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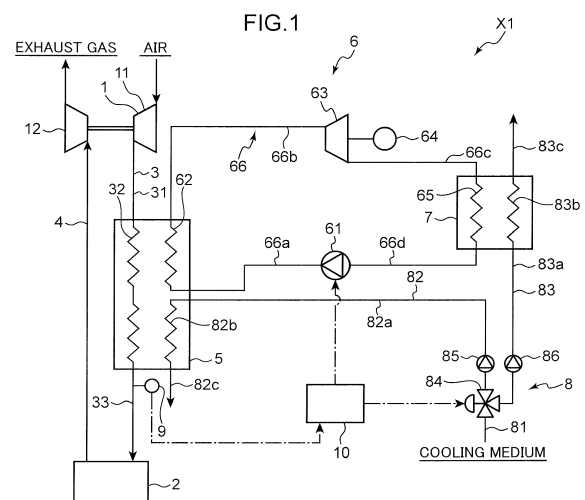
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(54) **SUPERCHARGED AIR COOLING UNIT**

(57) A supercharged air cooling unit comprises: an air supply conduit for allowing supercharged air being supplied from a supercharger to an engine to flow there-through; an energy recovery device including a first cooling section for allowing working fluid to be subjected to heat exchange with the supercharged air flowing through the air supply conduit to pass therethrough, an expander for receiving the working fluid vaporized in the first cooling section and flowing therefrom, and a power obtaining section for obtaining a power generated by the expander; a cooling device including a second cooling section for allowing cooling medium to be subjected to heat exchange with the supercharged air flowing through the air supply conduit to pass therethrough; and a single casing accommodating the air supply conduit, the first cooling section, the second cooling section, and the casing constitute a cooler.



Description

Background of the Invention

Field of the Invention

[0001] The present invention relates to a supercharged air cooling unit.

Background Art

[0002] Conventionally, there are known supercharged air cooling units for cooling supercharged air to be supplied to an engine of a vessel or the like. Japanese Unexamined Patent Publication No. 2015-200181 (hereinafter, referred to as "Patent Document 1") discloses an example of such a supercharged air cooling unit that includes a suction line connecting an engine and a supercharger, a waste heat recovery device for obtaining thermal energy of supercharged air passing through the suction line, and a gas cooler for cooling the supercharged air passing through the suction line.

[0003] In Patent Document 1, the waste heat recovery device includes a heater for heating working medium, an expander for receiving working medium flowing out of the heater, and a power obtaining section connected to the expander. The waste heat recovery device performs heat exchange between the supercharged air passing through a part of the air supply line and the working medium in the heater to thereby evaporate the working medium while cooling the supercharged air, and causes the evaporated working medium to flow into the expander so that thermal energy is obtained by the power obtaining section.

[0004] Further, in Patent Document 1, the gas cooler lies downstream of the heater of the waste heat recovery device in a flowing direction of the supercharged air, and performs heat exchange between supercharged air passing through a part of the air supply line that is provided in the gas cooler and cooling medium, to thereby further cool the supercharged air.

[0005] In Patent Document 1, the supercharged air is cooled by the heater of the waste heat recovery device and the gas cooler, which makes it possible to cool the supercharged air even when a fault occurs in one of the heater and the gas cooler. However, because the heater and the gas cooler are separately provided, it is necessary to secure a large installation space between the supercharger and the engine. This may lead to an increase in the entire size of the supercharged air cooling unit.

Summary of the Invention

[0006] An object of the present invention is to provide a supercharged air cooling unit that allows a compact design.

[0007] A supercharged air cooling unit according to an aspect of the present invention comprises: an air supply

conduit for allowing supercharged air being supplied from a supercharger to an engine to flow therethrough; an energy recovery device including a first cooling section for allowing working fluid to be subjected to heat exchange with the supercharged air flowing through the air supply conduit to pass therethrough, an expander for receiving the working fluid vaporized in the first cooling section and flowing therefrom, and a power obtaining section for obtaining a power generated by the expander; a cooling device including a second cooling section for allowing cooling medium to be subjected to heat exchange with the supercharged air flowing through the air supply conduit to pass therethrough; and a single casing accommodating the air supply conduit, the first cooling section, and the second cooling section, wherein the air supply conduit, the first cooling section, the second cooling section, and the casing constitute a cooler.

[0008] These and other objects, features and advantages of the present invention will become more apparent upon reading the following detailed description along with the accompanying drawings.

Brief Description of the Drawings

[0009]

FIG. 1 is a schematic configuration diagram of a supercharged air cooling unit according to a first embodiment.

FIG. 2 is a plan view showing a schematic configuration of a cooler of the supercharged air cooling unit according to the first embodiment.

FIG. 3 is a flowchart diagram showing operation steps of the supercharged air cooling unit according to the first embodiment.

FIG. 4 is a plan view showing a schematic configuration of a cooler of a supercharged air cooling unit according to a second embodiment.

FIG. 5 is a schematic configuration diagram of a supercharged air cooling unit according to a third embodiment.

Detailed Description of the Preferred Embodiments of the Invention

[0010] Hereinafter, embodiments of the present invention will be described with reference to the accompanying drawings. It should be noted that the drawings referred to hereinafter show, for the purpose of explanation, simplified essential portions of a configuration that are necessary for describing a supercharged air cooling unit X1 according to each embodiment of the present invention. Therefore, the supercharged air cooling unit X1 according to each embodiment of the present invention may include any configuration elements not shown in the drawings referred to in the present specification.

(First Embodiment)

[0011] As shown in FIG. 1, a supercharged air cooling unit X1 according to a first embodiment is provided for cooling supercharged air that is supplied from a supercharger 1 to an engine 2. In the first embodiment, the supercharged air cooling unit X1 is mounted on a vessel that travels by the power of the engine 2. Specifically, the supercharged air cooling unit X1 according to the first embodiment includes a cooler 5, an energy recovery device 6, a condenser 7, a cooling device 8, a detection sensor 9, and a controller 10, and these components are mounted on the vessel with the supercharger 1, the engine 2, a scavenging line 3, and an exhaust line 4.

[0012] Hereinafter, the supercharger 1, the engine 2, the scavenging line 3, the exhaust line 4, the cooler 5, the energy recovery device 6, the condenser 7, the cooling device 8, the detection sensor 9, and the controller 10 mounted on the vessel will be specifically described with reference to FIG. 1.

[0013] The supercharger 1 includes a compressor 11 and a turbine 12. The compressor 11 and the turbine 12 are connected to each other via a shaft. The compressor 11 is connected to the engine 2 via the scavenging line 3, and the turbine 12 is connected to the engine 2 via the exhaust line 4.

[0014] Air having been supplied to the compressor 11 is compressed in the compressor 11 to become supercharged air, and the supercharged air is supplied to the engine 2 through the scavenging line 3. Consequently, the engine 2 is driven to run the vessel mounted with the engine 2. At this time, exhaust gas having been generated in the engine 2 is sent to the turbine 12 through the exhaust line 4. The turbine 12 is driven by expansion energy of the exhaust gas, and the compressor 11 is driven by driving force of the turbine 12. Exhaust gas having passed through the turbine 12 is discharged to the outside of the turbine 12.

[0015] Here, the scavenging line 3 for supplying the supercharged air from the compressor 11 to the engine 2 includes a first portion 31, a second portion 32, and a third portion 33.

[0016] The first portion 31 receives the supercharged air flowing from the compressor 11, and lies upstream of the cooler 5 in a flowing direction of the supercharged air. The second portion 32 is provided in the cooler 5 and joins a downstream end of the first portion 31 in the supercharged air flowing direction. In other words, the second portion 32 corresponds to "an air supply conduit" for allowing the supercharged air being supplied from the supercharger 1 to the engine to flow therethrough. The third portion 33 introduces supercharged air flowing out of the second portion 32 into the engine 2, and connects a downstream end of the second portion 32 in the supercharged air flowing direction to the engine 2.

[0017] The supercharged air having been generated in the supercharger 1 is cooled to a predetermined temperature in the cooler 5 in the course of passage through

the scavenging line 3, i.e. the first portion 31, the second portion 32, and the third portion 33 in this order, and then supplied to the engine 2. A specific configuration of the cooler 5 will be described later.

