circ}\text{C}$ or higher, the operation mode decision unit 44 decides that the operation mode is set to the supercritical operation.

[0027] Hereinafter, a case in which the outside air temperature is lower than $X1^{\circ}\text{C}$ will be examined.

[0028] (2) When the exhaust heat recovery device 20 is not working (when the pump 22 is at a stop), exhaust heat of the freezer 10 is not supplied to the high-temperature load device 30. In this case, since the efficiency of the exhaust heat recovery freezer system 1 in its entirety is improved by improving the efficiency of the freezer 10 alone, necessity of heat recovery is low. Therefore, when the outside air temperature is lower than $X1^{\circ}\text{C}$ and the exhaust heat recovery device 20 is not working, the operation mode decision unit 44 decides that the operation mode is set to the subcritical operation.

[0029] It is possible to judge whether the exhaust heat recovery device 20 is working or at a stop based on a signal indicating the working state of the exhaust heat recovery device 20 (for example, detection values of various kinds of sensors measuring the rotation frequency of the pump 22, the flow rate of water flowing in piping 23, the flow speed, the temperature, the pressure, and the like) acquired by the signal acquisition unit 41 and the working log of the exhaust heat recovery device 20 recorded in the storage unit 46. For example, if the rotation frequency of the pump 22 is equal to or lower than a predetermined value (for example, 0 rpm) or the temperature of water is lower than a predetermined value, the operation mode decision unit 44 may judge that the exhaust heat recovery device 20 is at a stop. When the latest record of the records of the working log indicates "stop", the operation mode decision unit 44 may judge that the exhaust heat recovery device 20 is at a stop.

[0030] (3) When the high-temperature load device 30 is not working as well, the efficiency of the exhaust heat recovery freezer system 1 is improved by improving the efficiency of the freezer 10 alone (necessity of heat recovery is low). Therefore, when the outside air temperature is lower than $X1^{\circ}\text{C}$ and the high-temperature load device 30 is not working, the operation mode decision unit 44 decides that the operation mode is set to the subcritical operation.

[0031] It is possible to judge whether the high-temperature load device 30 is working or at a stop based on a signal indicating the working state of the high-temperature load device 30 (for example, detection values detected by various kinds of sensors included in an air conditioner or a water heater) acquired by the signal acquisition unit 41. For example, if the rotation frequency of a compressor provided in an air conditioner or a water heater is equal to or lower than a predetermined value (for example, 0 rps) or the refrigerant temperature is lower

than a predetermined value, the operation mode decision unit 44 may judge that the high-temperature load device 30 is at a stop.

[0032] (4) On condition that the outside air temperature is lower than $X1^{\circ}\text{C}$ and the exhaust heat recovery device 20 and the high-temperature load device 30 are working, the operation mode decision unit 44 may decide that the operation mode is set to the supercritical operation. For example, in a case in which heating is used throughout the year in a cold region or the like, when the exhaust heat recovery device 20 and the high-temperature load device 30 are in a working state, even if the efficiency of the freezer 10 alone has deteriorated, a heating load of the air conditioner may decrease and the efficiency of the exhaust heat recovery freezer system 1 in its entirety may be improved (necessity of heat recovery is high) by raising heat recovery ability through the supercritical operation and supplying more heat to the high-temperature load device 30. For example, when the outside air temperature is lower than $X1^{\circ}\text{C}$, if the efficiency in its entirety is improved by performing the supercritical operation, the conditions for switching as in (4) (the supercritical operation is performed when the exhaust heat recovery device 20 and the high-temperature load device 30 are working at an outside air temperature lower than $X1^{\circ}\text{C}$) can be set.

[0033] Regarding judgment whether or not the exhaust heat recovery device 20 and the high-temperature load device 30 are working, for example, if the rotation frequency of the pump 22 is equal to or higher than a predetermined value or the temperature of water flowing in the piping 23 is higher than a predetermined value, the operation mode decision unit 44 may judge that the exhaust heat recovery device 20 is working. When the latest record of the records of the working log indicates working, the operation mode decision unit 44 may judge that the exhaust heat recovery device 20 is working. For example, when the rotation frequency of the compressor provided in the air conditioner or the water heater is equal to or higher than a predetermined value or when the refrigerant temperature is equal to or higher than a predetermined value, the operation mode decision unit 44 may judge that the high-temperature load device 30 is working.

[0034] (5) While being in the case of the item number 4, and on condition that the load on the high-temperature load device 30 is large, the operation mode decision unit 44 may decide that the operation mode is set to the supercritical operation. For example, even when the air conditioner is performing a heating operation as the high-temperature load device 30, if the air-conditioning load is small, the efficiency of the exhaust heat recovery freezer system 1 may be improved (necessity of heat recovery is low) by prioritizing the efficiency of the freezer 10 alone. Therefore, the conditions for switching the operation mode to the supercritical operation may be set only when the outside air temperature is lower than $X1^{\circ}\text{C}$, the exhaust heat recovery device 20 is working, and the high-

temperature load device 30 is working with a considerable load, that is, under conditions in which necessity of heat recovery becomes high.

