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(54) **THERMAL ENERGY RECOVERY DEVICE AND METHOD FOR INSTALLATION OF THERMAL ENERGY RECOVERY DEVICE**

(57) The application discloses a thermal energy recovery device with which the space within an engine room of a marine vessel can be utilized effectively and a method for installation of such a device , the device including a condenser arranged to cause working medium circulating in a circulation flow path to exchange heat with seawater, an evaporator connected to an exhaust gas pipe that guides the exhaust gas to a funnel within a first floor that is provided higher than the sea level, and the circulation flow path and arranged to cause the working medium to recover the thermal energy from the exhaust gas, an expander arranged downstream the evaporator and arranged to be driven by the working medium, and a cooling pump unit arranged to pump up the seawater into the condenser. The condenser is arranged at a second floor that is provided lower than the first floor.

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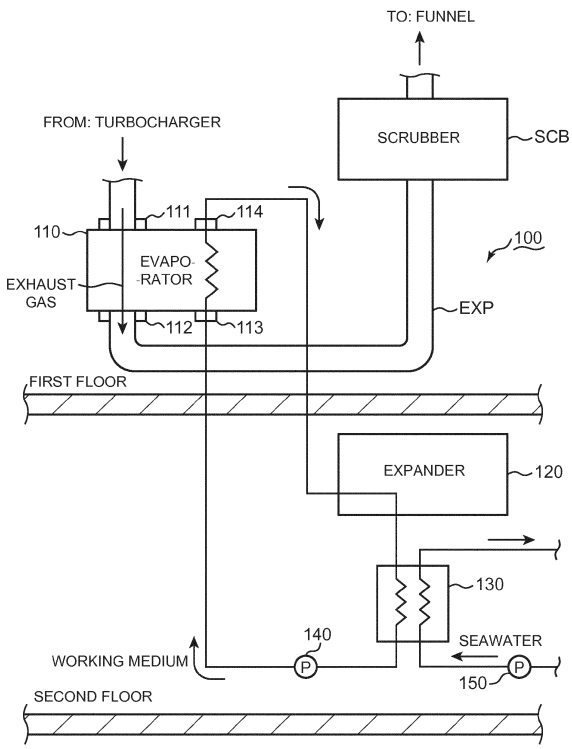

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Description

BACKGROUND OF THE INVENTION

(FIELD OF THE INVENTION)

[0001] The present invention relates to a thermal energy recovery device for recovering thermal energy from exhaust gas generated in a marine vessel and a method for installation of such a thermal energy recovery device.

(DESCRIPTION OF THE RELATED ART)

[0002] There have been developed various types of thermal energy recovery devices for marine vessels that recover thermal energy from exhaust gas discharged from an internal combustion engine and convert the recovered thermal energy into mechanical power (see JP 2016-160870 A, JP 2016-160868 A, and JP 2015-232424 A) . Such thermal energy recovery devices are formed with a circulation flow path for circulation of working medium (e.g. organic medium) therethrough. A condenser, an evaporator, and an expander are arranged in the circulation flow path. The condenser cools and condenses working medium. Through heat exchange, within the evaporator, with exhaust gas discharged from the internal combustion engine, the working medium is gasified. The gasified working medium is delivered to the expander to be expanded therein. The expander is driven by the expanded working medium, whereby the thermal energy of the working medium is partially converted into mechanical power.

SUMMARY OF THE INVENTION

[0003] Conventional thermal energy recovery devices for marine vessels have been designed with little consideration on adequately arranging the condenser, the evaporator, and the expander, which are generally arranged densely around a discharge path for exhaust gas within the engine room of the marine vessel. As a result, the operation efficiency for inspection and/or repair of such thermal energy recovery devices may be degraded.

[0004] It is hence an object of the present invention to provide a thermal energy recovery device with which the space within an engine room of a marine vessel can be utilized effectively and in which a condenser, an evaporator, and an expander can be arranged without excessive density and a method for installation of such a thermal energy recovery device.

[0005] A thermal energy recovery device according to an aspect of the present invention is arranged in an engine room or a funnel unit of a marine vessel having multiple separate floors and arranged to recover thermal energy from exhaust gas discharged from an internal combustion engine of the marine vessel. The thermal energy recovery device includes a condenser arranged to cause working medium circulating in a circulation flow path to exchange heat with cooling water to cool the working medium, an evaporator connected to an exhaust gas pipe that is provided in an extending manner to guide the exhaust gas within a first floor, which is provided as one of the multiple floors, and the circulation flow path and arranged to cause the working medium to recover the thermal energy from the exhaust gas through heat exchange between the working medium and the exhaust gas, an expander arranged downstream the evaporator in the circulation flow path and arranged to be driven by the working medium, and a cooling pump unit arranged to pump up the cooling water into the condenser. The condenser is arranged at a second floor, which is provided as a floor lower than the first floor.

[0006] In accordance with the arrangement above, the evaporator is arranged at the first floor, while the condenser is arranged at the second floor, which is provided as a floor lower than the first floor, so that the thermal energy recovery device is arranged in at least two separate floors. Accordingly, unlike conventional thermal energy recovery devices, relatively available one of the floors for the engine room and the funnel unit is utilized effectively for arranging the condenser, the evaporator, and the expander of the thermal energy recovery device. The condenser, the evaporator, and the expander are thus arranged in the engine room or the funnel unit of the marine vessel without excessive density.

[0007] Since the condenser is arranged at the second floor, which is provided as a floor lower than the first floor at which the evaporator and the exhaust gas pipe are arranged, the cooling pump unit is not required to pump up cooling water to the first floor. That is, the height of the second floor, which is lower than the first floor, is enough for the cooling pump unit to have a required pump-up height. The cooling pump unit is thus not required to have an excessive pump-up height. While in general, the cost of a pumping device increases as the pump-up height increases, the cooling pump unit is not required to have an increased pump-up height as described above, so that an inexpensive pumping device may be utilized as the cooling pump unit. It is therefore possible to manufacture the thermal energy recovery device at low cost.

[0008] The working medium is cooled within the condenser through heat exchange with cooling water pumped up by the cooling pump unit into the condenser and then circulated into the evaporator. Since the exhaust gas pipe to which the evaporator is connected is provided in an extending manner to guide exhaust gas within the first floor, which is higher than the second floor at which the condenser is arranged, heat exchange between the exhaust gas and the working medium is performed on an exhaust gas guide path similar to that in common marine vessels. The thermal energy recovery device is not required to be specially designed with respect to the exhaust gas guide path and thereby can be manufactured at low cost.

[0009] Since the working medium is cooled within the condenser, the exhaust gas has a temperature much higher than that of the working medium. It is therefore possible for the working medium to recover thermal energy from the exhaust gas efficiently within the evaporator. Having recovered thermal energy from the exhaust gas, the working medium has a high temperature and, when circulated from the evaporator into the expander, is expanded therein to drive the expander.

[0010] In relation to the arrangement above, the second floor may be immediately below the first floor.

[0011] In accordance with the arrangement above, since the second floor is immediately below the first floor, the distance between the condenser and the evaporator cannot be increased excessively. Accordingly, the working medium cannot undergo an excessive pressure loss while supplied from the condenser to the evaporator. In addition, the working medium cannot be included in the circulation flow path at an excessive amount.

[0012] In relation to the arrangement above, the first floor may be the uppermost floor among the multiple floors.

[0013] In accordance with the arrangement above, since the first floor is the uppermost floor among the multiple floors, heat exchange between the exhaust gas and the working medium is performed on an exhaust gas guide path similar to that in common marine vessels. The thermal energy recovery device is not required to be specially designed with respect to the exhaust gas guide path and thereby can be manufactured at low cost.

[0014] In relation to the arrangement above, the expander may be arranged at the second floor. The evaporator may include a medium inflow unit forming a medium inflow port through which the working medium flows in.

[0015] In accordance with the arrangement above, since the evaporator is arranged at the first floor, which is higher than the second floor, the medium inflow port of the evaporator is at a position higher than the liquid level of the working medium within the condenser. This results in a significantly low risk of the liquefied working medium flowing, under stoppage of the thermal energy recovery device, from the condenser into the evaporator to be gasified accidentally therein.

[0016] As for the expander arranged at the second floor, which is lower than the first floor at which the evaporator is arranged, a temperature decrease of the working medium due to expansion within the expander could cause the working medium flowing from the expander to the condenser to be divided into two phases: gas phase and liquid phase. In this case, the working medium could be more likely to undergo pressure loss. However, since the expander is arranged at the second floor as with the condenser and thereby the distance between the expander and the condenser cannot be increased excessively, the working medium supplied from the expander to the condenser cannot undergo an excessive pressure loss.

[0017] In relation to the arrangement above, the evaporator may include (i) a medium outflow unit forming a medium outflow port through which the working medium flows out at a position higher than that of the medium inflow port, (ii) a gas inflow unit forming a gas inflow port through which the exhaust gas flows in, and (iii) a gas outflow unit forming a gas outflow port through which the exhaust gas flows out at a position lower than that of the gas inflow port.

[0018] In accordance with the arrangement above, since the gas outflow unit forms the gas outflow port through which the exhaust gas flows out at a position lower than that of the gas inflow unit forming the gas inflow port through which the exhaust gas flows in, the exhaust gas flows downward within the evaporator. That is, the working medium flows in a direction opposite to the direction of flow of the exhaust gas within the evaporator. As a result, exhaust gas near the gas inflow port exchanges heat with working medium near the medium outflow port. Exhaust gas near the gas outflow port exchanges heat with working medium near the medium inflow port.

[0019] As for heat exchange between exhaust gas near the gas inflow port and working medium near the medium outflow port, the working medium near the medium outflow port has already exchanged heat with exhaust gas from the medium inflow port to near the medium outflow port to have an increased temperature, while the exhaust gas near the gas inflow port has undergo less heat exchange with working medium to remain at high temperature. The exhaust gas near the gas inflow port and the working medium near the medium outflow port thus have a sufficiently increased temperature difference therebetween, whereby heat exchange between the working medium and the exhaust gas is performed highly efficiently.

[0020] As for heat exchange between exhaust gas near the gas outflow port and working medium near the medium inflow port, the exhaust gas near the gas outflow port has already exchanged heat with working medium from the gas inflow port to near the gas outflow port to have a reduced temperature, while the working medium near the medium inflow port has undergo less heat exchange with exhaust gas to remain at low temperature. The exhaust gas near the gas outflow port and the working medium near the medium inflow port thus have a sufficiently increased temperature difference therebetween, whereby heat exchange between the working medium and the exhaust gas is performed highly efficiently.

[0021] In relation to the arrangement above, the thermal energy recovery device may further include a support body that supports the expander and the condenser thereon. The expander may be arranged on the support body at a position higher than that of the condenser.

[0022] In accordance with the arrangement above, both the expander and the condenser, which are supported by the support body, are installed stably within the second floor. In addition, the expander and the condenser are arranged vertically on the support body, without the need for a horizontally widened installation area, whereby the space within the second floor can be utilized effectively. The expander is arranged on the support body at a position higher than that of the condenser, resulting in a significantly low risk of the working medium cooled and liquefied within the condenser flowing back into the expander. In addition, even when the working medium may be cooled and liquefied due to expansion within the expander, the liquefied working medium can directly flow into the condenser.