[0018] The energy recovery device 6 is in the form of a power generation system using Rankine cycle of working medium. An example of the working medium for use in the energy recovery device 6 is an organic fluid having a lower boiling point than water, such as R245fa.

[0019] The energy recovery device 6 includes a pump 61, a first cooling section 62, an expander 63, a power obtaining section 64, a condensing section 65, and a circulation pipe 66. The pump 61, the first cooling section 62, the expander 63, and the condensing section 65 are connected via the circulation pipe 66 so that the working medium circulates in this order. Specifically, the pump 61 and the first cooling section 62 are connected to each other via a first pipe 66a of the circulation pipe 66. The first cooling section 62 and the expander 63 are connected to each other via a second pipe 66b of the circulation pipe 66. The expander 63 and the condensing section 65 are connected to each other via a third pipe 66c of the circulation pipe 66. The condensing section 65 and the pump 61 are connected to each other via a fourth pipe 66d of the circulation pipe 66.

[0020] The pump 61 pressurizes the working medium so that the working medium circulates through the circulation pipe 66. The pump 61 joins the first pipe 66a for pressure-feeding the working medium so as to allow the working medium to flow into the first cooling section 62 through the first pipe 66a. Examples of the pump 61 include a centrifugal pump having a rotor in the form of an impeller and a gear pump having rotors in the form of a pair of gears.

[0021] The first cooling section 62 performs heat exchange between supercharged air being supplied from the supercharger 1 to the engine 2 and working medium flowing in the first cooling section 62 to thereby evaporate the working medium while cooling the supercharged air. The first cooling section 62 lies downstream of the pump 61 in a flowing direction of the working medium. The first pipe 66a connects the first cooling section 62 and the pump 61 for allowing the working medium that is in the form of liquid and pressure-fed by the pump 61 to flow into the first cooling section 62. The first cooling section 62 is provided in the cooler 5, similarly to the second portion 32 of the scavenging line 3. Specifically, the first cooling section 62 is provided in the cooler 5 in such a way as to be able to cool supercharged air flowing through the second portion 32 of the scavenging line 3. Consequently, in the supercharged air cooling unit X1, heat exchange is performed between the working medium in the form of liquid and the supercharged air in the cooler 5, which allows evaporation of the working medium and cooling of the supercharged air.

[0022] The expander 63 lies downstream of the first cooling section 62 in the working medium flowing direction. The second pipe 66b connects the expander 63

and the first cooling section 62 for allowing the working medium vaporized into gas in the first cooling section 62 to flow into the expander 63. In the present embodiment, a screw expander is used as the expander 63, in which a rotor in the form of a screw is rotationally driven by expansion energy of the gaseous working medium. It should be noted that the expander 63 is not necessarily provided in the form of a screw expander, and an expander of centrifugal type, or an expander of scroll type may alternatively be used.

[0023] The power obtaining section 64 is connected to the expander 63. The power obtaining section 64 obtains power by means of the rotor rotationally driven by the expansion energy of the gaseous working medium. Consequently, the energy recovery device 6 obtains power by converting thermal energy of the supercharged air into electrical energy.

[0024] The condensing section 65 lies downstream of the expander 63 in the working medium flowing direction. The third pipe 66c connects the expander 63 and the condensing section 65 for allowing gaseous working medium flowing out of the expander 63 to flow into the condensing section 65.

[0025] Here, the condensing section 65 is provided in the condenser 7. The condenser 7 is provided for condensing the gaseous working medium to thereby convert it back into liquid form. The condenser 7 performs heat exchange between the gaseous working medium flowing in the condensing section 65 from the expander 63 and cooling medium described later to thereby condense the working medium flowing through the condensing section 65. The working medium having been condensed in the condensing section 65 flows into the pump 61 through the fourth pipe 66d to be delivered to the first cooling section 62 again.

[0026] The cooling device 8 is provided separately from the energy recovery device 6 for cooling the supercharged air. The cooling device 8 cools the supercharged air by means of the cooling medium, unlike the energy recovery device 6 that cools the supercharged air by means of the working medium. In the present embodiment, the supercharged air cooling unit X1 is mounted on the vessel, which makes it possible to use seawater as the cooling medium.

[0027] The cooling device 8 includes a supply flow channel 81, a first flow channel 82, a second flow channel 83, a flow rate regulator 84, and pumps 85 and 86.

[0028] The supply flow channel 81 connects with a supply source of the cooling medium.

[0029] The first flow channel 82 joins a downstream end of the supply flow channel 81 in a flowing direction of the cooling medium via the flow rate regulator 84. The first flow channel 82 includes an upstream portion 82a, a second cooling section 82b, and a downstream portion 82c.

[0030] The upstream portion 82a connects the supply flow channel 81 and the second cooling section 82b. The pump 85 is attached to the upstream portion 82a. Cooling

medium flowing in the upstream portion 82a via the flow rate regulator 84 is pressure-fed to the second cooling section 82b by the pump 85.

[0031] The second cooling section 82b performs heat exchange between the supercharged air being supplied from the supercharger 1 to the engine 2 and the cooling medium flowing in the second cooling section 82b to thereby cool the supercharged air. The second cooling section 82b connects the upstream portion 82a and the downstream portion 82c. The second cooling section 82b is provided in the cooler 5, similarly to the second portion 32 of the scavenging line 3 and the first cooling section 62 of the energy recovery device 6. Specifically, the second cooling section 82b is provided in the cooler 5 in such a way as to be able to cool the supercharged air flowing through the second portion 32 of the scavenging line 3 by the cooling medium flowing through the second cooling section 82b. Consequently, the supercharged air cooling unit X1 can cool the supercharged air by the heat exchange between the supercharged air and the working medium and also by the heat exchange between the supercharged air and the cooling medium in the cooler 5.

[0032] The downstream portion 82c joins a downstream end of the second cooling section 82b in the cooling medium flowing direction. Cooling medium flowing out of the second cooling section 82b is discharged to the outside of the cooling device 8 through the downstream portion 82c.

[0033] The second flow channel 83 branches from the first flow channel 82 and joins the downstream end of the supply flow channel 81 in the cooling medium flowing direction via the flow rate regulator 84. The second flow channel 83 includes an upstream portion 83a, a third cooling section 83b, and a downstream portion 83c.

[0034] The upstream portion 83a connects the supply flow channel 81 and the third cooling section 83b. A pump 86 is attached to the upstream portion 83a. Cooling medium flowing in the upstream portion 83a from the supply flow channel 81 via the flow rate regulator 84 is pressure-fed to the third cooling section 83b by the pump 86.

[0035] The third cooling section 83b connects the upstream portion 83a and the downstream portion 83c. The third cooling section 83b is provided in the condenser 7, similarly to the condensing section 65 of the energy recovery device 6. Specifically, the third cooling section 83b is provided in the condenser 7 in such a way as to be able to condense the working medium flowing through the condensing section 65. Consequently, the supercharged air cooling unit X1 can condense the working medium by performing heat exchange between the working medium and the cooling medium in the condenser 7.

[0036] The downstream portion 83c joins a downstream end of the third cooling section 83b in the cooling medium flowing direction. Cooling medium flowing out of the third cooling section 83b is discharged to the outside of the cooling device 8 through the downstream portion 83c.

[0037] The flow rate regulator 84 is in the form of a

valve, and operable to adjust a first flow rate F_1 that is a flow rate of a flow rate of cooling medium flowing through the first flow channel 82 and a second flow rate F_2 that is a flow rate of cooling medium flowing through the second flow channel 83. In the present embodiment, the flow rate regulator 84 is in the form of a three-way valve such as three-way electromagnetic valve or three-way motor operated valve. The cooling device 8 can adjust a ratio between the first flow rate F_1 and the second flow rate F_2 of cooling medium to be supplied to the second and third flow channels 82 and 83 from the supply source through the supply flow channel 81, by adjusting the valve opening degree of the flow rate regulator 84 with respect to each of the flow channels 82 and 83.

[0038] Here, the cooler 5, which includes the second portion 32 of the scavenging line 3, the first cooling section 62 of the energy recovery device 6, and the second cooling section 82b of the cooling device 8 will be specifically described with reference to FIG. 2.

[0039] FIG. 2 is a schematic top view of the cooler 5, which shows the first cooling section 62 and the second cooling section 82b disposed in an internal space S1 by solid line for the descriptive purpose. As shown in FIG. 2, in the present embodiment, the cooler 5 is in the form of a shell and tube type heat exchanger. The cooler 5 includes a single casing 51, the first cooling section 62, and the second cooling section 82b.