[0035] For example, when the rotation frequency of the compressor in the air conditioner or the water heater is equal to or higher than a predetermined value, the operation mode decision unit 44 may judge that the load on the high-temperature load device 30 is large. In addition, when the water level of a water storage tank in the water heater detected by a water level sensor is lower than a predetermined value, the operation mode decision unit 44 may judge that the load on the high-temperature load device 30 is large. Alternatively, when it becomes a timeslot in which the air-conditioning load or the load on the water heater is predicted to be large by means of a predetermined predictive model, the operation mode decision unit 44 may judge that the load on the high-temperature load device 30 is large.

[0036] (6) On condition that the outside air temperature is lower than $X1^{\circ}\text{C}$, the exhaust heat recovery device 20 is working, and it is a predetermined period and a predetermined timeslot, the operation mode decision unit 44 may decide that the operation mode is set to the supercritical operation. For example, a period during which heating is used (winter, or fall or spring depending on the region) is set for the period. When the outside air temperature is lower than $X1^{\circ}\text{C}$ and it becomes the set period (for example, November to February), since the heating load of the air conditioner is high during this period, it is considered that the efficiency of the exhaust heat recovery freezer system 1 in its entirety is improved (necessity of heat recovery is high) by performing exhaust heat recovery even if the efficiency of the freezer 10 alone is sacrificed. So that such a period may be adopted as the conditions for switching to the supercritical operation. Moreover, considering that heating is not used after business hours of the store even if it is the period during which heating is used, a timeslot in which the high-temperature load device 30 is working (for example, 9:00 to 20:00) may be set as the conditions for switching in addition to the period during which the high-temperature load device 30 is used. In addition, only a timeslot in which necessity of heat recovery becomes high may be set without setting a use period. In this case, when the outside air temperature is lower than $X1^{\circ}\text{C}$, the exhaust heat recovery device 20 is working, and it becomes a predetermined period and/or timeslot, the operation mode decision unit 44 decides that the operation mode is set to the supercritical operation. Otherwise, it is decided that the operation mode is set to the subcritical operation.

[0037] (7) While being in the case of the item number 4, and on condition that it is a timeslot in which the load on the high-temperature load device 30 is large, the operation mode decision unit 44 may decide that the operation mode is set to the supercritical operation. For example, it is assumed that a timeslot of using hot water of the water heater is concentrated during 10:00 to 15:00. At this timeslot, the efficiency of the exhaust heat recovery

ery freezer system 1 in its entirety is improved (necessity of heat recovery is high) by performing exhaust heat recovery and providing recovered heat to the water heater. However, when the load on the water heater is not so high at other timeslots, it is meaningless to perform exhaust heat recovery. The operation mode decision unit 44 decides that the operation mode is set to the supercritical operation when the outside air temperature is lower than $X1^{\circ}\text{C}$, the exhaust heat recovery device 20 and the high-temperature load device 30 are working, and it is the timeslot in which the load on the high-temperature load device 30 becomes large (10:00 to 15:00). Otherwise, it may be decided that the operation mode is set to the subcritical operation.

[0038] (8) On condition that the outside air temperature is $X2^{\circ}\text{C}$ or lower and the exhaust heat recovery device 20 is working, the operation mode decision unit 44 may decide that the operation mode is set to the supercritical operation. Here, $X2^{\circ}\text{C} < X1^{\circ}\text{C}$ is established. For example, $X2^{\circ}\text{C}$ is a temperature at which the heating load on the air conditioner becomes high, in other words, an outside air temperature at which necessity of heat recovery becomes high. If the outside air temperature is $X2^{\circ}\text{C}$ or lower, it is conceivable that the air conditioner be working with a high load even if the working state of the air conditioner (high-temperature load device 30) is not confirmed so that the operation mode decision unit 44 may decide that the operation mode is set to the supercritical operation on condition that the outside air temperature is $X2^{\circ}\text{C}$ or lower and the exhaust heat recovery device 20 is working. Otherwise, it may be decided that the operation mode is set to the subcritical operation.

[0039] (9) While being in the case of the item number 8, and on condition that the high-temperature load device 30 is working, the operation mode decision unit 44 decides that the operation mode is set to the supercritical operation. For example, even if the outside air temperature is $X2^{\circ}\text{C}$ or lower at which the heating load on the air conditioner becomes high, since the air conditioner is not working if the store is not open for business, the overall efficiency of the exhaust heat recovery freezer system 1 is improved (necessity of heat recovery is low) by improving the efficiency of the freezer 10 alone at the timeslot in which the air conditioner is not working. In such a case, on condition that the outside air temperature is $X2^{\circ}\text{C}$ or lower and the exhaust heat recovery device 20 and the high-temperature load device 30 are working, the operation mode decision unit 44 may decide that the operation mode is set to the supercritical operation. Otherwise, it may be decided that the operation mode is set to the subcritical operation.

