

Description

BACKGROUND OF THE INVENTION

(FIELD OF THE INVENTION)

[0001] The present invention relates to a thermal energy recovery device.

(DESCRIPTION OF THE RELATED ART)

[0002] There has been conventionally known a thermal energy recovery device configured to recover power from exhaust heat discharged from various facilities of a factory or the like. For example, JP 2012-97725 A describes a binary power generation system (thermal energy recovery device) including an evaporator, an oil separator, an expander, a generator, a condenser, a circulation pump, a circulation pipe, a lubrication oil supply pipe, an oil cooling pipe, and a heat exchanger. The circulation pipe is connected in series with the evaporator, the oil separator, the expander, the condenser, and the circulation pump in the mentioned order. The evaporator is configured to evaporate a mixed medium including a working medium and an oil. The oil separator is configured to separate the oil from the mixed medium discharged from the evaporator. The expander is configured to expand the working medium discharged from the oil separator. The lubrication oil supply pipe is a pipe configured to supply the oil separated in the oil separator to the expander. The generator is connected to the expander and is configured to derive electric power from expansion energy of the working medium in the expander. The condenser is configured to condense, with cooling water, the mixed medium discharged from the expander. The circulation pump is configured to send the mixed medium discharged from the condenser to the evaporator. The heat exchanger is provided in the lubrication oil supply pipe and is configured to cool the oil flowing through the lubrication oil supply pipe. The oil cooling pipe is configured to guide a portion of the mixed medium pumped out from the circulation pump in the circulation pipe and to allow the mixed medium discharged from the heat exchanger to join a portion between the circulation pump and the evaporator in the circulation pipe. That is, the heat exchanger is configured to cool the oil flowing through the lubrication oil supply pipe with the mixed medium flowing through the oil cooling pipe.

[0003] In the thermal energy recovery device described in JP 2012-97725 A, the working medium receives heat from the oil in the heat exchanger, but this heat is not effectively recovered. Specifically, in the thermal energy recovery device, the working medium receives heat from both the evaporator and the oil, which only differs, in the distribution of heat that the working medium receives, from a case where the working medium receives heat from only the evaporator unless the heat exchanger is provided. Such heat is partially re-

ceived in the heat exchanger. Thus, energy to be supplied into the expander rarely increases compared with the case not provided with the heat exchanger.

[0004] An object of the present invention is thus to provide a thermal energy recovery device that can cool an oil with a working medium and can increase energy to be supplied into an expander.

[0005] In order to achieve the above object, the present invention provides a thermal energy recovery device including: an evaporator configured to evaporate a mixed medium including a working medium and an oil; an oil separator configured to separate the oil from the mixed medium discharged from the evaporator; an expander configured to expand the working medium discharged from the oil separator; a power recovery machine connected to the expander; an oil supply flow passage configured to supply the oil, discharged from the oil separator, to the expander; a condenser configured to condense the mixed medium discharged from the expander; a pump configured to send the mixed medium, discharged from the condenser, to the evaporator; a circulation flow passage connecting the evaporator, the oil separator, the expander, the condenser, and the pump in the mentioned order; an oil cooler configured to cool the oil flowing through the oil supply flow passage; an oil cooling flow passage branched from a portion between the pump and the evaporator in the circulation flow passage and configured to pass the oil cooler; an expansion valve provided at a portion upstream of the oil cooler in the oil cooling flow passage and configured to adjust the opening; and an expansion valve adjustment portion configured to adjust the opening of the expansion valve so that the temperature of the oil flowing through a portion between the oil cooler and the expander in the oil supply flow passage is maintained at a value below a reference temperature. The oil cooler allows the oil flowing through the oil supply flow passage to be thermally exchanged with the mixed medium flowing through the oil cooling flow passage and evaporates at least a portion of the mixed medium, and a downstream end of the oil cooling flow passage is connected to a middle step of the expander.

[0006] In the thermal energy recovery device, the mixed medium pumped out from the pump passes the expansion valve and thereby is depressurized. Therefore, the mixed medium easily evaporates in the oil cooler, and the evaporation of the mixed medium in the oil cooler allows the oil to be effectively cooled. Then, the mixed medium evaporated in the oil cooler is supplied through the oil cooling flow passage into the middle step of the expander (i.e., a portion of the expander has pressure corresponding to the pressure of the mixed medium that has passed the expansion valve). Therefore, energy supplied into the expander (power to be recovered in the power recovery machine) increases. In addition, heat exchange including the evaporator phenomena of the mixed medium is performed in the oil cooler. Consequently, the oil cooler can be downsized compared with a case where only a sensible heat exchange of the oil

with the mixed medium is performed in the oil cooler.

[0007] Also, the thermal energy recovery device may further include: a branch flow passage branched from a portion between the oil cooler and the expander in the oil cooling flow passage and connected to a portion between the expander and the condenser in the circulation flow passage; a switching unit configured to switch a mode where the mixed medium discharged from the oil cooler flows into the expander, as a first mode, to a mode where the mixed medium discharged from the oil cooler flows into the branch flow passage, as a second mode, and vice versa; and a switching unit adjustment portion configured to switch the switching unit to the first mode when the mixed medium discharged from the oil cooler is determined to be in a gas phase, the switching unit adjustment portion being configured to switch the switching unit to the second mode when the mixed medium flowing through a portion between the oil cooler and the switching unit in the oil cooling flow passage is determined to contain a liquid phase.

[0008] In this aspect, the gas-phase mixed medium flows into the expander, and thereby power can be effectively recovered in the power recovery machine and the liquid-phase mixed medium can be inhibited from flowing into the expander.

[0009] Further, the thermal energy recovery device may further include: a gas-liquid separator provided at a portion between the oil cooler and the expander in the oil cooling flow passage; and a branch flow passage configured to guide, to the condenser, the liquid-phase mixed medium into which the mixed medium is separated in the gas-liquid separator.

[0010] In this aspect, even when the mixed medium is discharged in a gas-liquid two-phase from the oil cooler, the mixed medium is separated into a gas phase and a liquid phase in the gas-liquid separator and only the gas-phase mixed medium is guided to the expander. Consequently, the gas-phase mixed medium flows into the expander, and thereby power can be effectively recovered in the power recovery machine and the liquid-phase mixed medium can be inhibited from flowing into the expander.

[0011] In this case, the thermal energy recovery device may further include a check valve provided between the gas-liquid separator and the expander in the oil cooling flow passage. The check valve is configured to allow the mixed medium to pass from the gas-liquid separator to the expander and to prevent the mixed medium from passing from the expander to the gas-liquid separator.

[0012] With such a configuration, a backward flow of the mixed medium from the expander to the gas-liquid separator is prevented, that is, a reduction in power recovery in the power recovery machine is prevented.

