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(71) Applicant: **MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.**
Osaka 571-8501 (JP)

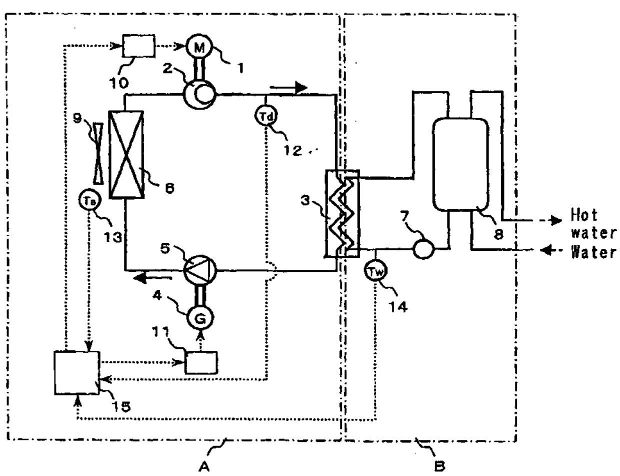
(72) Inventors:
- **Okaza, Noriho**
Matsushita Electric Industrial Co., Ltd.
1-chome,Chuo-ku
Osaka-shi,Osaka 540-6319 (JP)
- **Nakatani, Kazuo**
Matsushita Electric Industrial Co., Ltd.
1-chome,Chuo-ku
Osaka-shi,Osaka 540-6319 (JP)

(74) Representative: **Thun, Clemens**
Mitscherlich & Partner
Sonnenstrasse 33
80331 München (DE)

(54) Control method of refrigeration cycle apparatus

(57) It is an object of the present invention to stably operate the refrigeration cycle apparatus having an expansion mechanism capable of recovering pressure energy at the time of expansion, and to enhance the stability at the time of actuation. A control method of the refrigeration cycle apparatus including a compressing mechanism 2, a heat source-side heat exchanger 6, the expansion mechanism 5 which recovers power, and a utilizing-side heat exchanger 3. The number of revolutions of the expansion mechanism 5 is controlled such that the number of revolutions becomes equal to a target number of revolutions of the expansion mechanism 5 determined from a discharging temperature of the compressing mechanism 2. The number of revolutions of the expansion mechanism 5 can appropriately be controlled, the refrigeration cycle apparatus can be operated stably, and the stability of the refrigeration cycle apparatus at the time of actuation can be enhanced.

Fig. 1



EP 1 793 182 A2

Description

[Technical Field]

[0001] The present invention relates to a control method of a refrigeration cycle apparatus having an expansion mechanism which recovers power.

[Background Technique]

[0002] There is proposed a refrigeration cycle apparatus in which an expansion mechanism is provided instead of a decompressor, pressure energy at the time of expansion is recovered as power, thereby enhancing COP (see patent document 1 for example).
[Patent document 1] Japanese Patent Application Laid-open No.S56-112896

[Disclosure of the Invention]

[Problem to be Solved by the Invention]

[0003] In the conventional technique, when the temperature of heat source-side fluid which flows into a heat source-side heat exchanger, or the temperature of utilizing-side fluid which flows into a utilizing-side heat exchanger is high, the discharging temperature or high pressure-side pressure of a compressing mechanism is prone to increase, and there is a problem that the operation of the compressing mechanism is frequently stopped to protect devices.
[0004] To solve the above problem, in a refrigeration cycle apparatus having the expansion mechanism, it is an object of the present invention to appropriately control the number of revolutions of the expansion mechanism, and to stably operate the refrigeration cycle apparatus, and more particularly, to enhance the stability when the refrigeration cycle apparatus is actuated.

[Means for Solving the Problem]

[0005] To solve the problem of the conventional technique, according to a control method of a refrigeration cycle apparatus having an expansion mechanism which recovers power, the number of revolutions of the expansion mechanism is controlled such that it becomes equal to the first target number of revolutions of the expansion mechanism which is determined from the discharging temperature of the compressing mechanism. According to this control method, since the discharging temperature is not largely deviated from the target discharging temperature, it is unnecessary to stop the operation of the compressing mechanism to protect the refrigeration cycle apparatus, and it is possible to stably operate the refrigeration cycle apparatus.

[Effect of the Invention]

[0006] According to the control method of the refrigeration cycle apparatus having the expansion mechanism, it is possible to appropriately control the number of revolutions of the expansion mechanism, and to stably operate the refrigeration cycle apparatus, and to enhance the stability when the refrigeration cycle apparatus is actuated.

[Brief Description of the Drawings]

[0007]

Fig. 1 is a block diagram showing a refrigeration cycle apparatus according to first to fourth embodiments of the present invention;
Fig. 2 is a flowchart of control of an expansion mechanism according to the first embodiment of the invention;
Fig. 3 is a time chart of control of the second embodiment of the invention;
Fig. 4 is a flowchart of control of an expansion mechanism of a second embodiment of the invention:
Fig. 5 is a flowchart of control of a compressing mechanism of the second embodiment of the invention;
Fig. 6 is a time chart of control of a third embodiment of the invention;
Fig. 7 is a flowchart of control of an expansion mechanism of the third embodiment of the invention; and
Fig. 8 is a flowchart of control of an expansion mechanism of a fourth embodiment of the invention.

[Explanation of Symbols]

[0008]

1	electric motor
2	compressing mechanism
3	utilizing-side heat exchanger (radiator)
4	generator
5	expansion mechanism
6	heat source-side heat exchanger (evaporator)
7	utilizing fluid transfer means (water supply pump)
8	boiler
9	heat source fluid transfer means (air blowing apparatus)
10	compressing mechanism control means
11	expansion mechanism control means
12	discharging temperature detecting means
13	outside air temperature detecting means
14	entering-water temperature detecting means
15	electronic control means 15
A	refrigerant circuit
B	fluid circuit

[Best Mode for Carrying Out the Invention]

[0009] According to a first aspect of the invention, there is provided a control method of a refrigeration cycle apparatus including a compressing mechanism, a heat source-side heat exchanger, an expansion mechanism which recovers power, and a utilizing-side heat exchanger, wherein the number of revolutions of the expansion mechanism is controlled such that the number of revolutions becomes equal to a target number of revolutions of the expansion mechanism determined from a discharging temperature of the compressing mechanism. With this aspect, since the discharging temperature is not largely deviated from the target discharging temperature, it is unnecessary to stop the operation of the compressing mechanism to protect the refrigeration cycle apparatus, and it is possible to stably operate the refrigeration cycle apparatus.

[0010] According to a second aspect of the invention, when a discharging temperature of the compressing mechanism is higher than a predetermined target discharging temperature, the number of revolutions of the expansion mechanism is increased, and when the discharging temperature of the compressing mechanism is lower than the target discharging temperature, the number of revolutions of the expansion mechanism is reduced. With this aspect, when the discharging temperature is higher than the target discharging temperature, the number of revolutions of the expansion mechanism is increased, and when the discharging temperature of the compressing mechanism is lower than the target discharging temperature, the number of revolutions of the expansion mechanism is reduced and the discharging temperature is increased. With this aspect, since the discharging temperature is not largely deviated from the target discharging temperature, it is unnecessary to stop the operation of the compressing mechanism to protect the refrigeration cycle apparatus, and it is possible to stably operate the refrigeration cycle apparatus.

[0011] According to a third aspect of the invention, when a discharging temperature of the compressing mechanism is higher than a predetermined target discharging temperature and when the number of revolutions of the expansion mechanism exceeds an upper limit value of a using range of a predetermined number of revolutions of the expansion mechanism, the number of revolutions of the compressing mechanism is reduced. With this aspect, even when the number of revolutions of the expansion mechanism is greater than the using upper limit number of revolutions, the discharging temperature can be reduced. Therefore, it is unnecessary to stop the operation of the compressing mechanism to protect the expansion mechanism, and it is possible to stably operate the refrigeration cycle apparatus.

[0012] According to a fourth aspect of the invention, when a discharging temperature of the compressing mechanism is lower than a predetermined target discharging temperature, and when the number of revolutions of the expansion mechanism exceeds a lower limit value of a using range of a predetermined number of revolutions of the expansion mechanism, the number of revolutions of the compressing mechanism is increased. With this aspect, even when the number of revolutions of the expansion mechanism is smaller than the using lower limit number of revolutions, the discharging temperature can be increased. Therefore, it is unnecessary to stop the operation of the compressing mechanism to protect the expansion mechanism, and it is possible to stably operate the refrigeration cycle apparatus.

[0013] According to a fifth aspect of the invention, the number of revolutions of the expansion mechanism is changed before or at the same time when the number of revolutions of the compressing mechanism is changed. It is possible to prevent the high pressure-side pressure from abruptly changing when the number of revolutions of the compressing mechanism is changed, and the refrigeration cycle apparatus can stably be actuated.

[0014] Embodiments of the present invention will be explained with reference to the drawings. The invention is not limited to the embodiments. For example, in the following embodiments, the invention is explained based on a water heater, but the invention is not limited to the water heater, and the invention may be applied to an air conditioner.