[0040] (10) While being in the case of the item number 8, and on condition that it is a predetermined period and a predetermined timeslot of using the high-temperature load device 30 (only a period or only a timeslot may be adopted), the operation mode decision unit 44 may decide that the operation mode is set to the supercritical operation. If not, it may be decided that the subcritical

operation is set. For example, a heating operation of the air conditioner is presumed as a load, winter is set as a period, and the business hours of the store are set as a timeslot (necessity of heat recovery is high). In this case, when the outside air temperature is $X2^{\circ}\text{C}$ or lower, the exhaust heat recovery device 20 is working, and it is a predetermined period and a predetermined timeslot, the operation mode decision unit 44 may decide that the operation mode is set to the supercritical operation. Otherwise, it is decided that the operation mode is set to the subcritical operation.

[0041] The conditions for switching between the supercritical operation and the subcritical operation in the item numbers 1 to 10 described above are examples and are not limited thereto. For example, on condition that the outside air temperature is lower than $X1^{\circ}\text{C}$ (or is $X2^{\circ}\text{C}$ or lower), the exhaust heat recovery device 20 is working, the high-temperature load device 30 is working with a high load, and it is a predetermined period and a predetermined timeslot, the conditions for switching may be set such that it is decided to set the operation mode to the supercritical operation. Alternatively, the conditions for switching the operation mode to the supercritical operation when the outside air temperature is lower than $X1^{\circ}\text{C}$ (or is $X2^{\circ}\text{C}$ or lower) and it is a predetermined period and a predetermined timeslot, or the conditions for switching the operation mode to the supercritical operation when the outside air temperature is simply lower than $X1^{\circ}\text{C}$ (or is $X2^{\circ}\text{C}$ or lower) may be set.

(Operation)

[0042] Next, with reference to FIG. 4, switching control of the operation mode of the freezer 10 will be described.

[0043] FIG. 4 is a flowchart illustrating an example of switching control according to the embodiment.

[0044] First, a user sets conditions for switching between the supercritical operation and the subcritical operation. For example, a user sets conditions for the item numbers 1, 2, 5, and 9 in FIG. 3. The setting reception unit 42 receives a setting of the conditions for switching and records the set conditions for switching in the storage unit 46 (Step S1).

[0045] The operation mode decision unit 44 acquires the outside air temperature (Step S2). For example, the signal acquisition unit 41 acquires the outside air temperature detected by the temperature sensor tho3 from hour to hour and records the acquired outside air temperature together with the time in the storage unit 46. The operation mode decision unit 44 acquires the outside air temperature recorded in the storage unit 46.

[0046] Next, the operation mode decision unit 44 acquires the working state of the exhaust heat recovery device 20 (Step S3). For example, the signal acquisition unit 41 acquires a signal indicating the working state of the exhaust heat recovery device 20 from hour to hour, such as a measurement value including the rotation frequency of the pump 22, the temperature of water flowing

in the piping 23, or the like, and records these together with the time in the storage unit 46. The operation mode decision unit 44 acquires a signal indicating the working state of the exhaust heat recovery device 20 recorded in the storage unit 46. Alternatively, the operation mode decision unit 44 acquires the latest record of the working log recorded in the storage unit 46.

[0047] Next, the operation mode decision unit 44 acquires the working state or the load state of the high-temperature load device 30 (Step S4). For example, the signal acquisition unit 41 acquires a signal indicating the working state of the high-temperature load device 30 from hour to hour, such as the rotation frequency of the compressor or the water level of the water storage tank in the high-temperature load device 30 or a signal which can be used for estimation of the load state and records these together with the time in the storage unit 46. Alternatively, in the storage unit 46, a prediction value of the load on the high-temperature load device 30 predicted by means of a predetermined predictive model in advance (for example, a load prediction value for each daily timeslot during a predetermined period of time) may be recorded. The operation mode decision unit 44 acquires a signal indicating the working state or the load state of the high-temperature load device 30 recorded in the storage unit 46 and the prediction value of the load. The order of processing of Steps S2 to S4 can be arbitrarily changed, and Steps S2 to S4 may be simultaneously performed in parallel.

[0048] Next, the operation mode decision unit 44 decides the operation mode (Step S5). The operation mode decision unit 44 determines necessity of heat recovery and decides the operation mode on the basis of the signals acquired in Steps S2 to 4 and the conditions for switching set in Step S 1. For example, when the outside air temperature is $X1^{\circ}\text{C}$ or higher, the operation mode decision unit 44 decides that the operation mode is set to the supercritical operation (the conditions for switching of the item number 1).

For example, when a signal indicating that the outside air temperature is lower than $X1^{\circ}\text{C}$ and the exhaust heat recovery device 20 is at a stop is acquired, the operation mode decision unit 44 decides that the operation mode is set to the subcritical operation (the conditions for switching of the item number 2). For example, when either conditions whether a signal indicating that the outside air temperature is lower than $X1^{\circ}\text{C}$, the exhaust heat recovery device 20 is working, and the high-temperature load device 30 is working with a high load has been acquired (the conditions for switching of the item number 5), or whether a signal indicating that the outside air temperature is $X2^{\circ}\text{C}$ or lower, the exhaust heat recovery device 20 and the high-temperature load device 30 are working has been acquired (the conditions for switching of the item number 9) are satisfied, the operation mode decision unit 44 determines that necessity of heat recovery is high and decides that the operation mode is set to the supercritical operation. When none of the conditions

for switching of the item number 5 and the item number 9 is satisfied, the operation mode decision unit 44 determines that necessity of heat recovery is low and decides that the operation mode is set to the subcritical operation.

