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(54) HEAT CYCLE

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(57) ABSTRACT

The waste heat recovering operation mode (a Rankine cycle) is started and operated for a predetermined period of time T1 (s) (S430 to S450). In the case where the difference (P2−P1) between the upstream pressure P1 and the downstream pressure P2 of the liquid pump is higher than the predetermined pressure P, the waste heat recovering operation mode is continued. In the case where the difference (P2−P1) is not more than the predetermined pressure P, after the air conditioning mode is started (S480 to S500), the waste heat recovering operation mode is started again (S430 to S450). Due to the foregoing, it is possible to provide a heat cycle, which is provided with a refrigerating cycle and a Rankine cycle which are changeable each other, in which an incomplete start at the time of Rankine cycle can be reduced and a deterioration of the cycle efficiency can be reduced.

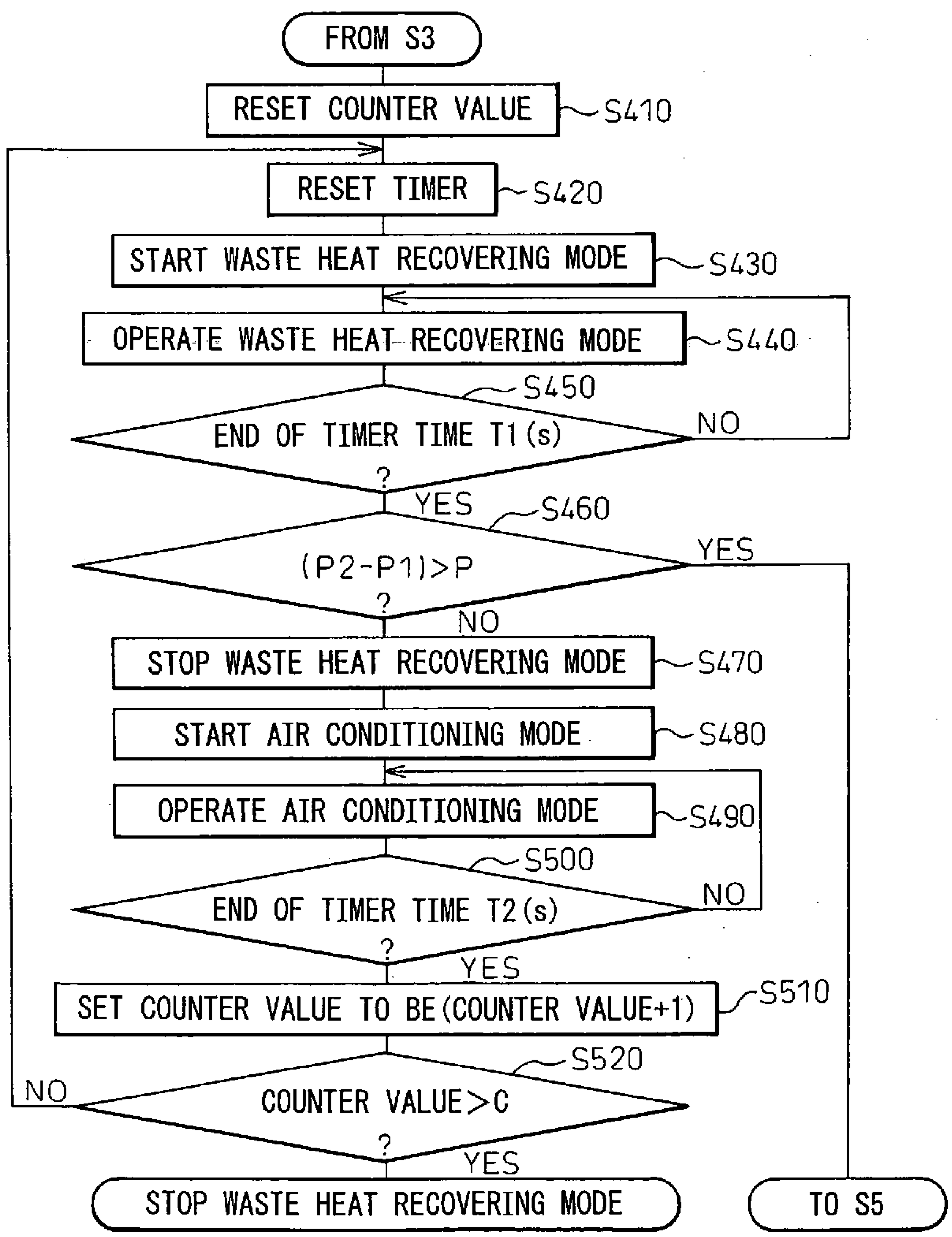


Fig.1

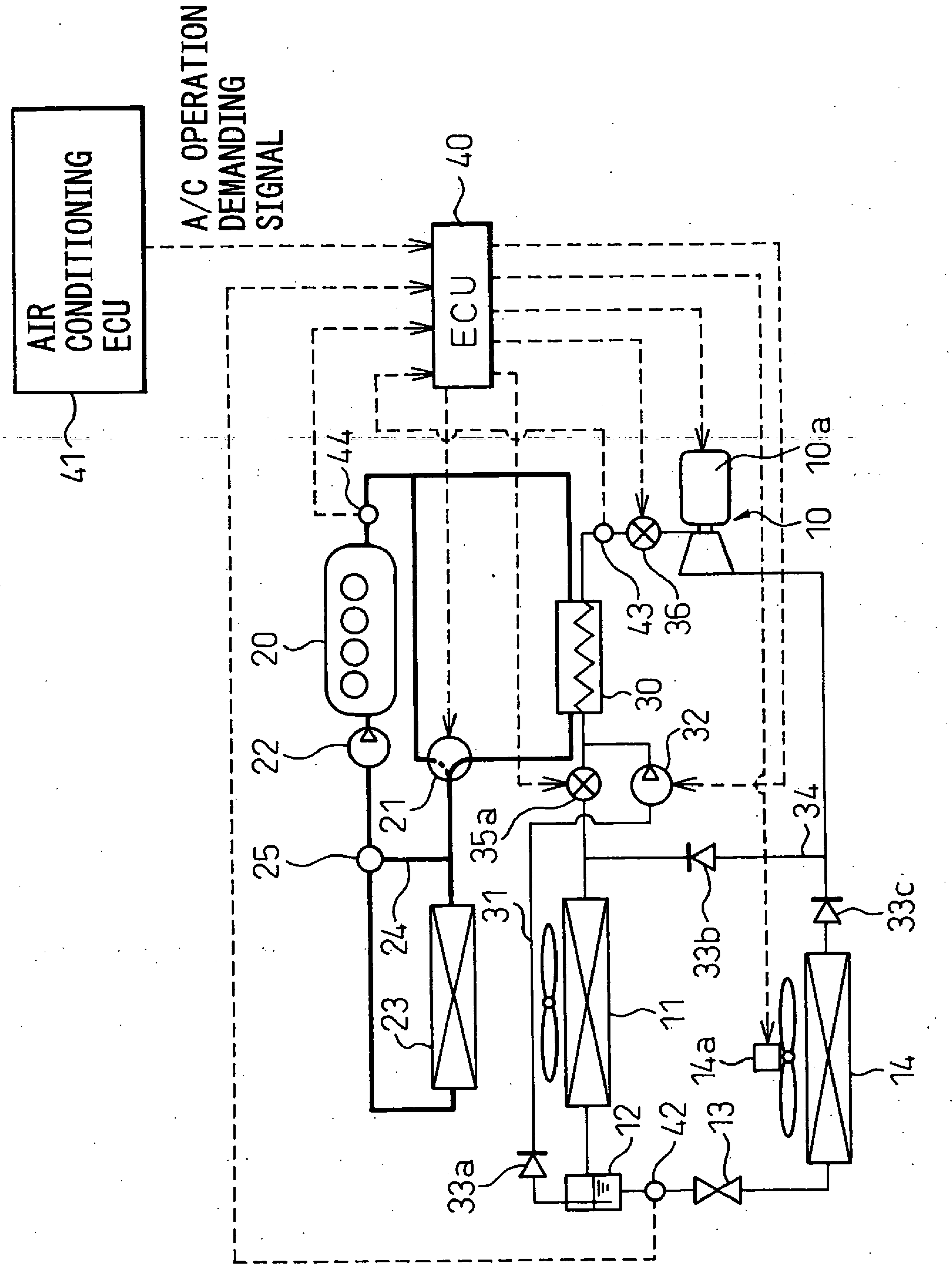

AIR CONDITIONING ECU
A/C OPERATION DEMANDING SIGNAL
ECU
40
41
44
43
36
10a
10
20
22
21
25
24
23
30
32
35a
31
11
34
33a
33b
33c
12
42
13
14
14a

Fig.2a

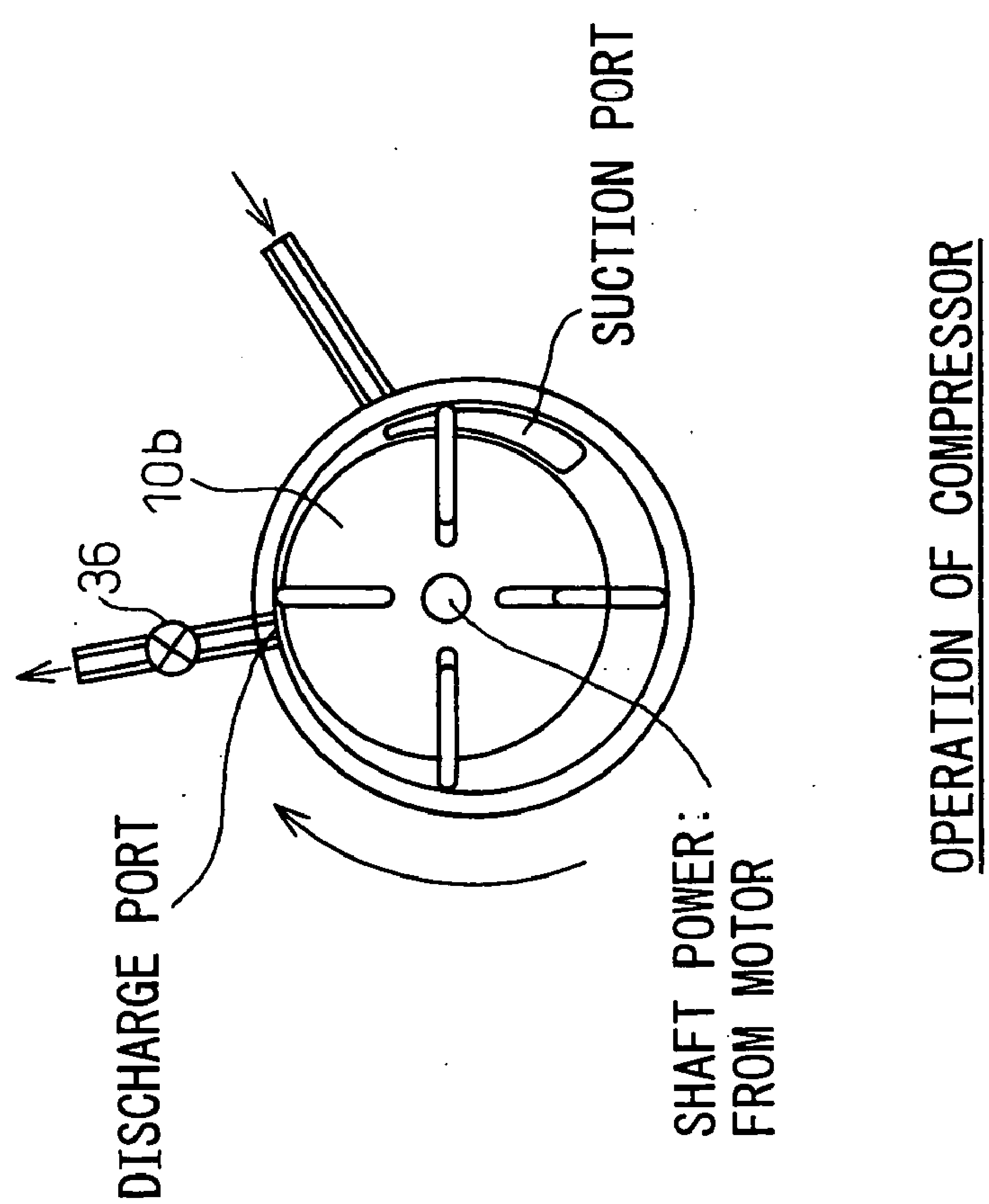

36
10b
DISCHARGE PORT
SUCTION PORT
SHAFT POWER:
FROM MOTOR
OPERATION OF COMPRESSOR

Fig.2b

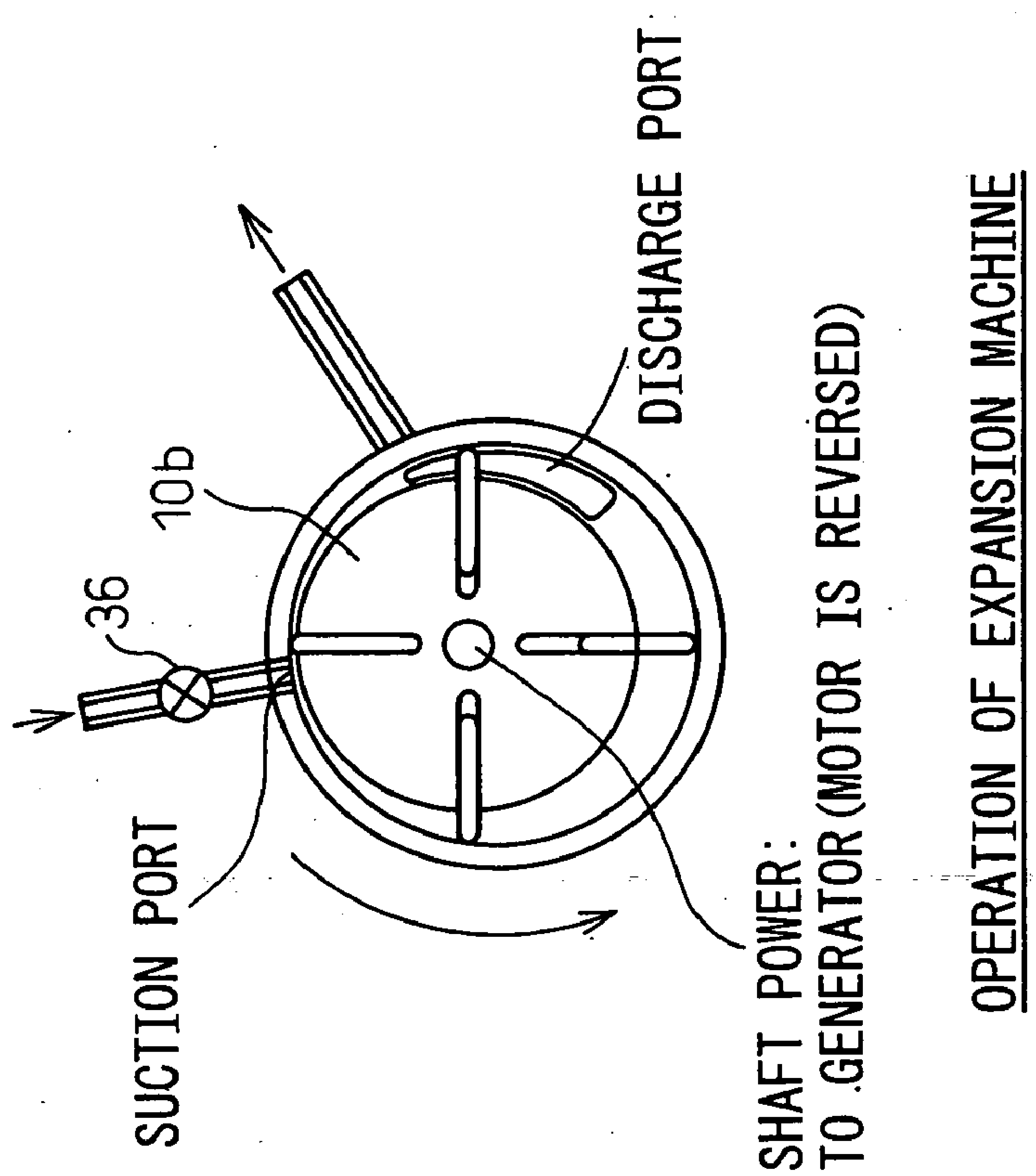

36
10b
SUCTION PORT
DISCHARGE PORT
SHAFT POWER:
TO GENERATOR (MOTOR IS REVERSED)
OPERATION OF EXPANSION MACHINE

Fig.3

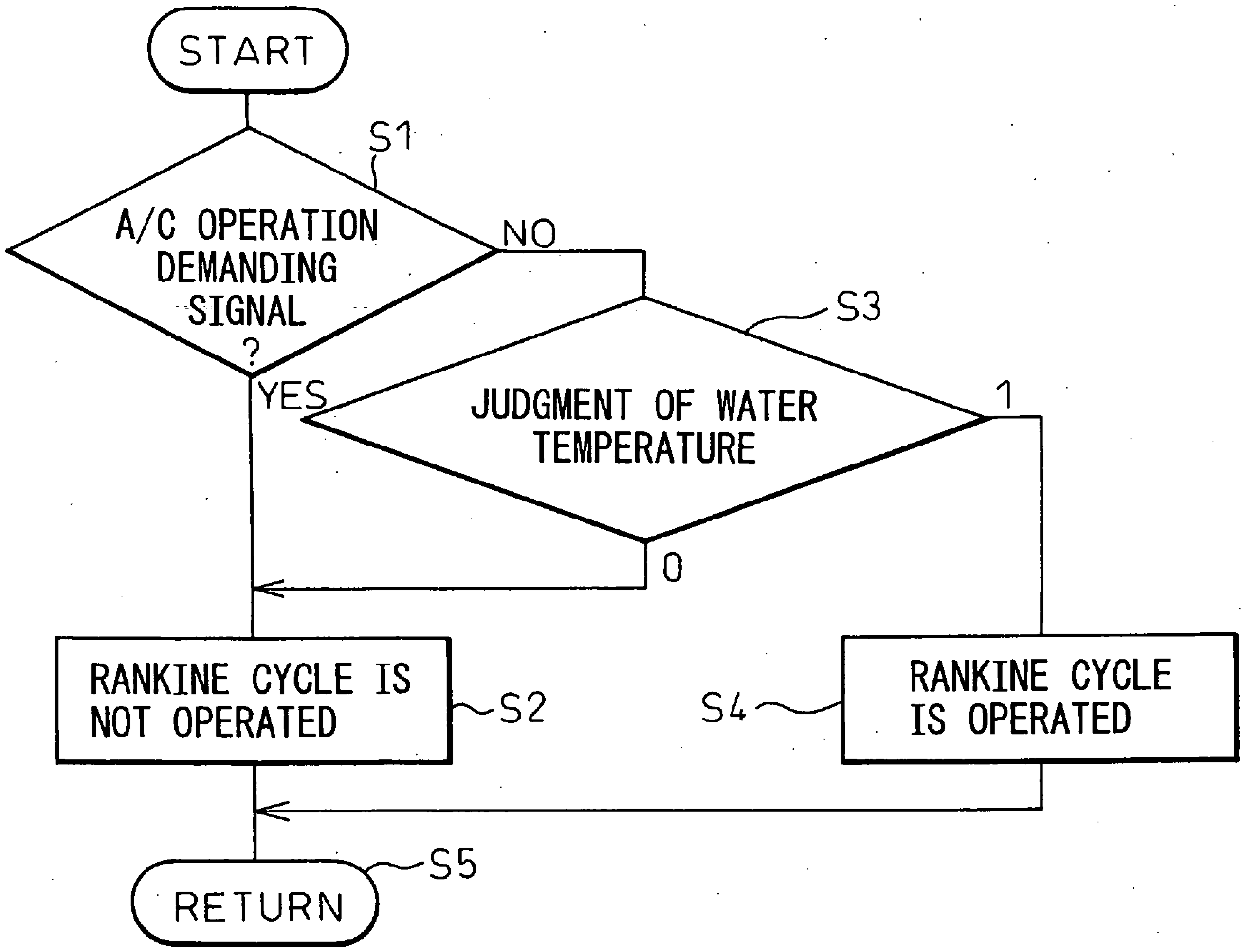

START
S1
A/C OPERATION DEMANDING SIGNAL ?
NO
YES
S3
JUDGMENT OF WATER TEMPERATURE
1
0
RANKINE CYCLE IS NOT OPERATED
S2
S4
RANKINE CYCLE IS OPERATED
S5
RETURN

Fig.4

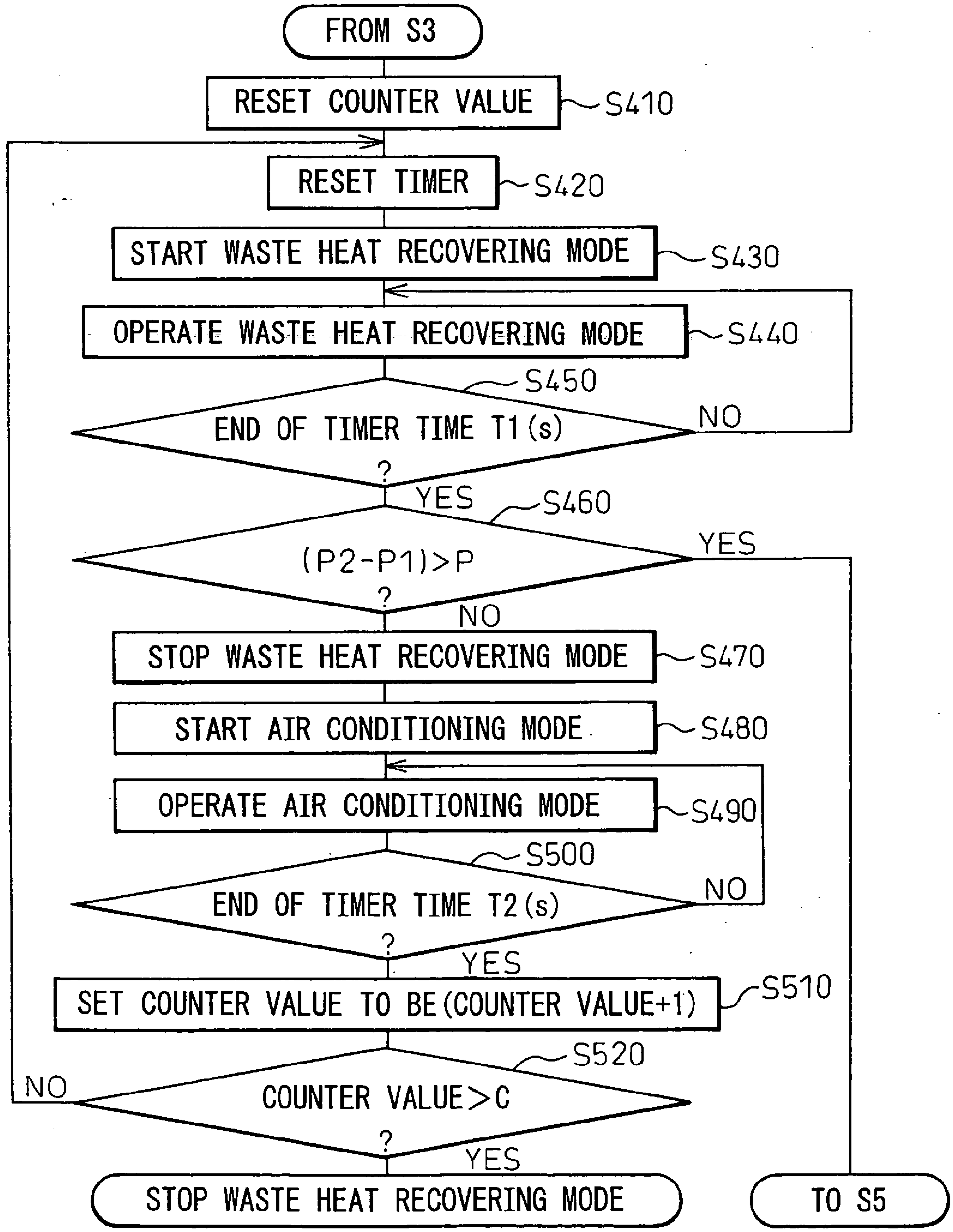

FROM S3
RESET COUNTER VALUE
S410
RESET TIMER
S420
START WASTE HEAT RECOVERING MODE
S430
OPERATE WASTE HEAT RECOVERING MODE
S440
S450
END OF TIMER TIME T1(s)
?
NO
YES
S460
(P2-P1)>P
?
YES
NO
STOP WASTE HEAT RECOVERING MODE
S470
START AIR CONDITIONING MODE
S480
OPERATE AIR CONDITIONING MODE
S490
S500
END OF TIMER TIME T2(s)
?
NO
YES
SET COUNTER VALUE TO BE (COUNTER VALUE+1)
S510
S520
COUNTER VALUE>C
?
NO
YES
STOP WASTE HEAT RECOVERING MODE
TO S5