[0013] Furthermore, the thermal energy recovery device may further include: a shut-off valve provided in the branch flow passage; and a shut-off valve adjustment portion configured to close the shut-off valve when the mixed medium flowing through a portion between the

gas-liquid separator and the expander in the oil cooling flow passage is determined to be in a gas phase, the shut-off valve adjustment portion being configured to close the shut-off valve when the mixed medium flowing through a portion between the gas-liquid separator and the expander in the oil cooling flow passage is determined to contain a liquid phase.

[0014] With such a configuration, the gas-phase mixed medium is inhibited from flowing out from the gas-liquid separator to the branch flow passage (a loss in recoverable power in the power recovery machine is prevented), and in addition, the liquid-phase mixed medium is inhibited from being excessively stored in the gas-liquid separator.

[0015] Also, the thermal energy recovery device may further include a heater provided at a portion between the oil cooler and the expander in the oil cooling flow passage and at a portion between the expander and the condenser in the circulation flow passage. The heater may be configured to heat the mixed medium discharged from the oil cooler with the mixed medium discharged from the expander.

[0016] With such a configuration, the mixed medium discharged from the oil cooler recovers heat from the mixed medium discharged from the expander; therefore, power to be recovered in the power recovery machine increases.

[0017] Further, in the thermal energy recovery device, a portion between the oil cooler and the expander in the oil cooling flow passage is connected to the power recovery machine so that the mixed medium discharged from the oil cooler is heated by the power recovery machine.

[0018] With such a configuration, the mixed medium discharged from the oil cooler recovers exhaust heat of the power recovery machine; therefore, power to be recovered in the power recovery machine increases.

[0019] As described above, according to the present invention, a thermal energy recovery device that cools the oil with a working medium and increases energy to be supplied into an expander can be provided.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020]

FIG. 1 is a diagram schematically illustrating the structure of a thermal energy recovery device according to a first embodiment of the present invention.

FIG. 2 is a flowchart illustrating the content of control by a control unit.

FIG. 3 is a diagram schematically illustrating the structure of the thermal energy recovery device according to a second embodiment of the present invention.

FIG. 4 is a flowchart illustrating the content of control by the control unit.

FIG. 5 is a diagram schematically illustrating the structure of the thermal energy recovery device according to a modified example of the first embodiment of the present invention.

FIG. 6 is a diagram schematically illustrating the structure of the thermal energy recovery device according to a modified example of the second embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0021] Hereinafter, embodiments for carrying out the present invention will be described with reference to the drawings.

[First Embodiment]

[0022] A thermal energy recovery device according to a first embodiment of the present invention will be described with reference to FIG. 1 and FIG. 2. As illustrated in FIG. 1, the thermal energy recovery device includes an evaporator 10, an oil separator 12, an expander 14, a power recovery machine 16, an oil supply flow passage 18, a condenser 20, a pump 22, a circulation flow passage 24 connecting the evaporator 10, the oil separator 12, the expander 14, the condenser 20, and the pump 22 in the mentioned order, an oil cooler 32, an oil cooling flow passage 40, an expansion valve V1, a branch flow passage 42, a switching unit 50, and a control unit 60.

[0023] The evaporator 10 is configured to allow a mixed medium including a working medium and an oil to be thermally exchanged with a heating medium, thereby evaporating at least the working medium of the mixed medium.

[0024] The oil separator 12 is provided at a portion downstream of the evaporator 10 in the circulation flow passage 24. The oil separator 12 is configured to separate the oil from the mixed medium discharged from the evaporator 10.

[0025] The expander 14 is provided at a portion downstream of the oil separator 12 in the circulation flow passage 24. The expander 14 is configured to expand the gas-phase working medium discharged from the oil separator 12. In the first embodiment, a positive displacement screw expander including a rotor to be rotatably driven by expansion energy of the gas-phase working medium is utilized as the expander 14.

[0026] The power recovery machine 16 is connected to the expander 14. The power recovery machine 16 is connected to the rotor and includes a rotation shaft rotatable with the rotor. The power recovery machine 16 is configured to recover power by the rotation of the rotation shaft. In the first embodiment, a generator is utilized as the power recovery machine 16. Also, a compressor or the like may be applied as the power recovery machine 16.

[0027] The oil supply flow passage 18 is a flow passage configured to supply the oil separated in the oil separator

12 at least to the expander 14. In the first embodiment, the oil supply flow passage 18 is configured to supply the oil separated in the oil separator 12 to a bearing of the expander 14 and a bearing of the power recovery machine (the generator in the first embodiment) 16.

[0028] The condenser 20 is provided at a portion downstream of the expander 14 in the circulation flow passage 24. The condenser 20 is configured to allow the mixed medium discharged from the expander 14 to be thermally exchanged with a cooling medium (cooling water or the like), thereby condensing the mixed medium.

[0029] The pump 22 is provided at a portion downstream of the condenser 20 (at a portion between the condenser 20 and the evaporator 10) in the circulation flow passage 24. The pump 22 is configured to send at a predetermined pressure the liquid-phase mixed medium discharged from the condenser 20 to the evaporator 10.

[0030] The oil cooler 32 is provided in the oil supply flow passage 18 and is configured to cool the oil flowing through the oil supply flow passage 18.

[0031] The oil cooling flow passage 40 is branched from a portion between the pump 22 and the evaporator 10 in the circulation flow passage 24 and is configured to pass the oil cooler 32. That is, the oil cooler 32 is configured to cool the oil flowing through the oil supply flow passage 18 with the mixed medium flowing through the oil cooling flow passage 40. In other words, the oil cooler 32 is connected to the oil supply flow passage 18 and the oil cooling flow passage 40 so that the oil flowing through the oil supply flow passage 18 is cooled with the mixed medium flowing through the oil cooling flow passage 40. A downstream end of the oil cooling flow passage 40 is connected to a middle step of the expander 14.

[0032] The expansion valve V1 is provided at a portion upstream of the oil cooler 32 in the oil cooling flow passage 40 and is configured to adjust the opening. The expansion valve V1 is configured to depressurize the mixed medium that is pumped out from the pump 22 to flow into the oil cooling flow passage 40, thereby facilitating evaporation of the mixed medium in the oil cooler 32. In addition, the position of the downstream end of the oil cooling flow passage 40, that is, the middle step of the expander 14 is a portion of the expander 14, which has pressure corresponding to the pressure of the mixed medium that has passed the expansion valve V1. In a case where a multi-step expander is applied as the expander 14, the middle step serves as a connection portion (a pipe or a reservoir) that is in the middle of expansion in the respective steps or that connects the respective steps.

[0033] The branch flow passage 42 is branched from a portion between the oil cooler 32 and the expander 14 in the oil cooling flow passage 40. A downstream end of the branch flow passage 42 is connected to a portion between the expander 14 and the condenser 20 in the circulation flow passage 24.

