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(54) **THERMAL ENERGY RECOVERY DEVICE**

(57) In order to take a precaution against corrosion of an exhaust gas passage following condensation of a SOX component contained in exhaust gas, a thermal energy recovery device includes a heater in which a working medium flowing through a circulation flow passage is heated with exhaust gas flowing through an exhaust gas passage as a heat source, a power recovery machine to be driven by the working medium on the downstream side of the heater in the circulation flow passage, a tem-

perature detector that detects a temperature of the exhaust gas on the downstream side of the heater in the exhaust gas passage, and a heat input amount control unit that performs control for adjusting a heat transfer amount from the exhaust gas to the working medium in the heater so that the detected temperature by the temperature detector is maintained to be not less than a set temperature.

EP 3 521 576 A1

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] Conventionally, for example, as disclosed in JP 2015-232424 A, JP 2016-160868 A, and JP 2016-160870 A, there are known devices that recover thermal energy of exhaust gas of an engine. In this type of thermal energy recovery devices, a circulation circuit of a working medium forming the Rankine cycle is formed. In this circulation circuit, an evaporator in which heat exchange is performed between the exhaust gas and the working medium is provided. In the evaporator, the working medium is evaporated whereas the exhaust gas is cooled. The working medium evaporated in the evaporator drives an expander. By generating electric power by a generator connected to the expander, the thermal energy of the exhaust gas is recovered as the electric power.

[0003] In the thermal energy recovery devices disclosed in JP 2015-232424 A, JP 2016-160868 A, and JP 2016-160870 A, the exhaust gas is cooled in the evaporator. Therefore, on the downstream side of the evaporator in an exhaust gas passage through which the exhaust gas flows, there is a concern that the exhaust gas passage is corroded following condensation of a SOX component contained in the exhaust gas.

SUMMARY OF THE INVENTION

[0004] The present invention is achieved in consideration with the above related art, and an object thereof is to take a precaution against corrosion of an exhaust gas passage following condensation of a SOX component contained in exhaust gas.

[0005] In order to achieve the above object, the present invention is a thermal energy recovery device including a heater in which a working medium flowing through a circulation flow passage is heated with exhaust gas flowing through an exhaust gas passage as a heat source, a power recovery machine to be driven by the working medium on the downstream side of the heater in the circulation flow passage, a temperature detector that detects a temperature of the exhaust gas on the downstream side of the heater in the exhaust gas passage, and a heat input amount control unit that performs control for adjusting a heat transfer amount from the exhaust gas to the working medium in the heater so that the detected temperature by the temperature detector is maintained to be not less than a set temperature.

[0006] In the present invention, heat received from the

exhaust gas by the working medium in the heater is recovered as energy in the power recovery machine. The heat input amount control unit performs the control for adjusting the heat transfer amount from the exhaust gas to the working medium in the heater so that the detected temperature by the temperature detector is maintained to be not less than the set temperature. Therefore, the temperature of the exhaust gas on the downstream side of the heater in the exhaust gas passage is maintained to be not less than a predetermined temperature. Thus, it is possible to prevent dropwise condensation of a corrosive component from the exhaust gas after the heat is recovered by the working medium. Consequently, it is possible to prevent corrosion of the exhaust gas passage, etc.

[0007] The thermal energy recovery device may further include a SOX meter that measures a content rate of sulfur oxide in the exhaust gas on the downstream side of the heater in the exhaust gas passage. In this case, the heat input amount control unit may perform the control for adjusting the heat transfer amount so that the detected temperature is maintained to be not less than a sulfuric acid dew point of the exhaust gas as the set temperature based on a detection result by the temperature detector and a measurement result by the SOX meter.

[0008] In this aspect, the heat input amount control unit performs the control of adjusting the heat transfer amount from the exhaust gas to the working medium in the heater based on the detection result by the temperature detector and the measurement result by the SOX meter. Thereby, the temperature of the exhaust gas on the downstream side of the heater in the exhaust gas passage is maintained to be not less than the sulfuric acid dew point of the exhaust gas. Therefore, in comparison to a case where the heat transfer amount from the exhaust gas to the working medium in the heater is controlled simply based on the detection result of the temperature of the exhaust gas by the temperature detector, it is possible to improve precision of control for suppressing the dropwise condensation of the corrosive component from the exhaust gas. As a result, it is possible to perform control of more increasing a heat release amount from the exhaust gas to the working medium in the heater, and hence, it is possible to increase an exhaust heat recovery amount.

[0009] The thermal energy recovery device may further include a SOX meter that measures a content rate of sulfur oxide in the exhaust gas on the downstream side of the heater in the exhaust gas passage, and a sulfuric acid dew point development unit that develops a sulfuric acid dew point of the exhaust gas on the downstream side of the heater in the exhaust gas passage based on a measured value by the SOX meter. In this case, the heat input amount control unit may perform the control for adjusting the heat transfer amount so that with the sulfuric acid dew point developed by the sulfuric acid dew point development unit as the set temperature, the

detected temperature is maintained to be not less than the temperature.

[0010] In this aspect, the heat input amount control unit performs the control of adjusting the heat transfer amount from the exhaust gas to the working medium in the heater by using the sulfuric acid dew point developed by the sulfuric acid dew point development unit. Thereby, the temperature of the exhaust gas on the downstream side of the heater in the exhaust gas passage is maintained to be not less than the developed sulfuric acid dew point. Therefore, in comparison to a case where the heat transfer amount from the exhaust gas to the working medium in the heater is controlled simply based on the detection result of the temperature of the exhaust gas by the temperature detector, it is possible to improve the precision of the control for suppressing the dropwise condensation of the corrosive component from the exhaust gas. As a result, it is possible to perform the control of more increasing the heat release amount from the exhaust gas to the working medium in the heater, and hence, it is possible to increase the exhaust heat recovery amount.

[0011] The SOX meter may be formed to measure a weight percentage of sulfur oxide in the exhaust gas. In this case, the sulfuric acid dew point development unit may be formed to include a storage unit that stores a relationship between the weight percentage of sulfur oxide and the sulfuric acid dew point of the exhaust gas, and to develop the sulfuric acid dew point of the exhaust gas by using the relationship stored in the storage unit and the measurement result by the SOX meter.

[0012] In this aspect, the sulfuric acid dew point in the exhaust gas can be estimated from the measurement result by the SOX meter, and based on this estimated sulfuric acid dew point, the control of adjusting the heat transfer amount from the exhaust gas to the working medium in the heater is performed. Therefore, while suppressing an increase in cost required for estimating the sulfuric acid dew point, it is possible to improve the precision of the control for suppressing the dropwise condensation of the corrosive component from the exhaust gas.

[0013] The thermal energy recovery device may further include a pump that circulates the working medium in the circulation flow passage. In this case, the pump may be formed so that the rotational speed is adjustable. The heat input amount control unit may perform control of adjusting the rotational speed of the pump so that the heat transfer amount from the exhaust gas to the working medium in the heater.

[0014] In this aspect, by the heat input amount control unit adjusting the rotational speed of the pump, an amount of the working medium passing through the heater is adjusted. Thereby, the heat transfer amount from the exhaust gas to the working medium in the heater is adjusted.

[0015] The thermal energy recovery device may further include a bypass passage that bypasses the heater, and a bypass valve that opens and closes the bypass

passage. In this case, the heat input amount control unit may control the bypass valve so that the heat transfer amount from the exhaust gas to the working medium in the heater is adjusted.

[0016] In this aspect, by the heat input amount control unit controlling the bypass valve, the heat transfer amount from the exhaust gas to the working medium in the heater is adjusted.

[0017] The heater may be formed by a heat exchanger connected to the exhaust gas passage and the circulation flow passage.

[0018] In this aspect, since heat exchange is performed directly between the exhaust gas and the working medium, additional constituent parts are not required.

[0019] The heater may include an intermediate medium heater that heats an intermediate medium flowing through a medium flow passage with the exhaust gas flowing through the exhaust gas passage, and a working medium heater that heats the working medium with the intermediate medium heated by the intermediate medium heater. In this case, the temperature detector may be formed to detect a temperature of the exhaust gas on the downstream side of the intermediate medium heater in the exhaust gas passage.

[0020] In this aspect, heat exchange is performed between the exhaust gas and the intermediate medium, and the heat of the exhaust gas is transferred to the intermediate medium. This heat of the intermediate medium is transferred to the working medium in the working medium heater. That is, in the heater, the heat is transferred from the exhaust gas to the working medium via the intermediate medium. By adjusting a heat exchange amount in at least one of the intermediate medium heater and the working medium heater, the heat release amount from the exhaust gas can be adjusted. Therefore, it is possible to more increase freedom of adjustment between a flow rate of the working medium and the heat release amount from the exhaust gas.

[0021] The present invention is a thermal energy recovery device including a heater in which a working medium flowing through a circulation flow passage is heated with exhaust gas flowing through an exhaust gas passage as a heat source, a power recovery machine to be driven by the working medium on the downstream side of the heater in the circulation flow passage, a temperature detector that detects a temperature of the exhaust gas on the downstream side of the heater in the exhaust gas passage, and a SOX meter that measures a content rate of sulfur oxide in the exhaust gas on the downstream side of the heater in the exhaust gas passage.

[0022] In the present invention, the heat received from the exhaust gas by the working medium in the heater is recovered as energy in the power recovery machine. The thermal energy recovery device includes the temperature detector that detects the temperature of the exhaust gas and the SOX meter that measures the content rate of sulfur oxide in the exhaust gas. Thus, at the time of operating the thermal energy recovery device, the detection

result by the temperature detector and the measurement result by the SOX meter can be utilized. Therefore, it is possible to control the heat exchange amount in the heater based on the detection result and the measurement result, and thereby, it is possible not to lower the temperature of the exhaust gas after heat recovery to less than the sulfuric acid dew point.

[0023] As described above, according to the present invention, it is possible to take a precaution against corrosion of the exhaust gas passage following condensation of a SOX component contained in the exhaust gas.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024]

FIG. 1 is a view showing a schematic configuration of a thermal energy recovery device according to a first embodiment.

FIG. 2 is a view partially showing a thermal energy recovery device according to a modified example of the first embodiment.

FIG. 3 is a flowchart for describing control actions by a heat input amount control unit of the thermal energy recovery device according to the first embodiment.

FIG. 4 is a view showing a schematic configuration of a thermal energy recovery device according to a second embodiment.

FIG. 5 is a graph showing a correlation between a weight percentage of sulfur oxide and a sulfuric acid dew point.