Fig.5

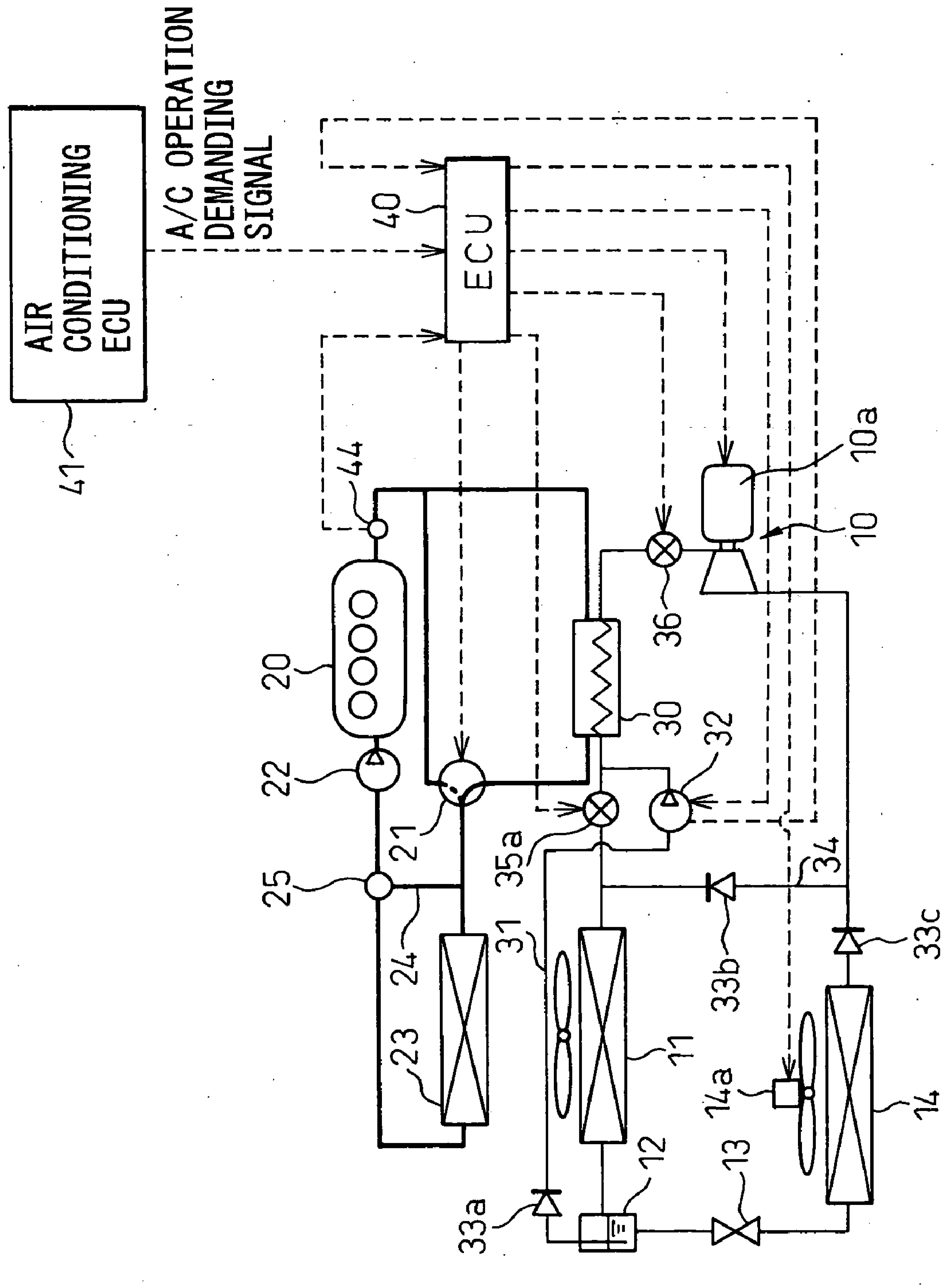

AIR CONDITIONING ECU
A/C OPERATION DEMANDING SIGNAL
ECU
40
41
44
20
22
21
25
24
23
30
32
36
35a
31
11
12
33a
13
14
14a
33b
33c
34
10
10a

Fig.6

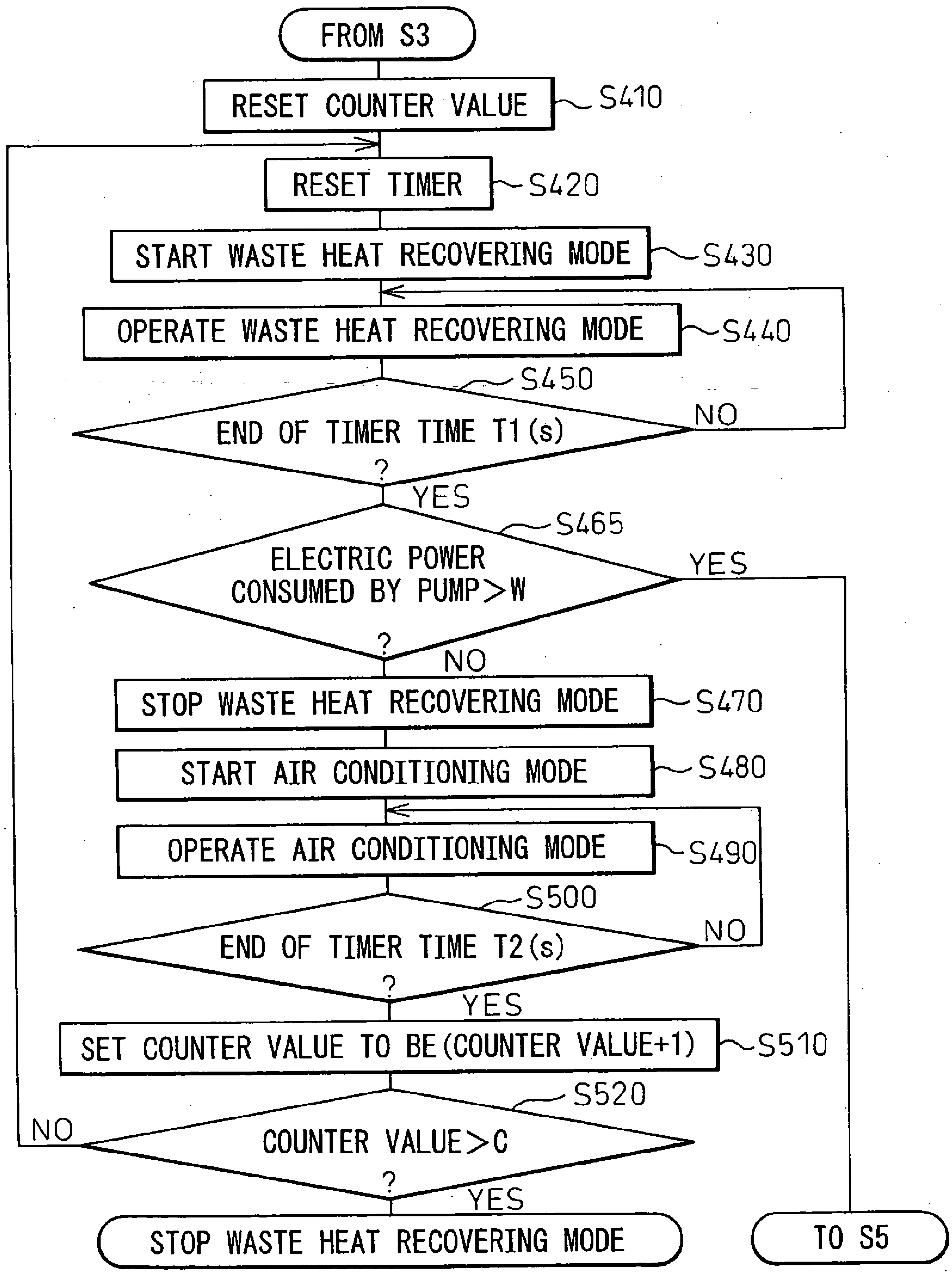

FROM S3
RESET COUNTER VALUE
S410
RESET TIMER
S420
START WASTE HEAT RECOVERING MODE
S430
OPERATE WASTE HEAT RECOVERING MODE
S440
S450
END OF TIMER TIME T1(s)
?
NO
YES
S465
ELECTRIC POWER
CONSUMED BY PUMP>W
?
YES
NO
STOP WASTE HEAT RECOVERING MODE
S470
START AIR CONDITIONING MODE
S480
OPERATE AIR CONDITIONING MODE
S490
S500
END OF TIMER TIME T2(s)
?
NO
YES
SET COUNTER VALUE TO BE(COUNTER VALUE+1)
S510
S520
COUNTER VALUE>C
?
NO
YES
STOP WASTE HEAT RECOVERING MODE
TO S5

Fig. 7

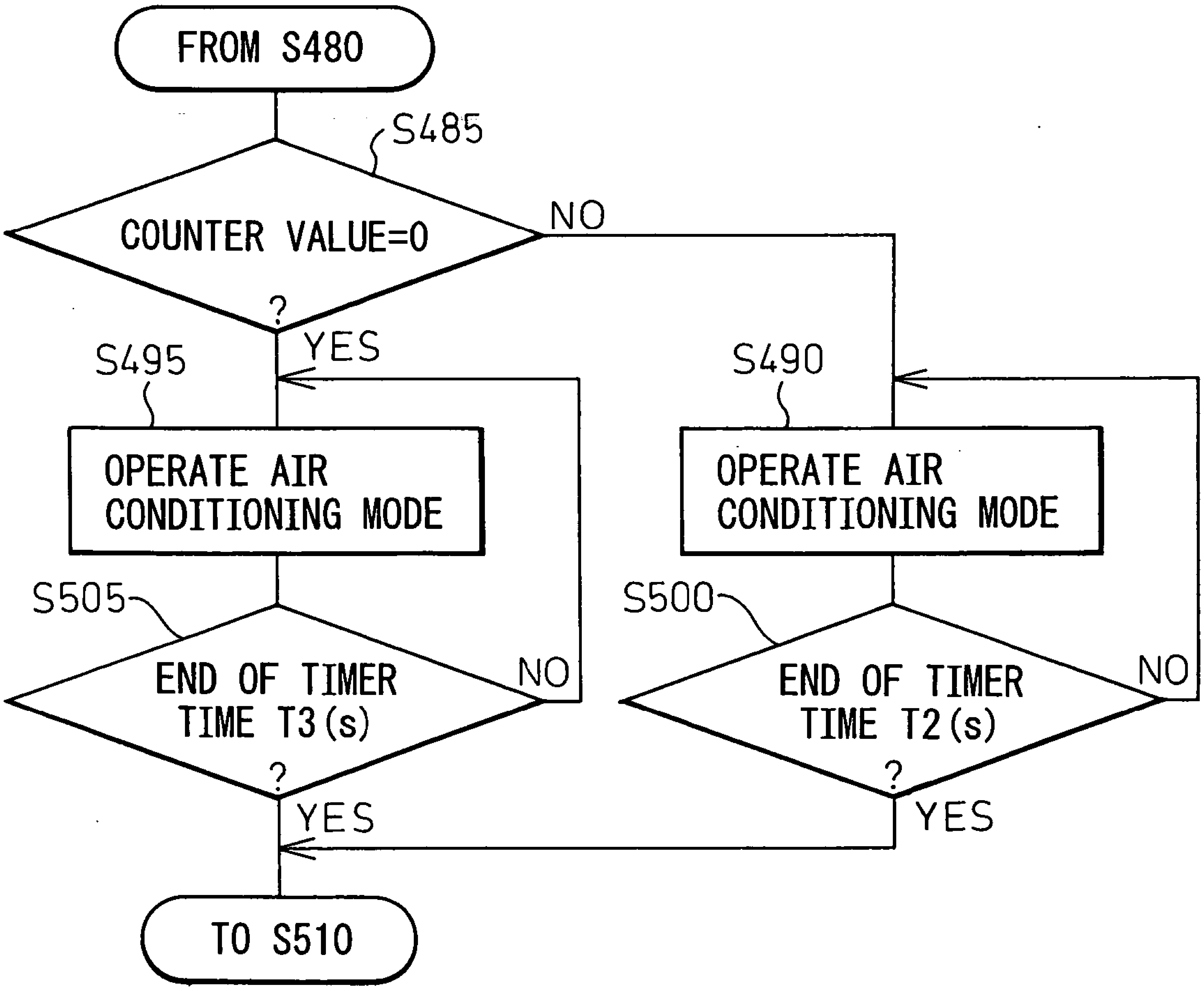

FROM S480
S485
COUNTER VALUE=0
?
NO
YES
S495
S490
OPERATE AIR CONDITIONING MODE
OPERATE AIR CONDITIONING MODE
S505
S500
END OF TIMER TIME T3(s)
?
NO
END OF TIMER TIME T2(s)
?
NO
YES
YES
TO S510

Fig.8

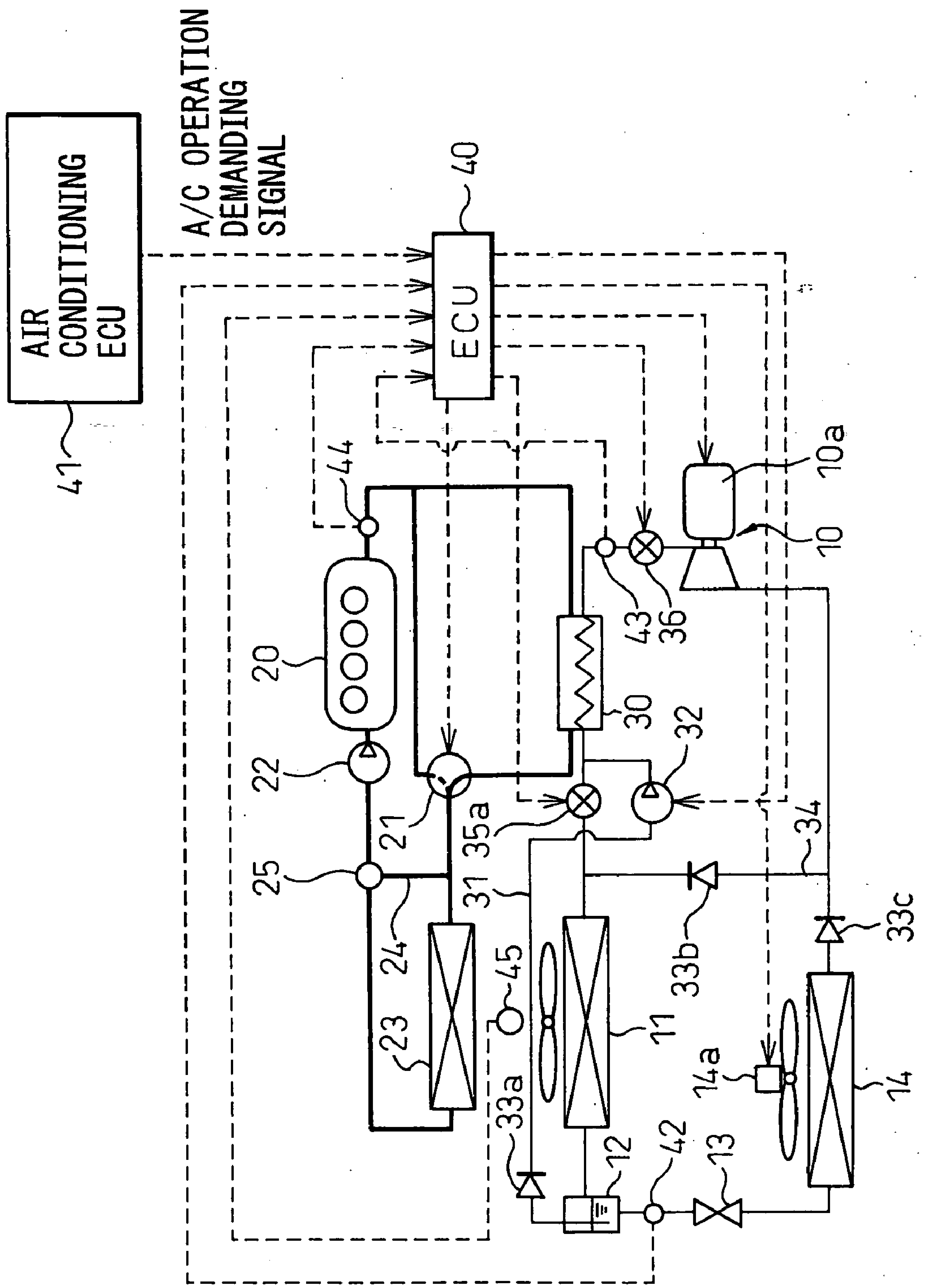
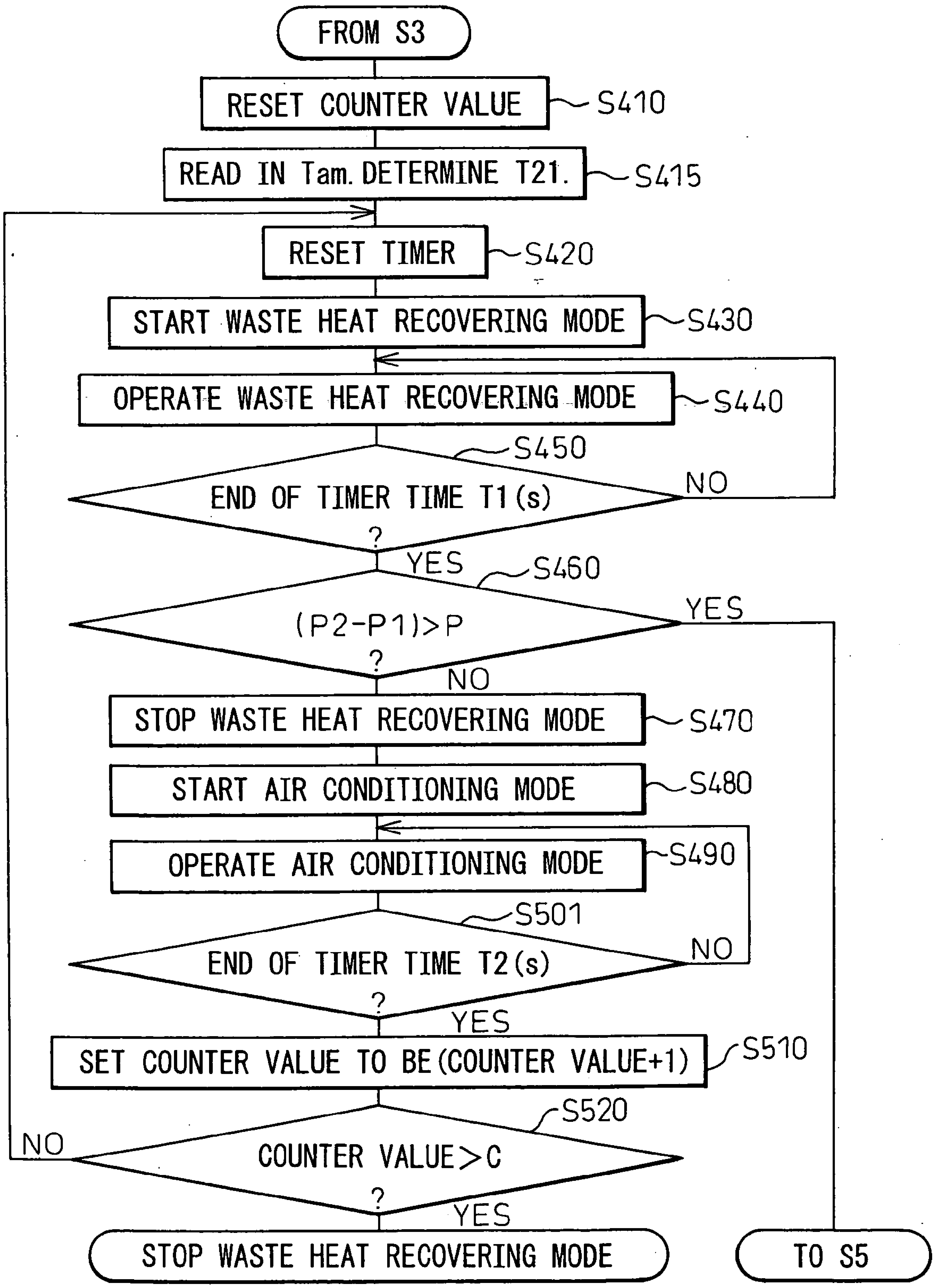

AIR CONDITIONING ECU
A/C OPERATION DEMANDING SIGNAL
ECU
41
40
44
10a
10
43
36
20
30
32
22
21
35a
25
31
34
24
33b
33c
45
23
11
14a
14
33a
12
42
13

Fig.9


FROM S3
RESET COUNTER VALUE
S410
READ IN Tam. DETERMINE T21.
S415
RESET TIMER
S420
START WASTE HEAT RECOVERING MODE
S430
OPERATE WASTE HEAT RECOVERING MODE
S440
S450
END OF TIMER TIME T1(s)
?
NO
YES
S460
(P2-P1)>P
?
YES
NO
STOP WASTE HEAT RECOVERING MODE
S470
START AIR CONDITIONING MODE
S480
OPERATE AIR CONDITIONING MODE
S490
S501
END OF TIMER TIME T2(s)
?
NO
YES
SET COUNTER VALUE TO BE(COUNTER VALUE+1)
S510
S520
COUNTER VALUE>C
?
NO
YES
STOP WASTE HEAT RECOVERING MODE
TO S5