(First Embodiment)

[0015] A control method of a refrigeration cycle apparatus according to a first embodiment of the invention will be explained using a refrigeration cycle apparatus whose schematic block diagram is shown in Fig. 1. The refrigeration cycle apparatus shown in Fig. 1 includes a compressing mechanism 2 driven by an electric motor 1, a refrigerant flow path of a radiator 3 as a utilizing-side heat exchanger, an expansion mechanism 5 whose power is recovered by a generator 4, an evaporator 6 as a heat source-side heat exchanger, a refrigerant circuit A into which CO_2 refrigerant is charged as a refrigerant, and a fluid circuit B comprising a water supply pump 7 as utilizing fluid transfer means, a fluid flow path of the radiator 3, and a boiler 8.

[0016] The refrigeration cycle apparatus also includes an air blowing apparatus 9 as a heat source fluid transfer means. The air blowing apparatus 9 blows heat source fluid (e.g., outside air) to the evaporator 6. The refrigeration cycle apparatus also includes a compressing mechanism control means 10 which controls the number of revolutions of the electric motor 1, and an expansion mechanism control means 11 which controls the number of revolutions of the generator 4. The number of revolutions of the expansion mechanism 5 is appropriately changed in accordance with the state of the refrigeration cycle by the expansion mechanism control means 11, and the high pressure-side pressure and the discharging temperature can be changed.

[0017] The discharging temperature detecting means

12 is provided on a refrigerant pipe from a discharge side of the compressing mechanism 2 to refrigerant inlet side of the radiator 3. The discharging temperature detecting means 12 detects the discharging temperature of the compressing mechanism 2. An outside air temperature detecting means 13 as heat source fluid inlet temperature detecting means is fixed to a fin of the evaporator 6, and detects the temperature of outside air flowing into the evaporator 6. An entering-water temperature detecting means 14 as a utilizing fluid temperature detecting means is provided in a fluid pipe from a bottom of the boiler 8 to the fluid inlet side of the radiator 3, and detects the temperature of utilizing fluid (e.g., water) flowing into the radiator 3. Electronic control means 15 determines a state of the refrigeration cycle from signals from the discharging temperature detecting means 12, the outside air temperature detecting means 13 and the entering-water temperature detecting means 14, and gives commands to the compressing mechanism control means 10 and the expansion mechanism control means 11.

[0018] Next, of the operation of the refrigeration cycle apparatus having the above-described structure, operation of a case where a variation of the refrigeration cycle is small. i.e., a case where a variation of the outside air temperature or entering-water temperature is small, or a case where there is no command from a user will be explained. In the refrigerant circuit A, CO_2 refrigerant is compressed by the compressing mechanism 2 to a pressure exceeding the critical pressure. The compressed refrigerant is brought into a high temperature and high pressure state, and when the refrigerant flows into a refrigerant flow path of the radiator 3, the refrigerant dissipates heat to water flowing through the fluid flow path of the radiator 3 and is cooled. Then, the refrigerant is decompressed by the expansion mechanism 5, and brought into a gas-liquid two-phase state of low temperature and low pressure. The pressure energy at the time of expansion recovered by the expansion mechanism 5 is transmitted to the generator 4 and is recovered as electric power.

[0019] That is, pressure energy at the time of expansion can be recovered as power and COP can be enhanced. The refrigerant decompressed by the expansion mechanism 5 is supplied to the evaporator 6. In the evaporator 6, the refrigerant is heated by outside air which is sent by the air blowing apparatus 9, and is brought into the gas-liquid two-phase state or a gas state. The refrigerant which flows out from the evaporator 6 is absorbed by the compressing mechanism 2 again. On the other hand, the utilizing fluid (e.g., water) which is sent into the fluid flow path of the radiator 3 by the water supply pump 7 from the bottom of the boiler 8 is heated by a refrigerant which flows through the refrigerant flow path of the radiator 3, and becomes fluid (e.g., hot water) of high temperature, and the high temperature fluid is stored from a top of the boiler 8. By repeating this cycle, the refrigeration cycle apparatus of the embodiment can be utilized as a water heater.

[0020] Next, the control method will be explained. The compressing mechanism 2. i.e., the electric motor 1 which is substantially a driving source is controlled by the compressing mechanism control means 10 such that the number of revolutions thereof becomes equal to the number of revolutions (first target number of revolutions of the compressing mechanism, hereinafter) calculated by the electronic control means 15 from the outside air temperature or the entering-water temperature detected by the outside air temperature detecting means 13 or the entering-water temperature detecting means 14, or a target billowing temperature which was set by a user (temperature of hot water stored in the boiler, or a target value of fluid outlet side temperature of the radiator 3).

[0021] The expansion mechanism 5, i.e., substantially the generator 4 is controlled by the expansion mechanism control means 11 as shown in the flowchart in Fig. 2. The electronic control means 15 calculates a target discharging temperature Td0 (step 100) at which the state of the refrigeration cycle becomes optimal from the outside air temperature or entering-water temperature detected by the outside air temperature detecting means 13 or the entering-water temperature detecting means 14, or a billowing temperature which was set by a user (temperature of hot water stored in the boiler, or fluid outlet side temperature of the radiator 3).

[0022] The target discharging temperature Td0 is set such that the target discharging temperature Td0 does not exceed a using temperature upper limit or pressure upper limit of a constituent element such as the compressing mechanism 2. Next, the discharging temperature Td is detected by the discharging temperature detecting means 12 (step 110). It is determined whether the detected discharging temperature Td is greater than a value in which a constant value $\Delta T1$ is added to the target discharging temperature Td0 (step 120). The constant value $\Delta T1$ is a very small value which is added so that the discharging temperature Td is in a constant temperature range so as to stabilize the refrigeration cycle state.

[0023] If it is determined in step 120 that the discharging temperature Td is higher than $Td0+\Delta T1$, it is determined in step 130 whether the number of revolutions Rexp of the expansion mechanism 5 is greater than the using upper limit number of revolutions Rexp_max of the expansion mechanism 5. The using upper limit number of revolutions of the expansion mechanism 5 is set as an upper limit value for protecting the expansion mechanism 5 or expansion mechanism control means 11. In step 130, if the number of revolutions Rexp of the expansion mechanism 5 is smaller than the using upper limit number of revolutions Rexp_max, the system instructs the expansion mechanism control means 11 to increase the number of revolutions of the expansion mechanism 5 and the number of revolutions of the generator 4 by a constant value (step 140). With this, the amount of refrigerant flowing through the expansion mechanism 5 is increased and thus, the discharging temperature Td and the high pressure-side pressure can be reduced.

[0024] In step 120, if it is determined that the discharging temperature Td is lower than Td0+(T1, it is determined whether the discharging temperature Td is smaller than a value obtained by subtracting the constant value (T2 from the target discharging temperature Td0 in step 150. Here, (T2 is a very small value which is subtracted so that the discharging temperature Td falls in the constant temperature range to stabilize the refrigeration cycle state. If it is determined in step 150 that the discharging temperature Td is smaller than Td0-(T2, it is determined in step 160 whether the number of revolutions Rexp of the expansion mechanism 5 is smaller than the using lower limit number of revolutions Rexp_min of the expansion mechanism 5.

[0025] The using lower limit number of revolutions Rexp_min of the expansion mechanism 5 is set as a lower limit value for protecting the expansion mechanism 5 or the expansion mechanism control means 11. If it is determined in step 160 that the number of revolutions Rexp of the expansion mechanism 5 is greater than the using lower limit number of revolutions Rexp_min, the system instructs the expansion mechanism control means 11 to reduce the number of revolutions of the expansion mechanism 5 and the number of revolutions of the generator 4 by a constant amount (step 170). With this, the amount of refrigerant flowing through the expansion mechanism 5 is reduced and thus, the discharging temperature Td and the high pressure-side pressure can be increased.

[0026] If it is determined in step 120 that the discharging temperature Td is lower than Td0+ΔT1 and it is determined in step 150 that the discharging temperature Td is higher than Td0-ΔT2, the discharging temperature is in a constant temperature range close to the target discharging temperature Td0. Therefore, the system instructs the expansion mechanism control means 11 to maintain the current number of revolutions of the expansion mechanism 5 and the generator 4 (step 180).

[0027] If it is determined in step 120 that the discharging temperature Td is higher than Td0+ΔT1 and it is determined in step 130 that the number of revolutions Rexp of the expansion mechanism 5 is greater than the using upper limit number of revolutions Rexp_max, there is an adverse possibility that the reliability is deteriorated if the number of revolutions of the expansion mechanism 5 is increased further. Therefore, the system instructs the compressing mechanism control means 10 to reduce the number of revolutions of the compressing mechanism 2 and the electric motor 1 by a constant amount (step 190). With this, it is possible to reduce the discharging temperature Td and high pressure-side pressure without exceeding the using upper limit number of revolutions Rexp_max of the expansion mechanism 5.

[0028] If it is determined in step 120 that the discharging temperature Td is lower than Td0+ΔT1 and it is determined in step 150 that the discharging temperature Td is lower than Td0-ΔT2 and it is determined in step 160 that the number of revolutions Rexp of the expansion mechanism 5 is smaller than the using lower limit number of revolutions Rexp_min, there is an adverse possibility that the reliability is deteriorated if the number of revolutions of the expansion mechanism 5 is reduced further. Therefore, the system instructs the compressing mechanism control means 10 to increase the number of revolutions of the compressing mechanism 2 and the electric motor 1 by a constant amount (step 200). With this, it is possible to increase the discharging temperature Td and high pressure-side pressure without exceeding the using lower limit number of revolutions Rexp_min of the expansion mechanism 5.