FIG. 6 is a flowchart for describing control actions by a heat input amount control unit of the thermal energy recovery device according to the second embodiment.

FIG. 7 is a view showing a schematic configuration of a thermal energy recovery device according to a third embodiment.

FIG. 8 is a view showing a schematic configuration of a thermal energy recovery device according to a fourth embodiment.

FIG. 9 is a view showing a schematic configuration of a thermal energy recovery device according to a fifth embodiment.

FIG. 10 is a flowchart for describing control actions by a heat input amount control unit of the thermal energy recovery device according to the fifth embodiment.

FIG. 11 is a view showing a schematic configuration of a thermal energy recovery device according to a sixth embodiment.

FIG. 12 is a flowchart for describing control actions by a heat input amount control unit of the thermal energy recovery device according to the sixth embodiment.

FIG. 13 is a view showing a schematic configuration of a thermal energy recovery device according to a

modified example of the sixth embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0025] Hereinafter, embodiments of the present invention will be described with reference to the drawings. However, for convenience of description, the figures to be cited below show major constituent elements required for describing thermal energy recovery devices according to the embodiments of the present invention in a simplified form. Therefore, the thermal energy recovery devices according to the embodiments of the present invention may include arbitrary constituent elements not shown in the figures to be cited in this description.

(First Embodiment)

[0026] As shown in FIG. 1, a thermal energy recovery device 10 according to a first embodiment is formed as a power generation system in which the Rankine cycle of a working medium is utilized. The thermal energy recovery device 10 is mounted on, for example, a marine vessel. The thermal energy recovery device 10 receives thermal energy of exhaust gas discharged from an engine EG of the marine vessel, the thermal energy flowing through an exhaust gas passage 3 toward a stack ST via the working medium. The thermal energy recovery device 10 converts energy of the working medium into electric energy by a power recovery machine 26. For the engine EG, C heavy oil may be used as fuel but the present invention is not limited to this.

[0027] As shown in FIG. 1, the thermal energy recovery device 10 includes a circulation flow passage 12 through which the working medium is circulated. In the circulation flow passage 12, a pump 14, a heater 16, an expander 18, and a condenser 20 are provided. By an action of the pump 14, the working medium flows through the pump 14, the heater 16, the expander 18, and the condenser 20 in the circulation flow passage 12 in this order.

[0028] The pump 14 pressurizes the working medium so that the working medium is circulated in the circulation flow passage 12. As the working medium, for example, an organic fluid having a lower boiling point than water such as R245fa can be used. As the pump 14, a centrifugal pump including an impeller as a rotor, a gear pump in which a rotor is formed by a pair of gears, etc. are used.

[0029] The heater 16 is connected to the exhaust gas passage 3 and the circulation flow passage 12 formed by pipes. In the heater 16, heat exchange is performed directly between the working medium fed from the pump 14 and the exhaust gas flowing through the exhaust gas passage 3. That is, the heater 16 is formed by a single heat exchanger, and in this heater 16, the working medium is heated by heat of the exhaust gas. Thereby, the working medium is evaporated. The heater 16 is formed by a shell-and-tube heat exchanger. A space in a shell 16a of the heater 16 communicates with the exhaust gas passage 3, and a heat transfer tube 16b provided in the

shell 16a communicates with the circulation flow passage 12.

[0030] FIG. 1 only shows the configuration of the heater 16 in a descriptive manner. In the figure, an inlet of the exhaust gas is positioned on the lower side of the shell 16a and an outlet of the exhaust gas is positioned on the upper side of the shell 16a. However, in reality, the heater 16 is connected to the exhaust gas passage 3 so that the inlet of the exhaust gas is positioned in an upper portion of the shell 16a and the outlet of the exhaust gas is positioned in a lower portion of the shell 16a. Therefore, in the heater 16, the working medium flows from the lower side to the upper side whereas the exhaust gas flows from the upper side to the lower side. In the heater 16, the working medium and the exhaust gas are opposing flows. Thus, heat exchange efficiency can be maintained in a high state. The inlet of the exhaust gas does not have to be provided on an upper surface of the shell 16a, and may be provided on a side surface of the shell 16a. The outlet of the exhaust gas does not have to be provided on a lower surface of the shell 16a but may be provided on the side surface of the shell 16a.

[0031] In the example of the figure, the heater 16 is formed as an evaporator that evaporates the working medium. However, the present invention is not limited to this. For example, as shown in FIG. 2, the heater 16 may be formed as a superheater arranged on the downstream side of an evaporator 24. In a case where the heater 16 is formed as a superheater, the superheater performs heat exchange between the working medium gasified in the evaporator 24 and the exhaust gas, so that the working medium is heated into a superheat state. The evaporator 24 at this time may be formed in such a manner that the working medium is heated by, for example, the scavenging air of the engine EG, water vapor generated in the marine vessel, engine cooling water, etc.

[0032] The heater 16 may be formed as a preheater arranged on the upstream side of an evaporator. In this case, in the evaporator (not shown) arranged on the downstream side of the preheater in the circulation flow passage 12, the working medium is evaporated.

[0033] The expander 18 is arranged on the downstream side of the heater 16 in the circulation flow passage 12. The expander 18 is formed by, for example, a screw expander. In the expander 18, a screw rotor is driven by expansion energy of the working medium. The expander 18 is not limited to the screw expander but for example, a centrifugal expander, a scrolling-type expander, etc. may be used.

[0034] The power recovery machine 26 is connected to the expander 18. The power recovery machine 26 has a driving unit (not shown) combined to a rotor of the expander 18. The power recovery machine 26 is formed as a generator that generates electric power by driving the driving unit with the rotor of the expander 18. That is, the power recovery machine 26 converts the expansion energy of the working medium into electric energy. Therefore, the thermal energy recovery device 10 can recover

thermal energy of the exhaust gas as electric energy. The power recovery machine 26 is not limited to a converter that converts the thermal energy of the exhaust gas into the electric energy, but for example, may be formed as a converter that changes into power of a compressor, etc.

[0035] The condenser 20 is arranged on the downstream side of the expander 18 in the circulation flow passage 12. The condenser 20 is connected to the circulation flow passage 12 and a cooling medium flow passage 30. Sea water serving as a cooling medium flows through the cooling medium flow passage 30. In the condenser 20, heat exchange is performed between the working medium and sea water, and the working medium is condensed. The cooling medium is not limited to sea water but only required to have a temperature at which the working medium can be condensed in the condenser 20. For example, in a case where a cooling water storage tank, etc. in which cooling water is stored is provided in the marine vessel, the cooling water may be used as the cooling medium.

[0036] The thermal energy recovery device 10 includes a temperature detector 34, a pressure sensor 35, a temperature sensor 36, and a controller 38. The temperature detector 34 is formed to detect a temperature of the exhaust gas on the downstream side of the heater 16 in the exhaust gas passage 3. The temperature detector 34 outputs a signal corresponding to the detected temperature. The pressure sensor 35 and the temperature sensor 36 are arranged between the heater 16 and the expander 18 in the circulation flow passage 12. The pressure sensor 35 detects pressure of the working medium flowing out of the heater 16 to the expander 18, and outputs a signal corresponding to the detected pressure. The temperature sensor 36 detects a temperature of the working medium flowing out of the heater 16 to the expander 18, and outputs a signal corresponding to the detected temperature.

[0037] The signals outputted from the temperature detector 34, the pressure sensor 35, and the temperature sensor 36 are inputted to the controller 38. The controller 38 includes a storage unit (not shown) in which a computer program, etc. are stored, and a calculation unit (not shown) that executes the computer program stored in the storage unit. By executing the computer program, the controller performs predetermined functions. The functions include an operation control unit 41 and a heat input amount control unit 42.

[0038] The operation control unit 41 performs control (superheat degree control) of adjusting the rotational speed of the pump 14 so that a superheat degree of the working medium introduced to the expander 18 is set within a predetermined range. Specifically, the operation control unit 41 reads out a saturation temperature corresponding to the detected pressure of the pressure sensor 35 by using a map stored in the storage unit, and develops the superheat degree from a temperature difference between the detected temperature of the temperature sen-

sor 36 and the read-out saturation temperature. When the developed superheat degree is lower than a lower limit value of the set range, the operation control unit 41 performs control of lowering the rotational speed of the pump 14. When the developed superheat degree exceeds an upper limit value of the set range, the operation control unit performs control of increasing the rotational speed of the pump 14.

[0039] The heat input amount control unit 42 performs control for adjusting a heat transfer amount from the exhaust gas to the working medium in the heater 16 so that the detected temperature by the temperature detector 34 is maintained to be not less than a preliminarily set temperature. Specifically, as shown in FIG. 3, even when performing the superheat degree control (Step ST1), the heat input amount control unit 42 receives the signal outputted from the temperature detector 34 and reads in a detected temperature TE (Step ST2). The heat input amount control unit 42 determines whether or not the detected temperature TE is not less than a preliminarily set threshold value TS (Step ST3), and when the detected temperature TE is not less than the threshold value TS, the flow returns to the first step and the superheat degree control is continued without any change. Meanwhile, in a case where the detected temperature TE is less than the threshold value TS, the heat input amount control unit 42 gives priority to the superheat degree control and performs the control of lowering the rotational speed of the pump 14 (Step ST4). Thereby, in the heater 16, an amount of heat released from the exhaust gas to the working medium can be reduced. Thus, it is possible to solve a state where the temperature of the exhaust gas is too low on the downstream side of the heater 16. When the detected temperature TE becomes not less than the threshold value TS, the superheat degree control is resumed.

[0040] As described above, in the present embodiment, the heat received from the exhaust gas by the working medium in the heater 16 is recovered as the electric energy in the power recovery machine 26. The heat input amount control unit 42 performs the control for adjusting the heat transfer amount from the exhaust gas to the working medium in the heater 16 so that the detected temperature by the temperature detector 34 is maintained to be not less than the preliminarily set temperature. Therefore, the temperature of the exhaust gas on the downstream side of the heater 16 in the exhaust gas passage 3 is maintained to be not less than a predetermined temperature. Thus, even in a case where C heavy oil is used as engine fuel, it is possible to prevent dropwise condensation of a corrosive component from the exhaust gas after the heat is recovered by the working medium. Consequently, it is possible to prevent corrosion of the exhaust gas passage 3, etc.

[0041] In the present embodiment, by the heat input amount control unit 42 adjusting the rotational speed of the pump 14, the amount of the working medium passing through the heater 16 is adjusted. Thereby, a heat ex-

change amount between the exhaust gas and the working medium in the heater 16 is adjusted. Therefore, by utilizing pump rotation control which is originally included in the controller 38, it is possible to prevent the dropwise condensation of the exhaust gas.