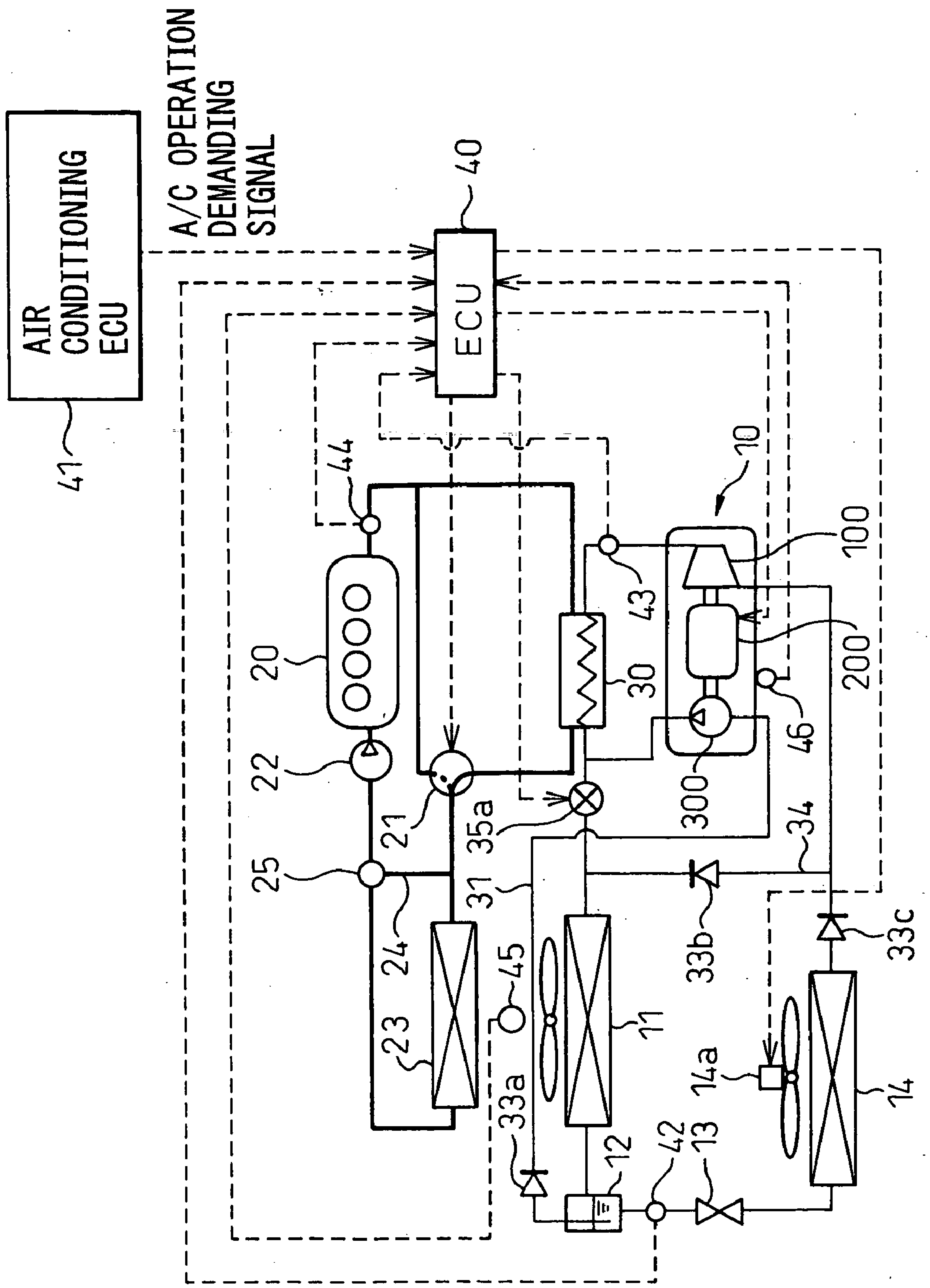

AIR
CONDITIONING
ECU
A/C OPERATION
DEMANDING
SIGNAL
ECU
40
41
44
43
10
100
200
300
46
20
22
21
25
24
23
30
35a
31
34
33b
33c
45
11
14a
14
33a
12
42
13

Fig.10

Fig.11

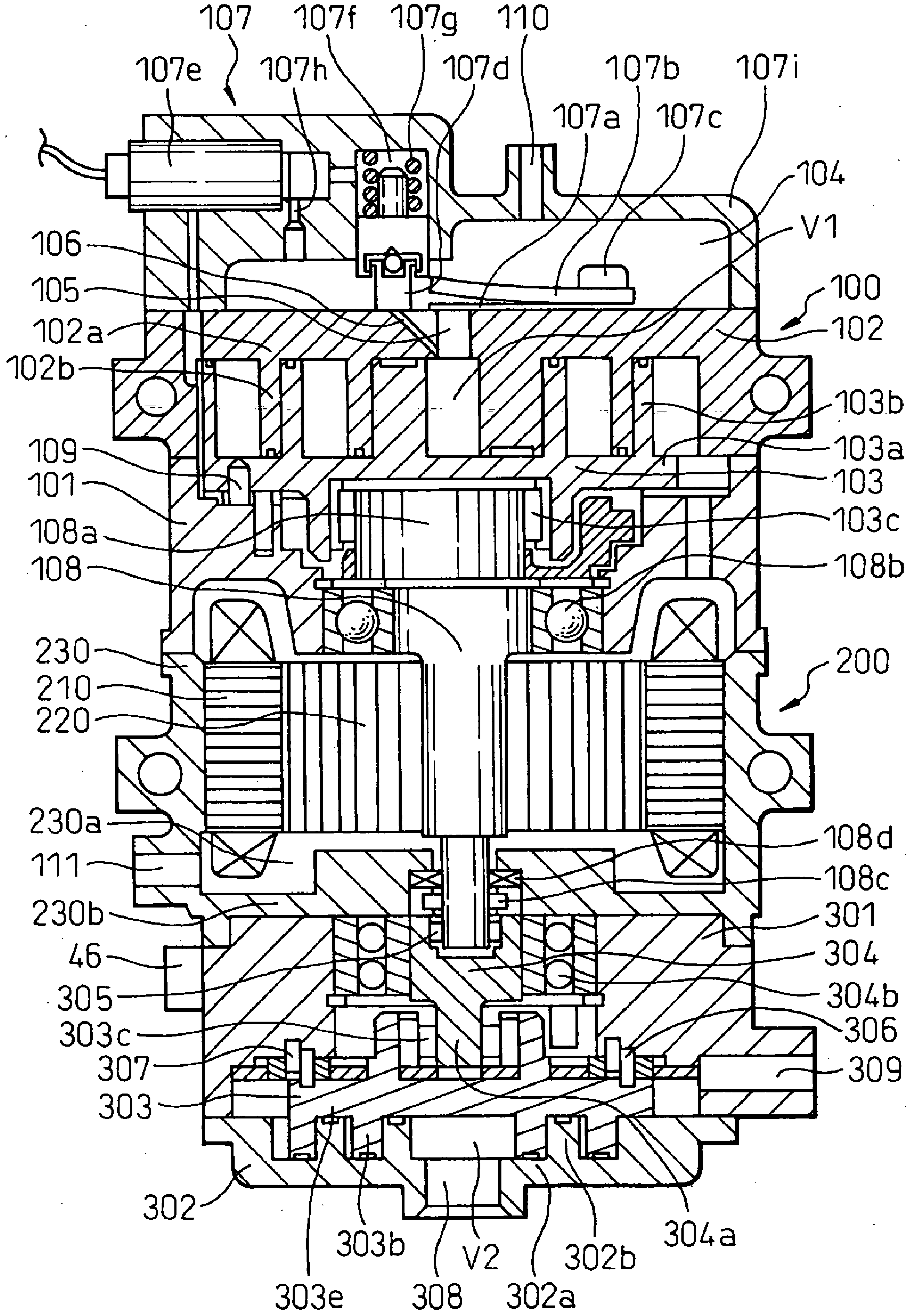
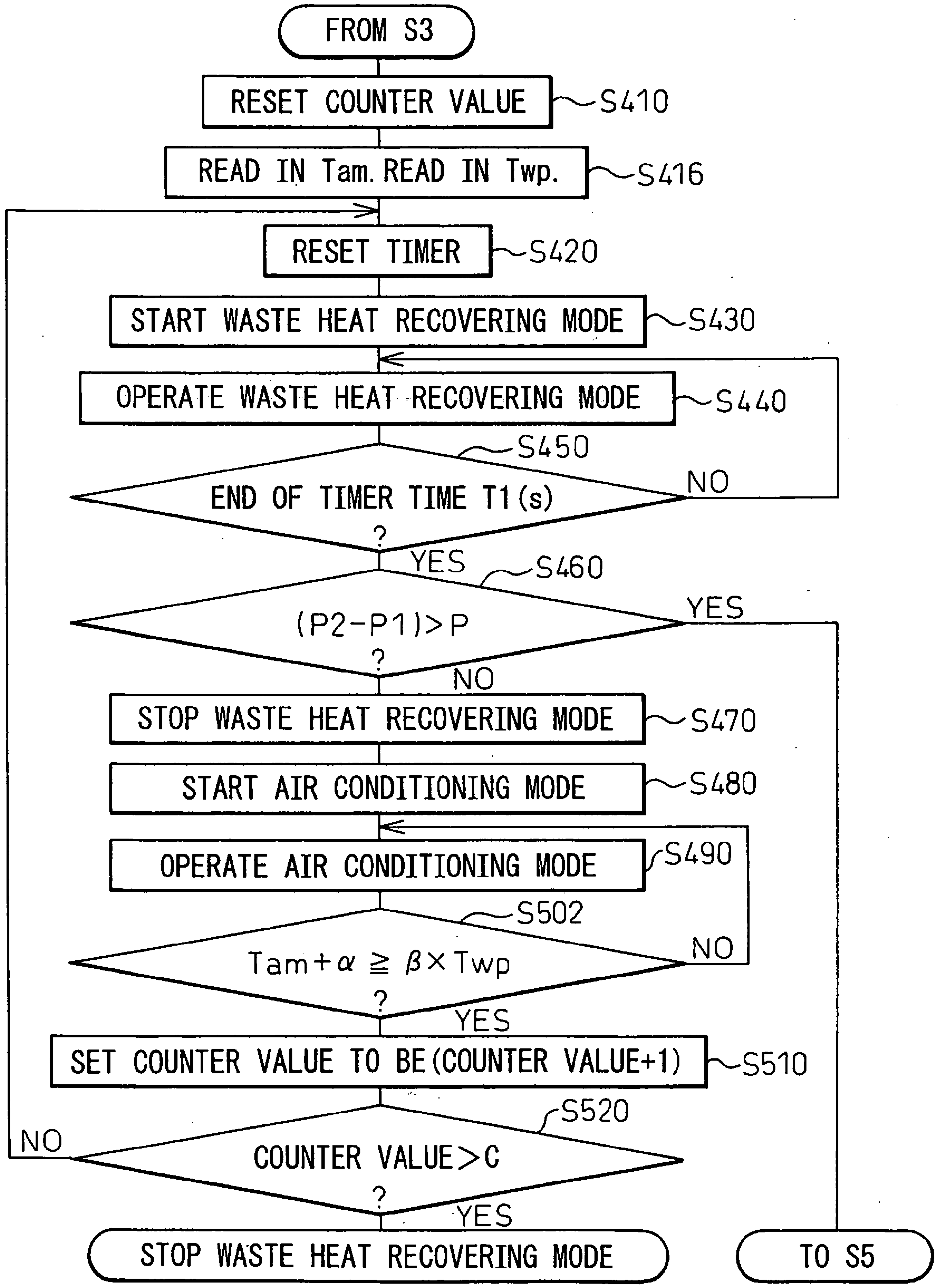

107
107f
107g
110
107e
107h
107d
107b
107i
107a
107c
104
V1
106
105
100
102a
102
102b
103b
103a
109
103
101
103c
108a
108
108b
230
200
210
220
230a
108d
111
108c
230b
301
46
304
305
304b
303c
306
307
309
303
302
304a
303b
V2
302b
303e
308
302a

Fig.12



FROM S3
RESET COUNTER VALUE
S410
READ IN Tam. READ IN Twp.
S416
RESET TIMER
S420
START WASTE HEAT RECOVERING MODE
S430
OPERATE WASTE HEAT RECOVERING MODE
S440
S450
END OF TIMER TIME T1 (s)
?
NO
YES
S460
(P2-P1)>P
?
YES
NO
STOP WASTE HEAT RECOVERING MODE
S470
START AIR CONDITIONING MODE
S480
OPERATE AIR CONDITIONING MODE
S490
S502
Tam+α ≧ β×Twp
?
NO
YES
SET COUNTER VALUE TO BE (COUNTER VALUE+1)
S510
S520
COUNTER VALUE>C
?
NO
YES
STOP WASTE HEAT RECOVERING MODE
TO S5

Fig.13

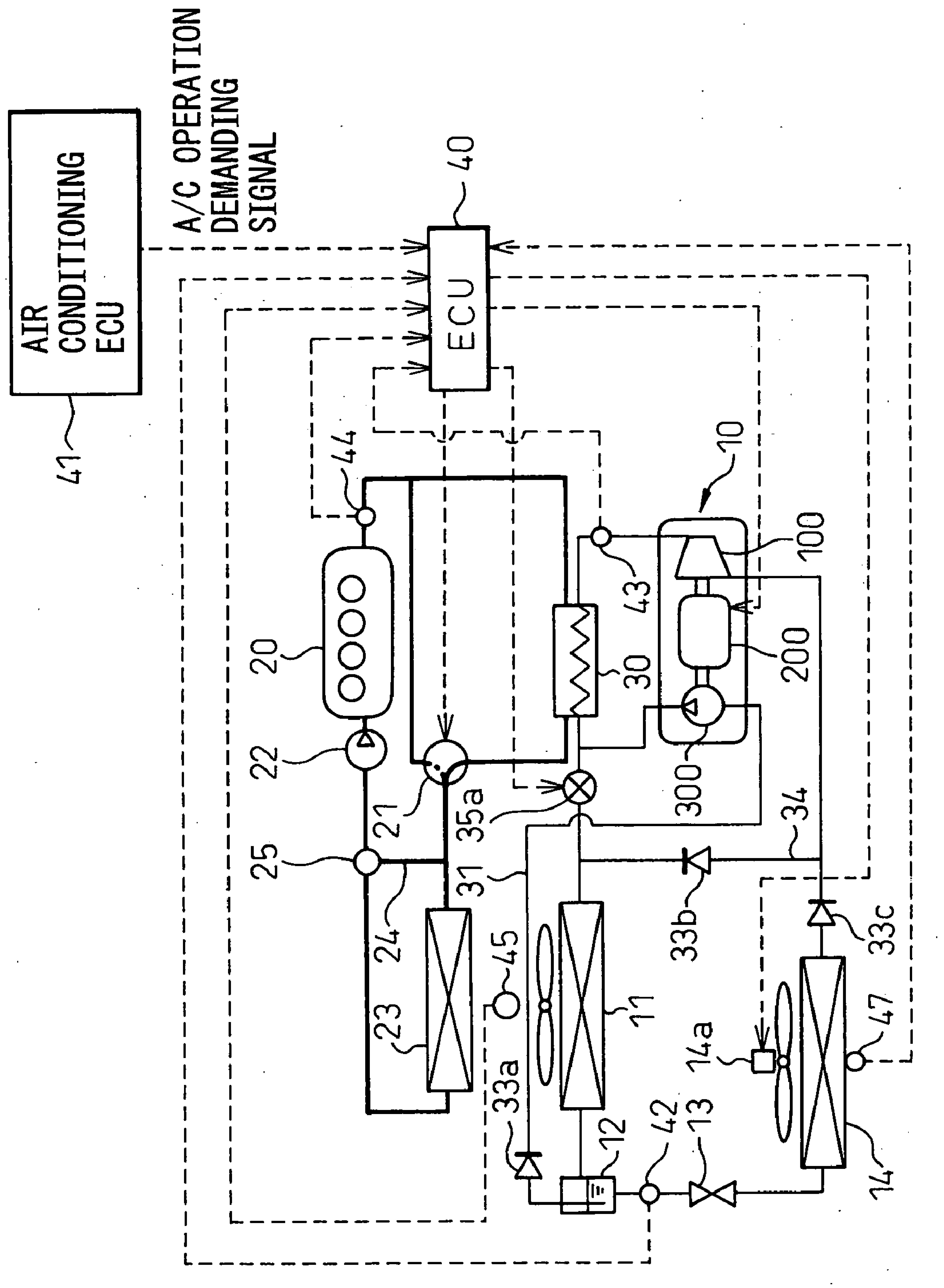

AIR CONDITIONING ECU
A/C OPERATION DEMANDING SIGNAL
ECU
41
40
44
43
10
100
200
300
20
22
21
25
24
23
30
35a
31
34
33a
33b
33c
45
11
12
42
13
14
14a
47

Fig.14

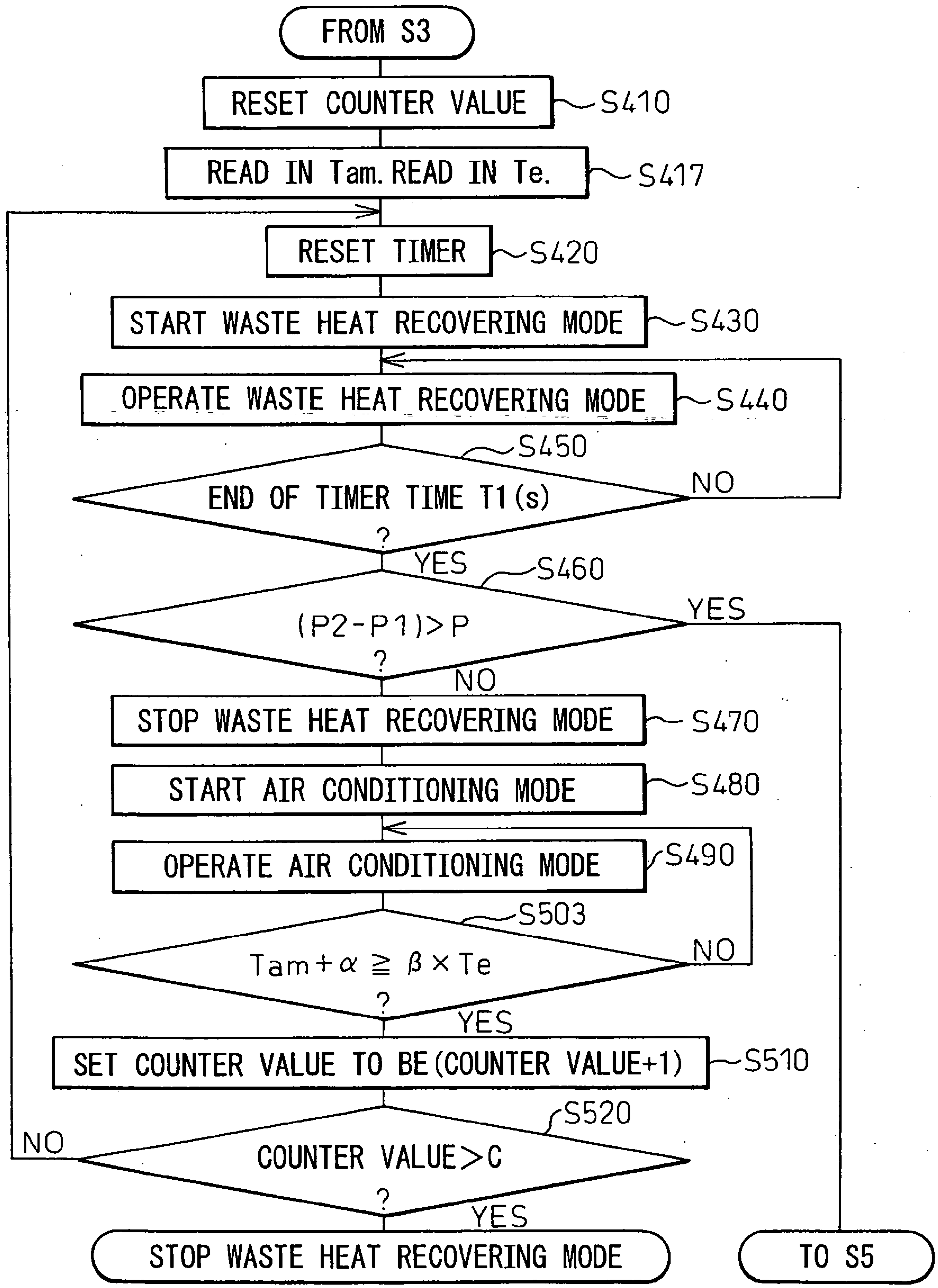
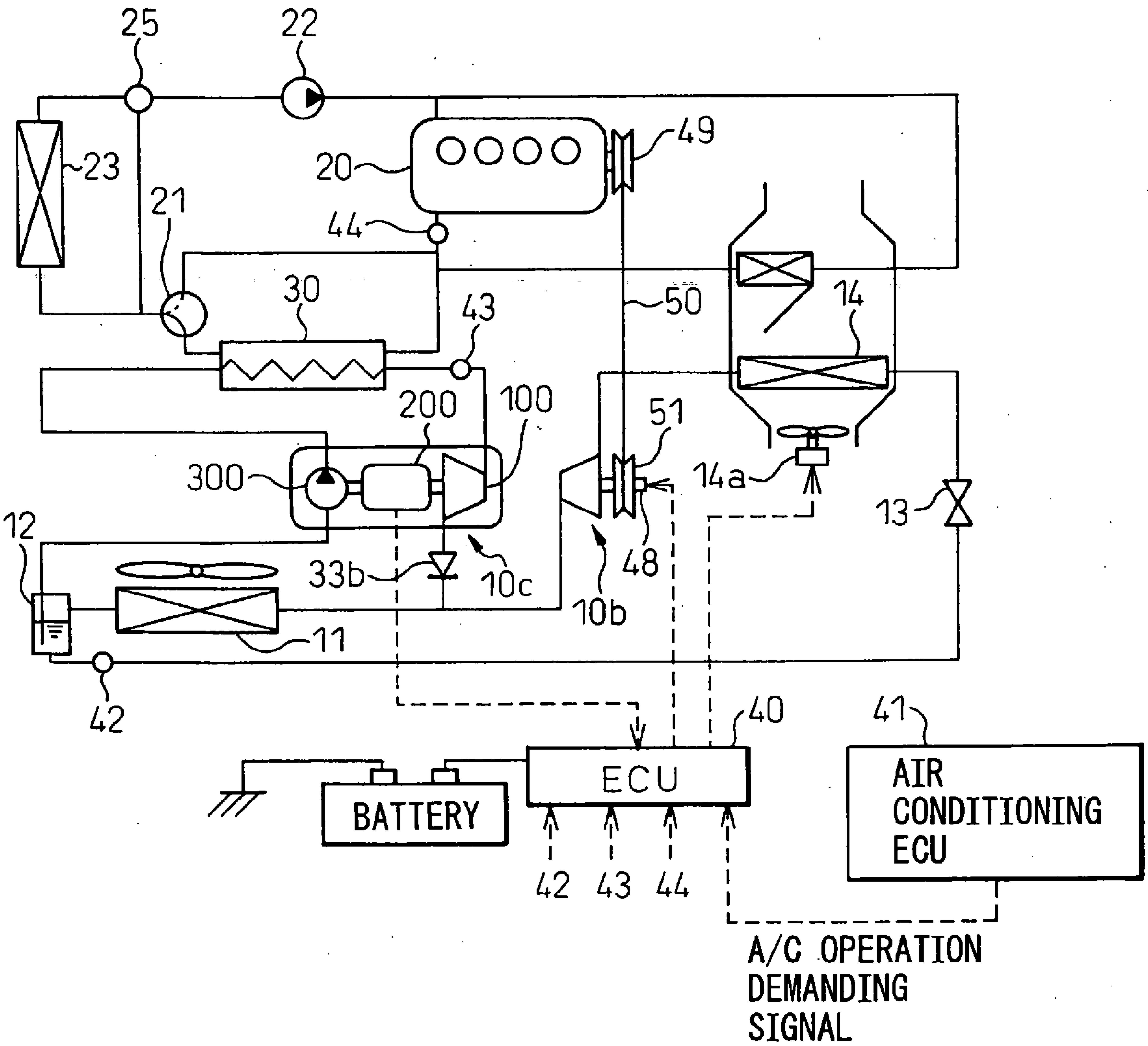

FROM S3
RESET COUNTER VALUE
S410
READ IN Tam. READ IN Te.
S417
RESET TIMER
S420
START WASTE HEAT RECOVERING MODE
S430
OPERATE WASTE HEAT RECOVERING MODE
S440
S450
END OF TIMER TIME T1(s) ?
NO
YES
S460
(P2-P1)>P ?
YES
NO
STOP WASTE HEAT RECOVERING MODE
S470
START AIR CONDITIONING MODE
S480
OPERATE AIR CONDITIONING MODE
S490
S503
Tam+α ≧ β×Te ?
NO
YES
SET COUNTER VALUE TO BE (COUNTER VALUE+1)
S510
S520
NO
COUNTER VALUE>C ?
YES
STOP WASTE HEAT RECOVERING MODE
TO S5

Fig.15



25
22
23
20
49
21
44
30
50
14
43
200
100
51
300
14a
13
12
48
33b
10c
10b
11
42
40
41
ECU
AIR CONDITIONING ECU
BATTERY
42 43 44
A/C OPERATION DEMANDING SIGNAL