[0023] In relation to the arrangement above, the support body may include (i) a first placement unit on which the expander is placed, (ii) a second placement unit formed in a manner drawable in a horizontal direction below the first placement unit and on which the condenser is placed, and (iii) a support unit that supports the first placement unit and the second placement unit thereon. The support unit may include a guide unit arranged to guide the second placement unit drawn out in the horizontal direction.

[0024] In accordance with the arrangement above, since the support unit that supports the first placement unit and the second placement unit thereon includes the guide unit arranged to guide the second placement unit drawn out in the horizontal direction, the operator can draw out the second placement unit easily in the horizontal direction. Since the second placement unit on which the condenser is placed is drawn out in the horizontal direction below the first placement unit on which the expander is placed, the operator can draw out the second placement unit in the horizontal direction to easily access the condenser without being disturbed by the expander and the first placement unit. The condenser can therefore be maintained efficiently.

[0025] In relation to the arrangement above, the thermal energy recovery device may further include a primary guide pipe arranged to guide seawater therethrough to be supplied to a scrubber arranged to remove sulfur oxides from the exhaust gas, a first secondary guide pipe branched from the primary guide pipe at a predetermined first branch portion and arranged to guide part of the seawater flowing through the primary guide pipe to the condenser as the cooling water, and a second secondary guide pipe branched from the primary guide pipe at a second branch portion upstream the first branch portion in the direction of flow of the seawater in the primary guide pipe and arranged to guide part of the seawater flowing through the primary guide pipe to the condenser as the cooling water. The cooling pump unit may include a primary pump mounted in the primary guide pipe between the first branch portion and the second branch portion and arranged to pump out the seawater into the primary guide pipe and the first secondary guide pipe and a secondary pump arranged in the second secondary guide pipe and arranged to pump out the seawater with power smaller than that by the primary pump. The secondary pump may be arranged to pump out the seawater into the condenser through the second secondary guide pipe under stoppage of the primary pump.

[0026] In accordance with the arrangement above, since the primary pump is mounted in the primary guide pipe between the first branch portion and the second branch portion upstream the first branch portion in the direction of flow of the seawater in the primary guide pipe, that is, arranged upstream the first branch portion. It is therefore possible for the primary pump to supply the seawater through the primary guide pipe into the scrubber and through the first secondary guide pipe, which is branched from the primary guide pipe at the first branch portion, into the condenser. This results in that the primary pump can cause the scrubber to remove sulfur oxides from the exhaust gas and, at the same time, cause the condenser to cool the working medium.

[0027] Since the secondary pump is arranged in the second secondary guide pipe branched from the primary guide pipe at the second branch portion, it is possible to suck up seawater through the second secondary guide pipe and the primary guide pipe. When the primary pump is stopped, the secondary pump pumps out the seawater through the second secondary guide pipe into the condenser, and it is therefore possible to cause the condenser to cool the working medium when sulfur oxides are not removed. Accordingly, the working medium can be cooled independently of the operation and stoppage of the scrubber.

[0028] When the scrubber is not used, since the secondary pump with power smaller than that of the primary pump pumps out the seawater to be used for cooling the working medium, the thermal energy recovery device cannot consume excessive electrical power. It is therefore possible to operate the thermal energy recovery device at low cost.

[0029] Since the primary pump and the secondary pump are used concurrently for cooling the working medium, the frequency of operation of the secondary pump is reduced. This results in a reduced risk of wear and/or breakage of the secondary pump. Accordingly, the operator is not required to inspect and/or repair the secondary pump at excessively high frequency. That is, the running cost of the secondary pump is reduced.

[0030] In relation to the arrangement above, the evaporator may be mounted to the exhaust gas pipe such that the length of a piping path from a turbocharger arranged to pump supercharged air into the internal combustion engine utilizing the flow of the exhaust gas to the evaporator is smaller than the length of a piping path from the evaporator to the scrubber.

[0031] In accordance with the arrangement above, the evaporator is mounted to the exhaust gas pipe such that the length of the piping path from the turbocharger arranged to pump supercharged air into the internal combustion engine utilizing the flow of the exhaust gas to the evaporator is smaller than the length of the piping path from the evaporator to the scrubber, whereby heat exchange between the exhaust gas and the working medium is performed within the evaporator before the natural heat dissipation from the exhaust gas increases. It is therefore possible for the working medium to recover thermal energy from the exhaust gas efficiently. The exhaust gas flows into the evaporator at high temperature, resulting in a reduced risk of the temperature of the exhaust gas falling below the acid dew point within the evaporator. Accordingly, corrosive substances that may corrode the evaporator are less likely to be precipitated within the evaporator, whereby the evaporator can be utilized over a long period of time without being corroded.

[0032] A method for installation of a thermal energy recovery device according to another aspect of the present invention is used to install a thermal energy recovery device arranged to recover thermal energy from exhaust gas discharged from an internal combustion engine of a marine vessel having multiple separate floors into an engine room or a funnel unit of the marine vessel. The installation method includes connecting an evaporator of the thermal energy recovery device to an exhaust gas pipe that is provided in an extending manner to guide the exhaust gas within a first floor, which is provided as one of the multiple floors, and a circulation flow path in which working medium circulates, arranging an expander of the thermal energy recovery device downstream the evaporator in the circulation flow path, arranging a condenser arranged to cause the working medium to exchange heat with cooling water to cool the working medium at a second floor, which is provided as a floor lower than the first floor, and connecting a cooling pump unit arranged to pump up cooling water into the condenser to the condenser.

[0033] In accordance with the above-described techniques, the space within the engine room can be utilized effectively, and the condenser, the evaporator, and the expander can be arranged without excessive density.

BRIEF DESCRIPTION OF THE DRAWINGS

[0034]

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

FIG. 2 shows a schematic layout of the thermal energy recovery device shown in FIG. 1.

FIG. 3A is a schematic side view of a support body used as a structure for holding a condenser of the thermal energy recovery device shown in FIG. 1 below an expander.

FIG. 3B is a schematic side view of the support body used as a structure for holding the condenser of the thermal energy recovery device shown in FIG. 1 below the expander.

FIG. 4A is a schematic view of a pumping facility that can be utilized as a cooling pump unit of the thermal energy recovery device shown in FIG. 1.

FIG. 4B is a schematic view of the pumping facility that can be utilized as the cooling pump unit of the thermal energy recovery device shown in FIG. 1.

FIG. 5 is a schematic block diagram showing the circulation of working medium within the thermal energy recovery device shown in FIG. 1.

FIG. 6 is a schematic view of a thermal energy recovery device according to a second embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

<First Embodiment>

[0035] FIG. 1 is a schematic view of a thermal energy recovery device 100 according to a first embodiment. The thermal energy recovery device 100 is carried on a marine vessel. With reference to FIG. 1, the marine vessel and the thermal energy recovery device 100 will be described generally.

[0036] The marine vessel includes a hull (not shown) and thermal energy recovery device 100. In addition to the thermal energy recovery device 100, FIG. 1 shows an internal combustion engine ENG, a turbocharger TBC, a funnel CMN, and a scrubber SCB as part of the marine vessel. The internal combustion engine ENG is arranged to combust supplied fuel and utilize explosive power generated within the internal combustion engine ENG to rotate a crankshaft (not shown). The rotation of the crankshaft is used as power for the marine vessel. Exhaust gas generated as a result of combustion within the internal combustion engine ENG is guided from the internal combustion engine ENG through the turbocharger TBC and the scrubber SCB to the funnel CMN. The exhaust gas undergoes processing of SOx (sulfur oxides) removal (in which seawater is sprayed into the exhaust gas to separate and remove SOx from the exhaust gas) through the scrubber SCB and then discharged outside the marine vessel through the funnel CMN. The turbocharger TBC, which is arranged upstream the scrubber SCB in the direction of flow of the exhaust gas, is arranged on a discharge path (see the dotted line in FIG. 1) of the exhaust gas from the internal combustion engine ENG toward the funnel CMN to receive torque from the flow of the exhaust gas. The thermal energy recovery device 100 is arranged to recover thermal energy from the exhaust gas after passing through the turbocharger TBC before undergoing the processing of SOx removal through the scrubber SCB. The thermal energy recovery device 100 is arranged to convert the recovered thermal energy into mechanical power.

[0037] The thermal energy recovery device 100 is formed with a working medium circulation flow path. Various types of organic medium for use in common binary thermal energy recovery systems are used suitably as the working medium.

[0038] The thermal energy recovery device 100 includes an evaporator 110, an expander 120, a condenser 130, a circulation pump 140, and a cooling pump unit 150 that are arranged on the working medium circulation flow path. The evaporator 110, the expander 120, the condenser 130, and the circulation pump 140 form a Rankine cycle. The cooling pump unit 150 is arranged to supply seawater into the condenser 130 to cool working medium within the condenser 130.

[0039] The evaporator 110 is arranged to cause heat exchange between working medium and exhaust gas. The evaporator 110 is connected to the working medium circulation flow path with circulation made by the circulation pump 140 and an exhaust gas discharge path from the turbocharger TBC toward the scrubber SCB. The evaporator 110 is arranged on the exhaust gas discharge path such that the length of the piping path between the evaporator 110 and the turbocharger TBC is smaller than the length of the piping path between the evaporator 110 and the scrubber SCB.

[0040] The expander 120 is arranged to convert the expansive energy of working medium after heat exchange within the evaporator 110 into mechanical power. The expander 120 may be a screw-type expander having a pair of screw rotors (not shown) to be rotated by the expansive energy of gasified working medium. In this case, the expander 120 has a casing (not shown) forming a rotor chamber (not shown) in which a pair of mutually engaged screw rotors are accommodated.

[0041] A power recovery device PRA such as a generator or a compressor is connected to the expander 120. The power recovery device PRA may be a generator that generates electrical power utilizing the rotation of one of the pair of screw rotors or may be a compressor that compresses gas to be used within the marine vessel utilizing the rotation of one of the pair of screw rotors.

[0042] The condenser 130 is arranged to cool working medium through heat exchange between seawater supplied through the cooling pump unit 150 and the working medium after passing through the expander 120. As a result, the working medium is condensed.

<Operation of the Thermal Energy Recovery Device>

[0043] Liquid working medium is delivered to the evaporator 110 by the circulation pump 140. The working medium, which has been cooled in the condenser 130 before supply to the evaporator 110, has a temperature, when supplied to the evaporator 110, much lower than that of the exhaust gas. The thermal energy of the exhaust gas can thus be transferred efficiently to the working medium. The working medium thus receives thermal energy from the exhaust gas to be gasified. The gasified working medium is then delivered to the expander 120.

[0044] When the gasified working medium flows into the rotor chamber of the expander 120, the expansive energy of the working medium rotates the pair of screw rotors. This results in that the thermal energy transferred from the exhaust gas to the working medium is partially converted into mechanical power as the rotation of the pair of screw rotors.