[0040] The casing 51 defines the internal space S 1. The internal space S1 corresponds to the second portion 32 of the scavenging line 3, i.e. the air supply conduit. Thus, the supercharged air having been pressure-fed by the compressor 11 flows into the internal space S1 of the casing 51 through the first portion 31 to be cooled by at least one of the first cooling section 62 and the second cooling section 82b in the internal space S1, and then flows out from the internal space S1 to the third portion 33. In the present embodiment, the casing 51 has a rectangular shape.

[0041] The first cooling section 62 is provided in the internal space S 1 of the casing 51. The first cooling section 62 includes a working medium inlet header 62a, a working medium outlet header 62b, and a plurality of branching flow channels 62c.

[0042] The working medium inlet header 62a and the working medium outlet header 62b are aligned at a distance from each other in a flowing direction of the supercharged air in the internal space S1. The supercharged air flowing direction in the internal space S1 refers to a direction in which the supercharged air flows from the inlet to the outlet of the cooler 5. Each of the plurality of branching flow channels 62c extends in the supercharged air flowing direction in such a way as to connect the working medium inlet header 62a and the working medium outlet header 62b. The working medium having been pressure-fed by the pump 61 of the energy recovery device 6 flows into each branching flow channel 62c in the internal space S1 from the first pipe 66a through the working medium inlet header 62a to flow through the

branching flow channels 62c in a direction substantially parallel to the supercharged air flowing direction, and flows out to the second pipe 66b through the working medium outlet header 62b.

[0043] The second cooling section 82b is provided in the internal space S 1 of the casing 51. The second cooling section 82b includes a cooling medium inlet header 82d, a cooling medium outlet header 82e, and a plurality of branching flow channels 82f. The second cooling section 82b is disposed adjacent to the first cooling section 62 in a horizontal direction (in the present embodiment, a horizontal direction that perpendicularly intersects the supercharged air flowing direction). In other words, the first cooling section 62 and the second cooling section 82b are arranged such that they do not overlap with each other in a vertical direction.

[0044] The cooling medium inlet header 82d and the cooling medium outlet header 82e are aligned at a distance from each other in the supercharged air flowing direction in the internal space S 1. Each of the plurality of branching flow channels 82f extends in the supercharged air flowing direction in such a way as to connect the cooling medium inlet header 82d and the cooling medium outlet header 82e. The cooling medium flowing in the upstream portion 82a of the first flow channel 82 through the supply flow channel 81 flows into each branching flow channel 82f in the internal space S1 through the cooling medium inflow header 82d to flow through the branching flow channels 82f in a direction substantially parallel to the supercharged air flowing direction, and flows out to the downstream portion 82c through the cooling medium outlet header 82e.

[0045] In this manner, in the present embodiment, the cooler 5 is provided with the single casing 51, the internal space S1 (the second portion 32 of the scavenging line 3) for allowing passage of the supercharged air, the first cooling section 62 for allowing passage of the working medium, and the second cooling section 82b for allowing passage of the cooling medium. Heat exchange is performed between the supercharged air passing through the internal space S1 and at least one of the working medium passing through each branching flow channel 62c of the first cooling section 62 and the cooling medium passing through each branching flow channel 82f of the second cooling section 82b, so that the supercharged air passing through the internal space S1 is cooled. Therefore, both the cooling of the supercharged air by means of the working medium and the cooling of the supercharged air by means of the cooling medium can be realized in the single casing 51.

[0046] The detection sensor 9 is attached to the third portion 33 of the scavenging line 3. The detection sensor 9 can detect a temperature T of supercharged air having been cooled by the first cooling section 62 and/or the second cooling section 82b in the cooler 5 and before flowing into the engine 2. A signal corresponding to the temperature T detected by the detection sensor 9 is sent to the controller 10 described later.

[0047] The controller 10 includes, for example, an unillustrated Micro Processing Unit (MPU) having a CPU, ROM, and RAM and the like, and executes programs stored in the ROM to thereby perform various controls described below. It should be noted that FIG. 1 shows the controller 10 in the form of a single rectangular component, but means for realizing the functions of the controller 10 can be in any form, and therefore, all the functions of the controller 10 are not necessarily performed by a single constituent element.

[0048] The controller 10 controls the energy recovery device 6 and the cooling device 8. The controller 10 functionally includes an energy recovery device control portion for controlling the driving of, for example, the pump 61 of the energy recovery device 6, a flow rate regulator control portion for controlling the valve opening degree of the flow rate regulator 84, a determination portion for making determination based on the signal corresponding to the temperature T received from the detection sensor 9, and a storage portion for storing various types of information.

[0049] The storage portion of the controller 10 stores first and second flow rate ratios P_1 and P_2 that are information relating to the flow rate ratio between the first flow rate F_1 and the second flow rate F_2 , and an upper limit temperature value T_1 that is information relating to the upper limit temperature of the supercharged air flowing into the engine 2. The first flow rate ratio P_1 is set such that the second flow rate F_2 is higher than the first flow rate F_1 . The second flow rate ratio P_2 is set such that the first flow rate F_1 is higher than the second flow rate F_2 . In the present embodiment, the first flow rate ratio P_1 is set as "the first flow rate F_1 : the second flow rate $F_2 = 1 : 9$ ", and the second flow rate ratio P_2 is set as "the first flow rate F_1 : the second flow rate $F_2 = 9 : 1$ ".

[0050] Upon start of driving of the energy recovery device 6 by the energy recovery device control portion, the flow rate regulator control portion of the controller 10 controls the flow rate regulator 84 to render the ratio between the first flow rate F_1 and the second flow rate F_2 be the first flow rate ratio P_1 . Further, the flow rate regulator control portion of the controller 10 controls the flow rate regulator 84 to render the ratio between the first flow rate F_1 and the second flow rate F_2 be the second flow rate ratio P_2 based on a determination result by the determination portion.

[0051] The determination portion of the controller 10 receives the temperature information from the detection sensor 9, and compares the received temperature information with the upper limit temperature value T_1 to determine whether the temperature of supercharged air having been cooled in the cooler 5 is equal to or greater than the upper limit temperature value T_1 .

[0052] Now, operational steps of the supercharged air cooling unit X1 will be described with reference to a flow-chart diagram shown in FIG. 3.

[0053] At the start of operation shown in FIG. 3, the energy recovery device 6 is in an undriven state, and the

cooling medium is supplied to the second and third flow channels 82 and 83 in a state that the flow rate regulator 84 is controlled to render the ratio between the first flow rate F_1 and the second flow rate F_2 be the second flow rate ratio P_2 . In other words, when the energy recovery device 6 is in an undriven state, the cooling medium flowing from the supply source to the supply channel 81 is mainly supplied to the first flow channel 82, so that the supercharged air is mainly cooled by the second cooling section 82b in the cooler 5.

[0054] A driving start button of the energy recovery device 6 is pushed by an operator of the supercharged air cooling unit X1 to send a start signal to the energy recovery device control portion of the controller 10. Upon receipt of the start signal from the driving start button, the energy recovery device control portion controls the pump 61 and the expander 63 to drive the pump 61 and the expander 63 of the energy recovery device 6. Consequently, the energy recovery device 6 starts operating (step ST1).

[0055] After the energy recovery device 6 is caused to operate at step ST1, the flow rate regulator control portion of the controller 10 controls the valve opening degree of the flow rate regulator 84 to change the ratio between the first flow rate F_1 and the second flow rate F_2 from the second flow rate ratio P_2 to the first flow rate ratio P_1 based on the first flow rate ratio P_1 stored in the storage portion (step ST2). Consequently, the cooling medium flowing from the supply source to the supply channel 81 is mainly supplied to the second flow channel 83, so that the supercharged air is mainly performed by the first cooling section 62 in the cooler 5.

[0056] After the ratio between the first flow rate F_1 and the second flow rate F_2 is adjusted to the first flow rate ratio P_1 at step ST2, the determination portion of the controller 10 compares, based on a signal received from the detection sensor 9, a temperature T and the upper limit temperature value T_1 stored in the storage portion to determine whether the temperature T is equal to or greater than T_1 (step ST3).