Fig.16

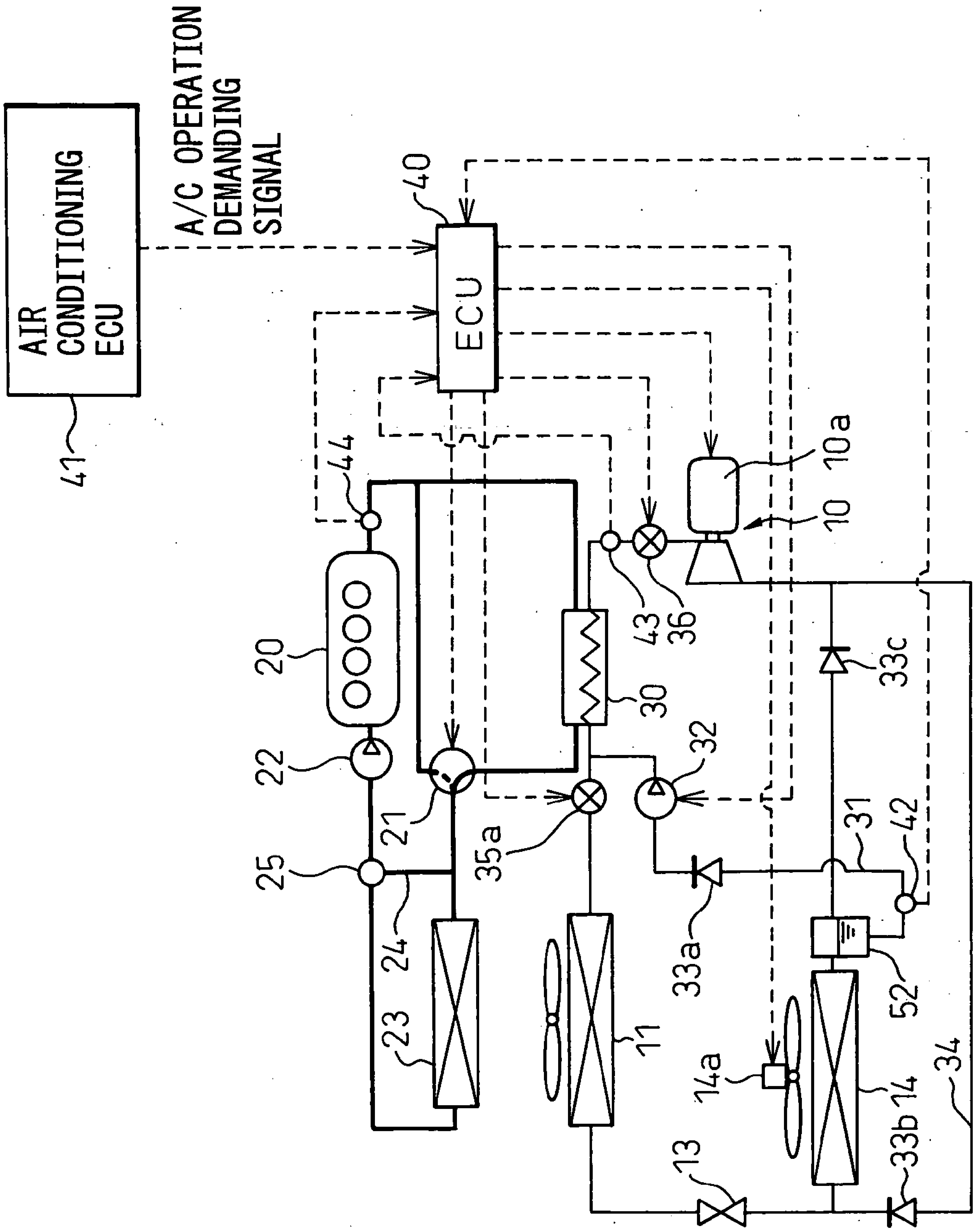
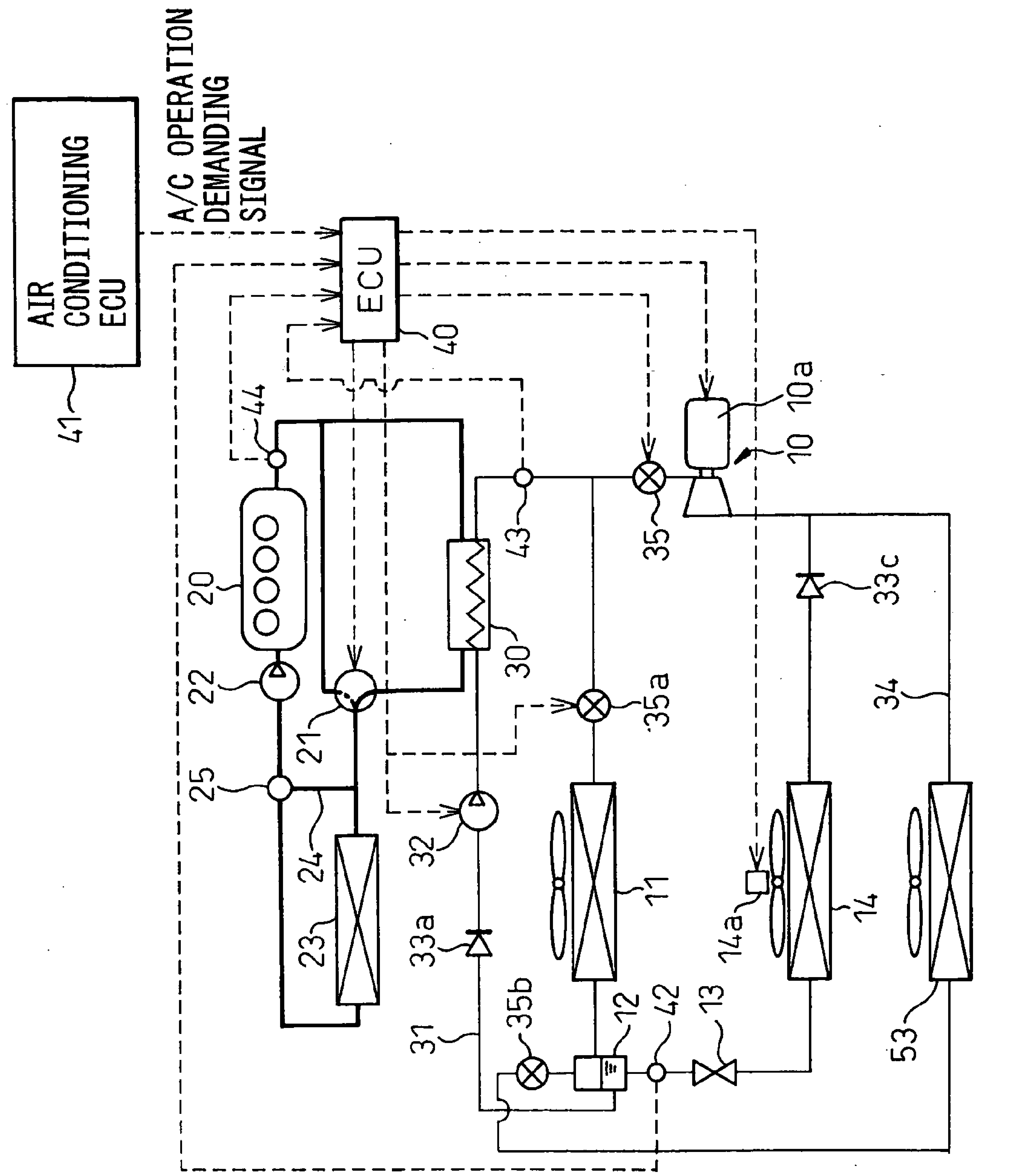

AIR CONDITIONING ECU
A/C OPERATION DEMANDING SIGNAL
ECU
41
40
44
10a
10
43
36
20
30
33c
22
21
32
35a
31
42
25
24
33a
52
23
11
14a
14
34
13
33b

Fig.17


AIR CONDITIONING ECU
A/C OPERATION DEMANDING SIGNAL
ECU
41
40
44
20
22
21
25
24
23
30
43
35
10
10a
33c
35a
34
32
11
14a
14
33a
31
35b
12
42
13
53

HEAT CYCLE

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to Rankine cycle in which power is obtained from heat energy given to a refrigerant.

[0003] 2. Description of the Related Art

[0004] Conventionally, a heat cycle device referred to as a refrigerating cycle device has been known, and a heat cycle device referred to as Rankine cycle device has also been known. According to the refrigerating cycle device, when refrigerant is compressed being given power so as to transfer heat, a high or a low temperature can be provided. According to Rankine cycle device, power can be obtained from heat energy given to refrigerant. For example, a Rankine cycle device is disclosed in Japanese Granted Patent Publication No. 3356449 and of Japanese Unexamined Utility Model Publication No. 63-92021. These Rankine cycle device can be used as an electric power generating device in which waste heat is recovered so as to generate electric power. Alternatively, this Rankine cycle device can be used as an automotive power generating device in which waste heat of an internal combustion engine of an automobile is recovered so as to generate automotive power.

[0005] In Japanese Patent Application No. 2003-390893, the present inventors proposed an air conditioner (refrigerating cycle) for vehicle use having Rankine cycle for recovering heat energy from waste heat exhausted from an engine mounted on a vehicle. This air conditioner for vehicle use will be referred to as an example of the prior application.

[0006] This example of the prior application will be explained below by referring to **FIG. 1**. The example of the prior application includes components to compose a refrigerating cycle device to provide an air-conditioning operation mode (refrigerating cycle operation) in which the refrigerant is made to flow in the order of the reversible rotary machine **10**→the radiator **11**→the gas-liquid separator **12**→the decompressor **13**→the evaporator **14**.

[0007] Further, this prior application includes a liquid-phase pipe **31** for connecting the pipe composing the refrigerating cycle with the vapor generator **30**; and a liquid pump **32**, which is arranged in the liquid-phase pipe **31**, for moving the liquid-phase refrigerant to the vapor generator **30**. The prior application further includes: components to compose a Rankine cycle device to provide a waste heat recovery operation mode (Rankine cycle operation) in which the refrigerant is made to flow in the order of the liquid pump **32**→the vapor generator **30**→the reversible rotary machine **10**→the radiator **11**.

[0008] Due to the foregoing, at the time of the air conditioning operation mode, the vehicle room can be air-conditioned, and at the time of the waste heat recovering operation mode, the waste heat exhausted from the engine **20** can be recovered by the reversible rotary machine **10** in the form of power.

[0009] However, in the example of the prior application, the following cases may occur. In the case where a quantity of the refrigerant staying the gas-liquid separator **12** is small on the basis of a state of operation of the air conditioner (the refrigerating cycle) for vehicle use or in the case where the liquid-phase refrigerant inside the liquid pump **32** is evaporated by a rise in the temperature inside the liquid pump **32**, bubbles of the gas-phase refrigerant may enter into the inside of the liquid pump **32**, and the liquid-phase refrigerant can not be moved to the vapor generator **30** even when the liquid pump **32** is operated. Due to the foregoing, there is a possibility that it becomes impossible to normally operate the waste heat recovering operation mode (Rankine cycle).

[0010] Even in the case where the liquid pump **32** can move the liquid-phase refrigerant to the vapor generator **30**, the operation efficiency of the liquid pump **32** is lowered by the bubbles of the gas-phase refrigerant mixed into the liquid pump **32**. In other words, a quantity of the refrigerant to be conveyed is decreased with respect to the power consumption of the pump. That is, a quantity of the refrigerant to be supplied to the vapor generator **30** is decreased, and there is a possibility that the efficiency of a Rankine cycle may be lowered.

[0011] One object of the present invention is to reduce the possibility of the occurrence of an incomplete start of a Rankine cycle device.

[0012] Another object of the present invention is to reduce the possibility of the deterioration of the efficiency of a Rankine cycle device.

[0013] Still another object of the present invention is to make it possible to stably operate a Rankine cycle device by utilizing the function of a refrigerating cycle device in the heat cycle device which can be used for both the Rankine cycle device and the refrigerating cycle device.

SUMMARY OF THE INVENTION

[0014] In order to accomplish the above objects, the present invention employs the following technical means.

[0015] The invention described in aspect **1** employs a heat cycle device comprising: a rotary fluid machine (**10**, **10***b*, **10***c*) for mutually converting between fluid energy of refrigerant and mechanical rotary energy; a condenser (**11**) for condensing the refrigerant supplied from the rotary fluid machine (**10**, **10***b*, **10***c*); a Rankine cycle system (**10**, **11**, **30**, **32**, **300**) including a fluid pump (**32**, **300**) for moving the refrigerant supplied from the condenser (**11**) and also including a vapor generator (**30**) for heating the refrigerant, which has been moved by the fluid pump, by the heat of a heat generating body (**20**); a refrigerating cycle system (**10**, **11**, **13**, **14**) including an evaporator (**14**) for evaporating the refrigerant supplied from the condenser (**11**); and a control unit (**40**) for conducting a refrigerant condensing operation in which the refrigerant in the refrigerating cycle system (**10**, **11**, **13**, **14**) is compressed by the rotary fluid machine (**10**, **10***b*, **10***c*) at the time of operating the Rankine cycle system (**10**, **11**, **30**, **32**, **300**) and the compressed refrigerant is condensed by the condenser (**11**).

[0016] According to this invention, when a Rankine cycle system is operated, the refrigerant in the refrigerating cycle system is compressed by the rotary fluid machine and condensed by the condenser. Therefore, the liquid-phase refrigerant can be supplied to a Rankine cycle system. As a result, it is possible to suppress the occurrence of an incomplete start of a Rankine cycle system. Further, it is possible to suppress the deterioration of the efficiency during the operation.

[0017] The invention described in aspect **2** employs a heat cycle device according to aspect **1**, the control unit **(40)** including: a judging means for judging whether or not the Rankine cycle system **(10, 11, 30, 32, 300)** is normally operated after the operation of the Rankine cycle system **(10, 11, 30, 32, 300)** was started; and a control means for continuing the operation of the Rankine cycle system **(10, 11, 30, 32, 300)** in the case where it is judged that the Rankine cycle system **(10, 11, 30, 32, 300)** is normally operated, and for conducting the refrigerant condensing operation in the case where it is judged that the Rankine cycle system **(10, 11, 30, 32, 300)** is not normally operated.

[0018] According to this invention, when it is judged that the Rankine cycle system is not normally operated, the refrigerant condensing operation is executed. Therefore, the liquid-phase refrigerant can be supplied to the Rankine cycle system. Accordingly, it is possible to suppress the occurrence of an abnormal state caused by lack of the liquid-phase refrigerant.

[0019] According to one embodiment of the present invention, the refrigerant condensing operation can be executed when the operation of the Rankine cycle system is temporarily stopped. According to another embodiment of the present invention, the refrigerant condensing operation can be executed simultaneously while the operation of the Rankine cycle system is being continued.

[0020] The invention described in aspect **3** employs a heat cycle device according to aspect **2**, further comprising: an upstream refrigerant pressure sensor **(42)** for measuring pressure of the refrigerant, arranged in an upstream side portion of the refrigerant flow of the fluid pump **(32, 300)**; and a downstream refrigerant pressure sensor **(43)** for measuring pressure of the refrigerant, arranged in a downstream side portion of the refrigerant flow of the fluid pump **(32, 300)**, wherein the judging means judges that the Rankine cycle **(10, 11, 30, 32, 300)** is normally operated at the time of operating the Rankine cycle system **(10, 11, 30, 32, 300)** in the case where a difference (P2–P1) between the detected pressure (P2) of the downstream refrigerant pressure sensor **(43)** and the detected pressure (P1) of the upstream refrigerant pressure sensor **(42)** is larger than the predetermined pressure (P), and the judging means judges that the Rankine cycle **(10, 11, 30, 32, 300)** is not normally operated at the time of operating the Rankine cycle system **(10, 11, 30, 32, 300)** in the case where the difference (P2–P1) between the detected pressure (P2) of the downstream refrigerant pressure sensor **(43)** and the detected pressure (P1) of the upstream refrigerant pressure sensor **(42)** is not more than the predetermined pressure (P).

[0021] According to this invention, it is possible to appropriately judge an abnormality of the Rankine cycle system caused by a lack of the liquid-phase refrigerant.

[0022] The invention described in aspect **4** employs a heat cycle device according to aspect **2**, wherein the judging means judges that the Rankine cycle system **(10, 11, 30, 32, 300)** is normally operated in the case where a work-load of the liquid pump **(32, 300)** is heavier than a predetermined work-load at the time of operating the Rankine cycle system **(10, 11, 30, 32, 300)**, and the judging means judges that the Rankine cycle system **(10, 11, 30, 32, 300)** is not normally operated in the case where the work-load of the liquid pump **(32, 300)** is not more than the predetermined work-load at the time of operating the Rankine cycle system **(10, 11, 30, 32, 300)**.

[0023] According to this invention, it is possible to appropriately judge an abnormality of the Rankine cycle system caused by a lack of the liquid-phase refrigerant.

[0024] The invention described in aspect **5** employs a heat cycle device according to aspect **4**, wherein the liquid pump is an electric liquid pump **(32)**, and the work-load is represented by electric power consumed by the electric liquid pump **(32)**.

[0025] According to this invention, it is possible to judge an abnormality of the Rankine cycle system by a simple structure.

[0026] The invention described in aspect **6** employs a heat cycle device according to one of aspects **1** to **5**, further comprising an air blowing means **(14*a*)** for blowing air, the temperature of which is adjusted by the refrigerating cycle system **(10, 11, 13, 14)**, wherein the control unit **(40)** conducts the refrigerant condensing operation under the condition that the air blowing means **(14*a*)** is not operated.

[0027] According to this invention, the refrigerant condensing operation can be provided when the cooling device or the refrigerating device in the refrigerating cycle system is operated, and a state in which the blast means is not operated is provided by the means for providing the operation in which the liquid-phase refrigerant is increased. As a result, the liquid-phase refrigerant can be positively supplied.

[0028] The invention described in aspect **7** employs a heat cycle device according to one of aspects **1** to **6**, further comprising a sensor **(46, 47)** for measuring a physical value having a correlation with the temperature of the refrigerant inside the liquid pump **(32, 300)**, wherein the control unit **(40)** determines the time, which has passed from the start of the refrigerant condensing operation to when the physical value measured by the sensor **(46, 47)** shows that the refrigerant inside the refrigerant pump **(32)** is in the supercooled state, to be the continuation time for continuing the refrigerant condensing operation.

[0029] According to this invention, it is possible to suppress an excessive refrigerant condensing operation.

[0030] The invention described in aspect **8** employs a heat cycle device according to one of aspects **1** to **6**, wherein the condenser **(11)** is a heat exchanger for condensing the refrigerant by exchanging heat between the outside air and the refrigerant, the heat cycle device further comprising: an outside air temperature sensor **(45)** for measuring the temperature of the outside air; and a sensor **(46, 47)** for measuring a physical value having a correlation with the temperature of the refrigerant inside the liquid pump **(32, 300)**, wherein the control unit **(40)** determines a target temperature at which the refrigerant inside the refrigerant pump **(32)** is in the supercooled state according to the outside air temperature measured by the outside air temperature sensor **(45)**, and further the control unit **(40)** determines the time, which has passed from the start of the refrigerant condensing operation to when the physical value measured by the sensor **(46, 47)** becomes the target temperature, to be the continuation time for continuing the refrigerant condensing operation.

[0031] According to this invention, it is possible to suppress an excessive refrigerant condensing operation.

[0032] The invention described in aspect **9** employs a heat cycle device according to aspect **7** or **8**, wherein the sensor is a temperature sensor **(46)** for measuring the temperature of the housing of the refrigerant pump.

[0033] According to this invention, it is possible to provide a simple structure of the heat cycle device.

[0034] The invention described in aspect **10** employs a heat cycle device according to aspect **7** or **8**, wherein the sensor is a temperature sensor **(47)** for measuring the temperature of air immediately after heat was exchanged with the refrigerant in the evaporator **(14)**.

[0035] According to this invention, it is possible to provide a simple structure of the heat cycle device.

[0036] The invention described in aspect **11** employs a heat cycle device according to one of aspects **1** to **6**, wherein the condenser **(11)** is a heat exchanger for condensing the refrigerant by exchanging heat between the outside air and the refrigerant, further comprising an outside air temperature sensor **(45)** for measuring the outside air temperature, wherein the control unit **(40)** includes a continuation time setting means for determining the continuation time (T**21**), in which the refrigerant condensing operation is continued, according to the temperature measured by the outside air temperature sensor **(45)**.

[0037] According to this invention, it is possible to suppress an excessive refrigerant condensing operation.

[0038] The invention described in aspect **12** employs a heat cycle device according to one of aspects **1** to **11**, wherein the rotary fluid machine is a reversible rotary machine **(10)** capable of being reversibly operated as an expansion machine for obtaining power when the refrigerant is expanded, or operated as a compressor for compressing the refrigerant when power is supplied to the compressor.

[0039] According to this invention, when the rotary fluid machine, which can reversibly function as an expansion machine or a compressor, is used, the refrigerant condensing operation can be executed when the rotary fluid machine functions as a compressor at the time of operating the Rankine cycle system.

[0040] The invention described in aspect **13** employs a heat cycle device according to aspect **12**, wherein the control unit **(40)** conducts the refrigerant condensing operation by operating the rotary fluid machine as a compressor before the rotary fluid machine is operated as an expansion machine and the operation of the Rankine cycle system **(10, 11, 30, 32, 300)** is started.

[0041] According to this invention, when the rotary fluid machine is made to function reversibly, the refrigerant condensing operation can be realized before the operation of the Rankine cycle system is started.

[0042] The invention described in aspect **14** employs a heat cycle device according to aspect **12** or **13**, wherein the reversible rotary machine **(10)** is integrated with the fluid pump **(32, 300)** into one body, and the fluid pump **(32, 300)** is arranged so that it can be cooled by the gas-phase refrigerant sucked into the reversible rotary machine **(10)** at the time of operating the refrigerating cycle system **(10, 11, 13, 14)**.

[0043] According to this invention, the temperature of the liquid pump can be decreased when the refrigerating cycle system is operated.

[0044] The invention described in aspect **15** employs a heat cycle device according to one of aspects **1** to **11**, wherein the rotary fluid machine includes an expansion machine **(10*c*)** for expanding the refrigerant to obtain power and a compressor **(10*b*)** for compressing the refrigerant when power is supplied to the compressor.

[0045] According to this invention, when both the expansion machine and the compressor are provided, the refrigerant condensing operation can be executed by using the compressor function at the time of operating Rankine cycle system.

[0046] The invention described in aspect **16** employs a heat cycle device according to aspect **15**, wherein the control unit **(40)** conducts the refrigerant condensing operation by operating the compressor **(10*b*)** before the expansion machine **(10*c*)** is operated and the operation of the Rankine cycle system **(10, 11, 30, 32, 300)** is started.

[0047] According to this invention, it is possible to realize the refrigerant condensing operation before the operation of Rankine cycle system is conducted.

[0048] The invention described in aspect **17** employs a heat cycle device according to aspect **15**, wherein the control unit **(40)** conducts the refrigerant condensing operation by operating the compressor **(10*b*)** simultaneously when the expansion machine **(10*c*)** is operated and the operation of the Rankine cycle system **(10, 11, 30, 32, 300)** is started.

[0049] According to this invention, at the time of starting the Rankine cycle system, the refrigerant condensing operation can be realized. The refrigerant condensing operation can be executed in parallel with the operation of the Rankine cycle system.

[0050] The invention described in aspect **18** employs a heat cycle device comprising: a Rankine cycle system **(10, 11, 30, 32, 300)** including a fluid pump **(32, 300)** for moving refrigerant and also including a vapor generator **(30)** for heating the refrigerant, which has been moved by the fluid pump, by the heat of a heat generating body **(20)**; a refrigerating cycle system **(10, 11, 13, 14)** including an evaporator **(14)** for evaporating the refrigerant; and a control unit **(40)** for conducting the cooling operation for cooling the fluid pump by operating the refrigerating cycle system **(10, 11, 13, 14)** at the time of operating the Rankine cycle system **(10, 11, 30, 32, 300)**.

[0051] According to this invention, when the Rankine cycle system is operated, the liquid pump can be cooled. Therefore, it is possible to prevent the occurrence of a problem caused by the gas-phase refrigerant.