[0049] Regarding judgment whether or not the high-temperature load device 30 in the item number 5 is working with a high load, for example, if it is a timeslot in which the prediction value of the load predicted by the predictive model is high, the operation mode decision unit 44 may judge that the high-temperature load device 30 is working with a high load, and if the compressor in the high-temperature load device 30 is in operation with a rotation frequency equal to or higher than a predetermined value, it may be judged that the high-temperature load device 30 is working with a high load. When it can be estimated that the exhaust heat recovery device 20 is working, the outside air temperature is lower than $X1^{\circ}\text{C}$, and the high-temperature load device 30 is working with a high load, the operation mode decision unit 44 determines that necessity of heat exchange is high. In addition, regarding the item number 9, when the exhaust heat recovery device 20 and the high-temperature load device 30 are working and the outside air temperature is $X2^{\circ}\text{C}$ or lower, the operation mode decision unit 44 determines that necessity of heat exchange is high. In addition, regarding the item number 6, if the exhaust heat recovery device 20 is working, the outside air temperature is lower than $X1^{\circ}\text{C}$, and it is a predetermined period and/or timeslot, the operation mode decision unit 44 determines that necessity of heat exchange is high.

[0050] The operation mode decision unit 44 outputs the decided operation mode to the freezer control unit 45. The freezer control unit 45 causes the freezer 10 to operate in accordance with the decision of the operation mode decision unit 44. When the operation mode decision unit 44 decides that the operation mode is set to the supercritical operation, the freezer control unit 45 instructs the two-stage compressor 11 to perform the supercritical operation. Accordingly, the high-pressure supercritical operation in which a refrigerant is in the supercritical state on the high-pressure side of the refrigerant circuit is executed (Step S6). When the operation mode decision unit 44 decides that the operation mode is set to the subcritical operation, the freezer control unit 45 instructs the two-stage compressor 11 to perform the subcritical operation. Accordingly, the high-pressure subcritical operation in which a refrigerant is in the subcritical state on the high-pressure side of the refrigerant circuit is executed (Step S7).

[0051] As described above, according to the present embodiment, the operation of the freezer 10 is controlled to be either the supercritical operation or the subcritical operation on the basis of a setting of the conditions for switching set such that the overall efficiency of the freezer 10 and the high-temperature load device 30 is improved (FIG. 3). The efficiency of the exhaust heat recovery freezer system 1 can be improved by switching between the high-pressure supercritical operation and the high-

pressure subcritical operation of the freezer in accordance with the efficiency of the exhaust heat recovery freezer system 1 in its entirety.

[0052] FIG. 5 is a diagram illustrating an example of a hardware constitution of a system controller according to the embodiment. A computer 900 includes a CPU 901, a main storage device 902, an auxiliary storage device 903, an input/output interface 904, and a communication interface 905. The system controller 40 is mounted in the computer 900. Further, each of the functions described above is stored in the auxiliary storage device 903 in a form of a program. The CPU 901 reads the program from the auxiliary storage device 903 and develops it in the main storage device 902, and the foregoing processing is executed in accordance with the program. In addition, the CPU 901 secures a storage domain in the main storage device 902 in accordance with the program. In addition, the CPU 901 secures the storage domain for storing data being processed in the auxiliary storage device 903 in accordance with the program.

[0053] Processing by each of the functional units may be performed by recording a program for realizing all or some of the functions of the system controller 40 in a computer readable recording medium, causing a computer system to read and execute the program recorded in this recording medium. Here, "a computer system" includes hardware such as an OS and peripheral equipment. In addition, when the WWW system is utilized, "a computer system" also includes a homepage-provided environment (or a display environment). In addition, "a computer readable recording medium" indicates a storage device including a portable medium such as a CD, a DVD, or a USB, and a hard disk built into the computer system. In addition, when this program is distributed in the computer 900 through a communication line, the computer 900 which has received the distribution may develop the program in the main storage device 902 to execute the foregoing processing. In addition, the foregoing program may be a program for realizing a part of the functions described above or may be a program capable of realizing the functions described above in combination with a program which has already been recorded in the computer system.

[0054] Furthermore, the constituent elements in the foregoing embodiment can be suitably replaced with known constituent elements within a range not departing from the gist of the present invention. In addition, the technical scope of this invention is not limited to the foregoing embodiment, and various changes can be added thereto within a range not departing from the gist of the present invention.

<Appendix>

[0055] The control device, the exhaust heat recovery freezer system, the control method, and the program according to each embodiment are ascertained as follows, for example.

(1) According to a first aspect, the control device (system controller 40) includes the operation mode decision unit 44 that decides, in accordance with necessity of heat recovery from a refrigerant circulating in the refrigerant circuit (or in accordance with the load state of the device supplying heat of the refrigerant circulating in the refrigerant circuit (high-temperature load device 30)), which operation of the supercritical operation in which the high pressure in the refrigerant circuit is in the supercritical state and the subcritical operation in which the high pressure is in the subcritical state is to be performed; and the freezer control unit 45 that controls the refrigerant circuit to be operated in either the supercritical operation or the critical operation on the basis of decision of the operation mode decision unit 44.

