

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
8 June 2006 (08.06.2006)

PCT

(10) International Publication Number
WO 2006/060252 A1

(51) International Patent Classification:
B63H 21/32 (2006.01)

(21) International Application Number:
PCT/US2005/042437

(22) International Filing Date:
22 November 2005 (22.11.2005)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
11/000,111 30 November 2004 (30.11.2004) US

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

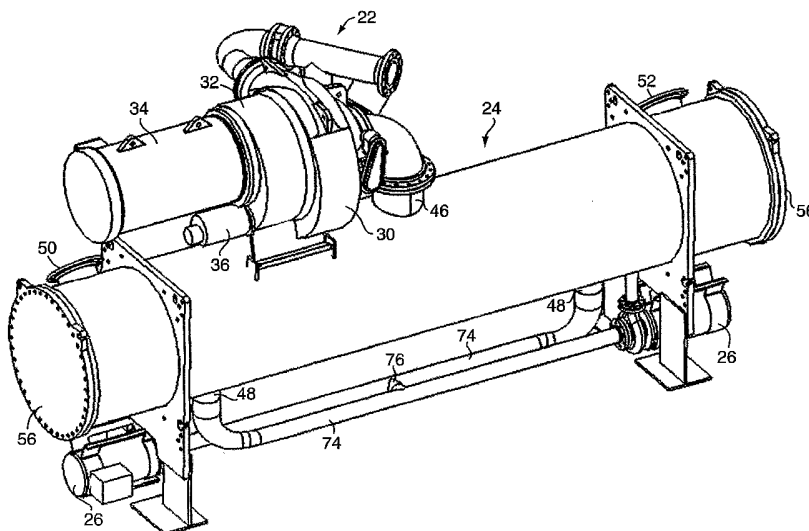
(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— with international search report

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: METHOD AND APPARATUS FOR DECREASING MARINE VESSEL POWER PLANT EXHAUST TEMPERATURE



(57) Abstract: According to the present invention, a method and apparatus for generating power aboard a marine vessel is provided. The method comprises the steps of: (a) providing a Rankine Cycle device that includes at least one of each of an evaporator, a turbo-generator that includes a turbine coupled with an electrical generator, a condenser, and a refrigerant feed pump; (b) disposing the one or more evaporators within an exhaust duct of a power plant of the marine vessel; (c) operating the power plant; and (d) selectively pumping refrigerant through the Rankine Cycle device, wherein refrigerant exiting the evaporator powers the turbine, which in turn powers the generator to produce power.

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METHOD AND APPARATUS FOR DECREASING MARINE VESSEL
POWER PLANT EXHAUST TEMPERATURE

BACKGROUND OF THE INVENTION

1. Technical Field

[0001] The present invention relates to methods and apparatus for infrared suppression in general, and to methods and apparatus for decreasing the exhaust temperature of a marine vessel power plant in particular.

2. Background Information

[0002] Marine power plants produce exhaust products typically in a temperature range of 350-1800 °F. In most applications, the exhaust products are passed through a sizable duct (typically referred to as a “stack”) and released to the environment. Once released to the environment, the thermal energy dissipates. A problem with releasing thermal energy directly to the environment is that the marine vessel emits a substantial, undesirable thermal signal.

[0003] What is needed is a method and apparatus for suppressing the thermal signal of a marine vessel.

SUMMARY OF THE INVENTION

[0004] According to the present invention, a method and apparatus for decreasing the exhaust temperature of a marine vessel power plant is provided. The present method comprises the steps of: 1) providing a Rankine Cycle device that includes at least one of each of an evaporator, a condenser, and a refrigerant feed pump; 2) disposing the evaporator within an exhaust duct of a power plant of the marine vessel; 3) operating the power plant; and 4) selectively pumping refrigerant through the Rankine Cycle device.

[0005] The present method and apparatus can be operated to significantly reduce the temperature of the exhaust products being released to the environment. As a result, the infrared signal of the vessel is significantly decreased.

[0006] The significantly reduced exhaust temperatures also enable the use of an exhaust duct, or stack, with a smaller cross-sectional area. The mass flow of the power plant exhaust is a function of the volumetric flow and density of the exhaust. The significant decrease in exhaust temperature increases the density of the exhaust. As a result, the mass flow is

substantially decreased, and the required size of the marine power plant exhaust duct is substantially less.

[0007] The present invention apparatus and method are operable any time the vessel's power plant is operational. There is no requirement that the vessel be underway, because the present method and apparatus are independent of the vessel's drive system.

[0008] The range of a marine vessel that burns liquid fossil fuel within its power plant is typically dictated by the fuel reserve it can carry. In most modern marine vessels, a portion of the fuel reserve is devoted to running a power plant that generates electrical energy. Hence, both the propulsion needs and the electrical energy needs draw on the fuel reserve. The present method and apparatus decreases the fuel reserve requirements by generating electricity using waste heat generated by the power plant of the vessel rather than fossil fuel. Hence, the vessel is able to carry less fuel and have the same range, or carry the same amount of fuel and have a greater range.