[0042] In the present embodiment, the operation control unit 41 of the controller 38 is formed to perform the control so that the superheat degree is set within the predetermined range. However, the present invention is not limited to this.

(Second Embodiment)

[0043] FIG. 4 shows a second embodiment of the present invention. The same constituent elements as those of the first embodiment will be given the same reference signs and detailed description thereof will be omitted.

[0044] In the first embodiment, the heat input amount control unit 42 is formed to perform the control of adjusting the rotational speed of the pump 14 so that the detected temperature TE of the temperature detector 34 is not less than the threshold value TS. Meanwhile, in the second embodiment, a heat input amount control unit 42 is formed to perform control of adjusting the rotational speed of a pump 14 so that a detected temperature TE is maintained to be not less than a sulfuric acid dew point estimated from a content rate of sulfur oxide (SOX) contained in exhaust gas.

[0045] Specifically, in a part of an exhaust gas passage 3 on the downstream side of a heater 16, a SOX meter 51 that measures the content rate (weight percentage) of sulfur oxide in the exhaust gas is provided. The SOX meter 51 outputs a signal corresponding to the measured content rate of sulfur oxide.

[0046] Functions of a controller 38 include a sulfuric acid dew point development unit 43. The sulfuric acid dew point development unit 43 develops the sulfuric acid dew point of the exhaust gas based on the measured value of sulfur oxide by the SOX meter 51. That is, in a storage unit of the controller 38, a relational expression or a map that relates the weight percentage of sulfur oxide and the sulfuric acid dew point as shown in FIG. 5 is stored. By using the relational expression or the map, the sulfuric acid dew point development unit 43 develops the sulfuric acid dew point of sulfur oxide contained in the exhaust gas from the measured value by the SOX meter 51. The relational expression or the map shows the fact that the sulfuric acid dew point is increased according to an increase in the content rate of sulfur oxide.

[0047] The heat input amount control unit 42 performs control for maintaining the detected temperature TE at not less than the sulfuric acid dew point. Specifically, as shown in FIG. 6, even when performing superheat degree control (Step ST1), the heat input amount control unit 42 receives signals outputted from a temperature detector 34 and the SOX meter 51 and reads in the detected temperature TE and a measured value MV of the

SOX meter 51 (Step ST12, ST13). The sulfuric acid dew point development unit 43 estimates a sulfuric acid dew point DP of sulfur oxide contained in the exhaust gas from the read-in measured value MV by using the relational expression or the map that relates the weight percentage of sulfur oxide and the sulfuric acid dew point (Step ST14).

[0048] The heat input amount control unit 42 determines whether or not the detected temperature TE is not less than the sulfuric acid dew point DP developed by the sulfuric acid dew point development unit 43 (Step ST15), and when the detected temperature TE is not less than the sulfuric acid dew point DP, the flow returns to the first step and the superheat degree control is continued without any change. Meanwhile, in a case where the detected temperature TE is less than the sulfuric acid dew point DP, the heat input amount control unit 42 gives priority to the superheat degree control and performs control of lowering the rotational speed of the pump 14 (Step ST16). Thereby, in the heater 16, an amount of heat released from the exhaust gas to a working medium can be reduced. Thus, it is possible to solve a state where a temperature of the exhaust gas is too low on the downstream side of the heater 16. When the detected temperature TE becomes not less than the sulfuric acid dew point DP, the superheat degree control is resumed.

[0049] In the second embodiment, the heat input amount control unit 42 performs control of adjusting a heat transfer amount from the exhaust gas to the working medium in the heater 16 by using the sulfuric acid dew point DP developed by the sulfuric acid dew point development unit 43. Thereby, the temperature of the exhaust gas on the downstream side of the heater 16 in the exhaust gas passage 3 is maintained to be not less than the developed sulfuric acid dew point DP. Therefore, in comparison to a case where a heat exchange amount in the heater 16 is controlled simply based on a detection result of the temperature of the exhaust gas by the temperature detector 34, it is possible to improve precision of control for suppressing dropwise condensation of a corrosive component from the exhaust gas. As a result, it is possible to perform control of more increasing the heat release amount from the exhaust gas to the working medium in the heater 16 (that is, control of not excessively lowering the heat release amount), and hence, it is possible to increase an exhaust heat recovery amount.

[0050] The sulfuric acid dew point DP in the exhaust gas can be estimated from a measurement result by the SOX meter 51, and based on this estimated sulfuric acid dew point DP, the control of adjusting the heat transfer amount from the exhaust gas to the working medium in the heater 16 is performed. Therefore, while suppressing an increase in cost required for estimating the sulfuric acid dew point DP, it is possible to improve the precision of the control for suppressing the dropwise condensation of the corrosive component from the exhaust gas.

[0051] In the second embodiment, the mode in which the sulfuric acid dew point development unit 43 is includ-

ed as the functions of the controller 38 is described. However, the present invention is not limited to this. For example, although the precision could be slightly inferior, the detected temperature TE of the temperature detector 34 may be corrected by a value corresponding to the content rate of sulfur oxide measured by the SOX meter 51, and the heat input amount control unit 42 may adjust the rotational speed of the pump 14 so that the detected temperature TE is not less than this corrected temperature.

[0052] In this mode, the heat input amount control unit 42 performs the control of adjusting the heat transfer amount from the exhaust gas to the working medium in the heater 16 based on the detected temperature TE by the temperature detector 34 and the measured value MV by the SOX meter 51. Thereby, the temperature of the exhaust gas on the downstream side of the heater 16 in the exhaust gas passage 3 is maintained to be not less than the sulfuric acid dew point of the exhaust gas. Therefore, in comparison to a case where the heat exchange amount in the heater 16 is controlled simply based on the detection result of the temperature of the exhaust gas by the temperature detector 34, it is possible to improve the precision of the control for suppressing the dropwise condensation of the corrosive component from the exhaust gas. As a result, it is possible to perform the control of more increasing the heat release amount from the exhaust gas to the working medium in the heater 16, and hence, it is possible to increase the exhaust heat recovery amount.

[0053] The other configurations, actions, and effects will not be described but the same as those of the first embodiment.

(Third Embodiment)

[0054] FIG. 7 shows a third embodiment of the present invention. The same constituent elements as those of the first embodiment will be given the same reference signs and detailed description thereof will be omitted.

[0055] In the first embodiment, the heat input amount control unit 42 performs the control of adjusting the rotational speed of the pump 14. Meanwhile, a heat input amount control unit 42 of the third embodiment does not adjust the rotational speed of a pump 14 but performs control for reducing a flow rate of a working medium flowing into a heater 16. Therefore, the pump 14 may not be formed so that the rotational speed is adjustable.

[0056] In the third embodiment, by using a return passage 53 connected to a circulation flow passage 12, part of the working medium discharged from the pump 14 is returned to the upstream side of the pump 14. Specifically, the return passage 53 is connected to the circulation flow passage 12 so as to divert from the pump 14. One end of the return passage 53 is connected to the downstream side of the pump 14 in the circulation flow passage 12. The other end of the return passage 53 is connected to the upstream side of the pump 14 in the

circulation flow passage 12.

[0057] In the return passage 53, a flow rate adjusting valve 54 whose opening degree is adjustable is provided. The heat input amount control unit 42 adjusts the opening degree of the flow rate adjusting valve 54 so that a detected temperature TE by a temperature detector 34 is maintained to be not less than a threshold value TS. Therefore, Step ST4 in FIG. 3 turns out to be control of increasing the opening degree of the flow rate adjusting valve 54 in place of the control of lowering the rotational speed of the pump 14. Anything other than that is the same as the first embodiment.

(Fourth Embodiment)

[0058] FIG. 8 shows a fourth embodiment of the present invention. The same constituent elements as those of the second embodiment will be given the same reference signs and detailed description thereof will be omitted.

[0059] In the second embodiment, the heat input amount control unit 42 performs the control of adjusting the rotational speed of the pump 14. Meanwhile, a heat input amount control unit 42 of the fourth embodiment does not adjust the rotational speed of a pump 14 but performs control for reducing a flow rate of a working medium flowing into a heater 16. Therefore, the pump 14 may not be formed so that the rotational speed is adjustable.

[0060] In the fourth embodiment, by using a return passage 53 connected to a circulation flow passage 12, part of the working medium discharged from the pump 14 is returned to the upstream side of the pump 14. Specifically, the return passage 53 is connected to the circulation flow passage 12 so as to divert from the pump 14. One end of the return passage 53 is connected to the downstream side of the pump 14 in the circulation flow passage 12. The other end of the return passage 53 is connected to the upstream side of the pump 14 in the circulation flow passage 12.

[0061] In the return passage 53, a flow rate adjusting valve 54 whose opening degree is adjustable is provided. The heat input amount control unit 42 adjusts the opening degree of the flow rate adjusting valve 54 so that a detected temperature TE by a temperature detector 34 is maintained to be not less than a sulfuric acid dew point DP. Therefore, Step ST16 in FIG. 6 turns out to be control of increasing the opening degree of the flow rate adjusting valve 54 in place of the control of lowering the rotational speed of the pump 14. Anything other than that is the same as the second embodiment.

(Fifth Embodiment)

[0062] FIG. 9 shows a fifth embodiment of the present invention. The same constituent elements as those of the first embodiment will be given the same reference signs and detailed description thereof will be omitted.

[0063] In the first embodiment, the heat input amount control unit 42 performs the control of adjusting the rotational speed of the pump 14. Meanwhile, in the fifth embodiment, a heat input amount control unit 42 is formed not to adjust the rotational speed of a pump 14 but to restrict a heat input amount to a working medium by reducing an inflow amount of the working medium to a heater 16. Specifically, a bypass passage 56 that bypasses the heater 16 is connected to a circulation flow passage 12. One end of the bypass passage 56 is connected to a part of the circulation flow passage 12 on the upstream side of the heater 16, that is, a part between the pump 14 and the heater 16. The other end of the bypass passage 56 is connected to a part of the circulation flow passage 12 on the downstream side of the heater 16, that is, a part between the heater 16 and an expander 18.

[0064] A bypass valve 57 that opens and closes the bypass passage 56 is provided in the bypass passage 56. The bypass valve 57 is formed by a valve that opens and closes upon a signal outputted from a controller 38. The bypass valve 57 may be formed by a valve whose opening degree is adjustable.