[0056] Accordingly, the freezer can switch between the high-pressure supercritical operation and the high-pressure subcritical operation in accordance with the overall efficiency of the freezer 10 and the high-temperature load device 30. Accordingly, the foregoing overall efficiency can be improved.

[0057] (2) According to a second aspect, the control device (system controller 40) is the control device according to (1), in which the operation mode decision unit 44 decides to perform the supercritical operation when the outside air temperature becomes equal to or lower than a predetermined temperature ($X2^{\circ}\text{C}$ or lower) at which the load of the device (high-temperature load device 30) is estimated to be large (for example, the item number 8 in FIG. 3).

[0058] When it can be determined that the load on the high-temperature load device 30 is large on the basis of the outside air temperature, the heat recovery ability of the exhaust heat recovery device 20 is raised and the operation load of the high-temperature load device 30 is reduced by switching the operation of the freezer 10 to the supercritical operation. Accordingly, the overall efficiency of the freezer 10 and the high-temperature load device 30 can be improved.

[0059] (3) According to a third aspect, the control device (system controller 40) is the control device according to (1) to (2), in which the operation mode decision unit 44 decides to perform the supercritical operation during a predetermined period and/or a predetermined timeslot in which the load of the device (high-temperature load device 30) becomes large (for example, the item number 6 in FIG. 3).

[0060] During a predetermined period or a predetermined timeslot in which it is known or predicted that the load on the high-temperature load device 30 becomes large, the heat recovery ability of the exhaust heat recovery device 20 is raised and the operation load of the high-temperature load device 30 is reduced by switching the operation of the freezer 10 to the supercritical operation. Accordingly, the overall efficiency of the freezer 10 and the high-temperature load device 30 can be improved.

[0061] (4) According to a fourth aspect, the control device (system controller 40) is the control device according to (1) to (3), in which the operation mode decision unit 44 judges whether or not necessity of the heat recovery is considerable (judges whether or not the load is considerable) on the basis of a signal indicating the operation state of the high-temperature load device 30 that is a supply destination of heat which has been subjected to heat recovery, and decides to perform the supercritical operation when it is judged that necessity of the heat recovery is high (the load is large) (for example, the item number 5 in FIG. 3).

[0062] When it can be determined that the load on the high-temperature load device 30 is large on the basis of a signal indicating the operation state of the high-temperature load device 30 (the rotation frequency of the compressor or the like), the operation of the freezer 10 is switched to the supercritical operation. Accordingly, the heat recovery ability of the exhaust heat recovery device 20 can be raised, the operation load of the high-temperature load device 30 can be reduced, and the overall efficiency of the freezer 10 and the high-temperature load device 30 can be improved.

[0063] (5) According to a fifth aspect, the control device (system controller 40) is the control device according to (1) to (4), in which the operation mode decision unit 44 judges whether or not the exhaust heat recovery device 20, which recovers heat through heat exchange with a refrigerant circulating in the refrigerant circuit between the compressor and the gas cooler in the refrigerant circuit and supplies the recovered heat to the load device, is working, and decides to perform the subcritical operation when the exhaust heat recovery device 20 is not working.

[0064] When the exhaust heat recovery device 20 is not working, the efficiency of the freezer 10 can be improved and the overall efficiency of the freezer 10 and the high-temperature load device 30 can be improved by performing the subcritical operation.

[0065] (6) According to a sixth aspect, the exhaust heat recovery freezer system 1 includes the freezer 10 that has a refrigerant circuit including the compressor (two-stage compressor 11) and the gas cooler 12; the exhaust heat recovery device 20 that recovers heat through heat exchange with a refrigerant circulating in the refrigerant circuit between the compressor and the gas cooler in the refrigerant circuit and supplies the recovered heat to the high-temperature load device; and the control device (system controller 40) according to any one of (1) to (5).

[0066] Accordingly, the freezer can switch between the high-pressure supercritical operation and the high-pressure subcritical operation in accordance with the overall efficiency of the freezer 10 and the high-temperature load device 30. Accordingly, the foregoing overall efficiency can be improved.

[0067] (7) According to a seventh aspect, the exhaust heat recovery freezer system 1 is the exhaust heat recovery freezer system according to (6), in which the con-

trol device (system controller 40) further includes the exhaust heat recovery device control unit 43 for controlling working and stopping of the exhaust heat recovery device 20.

[0068] Accordingly, it is possible to switch between the supercritical operation and the subcritical operation after the working state of the exhaust heat recovery device 20 is understood.

[0069] (8) According to an eighth aspect, the control method includes the step of deciding, in accordance with necessity of heat recovery from a refrigerant circulating in the refrigerant circuit or in accordance with the load state of the device supplying heat of a refrigerant circulating in the refrigerant circuit, which operation of the supercritical operation in which the high pressure in the refrigerant circuit is in the supercritical state and the subcritical operation in which the high pressure is in the subcritical state is to be performed; and the step of controlling the refrigerant circuit to be operated in either the supercritical operation or the critical operation on the basis of decision in the step of deciding an operation.