[0052] The invention described in aspect **19** employs a heat cycle device according to aspect **18**, wherein the refrigerating cycle system includes a compressor **(10, 10*b*)**, and the fluid pump **(32, 300)** is arranged so that it can be cooled by the gas-phase refrigerant sucked into the compressor **(10, 10*b*)**.

[0053] According to this invention, the rotary machine can be integratedly arranged. Further, in this constitution, it is possible to cool the liquid pump.

[0054] The invention described in aspect **20** employs a heat cycle device according to aspect **18** or **19**, wherein the control unit **(40)** conducts the cooling operation before the operation of the Rankine cycle system **(10, 11, 30, 32, 300)** is started and/or while the Rankine cycle system **(10, 11, 30, 32, 300)** is being operated.

[0055] According to this invention, the liquid pump can be cooled. Therefore, it is possible to prevent the occurrence of a problem caused by the gas-phase refrigerant. When the cooling operation is executed before the operation of the Rankine cycle system is started, it is possible to reduce the gas-phase refrigerant in the liquid pump. Therefore, the occurrence of an incomplete start of the Rankine cycle system can be suppressed. When the cooling operation is executed in the beginning of the start of the Rankine cycle system, that is, when the cooling operation is executed immediately after the Rankine cycle system is started, it is possible to suppress the occurrence of an incomplete start of the Rankine cycle system. When the cooling operation is executed during the operation of the Rankine cycle system, it is possible to suppress a deterioration of the efficiency of the Rankine cycle system.

[0056] The present invention has been devised in order to accomplish the above objects. The invention described in aspect **21** provides a heat cycle comprising: a refrigerating cycle **(10, 11, 13, 14)** in which refrigerant of low pressure is evaporated so as to absorb heat from a low temperature side and the evaporated gas-phase refrigerant is compressed so as to raise the temperature and the heat absorbed from the low temperature side is radiated to a high temperature side so as to condense the gas-phase refrigerant into the liquid-phase refrigerant; a Rankine cycle **(10, 11, 30, 32)** including a vapor generator **(30)** for generating the gas-phase refrigerant by heating the liquid-phase refrigerant of the refrigerating cycle **(10, 11, 12, 14)** by the waste heat of a heat generating body **(20)**, also including a liquid-phase pipe **(31)** for connecting a liquid-phase takeout section **(12, 52)** for taking out the liquid-phase refrigerant from the refrigerating cycle **(10, 11, 13, 14)** with the vapor generator **(30)**, also including a liquid pump **(32, 300)** arranged in the liquid-phase pipe **(31)**, for moving the liquid-phase refrigerant to the vapor generator **(30)**, also including an expansion machine **(10)** for obtaining power by expanding the gas-phase refrigerant, and also including a condenser **(11)** for condensing the gas-phase refrigerant which has been expanded by the expansion machine **(10)**; a control means **(40)** for controlling a state of operation of the refrigerating cycle **(10, 11, 13, 14)** and also controlling a state of operation of a Rankine cycle **(10, 11, 30, 32, 300)**; and a change-over means **(35*a*, 36)** for changing over between a case in which a Rankine cycle **(10, 11, 30, 32, 300)** is operated and a case in which the refrigerating cycle **(10, 11, 13, 14)** is operated by a signal sent from the control means **(40)**, wherein the control means **(40)** operates Rankine cycle **(10, 11, 30, 32, 300)** in such a manner that the refrigerating cycle **(10, 11, 13, 14)** is operated by the refrigerant condensing operation so as to condense the gas-phase refrigerant into the liquid-phase refrigerant and then the Rankine cycle **(10, 11, 30, 32, 300)** is operated.

[0057] Due to the foregoing, when the refrigerating cycle **(10, 11, 13, 14)** is operated before the Rankine cycle **(10, 11, 30, 32, 300)** is operated, the gas-phase refrigerant can be condensed to the liquid-phase refrigerant. As a result, the liquid pump **(32, 300)** can positively suck the liquid-phase refrigerant from the liquid-phase refrigerant takeout section **(12, 52)** and move it to the vapor generator **30**. Accordingly, the Rankine cycle **(10, 11, 30, 32, 300)** can be normally started.

[0058] In addition, it is possible to suppress a deterioration of the operation efficiency of the liquid pump **(32, 300)** caused by bubbles in the gas-phase refrigerant. Therefore, it is possible to prevent the efficiency of Rankine cycle from being deteriorated.

[0059] The invention described in aspect **22** provides a heat cycle comprising: a refrigerating cycle **(10, 11, 13, 14)** in which refrigerant at low pressure is evaporated so as to absorb heat from a low temperature side and the evaporated gas-phase refrigerant is compressed so as to raise the temperature and the heat absorbed from the low temperature side is radiated to a high temperature side so as to condense the gas-phase refrigerant into the liquid-phase refrigerant; a Rankine cycle **(10, 11, 30, 32, 300)** including a vapor generator **(30)** for generating the gas-phase refrigerant by heating the liquid-phase refrigerant of the refrigerating cycle **(10, 11, 12, 14)** by the waste heat of a heat generating body **(20)**, also including a liquid-phase pipe **(31)** for connecting a liquid-phase takeout section **(12, 52)** for taking out the liquid-phase refrigerant from the refrigerating cycle **(10, 11, 13, 14)** with the vapor generator **(30)**, also including a liquid pump **(32, 300)** arranged in the liquid-phase pipe **(31)**, for moving the liquid-phase refrigerant to the vapor generator **(30)**, also including an expansion machine **(10)** for obtaining power by expanding the gas-phase refrigerant, and also including a condenser **(11)** for condensing the gas-phase refrigerant which has been expanded by the expansion machine **(10)**; a control means **(40)** for controlling a state of operation of the refrigerating cycle **(10, 11, 13, 14)** and also controlling a state of operation of the Rankine cycle **(10, 11, 30, 32, 300)**; and a change-over means **(35*a*, 36)** for changing over between the case in which the Rankine cycle **(10, 11, 30, 32, 300)** is operated and the case in which the refrigerating cycle **(10, 11, 13, 14)** is operated by a signal sent from the control means **(40)** wherein, after the Rankine cycle **(10, 11, 30, 32, 300)** has been operated, the control means **(40)** judges whether or not the Rankine cycle **(10, 11, 30, 32, 300)** is normally operated, the Rankine cycle **(10, 11, 30, 32, 300)** is kept being operated in the case where the operation of the Rankine cycle **(10, 11, 30, 32, 300)** has been judged to be normal, and in the case where the operation of the Rankine cycle **(10, 11, 30, 32, 300)** has been judged to be not normal, the control means **(40)** operates in such a manner that it stops operation of the Rankine cycle **(10, 11, 30, 32, 300)** and operates the refrigerating cycle **(10, 11, 13, 14)** so as to conduct the refrigerant condensing operation for recovering the liquid-phase refrigerant and Rankine cycle **(10, 11, 30, 32, 300)** is operated again after the refrigerant condensing operation.

[0060] Due to the foregoing, and only when Rankine cycle **(10, 11, 30, 32, 300)** is abnormally operated, the refrigerating cycle **(10, 11, 13, 14)** is operated and the same effect as that of aspect **1** can be exhibited. Therefore, it is possible to prevent the occurrence of a case in which the refrigerating cycle is unnecessarily operated before the Rankine cycle **(10, 11, 30, 32, 300)** is operated.

[0061] The invention described in aspect **23** provides a heat cycle according to aspect **22**, further comprising: an upstream refrigerant pressure sensor **(42)** arranged in a portion on the upstream side of the flow of the refrigerant of the liquid pump **(32, 300)**, the upstream refrigerant pressure sensor **(42)** outputting a signal of the refrigerant pressure to the control means **(40)**; and a downstream refrigerant pressure sensor **(43)** arranged in a portion on the downstream side of the flow of the refrigerant of the liquid pump **(32; 300)**, the downstream refrigerant pressure sensor **(43)** outputting a signal of the refrigerant pressure to the control means **(40)** wherein, in the case where a value (P2–P1), which is obtained when a detected pressure value (P1) of the upstream refrigerant pressure sensor **(42)** is subtracted from a detected pressure value (P2) of the downstream refrigerant pressure sensor **(43)**, is higher than a predetermined pressure value (P) when the Rankine cycle **(10, 11, 30, 32, 300)** is operated, the control means **(40)** judges that the Rankine cycle **(10, 11, 30, 32, 300)** is normally operated, and in the case where the value (P2–P1), which is obtained when the detected pressure value (P1) of the upstream refrigerant pressure sensor **(42)** is subtracted from the detected pressure value (P2) of the downstream refrigerant pressure sensor **(43)**, is not more than the predetermined pressure value (P), the control means **(40)** judges that the Rankine cycle **(10, 11, 30, 32, 300)** is not normally operated.

[0062] In this connection, when the liquid pump **(32, 300)** is normally operated, the detected pressure (P1) of the upstream refrigerant pressure sensor **(42)** is lower than the detected pressure (P2) of the downstream refrigerant pressure sensor **(43)**. Therefore, and specifically when the difference (P2–P1) is not more than the predetermined pressure (P), it is possible to judge that the Rankine cycle **(10, 11, 30, 32, 300)** is not normally operated.

[0063] According to the invention described in aspect **24**, there is provided a heat cycle according to aspect **22**, in which the control means **(40)** judges that the Rankine cycle **(10, 11, 30, 32, 300)** is normally operated in the case where a work-load of the liquid pump **(32, 300)** is more than a predetermined work-load when the Rankine cycle **(10, 11, 30, 32, 300)** is operated, and the control means **(40)** judges that the Rankine cycle **(10, 11, 30, 32, 300)** is not normally operated in the case where the work-load of the liquid pump **(32, 300)** is not more than the predetermined work-load when the Rankine cycle **(10, 11, 30, 32, 300)** is operated.

[0064] The invention described in aspect **25** provides a heat cycle according to aspect **24**, in which the liquid pump is an electric liquid pump **(32)** driven by electricity, and the work-load is representated by electric power consumed by the electrically driven liquid pump **(32)**. Thus, the work-load can be specifically calculated.

[0065] According to the invention described in aspect **26**, there is provided a heat cycle according to one of aspects **21** to **25**, in which the expansion machine is a reversible rotary machine **(10)** having the function of a compressor for compressing the gas-phase refrigerant in the refrigerating cycle **(10, 11, 13, 14)**, the reversible rotary machine **(10)** is composed being integrated with the liquid pump **(32, 300)**, and the liquid pump **(32, 300)** is cooled by the gas-phase refrigerant sucked into the reversible rotary machine **(10)** at the time of operating the refrigerating cycle **(10, 11, 13, 14)**.

[0066] Due to the foregoing, the liquid pump **(32, 300)** is cooled by the gas-phase refrigerant of low temperature which is sucked when the reversible rotary machine **(10)** functions as a compressor. Therefore, the liquid-phase refrigerant inside the liquid pump **(32, 300)** is supercooled and the refrigerant inside the liquid pump **(32, 300)** can be prevented from evaporating. Accordingly, the liquid-phase refrigerant can be positively moved to the vapor generator **30**.

[0067] As the liquid pump **(32, 300)** and the expansion machine **(10)** are integrated with each other into one body, the parts composing the liquid pump **(32, 300)** and the expansion machine **(10)** can be used in common, which can make the fluid machine smaller in size.

[0068] The invention described in aspect **27** provides a heat cycle according to one of aspects **21** to **26**, further comprising: an air blowing means **(14*a*)** for blowing air conditioned by the refrigerating cycle **(10, 11, 13, 14)**; and an operation demand means **(41)** for demanding the operation of the refrigerating cycle wherein, in the case of conducting the refrigerant condensing operation, the control means **(40)** conducts the refrigerant condensing operation without operating the air blowing means **(14*a*)** when the operation of the refrigerating cycle **(10, 11, 13, 14)** is not demanded by the operation demand means **(41)**.

[0069] Due to the foregoing, in the refrigerant condensing operation, in which the refrigerating cycle **(10, 11, 13, 14)** is operated even when an operator of the heat cycle do not demand the operation of the refrigerating cycle **(10, 11, 13, 14)**, a blast of air, the temperature and humidity of which are adjusted, is not sent. Therefore, the refrigerant condensing operation can be conducted without causing discomfort to the operator. In this connection, in the present invention, the term air-conditioning includes temperature adjustment and humidity adjustment.

[0070] The invention described in aspect **28** provides a heat cycle according to one of aspects **21** to **27**, wherein the condenser **(11)** is a heat exchanger for condensing the gas-phase refrigerant by exchanging heat between the outside air and the refrigerant, the heat cycle further comprises an outside air temperature sensor **(45)** for measuring the temperature of the outside air, the control means **(40)** determines the continuation time (T21) for continuing the refrigerant condensing operation, and the continuation time (T21) is determined on the basis of the outside air temperature.

[0071] In this connection, in the refrigerating cycle, the condensing temperature and refrigerant pressure, at which the gas-phase refrigerant is condensed to the liquid-phase refrigerant, are determined by the outside air temperature. That is, in the case where the outside air temperature is high, the refrigerant pressure is increased so as to raise the condensing temperature. On the other hand, the higher the condensing temperature is, the higher the temperature the liquid-phase refrigerant is supercooled to.

[0072] Therefore, the control means **(40)** is made to determine the continuity time (T21) according to a relation between the outside air temperature and the period of time in which the liquid-phase refrigerant is supercooled by the continuous operation of the refrigerating cycle. As a result, the liquid-phase refrigerant can be positively cooled. Therefore, the liquid pump **(32, 300)** can positively supply the liquid-phase refrigerant to the vapor generator **30**.

[0073] The invention described in aspect **29** provides a heat cycle according to one of aspects **21** to **27**, further comprising a sensor **(46, 47)** for measuring a physical value having a correlation with a temperature of the refrigerant inside the liquid pump **(32, 300)**, wherein the control means **(40)** determines the continuation time in which the refrigerant condensing operation is continued, and the continuation time is the time from the start of the refrigerant condensing operation to when the physical value measured by the sensor **(46, 47)** becomes the temperature at which the refrigerant inside the refrigerant pump **(32)** is supercooled.

[0074] Due to the foregoing, the refrigerant inside the refrigerant pump **(32)** is positively put into the liquid-phase. Therefore, the liquid pump **(32, 300)** can positively supply the liquid-phase refrigerant to the vapor generator **30**.

[0075] For example, when the refrigerant condensing operation is continued until the refrigerant temperature inside the refrigerant pump **(32)** becomes lower than the minimum refrigerant condensing temperature which is determined by the minimum outside air temperature in the heat cycle using environment, the above effect can be exhibited.

[0076] The invention described in aspect **30** provides a heat-cycle according to one of aspects **21** to **27**, wherein the condenser **(11)** is a heat exchanger for condensing the gas-phase refrigerant by exchanging heat between the outside air and the refrigerant, the heat cycle further comprises an outside air temperature sensor **(45)** for measuring the temperature of the outside air and also comprises a sensor **(46, 47)** for measuring a physical value having a correlation with the temperature of the refrigerant inside the liquid pump **(32, 300)**, the control means **(40)** determines the temperature, at which the refrigerant inside the refrigerant pump **(32)** is supercooled by the outside air temperature, and also determines the continuation time in which the refrigerant condensing operation is continued, and the continuation time is the time from the start of the refrigerant condensing operation to when the physical value measured by the sensor **(46, 47)** becomes the temperature at which the refrigerant inside the refrigerant pump **(32)** is supercooled.

[0077] Due to the foregoing, the invention provides the same effect as that of aspect **29** and, further, the temperature to which the refrigerant inside the liquid pump **(32, 300)** is supercooled is determined by the outside air temperature. Therefore, the continuation time of the refrigerant condensing operation can be reduced.

[0078] As described in aspect **31**, in a heat cycle according to aspect **29** or **30**, the sensor for measuring the physical value may be a temperature sensor **(46)** for measuring the temperature of the housing of the refrigerant pump.

[0079] As described in aspect **32**, in a heat cycle according to aspect **29** or **30**, the refrigerating cycle **(10, 11, 13, 14)** may include an evaporator **(14)** for evaporating the refrigerant of low pressure by exchanging heat between the refrigerant of low pressure and air, and the sensor for measuring the physical value may be a temperature sensor **(47)** for measuring the temperature of air immediately after heat is exchanged with the refrigerant of low pressure.

[0080] In this connection, reference numerals in the parentheses described in each means correspond to the specific means shown in the embodiment described later.

[0081] These and other objects, features and advantages of the present invention will be more apparent in light of the detailed description of exemplary embodiments thereof as illustrated by the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0082] **FIG. 1** is an overall arrangement view showing the first embodiment. **FIG. 1** is also a schematic illustration for explaining the prior application.

[0083] **FIGS.** **2***a* and **2***b* are schematic illustrations for explaining a reversible rotary machine of the first embodiment.

[0084] **FIG. 3** is a flow chart showing a control operation of the electronic control unit of the first embodiment.

[0085] **FIG. 4** is a flow chart showing a primary portion of the control operation of the electronic control unit of the first embodiment.

[0086] **FIG. 5** is an overall arrangement view of the second embodiment.

[0087] **FIG. 6** is a flow chart showing a primary portion of the control operation of the electronic control unit of the second embodiment.

[0088] **FIG. 7** is a flow chart showing a primary portion of the control operation of the electronic control unit of the third embodiment.

[0089] **FIG. 8** is an overall arrangement view of the fourth embodiment.

[0090] **FIG. 9** is a flow chart showing a primary portion of the control operation of the electronic control unit of the fourth embodiment.

[0091] **FIG. 10** is an overall arrangement view of the fifth embodiment.

[0092] **FIG. 11** is a sectional view showing a reversible rotary machine of the fifth embodiment.

[0093] **FIG. 12** is a flow chart showing a primary portion of the control operation of the electronic control unit of the fifth embodiment.

[0094] **FIG. 13** is an overall arrangement view of the sixth embodiment.

[0095] **FIG. 14** is a flow chart showing a primary portion of the control operation of the electronic control unit of the sixth embodiment.

[0096] **FIG. 15** is an overall arrangement view of the seventh embodiment.

[0097] **FIG. 16** is an overall arrangement view showing a variation of the vapor compression type refrigerating machine of the first embodiment.

[0098] **FIG. 17** is an overall arrangement view showing another variation of the vapor compression type refrigerating machine of the first embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0099] In one embodiment of the present invention, at the time of operating a Rankine cycle system, the refrigerating cycle system is operated. According to one of the features of the embodiment, in the refrigerating cycle system, a refrigerant condensing operation is conducted in which the refrigerant is compressed by a rotary fluid machine and condensed by a condenser. When this refrigerant condensing operation is conducted, the liquid-phase refrigerant can be positively supplied to the Rankine cycle system. The refrigerant condensing operation can be conducted before the Rankine cycle system is started, or in the beginning of the starting of the Rankine cycle system immediately after the start of the Rankine cycle system or during the operation of the Rankine cycle system. The refrigerant condensing operation can be started in accordance with a signal to indicate the start of Rankine cycle system. When the refrigerant condensing operation is executed before the operation of Rankine cycle system is started, the liquid-phase refrigerant can be positively supplied at the time of starting the Rankine cycle system. When the refrigerant condensing operation is executed simultaneously when the Rankine cycle system is started or immediately after the Rankine cycle system is started, the liquid-phase refrigerant can be positively supplied at the time of starting the Rankine cycle or in the beginning of starting the Rankine cycle. When the refrigerant condensing operation is executed during the operation of the Rankine cycle system, the liquid-phase refrigerant can be positively supplied during the operation of the Rankine cycle system. The refrigerant condensing operation can be started by judging whether or not the liquid-phase refrigerant needs to be supplied to the Rankine cycle system. For example, a trial run of the Rankine cycle system is made, and it is judged from the behavior of the Rankine cycle whether or not the liquid-phase refrigerant is needed. When it is judged that the supply of the liquid-phase refrigerant is needed, the refrigerant condensing operation is started. Alternatively, according to the accumulation of experiential data, an environmental condition in which the liquid-phase refrigerant is lacking is set and, when this condition is satisfied, the refrigerant condensing operation may be started. The refrigerant condensing operation can be stopped after it is conducted for a predetermined period of time or after it has been conducted for a variable period of time. For example, after a fixed constant period of time has passed, the refrigerant condensing operation can be stopped. Alternatively, when it is detected that the state has become a state in which the liquid-phase refrigerant can be supplied or when it is detected that the liquid-phase refrigerant is being stably supplied to Rankine cycle system, the refrigerant condensing operation may be stopped. The refrigerant condensing operation can be conducted when the refrigerating cycle system is operated as a cooling device or a refrigerating device. In this case, a means for increasing the amount of the liquid-phase refrigerant can be provided. For example, a means for providing a state in which an air blowing means for blowing air to the evaporator in the refrigerating cycle is not operated, can be arranged. Alternatively, a means for providing a state in which a volume of blast air is suppressed, can be arranged.

[0100] The rotary fluid machine can be provided by a device having both the function of an expansion machine and the function of a compressor. The rotary fluid machine can convert energy between fluid energy and mechanical energy generated by rotation. When the rotary fluid machine is rotated, the fluid is compressed from low pressure to high pressure. When the fluid is moved from the high pressure side to the low pressure side, rotation is generated. The rotary fluid machine may be a displacement type machine or non-displacement type machine. For example, it is possible to use a reversible fluid machine which can reversibly function as an expansion machine or a compressor. In this case, the operation of Rankine cycle system and the operation of the refrigerating cycle system can be selectively executed. In this constitution, before the operation of Rankine cycle system, the refrigerant condensing operation can be executed by the refrigerating cycle system. The rotary fluid machine can be provided with both the expansion machine and the compressor. In this case, the expansion machine and the compressor can be selectively operated. In addition to that, the expansion machine and the compressor can be simultaneously operated.

[0101] Another feature will be described below. In the operation of the refrigerating cycle system, the cooling operation for cooling the liquid pump is executed. When the liquid pump is cooled, it is possible to prevent the occurrence of a problem caused by the existence of the gas-phase refrigerant. The cooling operation can be executed before the operation of Rankine cycle system is started and during the operation of Rankine cycle system. When the cooling operation is executed before the operation of the Rankine cycle system is started, it is possible to reduce the gas-phase refrigerant in the liquid pump, and the occurrence of an incomplete start of Rankine cycle system can be suppressed. When the cooling operation is executed at the beginning of the start of the Rankine cycle system immediately after the operation of the Rankine cycle system is started, it is possible to suppress the occurrence of an incomplete start of the Rankine cycle system. When the cooling operation is executed during the operation of the Rankine cycle system, it is possible to prevent the efficiency of the Rankine cycle system from deteriorating. The liquid pump composing the Rankine cycle system can be arranged in the neighborhood of the suction passage of the compressor composing the refrigerating cycle system.

First Embodiment

[0102] In this embodiment, the heat cycle of the present invention is applied to a vapor pressure compression type refrigerating machine (refrigerating cycle) having a Rankine cycle. **FIG. 1** is a schematic illustration showing a model of this embodiment. The vapor compression type refrigerating machine having a Rankine cycle of this embodiment recovers energy from waste heat generated from the engine **20** which is a heat engine for generating power used for running a vehicle. At the same time, the vapor compression type refrigerating machine having a Rankine cycle of this embodiment utilizes cold heat ("cold", which is similar hereinafter) and hot heat ("thermal heat", which is similar hereinafter), which is generated by the vapor compression type refrigerating machine, for air conditioning of a vehicle room.

[0103] The reversible rotary machine **10** shown in **FIG. 1** is a rotary type fluid machine having both the function of a compressor for sucking and compressing the refrigerant and the function of an expansion machine for isentropically expanding superheated vapor to obtain power. The reversible rotary machine **10** is a rotary type fluid machine capable of being reversibly operated as an expansion machine for obtaining power by expanding the refrigerant or operated as a compressor for compressing the refrigerant when power is supplied to the machine **10**. The reversible rotary machine **10** may be referred to as a compressor integrated with an expansion machine.