[0009] The present method and apparatus also provide advantages with respect to the stability of the vessel. For example, the present method and apparatus produces electrical energy via waste heat. Conventional marine systems produce electrical energy by consuming liquid fuel. As the fuel is depleted, the buoyancy characteristics of the vessel are changed. The weight of the present apparatus, on the other hand, remains constant and thereby facilitates stability control of the vessel. In addition, the weight of the present apparatus can be advantageously positioned within the vessel to optimize the stability of the vessel.

[0010] The stability of the vessel is also improved by the smaller exhaust duct, which is enabled by the present invention. The smaller exhaust duct decreases the weight of vessel components disposed above the center of gravity of the vessel, thereby increasing the stability of the vessel.

[0011] These and other objects, features and advantages of the present invention will become apparent in light of the detailed description of the best mode embodiment thereof, as illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] FIG. 1 is a diagrammatic perspective view of an embodiment of the present invention ORC device, having a single turbo-generator.

[0013] FIG. 2 is a diagrammatic perspective view of an embodiment of the present

invention ORC device, having a pair of turbo-generators.

[0014] FIG. 3 is a diagrammatic perspective view of an embodiment of the present invention ORC device, having three turbo-generators and a single condenser.

[0015] FIG. 4 is a diagrammatic perspective view of an embodiment of the present invention ORC device, having three turbo-generators and a pair of condensers.

[0016] FIG. 5 is a sectional planar view of a condenser.

[0017] FIG. 6 is a diagrammatic perspective view of an evaporator.

[0018] FIG. 7 is a schematic diagram of an ORC device that includes a single turbo-generator.

[0019] FIG. 8 is a schematic diagram of an ORC device that includes a pair of turbo-generators.

[0020] FIG. 9 is a schematic diagram of an ORC device that includes three turbo-generators.

[0021] FIG. 10 is a schematic diagram of an ORC device that includes three turbo-generators and a pair of condensers.

[0022] FIG. 11 is a diagrammatic pressure and enthalpy curve illustrating the Rankine Cycle.

DETAILED DESCRIPTION OF THE INVENTION

[0023] Referring to FIGS. 1 - 6, the present method and apparatus for reducing the exhaust temperature of a marine vessel power plant includes providing an organic Rankine cycle (ORC) device 20 for waste heat utilization. The ORC device 20 includes at least one of each of the following: 1) a turbine coupled with an electrical generator (together hereinafter referred to as the "turbo-generator 22"); 2) a condenser 24; 3) a refrigerant feed pump 26; 4) an evaporator 28; and 5) a control system. The ORC device 20 is preferably a closed "hermetic" system with no fluid makeup. In the event of leaks, either non-condensables are automatically purged from the device 20 or charge is manually replenished from refrigerant gas cylinders.

[0024] The ORC device 20 uses a commercially available refrigerant as the working

medium. An example of an acceptable working medium is R-245fa (1,1,1,3,3, pentafluoropropane). R-245fa is a non-flammable, non-ozone depleting fluid. R-245fa has a saturation temperature near 300 °F and 300 PSIG that allows capture of waste heat over a wide range of IGT exhaust temperatures.

[0025] Now referring to FIGS. 1 - 4, the turbo-generator includes a single-stage radial inflow turbine 30 that typically operates at about 18000 rpm, a gearbox 32 with integral lubrication system, and an induction generator 34 operating at 3600 rpm. The gearbox 32 includes a lubrication system. In some instances, the gearbox lubrication system is integral with the gearbox 32.

[0026] In one embodiment, the turbo-generator 22 is derived from a commercially available refrigerant compressor-motor unit; e.g., a Carrier Corporation model 19XR compressor-motor. As a turbine, the compressor is operated with a rotational direction that is opposite the direction it rotates when functioning as a compressor. Modifications performed to convert the compressor into a turbine include: 1) replacing the impeller with a rotor having rotor blades shaped for use in a turbine application; 2) changing the shroud to reflect the geometry of the rotor blades; 3) altering the flow area of the diffuser to enable it to perform as a nozzle under a given set of operating conditions; and 4) eliminating the inlet guide vanes which modulate refrigerant flow in the compressor mode. To the extent that there are elements within the 19XR compressor that have a maximum operating temperature below the operating temperature of the turbine 30, those elements are replaced or modified to accommodate the higher operating temperature of the turbine 30.

[0027] In some embodiments, the turbo-generator 22 includes peripheral components such as an oil cooler 36 (shown schematically in FIGS. 7 - 10) and oil reclaim eductor (not shown). Both the oil cooler 36 and the eductor and their associated plumbing are attached to the turbo-generator 22.