[0070] (9) According to a ninth aspect, the program causes a computer to execute the step of deciding, in accordance with necessity of heat recovery from a refrigerant circulating in the refrigerant circuit or in accordance with the load state of the device supplying heat of a refrigerant circulating in the refrigerant circuit, which operation of the supercritical operation in which the high pressure in the refrigerant circuit is in the supercritical state and the subcritical operation in which the high pressure is in the subcritical state is to be performed; and the step of controlling the refrigerant circuit to be operated in either the supercritical operation or the critical operation on the basis of decision in the step of deciding an operation.

EXPLANATION OF REFERENCES

[0071]

- 1 Exhaust heat recovery freezer system
- 10 Freezer
- 11 Two-stage compressor
- 11a High stage-side compressor
- 11b Low stage-side compressor
- 12 Gas cooler
- 13a First expansion valve
- 13b Second expansion valve
- 14 Receiver
- 15 Evaporator
- 16 Accumulator
- 17 Main piping
- 18 Piping (injection circuit)
- 18a Valve
- 19 Fan
- 20 Exhaust heat recovery device
- 21 Heat exchanger
- 22 Pump
- 23 Piping

30 High-temperature load device
 31 Low-temperature load device
 40 System controller (control device)
 41 Signal acquisition unit
 42 Setting reception unit
 43 Exhaust heat recovery device control unit
 44 Operation mode decision unit
 45 Freezer control unit
 46 Storage unit
 tho1 to tho3 Temperature sensor

wherein the operation mode decision unit (44) is configured to judge whether or not an exhaust heat recovery device (20), which recovers heat through heat exchange with a refrigerant circulating in the refrigerant circuit between a compressor (11) and a gas cooler (12) in the refrigerant circuit, is working, and to decide to perform the subcritical operation when the exhaust heat recovery device (20) is not working.

Claims

1. A control device (40) comprising:

an operation mode decision unit (44) that is configured to decide, in accordance with necessity of heat recovery from a refrigerant circulating in a refrigerant circuit, which operation of a supercritical operation in which a high pressure in the refrigerant circuit is in a supercritical state and a subcritical operation in which the high pressure is in a subcritical state is to be performed; and a freezer control unit (45) that is configured to control the refrigerant circuit to be operated in either the supercritical operation or the subcritical operation on the basis of decision of the operation mode decision unit (44).

2. The control device (40) according to claim 1, wherein the operation mode decision unit (44) is configured to decide to perform the supercritical operation when an outside air temperature becomes equal to or lower than a predetermined temperature indicating high necessity of the heat recovery.

3. The control device (40) according to any one of claims 1 and 2, wherein the operation mode decision unit (44) is configured to decide to perform the supercritical operation during a predetermined period and/or a predetermined timeslot in which necessity of the heat recovery becomes high.

4. The control device (40) according to any one of claims 1 to 3, wherein the operation mode decision unit (44) is configured to judge whether or not necessity of the heat recovery is considerable on the basis of a signal indicating an operation state of a high-temperature load device (30) that is a supply destination of the heat which has been subjected to heat recovery, and to decide to perform the supercritical operation when it is judged that necessity of the heat recovery is high.

5. The control device (40) according to any one of claims 1 to 4,

6. An exhaust heat recovery freezer system (1) comprising:

a freezer (10) that has a refrigerant circuit including a compressor (11) and a gas cooler (12); an exhaust heat recovery device (20) that is configured to recover heat through heat exchange with a refrigerant circulating in the refrigerant circuit between the compressor (11) and the gas cooler (12) in the refrigerant circuit and to supply the recovered heat to a high-temperature load device (30); and the control device (40) according to any one of claims 1 to 5.

7. The exhaust heat recovery freezer system (1) according to claim 6, wherein the control device (40) further includes an exhaust heat recovery device control unit (43) for controlling working and stopping of the exhaust heat recovery device (20).

8. A control method comprising:

a step of deciding, in accordance with necessity of heat recovery from a refrigerant circulating in a refrigerant circuit, which operation of a supercritical operation in which a high pressure in the refrigerant circuit is in a supercritical state and a subcritical operation in which the high pressure is in a subcritical state is to be performed; and a step of controlling the refrigerant circuit to be operated in either the supercritical operation or the subcritical operation on the basis of decision in the step of deciding an operation.

9. A program for causing a computer to execute

a step of deciding, in accordance with necessity of heat recovery from a refrigerant circulating in a refrigerant circuit, which operation of a supercritical operation in which a high pressure in the refrigerant circuit is in a supercritical state and a subcritical operation in which the high pressure is in a subcritical state is to be performed, and a step of controlling the refrigerant circuit to be operated in either the supercritical operation or the subcritical operation on the basis of decision in the step of deciding an operation.