[0029] According to the operations of steps 120 to 180, when the discharging temperature Td exceeds the upper limit value (Td0+ΔT1) of the target discharging temperature, the number of revolutions of the expansion mechanism 5 and the number of revolutions of the generator 4 are increased to reduce the discharging temperature Td. Therefore, it is unnecessary to stop the operation of the compressing mechanism 2 to protect the refrigeration cycle apparatus, and it is possible to stably operate the refrigeration cycle apparatus. When the discharging temperature Td is smaller than the lower limit value (Td0-(T2) of the target discharging temperature, the number of revolutions of the expansion mechanism 5 and the number of revolutions of the generator 4 are reduced and the discharging temperature Td is increased. Therefore, it is possible to stably operate the refrigeration cycle apparatus without reducing the discharging temperature Td more than necessary. The target number of revolutions of the expansion mechanism of the expansion mechanism 5 determined by the operations of steps 120 to 180 is called first target number of revolutions of the expansion mechanism, hereinafter.

[0030] According to the operations of steps 190 to 200, when the discharging temperature Td exceeds the upper limit value (Td0+(T1) of the target discharging temperature and the number of revolutions Rexp of the expansion mechanism 5 is greater than the using upper limit number of revolutions Rexp_max, the number of revolutions of the compressing mechanism 2 and the number of revolutions of the electric motor 1 are reduced instead of increasing the number of revolutions of the expansion mechanism 5 and the number of revolutions of the generator 4 and reducing the discharging temperature Td, so that the discharging temperature Td is lowered. Therefore, it is unnecessary to stop the operation of the compressing mechanism 2 to protect the expansion mechanism 5, and it is possible to stably operate the refrigeration cycle apparatus.

[0031] When the discharging temperature Td is smaller than the lower limit value (Td0-(T2) of the target discharging temperature and the number of revolutions Rexp of the expansion mechanism 5 is smaller than the using lower limit number of revolutions Rexp_min, the number of revolutions of the compressing mechanism 2 and the number of revolutions of the electric motor 1 are increased and the discharging temperature Td is increased instead of reducing the number of revolutions of the expansion mechanism 5 and the number of revolutions of the generator 4 and increasing the discharging temperature Td. Therefore, it is unnecessary to stop the operation of the compressing mechanism 2 to protect the expansion mechanism 5, and it is possible to stably operate the refrigeration cycle apparatus.

[0032] It is obvious that even if the operations of steps 190 to 200 are omitted, the effect caused by the operations of steps 120 to 180 can be obtained. It is obvious that even if one of the operations of steps 190 to 200 is omitted, the effect caused the other step can be obtained.

[0033] Further, the (T1 and (T2 may have the same values or different values. One of or both of the (T1 and (T2 may be 0.

(Second Embodiment)

[0034] A control method when a refrigeration cycle apparatus of a second embodiment of the invention is actuated will be explained using the time chart shown in Fig. 3, the flowchart of control of the expansion mechanism 5 shown in Fig. 4 and the flowchart of control of the compressing mechanism 2 shown in Fig. 5. The schematic structure of the refrigeration cycle apparatus is the same as that shown in Fig. 1, explanation thereof will be omitted.

[0035] If a user instructs are given or at the preset operating time, the refrigeration cycle apparatus is actuated by the electronic control means 15. In the embodiment, before the compressing mechanism 2 is actuated, the expansion mechanism 5 is actuated. The expansion mechanism 5, i.e., substantially the generator 4 is controlled by the expansion mechanism control means 11 as shown in the flowchart in Fig. 4. The electronic control means 15 detects the outside air temperature by the outside air temperature detecting means 13 (step 300), and detects the entering-water temperature by the entering-water temperature detecting means 14 (step 310). The second target number of revolutions of the expansion mechanism which is the number of revolutions of the expansion mechanism 5 when the refrigeration cycle apparatus is actuated is calculated from the detected outside air temperature or entering-water temperature (step 320). The second target number of revolutions of the expansion mechanism is set smaller than the first target number of revolutions of the expansion mechanism explained in the first embodiment. The second target number of revolutions of the expansion mechanism is set smaller than the first target number of revolutions of the expansion mechanism explained in the first embodiment, and is set such that this number of revolutions is higher as the outside air temperature is higher and as the entering-water temperature is higher so that the second target number of revolutions of the expansion mechanism does not exceed the using temperature upper limit and pressure upper limit of the constituent elements such as the compressing mechanism 2 and the expansion mechanism 5 at the time of actuation.

[0036] Next, the expansion mechanism 5 is operated (actuated) by the second target number of revolutions of the expansion mechanism (step 330). Further, after the expansion mechanism 5 is actuated, it is determined whether predetermined time Te1 is elapsed (step 340). If the predetermined time Te1 is not elapsed, the procedure is returned to step 330, and the operation of the second target number of revolutions of the expansion mechanism is continued. If the predetermined time Te1 is elapsed, the procedure is advanced to steps 100 to 200 of the flowchart in Fig. 2 explained in the first embodiment, and the refrigeration cycle apparatus is operated at the first target number of revolutions of the expansion mechanism.

[0037] The compressing mechanism 2, i.e., substantially the electric motor 1 which is a driving source is controlled by the compressing mechanism control means 10 as shown in the flowchart in Fig. 5. The electronic control means 15 detects the outside air temperature by the outside air temperature detecting means 13 (step 400), and detects the entering-water temperature by the entering-water temperature detecting means 14 (step 410). The second target number of revolutions of the compressing mechanism which is the number of revolutions of the compressing mechanism 2 when the refrigeration cycle apparatus is actuated is calculated from the detected outside air temperature or entering-water temperature (step 420). The second target number of revolutions of the compressing mechanism is set smaller than the first target number of revolutions of the compressing mechanism explained in the first embodiment, and is set such that the second target number of revolutions of the compressing mechanism does not exceed the using temperature upper limit or pressure upper limit of the constituent elements of the compressing mechanism 2 and the expansion mechanism 5 at the time or actuation.

[0038] This can avoid the deterioration of reliability such as lubrication oil shortage which may be caused when the number of revolutions of the compressing mechanism 2 is abruptly increased from the stopped state at the time of actuation. Next, it is determined whether a predetermined time T0 is elapsed after the expansion mechanism 5 is actuated (step 430). If the predetermined time T0 is not elapsed, the procedure is returned to step 400, detections of the outside air temperature and entering-water temperature are renewed, and calculation of the second target number of revolutions of the compressing mechanism is renewed. If the predetermined time T0 is elapsed, the compressing mechanism 2 is operated at the second target number of revolutions of the compressing mechanism (step 440).

[0039] Next, it is determined whether predetermined time Tc1 is elapsed after the compressing mechanism 2 is actuated (step 450). If the predetermined time Tc1 is not elapsed, the procedure is returned to step 440, the operation at the second target number of revolutions of the compressing mechanism is continued. If the predetermined time Tc1 is elapsed, the outside air temperature is again detected by the outside air temperature detecting means 13 (step 460), and the entering-water temperature is detected by the entering-water temperature detecting means 14 (step 470). The first target number of revolutions of the compressing mechanism which is the number of revolutions of the compressing mechanism 2 when the refrigeration cycle apparatus is stable is calculated from the detected outside air temperature or entering-water temperature (step 480).

[0040] The first target number of revolutions of the compressing mechanism is set such that necessary heating amount can be secured when the refrigeration cycle is relatively stable. The predetermined time Tc1 is set greater than (predetermined time Te1 - predetermined time T0). Next, the number of revolutions of the compressing mechanism 2 is changed to the first target number of revolutions of the compressing mechanism and the refrigeration cycle apparatus is operated (step 490). Then, the procedure is returned to step 460, renewal of detection of each of the outside air temperature and entering-water temperature, and renewal of calculation of the first target number of revolutions of the compressing mechanism are repeated by determined control cycle, and the operation at the first target number of revolutions of the compressing mechanism is continued until another instructions or stopping instructions of the refrigeration cycle apparatus are issued.

[0041] According to the above operation , as shown in the time chart in Fig. 2, the expansion mechanism 5 is actuated at the second target number of revolutions of the expansion mechanism calculated from the outside air temperature and the entering-water temperature and then, after the predetermined time T0 is elapsed, the compressing mechanism 2 is actuated at the second target number of revolutions of the compressing mechanism calculated from the outside air temperature and the entering-water temperature. Therefore, when the compressing mechanism 2 is actuated, an inconvenient case in which the high pressure-side pressure is increased abruptly because the expansion mechanism 5 is stopped is not caused, and the refrigeration cycle apparatus can be actuated stably. The second target number of revolutions of the expansion mechanism is set such that the number of revolutions is increased as the high pressure-side pressure is prone to be increased in accordance with the outside air temperature and the entering-water temperature. Therefore, it is possible to prevent the high pressure-side pressure from abruptly increasing, and the refrigeration cycle apparatus can be actuated stably.