[**0104**] The motor generator **10***a* is operated as a power source for supplying power (torque) to the reversible rotary machine **10** in the case where the reversible rotary machine **10** is operated as a compressor. On the other hand, the motor generator **10***a* is a dynamo-electric machine operated as a generator for generating electric power from the power recovered by the expansion machine, that is, as a generator for generating electric power by the reversible rotary machine **10** in the case where the reversible rotary machine **10** is operated as an expansion machine. In this connection, the structure of the reversible rotary machine **10** will be described later.

[**0105**] The radiator **11** is connected to the discharge side of the reversible rotary machine **10** when the reversible rotary machine **10** is operated as a compressor, and heat is radiated from the refrigerant to the outside air. That is, the radiator **11** is a cooler for cooling the refrigerant by the outside air. The refrigerant flowing out from the radiator **11** flows into the gas-liquid separator **12** (receiver) for separating the gas-phase refrigerant and the liquid-phase refrigerant from each other.

[**0106**] The decompressor **13** decompresses and expands the liquid-phase refrigerant which has been separated by the gas-liquid separator **12**. This embodiment adopts a temperature-type expansion valve which isentropically decomprresses the refrigerant and controls the degree of opening of the valve so that the degree of superheat of the refrigerant sucked into the reversible rotary machine **10** can become a predetermined value when the reversible rotary machine **10** is operated as a compressor.

[**0107**] The evaporator **14** is a heat absorber for absorbing heat from the refrigerant when the refrigerant decompressed by the decompressor **13** is evaporated. The refrigerant flowing out from the evaporator **14** flows into the reversible rotary machine **10** again. As described above, the vapor compression type refrigerating machine (the refrigerating cycle) to move the heat from the low temperature side to the high temperature side is composed of the compressor (the reversible rotary machine **10**), the radiator **11**, the gas-liquid separator **12**, the decompressor **13** and the evaporator **14**. In this connection, the evaporator **14** is provided with a blower **14***a* for sending a blast of air, which has been conditioned when the refrigerant is evaporated and absorbs heat, into a vehicle room. This blower **14***a* is controlled by the electronic control unit **40**.

[**0108**] In this connection, this embodiment includes an engine cooling circuit for circulating the cooling water to cool the engine **20** which is a heat generating body. The water pump **22** arranged in the engine cooling circuit circulates the engine cooling water, and the radiator **23** is a heat exchanger for cooling the engine cooling water by exchanging heat between the engine cooling water and the outside air. The bypass circuit **24** is a detour circuit by which the cooling water can be flown while by passing the radiator **23**, and the thermostat **25** is a flow regulating valve for adjusting a quantity of cooling water which flows into the bypass circuit **24**, and a quantity of water which flows into the radiator **23**.

[**0109**] In this connection, the water pump **22** is a mechanical type pump driven by the power of the engine **20**. However, of course, the water pump **22** may be an electric pump driven by an electric motor.

[**0110**] There is provided a vapor generator **30** in a portion on the downstream side of the refrigerant flow of the engine **20** in the engine cooling circuit, and in the refrigerant circuit to connect the reversible rotary machine **10** with the radiator **11** in the refrigerating cycle. In this vapor generator **30**, the refrigerant is heated when heat is exchanged between the refrigerant flowing in the refrigerant circuit and the engine cooling water which has recovered the waste heat from the engine **20**.

[**0111**] The three-way valve **21** arranged in the engine cooling circuit changes over between a case in which the engine cooling water flowing out from the engine **20** is circulated in the vapor generator **30** and a case in which the engine cooling water flowing out from the engine **20** is not circulated in the vapor generator **30**. In this embodiment, operation of the three-way valve **21** is controlled by the electronic control unit **40**.

[**0112**] In this connection, the first bypass circuit **31**, which is a liquid-phase pipe, is a refrigerant passage for introducing the liquid-phase refrigerant, which has been separated by the gas-liquid separator **12**, to the refrigerant inlet and outlet side of the vapor generator **30** on the radiator **11** side. This first bypass circuit **31** includes: a liquid pump **32** to circulate the liquid-phase refrigerant; and a check valve **33***a* to allow the refrigerant to flow only onto the vapor generator **30** side from the gas-liquid separator **12** side. In this connection, in this embodiment, the liquid pump **32** is an electrically driven pump and is controlled by the electronic control unit **40**.

[**0113**] The second bypass circuit **34** is a refrigerant passage to connect the refrigerant outlet side when the reversible rotary machine **10** is operated as an expansion machine, with the refrigerant inlet side of the radiator **11**. This second bypass circuit **34** includes a check valve **33***b* to allow the refrigerant to flow only onto the refrigerant inlet side of the radiator **11** from the refrigerant outlet side when the reversible rotary machine **10** is operated as an expansion machine.

[**0114**] In this connection, the check valve **33***c* allows the refrigerant to flow only from the refrigerant outlet side of the evaporator **14** to the suction side of the compressor **10**. The opening and closing valve **35***a* arranged between the vapor generator **30** and the radiator **11** is opened and closed under the control of the electronic control unit **40**. The control valve **36** functions as a discharge valve when the reversible rotary machine **10** is operated as a compressor, that is, the control valve **36** functions as a check valve to allow the refrigerant only to flow onto the vapor generator **30** side from the reversible rotary machine **10** side. When the reversible rotary machine **10** is operated as an expansion machine, the control valve **36** is opened. Operation of this control valve **36** is controlled by the electronic control unit **40**. As described above, a Rankine cycle is composed in which the refrigerant flows in the reversible rotary machine **10**, the condenser **11**, the gas-liquid separator **12** and the liquid pump **32**.

[**0115**] The electronic control unit **40** includes an input section into which the detection temperature T_w of the water temperature sensor **44** for detecting the temperature of the engine cooling water after the engine cooling water absorbed heat from the engine **20**, the air conditioner operation signal (A/C operation demanding signal) sent from the electronic control unit **41** for an air-conditioner, the detection pressure **P1** of the upstream refrigerant pressure sensor **42** for detecting the pressure on the upstream side of the liquid pump **32** and the detection pressure **P2** of the downstream refrigerant pressure sensor **43** for detecting the pressure on the downstream side of the liquid pump **32** are inputted.

[0116] The electronic control unit **40** controls the operations of the control valve **36**, the liquid pump **32** and the three-way valve **21** according to the previously stored program on the basis of the detection temperature of the water temperature sensor **44**, that is, on the basis of the waste heat temperature T_w and also on the basis of presence or absence of A/C operation demanding signal.

[0117] The structure and operation of the reversible rotary machine **10** will be briefly explained as follows.

[0118] **FIG. 2***a* is a view showing a case in which the reversible rotary machine **10** is operated as a compressor, and **FIG. 2***b* is a view showing a case in which the reversible rotary machine **10** is operated as an expansion machine. In this embodiment, the reversible rotary machine **10** is composed of a well-known vane-type fluid machine.

[0119] In the case where the reversible rotary machine **10** is operated as a compressor, the rotor **10***b* is rotated by the motor generator **10***a* so that the refrigerant can be sucked and compressed. At the same time, the discharged refrigerant of high pressure is prevented from flowing backward onto the rotor **10***b* side by the control valve **36**.

[0120] In the case where the reversible rotary machine **10** is operated as an expansion machine, the control valve **36** is opened and superheated vapor generated by the vapor generator **30** is introduced into the reversible rotary machine **10**, so that the rotor **10***b* can be rotated and thermal energy can be converted into mechanical energy.

[0121] Next, operation of the vapor compression type refrigerating machine (the air conditioner) having a Rankine cycle according to this embodiment will be described below. In the vapor compression type refrigerating machine provided with Rankine cycle relating to this embodiment, the operation mode is controlled being changed over by the control means **40** according to the presence or absence of the A/C operation demanding signal and the waste heat temperature T_w. First, the air conditioning operation mode and the waste heat recovering operation mode will be explained as follows.

[0122] 1. Air Conditioning Operation Mode

[0123] In this air conditioning operation mode, while the evaporator **14** is exhibiting a refrigerating capacity, the refrigerant is cooled by the radiator **11**. In this connection, in this embodiment, the vapor compression type refrigerating machine is operated only for the cooling operation and the dehumidifying operation in which the cold heat generated by the vapor compression type refrigerating machine is utilized, that is, the heat absorbing action is utilized. The vapor compression type refrigerating machine is not operated for the heating operation, in which the hot heat generated by the radiator **11** is utilized. However, even at the time of heating operation, the operation of the vapor compression type refrigerating machine is the same as that of the cooling operation and the dehumidifying operation.

[0124] Specifically, the operation is conducted as follows. Under the condition that the liquid pump **32** is stopped, the opening and closing valve **35***a* is opened and the control valve **36** is made to function as a discharge valve, the motor generator **10***a* is energized so as to rotate the rotor **10***b*, and the three-way valve **21** is operated as shown by the broken line in **FIG. 1**, so that the cooling water is circulated while bypassing the vapor generator **30**.

[0125] Due to the foregoing, the refrigerant circulates in the order of the reversible rotary machine (compressor) **10**→the vapor generator **30**→the radiator **11**→the gas-liquid separator **12**→the decompressor **13**→the evaporator **14**→the reversible rotary machine (compressor) **10**. In this connection, as the engine cooling water is not circulated in the vapor generator **30**, the refrigerant is not heated by the vapor generator **30**, and the vapor generator **30** functions only as a refrigerant passage.

[0126] Accordingly, the refrigerant of low pressure, which has been decompressed by the decompressor **13**, absorbs heat from the air blowing out into the vehicle room by the blower **14***a*, and the thus evaporated gas-phase refrigerant is compressed by the reversible rotary machine **10** and the temperature of the refrigerant is raised. The refrigerant of high temperature is cooled and condensed by the outside air in the radiator **11**.

[0127] In this connection, in the present embodiment, the refrigerant is alternate fleon (HFC-134a). However, as long as the refrigerant can be liquidized on the high pressure side, the refrigerant is not limited to HFC-134a.

[0128] 2. Waste Heat Recovering Operation Mode

[0129] In this operation mode, the air conditioner, that is, the reversible rotary machine **10** is stopped and the waste heat of the engine **20** is recovered so that it can be utilized as usable energy.

[0130] Specifically, the liquid pump **32** is operated under the condition that the opening and closing valve **35***a* is closed and that the control valve **36** is open, and the three-way valve **21** is operated as shown by the solid line in **FIG. 1**, so that the engine cooling water flowing out from the engine **20** is circulated in the vapor generator **30**.

[0131] Due to the foregoing, the refrigerant circulates in the order to the gas-liquid separator **12**→the first bypass circuit **31**→the vapor generator **30**→the reversible rotary machine (expansion machine) **10**→the second bypass circuit **34**→the radiator **11**→the gas-liquid separator **12**.

[0132] Accordingly, the superheated vapor heated by the vapor generator **30** flows into the reversible rotary machine **10**. While the vapor refrigerant, which has flowed into the reversible rotary machine **10**, is being isentropically expanded in the reversible rotary machine **10**, the enthalpy is decreased. Therefore, the reversible rotary machine **10** gives mechanical energy, which corresponds to decreased enthalpy, to the motor generator **10***a*. Electric power generated by the motor generator **10***a* is stored in a capacitor or a battery.

[0133] The refrigerant flowing out from the reversible rotary machine **10** is cooled and condensed by the radiator

11 and stored in the gas-liquid separator **12**. The liquid-phase refrigerant in the gas-liquid separator **12** is moved to the vapor generator **30** side by the liquid pump **32**.

[**0134**] As described above, in the waste heat recovering operation mode, the heat energy, which was lost from the radiator **23** into the atmosphere as the waste heat, is converted into energy such as electric power which can be easily utilized. Therefore, the fuel consumption of the vehicle, that is, the fuel consumption of the engine **20** can be reduced.

[**0135**] Further, in the waste heat recovering operation mode, electric power is generated by the waste heat of the engine **20**. Therefore, it becomes unnecessary to drive a generator such as an alternator by the engine **20**. Accordingly, the fuel consumption of the engine **20** can be further reduced.

[**0136**] Next, the control conducted by the electronic control unit **40** will be described as follows. In this embodiment, when an A/C operation demand signal is sent from the electronic control unit **41** for the air conditioner to the electronic control unit **40**, the compressor **10** integrated with the expansion machine is operated as a compressor, and the supply of the engine cooling water to the vapor generator **30** is stopped, so that the priority can be given to the air conditioning operation mode.

[**0137**] On the contrary, even when an A/C operation demanding signal is not sent from the electronic control unit **41** for the air conditioner to the electronic control unit **40** and when the waste heat temperature T_w is not less than a predetermined temperature, the engine cooling water is supplied to the vapor generator **30**, and the reversible rotary machine **10** is operated as an expansion machine, so that the waste heat recovering operation mode can be conducted.

[**0138**] When an A/C operation demanding signal is not sent from the electronic control unit **41** for the air conditioner to the electronic control unit **40** and when the waste heat temperature T_w is not more than a predetermined temperature, under the condition that the supply of the engine cooling water to the vapor generator **30** is stopped, an electric current supplied to the reversible rotary machine **10** is stopped, that is, an electric current supplied to the motor generator **10***a* is stopped.

[**0139**] In this connection, **FIG. 3** is an example of the flow chart showing the controlling operation described above. An outline of this flow chart will be explained as follows. Simultaneously when the starting signal to start a vehicle is inputted, the control program shown in **FIG. 3** is started. First, it is judged whether or not the A/C operation demanding signal has been sent from the electronic control unit **41** for the air conditioner to the electronic control unit **40** (S1).

[**0140**] In the case where the A/C operation demanding signal has been sent from the electronic control unit **41** for the air conditioner to the electronic control unit **40**, the Rankine cycle is not operated, and the air conditioning operation mode is executed (S2).

[**0141**] On the other hand in the case where the A/C operation demanding signal has not been sent from the electronic control unit **41** for the air conditioner to the electronic control unit **40**, it is judged whether or not the Rankine cycle is operated according to the waste heat temperature T_w, that is, it is judged whether or not the waste heat recovering operation mode is executed (**S3**). When the waste heat temperature T_w is not less than the predetermined temperature, the result of judgment is determined to be 1, and the Rankine cycle is executed (**S4**). When the waste heat temperature T_w is lower than the predetermined temperature, the result of judgment is determined to be 0, and Rankine cycle is not executed.

[**0142**] In this connection, in this embodiment, whether or not the Rankine cycle is operated according to the waste heat temperature T_w is judged according to the following predetermined hysteresis control judgment. When the waste heat temperature T_w is decreasing, in the case where the waste heat temperature T_w is not less than the predetermined temperature T_{w1}, the result of judgment is determined to be 1 and the Rankine cycle is executed. In the case where the waste heat temperature T_w is lower than the predetermined temperature T_{w1}, the result of judgment is determined to be 0 and the Rankine cycle is not executed. When the waste heat temperature T_w is increasing, in the case where the waste heat temperature T_w is not less than the predetermined temperature T_{w2}, which is higher than the predetermined temperature T_{w1} by a predetermined temperature, the result of judgment is determined to be 1 and the Rankine cycle is executed. In the case where the waste heat temperature T_w is lower than the predetermined temperature T_{w2}, the result of judgment is determined to be 0 and the Rankine cycle is not executed. In this way, a predetermined hysteresis control judgment is conducted.

[**0143**] Next, referring to **FIG. 4**, the control in which the electronic control unit **40** operates the Rankine cycle (S4) will be explained below in more detail. First, the counter value is reset (**S410**). This counter value represents the number of times of the refrigerant condensing operation (**S470** to **S500**) which will be described later.

[**0144**] Next, the timer is reset (**S420**). This timer stores the elapsed time (seconds) from the start of the waste heat recovering operation mode and the air conditioning operation mode. After that, the electronic control unit **40** sets the liquid pump **32** in motion and starts the waste heat recovering operation mode (**S430**). After that, in **S440** and **S450**, the waste heat recovering operation mode is operated until the predetermined period of time T_1 (s) (20 seconds in this embodiment) passes.

[**0145**] After that, the electronic control unit **40** judges whether or not the pressure difference (**P2**−**P1**) between the detection pressure **P1** of the upstream refrigerant pressure sensor **42** and the detection pressure **P2** of the downstream refrigerant pressure sensor **43** is higher than the setting pressure P (0.3 MPa in this embodiment) (**S460**). In the case where the pressure difference (**P2**−**P1**) is higher than the setting pressure P (0.3 MPa in this embodiment), that is, in the case where the liquid pump **32** gives pressure to the liquid-phase refrigerant and feeds the refrigerant, the program proceeds to **S5** in **FIG. 3**.

[**0146**] In the case where the pressure difference (**P2**−**P1**) is lower than the setting pressure P (0.3 MPa in this embodiment), it is judged that the liquid pump **32** cannot apply pressure to the liquid-phase refrigerant. In more detail, it is judged that the gas-phase refrigerant is mixed in the liquid-phase refrigerant so that the liquid pump **32** can not apply pressure to the refrigerant. Therefore, the refrigerant condensing operation (**S470** to **S500**) is conducted.

[0147] In the refrigerant condensing operation (**S470** to **S500**), after the stopping of the waste heat recovering operation mode (**S470**), the air conditioning operation mode is started (**S480**). After that, in **S490** and **S500**, the air conditioning operation mode is operated until the predetermined period of time T_2 (s) (10 seconds in this embodiment) passes. Then, after the refrigerant condensing operation has been conducted (**S470** to **S500**), the counter value is set at (the counter value +1).

[0148] In **S520**, it is judged whether or not the counter value is higher than the normal value C (3 times in this embodiment). In the case where the counter value is not more than the normal value C, the program returns to **S420**. In the case where the counter value is higher than the normal value C, it is judged that Rankine cycle is in an abnormal state, and operation of the system is stopped.

[0149] In this connection, in the refrigerant condensing operation (**S470** to **S500**), A/C operation demanding signal is not issued. Therefore, the blower **14***a* is not operated. Due to the foregoing, conditioned air is not blown into the vehicle compartment. Therefore, the refrigerant condensing operation can be conducted without a making the passenger uncomfortable.

[0150] Next, the operational effects of the first embodiment will be enumerated as follows.

[0151] (1) It is possible to prevent bubbles from being mixed into the liquid-phase pipe **31** and the liquid pump **32**. Therefore, the occurrence of such a problem that the refrigerant can not be supplied by the liquid pump **32** can be prevented, and the operation efficiency of the refrigerant can be prevented from being deteriorated.

[0152] According to this embodiment, in the case where the Rankine cycle is judged to be in an abnormal state, the air conditioning operation mode (the refrigerating cycle) is operated, so that the gas-phase refrigerant can be condensed to the liquid-phase refrigerant. Further, the refrigerant staying in a complicated portion of the refrigerant passage in the refrigerating cycle, for example, the refrigerant staying in the evaporator **14**, can be accumulated in the gas-liquid separator **12** in the form of liquid refrigerant. After that, by operating the waste heat recovering operation mode (the Rankine cycle), it is possible to prevent bubbles from being mixed into the liquid-phase pipe **31**, which is different from the conventional example.

[0153] Accordingly, the liquid pump **32** can positively supply the liquid-phase refrigerant to the vapor evaporator **30**. Accordingly, the waste heat recovering operation mode (the Rankine cycle) can be normally started and operated.

[0154] In addition, it is possible to prevent the deterioration of the operational efficiency of the liquid pump **32** which is caused when bubbles of the gas-phase refrigerant are mixed into the liquid-phase pipe **31** and the liquid pump **32**. That is, it is possible to prevent the occurrence of the problem that the efficiency of the Rankine cycle is deteriorated.

[0155] (2) The control means **40** judges whether the waste heat recovering operation mode (the Rankine cycle) is normal or abnormal. In the case where the waste heat recovering operation mode (the Rankine cycle) is normal, the waste heat recovering operation mode is continued. In the case where the waste heat recovering operation mode (the Rankine cycle) is abnormal, the air conditioning operation mode is operated. Accordingly, it is possible to prevent the air conditioning mode being unnecessarily executed.

[0156] (3) As the difference value (**P2**−**P1**) between the upstream side pressure value **P1** and the downstream side pressure value **P2** of the liquid pump **32** is compared with the predetermined pressure value P, it is possible to specifically judge whether the waste heat recovering operation mode is normal or abnormal.

[0157] In this connection, when the liquid pump **32** is normally operated, the pressure value **P1** detected by the upstream side refrigerant pressure sensor **42** becomes lower than the pressure value **P2** detected by the downstream side refrigerant pressure sensor **43**. Due to the foregoing, in the case where the difference value (**P2**.

[0158] **P1**) is specifically not more than the predetermined pressure value P, it is possible to judge that operation of the waste heat recovering operation mode is abnormal.

[0159] (4) Due to the waste heat recovering operation mode, it is possible to convert the thermal energy which used to be lost from the radiator **23** into the atmosphere into energy such as electric power which can be easily put into practical use. Therefore, it is possible to reduce the fuel consumption of the vehicle, that is, it is possible to reduce the fuel consumption of the engine **20**. In more detail, as electric power is generated by the waste heat of the engine **20**, it is possible to reduce the necessity to drive the generator such as an alternator by the engine **20**. Accordingly, the fuel consumption of the engine **20** can be reduced.

[0160] In this connection, the pressure in the evaporator at the time of the air conditioning operation mode, that is, the pressure at the check valve **33***c* on the evaporator side, which is approximately 0.3 MPa in this embodiment, is lower than the pressure at the check valve **33***c* on the side opposite to the evaporator, which is approximately 1 MPa in this embodiment, in the case of recovering energy by the compressor integrated with an expansion machine. The check valve **33***c* prevents the refrigerant from flowing backward to the evaporator, due to this difference in pressure, at the time of waste heat recovery operation mode. However, at the time of the waste heat recovery operation mode, when the radiator and the evaporator are communicated with each other, the pressure on the evaporator side, that is, the pressure in the evaporator, which is approximately 0.3 MPa in this embodiment, may be increased to the pressure of the check valve **33***c* on the side opposite to the evaporator, which is approximately 1 MPa in this embodiment, and a malfunction of the check valve **33***c* may be caused and the energy recovering operation mode (Rankine cycle) may fuil.

[0161] Therefore, this embodiment includes a temperature type expansion valve in which the flow rate adjusting section and the decompressing section for decompressing the passing refrigerant are integrated with each other into one body. In this case, the flow rate adjusting section adjusts the degree of opening of the refrigerant passage to the shutoff side in the case where the degree of superheat of the refrigerant at the outlet of the evaporator is low, and the flow rate adjusting section also adjusts the degree of opening of the refrigerant passage to the full opening side in the case where the degree of superheat of the refrigerant at the outlet of the evaporator is high. This temperature-type expansion valve functions as a refrigerant shutoff means for shutting off a flow of the refrigerant into the evaporator at the time of recovering energy.

[0162] Due to the foregoing, when the compressor stops sucking the refrigerant, the pressure at the outlet of the evaporator becomes the saturated pressure of the evaporator temperature in a very short period of time. At this time, the temperature-type expansion valve is completely closed and shuts off the refrigerant passage, and therefore the pressure in the evaporator can be prevented from increasing in the case where energy is recovered by the energy recovering machine. Therefore, even when the energy recovering operation is continuously conducted, the pressure in the evaporator is not increased so that the pipe can be prevented from being damaged and a malfunction of the back-flow preventing means can be prevented.

Second Embodiment

[0163] The constitution of this embodiment is the same as that of the first embodiment except that the upstream refrigerant pressure sensor **42** and the downstream refrigerant pressure sensor **43**, which are provided in the first embodiment, are eliminated and, further, except that an electric current consumed by the liquid pump **32** is measured by the electronic control unit **40** (shown in **FIG. 5**). The control shown in **FIG. 3** is the same as that of the first embodiment.

[0164] However, concerning the detail of S**4** of **FIG. 3** shown in **FIG. 6**, the following point is different. Whether or not the Rankine cycle is normally operated is judged by the electric power consumption of the liquid pump **32** in this embodiment (S**465**). That is, in the case where the liquid pump **32** is normally operated and the liquid refrigerant can be supplied to the vapor generator **30**, the electric power consumption of the liquid pump **32** is increased higher than the predetermined value. Therefore, in the case in which the liquid pump **32** consumes more electric power than the predetermined electric power consumption W (50 W in this embodiment), it is judged to be normal. In this connection, the electric power consumption of the liquid pump **32** is measured by an electric current sensor in this embodiment.