FIG. 1

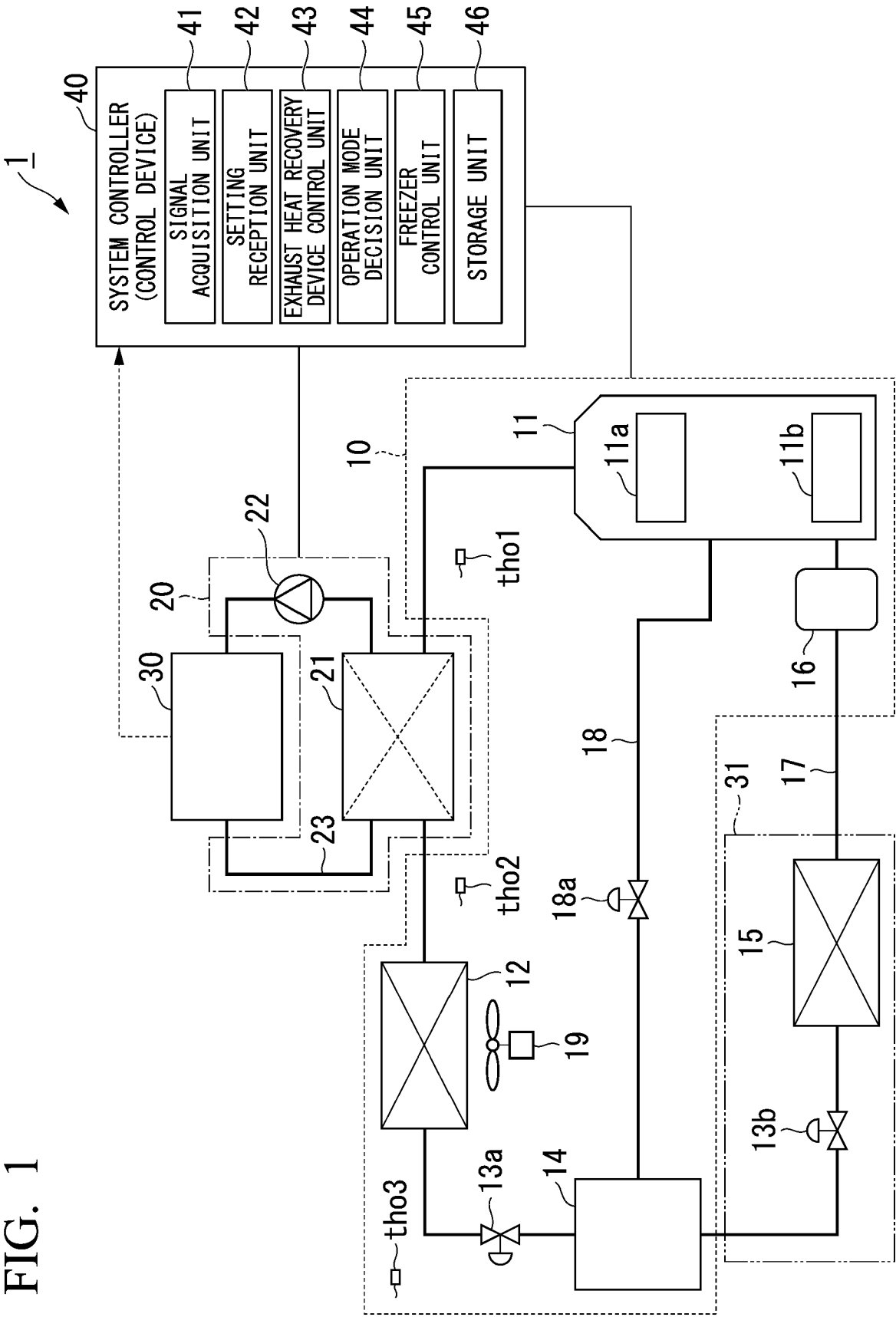


FIG. 2

	HEAT RECOVERY ABILITY	FREEZER EFFICIENCY
SUPERCRITICAL OPERATION	HIGH	LOW
SUBCRITICAL OPERATION	LOW	HIGH

FIG. 3

ITEM NUMBER	HEAT RECOVERY DEVICE	OUTSIDE AIR TEMPERATURE	STATE OF HIGH-TEMPERATURE LOAD DEVICE	PERIOD/TIMESLOT	OPERATION MODE
1	—	X1°C OR HIGHER	—	—	SUPERCRITICAL MODE
2	OFF	LOWER THAN X1°C	—	—	SUBCRITICAL MODE
3	ON	LOWER THAN X1°C	OFF	—	SUBCRITICAL MODE
4	ON	LOWER THAN X1°C	ON	—	SUPERCRITICAL MODE
5	ON	LOWER THAN X1°C	ON (CONSIDERABLE LOAD)	—	SUPERCRITICAL MODE
6	ON	LOWER THAN X1°C	—	PERIOD/TIMESLOT OF USE	SUPERCRITICAL MODE
7	ON	LOWER THAN X1°C	ON	TIMESLOT (CONSIDERABLE LOAD)	SUPERCRITICAL MODE
8	ON	X2°C OR LOWER	—	—	SUPERCRITICAL MODE
9	ON	X2°C OR LOWER	ON	—	SUPERCRITICAL MODE
10	ON	X2°C OR LOWER	—	PERIOD/TIMESLOT OF USE	SUPERCRITICAL MODE