[0042] If the predetermined time Tc1 is elapsed after the compressing mechanism 2 is actuated, the number of revolutions of the compressing mechanism 2 is increased to the first target number of revolutions of the compressing mechanism calculated from the outside air temperature and the entering-water temperature. However, if the predetermined time Te1 is elapsed after the expansion mechanism 5 is actuated, the number of revolutions of the expansion mechanism 5 is previously increased to the first target number of revolutions of the expansion mechanism explained in the first embodiment. In this manner, the number of revolutions of the expansion mechanism 5 is set such that it previously becomes greater before the number of revolutions of the compressing mechanism 2 is increased. Thus, it is possible to prevent the high pressure-side pressure from abruptly increasing when the number of revolutions of the compressing mechanism 2 is increased, and the refrigeration cycle apparatus can be actuated stably.

[0043] Although the number of revolutions of the expansion mechanism 5 is increased before the number of revolutions of the compressing mechanism 2 is increased in the embodiment. However, even when the number of revolutions of the expansion mechanism 5 is increased simultaneously when the number of revolutions of the compressing mechanism 2 is increased (i.e., T0 is set to 0), the same effect can be obtained.

[0044] In the embodiment, the first target number of revolutions of the expansion mechanism and the second target number of revolutions of the expansion mechanism are determined in accordance with the outside air temperature and the entering-water temperature, but they may be determined in accordance with one of the temperatures.

[0045] In the embodiment, before the number of revolutions reaches the first target number of revolutions of the compressing mechanism which is the target number of revolutions of the compressing mechanism 2 when the variation in the refrigeration cycle is small, or the first target number of revolutions of the expansion mechanism which is the target number of revolutions of the expansion mechanism 5, the second target number of revolutions of the compressing mechanism which is set to the number of revolutions smaller than those, and the second target number of revolutions of the compressing mechanism are provided. However, the section before the number of revolutions reaches the first target number of revolutions of the compressing mechanism and the first target number of revolutions of the expansion mechanism may be divided into a plurality of sections, and a plurality of second target number of revolutions of the compressing mechanism and a plurality of second target number of revolutions of the expansion mechanism may be provided such that the target number of revolutions of the compressing mechanism and the target number of revolutions of the expander are varied in stages.

(Third Embodiment)

[0046] A control method when a refrigeration cycle apparatus according to a third embodiment of the invention is actuated will be explained using the time chart shown in Fig. 6 and the flowchart of control of the expansion mechanism 5 shown in Fig. 7. Since the schematic structure of the refrigeration cycle apparatus is the same as that shown in Fig. 1, explanation thereof will be omitted.

Further, the control method of the compressing mechanism 2 is the same as that of the second embodiment, explanation thereof will be omitted.

[0047] If a user instructs are given or at the preset operating time, the refrigeration cycle apparatus is actuated by the electronic control means 15. In the embodiment, before the compressing mechanism 2 is actuated, the expansion mechanism 5 is actuated. The expansion mechanism 5, i.e., substantially the generator 4 is controlled by the expansion mechanism control means 11 as shown in the flowchart in Fig. 7. The electronic control means 15 detects the outside air temperature by the outside air temperature detecting means 13 (step 500), and detects the entering-water temperature by the entering-water temperature detecting means 14 (step 510). The second target number of revolutions of the expansion mechanism which is the number of revolutions of the expansion mechanism 5 when the refrigeration cycle apparatus is actuated is calculated from the detected outside air temperature or entering-water temperature (step 520). The second target number of revolutions of the expansion mechanism is set smaller than the first target number of revolutions of the expansion mechanism explained in the first embodiment. The second target number of revolutions of the expansion mechanism is set smaller than the first target number of revolutions of the expansion mechanism explained in the first embodiment, and is set such that this number of revolutions is higher as the outside air temperature is higher and as the entering-water temperature is higher so that the second target number of revolutions of the expansion mechanism does not exceed the using temperature upper limit and pressure upper limit of the constituent elements such as the compressing mechanism 2 and the expansion mechanism 5 at the time of actuation.

[0048] Next, the expansion mechanism 5 is operated (actuated) by the second target number of revolutions of the expansion mechanism (step 530). Further, after the expansion mechanism 5 is actuated, it is determined whether predetermined time Te2 is elapsed (step 540). If the predetermined time Te2 is not elapsed, the procedure is returned to step 530, and the operation of the second target number of revolutions of the expansion mechanism is continued. If the predetermined time Te2 is elapsed, the detection of the outside air temperature is renewed by the outside air temperature detecting means 13 (step 550), and the detection of the entering-water temperature is renewed by the entering-water temperature detecting means 14 (step 560).

[0049] The third target number of revolutions of the expansion mechanism which is the number of revolutions of the expansion mechanism 5 when the refrigeration cycle apparatus is actuated is calculated from the detected outside air temperature and entering-water temperature (step 570). The third target number of revolutions of the expansion mechanism is set greater than the first target number of revolutions of the expansion mechanism explained in the first embodiment, and is set such that this number of revolutions is higher as the outside air temperature is higher and as the entering-water temperature is higher so that the third target number of revolutions of the expansion mechanism does not exceed the using temperature upper limit and pressure upper limit of the constituent element such as the compressing mechanism 2 and the expansion mechanism 5 at the time of actuation.

[0050] Next, the expansion mechanism 5 is operated at the third target number of revolutions of the expansion mechanism (step 580). It is determined whether predetermined time Te3 is elapsed after the expansion mechanism 5 is actuated (step 590). If the predetermined time Te3 is not elapsed, the procedure is returned to step 550, detections of the outside air temperature and entering-water temperature are renewed and the third target number of revolutions of the expansion mechanism is calculated again and then, the operation at the third target number of revolutions of the expansion mechanism is continued. If the predetermined time Te3 is elapsed, the procedure is advanced to steps 100 to 200 in the flowchart in Fig. 2 explained in the first embodiment, and the refrigeration cycle apparatus is operated at the first target number of revolutions of the expansion mechanism.

[0051] According to the above operations, if the predetermined time Te3 is elapsed after the expansion mechanism 5 is actuated at the second target number of revolutions of the expansion mechanism calculated from the outside air temperature and the entering-water temperature as shown in the time chart in Fig. 6, the number of revolutions of the expansion mechanism 5 is increased to the first target number of revolutions of the expansion mechanism explained in the first embodiment. However, if the predetermined time Te2 before the predetermined time Te3 is elapsed is elapsed, the expansion mechanism 5 is operated at the third target number of revolutions of the expansion mechanism which is set greater than the second target number of revolutions of the expansion mechanism. Therefore, it is possible to avoid abrupt variation in the high pressure-side pressure when the number of revolutions of the expansion mechanism 5 is increased from the second target number of revolutions of the expansion mechanism to the first target number of revolutions of the expansion mechanism, and the refrigeration cycle apparatus can be actuated stably while shortening the actuation time.

[0052] In the embodiment, the third target number of revolutions of the expansion mechanism is determined in accordance with the outside air temperature and the entering-water temperature, but it may be determined in accordance with one of the temperatures.

(Fourth Embodiment)

[0053] A control method when a refrigeration cycle apparatus of a fourth embodiment of the invention is actuated will be explained using the flowchart of control of the expansion mechanism 5 shown in Fig. 8. In Fig. 8, the same control steps as those shown in Fig. 7 are designated with the same numbers, and explanation thereof will be omitted. Since the schematic structure of the refrigeration cycle apparatus is the same as that shown in Fig. 1, explanation thereof will be omitted. Further, the control method of the compressing mechanism 2 is the same as that of the second embodiment, explanation thereof will be omitted.

[0054] In step 580, the expansion mechanism 5 is operated at the third target number of revolutions of the expansion mechanism, and it is determined whether the predetermined time Te3 is elapsed after the expansion mechanism 5 is actuated (step 590). If the predetermined time Te3 is not elapsed, the discharging temperature Td is detected by the discharging temperature detecting means 12 (step 600). It is determined whether a difference between the target discharging temperature Td0 and the discharging temperature Td is smaller than a constant value ΔT3 (step 610). Like the first embodiment, the target discharging temperature Td0 is set such that the refrigeration cycle state becomes optimal from the outside air temperature, the entering-water temperature, and the target billowing temperature (temperature of hot water stored in the boiler, or a target value of fluid outlet side temperature of the radiator 3) which was set by a user, and the (T3 is a vary small value used for determining that the discharging temperature Td approached the target discharging temperature Td0.

[0055] If it is determined in step 610 that a difference between the target discharging temperature Td0 and the detected discharging temperature Td is greater than the constant value (T3, since the discharging temperature Td does not sufficiently approach the target discharging temperature Td0, the procedure is returned to step 550, the detections of the outside air temperature and the entering-water temperature are renewed and the third target number of revolutions of the expansion mechanism is calculated and then, the operation at the third target number of revolutions of the expansion mechanism is continued. On the other hand, if it is determined in step 610 that the difference between the target discharging temperature Td0 and the detected discharging temperature Td is smaller than the constant value (T3, since the discharging temperature Td sufficiently approaches the target discharging temperature Td0, the procedure is advanced to steps 100 to 200 in the flowchart in Fig. 2 explained in the first embodiment, the refrigeration cycle apparatus is operated at the first target number of revolutions of the expansion mechanism which is the number of revolutions of the expansion mechanism 5 that brings the discharging temperature close to the target discharging temperature.