[0165] On the other hand, in the case where electric power is not more than the predetermined electric power consumption W, the program proceeds to S**470**. An operation to be conducted after that is the same as that of the first embodiment.

[0166] Due to the foregoing, without providing the upstream refrigerant pressure sensor **42** and the downstream refrigerant pressure sensor **43** which are indispensable components for the first embodiment, it is possible to judge whether the waste heat recovering operation mode (Rankine cycle) is normal or abnormal. Therefore, the cost of the overall heat cycle can be reduced.

[0167] In this connection, in this embodiment, the operational effects (1) to (4) described in the first embodiment can also be exhibited.

Third Embodiment

[0168] The constitution of this embodiment is the same as that of the first embodiment, however, a portion of the control in S**4** (shown in **FIG. 4**) is different as shown in **FIG. 7**. The difference will be explained in more detail as follows. After the electronic control unit **40** has started the air conditioning operation mode in S**480**, it is judged whether or not the counter value is 0 (S**485**). In the case where the counter value is 0, the program proceeds to S**495** and S**505**, and the air conditioning operation mode T**3** (s) is operated until the time T**3** (s) passes. The predetermined period of time of this T**3** (s) is shorter than the predetermined period of time of T**2** (s). In this embodiment, the predetermined period of time of this T**3** (s) is 2 seconds. On the other hand, in the case where the counter value is not 0, the air conditioning operation mode is continued until the time T**2** (s) passes which is 10 seconds as described before (S**490**, S**500**). After that, the program proceeds to S**510**. Operation to be conducted after this is the same as that of the first embodiment.

[0169] In this connection, in the case where the liquid refrigerant in the gas-liquid separator **12** is a saturated liquid, although the liquid refrigerant remains in the gas-liquid separator **12**, cavitation is caused in a portion of low pressure in the liquid pump **32**. In this case, when the air conditioning operation mode is started for a short period of time and pressure in the gas-liquid separator **12** is raised so as to change the liquid-phase refrigerant into supercooled liquid, the generation of cavitation can be reduced.

[0170] In this embodiment, when the counter value is 0, that is, after it has been judged that the waste heat recovering operation mode is in an abnormal state (S**460** in **FIG. 4**), the air conditioning operation mode of the first time is made to be shorter than the air conditioning operation mode of the second time and after. Due to the foregoing, without conducting a needless air conditioning operation mode, the waste heat recovering operation mode can be quickly put into a normal operation.

[0171] In this connection, the operational effects (1) to (4) described in the first embodiment can also be exhibited in this embodiment.

Fourth Embodiment

[0172] In the first, the second and third embodiment, the time T_2 (S), in which the refrigerant condensing operation is conducted, is set at a predetermined period of time (10 seconds). However, in this embodiment, the time T_2 is changed according to the state of operation of the air conditioning operation mode. This is a point different from the first, the second and the third embodiment.

[0173] **FIG. 8** is an overall arrangement view showing a vapor compression type refrigerating machine of this embodiment. The only different point of this arrangement from the arrangement shown in **FIG. 1** is that the outside air temperature sensor **45** is provided on the upstream side in the air flowing direction of the condenser **11**. The output value T_{am} of the outside air temperature sensor **45** is inputted into the electronic control unit **40**. In the electronic control unit **40**, the continuation time T_{21} (s) to continue the refrigerant condensing operation is determined according to the output value T_{am} of the outside air temperature sensor **45**.

[0174] In this embodiment, it is determined so that T_{21} can be extended as the value of T_{am} is increased. When the outside temperature is high, the condensing temperature is made high. Therefore, the temperature at which the liquid-phase refrigerant can be supercooled is also made high. However, the time to cool the refrigerant is extended due to the heat capacities of the other parts composing the heat cycle. Therefore, the relation between the outside air temperature which was previously measured and the time at which the liquid-phase refrigerant can be supercooled is stored in the electronic control unit **40**, and T_{21} is determined by the value of T_{am}.

[**0175**] The control flow of the electronic control unit **40** of this embodiment is different as follows. As shown in **FIG. 9**, with respect to the first embodiment (shown in **FIG. 4**), T_{am} is read in and T_{21} is determined in step **S415**. In steps **S490** and **S501**, the air conditioning operation mode is operated until the continuity time T_{21} (s) passes.

[**0176**] Due to the foregoing, it is possible to ensure the operating time of the air conditioning operation mode necessary for making the liquid-phase refrigerant put into the supercooled state. Therefore, the operating time of the air conditioning operation mode in the unnecessary refrigerant condensing operation can be reduced. Further, the operational effects (1) to (4) described in the first embodiment can be exhibited.

Fifth Embodiment

[**0177**] In the first to the fourth embodiment, the reversible rotary machine **10** and the liquid pump **32** are composed separately from each other. However, in the present invention, as shown in the overall arrangement view of **FIG. 10**, the reversible rotary machine **10** includes: an expansion and compression section **100**, a generator and motor section **200**, a liquid pump section **300** and a valve mechanism section **107**, etc. which are integrated with each other into one body. Accordingly, the liquid pump **32** and the control valve **36** are not independently provided.

[**0178**] Further, this embodiment is different in the following points. The reversible rotary machine **10** is attached with a liquid pump section housing temperature sensor **46** for measuring the temperature of the pump housing of the liquid pump section **300**, and the output value T_{wp} of the liquid pump section housing temperature sensor **46** is inputted into the electronic control unit **40**. The other points of the structure of this embodiment are the same as those of the fourth embodiment.

[**0179**] Next, referring to the sectional view of **FIG. 11**, the reversible rotary machine **10** of this embodiment will be explained below. The reversible rotary machine **10** includes: a compression and expansion section **100** for compressing and expanding the gas-phase refrigerant; a generator and motor section **200** from which electric energy is outputted when rotary energy is inputted into it and rotary energy is outputted when electric power is inputted into it; and a liquid pump section **300** for supplying the liquid-phase refrigerant to the compression and expansion section **100** with pressure when the waste heat recovery operation mode is operated.

[**0180**] The compression and expansion section **100** has the same structure as that of the well known scroll-type compression mechanism. Specifically, the compression and expansion section **100** includes: a stationary scroll (shell) **102** fixed to the stator housing **230** of the generator and motor section **200** via the middle housing **101**; a movable scroll **103** composing a movable member which is rotated in the space formed between the middle housing **101** and the stationary scroll **102**; and a valve mechanism section **107** for opening and closing the communicating passage **105**, **106** to communicate the operation chamber **V1** with the high pressure chamber **104**.

[**0181**] In this case, the stationary scroll **102** includes: a plate-shaped base plate portion **102***a*; and a spiral tooth portion **102***b* protruding from the base plate portion **102***a* to the movable scroll **103** side. On the other hand, the movable scroll **103***a* includes: a spiral tooth portion **103***b* contacted and meshed with the tooth portion **102***b*; and a base plate portion **103***a* in which the tooth portion **103***b* is formed. When the movable scroll **103** is rotated under the condition that both the tooth portions **102***b* and **103***b* are contacted with each other, the volume of the operation chamber **V1**, which is composed of both the scrolls **102** and **103**, can be extended and reduced.

[**0182**] The shaft **108** is pivotally supported by the middle housing **101** via the bearing **108***b* and is also pivotally supported by the stator housing **230** via the bearing **108***c*. One end portion in the longitudinal direction of the shaft **108** is a crank shaft having an eccentric portion **108***a* which is eccentric with respect to the rotary central axis. The lip seal **108***d* is a shaft seal device for preventing the refrigerant from leaking outside the stator housing **230** from a gap between the shaft **108** and the stator housing **230**. The movable scroll **103** is pivotally attached to the eccentric portion **108***a* via the bearing **103***c*.

[**0183**] The rotation preventing mechanism **109** is composed so that the movable scroll **103** can be rotated around the eccentric portion **108***a* by one rotation while the shaft **108** is being rotated by one rotation. Therefore, when the shaft **108** is rotated, the movable scroll **103** is revolved round the rotary central axis of the shaft **108** without being rotated. Further, as the operation chamber **V1** is displaced to the central side from the outer diameter side of the movable scroll **103**, the volume of the operation chamber **V1** is reduced. In this connection, a pin-ring-(pin-hole) type rotation-preventing mechanism **109** is adopted in this embodiment.

[**0184**] The communication passage **105** makes the operation chamber **V1**, the volume of which becomes minimum at the time of pump mode, communicate with the high pressure chamber **104**, that is, the communication passage **105** is a discharge port for discharging the compressed refrigerant. The communication passage **106** makes the operation chamber **V1**, the volume of which becomes minimum at the time of the waste heat recovery operation mode, communicate with the high pressure chamber **104**, that is, the communication passage **106** is a inflow port for guiding the superheated vapor (the gas-phase refrigerant) of high temperature and high pressure from the high pressure chamber **104** into the operation chamber **V1**.

[**0185**] The high pressure chamber **104** is a space formed in a gap between the valve mechanism housing **107***i* and the opposite surface to the surface on which the tooth portion **102***b* of the base plate portion **102***a* of the movable scroll **102** is composed. The high pressure chamber **104** has a function of smoothing a pulsation of the refrigerant discharged from the communicating passage **105** (referred to as a discharge port **105** hereinafter). In this high pressure chamber **104**, the high pressure port **110**, which is connected to the heater **30** and the radiator **11** side, is provided.

[0186] The low pressure port **111** connected to the evaporator **14** and the second bypass circuit **34** side is provided in the stator housing **230** and communicated with the outermost diameter portion of the operation chamber V1 via the inner space **230***a* in the generator and motor section **200** and via the middle housing **101**.

[0187] Next, the valve mechanism section **107** will be explained in detail as follows. In the high pressure chamber **104**, on the opposite face to the face on which the tooth portion **102***b* of the base plate portion **102***a* of the movable scroll **102** is composed, the discharge valve **107***a* and the valve stopping plate or stopper **107***b* are fixed by the bolts **107***c*. The discharge valve **107***a* is a read-valve-shaped check valve for preventing the refrigerant, which has been discharged from the discharge port **105**, from flowing backward from the high pressure chamber **104** into the operation chamber V1. The stopper **107***b* is a valve stopping plate for regulating the degree of the maximum opening of the discharge valve **107***a*.

[0188] The spool **107***d* is a valve body for opening and closing the communicating passage **106** (referred to as an inflow port **106** hereinafter). The electromagnetic valve **107***e* is a control valve for controlling pressure in the back pressure chamber **107***f* by controlling the communicating state of the low pressure port **111** side with the back pressure chamber **107***f*. The spring **107***g* is an elastic means for giving an elastic force to the spool **107***d* so that the inflow port **106** can be closed. The throttle **107***h* is a resistance means for communicating the back pressure chamber **107***f* with the high pressure chamber **104** while the throttle **107***h* has a predetermined passage resistance. In this connection, the spool **107***d*, the electromagnetic valve **107***e* and the spring **107***g* are arranged in the valve mechanism housing **107***i*, and the back pressure chamber **107***f* and the throttle **107***h* are integrated with the valve mechanism housing **107***i* into one body.

[0189] When the electromagnetic valve **107***e* is opened, the pressure in the back pressure chamber **107***f* is decreased to be lower than the pressure in the high pressure chamber **104**. Therefore, while the spool **107***d* is compressing the spring **107***g*, it is displaced to the right in the drawing, so that the inflow port **106** can be opened. In this connection, a pressure loss in the throttle **107***h* is very large. Therefore, the quantity of the refrigerant flowing from the high pressure chamber **104** into the back pressure chamber **107***f* is negligibly small.

[0190] On the contrary, when the electromagnetic valve **107***e* is closed, the pressure in the back pressure chamber **107** and the pressure in the high pressure chamber **104** become equal to each other. Accordingly, the spool **107***d* is displaced to the lower side in the drawing by a force generated by the spring **107***g*. Therefore, the inflow port **106** can be closed. Accordingly, a pilot-type electric opening and closing valve for opening and closing the inflow port **106** can be composed of the spool **107***d*, the electromagnetic valve **107***e*, the back pressure chamber **107***f*, the spring **107***g* and the throttle **107***h* etc. In this connection, the electromagnetic valve **107***e* is controlled by the electronic control unit **40**. The generator and motor section **200** is a brushless DC motor having a stator **210** and a rotor **220** rotated on the inner circumferential side of the stator **210**. The stator **210** is a stator coil in which a coil is wound round an iron core made of magnetic material such as steel. This stator **210** is fixed in the inner circumferential section of the stator housing **230**.

[0191] The rotor **220** is a magnet rotor in which a permanent magnet is embedded. On the inner circumferential side of the rotor **220**, a key groove not shown is formed, so that the rotor **220** can be integrally fixed to the shaft **108** by the key groove.

[0192] The liquid pump section **300** has the same structure as that of a well-known scroll-type compressor mechanism. Specifically, the liquid pump section **300** includes: a stationary scroll (shell) **302** fixed to the stator housing **230** of the generator and motor section **200** via the pump housing **301**; a movable scroll **303** which is a movable member rotated in a space formed between the pump housing **301** and the stationary scroll **302**; and an operation chamber V2 etc.

[0193] In this case, the stationary scroll **302** includes: a plate-shaped base plate portion **302***a*; and a spiral tooth portion **302***b* protruding from the base plate portion **302***a* to the movable scroll **303** side. On the other hand, the movable scroll **303** includes: a spiral tooth portion **303***b* contacted and meshed with the tooth portion **302***b*; and a base plate portion **303***a* in which the tooth portion **303***b* is formed. When the movable scroll **303** is rotated while both the tooth portions **302***b*, **303***b* are in contact with each other, the operation chamber V2 composed of both the scrolls **302**, **303** is moved from the refrigerant suction port **309** side described later to the refrigerant discharge port **308** side.

[0194] In this connection, the compression ratio of the scroll type compression mechanism of the liquid pump section **300** is 1. Therefore, even when the liquid-phase refrigerant is sucked into the operation chamber V2, the liquid-phase refrigerant is not compressed. Accordingly, a malfunction of the liquid pump section **300** is not caused by compression of the liquid-phase refrigerant.

[0195] The pump shaft **304** is pivotally supported by the pump housing **301** via the bearing **304***b*. One end portion of the pump shaft **304** in the longitudinal direction is a crank shaft having an eccentric portion **304***a* which is eccentric with respect to the rotary central axis. The pump shaft **304** is connected to an end portion of the shaft **108**, which is a member composing the compression expansion section **100** and the generator and motor section **200**, on the side opposite to the side on which the eccentric portion **108***a* is provided via the one-way clutch **305**.

[0196] The one-way clutch **305** is a power transmission means having a function of transmitting a rotary drive force of the shaft **108** to the pump shaft **304** only in the waste heat recovery operation mode. The movable scroll **303** is pivotally connected to the eccentric portion **304***a* via the bearing **303***c*.

[0197] By the rotation preventing mechanism **306**, **307**, while the pump shaft **304** is being rotated by one rotation, the movable scroll **303** is rotated round the eccentric portion **304***a* by one rotation. Therefore, when the pump shaft **304** is rotated, the movable scroll **303** is revolved round the rotary central axis of the pump shaft **304** without being rotated. Further, the operation chamber V2 is gradually displaced from the outer diameter side to the central side. In this connection, the pin-ring-type (pin-hole-type) mechanism is adopted as the rotation preventing mechanism **306**, **307** in this embodiment.

[**0198**] The refrigerant discharge port **308** is a port from which the liquid-phase refrigerant is discharged. The refrigerant discharge port **308** is arranged at a position so that the refrigerant discharge port **308** can be communicated with the operation chamber **V2** when the operation chamber **V2** is moved to the central side of the liquid pump section **200**. The refrigerant suction port **309** is a port from which the liquid-phase refrigerant is sucked. The refrigerant suction port **309** is arranged at a position so that the refrigerant suction port **309** can be communicated with the operation chamber **V2** when the operation chamber **V2** is moved to the outer diameter side of the liquid pump section **200**.

[**0199**] In this connection, the liquid pump section housing temperature sensor **46** is attached to the pump housing **301**, and the output value T_{wp} of the liquid pump section housing temperature sensor **46** is inputted into the electronic control unit **40**.

[**0200**] Next, the operation of the vapor compression type refrigerating machine having a Rankine cycle of this embodiment will be described below.

[**0201**] In the air conditioning operation mode, electric power is supplied to the generator and motor section **200** of the reversible rotary machine **10**, and the electromagnetic valve **107*e*** is closed and the three-way valve **21** is changed over as shown by the broken line in **FIG. 10** by the electronic control unit **40**.

[**0202**] When electric power is supplied to the generator and motor section **200**, the rotor **220** and the shaft **108** are rotated integrally with each other. Due to this rotation, the reversible rotary machine **10** sucks the gas-phase refrigerant from the low pressure port **111**, compresses the gas-phase refrigerant in the operation chamber **V1** and discharges the gas-phase refrigerant from the high pressure port **110**.

[**0203**] As the electromagnetic valve **107*c*** is closed, the valve mechanism section **107** functions as a check valve which only allows the refrigerant to flow from the reversible rotary machine **10** side to the vapor generator **30** side. In the air conditioning operation mode, the one-way clutch **305** does not transmit the rotary drive force from the shaft **108** to the pump shaft **304**. Therefore, the liquid pump section **300** is not operated.

[**0204**] Due to the foregoing, in the air conditioning operation mode, the same refrigerating cycle as that of the first embodiment can be composed. Further, as the gas-phase refrigerant of low pressure, which is sucked from the low pressure port **111** of the compression and expansion section **100**, is evaporated in the evaporator **14** and the temperature of the gas-phase refrigerant is lowered, when the gas-phase refrigerant passes the inner space **230*a***, it cools the liquid pump section **300** via the contact face **230*b*** of the liquid pump section **300** of the stator housing **230**. Due to the foregoing, the liquid-phase refrigerant in the liquid pump section **300** is supercooled. Accordingly, when the waste heat recovery operation mode is conducted after the air conditioning operation mode, the liquid pump section **300** can positively supply the liquid-phase refrigerant to the vapor generator **30**.

[**0205**] Next, in the waste heat recovery operation mode, the electromagnetic valve **107*e*** is opened, and the three-way valve **21** is changed over as shown by the solid line in **FIG. 10** by the electronic control unit **40**. In this case, although the electronic control unit **40** does not drive the liquid pump section **300**, the shaft **108** is rotated when the refrigerant is expanded in the compression and expansion section **100**. Accordingly, the rotary drive force generated at this time is transmitted to the pump shaft **304** via the one-way clutch **305**. Therefore, the liquid pump section **300** is operated.

[**0206**] Due to the foregoing, in the waste heat recovery operation mode, the same Rankine cycle as that of the first embodiment can be composed.

[**0207**] In this connection, in the waste heat recovery operation mode, the gas-phase refrigerant of low pressure flowing out from the low pressure port **111** of the compression and expansion section **100** is superheated by the vapor generator **30**. Thus, the temperature of the gas-phase refrigerant is raised high. Therefore, the following problems may be encountered. As the gas-phase refrigerant of high temperature also passes through the inner space **230*a***, the liquid pump section **300** may be heated by the gas-phase refrigerant of high temperature via the contact face **230*b***, and the liquid-phase refrigerant in the liquid pump section **300** may be heated and evaporated.

[**0208**] However, in the waste heat recovery operation mode, the liquid pump section **300** is operated, and the liquid-phase refrigerant does not stay in the liquid pump section **300**, which is different from the air conditioning operation mode, but passes through inside the liquid pump section **300**. Therefore, as the liquid-phase refrigerant is sent to the vapor generator **30** before it is evaporated, there is no possibility that the refrigerant inside the liquid pump **300** is evaporated.

[**0209**] Next, the control operation conducted by the electronic control unit **40** will be described as follows. In this embodiment, in the same manner as that of the first embodiment, the electronic control unit **40** controls the air conditioning operation mode and the waste heat recovery mode. However, in this embodiment, the control in the case of operating the Rankine cycle (S4) is different from that of the first embodiment.

[**0210**] Specifically, the control is conducted as follows. As shown in **FIG. 12**, in step **S416**, the outside air temperature T_{am} and the liquid pump section housing temperature T_{wp} are read in. Concerning the operation of the air conditioning operation mode for conducting the refrigerant condensing operation, as shown in step **S502**, the operation is continued until the following relationship is established (outside air temperature $T_{am}+\alpha$)>($\beta\times$liquid pump section housing temperature T_{wp}).

[**0211**] In this case, it is possible to grasp the refrigerant condensing temperature from the outside air temperature T_{am}. Since the liquid pump section housing temperature T_{wp} has a correlation with the refrigerant temperature in the liquid pump section **300**, it is possible to grasp the refrigerant temperature in the liquid pump section **300**. Further, when the refrigerant temperature in the liquid pump section **300** is lower than the refrigerant condensing temperature, it can be judged that the refrigerant in the liquid pump section **300** is in the supercooled state.

[0212] Therefore, in this embodiment, the refrigerant condensing temperature is set aft (outside air temperature $T_{am}+\alpha$), wherein α=15° C. in this embodiment, and the refrigerant condensing operation is conducted until (β×liquid pump section housing temperature T_{wp}) is decreased to a value not higher than (outside air temperature $T_{am}+\alpha$). In this case, β is a multiplier for controlling. Therefore, when the waste heat recovery mode is operated after the completion of the refrigerant condensing operation, because the refrigerant inside the liquid pump is in the supercooled state, the liquid pump section **300** can positively move the liquid-phase refrigerant to the vapor generator **30**.

[0213] Of course, the operation may be conducted as follows. Even in the case where the outside air temperature T_{am} is not measured, the minimum refrigerant condensing temperature (for example, 10° C.) is previously determined from the minimum outside air temperature in the environment in which the heat cycle is used, and the refrigerant condensing operation is conducted until (β×liquid pump section housing temperature T_{wp}) is decreased to a value not higher than the minimum refrigerant condensing temperature. Due to the foregoing, it is possible to eliminate the outside air temperature sensor **45**. Accordingly, the manufacturing cost of the entire heat cycle can be reduced.

[0214] In this connection, even in this embodiment, the operational effects (1) to (4) described in the first embodiment can be exhibited.

Sixth Embodiment

[0215] The above explanations are made into the fifth embodiment in which the liquid pump section housing temperature sensor **46** for measuring the pump housing temperature of the liquid pump section **300** is provided. However, in this embodiment, as shown in **FIG. 13**, instead of the liquid pump section housing temperature sensor **46**, the evaporator blowout temperature sensor **47** is provided which measures the temperature of air, the heat of which is exchanged by the evaporator **14**. The other points of the structure are the same as those of the fifth embodiment.

[0216] The evaporator blowout temperature T_e outputted from the evaporator blowout temperature sensor **47** is a temperature of the gas-phase refrigerant of low pressure in the air conditioning operation mode and a temperature of the gas-phase refrigerant of low pressure sucked into the reversible rotary machine **10**. That is, the evaporator blowout temperature T_e outputted from the evaporator blowout temperature sensor **47** is the same temperature as that of the gas-phase refrigerant to cool the liquid pump section **300**. Therefore, the evaporator blowout temperature T_e outputted from the evaporator blowout temperature sensor **47** has a correlation with the temperature inside the liquid pump section **300**. Accordingly, as shown in steps S417 and S**503** shown in **FIG. 14**, by using the evaporator blowout temperature T_e instead of the liquid pump section housing temperature T_{wp}, the same effect as that of the fifth embodiment can be obtained.

Seventh Embodiment

[0217] In the first to the sixth embodiment, a reversible rotary machine **10** is used which functions as a compressor in a refrigerating cycle and also functions as an expansion machine in a Rankine cycle. However, in this embodiment, as shown in **FIG. 15**, a reversible rotary machine **10** is not used but a compressor **10***b* exclusively used for the refrigerating cycle and an expansion machine **10***c* exclusively used for Rankine cycle are used so as to compose the vapor compression type refrigerating machine.

[0218] The compressor **10***b* has a function of sucking, compressing and discharging the refrigerant. This compressor **10***b* is driven by the engine **20** via the engine side pulley **49**, the belt **50** and the compressor side pulley **51** through the electromagnetic clutch **48**, which is controlled by the electronic control unit **40**.