[0065] The heat input amount control unit 42 controls the bypass valve 57 so that a heat transfer amount from exhaust gas to the working medium in the heater 16 is adjusted. Specifically, when superheat degree control is executed, the bypass valve 57 is in a closed state. Therefore, the entire amount of the working medium fed from the pump 14 passes through the heater 16. As shown in FIG. 10, even when performing the superheat degree control (Step ST1), the heat input amount control unit 42 receives a signal outputted from a temperature detector 34 and reads in a detected temperature TE (Step ST2). The heat input amount control unit 42 determines whether or not the detected temperature TE is not less than a preliminarily set threshold value TS (Step ST3), and when the detected temperature TE is not less than the threshold value TS, the flow returns to the first step and the superheat degree control is continued without any change. Meanwhile, in a case where the detected temperature TE is less than the threshold value TS, the heat input amount control unit 42 performs control of opening the bypass valve 57 (Step ST24). Thereby, part of the working medium fed from the pump 14 flows through the bypass passage 56. Thus, for the part, an amount of the working medium flowing into the heater 16 is reduced. Therefore, in the heater 16, a heat amount transferred from the exhaust gas to the working medium can be reduced. Thus, it is possible to solve a state where a temperature of the exhaust gas is too low. When the detected temperature TE becomes not less than the threshold value TS, the superheat degree control is resumed.

[0066] In the present embodiment, the case where the heat input amount control unit 42 performs the control of maintaining the state where the detected temperature TE of the temperature detector 34 is not less than the threshold value TS is described. However, the present invention is not limited to this. For example, as in the

fourth embodiment (FIG. 8), the heat input amount control unit 42 may perform the control of maintaining the state where the detected temperature TE of the temperature detector 34 is not less than the sulfuric acid dew point DP.

[0067] The other configurations, actions, and effects will not be described but the same as those of the first embodiment.

(Sixth Embodiment)

[0068] FIG. 11 shows a sixth embodiment of the present invention. The same constituent elements as those of the first embodiment will be given the same reference signs and detailed description thereof will be omitted.

[0069] In the first embodiment, the heater 16 is formed by a single heat exchanger. Meanwhile, in the sixth embodiment, a heater 16 includes an intermediate medium heater 61 and a working medium heater 62. That is, the heater 16 includes two separately-formed heat exchangers.

[0070] Specifically, in the sixth embodiment, a medium flow passage 63 through which an intermediate medium flows is provided between an exhaust gas passage 3 and a circulation flow passage 12. The intermediate medium heater 61 is connected to the exhaust gas passage 3 and the medium flow passage 63, and formed to perform heat exchange between exhaust gas and the intermediate medium. Meanwhile, the working medium heater 62 is connected to the medium flow passage 63 and the circulation flow passage 12, and formed to perform heat exchange between the intermediate medium and a working medium.

[0071] The intermediate medium heater 61 is formed by a shell-and-tube heat exchanger. A space in a shell 61a of the intermediate medium heater 61 communicates with the exhaust gas passage 3, and a heat transfer tube 61b provided in the shell 61a communicates with the medium flow passage 63.

[0072] The working medium heater 62 includes a primary side flow passage 62a through which the intermediate medium flows and a secondary side flow passage 62b through which the working medium flows. The working medium heater 62 may be any type of heat exchanger such as a shell-and-tube heat exchanger and a plate heat exchanger.

[0073] An intermediate pump 64 that pressure-feeds the intermediate medium, and an adjusting valve 65 that adjusts a flow rate or a decompression amount of the intermediate medium are provided in the medium flow passage 63. By adjusting an opening degree of the adjusting valve 65, the flow rate of the intermediate medium flowing through the medium flow passage 63 is adjusted. Thereby, a heat exchange amount between the exhaust gas and the intermediate medium in the intermediate medium heater 61 is adjusted. Therefore, without adjusting the rotational speed of the pump 14 of the circulation flow

passage 12, it is possible to adjust a heat transfer amount from the exhaust gas to the working medium.

[0074] The heat input amount control unit 42 controls the adjusting valve 65 so that the heat transfer amount from the exhaust gas to the working medium in the heater 16 (the intermediate medium heater 61 and the working medium heater 62) is adjusted. Specifically, as shown in FIG. 12, even when performing superheat degree control (Step ST1), the heat input amount control unit 42 receives a signal outputted from a temperature detector 34 and reads in a detected temperature TE (Step ST2). In a case where the detected temperature TE is less than a threshold value TS in Step ST3, the heat input amount control unit 42 controls the adjusting valve 65 so that the current opening degree of the adjusting valve 65 is decreased by a predetermined opening degree (Step ST34). Thereby, the flow rate of the intermediate medium flowing through the medium flow passage 63 is reduced, and the heat exchange amount between the exhaust gas and the intermediate medium in the intermediate medium heater 61 is reduced. As a result, the heat transfer amount from the exhaust gas to the working medium is reduced. Therefore, it is possible to solve a state where a temperature of the exhaust gas is too low. When the detected temperature TE becomes not less than the threshold value TS, the superheat degree control is resumed.

[0075] In the present embodiment, by the heat input amount control unit 42 adjusting the flow rate of the intermediate medium, the heat transfer amount from the exhaust gas to the working medium is adjusted. However, the present invention is not limited to this. The heat input amount control unit 42 may be formed to adjust the heat transfer amount from the exhaust gas to the working medium by controlling the pump 14 provided in the circulation flow passage 12. In this case, a heat transfer amount from the exhaust gas to the intermediate medium is also adjusted following adjustment of a heat transfer amount from the intermediate medium to the working medium.

[0076] The present invention is also not limited to the configuration in which the flow rate of the intermediate medium flowing into the intermediate medium heater 61 is adjusted by adjusting the rotational speed of the intermediate pump 64. For example, a bypass flow passage (not shown) may be connected to the medium flow passage 63 so as to divert from the intermediate medium heater 61, so that the flow rate of the intermediate medium flowing into the intermediate medium heater 61 is adjusted. A return flow passage (not shown) which is similar to the return passage 53 (FIG. 7) may be provided in the medium flow passage 63, so that the flow rate of the intermediate medium flowing into the intermediate medium heater 61 is adjusted.

[0077] In the present embodiment, the case where the heat input amount control unit 42 performs the control of maintaining the state where the detected temperature TE of the temperature detector 34 is not less than the threshold value TS is described. However, the present

invention is not limited to this. For example, as shown in FIG. 13, a SOX meter 51 may be provided and the heat input amount control unit 42 may perform control of maintaining the state where the detected temperature TE of the temperature detector 34 is not less than a sulfuric acid dew point DP. That is, in a case where the detected temperature TE is less than the sulfuric acid dew point DP, the heat input amount control unit 42 controls the adjusting valve 65 so that the current opening degree of the adjusting valve 65 is decreased by a predetermined opening degree.

[0078] The other configurations, actions, and effects will not be described but the same as those of the above embodiments.

[0079] In order to take a precaution against corrosion of an exhaust gas passage following condensation of a SOX component contained in exhaust gas, a thermal energy recovery device includes a heater in which a working medium flowing through a circulation flow passage is heated with exhaust gas flowing through an exhaust gas passage as a heat source, a power recovery machine to be driven by the working medium on the downstream side of the heater in the circulation flow passage, a temperature detector that detects a temperature of the exhaust gas on the downstream side of the heater in the exhaust gas passage, and a heat input amount control unit that performs control for adjusting a heat transfer amount from the exhaust gas to the working medium in the heater so that the detected temperature by the temperature detector is maintained to be not less than a set temperature.

Claims

1. A thermal energy recovery device comprising:

a heater in which a working medium flowing through a circulation flow passage is heated with exhaust gas flowing through an exhaust gas passage as a heat source;
a power recovery machine to be driven by the working medium on the downstream side of the heater in the circulation flow passage;
a temperature detector that detects a temperature of the exhaust gas on the downstream side of the heater in the exhaust gas passage; and
a heat input amount control unit that performs control for adjusting a heat transfer amount from the exhaust gas to the working medium in the heater so that the detected temperature by the temperature detector is maintained to be not less than a set temperature.

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

a SOX meter that measures a content rate of

sulfur oxide in the exhaust gas on the downstream side of the heater in the exhaust gas passage, wherein

the heat input amount control unit performs the control for adjusting the heat transfer amount so that the detected temperature is maintained to be not less than a sulfuric acid dew point of the exhaust gas as the set temperature based on a detection result by the temperature detector and a measurement result by the SOX meter.

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

a SOX meter that measures a content rate of sulfur oxide in the exhaust gas on the downstream side of the heater in the exhaust gas passage; and

a sulfuric acid dew point development unit that develops a sulfuric acid dew point of the exhaust gas on the downstream side of the heater in the exhaust gas passage based on a measured value by the SOX meter, wherein

the heat input amount control unit performs the control for adjusting the heat transfer amount so that with the sulfuric acid dew point developed by the sulfuric acid dew point development unit as the set temperature, the detected temperature is maintained to be not less than the temperature.

4. The thermal energy recovery device according to claim 3, wherein

the SOX meter is formed to measure a weight percentage of sulfur oxide in the exhaust gas, and the sulfuric acid dew point development unit is formed to include a storage unit that stores a relationship between the weight percentage of sulfur oxide and the sulfuric acid dew point of the exhaust gas, and to develop the sulfuric acid dew point of the exhaust gas by using the relationship stored in the storage unit and the measurement result by the SOX meter.

5. The thermal energy recovery device according to any one of claims 1 to 4, further comprising:

a pump that circulates the working medium in the circulation flow passage, wherein the pump is formed so that the rotational speed is adjustable, and the heat input amount control unit performs control of adjusting the rotational speed of the pump so that the heat transfer amount from the exhaust gas to the working medium in the heater.

6. The thermal energy recovery device according to any one of claims 1 to 4, further comprising:

a bypass passage that bypasses the heater; and
 a bypass valve that opens and closes the bypass
 passage, wherein
 the heat input amount control unit controls the
 bypass valve so that the heat transfer amount
 from the exhaust gas to the working medium in
 the heater is adjusted. 5

7. The thermal energy recovery device according to
 any one of claims 1 to 6, wherein 10
 the heater is formed by a heat exchanger connected
 to the exhaust gas passage and the circulation flow
 passage.

8. The thermal energy recovery device according to 15
 any one of claims 1 to 6, wherein
 the heater includes an intermediate medium heater
 that heats an intermediate medium flowing through
 a medium flow passage with the exhaust gas flowing
 through the exhaust gas passage, and a working me- 20
 dium heater that heats the working medium with the
 intermediate medium heated by the intermediate
 medium heater, and
 the temperature detector is formed to detect a tem- 25
 perature of the exhaust gas on the downstream side
 of the intermediate medium heater in the exhaust
 gas passage.