[0034] The switching unit 50 can switch a mode where

the mixed medium discharged from the oil cooler 32 flows into the expander 14, as a first mode, to a mode where the mixed medium discharged from the oil cooler 32 flows into the branch flow passage 42, as a second mode, and vice versa. In the first embodiment, the switching unit 50 includes a first shut-off valve V2 and a second shut-off valve V3. The first shut-off valve V2 is provided at a portion downstream of a connection portion between the oil cooling flow passage 40 and an upstream end of the branch flow passage 42 in the oil cooling flow passage 40. The second shut-off valve V3 is provided in the branch flow passage 42. That is, the first shut-off valve V2 is opened and the second shut-off valve V3 is closed and thereby the switching unit 50 is brought into the first mode. The first shut-off valve V2 is closed and the second shut-off valve V3 is opened and thereby the switching unit 50 is brought into the second mode.

[0035] The control unit 60 is configured to control the expansion valve V1 and the switching unit 50. In the first embodiment, the control unit 60 includes an expansion valve adjustment portion 61, a gasification determination portion 62, and a switching unit adjustment portion 63.

[0036] The expansion valve adjustment portion 61 is configured to adjust the opening of the expansion valve 1 so that the temperature of a portion between the oil cooler 32 and the expander 14 in the oil supply flow passage 18 (the temperature of the oil flowing into the expander 14) is maintained at a level below a reference temperature, i.e., so that the viscosity of the oil supplied to the expander 14 is maintained at a level equal to or greater than a required value. Also, the temperature of a portion between the oil cooler 32 and the expander 14 in the oil supply flow passage 18 is detected by a temperature sensor 71 provided in the portion.

[0037] The gasification determination portion 62 is configured to determine whether the mixed medium discharged from the oil cooler 32 is in a gas phase. In the first embodiment, the gasification determination portion 62 is configured to calculate the degree of superheat of the mixed medium discharged from the oil cooler 32. In addition, when the degree of super heat is greater than a set value, the gasification determination portion 62 determines that the mixed medium is in a gas phase. Meanwhile, when the degree of superheat is equal to or smaller than the set value, the gasification determination portion 62 determines that the mixed medium contains a liquid phase. In addition, the degree of superheat of the mixed medium discharged from the oil cooler 32 is calculated based on detection values by a pressure sensor 72 and a temperature sensor 73 that are provided at a portion between the oil cooler 32 and the first shut-off valve V2 in the oil cooling flow passage 40 or at a portion upstream of the second shut-off valve V3 in the branch flow passage 42.

[0038] The switching unit adjustment portion 63 is configured to switch the switching unit 50 to the first mode (open the first shut-off valve V2 and close the second shut-off valve V3) when the gasification determination

portion 62 has determined that the entire mixed medium discharged from the oil cooler 32 is in a gas phase (in the first embodiment, when the degree of superheat of the mixed medium discharged from the oil cooler 32 is greater than the set value). On the other hand, the switching unit adjustment portion 63 is configured to switch the switching unit 50 to the second mode (close the first shut-off valve V2 and open the second shut-off valve V3) when the gasification determination portion 62 has determined that the mixed medium discharged from the oil cooler 32 contains a liquid phase.

[0039] Herein, the concrete content of control by the control unit 60 will be described with reference to FIG. 2.

[0040] First, the switching unit adjustment portion 63 of the control unit 60 closes the first shut-off valve V2 and opens the second shut-off valve V3 (step ST11). Next, the expansion valve adjustment portion 61 of the control unit 60 determines whether a detection value T_o by the temperature sensor 71 is below a reference temperature T_1 (step ST12). As a result, when the detection value T_o is equal to or greater than the reference temperature T_1 , that is, when the viscosity of the oil supplied to the expander 14 is below the required value, the expansion valve adjustment portion 61 increase the opening of the expansion valve V1 to increase the volume of the oil to be cooled in the oil cooler 32 (step ST13).

[0041] Also, when the detection value T_o is below the reference temperature T_1 in step ST12 (when YES in step ST12) or after step ST13, the gasification determination portion 62 of the control unit 60 determines whether the degree of superheat S calculated based on a detection value by the pressure sensor 72 and a detection value by the temperature sensor 73 is greater than a set value α (step ST14). As a result, when the degree of superheat S is greater than the set value α , that is, when the entire mixed medium discharged from the oil cooler 32 is in a gas phase and the mixed medium is supplied into the expander 14 whereby power can be recovered in the power recovery machine 16, the switching unit adjustment portion 63 of the control unit 60 opens the first shut-off valve V2 and closes the second shut-off valve V3 (brings the switching unit 50 to the first mode) (step ST15), and the processing returns to step ST12. Meanwhile, when the degree of superheat S is equal to or smaller than the set value α , that is, when the mixed medium discharged from the oil cooler 32 may contain a liquid phase, the expansion valve adjustment portion 61 decreases the opening of the expansion valve V1 to decrease the flow volume of the mixed medium into the oil cooler 32 (step ST16). Then, at the same time as step ST16 or after step ST16, the switching unit adjustment portion 63 closes the first shut-off valve V2 and opens the second shut-off valve V3 (brings the switching unit 50 to the second mode) (step ST17), and the processing returns to step ST12.

[0042] As described above, in the thermal energy recovery device according to the first embodiment, the mixed medium pumped out from the pump 22 passes

the expansion valve V1 and thereby is depressurized. Therefore, the mixed medium easily evaporates in the oil cooler 32, and the evaporation of the mixed medium in the oil cooler 32 allows the oil to be effectively cooled. Then, the mixed medium evaporated in the oil cooler 32 is supplied through the oil cooling flow passage 40 to the middle step of the expander 14. Thus, energy supplied into the expander 14 (power to be recovered in the power recovery machine 16) increases. In addition, a heat exchange including the evaporation phenomenon of the mixed medium is performed in the oil cooler 32. Consequently, the oil cooler 32 can be downsized compared with a case where only a sensible heat exchange of the oil with the mixed medium is performed in the oil cooler 32.

[0043] Also, since the control unit 60 includes the switching unit adjustment portion 63, the gas-phase mixed medium flows into the expander 14, and thereby power can be effectively recovered in the power recovery machine 16 and the liquid-phase mixed medium can be inhibited from flowing into the expander 14.

[Second Embodiment]

[0044] Next, the thermal energy recovery device according to a second embodiment of the present invention will be described with reference to FIG. 3. In addition, only differences from the first embodiment will be described in the second embodiment, and descriptions of the same structures, functions, and effects as those of the first embodiment will be omitted in the second embodiment.

[0045] In the second embodiment, in place of the switching unit 50, a gas-liquid separator 44 is provided at a portion between the oil cooler 32 and the expander 14 in the oil cooling flow passage 40. The upstream end of the branch flow passage 42 is connected to, for example, a lower portion of the gas-liquid separator 44. A shut-off valve V4 is provided in the branch flow passage 42. A fluid level sensor 74 is provided at the gas-liquid separator 44. Further, a check valve 45 is provided at a portion downstream of the gas-liquid separator 44 in the oil cooling flow passage 40. The check valve 45 is configured to allow the mixed medium to pass from the gas-liquid separator 44 to the expander 14 and to prevent the mixed medium from passing from the expander 14 to the gas-liquid separator 44.