[0219] The structure of the expansion machine **10***c* is the same as that of the reversible rotary machine **10** of the fifth embodiment. In the expansion machine **10***c*, the expansion section **100**, the generator section **200** and the liquid pump section **300** are integrated with each other into one body. However, there is no chance that the expansion machine functions as a compressor. Therefore, the shaft **108** and the pump shaft **30** are connected with each other into one body without using a one-way clutch or other devices.

[0220] When a drive force is transmitted to the compressor by the electronic control unit **40**, the refrigerant is circulated in the order of the compressor **10***b*→the radiator **11**→the gas-liquid separator **12**→the decompressor **13**→the evaporator **14**→the compressor **10***b*. Due to the foregoing, the same refrigerating cycle, as that of the first embodiment, can be composed.

[0221] When the electronic control unit **40** changes over the three-way valve **21** so that the engine coolant can flow through the vapor generator **30**, the refrigerant, which has been superheated by the vapor generator **30**, expands in the expansion section **100**, so that the generator section **200** and the liquid pump section **300** are operated. Electric power generated by the generator section **200** is stored in the battery via the electronic control unit **40**. The liquid pump section **300** further moves the liquid-phase refrigerant to the vapor generator **30**.

[0222] The gas-phase refrigerant flowing out from the expansion section **100** is circulated in the order of the expansion machine **10***c*→the radiator **11**→the gas-liquid separator **12**→the liquid pump section **300**→the vapor generator **30**→the expansion machine **10***c*. Due to the foregoing, the same Rankine cycle as that of the first embodiment can be composed.

[0223] In this case, the high pressure refrigerant discharge port of the compressor **10***b* and the low pressure refrigerant flow-out port of the expansion machine **10***c* are joined to each other at the pipe confluence section X. However, as the compressor **10***b* has a discharge valve, the refrigerant of low pressure flowing out from the expansion machine **10***c* does not flow backward from the high pressure refrigerant discharge port of compressor **10***b* into the compressor **10***b*. Further, the high pressure refrigerant discharged from the compressor **10***b* does not flow backward from the low pressure refrigerant flow-out port of the expansion machine **10***c* into the expansion machine **10***c* because the check valve **33***b* is provided.

[0224] The upstream refrigerant pressure sensor **42**, the downstream refrigerant pressure sensor **43** and the water temperature sensor **44** measure the same physical values as those of the first embodiment, and the measured values are inputted into the electronic control unit **40**.

[**0225**] Therefore, according to this embodiment, it is possible to conduct control in the same manner as that of the first embodiment. Further, it is possible to conduct control while the refrigerating cycle and Rankine cycle are independent from each other. That is, when the refrigerant condensing operation is conducted by the refrigerating cycle before the waste heat recovery operation mode is operated by a Rankine cycle, the same effect as that of the first embodiment can be provided. When the refrigerating cycle is operated simultaneously when a Rankine cycle is operated, a sufficiently large quantity of the liquid-phase refrigerant can be stored in the gas-liquid separator **12** by the refrigerating cycle. Therefore, no bubbles of the gas-phase refrigerant enter the liquid pump section **300**. Accordingly, the liquid-phase refrigerant can be positively sent to the vapor generator **30**.

Another Embodiment

[**0226**] The vapor compression type refrigerating machine provided with Rankine cycle, to which the present invention can be applied, is not limited to the specific constitution described in the above embodiments. The vapor compression type refrigerating machine may have the constitution shown in **FIG. 16** in which the evaporator is used as the condenser in a Rankine cycle and the liquid-phase refrigerant in the gas-liquid separator **52** in the downstream of the evaporator **14** is supplied to the vapor generator **30** by the liquid pump **32**. Alternatively, as shown in **FIG. 17**, the condenser **53** in a Rankine cycle may be arranged separately from the radiator **11** and the evaporator **14** arranged in the refrigerating cycle.

[**0227**] In the control conducted in the third to the seventh embodiment, the refrigerant pressure sensor **42**, **43** of the first embodiment is used. However, of course, the same effect can be provided when the control conducted according to the electric power consumption of the liquid pump of the second embodiment may be applied. The control of the third embodiment may be applied to the fourth to the seventh embodiment.

[**0228**] The heat transfer fin temperature of the evaporator **14** or the pressure of the low pressure port **111** of the compressor may be used as physical values having a correlation with the refrigerant temperature in the liquid pump **32** and the liquid pump section **300** used in the fifth or the sixth embodiment.

[**0229**] In the embodiments described above, the recovered energy is stored in a capacitor. However, the recovered energy may be stored as mechanical energy such as kinetic energy stored by a flywheel or elastic energy stored by a spring.

[**0230**] In the above embodiments, the reversible rotary machine **10** is used, that is, the vane type and the scroll type fluid machine are used as a compressor and an expansion machine. However, it should be noted that the present invention is not limited to the above specific embodiment.

[**0231**] In the above embodiments, when the waste heat recovering operation mode is controlled, a predetermined hysteresis is provided. However, it should be noted that the present invention is not limited to the above specific embodiments.

[**0232**] It should be noted that the application of the present invention is not limited to a vehicle.

[**0233**] The heat generating body is not limited to an internal combustion engine, that is, the heat generating body can be variously changed, for example, the heat generating body may be a fuel cell (FC).

[**0234**] An opening and closing valve (for example, an electromagnetic valve for opening and closing when it is energized) and a capillary tube may be arranged as a refrigerant shutoff means.

[**0235**] Due to the foregoing, as the electromagnetic valve positively shuts off the refrigerant passage, the type of the decompressing means is not limited to the temperature-type expansion valve, but an inexpensive capillary tube can be used. Further, it is possible to make the accumulator cycle, in which an accumulator is arranged on the downstream side of the refrigerant flow of the evaporator **14** at the time of air conditioning operation mode instead of the gas-liquid separator (receiver) arranged on the downstream side of the refrigerant flow of the radiator **11** at the time of air conditioning operation mode, exhibit the above operational effects.

[**0236**] In the above embodiment, the heater is arranged in series between the radiator and the compressor integrated with an expansion machine. However, it is possible to operate Rankine cycle even when the heater is arranged in parallel between the radiator and the compressor integrated with an expansion machine.

[**0237**] Waste heat generated from various devices mounted on a vehicle, for example, suction heat generated from a turbine, heat generated from an inverter and waste heat generated from auxiliary devices may be used as a heat source to heat the refrigerant. Only one heat source may be used to heat the refrigerant. Alternatively, a plurality of heat sources may be used to heat the refrigerant.

[**0238**] The application of the present invention is not limited to an air conditioner for vehicle use. It is possible to apply the present invention to a stationary type refrigerating cycle (refrigerating machine).

[**0239**] In the above embodiment, the temperature-type expansion valve is exemplarily shown in which a flow rate of the refrigerant is adjusted according to the temperature of a temperature-detecting cylinder and the temperature at the outlet of the evaporator. However, the temperature-type expansion valve is not limited to the above type. For example, it is possible to use an electronic-type expansion valve having a flow rate adjusting section in which a thermistor is used for the temperature detecting section and the degree of opening of a refrigerant passage is adjusted by an actuator according to the detected temperature.

[**0240**] As long as it agrees with the concept of the present invention described in the scope of claim of the patent, any embodiment may be included in the present invention. It should be noted that the present invention is not limited to the above specific embodiments.

What is claimed is:

1. A heat cycle device comprising:

a rotary fluid machine for mutually converting between fluid energy of refrigerant and mechanical rotary energy;

a condenser for condensing the refrigerant supplied from the rotary fluid machine;

a Rankine cycle system including a fluid pump for moving the refrigerant supplied from the condenser and also including a vapor generator for heating the refrigerant, which has been moved by the fluid pump, by the heat of a heat generating body;

a refrigerating cycle system including an evaporator for evaporating the refrigerant supplied from the condenser; and

a control unit for conducting a refrigerant condensing operation in which the refrigerant in the refrigerating cycle system is compressed by the rotary fluid machine at the time of operating the Rankine cycle system and the compressed refrigerant is condensed by the condenser.

2. A heat cycle device according to claim 1, the control unit including:

a judging means for judging whether or not the Rankine cycle system is normally operated after the operation of the Rankine cycle system was started; and

a control means for continuing the operation of the Rankine cycle system in the case where it is judged that the Rankine cycle system is normally operated, and for conducting the refrigerant condensing operation in the case where it is judged that the Rankine cycle system is not normally operated.

3. A heat cycle device according to claim 2, further comprising:

an upstream refrigerant pressure sensor for measuring pressure of the refrigerant, arranged in an upstream side portion of the refrigerant flow of the fluid pump; and

a downstream refrigerant pressure sensor for measuring pressure of the refrigerant, arranged in a downstream side portion of the refrigerant flow of the fluid pump, wherein

the judging means judges that the Rankine cycle is normally operated at the time of operating the Rankine cycle system in the case where a difference (**P2**–**P1**) between the detected pressure of the downstream refrigerant pressure sensor and the detected pressure (P) of the upstream refrigerant pressure sensor is larger than the predetermined pressure (P), and the judging means judges that the Rankine cycle is not normally operated at the time of operating the Rankine cycle system in the case where the difference (**P2**–**P1**) between the detected pressure (**P2**) of the downstream refrigerant pressure sensor and the detected pressure (**P1**) of the upstream refrigerant pressure sensor is not more than the predetermined pressure (P).

4. A heat cycle device according to claim 2, wherein the judging means judges that the Rankine cycle system is normally operated in the case where a work-load of the liquid pump is heavier than a predetermined work-load at the time of operating the Rankine cycle system, and the judging means judges that the Rankine cycle system is not normally operated in the case where the work-load of the liquid pump is not more than the predetermined work-load at the time of operating the Rankine cycle system.

5. A heat cycle device according to claim 4, wherein the liquid pump is an electric liquid pump, and the work-load is represented by electric power consumed by the electric liquid pump.

6. A heat cycle device according to one of claim 1, further comprising an air blowing means for blowing air, the temperature of which is adjusted by the refrigerating cycle system, wherein

the control unit conducts the refrigerant condensing operation under the condition that the air blowing means is not operated.

7. A heat cycle device according to claim 1, further comprising a sensor for measuring a physical value having a correlation with the temperature of the refrigerant inside the liquid pump, wherein

the control unit determines the time, which has passed from the start of the refrigerant condensing operation to when the physical value measured by the sensor shows that the refrigerant inside the refrigerant pump is in the supercooled state, to be the continuation time for continuing the refrigerant condensing operation.

8. A heat cycle device according to claim 1, wherein the condenser is a heat exchanger for condensing the refrigerant by exchanging heat between the outside air and the refrigerant,

the heat cycle device further comprising:

an outside air temperature sensor for measuring the temperature of the outside air; and

a sensor for measuring a physical value having a correlation with the temperature of the refrigerant inside the liquid pump, wherein

the control unit determines a target temperature at which the refrigerant inside the refrigerant pump is in the supercooled state according to the outside air temperature measured by the outside air temperature sensor, and further the control unit determines the time, which has passed from the start of the refrigerant condensing operation to when the physical value measured by the sensor becomes the target temperature, to be the continuation time for continuing the refrigerant condensing operation.

9. A heat cycle device according to claim 7, wherein the sensor is a temperature sensor for measuring the temperature of the housing of the refrigerant pump.

10. A heat cycle device according to claim 7, wherein the sensor is a temperature sensor for measuring the temperature of air immediately after heat was exchanged with the refrigerant in the evaporator.

11. A heat cycle device according to claim 1, wherein the condenser is a heat exchanger for condensing the refrigerant by exchanging heat between the outside air and the refrigerant,

further comprising an outside air temperature sensor for measuring the outside air temperature, wherein the control unit includes a continuation time setting means for determining the continuation time (**T21**), in which the refrigerant condensing operation is continued, according to the temperature measured by the outside air temperature sensor.

12. A heat cycle device according to claim 1, wherein the rotary fluid machine is a reversible rotary machine capable of being reversibly operated as an expansion machine for obtaining power when the refrigerant is expanded, or operated as a compressor for compressing the refrigerant when power is supplied to the compressor.

13. A heat cycle device according to claim 12, wherein the control unit conducts the refrigerant condensing operation by operating the rotary fluid machine as a compressor before the rotary fluid machine is operated as an expansion machine and the operation of the Rankine cycle system is started.

14. A heat cycle device according to claim 12, wherein the reversible rotary machine is composed being integrated with the fluid pump into one body, and

the fluid pump is arranged so that it can be cooled by the gas-phase refrigerant sucked into the reversible rotary machine at the time of operating the refrigerating cycle system.

15. A heat cycle device according to claim 1, wherein the rotary fluid machine includes an expansion machine for expanding the refrigerant to obtain power and a compressor for compressing the refrigerant when power is supplied to the compressor.

16. A heat cycle device according to claim 15, wherein the control unit conducts the refrigerant condensing operation by operating the compressor before the expansion machine is operated and the operation of the Rankine cycle system is started.

17. A heat cycle device according to claim 15, wherein the control unit conducts the refrigerant condensing operation by operating the compressor simultaneously when the expansion machine is operated and the operation of the Rankine cycle system is started.

18. A heat cycle device comprising:

a Rankine cycle system including a fluid pump for moving refrigerant and also including a vapor generator for heating the refrigerant, which has been moved by the fluid pump, by the heat of a heat generating body;

a refrigerating cycle system including an evaporator for evaporating the refrigerant; and

a control unit for conducting the cooling operation for cooling the fluid pump by operating the refrigerating cycle system at the time of operating the Rankine cycle system.

19. A heat cycle device according to claim 18, wherein the refrigerating cycle system includes a compressor, and the fluid pump is arranged so that it can be cooled by the gas-phase refrigerant sucked into the compressor.

20. A heat cycle device according to claim 18, wherein the control unit conducts the cooling operation before the operation of the Rankine cycle system is started and/or while the Rankine cycle system is being operated.

21. A heat cycle comprising:

a refrigerating cycle in which refrigerant of low pressure is evaporated so as to absorb heat from a low temperature side and the evaporated gas-phase refrigerant is compressed so as to raise the temperature and the heat absorbed from the low temperature side is radiated to a high temperature side so as to condense the gas-phase refrigerant into the liquid-phase refrigerant;

a Rankine cycle including a vapor generator for generating the gas-phase refrigerant by heating the liquid-phase refrigerant of the refrigerating cycle by the waste heat of a heat generating body, also including a liquid-phase pipe for connecting a liquid-phase takeout section for taking out the liquid-phase refrigerant from the refrigerating cycle, with the vapor generator, also including a liquid pump arranged in the liquid-phase pipe, for moving the liquid phase refrigerant to the vapor generator, also including an expansion machine for obtaining power by expanding the gas-phase refrigerant, and also including a condenser for condensing the gas-phase refrigerant which has been expanded by the expansion machine;

a control means for controlling a state of operation of the refrigerating cycle and also controlling a state of operation of Rankine cycle; and

a change-over means for changing over between a case in which the Rankine cycle is operated and a case in which the refrigerating cycle is operated by a signal sent from the control means, wherein

the control means operates the Rankine cycle in such a manner that the refrigerating cycle is operated by the refrigerant condensing operation so as to condense the gas-phase refrigerant into the liquid-phase refrigerant and then the Rankine cycle is operated.

22. A heat cycle comprising:

a refrigerating cycle in which refrigerant of low pressure is evaporated so as to absorb heat from a low temperature side and the evaporated gas-phase refrigerant is compressed so as to raise the temperature and the heat absorbed from the low temperature side is radiated to a high temperature side so as to condense the gas-phase refrigerant into the liquid-phase refrigerant;

a Rankine cycle including a vapor generator for generating the gas-phase refrigerant by heating the liquid-phase refrigerant of the refrigerating cycle by the waste heat of a heat generating body, also including a liquid-phase pipe for connecting a liquid-phase takeout section for moving the liquid-phase refrigerant from the refrigerating cycle, with the vapor generator, also including a liquid pump arranged in the liquid-phase pipe, for moving the liquid-phase refrigerant to the vapor generator, also including an expansion machine for obtaining power by expanding the gas-phase refrigerant, and also including a condenser for condensing the gas-phase refrigerant which has been expanded by the expansion machine;

a control means for controlling a state of operation of the refrigerating cycle and also controlling a state of operation of Rankine cycle; and

a change-over means for changing over between the case in which the Rankine cycle is operated and the case in which the refrigerating cycle is operated by a signal sent from the control means, wherein

after the Rankine cycle has been operated, the control means judges whether or not the Rankine cycle is normally operated, in the case where operation of the Rankine cycle has been judged to be normal, the Rankine cycle is kept operated and

in the case where operation of the Rankine cycle has been judge to be not normal, the control means operates in such a manner that it stops the operation of the Rankine cycle and operates the refrigerating cycle so as to conduct the refrigerant condensing operation for recovering the liquid-phase refrigerant and the Rankine cycle is operated again after the refrigerant condensing operation.

23. A heat cycle according to claim 22, further comprising:

an upstream refrigerant pressure sensor arranged in a portion on the upstream side of the flow of the refrigerant of the liquid pump, the upstream refrigerant pressure sensor outputting a signal of the refrigerant pressure to the control means; and

a downstream refrigerant pressure sensor arranged in a portion on the downstream side of the flow of the refrigerant of the liquid pump, the downstream refrigerant pressure sensor outputting a signal of the refrigerant pressure to the control means, wherein

in the case where a value (P2–P1), which is obtained when a detected pressure value (P1) of the upstream refrigerant pressure sensor is subtracted from a detected pressure value (P2) of the downstream refrigerant pressure sensor, is higher than a predetermined pressure value (P) when the Rankine cycle is operated, the control means judges that the Rankine cycle is normally operated, and in the case where the value (P2–P1), which is obtained when the detected pressure value (P1) of the upstream refrigerant pressure sensor is subtracted from the detected pressure value of the downstream refrigerant pressure sensor, is not more than the predetermined pressure value (P), the control means judges that the Rankine cycle is not normally operated.

24. A heat cycle according to claim 22, wherein the control means judges that the Rankine cycle is normally operated in the case where a work-load of the liquid pump is more than a predetermined work-load when the Rankine cycle is operated, and

the control means judges that the Rankine cycle is not normally operated in the case where the work-load of the liquid pump is not more than the predetermined work-load when the Rankine cycle is operated.

25. A heat cycle according to claim 24, wherein the liquid pump is an electric liquid pump driven by electricity, and

the work-load is represented by electric power consumed by the electrically-driven liquid pump.

26. A heat cycle according to claim 21, wherein the expansion machine is a reversible rotary machine having the function of a compressor for compressing the gas-phase refrigerant in the refrigerating cycle,

the reversible rotary machine is integrated with the liquid pump, and

the liquid pump is cooled by the gas-phase refrigerant sucked into the reversible rotary machine at the time of operating the refrigerating cycle.

27. A heat cycle according to claim 21, further comprising:

an air blowing means for blowing air conditioned by the refrigerating cycle; and

an operation demand means for demanding the operation of the refrigerating cycle, wherein

in the case of conducting the refrigerant condensing operation, the control means conducts the refrigerant condensing operation without operating the air blowing means when the operation of the refrigerating cycle is not demanded by the operation demand means.

28. A heat cycle according to claim 21, wherein,

the condenser is a heat exchanger for condensing the gas-phase refrigerant by exchanging heat between the outside air and the refrigerant,

the heat cycle further comprises an outside air temperature sensor for measuring the temperature of the outside air,

the control means determines the continuation time (T21) for continuing the refrigerant condensing operation, and

the continuation time (T21) is determined on the basis of the outside air temperature.

29. A heat cycle according to claim 21, further comprising a sensor for measuring a physical value having a correlation with a temperature of the refrigerant inside the liquid pump, wherein

the control means determines the continuation time in which the refrigerant condensing operation is continued, and

the continuation time is the time from the start of the refrigerant condensing operation to when the physical value measured by the sensor becomes the temperature at which the refrigerant inside the refrigerant pump is supercooled.

30. A heat cycle according to claim 21, wherein

the condenser is a heat exchanger for condensing the gas-phase refrigerant by exchanging heat between the outside air and the refrigerant,

the heat cycle further comprises an outside air temperature sensor for measuring the temperature of the outside air and also comprises a sensor for measuring a physical value having a correlation with the temperature of the refrigerant inside the liquid pump,

the control means determines the temperature at which the refrigerant inside the refrigerant pump is supercooled by the outside air temperature, and also determines the continuation time in which the refrigerant condensing operation is continued, and

the continuation time is the time from the start of the refrigerant condensing operation to when the physical value measured by the sensor becomes the temperature at which the refrigerant inside the refrigerant pump is supercooled.

31. A heat cycle according to claim 30, wherein the sensor for measuring the physical value is a temperature sensor for measuring the temperature of the housing of the refrigerant pump

32. A heat cycle according to claim 30, wherein the refrigerating cycle includes an evaporator for evaporating the refrigerant of low pressure by exchanging heat between the refrigerant of low pressure and air, and

the sensor for measuring the physical value is a temperature sensor for measuring the temperature of air immediately after heat is exchanged with the refrigerant of low pressure.

33. A heat cycle device according to claim 8, wherein the sensor is a temperature sensor for measuring the temperature of the housing of the refrigerant pump.

34. A heat cycle device according to claim 8, wherein the sensor is a temperature sensor for measuring the temperature of air immediately after heat was exchanged with the refrigerant in the evaporator.

35. A heat cycle according to claim 22, wherein the expansion machine is a reversible rotary machine having the function of a compressor for compressing the gas-phase refrigerant in the refrigerating cycle,

the reversible rotary machine is integrated with the liquid pump, and

the liquid pump is cooled by the gas-phase refrigerant sucked into the reversible rotary machine at the time of operating the refrigerating cycle.

36. A heat cycle according to claim 22, further comprising:

an air blowing means for blowing air conditioned by the refrigerating cycle; and

an operation demand means for demanding the operation of the refrigerating cycle, wherein

in the case of conducting the refrigerant condensing operation, the control means conducts the refrigerant condensing operation without operating the air blowing means when the operation of the refrigerating cycle is not demanded by the operation demand means.

37. A heat cycle according to claim 22, wherein,

the condenser is a heat exchanger for condensing the gas-phase refrigerant by exchanging heat between the outside air and the refrigerant,

the heat cycle further comprises an outside air temperature sensor for measuring the temperature of the outside air,

the control means determines the continuation time (T**21**) for continuing the refrigerant condensing operation, and

the continuation time (T**21**) is determined on the basis of the outside air temperature.

38. A heat cycle according to claim 22, further comprising a sensor for measuring a physical value having a correlation with a temperature of the refrigerant inside the liquid pump, wherein

the control means determines the continuation time in which the refrigerant condensing operation is continued, and

the continuation time is the time from the start of the refrigerant condensing operation to when the physical value measured by the sensor becomes the temperature at which the refrigerant inside the refrigerant pump is supercooled.

39. A heat cycle according to claim 22, wherein

the condenser is a heat exchanger for condensing the gas-phase refrigerant by exchanging heat between the outside air and the refrigerant,

the heat cycle further comprises an outside air temperature sensor for measuring the temperature of the outside air and also comprises a sensor for measuring a physical value having a correlation with the temperature of the refrigerant inside the liquid pump,

the control means determines the temperature at which the refrigerant inside the refrigerant pump is supercooled by the outside air temperature, and also determines the continuation time in which the refrigerant condensing operation is continued, and

the continuation time is the time from the start of the refrigerant condensing operation to when the physical value measured by the sensor becomes the temperature at which the refrigerant inside the refrigerant pump is supercooled.

40. A heat cycle according to claim 29, wherein the sensor for measuring the physical value is a temperature sensor for measuring the temperature of the housing of the refrigerant pump

41. A heat cycle according to claim 29, wherein the refrigerating cycle includes an evaporator for evaporating the refrigerant of low pressure by exchanging heat between the refrigerant of low pressure and air, and

the sensor for measuring the physical value is a temperature sensor for measuring the temperature of air immediately after heat is exchanged with the refrigerant of low pressure.

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