[0045] The working medium flowing into the expander 120 expands within the expander 120 to result in a reduction in the pressure and temperature. The working medium thus reduced in the pressure and temperature is then supplied to the condenser 130.

[0046] The working medium has a low temperature as a result of expansion within the expander 120, though higher than that of the seawater. The working medium delivered from the expander 120 to the condenser 130 exchanges heat with the seawater delivered to the condenser 130 by the cooling pump unit 150. As a result, the thermal energy of the working medium is transferred to the seawater within the condenser 130. That is, the seawater is used as cooling medium for cooling the working medium within the condenser 130. The working medium is thus cooled and condensed by the seawater to be liquefied. The liquefied working medium is delivered to the evaporator 110 by the circulation pump 140 as described above.

[0047] The thermal energy recovery device 100 thus includes various devices. A technique for arranging the devices making up the thermal energy recovery device 100 to effectively utilize the space within the engine room of the marine vessel will hereinafter be described.

[0048] FIG. 2 shows a schematic layout of the thermal energy recovery device 100 within the marine vessel. With reference to FIGS. 1 and 2, a technique for requiring the cooling pump unit 150 to have only a reduced pump-up height will be described.

[0049] FIG. 2 shows that the engine room of the marine vessel in which the thermal energy recovery device 100 is arranged is divided into multiple floors. FIG. 2 shows a first floor and a second floor lower than the first floor as the multiple floors of the engine room. The first floor is the uppermost floor among the multiple floors of the engine room at a position higher than the sea level. The second floor is immediately below the first floor.

[0050] At the first floor, an exhaust gas pipe EXP is arranged provided in an extending manner to guide exhaust gas from the turbocharger TBC toward the funnel CMN and forming a portion of the exhaust gas discharge path described with reference to FIG. 1. The exhaust gas pipe EXP is connected with the evaporator 110. Accordingly, like the exhaust gas pipe EXP, the evaporator 110 is also arranged at the first floor.

[0051] FIG. 2 shows a gas inflow unit 111 and a gas outflow unit 112 lower than the gas inflow unit 111 as two connection sites at which the evaporator 110 is connected to the exhaust gas pipe EXP. The gas inflow unit 111 and the gas outflow unit 112 are portions of the evaporator 110. The gas inflow unit 111 forms a gas inflow port through which exhaust gas flows in, while the gas outflow unit 112 forms a gas outflow port through which exhaust gas flows out. The exhaust gas flowing through the gas inflow unit 111 into the evaporator 110 flows downward. The exhaust gas is then discharged from the evaporator 110 through the gas outflow unit 112. Downward flow of the exhaust gas is thus formed within the evaporator 110.

[0052] As described above, the evaporator 110 is connected not only to the exhaust gas pipe EXP, but also to the working medium circulation flow path. FIG. 2 shows a medium inflow unit 113 and a medium outflow unit 114 above the medium inflow unit 113 as two connection sites at which the evaporator 110 is connected to the working medium circulation flow path. The medium inflow unit 113 and the medium outflow unit 114 are portions of the evaporator 110. The medium inflow unit 113 forms an inflow port (not shown) through which liquid working medium flows in, while the medium outflow unit 114 forms a medium outflow port through which gasified working medium after heat exchange with exhaust gas flows out. The liquid working medium flowing through the medium inflow unit 113 into the evaporator 110 flows upward. The working medium then exchanges heat with exhaust gas to be gasified. The gasified working medium is then discharged from the evaporator 110 through the medium outflow unit 114. Upward flow of the working medium, opposite to the downward flow of the exhaust gas, is thus formed within the evaporator 110. The working medium flowing out of the evaporator 110 flows from the medium outflow unit 114 along the circulation flow path curved downward to be guided into the second floor.

[0053] The expander 120, the condenser 130, the circulation pump 140, and the cooling pump unit 150 are arranged at the second floor. The circulation flow path through which working medium sequentially passes the evaporator 110, the expander 120, and the condenser 130 under operation of the circulation pump 140 is formed across the first floor and the second floor.

[0054] As described above, the second floor is at a position lower than that of the first floor, which is positioned higher than the sea level. Since the condenser 130 is arranged at the second floor, the cooling pump unit 150, which is arranged to pump out seawater into the condenser 130 as cooling medium, is not required to pump up the seawater to the first floor, which is significantly away upward from the sea level, but only required to pump up the seawater to the second floor, which is closer to the sea level than the first floor. The cooling pump unit 150 is therefore not required to have an excessive pump-up height.

[0055] The condenser 130 is arranged below the expander 120 within the second floor. This also contributes to the reduction in the pump-up height the cooling pump unit 150 is required to have. The expander 120 and a structure for holding the condenser 130 below the expander 120 will hereinafter be described.

<Layout within the Second Floor>

[0056] FIGS. 3A and 3B are schematic side views of a support body 160 used as a structure for holding the condenser 130 below the expander 120. With reference to FIGS. 2 to 3B, the support body 160 will be described.

[0057] The support body 160 is used as a portion of the thermal energy recovery device 100 to support the condenser 130 and the expander 120 thereon. The support body 160 includes a first placement unit 161 on which the expander 120 is placed and a second placement unit 162 on which the condenser 130 is placed (see FIG. 3B). Both the first placement unit 161 and the second placement unit 162 are approximately rectangular plate members. The second placement unit 162 is arranged to be drawn out approximately horizontally below the first placement unit 161.

[0058] The support body 160 includes a pair of lower frames 163 formed to guide the horizontal drawing of the second placement unit 162. In FIGS. 3A and 3B, one of the pair of lower frames 163 is shown. The other of the pair of lower frames 163 is behind the lower frame 163 shown in FIGS. 3A and 3B. The second placement unit 162 is arranged between the pair of lower frames 163. The second placement unit 162 is supported by the pair of lower frames 163. The pair of lower frames 163 are each assembled with a rail (not shown) or another structure through which the second placement unit 162 can be drawn out smoothly in the horizontal direction as a guide unit for guiding the second placement unit 162.

[0059] The support body 160 further includes four lower support pillars 164 provided in a manner extending upward, respectively, from end portions of the pair of lower frames 163. The pair of lower frames 163 are used to support the second placement unit 162, while the four lower support pillars 164 are used to support the first placement unit 161. That is, the four lower support pillars 164 and the pair of lower frames 163 form a support unit that supports the first placement unit 161 and the second placement unit 162 thereon.

[0060] In FIGS. 3A and 3B, two of the four lower support pillars 164 are shown. The two remaining lower support pillars 164 are behind the two lower support pillars 164 shown in FIGS. 3A and 3B. The lower ends of the four lower support pillars 164 are connected, respectively, to the end portions of the pair of lower frames 163, while the upper ends of the four lower support pillars 164 are connected, respectively, to the four corners of the lower surface of the first placement unit 161. The condenser 130 and the second placement unit 162 shown in FIG. 3A are arranged within the space surrounded by the pair of lower frames 163, the four lower support pillars 164, and the first placement unit 161. The condenser 130 and the second placement unit 162 shown in FIG. 3B are horizontally drawn out from the space surrounded by the pair of lower frames 163, the four lower support pillars 164, and the first placement unit 161.

[0061] The support body 160 further includes four upper support pillars 165 provided in a manner extending upward from the four corners of the upper surface of the first placement unit 161 and an approximately rectangular top plate 166 connected to the upper ends of the four upper support pillars 165. In FIGS. 3A and 3B, two of the four upper support pillars 165 are shown. The two remaining upper support pillars 165 are behind the two upper support pillars 165 shown in FIGS. 3A and 3B. The expander 120 is fixed within the space surrounded by the first placement unit 161, the four upper support pillars, and the top plate 166.

[0062] Since the condenser 130 is supported by the support body 160 below the expander 120, the cooling pump unit 150 is only required to have a reduced pump-up height. Pumping facilities achieving increased pump-up height are generally expensive. On the other hand, as a result of the above-described layout, the cooling pump unit 150 is not required to have an excessive pump-up height and therefore may not employ an expensive pumping facility.

[0063] It may be contemplated, for the purpose of cost reduction of the cooling pump unit 150, that a pumping facility used to supply seawater to other facilities carried on the marine vessel is shared with the cooling pump unit 150. In FIG. 2, the scrubber SCB is shown as one of the other facilities that utilize seawater. As described above, the scrubber SCB is arranged to spray seawater into the exhaust gas flowing through the exhaust gas pipe EXP downstream the evaporator 110 to remove SOx (sulfur oxides) from the exhaust gas. A technique in which the pumping facility for suppling seawater into the scrubber SCB is also utilized for suppling seawater into the condenser 130 will hereinafter be described.

<Supply of Seawater into the Condenser>

[0064] FIG. 4A is a schematic view of a pumping facility 250 that can be utilized as the cooling pump unit 150. With reference to FIG. 4A, the pumping facility 250 will be described.

[0065] The pumping facility 250 includes a primary pump 251, a secondary pump 252, and a control unit 253. While the primary pump 251 is mainly used to supply seawater into the scrubber SCB, part of the seawater discharged from the primary pump 251 is also supplied into the condenser 130. The secondary pump 252 is used to supply seawater into the condenser 130 in substitution for the primary pump 251. The control unit 253 is arranged to control the primary pump 251 and the secondary pump 252.

[0066] The primary pump 251 is mounted in a primary guide pipe 170 that guides seawater to be supplied into the scrubber SCB. The primary guide pipe 170 is formed with two branch points. One of the two branch points is a first branch portion BF1 formed downstream the primary pump 251 (in the direction of seawater flow) . The other of the two branch points is a second branch portion BF2 formed upstream the primary pump 251 (in the direction of seawater flow). The primary pump 251 is mounted in the primary guide pipe 170 between the first branch portion BF1 and the second branch portion BF2.

[0067] A first secondary guide pipe 171 is branched from the primary guide pipe 170 at the first branch portion BF1 to be provided in a manner extending to the condenser 130. Part of the seawater discharged from the primary pump 251 through the primary guide pipe 170 is supplied into the scrubber SCB, while the remaining of the seawater discharged from the primary pump 251 is supplied into the condenser 130 through the first secondary guide pipe 171.

[0068] A second secondary guide pipe 172 branched from the primary guide pipe 170 at the second branch portion BF2 is used as a portion of the thermal energy recovery device 100 together with the primary guide pipe 170 and the first secondary guide pipe 171. The second secondary guide pipe 172 is provided in a manner extending from the second branch portion BF2 to the condenser 130. The secondary pump 252 is mounted in the second secondary guide pipe 172. The secondary pump 252 is positioned downstream the second branch portion BF2 in the direction of seawater flow. The secondary pump 252 is arranged to be operated by receiving a control signal from the control unit 253 while the primary pump 251 is stopped under control of the control unit 253. Upon this, the seawater discharged from the secondary pump 252 is supplied through the second secondary guide pipe 172 into the condenser 130.

[0069] Unlike the primary pump 251, which is required to supply a great mount of seawater into the scrubber SCB, the secondary pump 252 is utilized exclusively to supply seawater into the condenser 130. Accordingly, the secondary pump 252 may provide power much smaller than that by the primary pump 251.