9. A thermal energy recovery device comprising: 30
 a heater in which a working medium flowing
 through a circulation flow passage is heated with
 exhaust gas flowing through an exhaust gas
 passage as a heat source;
 a power recovery machine to be driven by the 35
 working medium on the downstream side of the
 heater in the circulation flow passage;
 a temperature detector that detects a tempera-
 ture of the exhaust gas on the downstream side
 of the heater in the exhaust gas passage; and 40
 a SOX meter that measures a content rate of
 sulfur oxide in the exhaust gas on the down-
 stream side of the heater in the exhaust gas pas-
 sage. 45

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FIG. 1

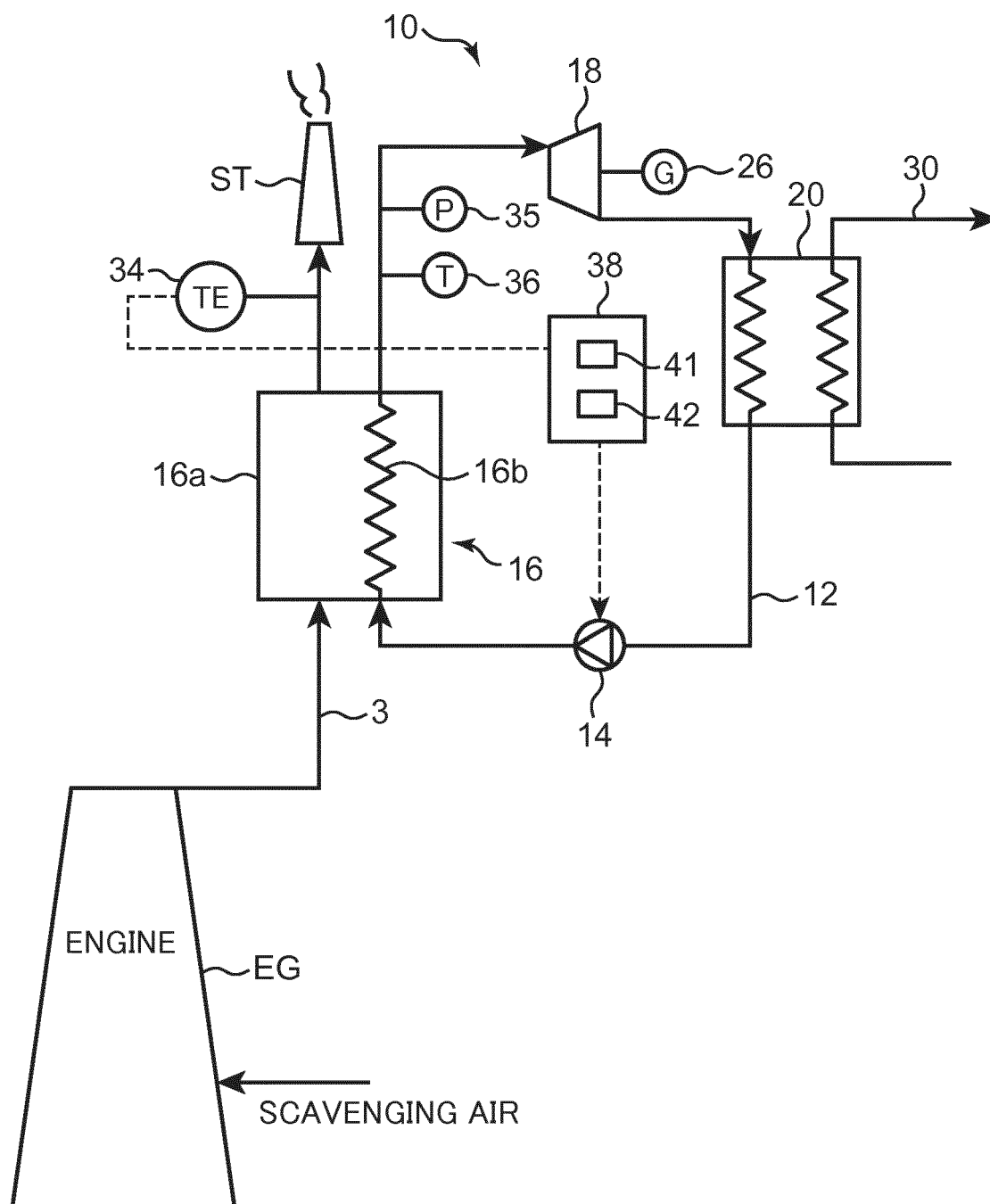


FIG. 2

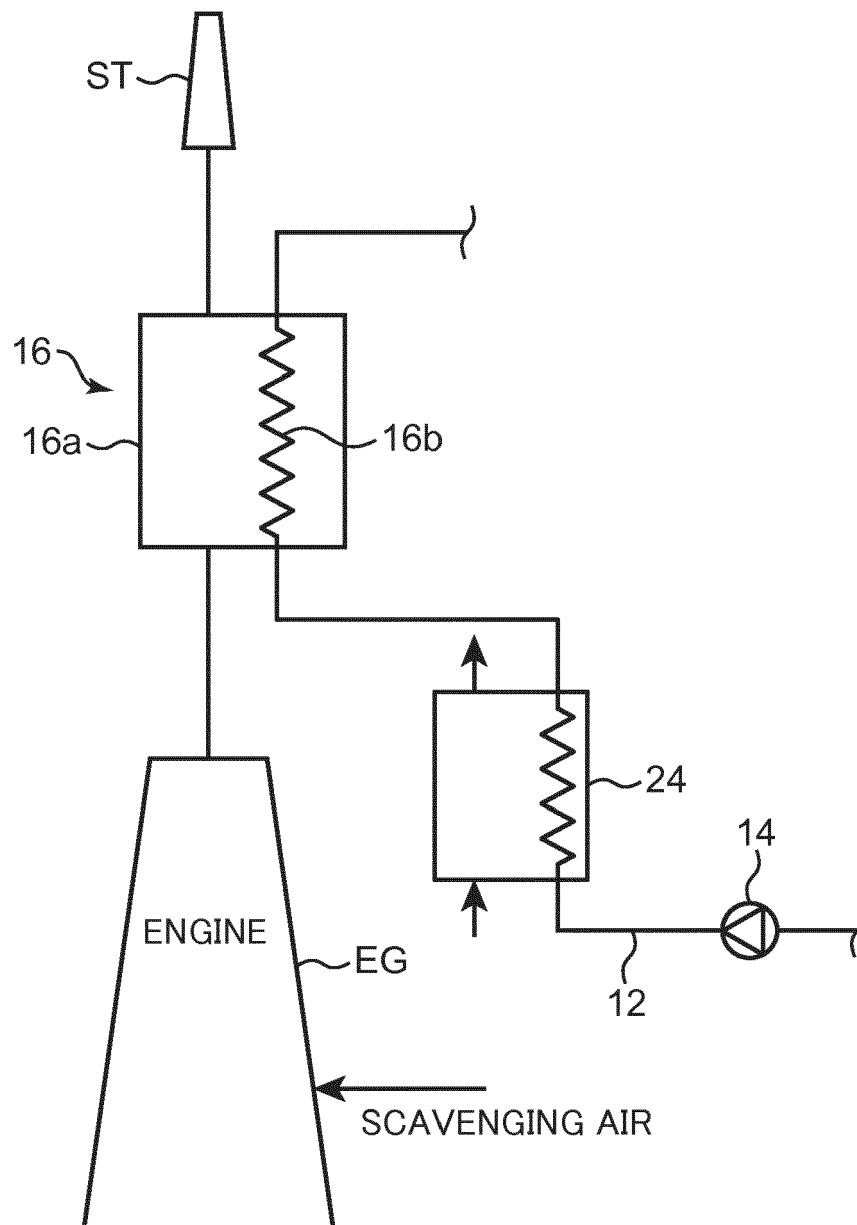


FIG. 3