[0057] When the determination portion of the controller 10 determines that the temperature T is not equal to or greater than T_1 (NO at step ST3), the controller 10 maintains a current valve opening degree of the flow rate regulator 84 and the determination portion repeatedly performs determination.

[0058] On the other hand, when the determination portion of the controller 10 determines that T is equal to or greater than T_1 (YES at step ST3), it is likely that the cooling of supercharged air is not performed normally in the cooler 5 due to a fault in the energy recovery device 6. Therefore, the section that mainly cools the supercharged air in the cooler 5 is changed from the first cooling section 62 of the energy recovery device 6 to the second cooling section 82b of the cooling device 8. Specifically, when it is determined YES at step ST3, the flow rate regulator control portion of the controller 10 controls the valve opening degree of the flow rate regulator 84 to

change the ratio between the first flow rate F_1 and the second flow rate F_2 from the first flow rate ratio P_1 to the second flow rate ratio P_2 based on the second flow rate ratio P_2 stored in the storage portion (step ST4). Consequently, the cooling medium flowing from the supply source to the supply flow channel 81 is mainly supplied to the first flow channel 82, so that the supercharged air is mainly cooled by the second cooling section 82b in the cooler 5.

[0059] As described above, in the supercharged air cooling unit X1 according to the present embodiment, the first cooling section 62 of the energy recovery device 6 and the second cooling section 82b of the cooling device 8 constitute the single cooler 5. Therefore, it is possible to cool the supercharged air both by the heat exchange between the working medium of the energy recovery device 6 and the supercharged air and by the heat exchange between the cooling medium of the cooling device 8 and the supercharged air by the single cooler 5. In this manner, the cooling of the supercharged air by means of the working medium and the cooling of the supercharged air by means of the cooling medium are performed in the single cooler 5 in the above-described supercharged air cooling unit X1, which allows a compact design as compared with a case where the cooling by means of the working medium and the cooling by means of the cooling medium are performed respectively by separate two coolers.

[0060] Further, in the supercharged air cooling unit X1 according to the present embodiment, the cooling device 8 includes the first flow channel 82 and the second flow channel 83 branching separately from the supply flow channel 81. This makes it possible to supply the cooling medium from the single supply source to the second cooling section 82b and the third cooling section 83b through the first and second flow channels 82 and 83, respectively, to thereby realize both the cooling of the supercharged air and the condensation of the working medium while simplifying the configuration of the supercharged air cooling unit X1.

[0061] Further, in the supercharged air cooling unit X1 according to the present embodiment, the first cooling section 62 and the second cooling section 82b are aligned in the horizontal direction. This allows reduction in height of the cooler 5 as compared with a case where the first cooling section 62 and the second cooling section 82b are aligned in the vertical direction, which makes it possible to mount the cooler 5 on a small vessel or the like having a small space in the vertical direction.

[0062] Further, in the supercharged air cooling unit X1 according to the present embodiment, the controller 10 controls the flow rate regulator 84 based on the information received from the detection sensor 9, the information relating to the temperature of the supercharged air. This makes it possible to reliably cool the supercharged air even when a fault occurs in the energy recovery device 6, specifically as follows.

[0063] When the energy recovery device 6 is in a nor-

mal condition of operating normally, the controller 10 controls the flow rate regulator 84 such that the ratio between the first flow rate F_1 and the second flow rate F_2 is adjusted to the first flow rate ratio P_1 in order to render the first flow rate F_1 lower than the second flow rate F_2 . Consequently, when the energy recovery device 6 is in the normal condition of operating normally, the supercharged air is mainly cooled by the first cooling section 62 in the cooler 5. Here, the detection sensor 9 detects the information relating to the temperature T of supercharged air having been cooled in the cooler 5, and the controller 10 receives the information detected by the detection sensor 9. This allows the controller 10 to determine based on the received information whether the temperature T of supercharged air flowing into the engine is equal to or greater than the upper limit temperature value T_1 . The controller 10, when determining that the temperature T is equal to or greater than the upper limit temperature value T_1 , determines that a fault occurs in the energy recovery device 6, and controls the flow rate regulator 84 to render the ratio between the first flow rate F_1 and the second flow rate F_2 be the second flow rate ratio P_2 so that the first flow rate F_1 is higher than the second flow rate F_2 . Therefore, in the supercharged air cooling unit X1, it is possible to cool the supercharged air mainly by the first cooling section 62 when the energy recovery device 6 operates normally, and cool the supercharged air mainly by the second cooling section 82b when a fault occurs in the energy recovery device 6.

[0064] Further, in the supercharged air cooling unit X1 according to the present embodiment, the controller 10 controls the flow rate regulator 84 to render the ratio between the first flow rate F_1 and the second flow rate F_2 be the first flow rate ratio P_1 , in response to the start signal for starting operation of the energy recovery device 6. This makes it possible to cool the supercharged air mainly by the first cooling section 62 of the energy recovery device 6 upon the start of operation of the energy recovery device 6.

[0065] Further, in the supercharged air cooling unit X1 according to the present embodiment, the controller 10 determines whether the temperature T is equal to or greater than the upper limit temperature value T_1 , after controlling the flow rate regulator 84 to render the ratio between the first flow rate F_1 and the second flow rate F_2 be the first flow rate ratio P_1 . When determining that the temperature T is equal to or greater than the upper limit temperature value T_1 , the controller 10 controls the flow rate regulator 84 to render the ratio between the first flow rate F_1 and the second flow rate F_2 be the second flow rate ratio P_2 . This makes it possible to cool the supercharged air mainly by the first cooling section 62 of the energy recovery device 6 in the normal condition in response to the start signal for starting operation of the energy recovery device 6, and cool the supercharged air mainly by the second cooling section 82b of the cooling device 8 only when a fault occurs in the energy recovery device 6. Consequently, the cooling of the supercharged

air can be reliably performed.

(Second Embodiment)

[0066] Now, a supercharged air cooling unit X1 according to a second embodiment will be described with reference to FIG. 4. In the second embodiment, description will be made only on different features from the first embodiment, and therefore, descriptions of structures, operations and effects that are same as those of the first embodiment will be omitted.

[0067] FIG. 4 is, similarly to FIG. 2, a schematic top view of a cooler 5, which shows a first cooling section 62 and a second cooling section 82b disposed in an internal space S1 by solid line for the descriptive purpose.

[0068] In the supercharged air cooling unit X1 according to the second embodiment, branching flow channels 62c of the first cooling section 62 and branching flow channels 82f of the second cooling section 82b are arranged alternately in a direction intersecting a flowing direction of supercharged air, as shown in FIG. 4.

[0069] A working medium inlet header 62a of the first cooling section 62 and a cooling medium inlet header 82d of the second cooling section 82b extend in a direction perpendicularly intersecting the supercharged air flowing direction and substantially in parallel with each other. On the other hand, a working medium outlet header 62b of the first cooling section 62 and a cooling medium outlet header 82e of the second cooling section 82b extend in the direction perpendicularly intersecting the supercharged air flowing direction and substantially in parallel with each other. In addition, the branching flow channels 62c of the first cooling section 62 and the branching flow channels 82f of the second cooling section 82b are arranged alternately in the direction perpendicularly intersecting the supercharged air flowing direction so as not to overlap each other in the vertical direction. Consequently, the branching flow channels 62c and 82f are arranged at intervals over the entire internal space S1 in the direction perpendicularly intersecting the supercharged air flowing direction.

[0070] As described, in the supercharged air cooling unit X1 according to the second embodiment, the branching flow channels 62c of the first cooling section 62 and the branching flow channels 82f of the second cooling section 82b are arranged alternately in the direction perpendicularly intersecting the supercharged air flowing direction in the internal space S1. This makes it possible to reduce the occurrence of non-uniformity in the cooling of the supercharged air between the case of cooling the supercharged air flowing through the internal space S1 mainly by the first cooling section 62 and the case of cooling the supercharged air flowing through the internal space S1 mainly by the second cooling section 82b.

(Third Embodiment)

[0071] A supercharged air cooling unit X1 according

to a third embodiment will be described with reference to FIG. 5. In the third embodiment, description will be made only on different features from the first embodiment, and therefore, descriptions of structures, operations and effects that are same as those of the first embodiment will be omitted.

[0072] FIG. 5 is, similarly to FIG. 1, a view showing a schematic configuration of the supercharged air cooling unit X1.