[0056] Also if it is determined that the predetermined time Te3 is elapsed in step 590, the procedure is advanced to steps 100 to 200 in the flowchart in Fig. 2 explained in the first embodiment, and the refrigeration cycle apparatus is operated at the first target number of revolutions of the expansion mechanism.

[0057] According to the above operation, even if the predetermined time Te3 is not elapsed, when the discharging temperature Td approaches the target discharging temperature Td0, the number of revolutions is shifted to the next target number of revolutions of the expansion mechanism like the case where the predetermined time Te3 is elapsed. That is, when the discharging temperature Td approaches the target discharging temperature Td0, it is assumed that the predetermined time Te3 is elapsed.

[0058] According to such operation, even before the predetermined time Te3 is elapsed, when the discharging temperature Td approaches the target discharging temperature Td0, the number of revolutions of the expansion mechanism 5 is shifted to the first target number of revolutions of the expansion mechanism. Therefore, time during which the refrigeration cycle apparatus is operated at the third target number of revolutions of the expansion mechanism unnecessarily can be shortened, and it is possible to stably actuate the refrigeration cycle apparatus while shortening the actuation time.

[0059] In the embodiment, when the discharging temperature Td approaches the target discharging temperature Td0, it is assumed that the predetermined time Te3 is elapsed. Alternatively, it is also possible to assume that the predetermined time Te3 is elapsed when the utilizing-side fluid outlet temperature flowing from the radiator 3 which is the utilizing-side heat exchanger (e.g., billowing temperature) approaches a predetermined target temperature of the utilizing-side fluid outlet temperature (i.e., target billowing temperature). Further, it is also possible to assume that the predetermined time Te3 is elapsed when the discharging temperature Td becomes higher than a predetermined target billowing temperature by a constant temperature. Further, (T3 may be 0.

[0060] Concerning the predetermined times Te1, Te2 and Tc1 in the second and third embodiments, it is also possible to assume that the predetermined time is elapsed even when the discharging temperature Td approaches the target discharging temperature Td0, or when the billowing temperature approaches the target billowing temperature, or when the discharging temperature Td becomes higher than the target billowing temperature by a constant temperature.

[0061] When a refrigerant is CO_2 refrigerant, a high pressure-side pressure becomes supercritical pressure which does not depend on condensation temperature. Therefore, the high pressure-side pressure is prone to increase. According to the above embodiments, however, it is possible to stably operate the refrigeration cycle apparatus without stopping the operation of the compressing mechanism which to protects devices.

[Industrial Applicability]

[0062] A control method of a refrigeration cycle apparatus of the present invention, in the refrigeration cycle apparatus having an expansion mechanism, can control the number of revolutions of the expansion mechanism appropriately, and operate the refrigeration cycle apparatus stably. Therefore, the invention can be applied to a water heater having the expansion mechanism and an air conditioner.

Claims

1. A control method of a refrigeration cycle apparatus including a compressing mechanism, a heat source-side heat exchanger, an expansion mechanism which recovers power, and a utilizing-side heat exchanger, wherein the number of revolutions of said expansion mechanism is controlled such that the number of revolutions becomes equal to a target number of revolutions of the expansion mechanism determined from a discharging temperature of said compressing mechanism.

2. The control method of the refrigeration cycle apparatus according to claim 1, wherein when a discharging temperature of said compressing mechanism is higher than a predetermined target discharging temperature, the number of revolutions of said expansion mechanism is increased, and when the discharging temperature of said compressing mechanism is lower than the target discharging temperature, the number of revolutions of said expansion mechanism is reduced.

3. The control method of the refrigeration cycle apparatus according to claim 1, wherein when a discharging temperature of said compressing mechanism is higher than a predetermined target discharging temperature and when the number of revolutions of said expansion mechanism exceeds an upper limit value of a using range of a predetermined number of revolutions of said expansion mechanism, the number of revolutions of said compressing mechanism is reduced.

4. The control method of the refrigeration cycle apparatus according to claim 1, wherein when a discharging temperature of said compressing mechanism is lower than a predetermined target discharging temperature, and when the number of revolutions of said expansion mechanism exceeds a lower limit value of a using range of a predetermined number of revolutions of said expansion mechanism, the number of revolutions of said compressing mechanism is increased.

5. The control method of the refrigeration cycle apparatus according to claim 1, wherein the number of revolutions of said expansion mechanism is changed before or at the same time when the number of revolutions of said compressing mechanism is changed.