[0070] The secondary pump 252 is mounted in the second secondary guide pipe 172, which is completely independent of the first secondary guide pipe 171. The secondary pump 252 may, however, be mounted in a group of branch pipes branched from the primary guide pipe at two branch points and merging upstream the condenser 130 (in the direction of seawater flow) .

[0071] FIG. 4B is a schematic view of the pumping facility 250 with the secondary pump 252 mounted in a group of branch pipes branched from the primary guide pipe at two branch points and merging upstream the condenser 130 (in the direction of seawater flow). With reference to FIGS. 2, 4A, and 4B, the pumping facility 250 with the secondary pump 252 mounted in a group of branch pipes merging upstream the condenser 130 (in the direction of seawater flow) will be described.

[0072] In FIG. 4B, the primary pump 251, the secondary pump 252, the primary guide pipe 170, and the scrubber SCB are shown, as is the case in FIG. 4A. The description of FIG. 4A is incorporated in describing these components.

[0073] In FIG. 4B, a first secondary guide pipe 171A branched at the first branch portion BF1 and a second secondary guide pipe 172A branched at the second branch portion BF2 are further shown. Unlike the first secondary guide pipe 171 and the second secondary guide pipe 172 described with reference to FIG. 4A, the first secondary guide pipe 171A and the second secondary guide pipe 172A merge at a merge point JCT positioned upstream the condenser 130 (in the direction of seawater flow) to form one guide path throughout the section from the merge point JCT to the condenser 130. The secondary pump 252 is mounted in the second secondary guide pipe 172A within the section between the merge point JCT and the second branch portion BF2. A control valve 254 operative under control of the control unit 253A is arranged in the section between the merge point JCT and the first branch portion BF1.

[0074] The control valve 254 is arranged to open and close the first secondary guide pipe 171A in the section between the merge point JCT and the first branch portion BF1 under control of the control unit 253A. When the control unit 253A activates the primary pump 251 and opens the control valve 254, the seawater discharged from the primary pump 251 is supplied to the scrubber SCB and the condenser 130. When the control unit 253A activates the primary pump 251 and closes the control valve 254, the seawater discharged from the primary pump 251 is supplied exclusively to the scrubber SCB. Like the control unit 253 described with reference to FIG. 4A, the control unit 253A can activate the secondary pump 252 to deliver seawater to the condenser 130 during stoppage of the primary pump 251. During this, the control unit 253A closes the control valve 254 to prevent the seawater pumped out of the secondary pump 252 from flowing into the scrubber SCB.

[0075] As described with reference to FIGS. 4A and 4B, the seawater flows into the condenser 130 under operation of the primary pump 251 or the secondary pump 252. Since the condenser 130 has a function of causing the working medium flowing into the condenser 130 to exchange heat with seawater, the thermal energy of the working medium is transferred to the seawater and thereby the working medium is cooled and liquefied. The thermal energy recovery device 100 may have a reserving function of temporarily reserving working medium liquefied through the condenser 130. In this case, the thermal energy recovery device 100 can retain working medium of an amount significantly higher than required for circulation, whereby the circulation pump 140 can circulate the working medium stably without causing cavitation. The thermal energy recovery device 100 with such a reserving function will hereinafter be described.

<Condenser with a Reserving Function>

[0076] FIG. 5 is a schematic block diagram showing the circulation of working medium within the thermal energy recovery device 100. With reference to FIG. 5, the thermal energy recovery device 100 with such a reserving function will be described.

[0077] In FIG. 5, a reservoir unit 180 is shown having a reserving function of temporarily reserving working medium liquefied through the condenser 130. The reservoir unit 180 is arranged below the condenser 130 to form a condensing unit 190 together with the condenser 130. The condenser 130 is arranged between the reservoir unit 180 and the expander 120 to cause the working medium from the expander 120 to exchange heat with seawater. This results in that the working medium is cooled and liquefied. The liquefied working medium flows down into the reservoir unit 180 to be reserved therein. The reservoir unit 180 may be a reservoir tank or another member (e.g. a thick pipe member) designed to be capable of reserving working medium.

[0078] The working medium reserved in the reservoir unit 180 is sucked out by the circulation pump 140 to be supplied to the evaporator 110 arranged at the first floor. The evaporator 110 causes the liquid working medium supplied by the circulation pump 140 to exchange heat with exhaust gas to transfer thermal energy from the exhaust gas to the working medium. This results in that the working medium is heated and gasified. The gasified working medium flows into and drives the expander 120 with expansive energy. Thereafter, the working medium again flows into the condenser 130.

<Second Embodiment>

[0079] The thermal energy recovery device 100 according to the first embodiment is arranged to recover thermal energy from exhaust gas discharged from the internal combustion engine ENG. The thermal energy recovery device may, however, recover thermal energy from supercharged air supplied from the turbocharger TBC to the internal combustion engine ENG or cooling water after cooling the internal combustion engine ENG. In a second embodiment, a thermal energy recovery device will be described arranged to recover thermal energy from supercharged air pumped out from the turbocharger TBC.

[0080] FIG. 6 is a schematic view of a thermal energy recovery device 100A according to a second embodiment. Like the thermal energy recovery device 100 according to the first embodiment, the thermal energy recovery device 100A is carried on a marine vessel. With reference to FIGS. 5 and 6, the marine vessel and the thermal energy recovery device 100A will be described generally.

[0081] The two dashed lines shown in FIG. 6 represent that the engine room of the marine vessel is divided into a first floor, a second floor, and a third floor. The description of the first embodiment is incorporated in describing the first floor and the second floor. The third floor is below the second floor.

[0082] FIG. 6 shows an internal combustion engine ENG, a turbocharger TBC, a gas cooler ICL, a scrubber SCB, and a funnel CMN as part of the marine vessel. The internal combustion engine ENG, the turbocharger TBC, and the gas cooler ICL are arranged at the third floor, while the scrubber SCB and the funnel CMN are arranged at the first floor, as is the case in the first embodiment. The description of the first embodiment is incorporated in describing the scrubber SCB and the funnel CMN.

[0083] As for the internal combustion engine ENG, the turbocharger TBC, and the gas cooler ICL, since the internal combustion engine ENG is one of the heaviest components in the marine vessel, thus arranging the internal combustion engine ENG at the third floor, which forms the lowest portion among the multiple floors of the engine room, allows the marine vessel's center of gravity to be positioned within a lower portion of the marine vessel. This contributes to stable navigation of the marine vessel. Exhaust gas discharged from the internal combustion engine ENG is directed to and rotates the turbocharger TBC, as is the case in the first embodiment. The turbocharger TBC sucks in outside air while rotating. The sucked outside air is compressed through the turbocharger TBC to flow into the gas cooler ICL as supercharged air. The supercharged air, which has been heated due to compressed through the turbocharger TBC, is cooled in the gas cooler ICL. The supercharged air then flows into the internal combustion engine ENG.

[0084] The exhaust gas passing through the turbocharger TBC also passes through the second floor to reach the first floor. The scrubber SCB within the first floor sprays seawater into the exhaust gas to remove sulfur oxides from the exhaust gas. The exhaust gas is then discharged through the funnel CMN.

[0085] The thermal energy of the exhaust gas flowing within the first floor is recovered by the thermal energy recovery device 100A in a similar way as in the first embodiment. In addition, the thermal energy recovery device 100A also recovers thermal energy from supercharged air pumped out of the turbocharger TBC within the third floor.

[0086] The thermal energy recovery device 100A includes an evaporator 110, an expander 120, a condenser 130, and a cooling pump unit 150, as is the case in the first embodiment. The description of the first embodiment is incorporated in describing these components.

[0087] The thermal energy recovery device 100A further includes a circulation pump 140A, a reservoir unit 180A, and a heat exchanger 210 arranged to heat working medium through heat exchange between supercharged air pumped out of the turbocharger TBC and the working medium. The reservoir unit 180A is used to temporarily reserve working medium cooled and liquefied through the condenser 130, as is the case in the first embodiment. The circulation pump 140A is used to circulate working medium within the thermal energy recovery device 100A.

[0088] Unlike the reservoir unit 180 described with reference to FIG. 5, the reservoir unit 180A is arranged at the third floor. The working medium liquefied through the condenser 130 within the second floor flows down to the third floor to be reserved temporarily within the reservoir unit 180A.

[0089] Like the reservoir unit 180A, the circulation pump 140A is also arranged at the third floor. The circulation pump 140A is arranged to suck out working medium reserved in the reservoir unit 180A and pump out into the heat exchanger 210.

[0090] The heat exchanger 210 is arranged between the turbocharger TBC and the gas cooler ICL. Within the heat exchanger 210, supercharged air flows downward from the turbocharger TBC toward the gas cooler ICL, while working medium pumped out of the circulation pump 140 flows upward. After exchanging heat with the supercharged air, the working medium flows through the second floor into the evaporator 110 arranged at the first floor. As described above, the working medium further exchanges heat with exhaust gas in the evaporator 110.

[0091] The heat exchanger 210 may serve as a preheater arranged to heat working medium passing through the heat exchanger 210 without evaporation. Alternatively, the heat exchanger 210 may serve as an evaporator arranged to evaporate part of working medium passing through the heat exchanger 210. Further alternatively, the heat exchanger 210 may be arranged to wholly evaporate working medium passing through the heat exchanger 210. In this case, the evaporator 110 downstream the heat exchanger 210 serves as a superheater.

<Advantageous Effects of the Thermal Energy Recovery Device>

[0092] In general, a discharge path through which exhaust gas discharged from an internal combustion engine is guided toward a funnel is formed at the uppermost floor within an engine room of a marine vessel. In accordance with the above-described embodiments, the evaporator 110 is arranged at the first floor (i.e. the uppermost floor), which is highest within the engine room of the marine vessel and therefore can be arranged on the exhaust gas discharge path without a major modification to the design of an exhaust gas discharge path of a common marine vessel. In addition, since the evaporator 110 is mounted to the exhaust gas pipe EXP arranged at the first floor such that the piping path from the evaporator 110 to the turbocharger TBC is shorter than the piping path from the evaporator 110 to the scrubber SCB, the evaporator 110 can cause the working medium to exchange heat with the exhaust gas before the natural heat dissipation from the exhaust gas increases excessively. Additionally, this reduces the risk of the temperature of the exhaust gas falling below the acid dew point within the evaporator 110. That is, the risk of precipitation of corrosive substances within the evaporator 110 is reduced.

[0093] Unlike the evaporator 110, the condenser 130 is arranged at the second floor, which is lower than the first floor. As a result, the thermal energy recovery device 100, 100A is arranged separately in at least two floors. Unlike the layout of conventional thermal energy recovery devices, relatively available one of the floors for the engine room can be utilized effectively for arrangement of the components of the thermal energy recovery device 100, 100A. In addition, the components of the thermal energy recovery device 100, 100A are arranged without excessive density.