[0073] In the supercharged air cooling unit X1 according to the third embodiment, as shown in FIG. 5, a detection sensor 9 is attached to a downstream portion 82c of a first flow channel 82, instead of being attached to a third portion 33 of a scavenging line 3 as in the first embodiment.

[0074] Here, in the supercharged air cooling unit X1 according to the third embodiment, the ratio between a first flow rate F_1 and a second flow rate F_2 is switched between a first flow rate ratio P_1 and a second flow rate ratio P_2 , as in the first embodiment. Because the first flow rate F_1 is not set to zero in either the case of the flow rate ratio P_1 or the flow rate ratio P_2 , the first flow channel 82 is constantly supplied with cooling medium. Therefore, the detection sensor 9 constantly detects the temperature of cooling medium having been subjected to heat exchange with supercharged air in the course of passing through a second cooling section 82b of the first flow channel 82. The temperature of the cooling medium detected by the detection sensor 9 is transmitted to the controller 10.

[0075] The controller 10 estimates a temperature T of supercharged air having been cooled in the cooler 5, based on the temperature of the cooling medium detected by the detection sensor 9, and compares the temperature T with an upper limit temperature value T_1 that is an upper limit temperature of the supercharged air flowing into the engine. Specifically, the controller 10 estimates the temperature T of the supercharged air flowing out of the internal space S1 of the cooler 5 based on, for example, the temperature of the cooling medium in the first pipe 66a, the ratio between the first flow rate F_1 and the second flow rate F_2 , and information of the temperature detected by the detection sensor 9 or the like. Consequently, the controller 10, when determining that the estimated temperature T is equal to or greater than the upper limit temperature value T_1 , controls the valve opening degree of the flow rate regulator 84 to render the ratio between the first flow rate F_1 and the second flow rate F_2 be the second flow rate ratio P_2 .

[0076] As described, the supercharged air cooling unit X1 according to the third embodiment detects the temperature of cooling medium having passed through the second cooling section 82b by means of the detection sensor 9, and controls the valve degree opening of the flow rate regulator 84 based on the detected temperature. In other words, it is possible, without directly detecting the temperature T of supercharged air having been cooled in the cooler 5 as in the first embodiment, to de-

termine whether a fault occurs in the energy recovery device 6 similarly to the first embodiment, by detecting the temperature information of the cooling medium that allows estimation of the temperature T.

[0077] It should be noted that each of the above-described embodiments is exemplary in all respects and should not be regarded as restrictive. The scope of the present invention is indicated by the scope of the claims and not by the description of the embodiments described above, and includes all modifications within the same sense and scope as the claims.

[0078] For example, each of the above-described embodiments shows the case where the supercharged air cooling unit X1 is applied to a vessel, but it is not an exclusive configuration. The supercharged air cooling unit X1 is only required to cool the supercharged air being supplied from the supercharger 1 to the engine 2, and may be applied to a vehicle or the like mounted with a supercharger 1 and an engine 2. In the case where the supercharged air cooling unit X1 is applied to a vehicle or the like, it is possible to use, instead of seawater, cooling water stored in a storage tank, for example, as the cooling medium in the cooling device 8.

[0079] Further, each of the above-described embodiments shows the case where a three-way valve is used as the flow rate regulator 84, but it is not an exclusive configuration. The flow rate regulator 84 is only required to adjust the ratio between the first flow rate F_1 and the second flow rate F_2 . For example, the flow rate regulator 84 may be configured to include two two-way valves. In this case, one two-way valve is attached to a part of the upstream portion 82a of the first flow channel 82 that is upstream of the pump 85, and the other two-way valve is attached to a part of the upstream portion 83a of the second flow channel 83 that is upstream of the pump 86. This configuration makes it possible to adjust the ratio between the first flow rate F_1 and the second flow rate F_2 by controlling the opening degree of each of the two-way valves by the controller 10.

[0080] Further, in each of the above-described embodiments, the flowing direction of the supercharged air flowing through the internal space S1 agrees with the flowing directions of the working medium and the cooling medium flowing through the branching flow channels 62c and 82f, respectively, but this is not an exclusive configuration. It may be configured such that the supercharged air flowing direction is opposite to the flowing directions of the working medium and the cooling medium in the cooler 5, for example.

[0081] Further, in each of the above-described embodiments, the cooler 5 is in the form of a shell and tube type heat exchanger, but it is not an exclusive configuration. The cooler 5 may be provided as a plate type heat exchanger configured by stacking a plurality of plates. In this case, the second portion 32 of the scavenging line 3, the first cooling section 62 of the energy recovery device 6, and the second cooling section 82b of the cooling device 8 are provided in the single cooler 5 constituted

by the integrally formed plurality of plates.

[0082] Further, the above-described embodiments show the case where the detection sensor 9 is attached to the third portion 33 of the scavenging line 3 and the case where the detection sensor 9 is attached to the downstream portion 82c of the first flow channel 82, but these are not exclusive configurations. The detection sensor 9 is only required to detect information relating to the temperature of supercharged air having been cooled in the cooler 5, and may be attached to the cooler 5, for example.

[0083] Further, in each of the above-described embodiments, the first flow rate ratio P_1 is set as "the first flow rate F_1 : the second flow rate $F_2 = 1 : 9$ ", and the second flow rate ratio P_2 is set as "the first flow rate F_1 : the second flow rate $F_2 = 9 : 1$ ", but this is not an exclusive configuration. The first flow rate ratio P_1 is only required to be set such that the second flow rate F_2 is higher than the first flow rate F_1 , and the second flow rate ratio P_2 is only required to be set such that the first flow rate F_1 is higher than the second flow rate F_2 . Therefore, the first flow rate ratio P_1 may be set such that the first flow rate F_1 is zero, and the second flow rate ratio P_2 may be set such that the second flow rate F_2 is zero. In this case, the supercharged air is cooled only by the first cooling section 62 in the cooler 5 when the energy recovery device 6 is normally operating after the start of driving, and the supercharged air is cooled only by the second cooling section 82b in the cooler 5 when a fault occurs in the energy recovery device 6.

[0084] The embodiments described above are now summarized.

[0085] A supercharged air cooling unit according to the above-described embodiments comprises: an air supply conduit for allowing supercharged air being supplied from a supercharger to an engine to flow therethrough; an energy recovery device including a first cooling section for allowing working fluid to be subjected to heat exchange with the supercharged air flowing through the air supply conduit to pass therethrough, an expander for receiving the working fluid vaporized in the first cooling section and flowing therefrom, and a power obtaining section for obtaining a power generated by the expander; a cooling device including a second cooling section for allowing cooling medium to be subjected to heat exchange with the supercharged air flowing through the air supply conduit to pass therethrough; and a single casing accommodating the air supply conduit, the first cooling section, and the second cooling section. The air supply conduit, the first cooling section, the second cooling section, and the casing constitute a cooler.

[0086] In the above-described supercharged air cooling unit, the first cooling section of the energy recovery device and the second cooling section of the cooling device constitute the single cooler. Therefore, it is possible to cool the supercharged air both by the heat exchange between the working medium of the energy recovery device and the supercharged air and by the heat exchange

between the cooling medium of the cooling device and the supercharged air by the single cooler. In this manner, the cooling of the supercharged air by means of the working medium and the cooling of the supercharged air by means of the cooling medium are performed in the single cooler in the above-described supercharged air cooling unit, which allows a compact design as compared with a case where the cooling by means of the working medium and the cooling by means of the cooling medium are performed respectively by separate two coolers.

[0087] It is preferred that the supercharged air cooling unit further comprises a condenser for condensing the working medium flowing out of the expander, and that the cooling device includes a first flow channel for allowing the cooling medium supplied from a supply source to flow therethrough, and a second flow channel branching from the first flow channel, the first flow channel including the second cooling section, and the second flow channel including a third cooling section for performing heat exchange between the cooling medium supplied from the supply source and the working medium flowing in the condenser.

[0088] In the above-described supercharged air cooling unit, the cooling device connects with the supply source of the cooling medium and includes the first flow channel and the second flow channel branching separately from each other. This makes it possible to supply the cooling medium from the single supply source to the second cooling section and the third cooling section through the first and second flow channels, respectively. Therefore, it is possible to realize both the cooling of the supercharged air and the condensation of the working medium while simplifying the configuration of the supercharged air cooling unit.