Fig. 1

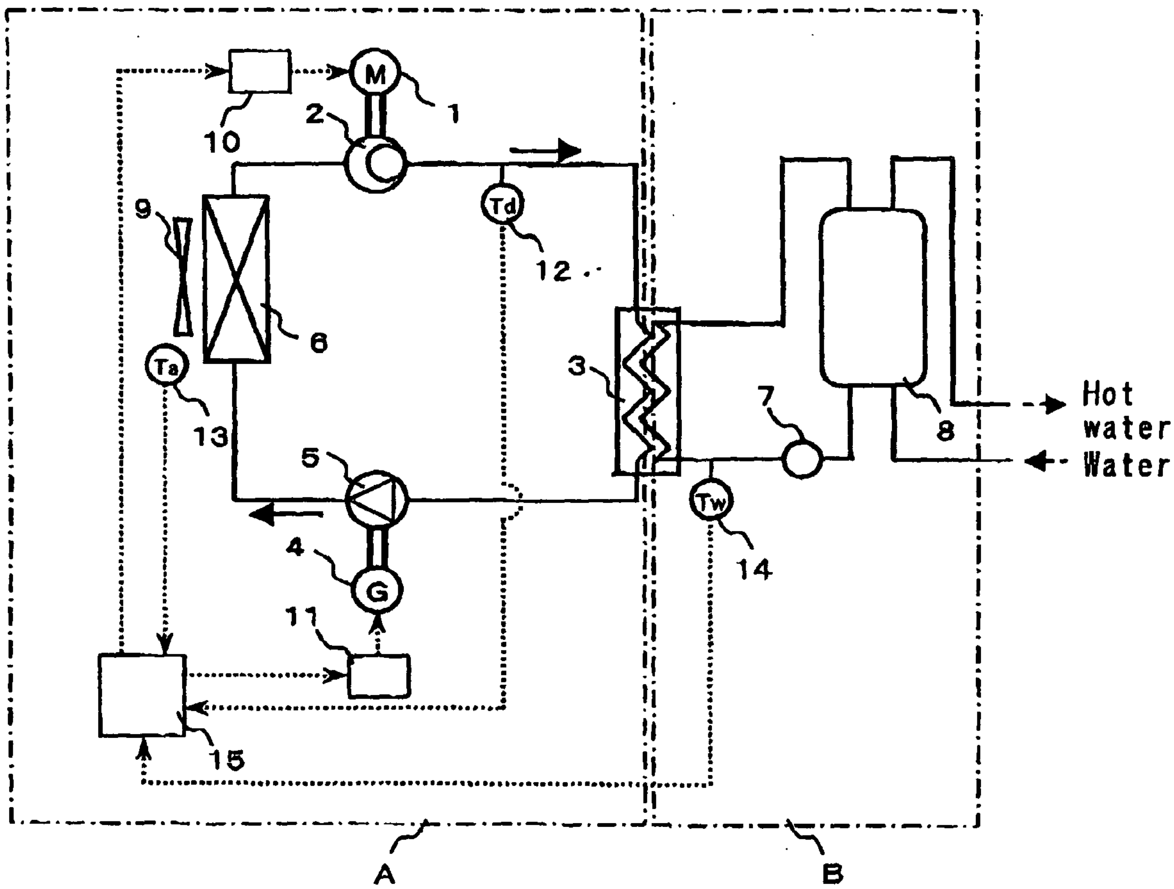


Fig. 2

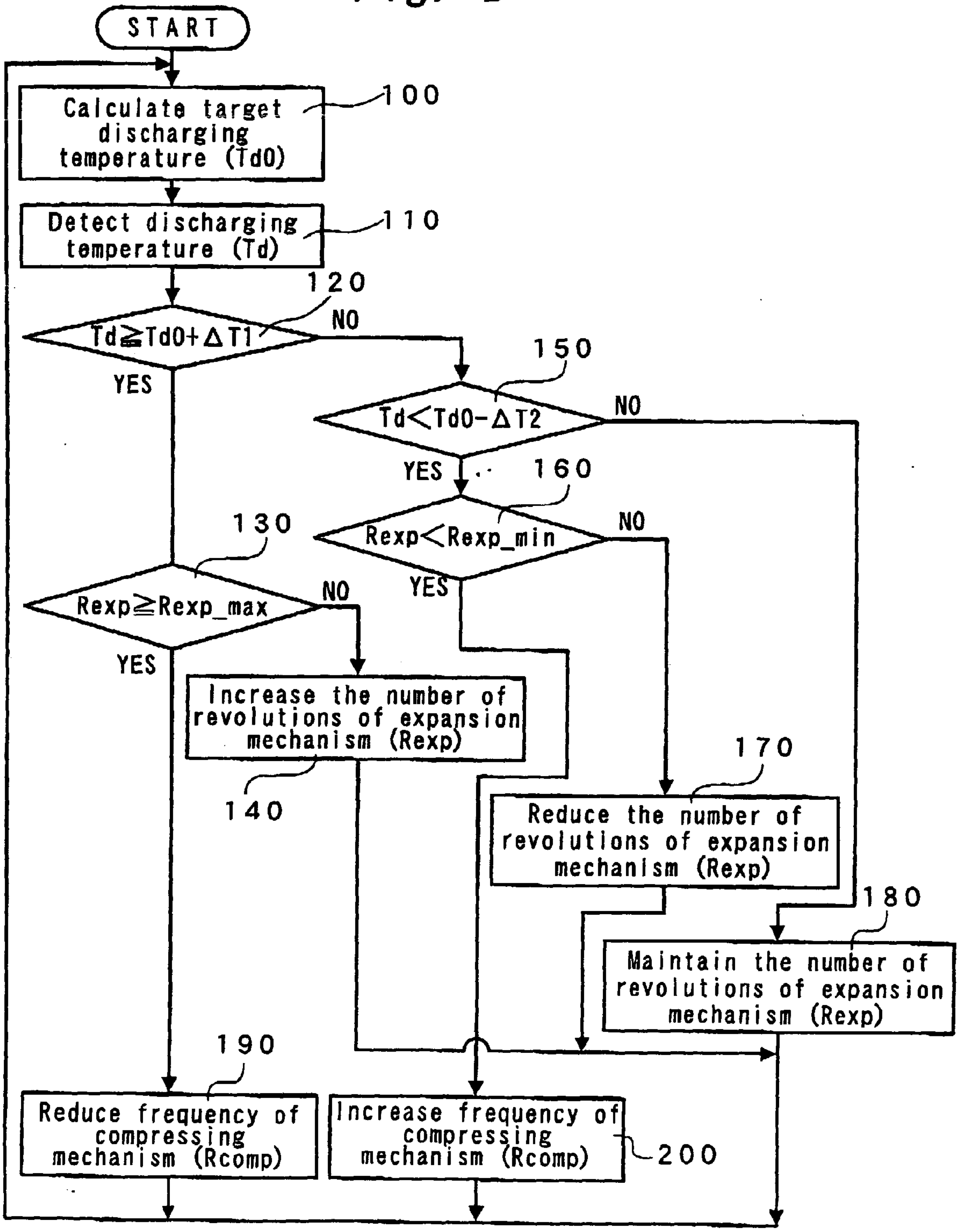

START
Calculate target discharging temperature (Td0)
100
Detect discharging temperature (Td)
110
120
Td≧Td0+ΔT1
NO
YES
150
Td<Td0-ΔT2
NO
YES
160
Rexp<Rexp_min
NO
YES
130
Rexp≧Rexp_max
NO
YES
Increase the number of revolutions of expansion mechanism (Rexp)
140
170
Reduce the number of revolutions of expansion mechanism (Rexp)
180
Maintain the number of revolutions of expansion mechanism (Rexp)
190
Reduce frequency of compressing mechanism (Rcomp)
Increase frequency of compressing mechanism (Rcomp)
200

Fig. 3

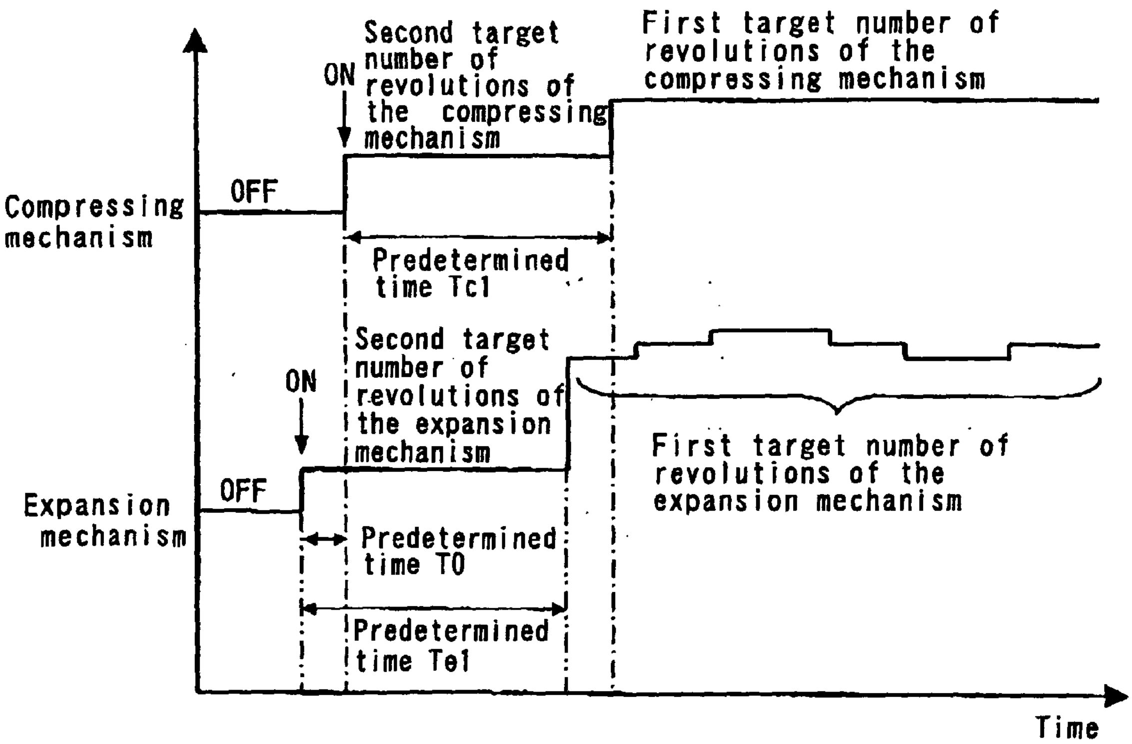

Compressing mechanism
OFF
ON
Second target number of revolutions of the compressing mechanism
First target number of revolutions of the compressing mechanism
Predetermined time Tc1
Expansion mechanism
OFF
ON
Second target number of revolutions of the expansion mechanism
First target number of revolutions of the expansion mechanism
Predetermined time T0
Predetermined time Te1
Time

Fig. 4

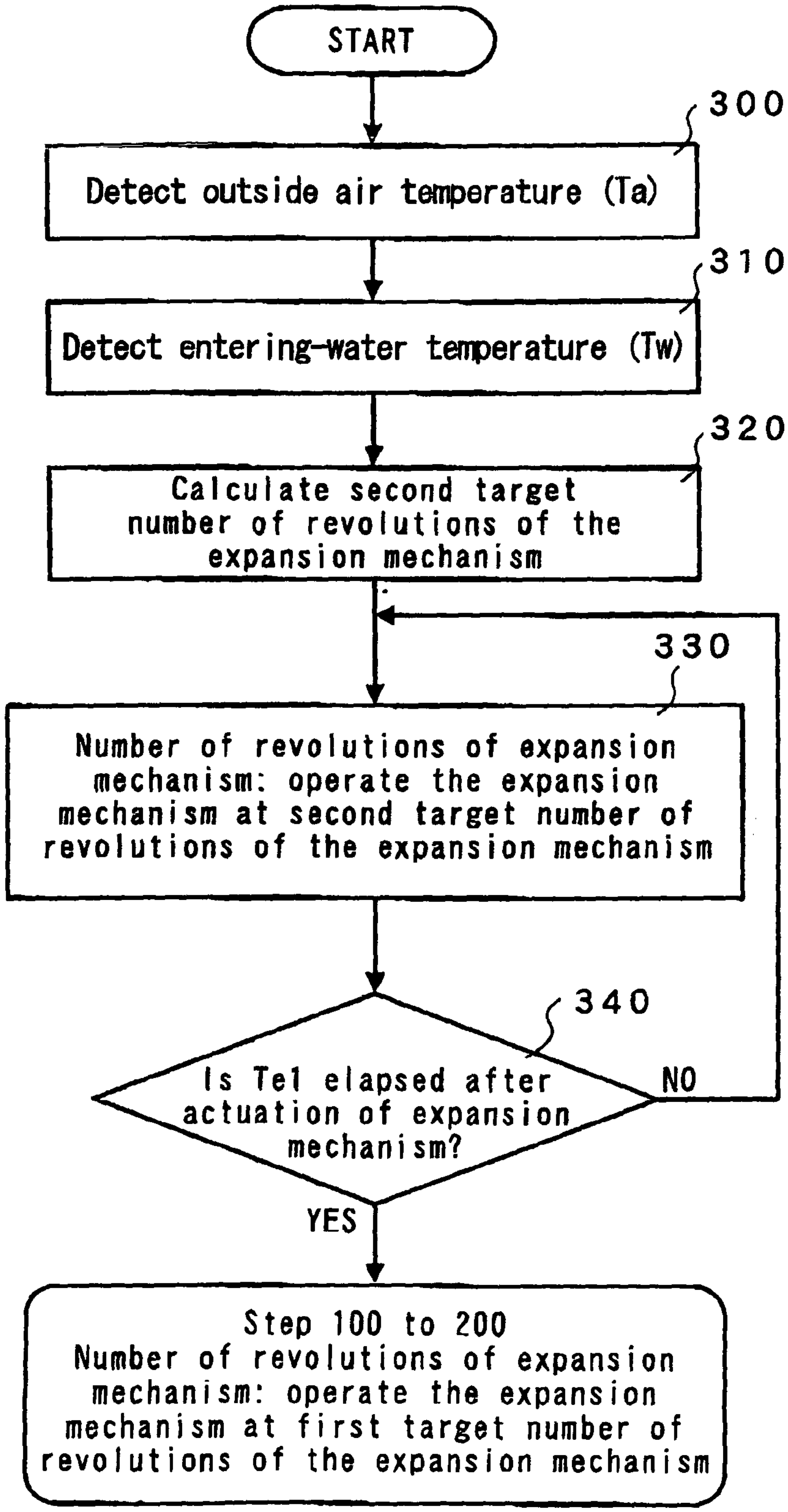

START
300
Detect outside air temperature (Ta)
310
Detect entering-water temperature (Tw)
320
Calculate second target number of revolutions of the expansion mechanism
330
Number of revolutions of expansion mechanism: operate the expansion mechanism at second target number of revolutions of the expansion mechanism
340
Is Te1 elapsed after actuation of expansion mechanism?
NO
YES
Step 100 to 200
Number of revolutions of expansion mechanism: operate the expansion mechanism at first target number of revolutions of the expansion mechanism