[0046] Furthermore, in the second embodiment, the control unit 60 includes, in place of the switching unit adjustment portion 63, a shut-off valve adjustment portion 64 configured to regulate opening/closing of the shut-off valve V4. When the gasification determination portion 62 has determined that the entire mixed medium discharged from the gas-liquid separator 44 into the oil cooling flow passage 40 is in a gas phase (in the second embodiment, when the degree of superheat of the mixed medium discharged from the gas-liquid separator 44 into the oil cooling flow passage 40 is greater than a set val-

ue), the shut-off valve adjustment portion 64 closes the shut-off valve V4. In addition, when the gasification determination portion 62 has determined that the mixed medium discharged from the gas-liquid separator 44 into the oil cooling flow passage 40 contains a liquid phase, the shut-off valve adjustment portion 64 closes the shut-off valve V4.

[0047] Specifically, the content of control by the control unit 60 according to the second embodiment will be described with reference to FIG. 4.

[0048] First, the shut-off valve adjustment portion 64 of the control unit 60 opens the shut-off valve V4 (step ST21). Also, steps ST22 to ST24 are the same as steps ST12 to ST14 and therefore the descriptions will be omitted.

[0049] In step ST24, when the degree of superheat S is greater than a set value α (when YES in step ST24), the shut-off valve adjustment portion 64 closes the shut-off valve V4 (step ST25), and the processing returns to step ST22. Meanwhile, in step ST24, when the degree of superheat S is equal to or smaller than the set value α (when NO in step ST24), the expansion valve adjustment portion 61 decreases the opening of the expansion valve V1 (step ST26). Then, at the same time as step ST26 or after step ST26, the shut-off valve adjustment portion 64 opens the shut-off valve V4 (step ST27), and the processing returns to step ST22.

[0050] As described above, the thermal energy recovery device according to the second embodiment includes the gas-liquid separator 44 and the branch flow passage 42. Therefore, even when the mixed medium is discharged in a gas-liquid two-phase from the oil cooler 32, the mixed medium is separated into a gas phase and a liquid phase in the gas-liquid separator 44 and only the gas-phase mixed medium is guided through the oil cooling flow passage 40 to the expander 14. Consequently, the gas-phase mixed medium flows into the expander 14, and thereby power can be effectively recovered in the power recovery machine 16 and the liquid-phase mixed medium can be inhibited from flowing into the expander 14.

[0051] Further, the check valve V5 is provided at a portion downstream of the gas-liquid separator 44 in the oil cooling flow passage 40; therefore, a backward flow of the mixed medium from the expander 14 to the gas-liquid separator 44 is prevented, that is, a reduction in power recovery in the power recovery machine 16 is prevented.

[0052] Furthermore, the thermal energy recovery device according to the second embodiment includes the shut-off valve V4 provided in the branch flow passage 42 and the shut-off valve adjustment portion 64. Therefore, the gas-phase mixed medium is inhibited from flowing out from the gas-liquid separator 44 to the branch flow passage 42 (a loss in recoverable power in the power recovery machine 16), and in addition, the liquid-phase mixed medium is inhibited from being excessively stored in the gas-liquid separator 44.

[0053] Here, in the second embodiment, when a de-

tection value by the fluid level sensor 74 is below a set value, the shut-off valve adjustment portion 64 may close the shut-off valve V4. When a detection value by the fluid level sensor 74 is equal to or greater than the set value, the shut-off valve adjustment portion 64 may open the shut-off valve V4. In such a case, steps ST21, ST25, and ST27 are omitted and the control unit 60 performs operations of steps ST22 to ST24 and step ST26 in parallel with an operation by the shut-off valve adjustment portion 64.

[0054] Also, the embodiments described here are to be considered in all respects as illustrative and as non-restrictive. The scope of the present invention is indicated not by the descriptions of the foregoing embodiments but by the claims, and the scope of the present invention may include all changes within the meaning equivalent to the claims and within the claims.

[0055] For example, as illustrated in FIG. 5 and FIG. 6, in each embodiment, a heater 26 may be provided at a portion between the oil cooler 32 and the expander 14 in the oil cooling flow passage 40 and at a portion between the expander 14 and the condenser 20 in the circulation flow passage 24. The heater 26 is configured to heat the mixed medium discharged from the oil cooler 32 with the mixed medium discharged from the expander 14. Thus, evaporation of the mixed medium discharged from the oil cooler 32 is facilitated. Further, in the second embodiment, the heater 26 is preferably provided at a portion between the gas-liquid separator 44 and the expander 14 in the oil cooling flow passage 40.

[0056] Furthermore, a portion 41 between the oil cooler 32 and the expander 14 in the oil cooling flow passage 40 may be connected to the power recovery machine 16 so that the mixed medium discharged from the oil cooler 32 is heated by the power recovery machine 16. With such a configuration, the mixed medium discharged from the oil cooler 32 recovers exhaust heat of the power recovery machine 16; therefore, power to be recovered in the power recovery machine 16 increases. Further, in the second embodiment, the portion 41 is preferably selected from a portion downstream of the gas-liquid separator 44 in the oil cooling flow passage 40. Moreover, the portion 41 may be provided in parallel with or in series with a portion connected to the heater 26 in the oil cooling flow passage 40. Further, at least one of the heater 26 and the portion 41 may be provided at a portion upstream of the oil cooler 32 in the oil cooling flow passage 40.

[0057] Furthermore, in the first embodiment, a sensor is provided at a portion between the oil cooler 32 and the first shut-off valve V2 in the oil cooling flow passage 40, and the sensor may be configured to detect whether the mixed medium flowing through the portion contains a liquid phase. Thus, the gasification determination portion 62 may determine based on a detection result of the sensor whether the mixed medium in the portion is in a gas phase. Likewise, in the second embodiment, the above sensor is provided at a portion between the gas-liquid separator 44 and the expander 14 in the oil cooling flow

passage 40, and the gasification determination portion 62 may determine based on a detection result of the sensor whether the mixed medium in the portion is in a gas phase.

[0058] A thermal energy recovery device includes an evaporator, an oil separator, an expander, a power recovery machine, an oil supply flow passage, a condenser, a pump, a circulation flow passage, an oil cooler, an oil cooling flow passage, an expansion valve provided at a portion upstream of the oil cooler in the oil cooling flow passage, and an expansion valve adjustment portion configured to adjust the opening of the expansion valve. The oil cooler allows an oil flowing through the oil supply flow passage to be thermally exchanged with a mixed medium flowing through the oil cooling flow passage and evaporates at least a portion of the mixed medium, and a downstream end of the oil cooling flow passage is connected to a middle step of the evaporator.