[0094] Since the condenser 130 is arranged at the second floor, which is lower than the first floor at which the evaporator 110 is arranged, the cooling pump unit 150 arranged to pump out seawater as cooling medium for cooling working medium within the condenser 130 into the condenser 130 is not required to have a pump-up height reaching the first floor. That is, the cooling pump unit 150 is only required to be capable of achieving a pump-up height reaching the second floor. While in general, pumping facilities achieving an increased pump-up height are expensive, the cooling pump unit 150 is not required to have an excessively increased pump-up height as described above, so that an inexpensive pumping device may be utilized as the cooling pump unit 150.

[0095] Since the second floor, at which the condenser 130 fed with seawater by the cooing pump unit 150 and the expander 120 to be driven under expansion of working medium are arranged, is immediately below the first floor, at which the evaporator 110 is arranged, the working medium circulation flow path formed to pass through the condenser 130, the evaporator 110, and the expander 120 cannot have an excessive length. Accordingly, the working medium flowing along the circulation flow path also cannot undergo excessive loss. In addition, the working medium cannot be included in the circulation flow path at an excessive amount.

[0096] Since the condenser 130 liquefies working medium gasified through heat exchange with exhaust gas within the evaporator 110, the liquid level of the working medium is formed in the condenser 130 or within the reservoir unit 180 that is arranged below the condenser 130. Since the evaporator 110 is arranged at the first floor, which is higher than the second floor at which the condenser 130 is arranged, the medium inflow port formed by the medium inflow unit 113 of the evaporator 110 is also at a position higher than that of the condenser 130. Since the medium inflow port formed by the medium inflow unit 113 of the evaporator 110 is thus at a position higher than that of the condenser 130, the liquid level of the working medium within the condenser 130 or the reservoir unit 180 is at a position lower than that of the medium inflow port formed by the medium inflow unit 113. The working medium within the reservoir unit 180 can flow over the circulation pump 140 when the circulation pump 140 is stopped. Even in such a case, since the liquid level of the working medium within the condenser 130 or the reservoir unit 180 is at a position lower than that of the medium inflow port formed by the medium inflow unit 113, the working medium cannot reach the evaporator 110. Accordingly, the working medium cannot be evaporated accidentally in the evaporator 110 under stoppage of the circulation pump 140.

[0097] Since the medium outflow unit 114 forms the medium outflow port through which the working medium flows out at a position higher than that of the medium inflow port, the working medium flows upward within the evaporator 110. In addition to the medium outflow unit 114 and the medium inflow unit 113, the evaporator 110 has the gas inflow unit 111 and the gas outflow unit 112. The gas inflow unit 111 is positioned above the gas outflow unit 112. Accordingly, the exhaust gas flows downward within the evaporator 110. That is, the direction of flow of the exhaust gas is opposite to the direction of upward flow of the working medium within the evaporator 110. As a result, exhaust gas near the gas inflow port will exchange heat with working medium near the medium outflow port. Exhaust gas near the gas outflow port will exchange heat with working medium near the medium inflow port.

[0098] As for heat exchange between exhaust gas near the gas inflow port and working medium near the medium outflow port, the working medium near the medium outflow port has already exchanged heat with exhaust gas from the medium inflow port to near the medium outflow port to have an increased temperature, while the exhaust gas near the gas inflow port has undergo less heat exchange with working medium to remain at high temperature. The exhaust gas near the gas inflow port and the working medium near the medium outflow port thus have a sufficiently increased temperature difference therebetween, whereby heat exchange between the working medium and the exhaust gas can be performed highly efficiently.

[0099] As for heat exchange between exhaust gas near the gas outflow port and working medium near the medium inflow port, the exhaust gas near the gas outflow port has already exchanged heat with working medium from the gas inflow port to near the gas outflow port to have a reduced temperature, while the working medium near the medium inflow port has undergo less heat exchange with exhaust gas to remain at low temperature. The exhaust gas near the gas outflow port and the working medium near the medium inflow port thus also have a sufficiently increased temperature difference therebetween, whereby heat exchange between the working medium and the exhaust gas can be performed highly efficiently.

[0100] The working medium after exchanging heat with the exhaust gas flows sequentially into the expander 120 and the condenser 130. A temperature decrease of the working medium due to expansion within the expander 120 could cause the working medium flowing from the expander 120 to the condenser 130 to be divided into two phases: gas phase and liquid phase. In this case, the working medium could be more likely to undergo pressure loss. However, since the expander 120 is arranged at the second floor as with the condenser 130 and thereby the distance between the expander and the condenser cannot be increased excessively, the working medium supplied from the expander 120 to the condenser 130 cannot undergo an excessive pressure loss.

[0101] Both the expander 120 and the condenser 130 are supported by the support body 160 within the second floor. The expander 120 and the condenser 130 are thus installed stably within the second floor. Since the condenser 130 is arranged below the expander 120, the working medium cooled and liquefied under expansion within the expander 120 can flow down smoothly from the expander 120 to the condenser 130.

[0102] The second placement unit 162 supporting the condenser 130 below the expander 120 is drawable in the horizontal direction. The operator can therefore draw out the second placement unit 162 in the horizontal direction to access the condenser 130 easily without being disturbed by the expander 120. As a result, the operator can inspect and repair the condenser 130 efficiently.

[0103] Since the condenser 130 supported by the second placement unit 162 and the expander 120 supported by the first placement unit 161 are arranged vertically, no horizontally and excessively large installation area is not required and the space within the second floor can be utilized effectively.

[0104] As for cooling of the working medium within the condenser 130, since the cooling pump unit 150 has the primary pump 251 arranged to pump seawater through the primary guide pipe 170 to the scrubber SCB, the condenser 130 can receive seawater through the first secondary guide pipe 171, 171A branched from the primary guide pipe 170 at the first branch portion BF1 downstream the primary pump 251 while the primary pump 251 supplies seawater to the scrubber SCB. Since the secondary pump 252 is mounted in the second secondary guide pipe 172, 172A branched from the primary guide pipe 170 at the second branch portion BF2 upstream the primary pump 251, the condenser 130 can receive seawater from the secondary pump 252 even under stoppage of the primary pump 251. Since the primary pump 251 and the secondary pump 252 are used concurrently, the risk of wear and/or breakage of the secondary pump 252 is reduced. Accordingly, the operator is not required to inspect and/or repair the secondary pump 252 at excessively high frequency. As a result, the running cost of the secondary pump 252 is reduced.

[0105] When the primary pump 251 is stopped, the secondary pump 252 pumps out the seawater through the second secondary guide pipe 172, 172A into the condenser 130, and it is therefore possible to cause the condenser 130 to cool the working medium even when SOx is not removed. Accordingly, the working medium can be cooled independently of the operation and stoppage of the scrubber SCB.

[0106] When the scrubber SCB is not used, since the secondary pump 252 with power smaller than that of the primary pump 251 pumps out the seawater to be used for cooling the working medium, the thermal energy recovery device 100, 100A cannot consume excessive electrical power. It is therefore possible to operate the thermal energy recovery device 100, 100A at low cost.

[0107] Since the scrubber SCB is arranged at the first floor, the primary pump 251 is designed to achieve an increased pump-up height. On the other hand, the secondary pump 252, which is used exclusively for seawater supply to the condenser 130, is not required to have a pump-up height increased as high as the primary pump 251. The secondary pump 252 may therefore employ an inexpensive pumping device.

[0108] As for the above-described embodiments, a screw-type expander is used as the expander 120. However, the expander 120 may employ a centrifugal expander or a scroll-type expander.

[0109] As for the above-described embodiments, the expander 120 is arranged at the second floor. However, the expander 120 may be arranged at the first floor.

[0110] As for the above-described embodiments, the first floor is the uppermost floor within the engine room of the marine vessel. However, the first floor may be determined so as to fit the exhaust gas discharge path defined by the design of the marine vessel. Accordingly, the first floor may be a floor other than the uppermost floor.

[0111] As for the above-described embodiments, the second floor is immediately below the first floor. However, the second floor may be another floor lower than the first floor. If the floor immediately below the first floor is narrow, the next floor therebelow may be utilized as the second floor.

[0112] As for the above-described embodiments, the thermal energy recovery device 100, 100A is arranged in the engine room of the marine vessel. However, the thermal energy recovery device may be arranged in the funnel unit of the marine vessel.

[0113] As for the above-described embodiments, seawater is utilized as cooling water for cooling working medium. However, water circulating within the marine vessel may be used as cooling water for cooling working medium.

[0114] As for the above-described embodiments, the expander 120 and the condenser 130 are supported by the support body 160. However, the expander 120 and the condenser 130 may be installed on the floor surface of the second floor.

[0115] As for the above-described embodiments, the condenser 130, 130A has the reservoir unit 180, 180A. However, the condenser may not have the reservoir unit.

[0116] The above-disclosed embodiments should be construed as illustrative only and not restrictive in all aspects. The scope of the present invention is defined not by the description above but by the appended claims and is intended to further include all modifications within the meaning and scope equivalent to the appended claims.

[0117] The techniques according to the above-described embodiments can be utilized preferably in various types of marine vessels.

[0118] The application discloses a thermal energy recovery device with which the space within an engine room of a marine vessel can be utilized effectively and a method for installation of such a device , the device including a condenser arranged to cause working medium circulating in a circulation flow path to exchange heat with seawater, an evaporator connected to an exhaust gas pipe that guides the exhaust gas to a funnel within a first floor that is provided higher than the sea level, and the circulation flow path and arranged to cause the working medium to recover the thermal energy from the exhaust gas, an expander arranged downstream the evaporator and arranged to be driven by the working medium, and a cooling pump unit arranged to pump up the seawater into the condenser. The condenser is arranged at a second floor that is provided lower than the first floor.

Claims

1. A thermal energy recovery device arranged in an engine room or a funnel unit of a marine vessel having a plurality of separate floors and arranged to recover thermal energy from exhaust gas discharged from an internal combustion engine of the marine vessel, the thermal energy recovery device comprising:

    a condenser arranged to cause working medium circulating in a circulation flow path to exchange heat with cooling water to cool the working medium;
    an evaporator connected to an exhaust gas pipe that is provided in an extending manner to guide the exhaust gas within a first floor, which is provided as one of the plurality of floors, and the circulation flow path and arranged to cause the working medium to recover the thermal energy from the exhaust gas through heat exchange between the working medium and the exhaust gas;
    an expander arranged downstream the evaporator in the circulation flow path and arranged to be driven by the working medium; and
    a cooling pump unit arranged to pump up the cooling water into the condenser, wherein
    the condenser is arranged at a second floor, which is provided as a floor lower than the first floor.

2. The thermal energy recovery device according to claim 1, wherein
the second floor is immediately below the first floor.

3. The thermal energy recovery device according to claim 1 or 2, wherein
the first floor is the uppermost floor among the plurality of floors.

4. The thermal energy recovery device according to any one of claims 1 to 3, wherein
the expander is arranged at the second floor, and
the evaporator includes a medium inflow unit forming a medium inflow port through which the working medium flows in.