[0089] It is preferred that the supercharged air cooling unit further comprises: a detection sensor for detecting information relating to a temperature of the supercharged air having been cooled in the cooler; and a controller for receiving the information from the detection sensor, that the cooling device further includes a flow rate regulator operable to adjust a ratio between a first flow rate that is a flow rate of the cooling medium flowing through the first flow channel and a second flow rate that is a flow rate of the cooling medium flowing through the second flow channel, and that the controller, when determining based on the information received from the detection sensor that the temperature of the supercharged air having been cooled in the cooler is equal to or greater than a predetermined temperature in a state that the first flow rate is lower than the second flow rate, controls the flow rate regulator to render the first flow rate higher than the second flow rate.

[0090] In the above-described supercharged air cooling unit, the controller controls the flow rate regulator based on the information received from the detection sensor, the information relating to the temperature of the supercharged air. This makes it possible to reliably cool the supercharged air even when a fault occurs in the

energy recovery device, specifically as follows.

[0091] In the above-described supercharged air cooling unit, when the energy recovery device is in a normal condition of operating normally, the flow rate regulator is adjusted such that the flow rate of cooling medium flowing through the first flow channel is lower than the flow rate of cooling medium flowing through the second flow channel. Consequently, the supercharged air is mainly cooled by the first cooling section of the energy recovery device. Here, the detection sensor detects the information relating to the temperature of supercharged air having been cooled in the cooler, and the controller receives the information detected by the detection sensor. This allows the controller to determine based on the received information whether the temperature of supercharged air flowing into the engine is equal to or greater than the predetermined temperature. The controller, when determining that the temperature of supercharged air flowing into the engine is equal to or greater than the predetermined temperature, determines that a fault occurs in the energy recovery device, and controls the flow rate regulator such that the flow rate of the cooling medium flowing through the first flow channel is higher than the flow rate of the cooling medium flowing through the second flow channel. Therefore, in the above-described supercharged air cooling unit, it is possible to cool the supercharged air mainly by the first cooling section of the energy recovery device when the energy recovery device operates normally, and cool the supercharged air mainly by the second cooling section of the cooling device when a fault occurs in the energy recovery device.

[0092] It is preferred that the controller performs, upon start of operation of the energy recovery device, a first control of controlling the flow rate regulator to render the ratio between the first flow rate and the second flow rate be a first flow rate ratio at which the first flow rate is lower than the second flow rate.

[0093] In the above-described supercharged air cooling unit, the controller performs the first control upon start of driving of the energy recovery device, to thereby make it possible to cool the supercharged air mainly by the first cooling section of the energy recovery device when the energy recovery device is normally operating.

[0094] It is preferred that the controller performs a second control of controlling the flow rate regulator to render the ratio between the first flow rate and the second flow rate be a second flow rate ratio at which the first flow rate is higher than the second flow rate, when determining based on the information received from the detection sensor that a temperature of the supercharged air having been cooled in the cooler is equal to or greater than the predetermined temperature, after performing the first control.

[0095] In the above-described supercharged air cooling unit, the controller performs, when determining that the temperature of the supercharged air is equal to or greater than the predetermined temperature, performs the second control, after performing the first control.

Therefore, when a fault occurs in the energy recovery device after the start of driving of the energy recovery device, the controller adjusts the ratio between the first flow rate and the second flow rate such that the supercharged air is cooled mainly by the second cooling section of the cooling device. This makes it possible to reliably cool the supercharged air after the start of driving of the energy recovery device.

[0096] It is preferred that each of the first cooling section and the second cooling section includes a plurality of branching flow channels, the branching flow channels of the first cooling section and the branching flow channels of the second cooling section are arranged alternately in a direction intersecting a flowing direction of the supercharged air.

[0097] In the above-described supercharged air cooling unit, the branching flow channels of the first cooling section and the branching flow channels of the second cooling section are arranged alternately in the direction intersecting the supercharged air flowing direction in the internal space. This makes it possible to reduce the occurrence of non-uniformity in the cooling of the supercharged air between the case of cooling the supercharged air mainly by the first cooling section and the case of cooling the supercharged air mainly by the second cooling section.

[0098] A supercharged air cooling unit comprises: an air supply conduit for allowing supercharged air being supplied from a supercharger to an engine to flow therethrough; an energy recovery device including a first cooling section for allowing working fluid to be subjected to heat exchange with the supercharged air flowing through the air supply conduit to pass therethrough, an expander for receiving the working fluid vaporized in the first cooling section and flowing therefrom, and a power obtaining section for obtaining a power generated by the expander; a cooling device including a second cooling section for allowing cooling medium to be subjected to heat exchange with the supercharged air flowing through the air supply conduit to pass therethrough; and a single casing accommodating the air supply conduit, the first cooling section, and the second cooling section. The air supply conduit, the first cooling section, the second cooling section, and the casing constitute a cooler.

Claims

1. A supercharged air cooling unit, comprising:

an air supply conduit for allowing supercharged air being supplied from a supercharger to an engine to flow therethrough;
an energy recovery device including

a first cooling section for allowing working fluid to be subjected to heat exchange with the supercharged air flowing through the air

supply conduit to pass therethrough,
an expander for receiving the working fluid vaporized in the first cooling section and flowing therefrom, and
a power obtaining section for obtaining a power generated by the expander;

a cooling device including

a second cooling section for allowing cooling medium to be subjected to heat exchange with the supercharged air flowing through the air supply conduit to pass therethrough; and

a single casing accommodating the air supply conduit, the first cooling section, and the second cooling section, wherein
the air supply conduit, the first cooling section, the second cooling section, and the casing constitute a cooler.

2. The supercharged air cooling unit according to claim 1, further comprising a condenser for condensing the working medium flowing out of the expander, wherein the cooling device includes a first flow channel for allowing the cooling medium supplied from a supply source to flow therethrough, and a second flow channel branching from the first flow channel, the first flow channel including the second cooling section, and the second flow channel including a third cooling section for performing heat exchange between the cooling medium supplied from the supply source and the working medium flowing in the condenser.
3. The supercharged air cooling unit according to claim 2, further comprising:

a detection sensor for detecting information relating to a temperature of the supercharged air having been cooled in the cooler; and
a controller for receiving the information from the detection sensor, wherein
the cooling device further includes a flow rate regulator operable to adjust a ratio between a first flow rate that is a flow rate of the cooling medium flowing through the first flow channel and a second flow rate that is a flow rate of the cooling medium flowing through the second flow channel, and
the controller, when determining based on the information received from the detection sensor that the temperature of the supercharged air having been cooled in the cooler is equal to or greater than a predetermined temperature in a state that the first flow rate is lower than the second flow rate, controls the flow rate regulator to

render the first flow rate higher than the second flow rate.