Claims

1. A thermal energy recovery device comprising:

an evaporator configured to evaporate a mixed medium including a working medium and an oil;
 an oil separator configured to separate the oil from the mixed medium discharged from the evaporator;
 an expander configured to expand the working medium discharged from the oil separator;
 a power recovery machine connected to the expander;
 an oil supply flow passage configured to supply the oil, discharged from the oil separator, to the expander;
 a condenser configured to condense the mixed medium discharged from the expander;
 a pump configured to send the mixed medium, discharged from the condenser, to the evaporator;
 a circulation flow passage connecting the evaporator, the oil separator, the expander, the condenser, and the pump in the mentioned order;
 an oil cooler configured to cool the oil flowing through the oil supply flow passage;
 an oil cooling flow passage branched from a portion between the pump and the evaporator in the circulation flow passage and configured to pass the oil cooler;
 an expansion valve provided at a portion upstream of the oil cooler in the oil cooling flow passage and configured to adjust the opening; and
 an expansion valve adjustment portion configured to adjust the opening of the expansion valve so that the temperature of the oil flowing through a portion between the oil cooler and the

expander in the oil supply flow passage is maintained at a value below a reference temperature, wherein the oil cooler allows the oil flowing through the oil supply flow passage to be thermally exchanged with the mixed medium flowing through the oil cooling flow passage and evaporates at least a portion of the mixed medium, and a downstream end of the oil cooling flow passage is connected to a middle step of the expander.

2. The thermal energy recovery device according to claim 1, further comprising:

a branch flow passage branched from a portion between the oil cooler and the expander in the oil cooling flow passage and connected to a portion between the expander and the condenser in the circulation flow passage;

a switching unit configured to switch a mode where the mixed medium discharged from the oil cooler flows into the expander, as a first mode, to a mode where the mixed medium discharged from the oil cooler flows into the branch flow passage, as a second mode, and vice versa; and

a switching unit adjustment portion configured to switch the switching unit to the first mode when the mixed medium discharged from the oil cooler is determined to be in a gas phase, the switching unit adjustment portion being configured to switch the switching unit to the second mode when the mixed medium flowing through a portion between the oil cooler and the switching unit in the oil cooling flow passage is determined to contain a liquid phase.

3. The thermal energy recovery device according to claim 1, further comprising:

a gas-liquid separator provided at a portion between the oil cooler and the expander in the oil cooling flow passage; and

a branch flow passage configured to guide, to the condenser, the liquid-phase mixed medium into which the mixed medium is separated in the gas-liquid separator.

4. The thermal energy recovery device according to claim 3, further comprising:

a check valve provided between the gas-liquid separator and the expander in the oil cooling flow passage, the check valve being configured to allow the mixed medium to pass from the gas-liquid separator to the expander and to prevent the mixed medium from passing from the ex-

pander to the gas-liquid separator.

5. The thermal energy recovery device according to claim 3 or 4, further comprising:

a shut-off valve provided in the branch flow passage;

a shut-off valve adjustment portion configured to close the shut-off valve when the mixed medium flowing through a portion between the gas-liquid separator and the expander in the oil cooling flow passage is determined to be in a gas phase, the shut-off valve adjustment portion being configured to close the shut-off valve when the mixed medium flowing through a portion between the gas-liquid separator and the expander in the oil cooling flow passage is determined to contain a liquid phase.

6. The thermal energy recovery device according to any one of claims 1 to 5, further comprising:

a heater provided at a portion between the oil cooler and the expander in the oil cooling flow passage and at a portion between the expander and the condenser in the circulation flow passage and configured to heat the mixed medium discharged from the oil cooler with the mixed medium discharged from the expander.

7. The thermal energy recovery device according to any one of claims 1 to 6, wherein a portion between the oil cooler and the expander in the oil cooling flow passage is connected to the power recovery machine so that the mixed medium discharged from the oil cooler is heated by the power recovery machine.