5. The thermal energy recovery device according to claim 4, wherein the evaporator includes:

    (i) a medium outflow unit forming a medium outflow port through which the working medium flows out at a position higher than that of the medium inflow port;
    (ii) a gas inflow unit forming a gas inflow port through which the exhaust gas flows in; and
    (iii) a gas outflow unit forming a gas outflow port through which the exhaust gas flows out at a position lower than that of the gas inflow port.

6. The thermal energy recovery device according to any one of claims 1 to 5, further comprising a support body that supports the expander and the condenser thereon, wherein
the expander is arranged on the support body at a position higher than that of the condenser.

7. The thermal energy recovery device according to claim 6, wherein the support body includes:

    (i) a first placement unit on which the expander is placed;
    (ii) a second placement unit formed in a manner drawable in a horizontal direction below the first placement unit and on which the condenser is placed; and
    (iii) a support unit that supports the first placement unit and the second placement unit thereon, wherein

    the support unit includes a guide unit arranged to guide the second placement unit drawn out in the horizontal direction.

8. The thermal energy recovery device according to any one of claims 1 to 7, further comprising:

    a primary guide pipe arranged to guide seawater therethrough to be supplied to a scrubber arranged to remove sulfur oxides from the exhaust gas;
    a first secondary guide pipe branched from the primary guide pipe at a predetermined first branch portion and arranged to guide part of the seawater flowing through the primary guide pipe to the condenser as the cooling water; and
    a second secondary guide pipe branched from the primary guide pipe at a second branch portion upstream the first branch portion in the direction of flow of the seawater in the primary guide pipe and arranged to guide part of the seawater flowing through the primary guide pipe to the condenser as the cooling water, wherein
    the cooling pump unit includes a primary pump mounted in the primary guide pipe between the first branch portion and the second branch portion and arranged to pump out the seawater into the primary guide pipe and the first secondary guide pipe and a secondary pump arranged in the second secondary guide pipe and arranged to pump out the seawater with power smaller

than that by the primary pump, and
the secondary pump is arranged to pump out the seawater into the condenser through the second secondary guide pipe under stoppage of the primary pump.

9. The thermal energy recovery device according to claim 8, wherein
the evaporator is mounted to the exhaust gas pipe such that the length of a piping path from a turbocharger arranged to pump supercharged air into the internal combustion engine utilizing the flow of the exhaust gas to the evaporator is smaller than the length of a piping path from the evaporator to the scrubber.

10. A method for installation of a thermal energy recovery device arranged to recover thermal energy from exhaust gas discharged from an internal combustion engine of a marine vessel having a plurality of separate floors into an engine room or a funnel unit of the marine vessel, the method comprising:

connecting an evaporator of the thermal energy recovery device to an exhaust gas pipe that is provided in an extending manner to guide the exhaust gas within a first floor, which is provided as one of the plurality of floors, and a circulation flow path in which working medium circulates;
arranging an expander of the thermal energy recovery device downstream the evaporator in the circulation flow path;
arranging a condenser arranged to cause the working medium to exchange heat with cooling water to cool the working medium at a second floor, which is provided as a floor lower than the first floor; and
connecting a cooling pump unit arranged to pump up cooling water into the condenser to the condenser.

FIG. 1

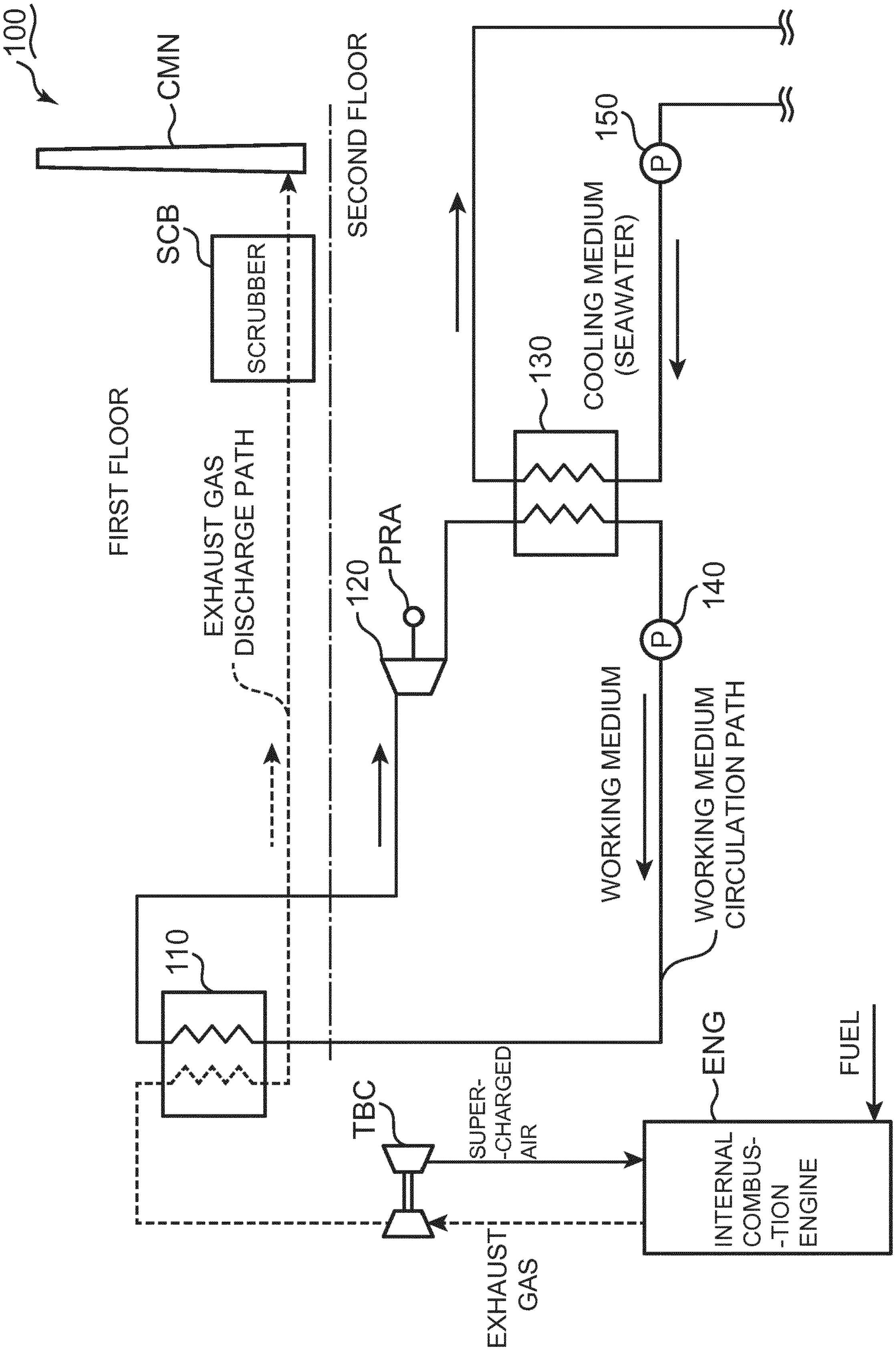

100
CMN
SCB
SCRUBBER
SECOND FLOOR
FIRST FLOOR
EXHAUST GAS DISCHARGE PATH
120
PRA
130
150
P
COOLING MEDIUM (SEAWATER)
140
P
WORKING MEDIUM
WORKING MEDIUM CIRCULATION PATH
110
TBC
SUPER- -CHARGED AIR
EXHAUST GAS
ENG
FUEL
INTERNAL COMBUS- -TION ENGINE

FIG. 2

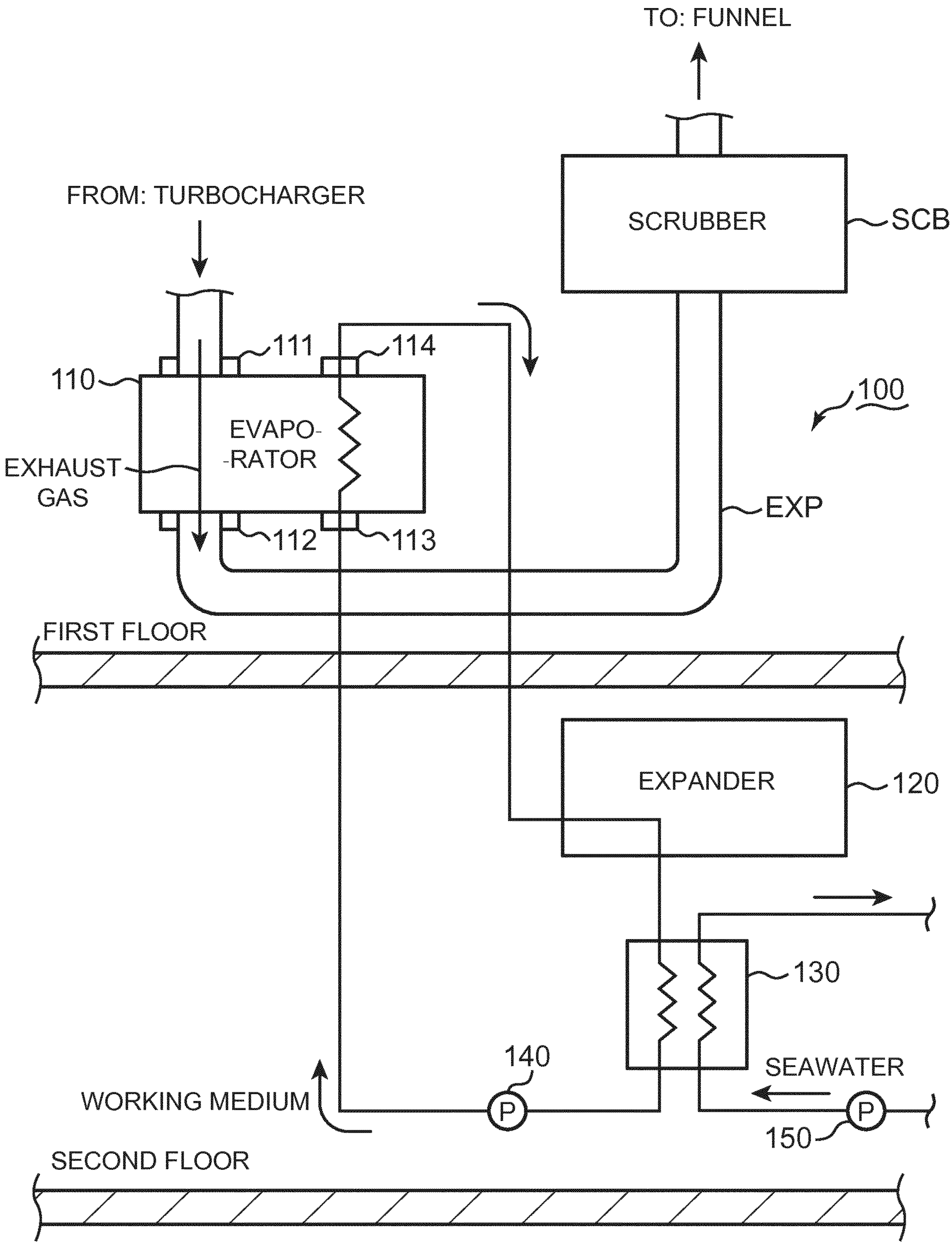

TO: FUNNEL
FROM: TURBOCHARGER
SCRUBBER
SCB
111
114
110
100
EVAPO-
-RATOR
EXHAUST
GAS
EXP
112
113
FIRST FLOOR
EXPANDER
120
130
140
SEAWATER
WORKING MEDIUM
P
P
150
SECOND FLOOR