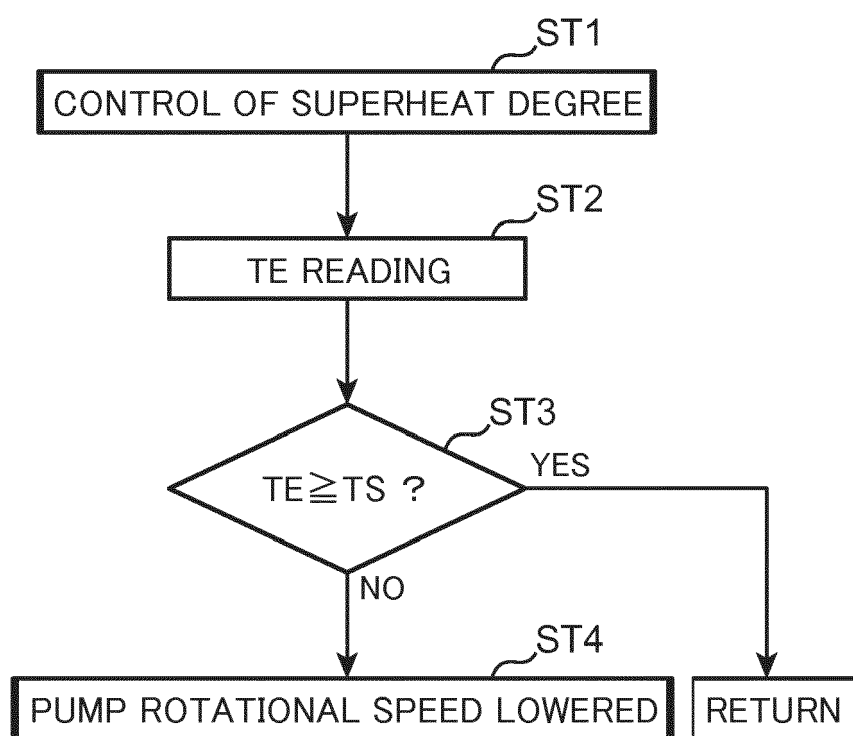


FIG. 4

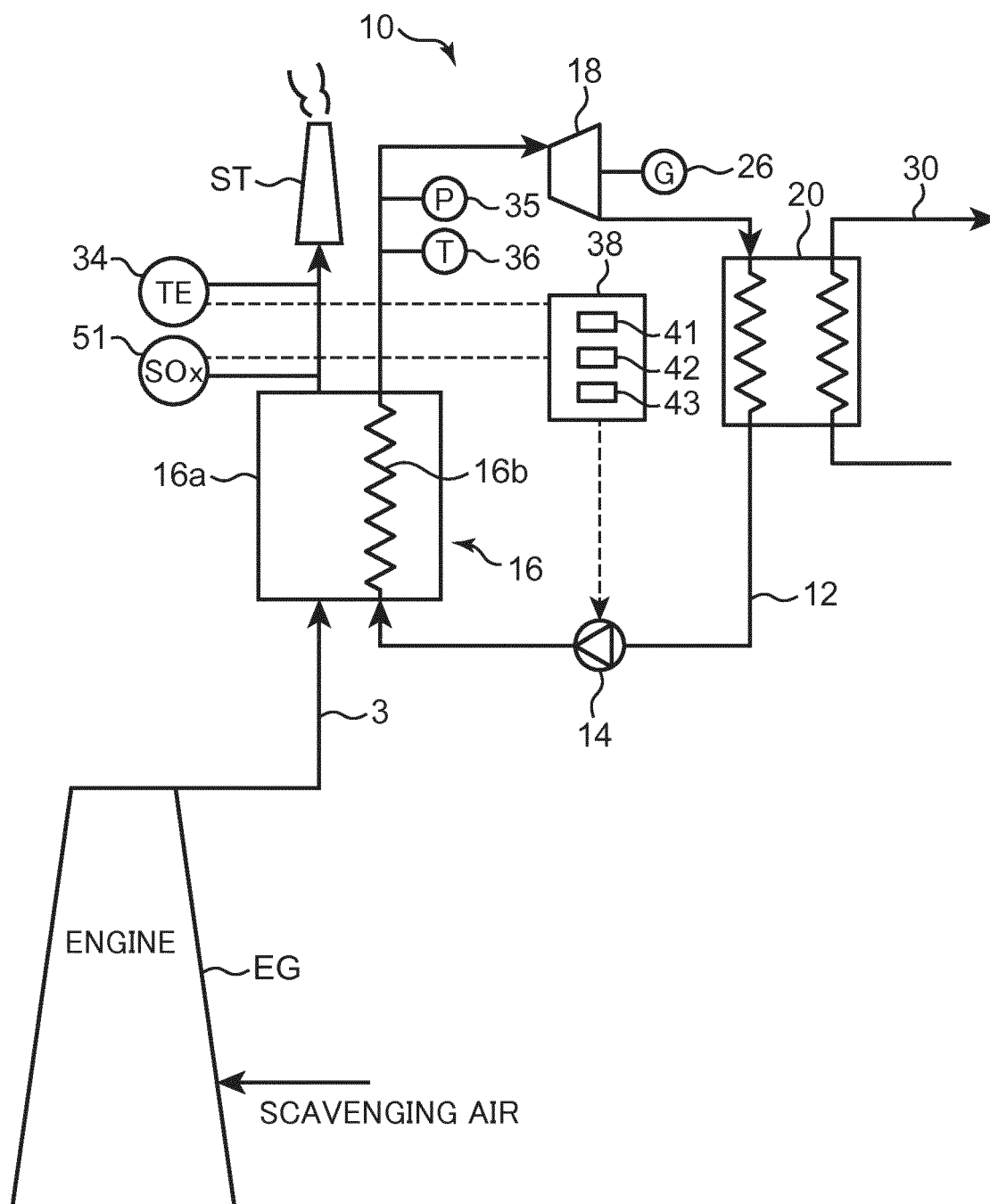


FIG. 5

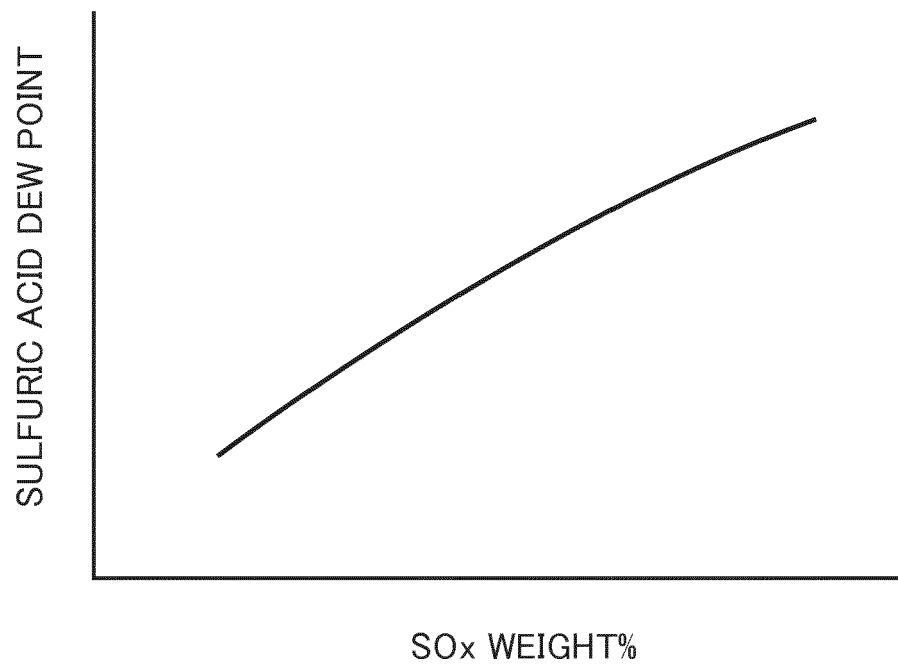


FIG. 6

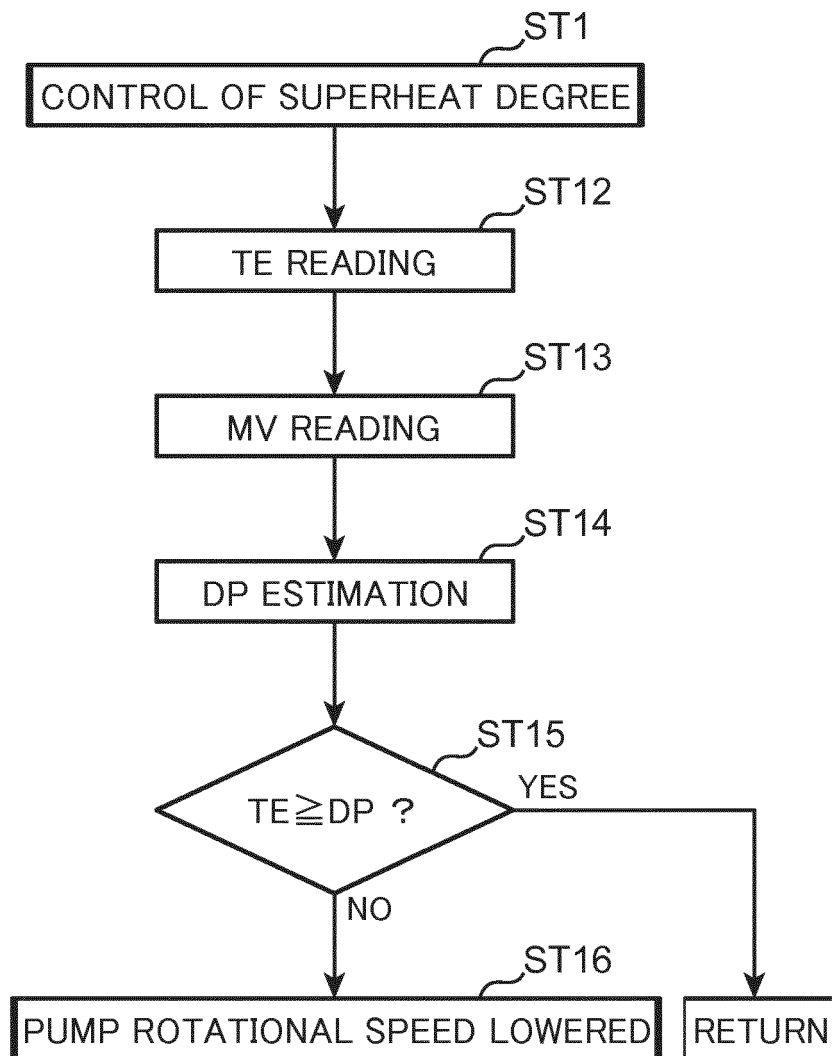


FIG. 7

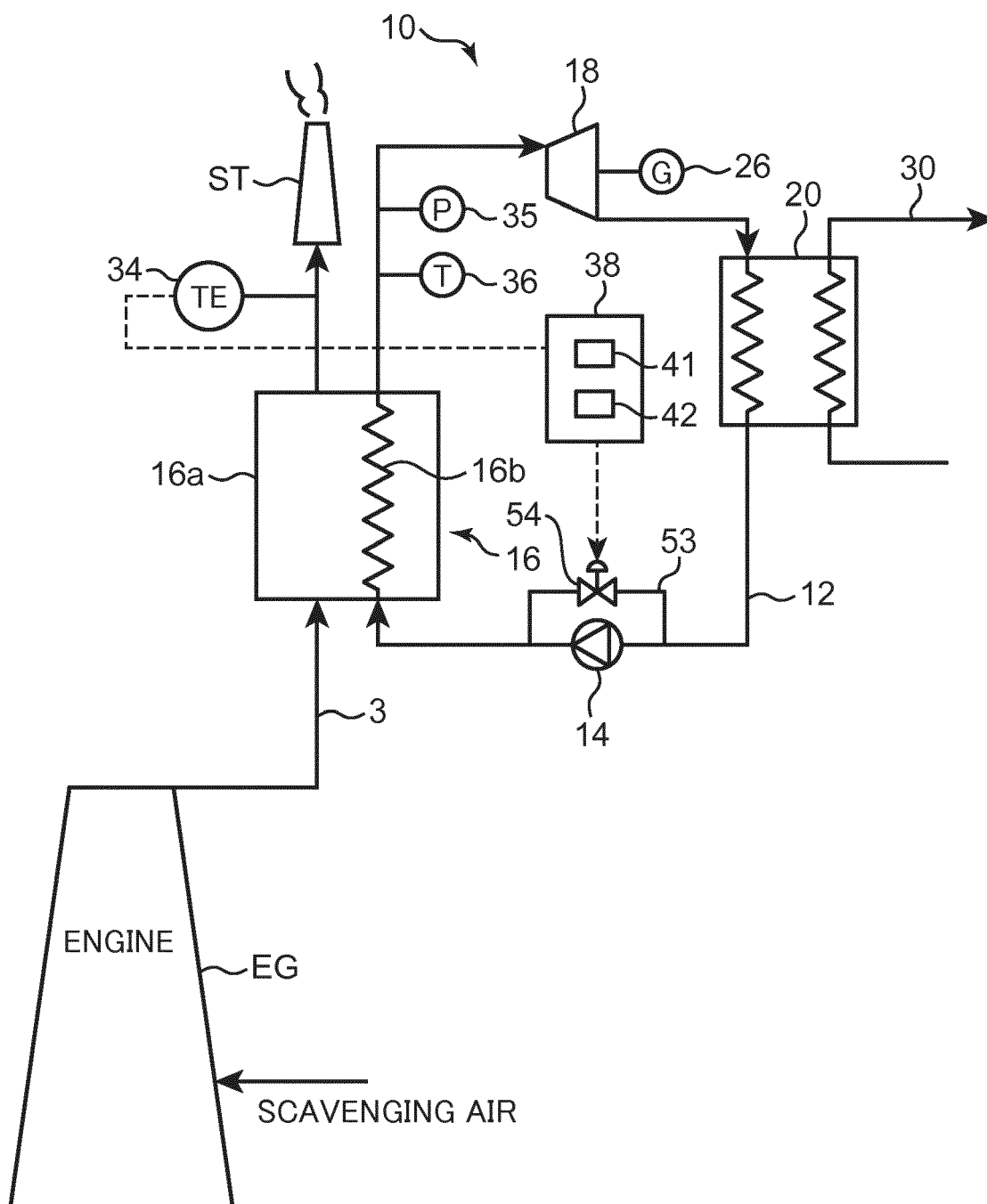


FIG. 8

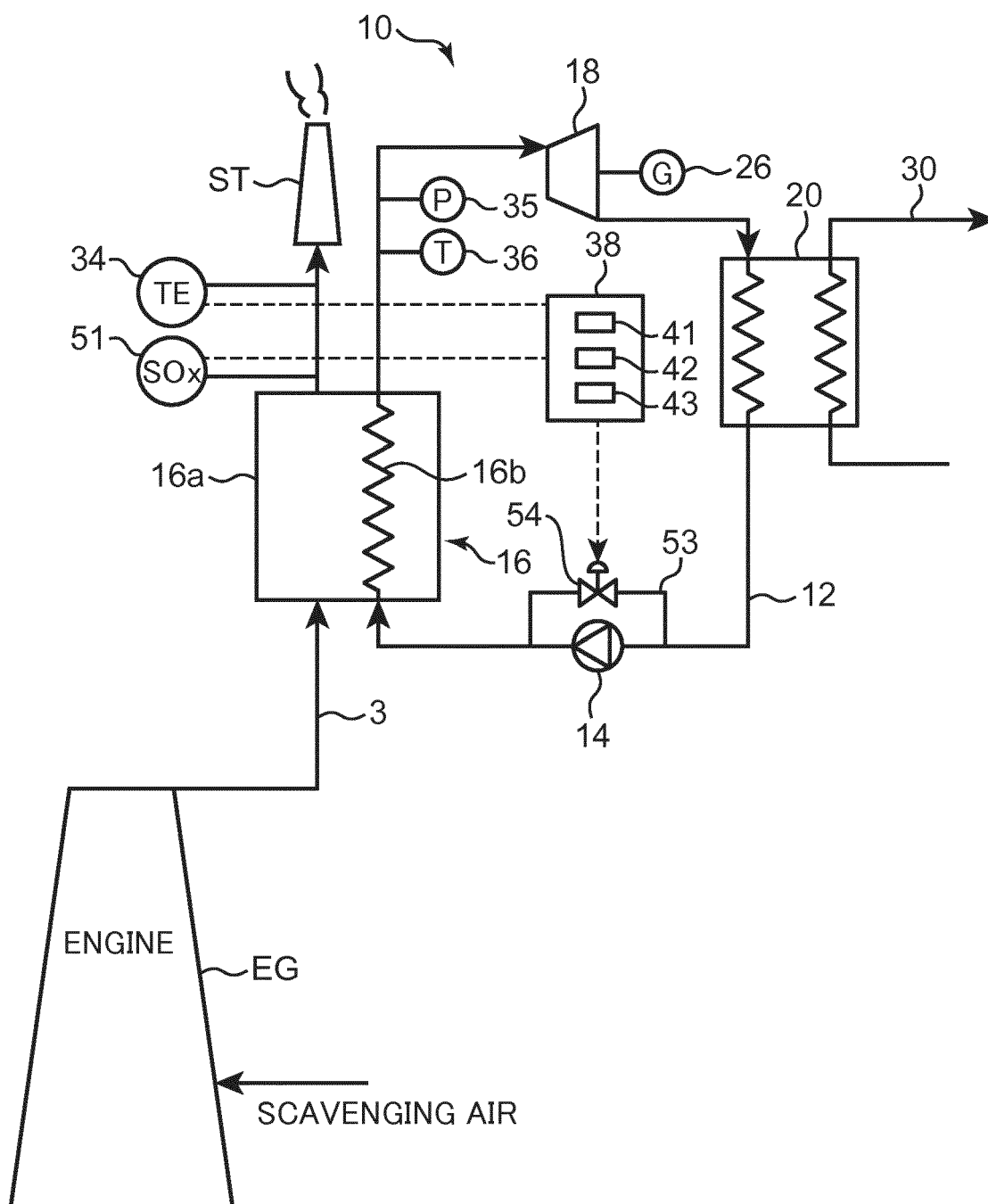


FIG. 9

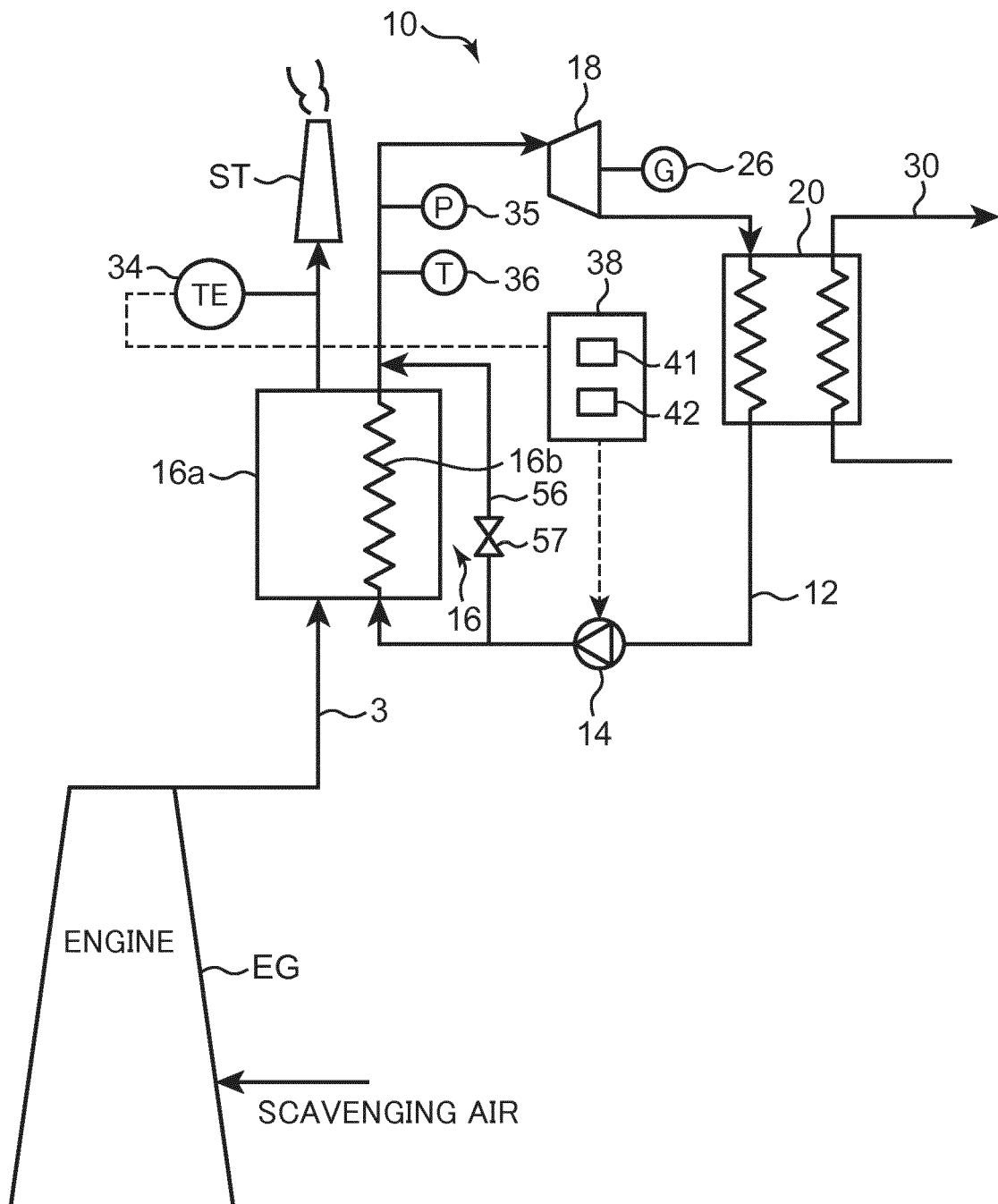


FIG. 10

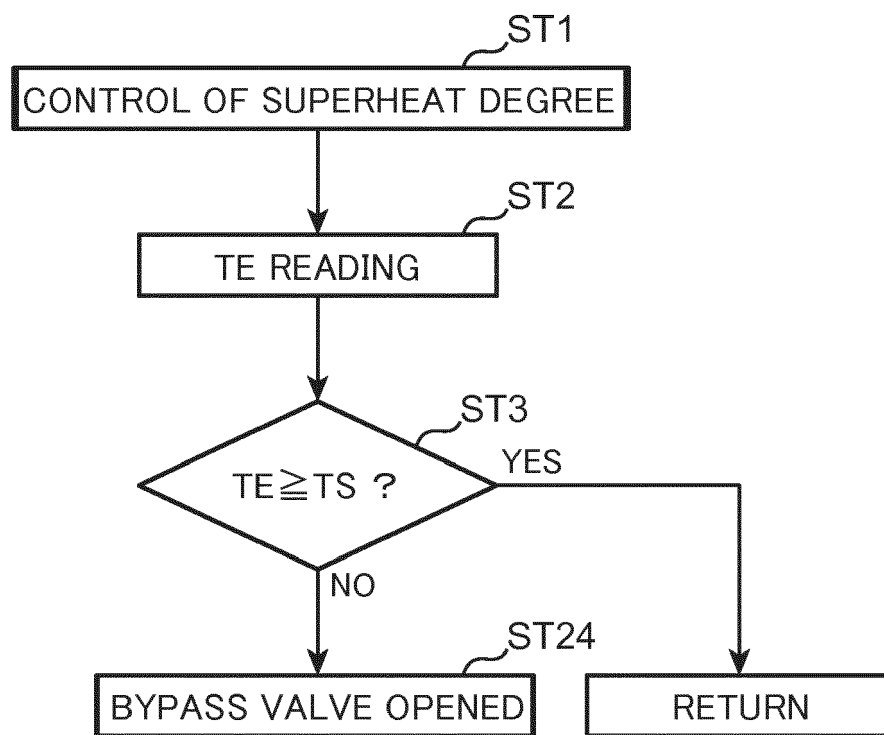


FIG. 11