FIG. 1

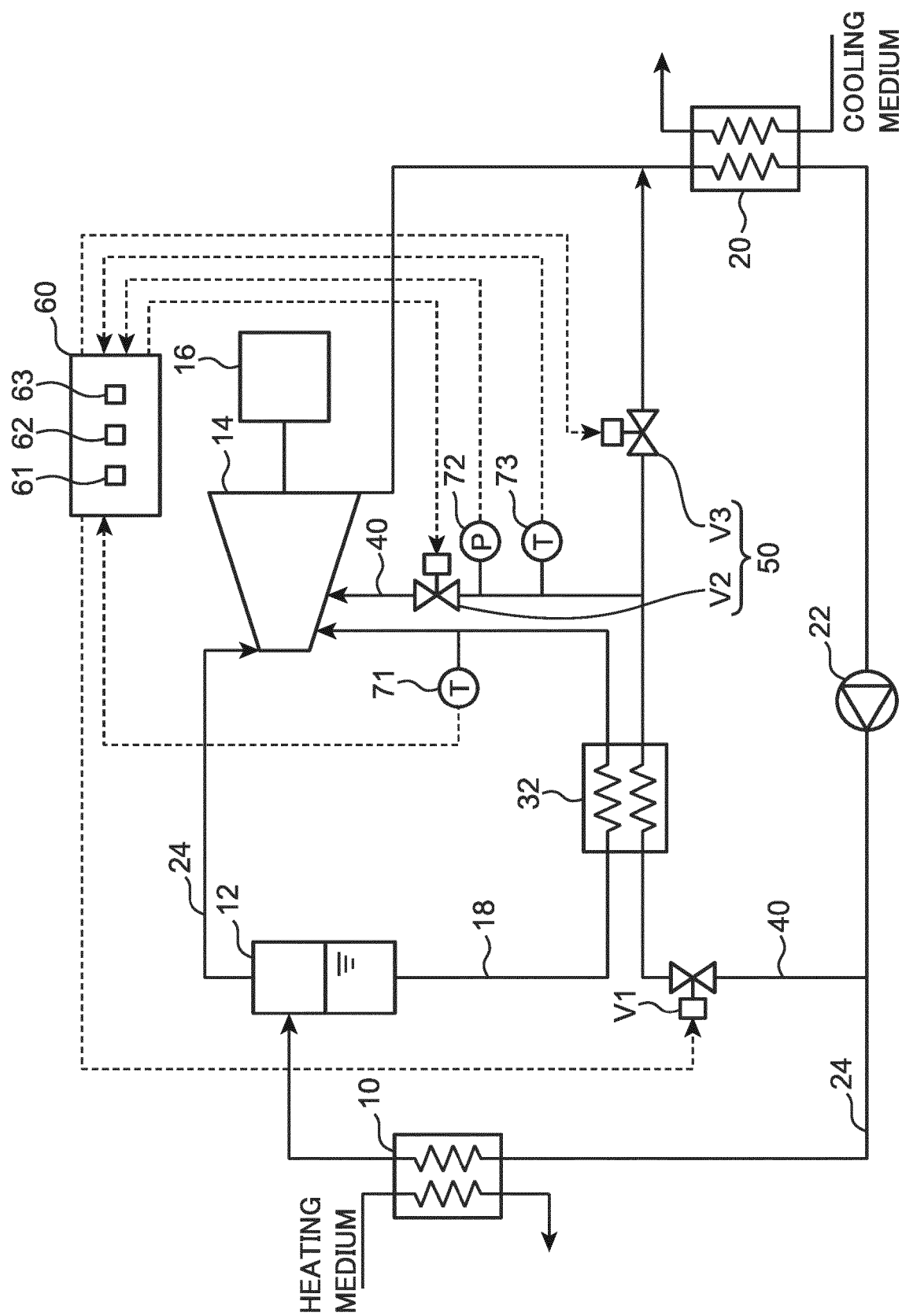


FIG. 2

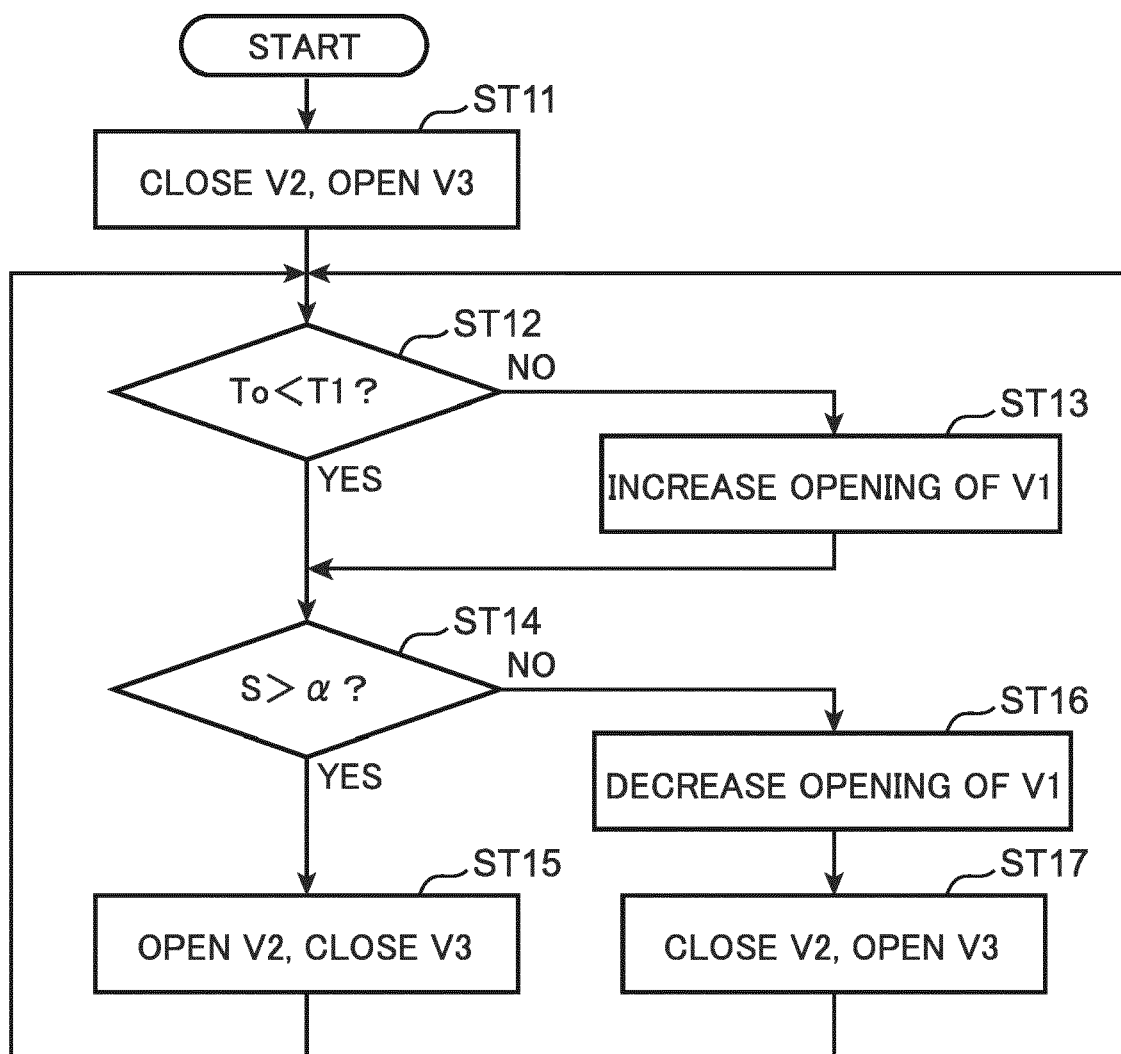


FIG. 3