FIG. 3A

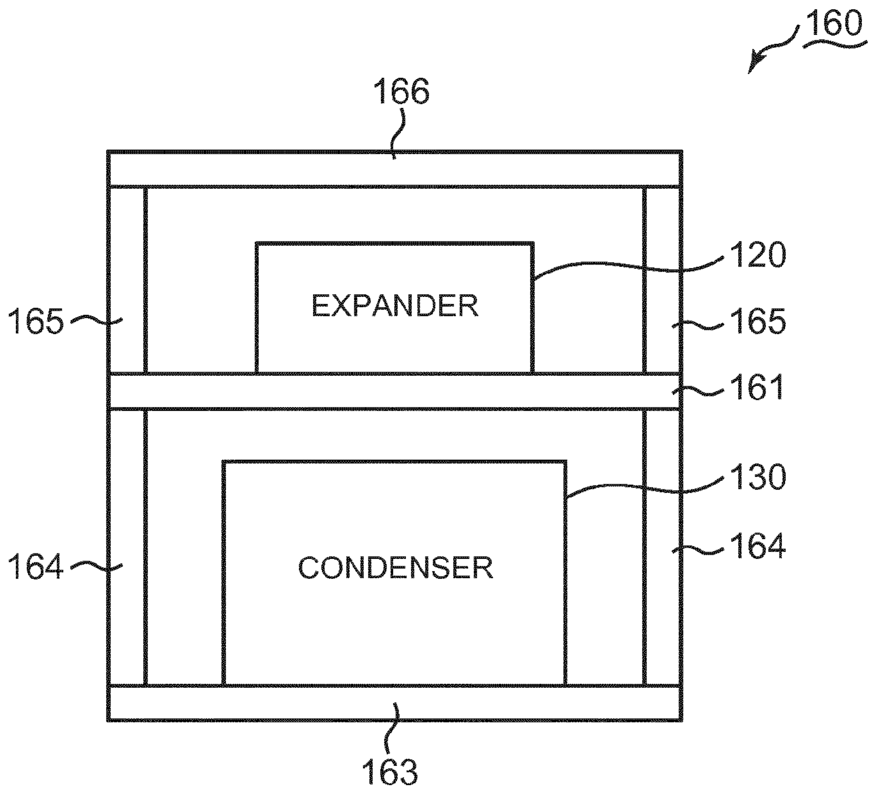
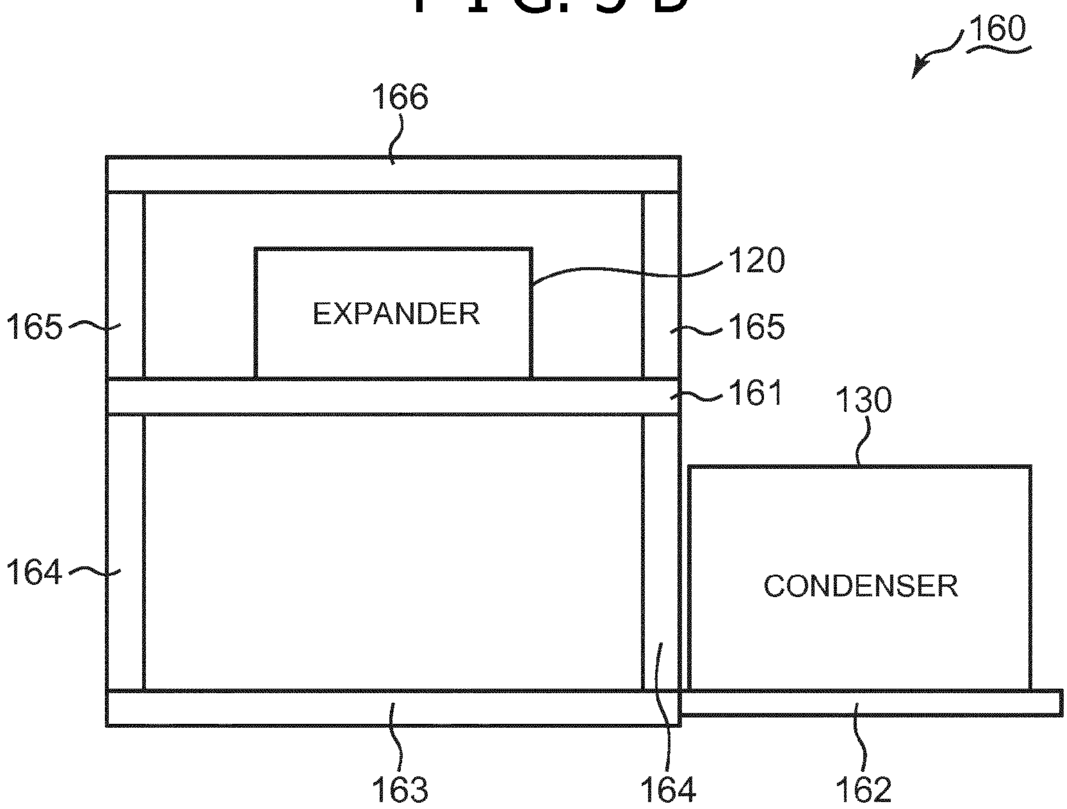

160
166
EXPANDER
120
165
165
161
130
CONDENSER
164
164
163

FIG. 3B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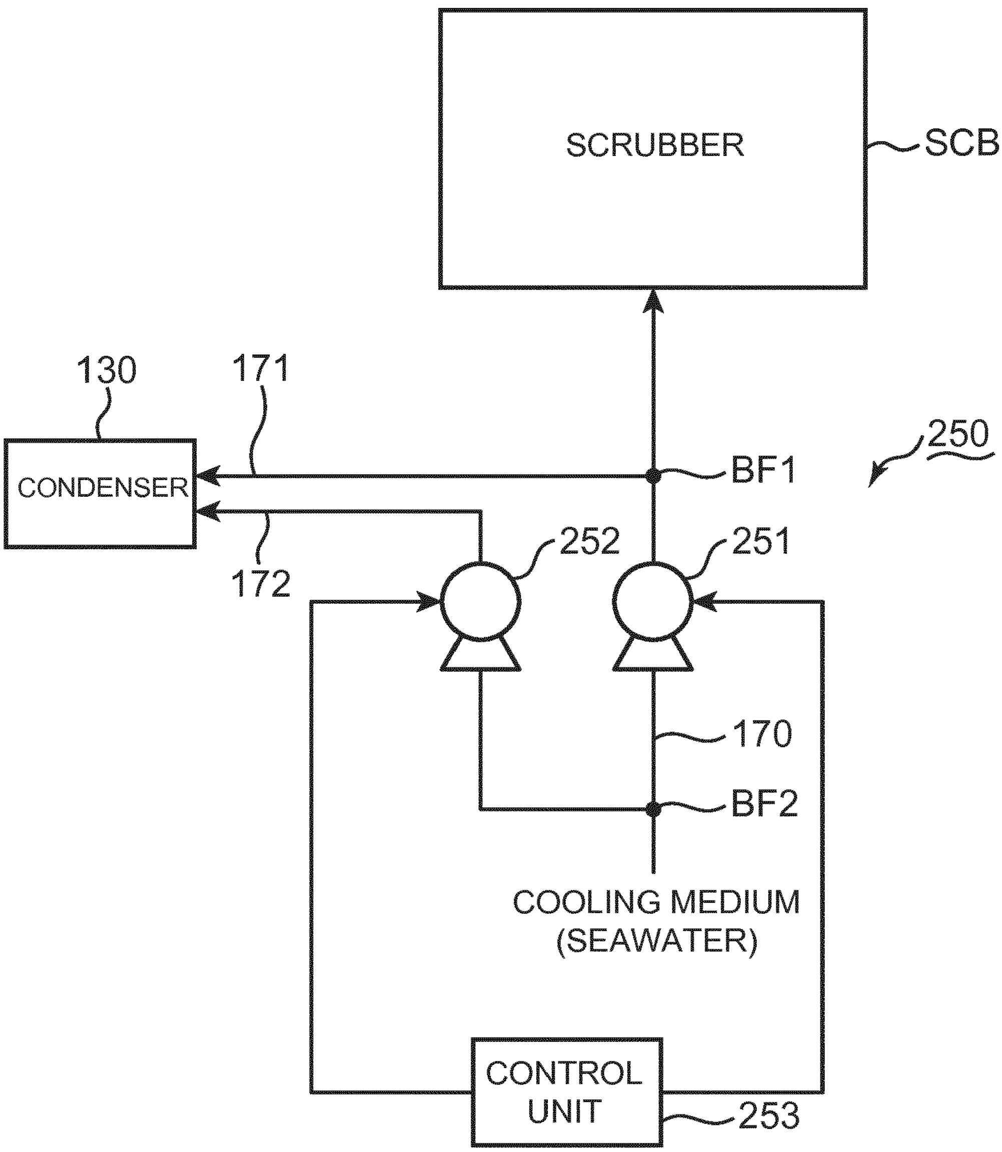
166
EXPANDER
120
165
165
161
130
CONDENSER
164
163
164
162