※ X1 > X2

FIG. 4

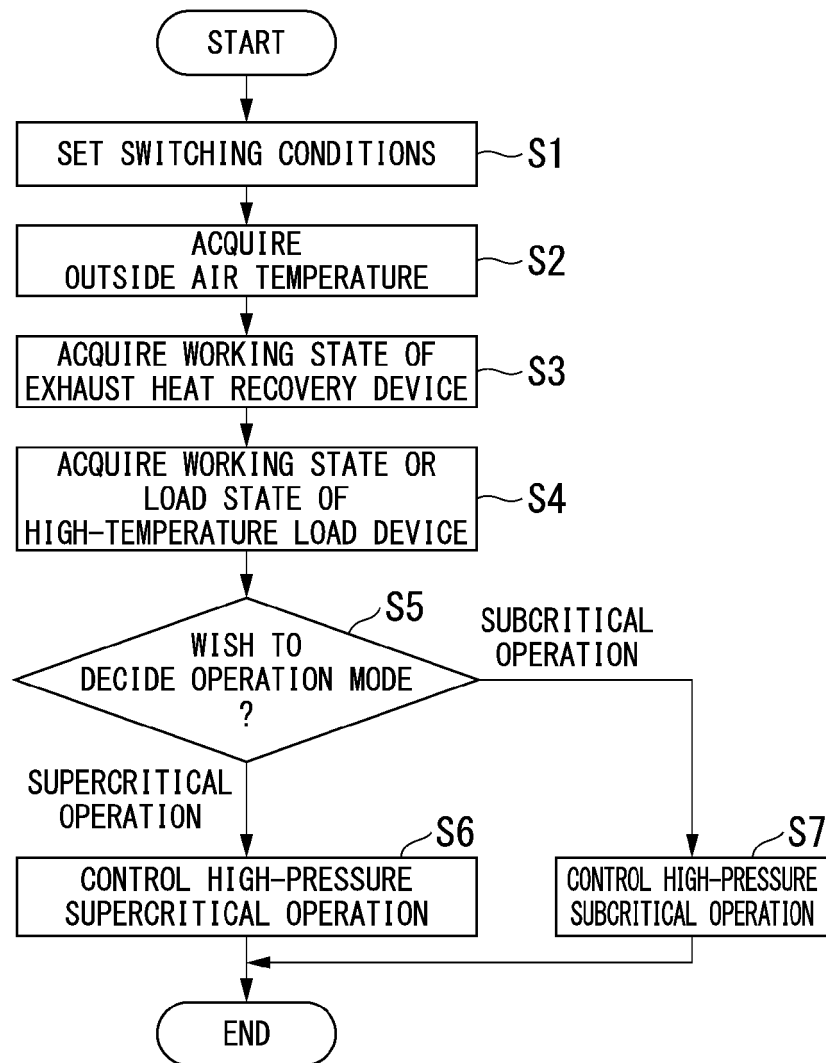
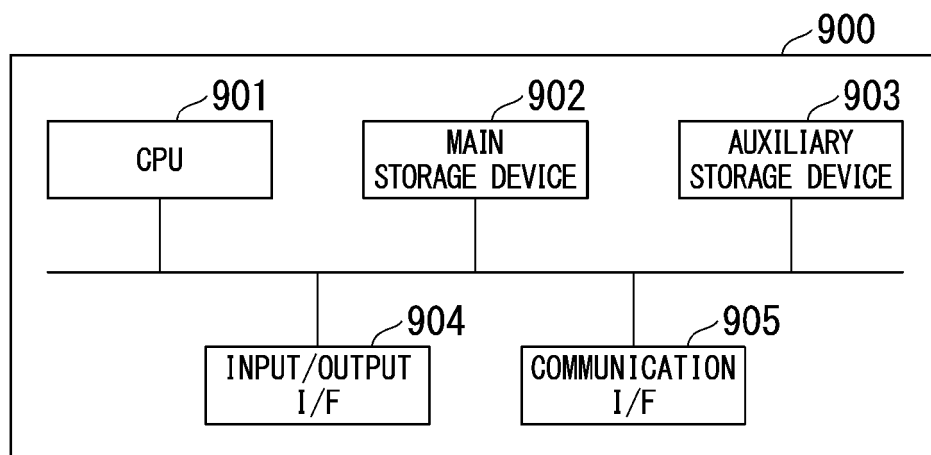


FIG. 5





EUROPEAN SEARCH REPORT

Application Number

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A	* figures 2, 3, 5, 19 *	5	F25B6/04
	* page 1, line 4 - line 6 *		F25B9/00
	* page 1, line 34 - page 4, line 13 *		F25B30/02
	* page 9, line 10 - page 16, line 11 *		F25B49/02
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	* claims 1-27 *		F25B1/10
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A	* figure 1 *	4, 5, 7	
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	* page 7, line 2 - line 8 *		

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A	* figure 1 *	3, 5, 7	
	* paragraph [0001] *		
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The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
Munich		8 August 2023	Karspeck, Sabine
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention	
X : particularly relevant if taken alone		E : earlier patent document, but published on, or after the filing date	
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A : technological background		L : document cited for other reasons	
O : non-written disclosure			
P : intermediate document		& : member of the same patent family, corresponding document	

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

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