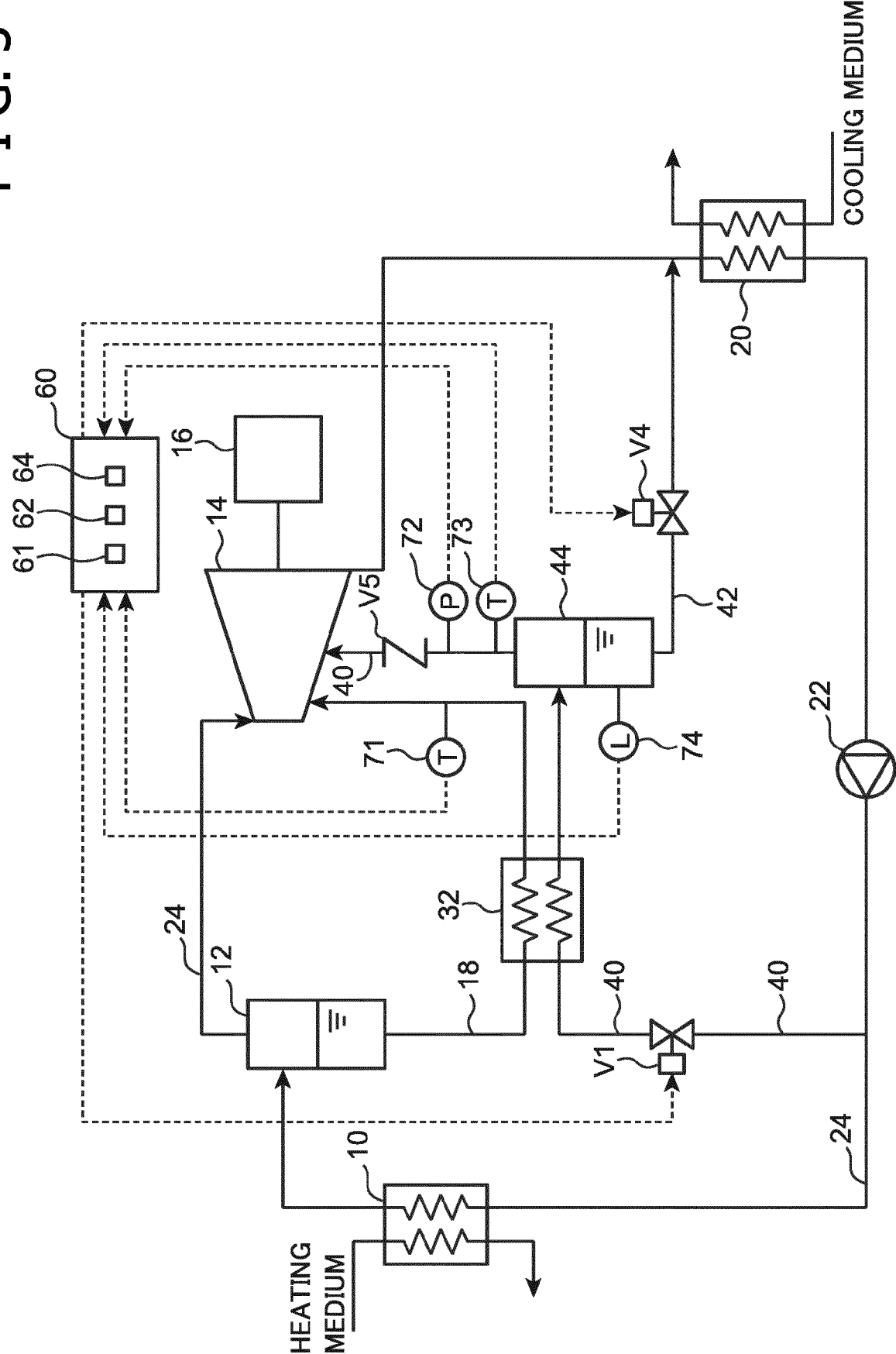


FIG. 4

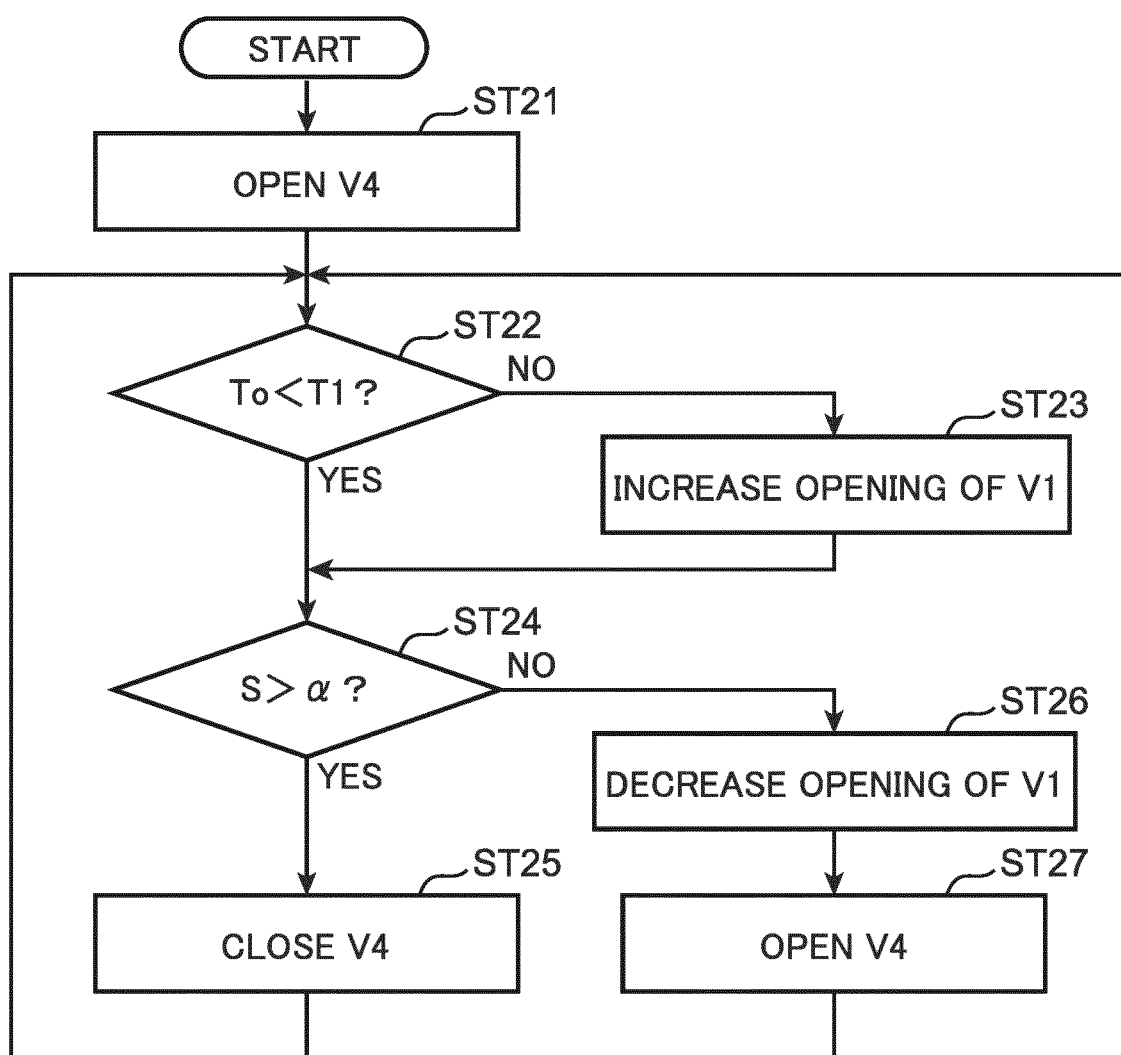


FIG. 5

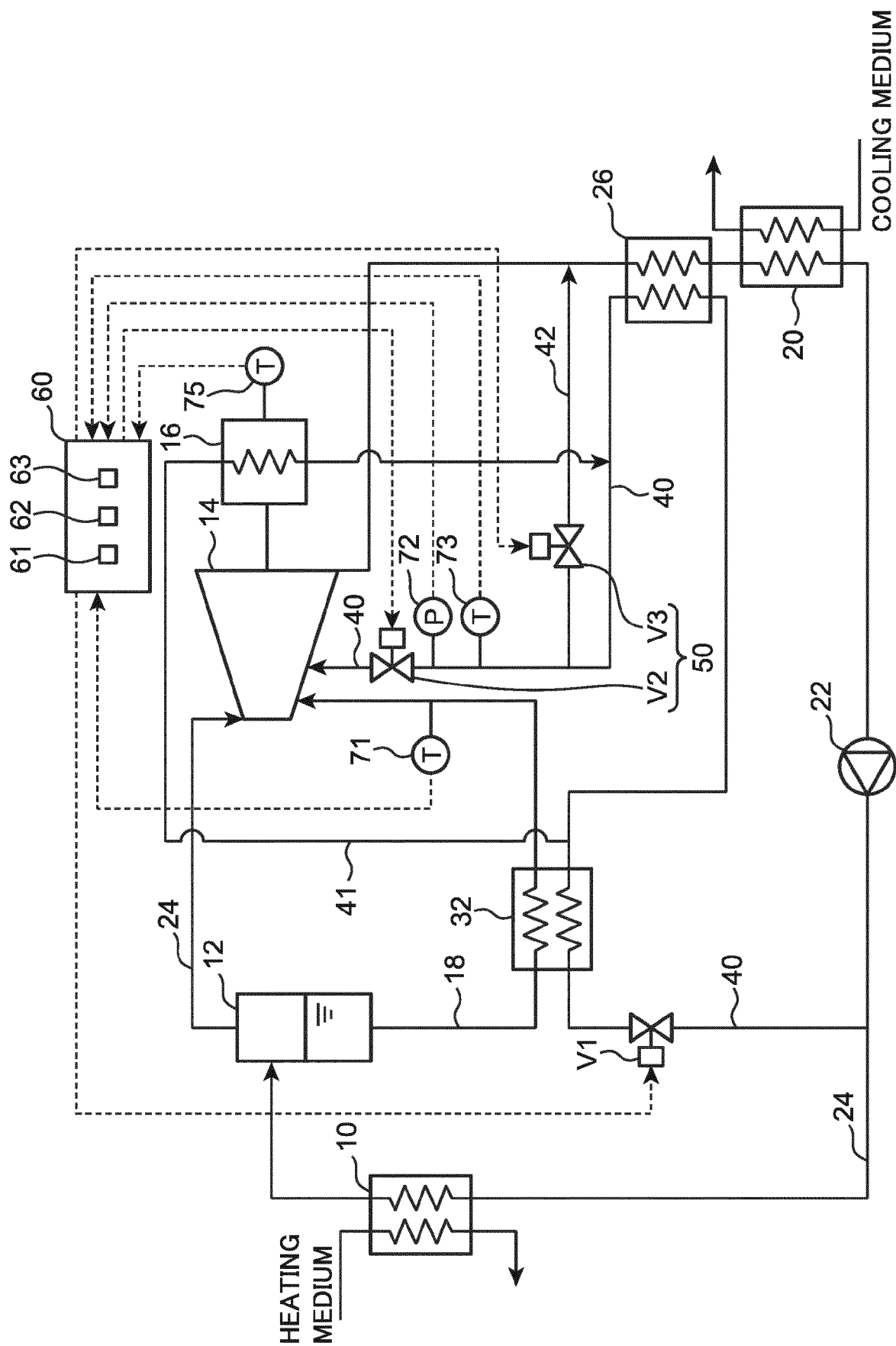