Fig. 5

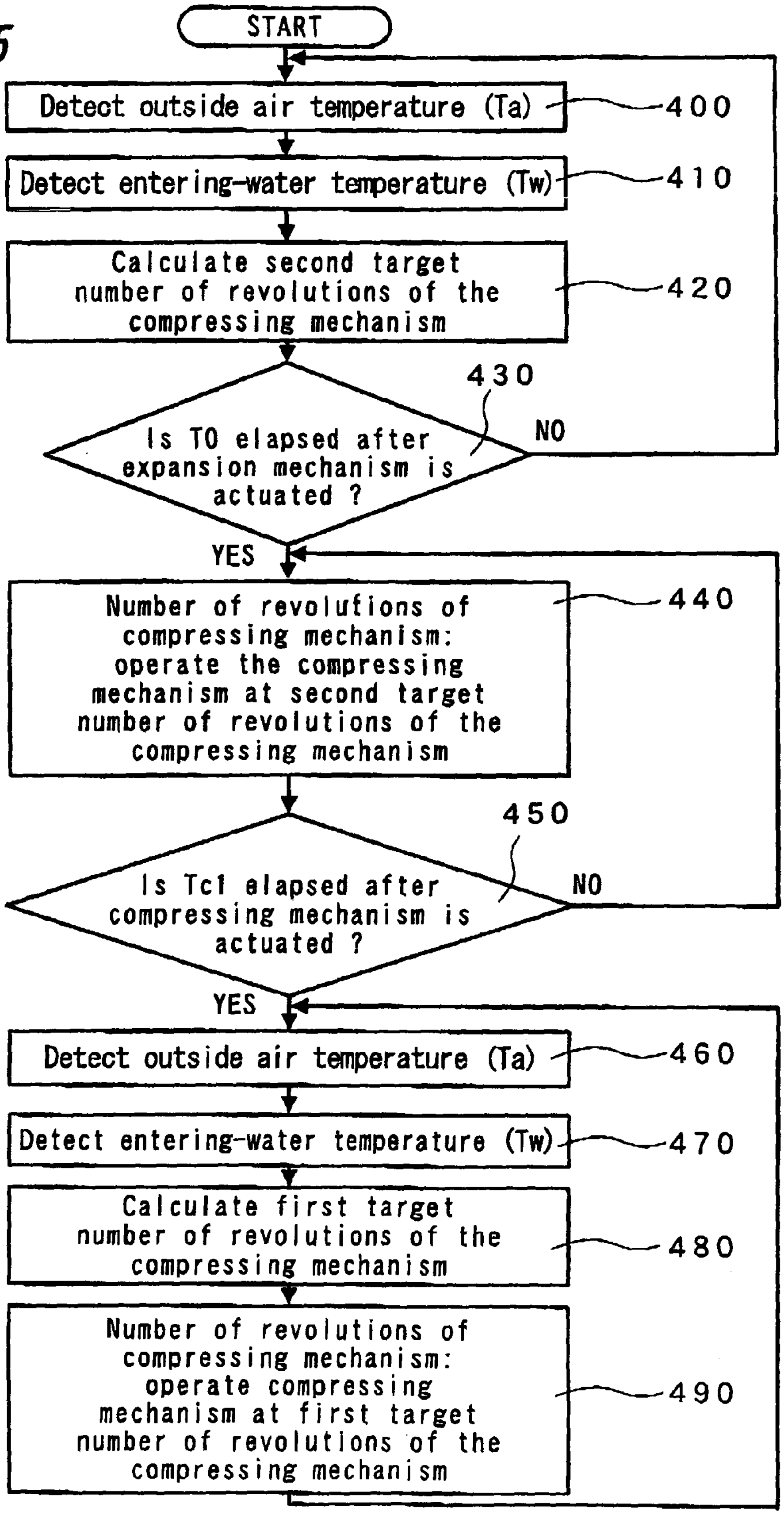

START
Detect outside air temperature (Ta)
400
Detect entering-water temperature (Tw)
410
Calculate second target number of revolutions of the compressing mechanism
420
430
Is T0 elapsed after expansion mechanism is actuated ?
NO
YES
Number of revolutions of compressing mechanism: operate the compressing mechanism at second target number of revolutions of the compressing mechanism
440
450
Is Tc1 elapsed after compressing mechanism is actuated ?
NO
YES
Detect outside air temperature (Ta)
460
Detect entering-water temperature (Tw)
470
Calculate first target number of revolutions of the compressing mechanism
480
Number of revolutions of compressing mechanism: operate compressing mechanism at first target number of revolutions of the compressing mechanism
490