FIG. 4A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SCB
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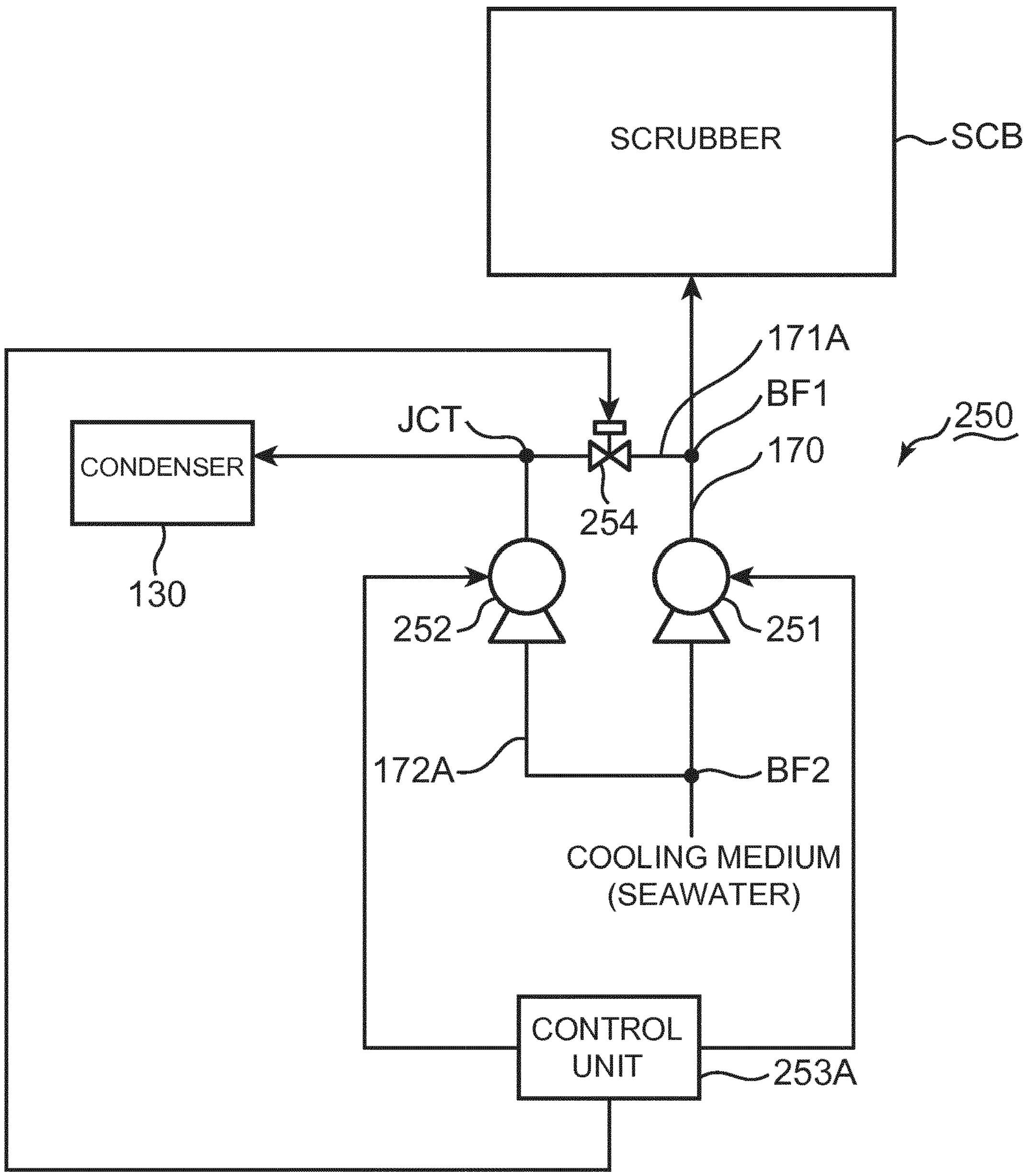
171
CONDENSER
BF1
250
172
252
251
170
BF2
COOLING MEDIUM
(SEAWATER)
CONTROL
UNIT
253

FIG. 4B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SCB
171A
BF1
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JCT
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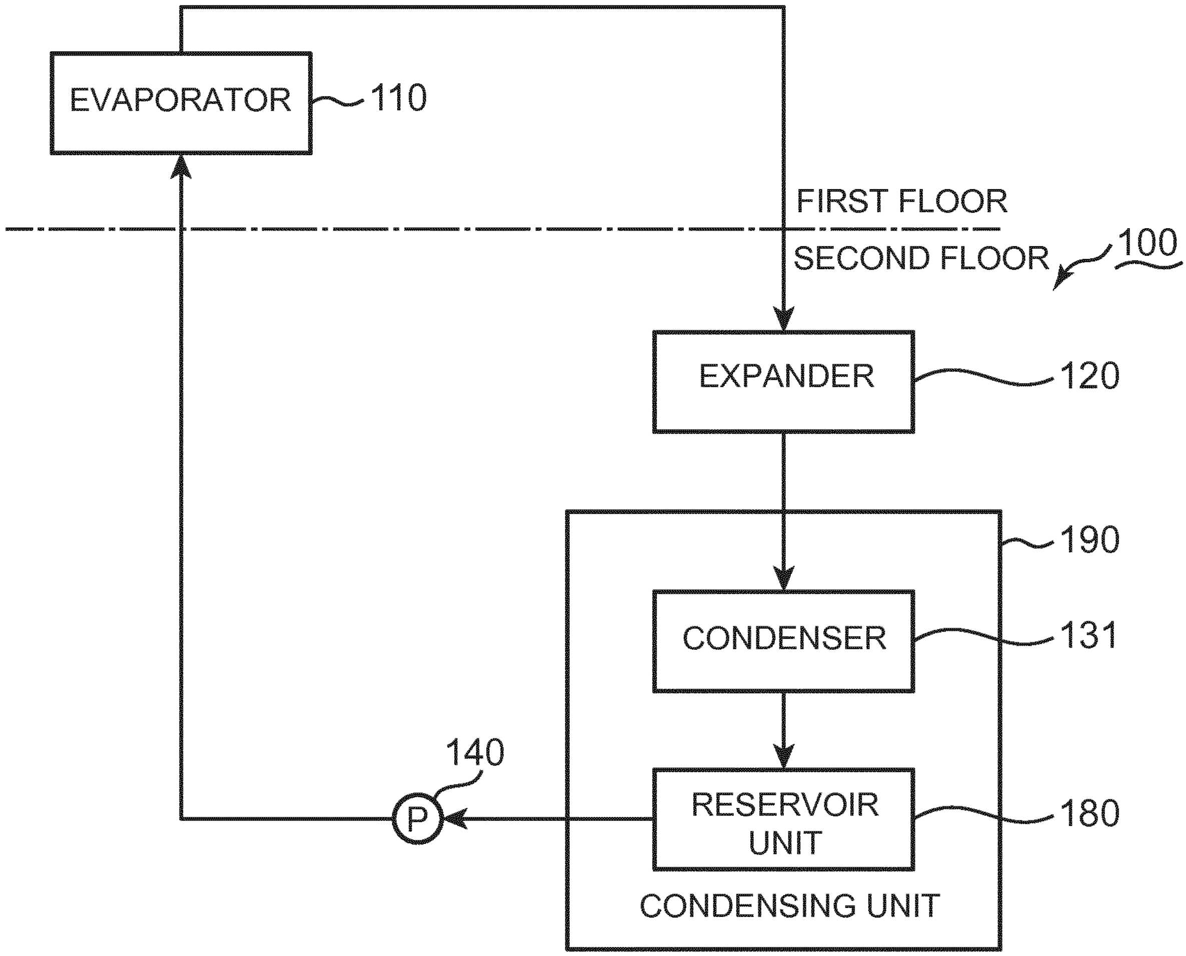
172A
BF2
COOLING MEDIUM
(SEAWATER)
CONTROL
UNIT
253A

FIG. 5


EVAPORATOR
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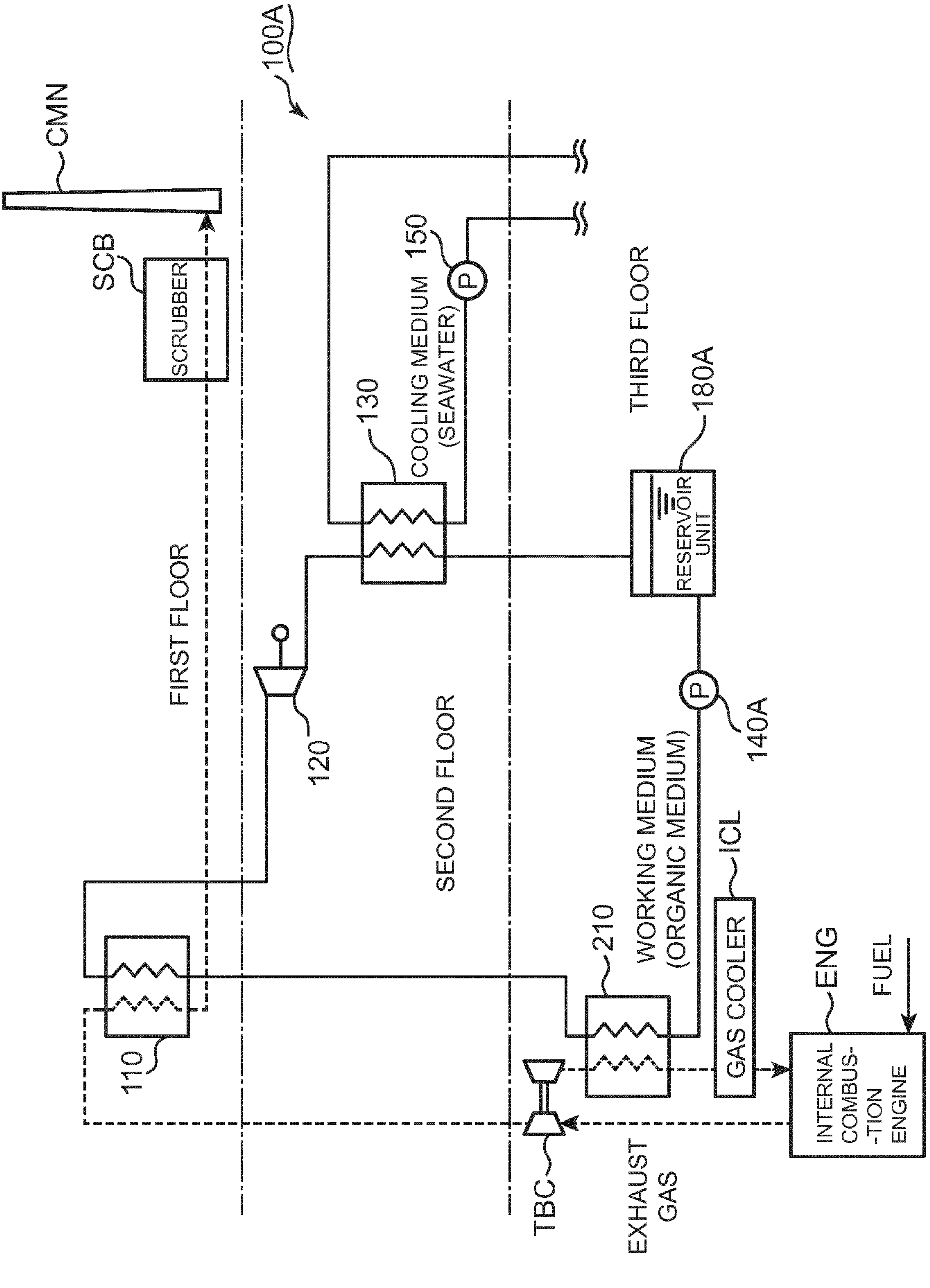
FIRST FLOOR
SECOND FLOOR
100
EXPANDER
120
190
CONDENSER
131
140
P
RESERVOIR UNIT
180
CONDENSING UNIT

FIG. 6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CMN
SCB
SCRUBBER
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130
COOLING MEDIUM
(SEAWATER)
150
P
SECOND FLOOR
THIRD FLOOR
180A
RESERVOIR
UNIT
P
140A
WORKING MEDIUM
(ORGANIC MEDIUM)
110
210
ICL
GAS COOLER
ENG
FUEL
INTERNAL
COMBUS-
-TION
ENGINE
TBC
EXHAUST
GAS

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EUROPEAN SEARCH REPORT

Application Number
EP 19 15 8198

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			F01K

The present search report has been drawn up for all claims

3

Place of search	Date of completion of the search	Examiner
Munich	7 October 2019	Röberg, Andreas

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07-10-2019

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