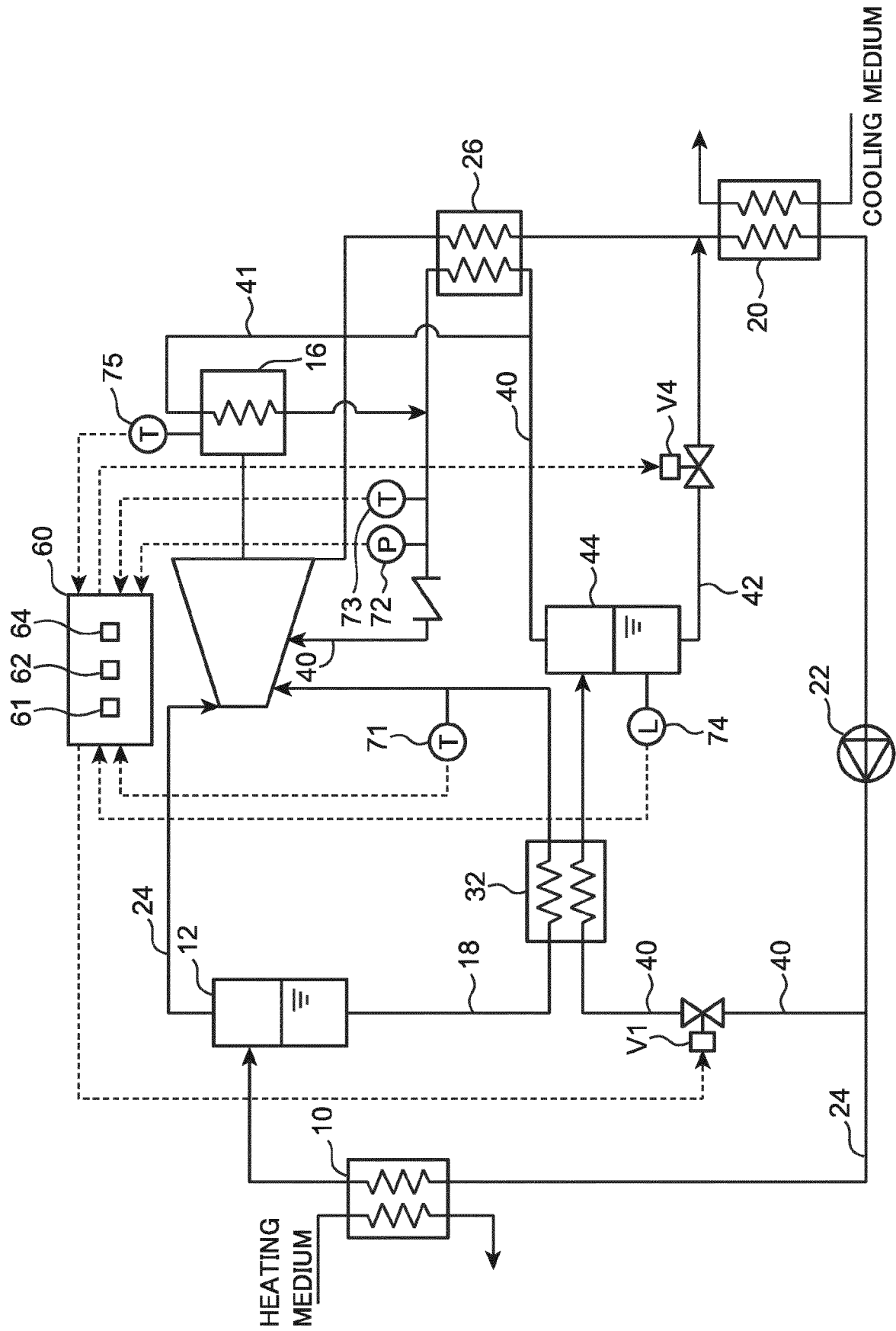


FIG. 6





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