4. The supercharged air cooling unit according to claim 3, wherein
the controller performs, upon start of operation of the energy recovery device, a first control of controlling the flow rate regulator to render the ratio between the first flow rate and the second flow rate be a first flow rate ratio at which the first flow rate is lower than the second flow rate. 5
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5. The supercharged air cooling unit according to claim 4, wherein
the controller performs a second control of controlling the flow rate regulator to render the ratio between the first flow rate and the second flow rate be a second flow rate ratio at which the first flow rate is higher than the second flow rate, when determining based on the information received from the detection sensor that a temperature of the supercharged air having been cooled in the cooler is equal to or greater than the predetermined temperature, after performing the first control. 15
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6. The supercharged air cooling unit according to claim 3 or 4, wherein
each of the first cooling section and the second cooling section includes a plurality of branching flow channels, the branching flow channels of the first cooling section and the branching flow channels of the second cooling section are arranged alternately in a direction intersecting a flowing direction of the supercharged air. 30
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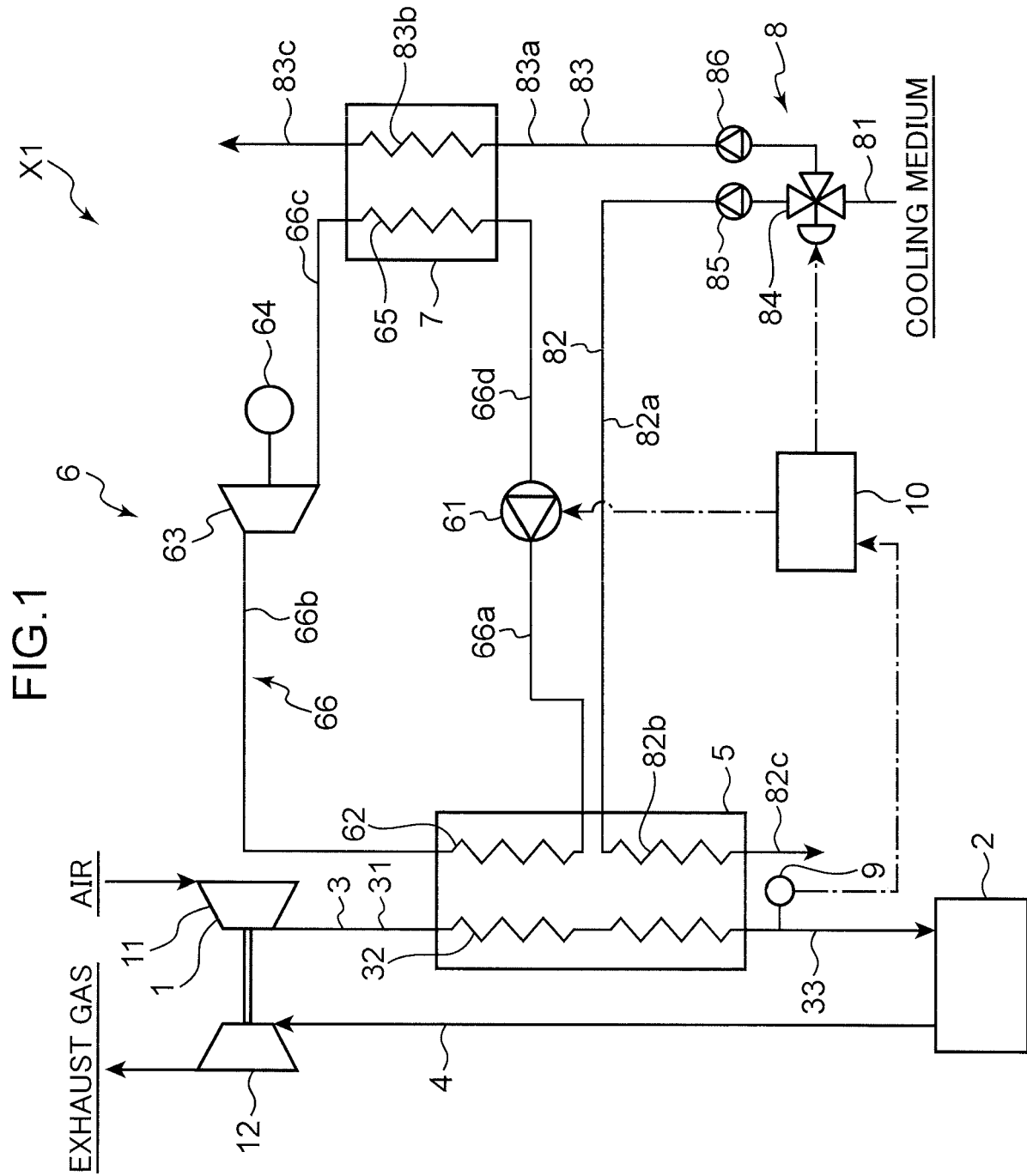