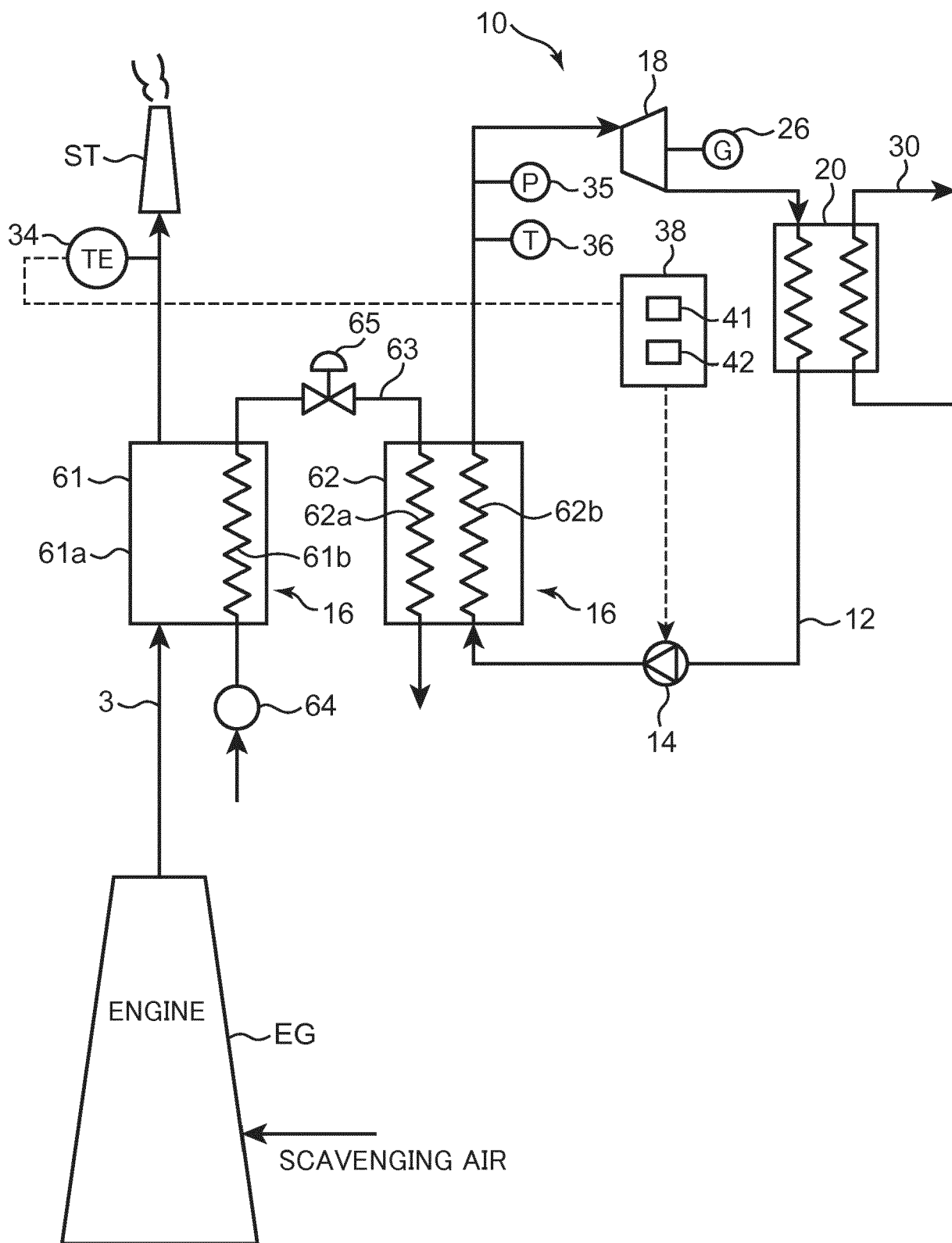


FIG. 12

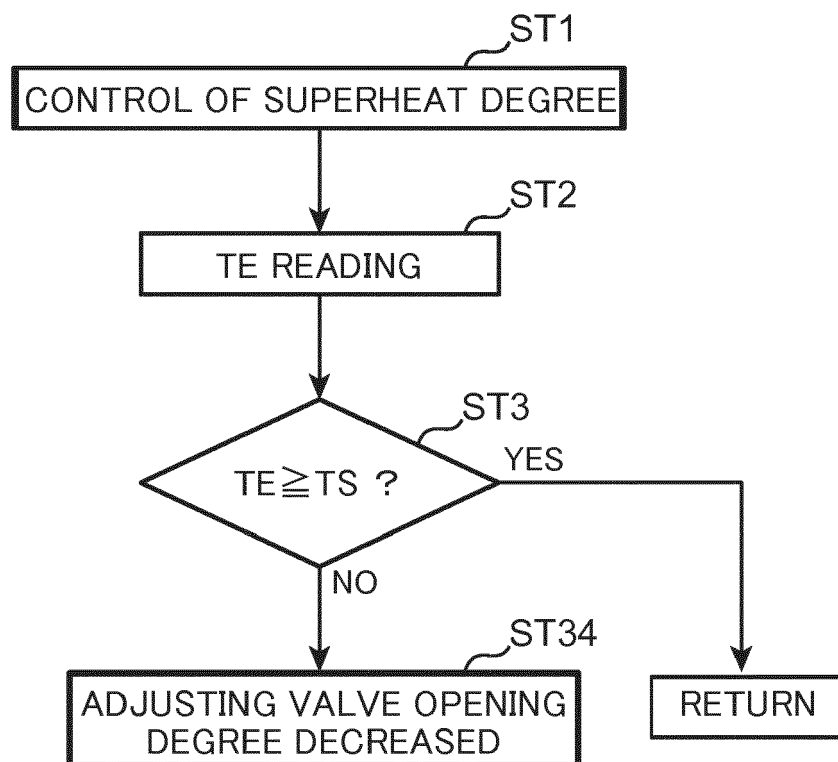
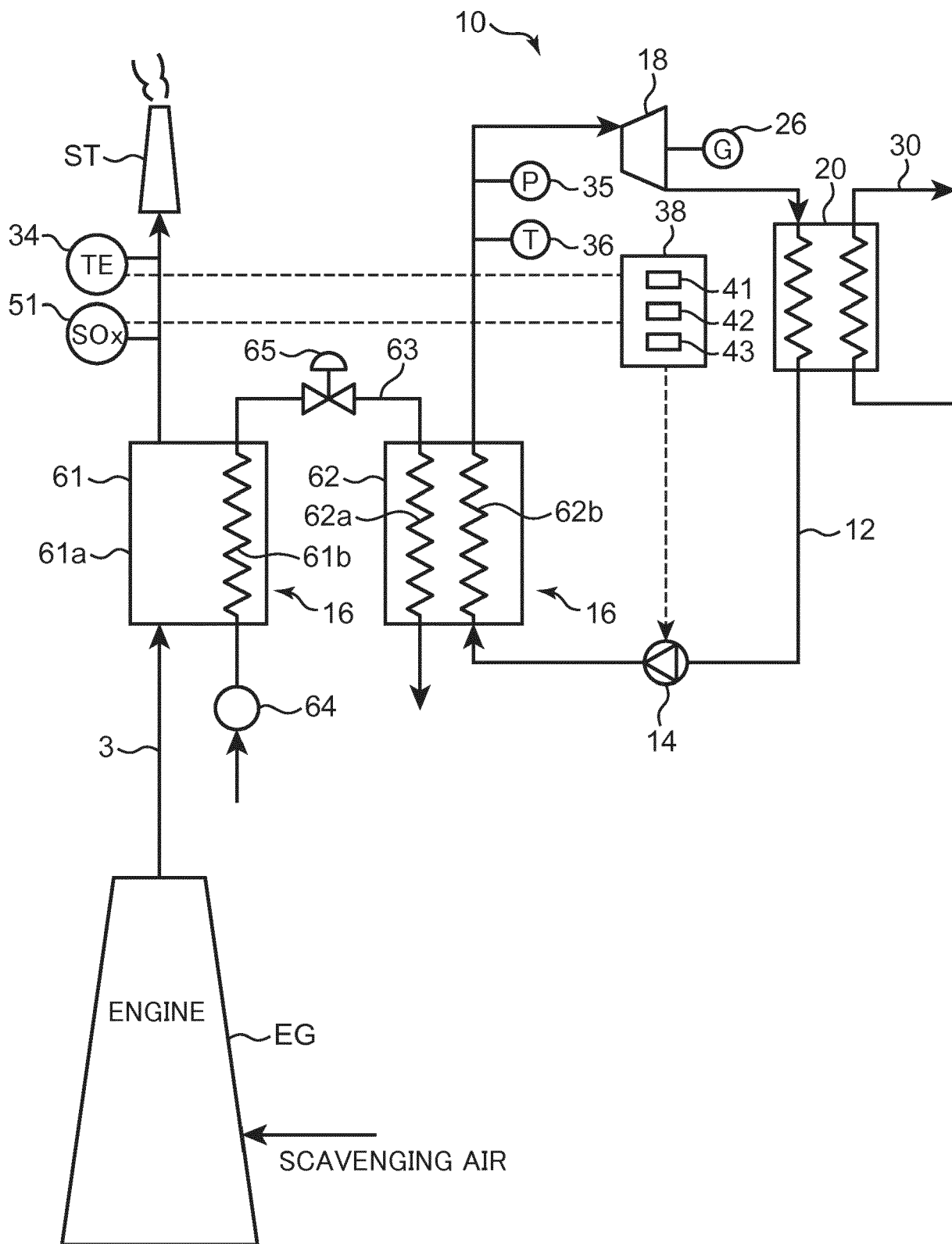


FIG. 13





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Application Number
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			F01K
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 24 April 2019	Examiner Varelas, Dimitrios
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