Fig. 6

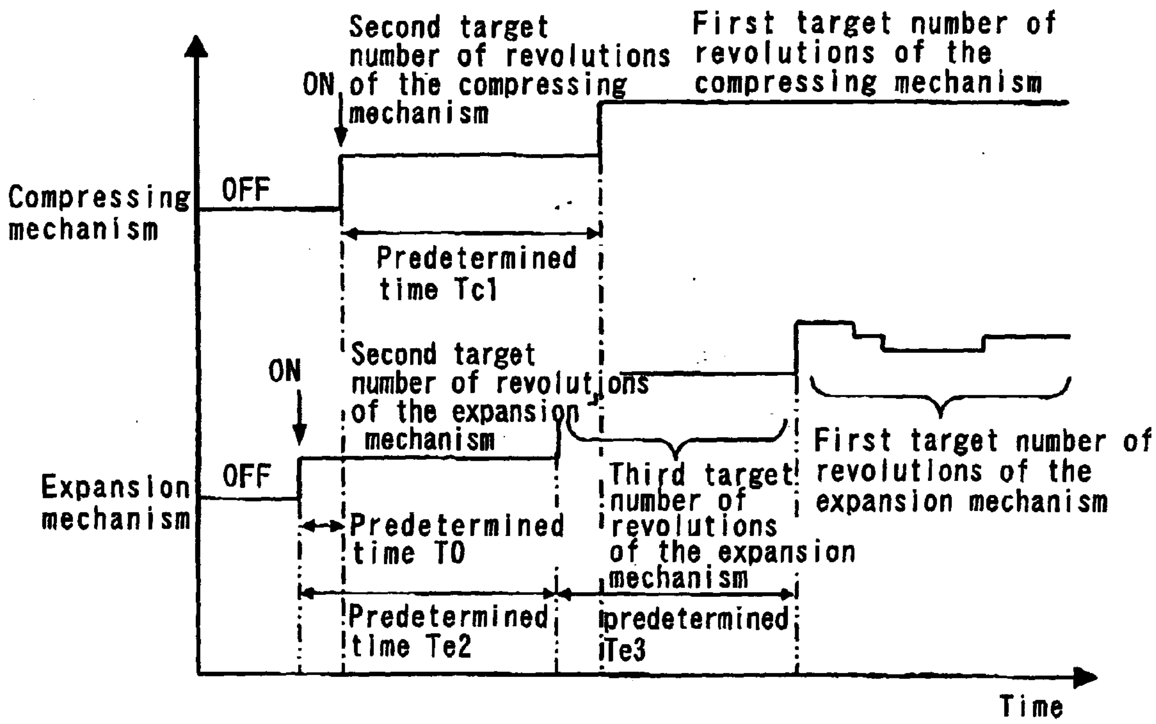
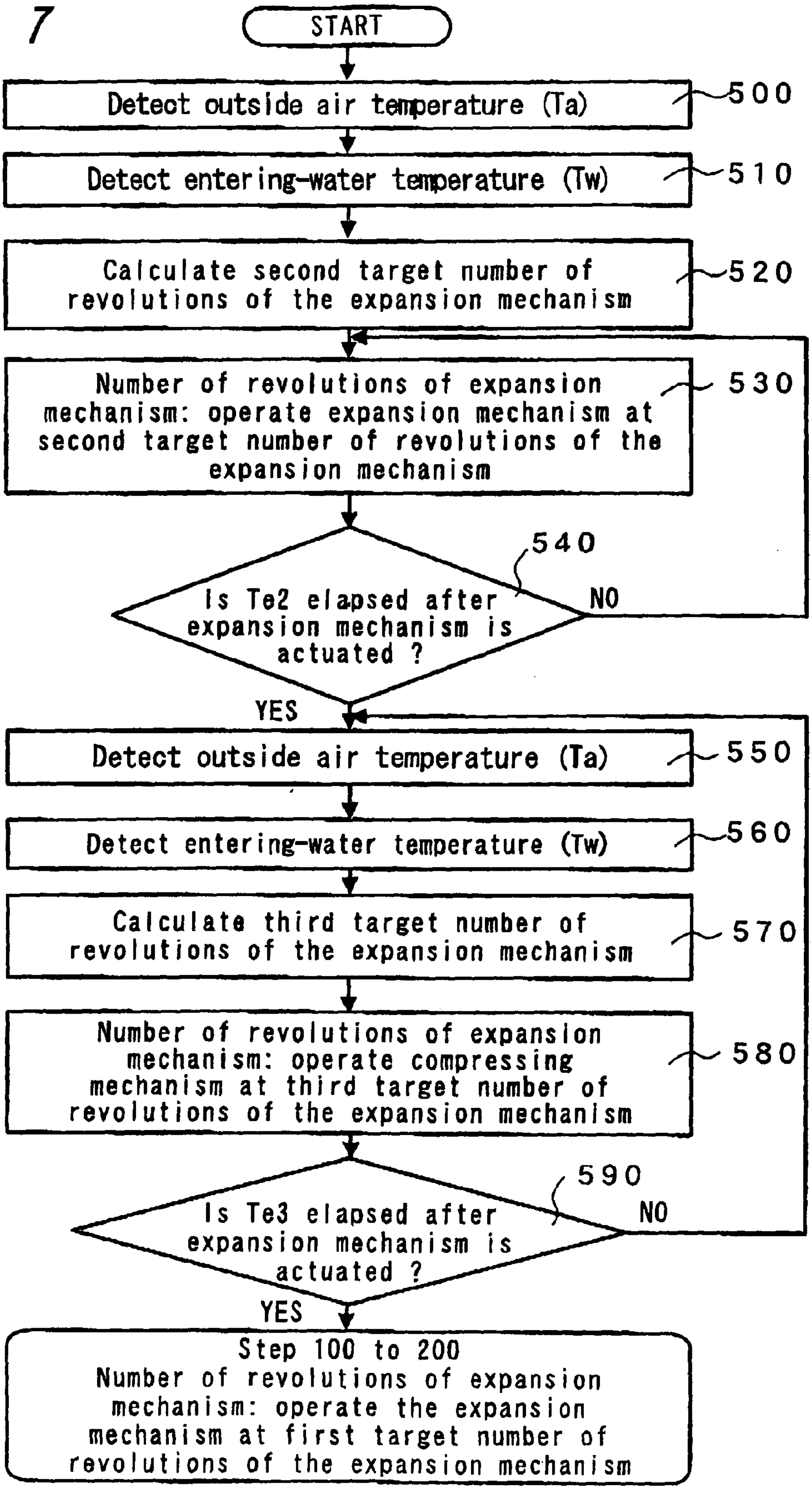
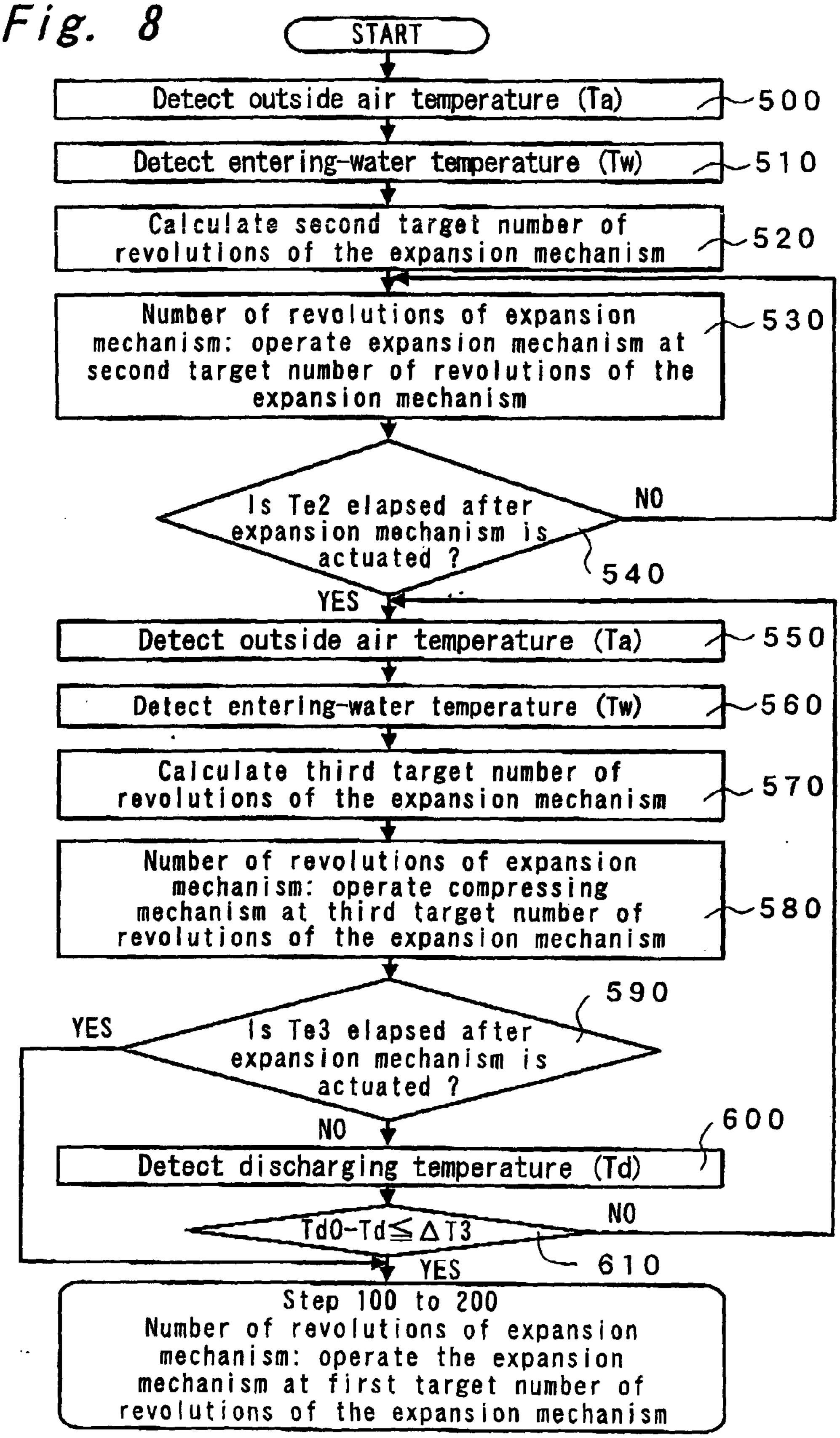

Second target number of revolutions of the compressing mechanism
First target number of revolutions of the compressing mechanism
ON
Compressing mechanism
OFF
Predetermined time Tc1
ON
Second target number of revolutions of the expansion mechanism
Expansion mechanism
OFF
Third target number of revolutions of the expansion mechanism
First target number of revolutions of the expansion mechanism
Predetermined time T0
Predetermined time Te2
predetermined Te3
Time

Fig. 7



START
Detect outside air temperature (Ta)
500
Detect entering-water temperature (Tw)
510
Calculate second target number of revolutions of the expansion mechanism
520
Number of revolutions of expansion mechanism: operate expansion mechanism at second target number of revolutions of the expansion mechanism
530
Is Te2 elapsed after expansion mechanism is actuated ?
540
NO
YES
Detect outside air temperature (Ta)
550
Detect entering-water temperature (Tw)
560
Calculate third target number of revolutions of the expansion mechanism
570
Number of revolutions of expansion mechanism: operate compressing mechanism at third target number of revolutions of the expansion mechanism
580
Is Te3 elapsed after expansion mechanism is actuated ?
590
NO
YES
Step 100 to 200
Number of revolutions of expansion mechanism: operate the expansion mechanism at first target number of revolutions of the expansion mechanism

Fig. 8


START
Detect outside air temperature (Ta)
500
Detect entering-water temperature (Tw)
510
Calculate second target number of revolutions of the expansion mechanism
520
Number of revolutions of expansion mechanism: operate expansion mechanism at second target number of revolutions of the expansion mechanism
530
Is Te2 elapsed after expansion mechanism is actuated ?
NO
540
YES
Detect outside air temperature (Ta)
550
Detect entering-water temperature (Tw)
560
Calculate third target number of revolutions of the expansion mechanism
570
Number of revolutions of expansion mechanism: operate compressing mechanism at third target number of revolutions of the expansion mechanism
580
590
YES
Is Te3 elapsed after expansion mechanism is actuated ?
NO
600
Detect discharging temperature (Td)
NO
Td0-Td≦ΔT3
YES
610
Step 100 to 200
Number of revolutions of expansion mechanism: operate the expansion mechanism at first target number of revolutions of the expansion mechanism

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 56112896 A **[0002]**