FIG.2

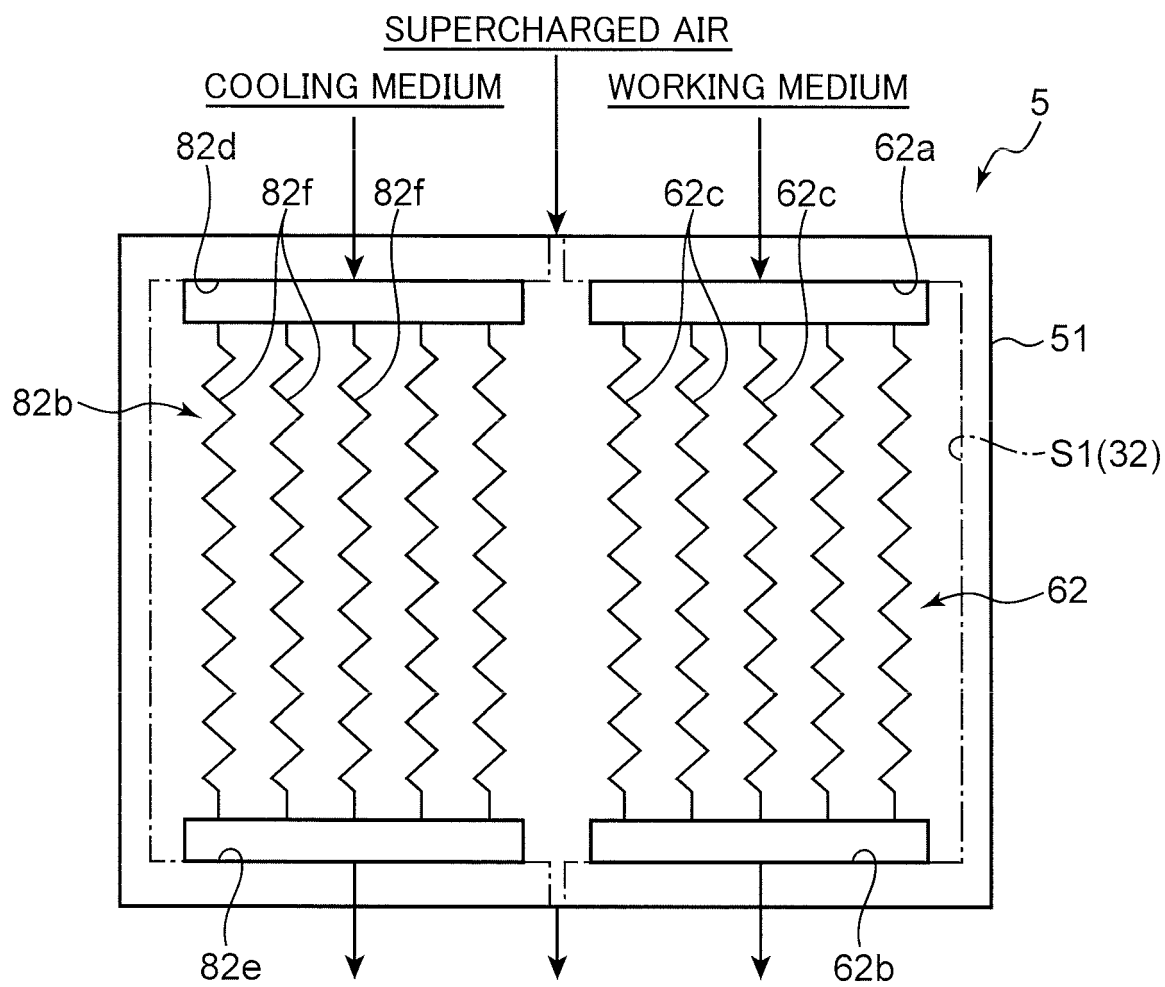


FIG.3

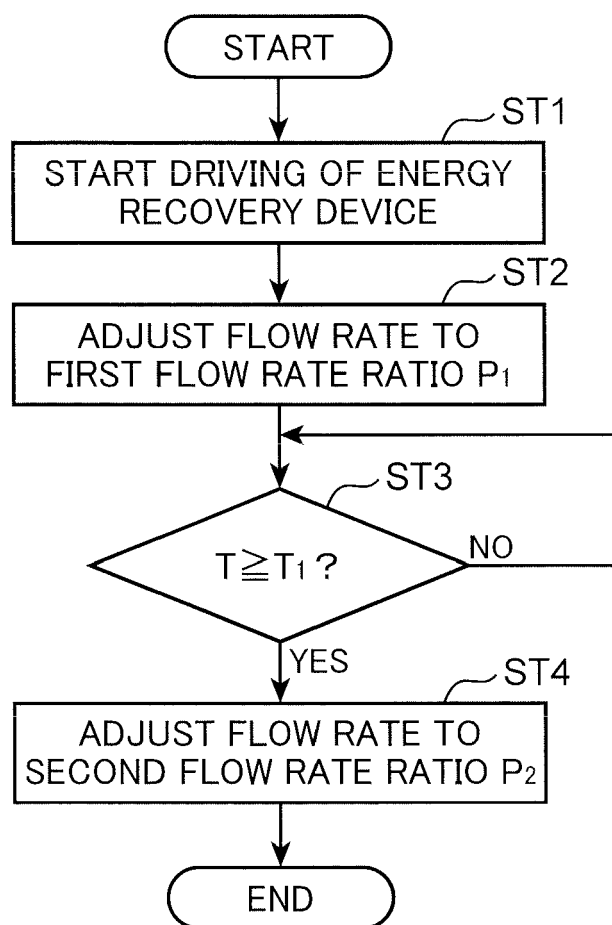
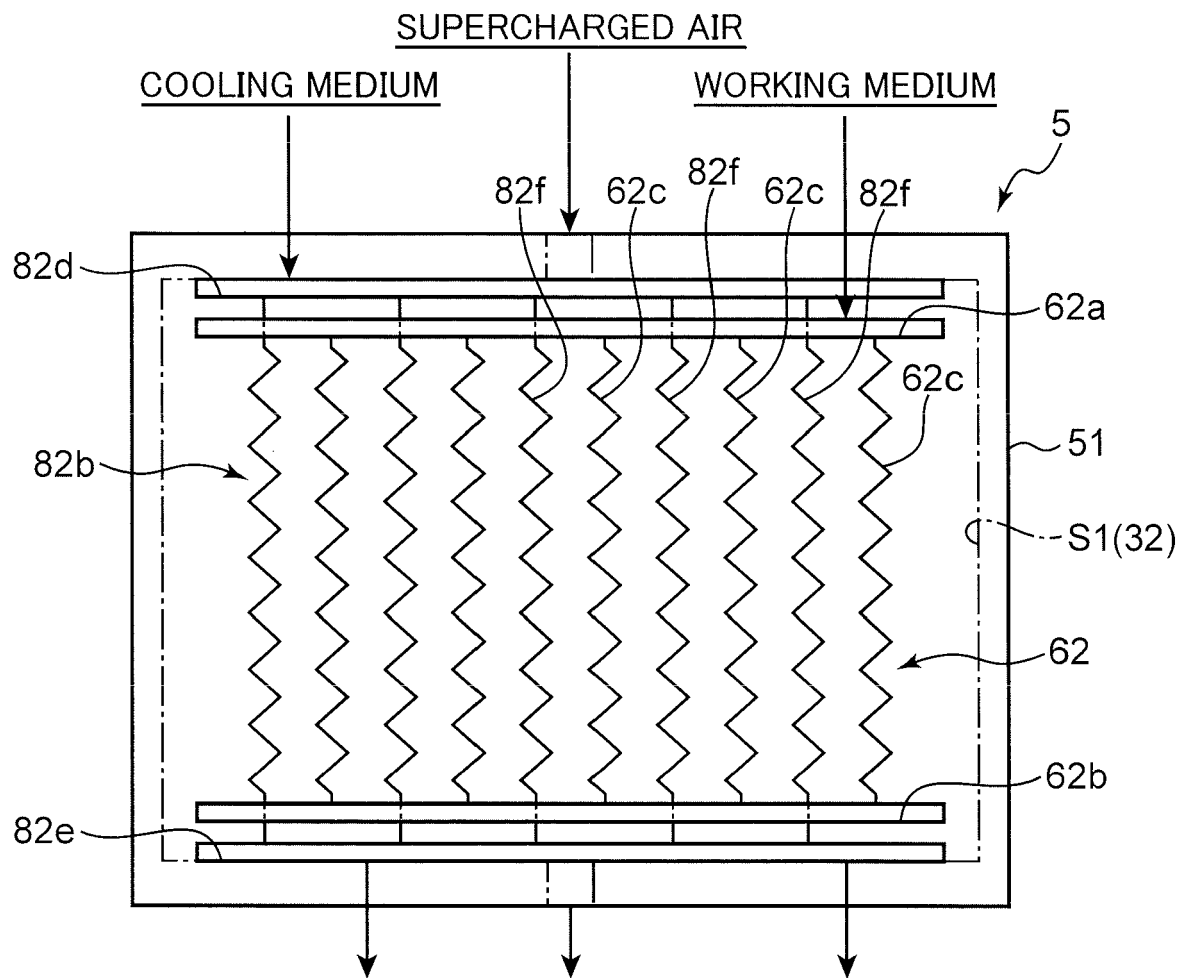
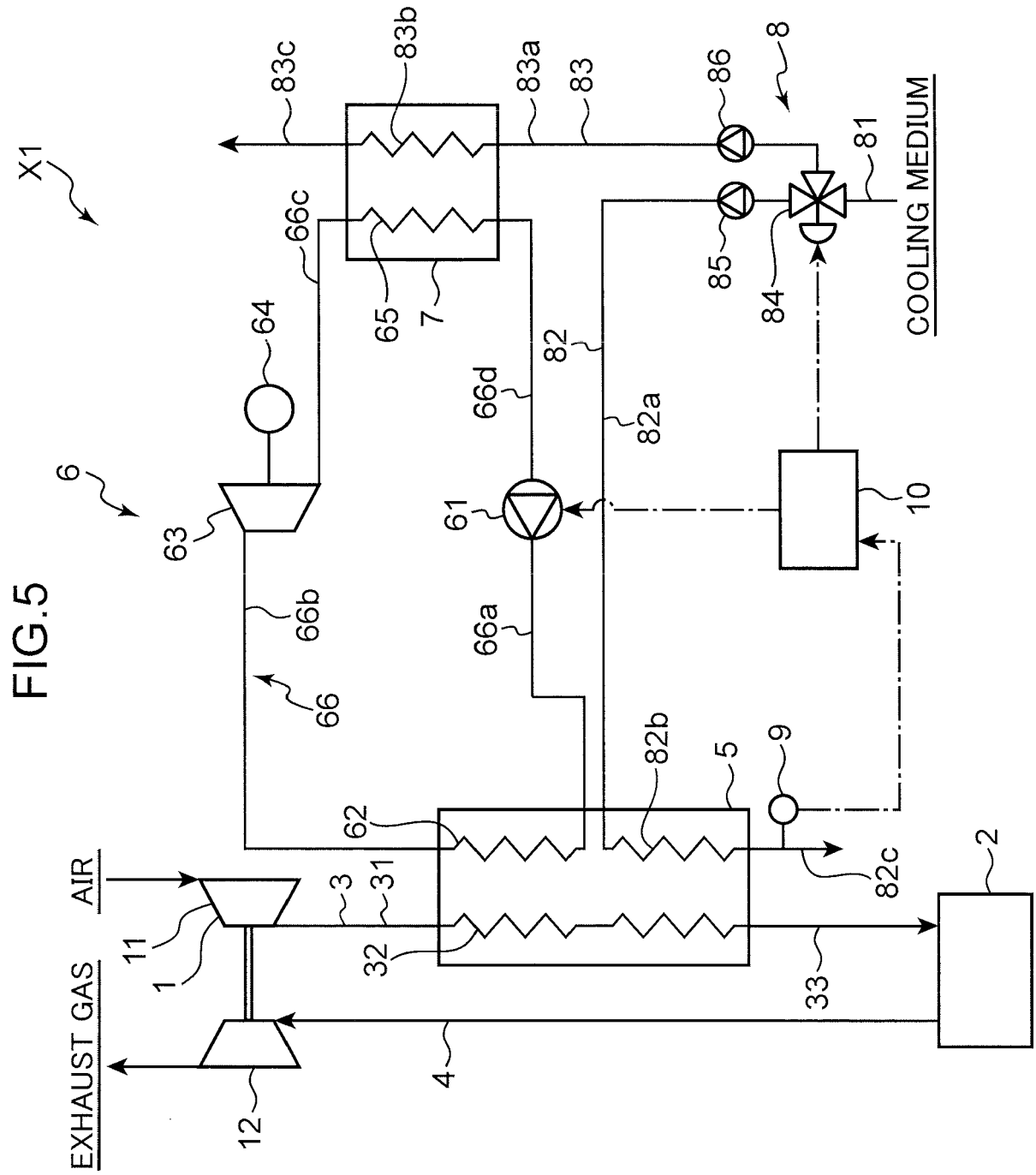


FIG.4







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Application Number
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