[0028] Referring to FIG. 6, a number of different evaporators 28 can be used with the ORC device 20. A single pressure once-through evaporator 28 with vertical hot gas flow and horizontal flow of refrigerant through fin-tube parallel circuits serviced by vertical headers is an acceptable type of evaporator 28. Examples of acceptable evaporator tube materials include carbon steel tubes with carbon steel fins, and stainless steel tubes with carbon steel fins, both of which have been successfully demonstrated in exhaust gas flows at up to 900 °F. Other evaporator tube materials may be used alternatively. Inlet header flow orifices are

used to facilitate refrigerant flow distribution. Different refrigerant flow configurations through the evaporator 28 can be utilized; e.g., co-flow, co-counterflow, co-flow boiler/superheater and a counterflow preheater, etc. The present evaporator 28 is not limited to any particular flow configuration.

[0029] In all the evaporator 28 embodiments, the number of preheater tubes and the crossover point are selected in view of the desired hot gas exit temperature as well as the boiler section inlet subcooling. A pair of vertical tube sheets 38, each disposed on an opposite end of the evaporator 28, supports evaporator coils. Insulated casings 40 surround the entire evaporator 28 with removable panels for accessible cleaning.

[0030] The number of evaporators 28 can be tailored to the application. For example, if there is more than one exhaust duct, an evaporator 28 can be disposed in each exhaust duct. More than one evaporator 28 disposed in a single duct also offers the advantages of redundancy and the ability to handle a greater range of exhaust mass flow rates. At lower exhaust flow rates a single evaporator 28 may provide sufficient cooling, while still providing the energy necessary to power the turbo-generator 22. At higher exhaust flow rates, a plurality of evaporators 28 may be used to provide sufficient cooling and the energy necessary to power one or more turbo-generators 22.

[0031] Referring to FIGS. 1 - 5, the condenser 24 is a shell-and-tube type unit that is sized to satisfy the requirements of the ORC device. The condenser 24 includes a housing 42 and a plurality of tubes 44 (hereinafter referred to as a "bank of tubes") disposed within the housing 42. The housing 42 includes a working medium inlet port 46, a working medium exit port 48, a coolant inlet port 50, and a coolant exit port 52. The coolant inlet and exit ports 50,52 are connected to the bank of tubes 44 to enable cooling fluid to enter the condenser 24 housing, pass through the bank of tubes 44, and subsequently exit the condenser housing 42. Likewise, the working medium inlet and exit ports 46,48 are connected to the condenser housing 42 to enable working medium to enter the housing 42, pass around the bank of tubes 44, and subsequently exit the housing 42. In some embodiments, one or more diffuser plates 54 (see FIG. 5) are positioned adjacent the working medium inlet 46 to facilitate distribution of the working medium within the condenser 24. In the embodiment shown in FIGS. 1 - 4, the housing 42 includes a removable access panel 56 at each axial end of the housing 42. In a preferred embodiment, one of the access panels 56 is pivotally attached to one circumferential side of the housing 42 and attachable to the opposite circumferential side via a selectively operable latch (not shown) so that the access

panel 56 may be readily pivoted to provide access to the bank of tubes 44.

[0032] In some embodiments, a non-condensable purge unit 58 (shown schematically in FIGS. 7 - 9) is attached to the condenser 24. The purge unit 58 is operable to extract air and water vapor that may accumulate in the vapor region of a condenser housing 42 to minimize or eliminate their contribution to oil hydrolysis or component corrosion. The purge unit 58 is actuated only when the system controller thermodynamically identifies the presence of non-condensable gas.

[0033] Referring to FIG. 5, in some embodiments, the ORC device 20 includes a recuperator 60 for preheating the working medium prior to its entry into the evaporator 28. The recuperator 60 is operable to receive thermal energy from at least a portion of the working medium exiting the turbo-generator 22 and use it to preheat working medium entering the evaporator 28. In the embodiment shown in FIG. 5, the recuperator 60 includes a plurality of ducts 62 disposed within the housing 42 of the condenser 24. The ducts 62 are connected inline downstream of the working medium exit port 48 of the condenser 24 and upstream of the evaporator 28. A partition 64 partially surrounds the recuperator ducts 62 to separate them from the remainder of the condenser 24. Working medium enters the condenser 24 through the working medium inlet port 46 and passes through the recuperator 60 prior to entering the remainder of the condenser 24. One or more diffusers 54 can be disposed within the recuperator to facilitate distribution of the working medium within the recuperator 60. Placing the recuperator 60 within the condenser 24 advantageously minimizes the size of the ORC device 20. A recuperator 60 disposed outside of the condenser 24 can be used alternatively, however.

[0034] Referring to FIGS. 1 - 4, the ORC device 20 includes one or more variable speed refrigerant feed pumps 26 to supply liquid refrigerant to the evaporator 28. In one embodiment, the refrigerant feed pump 26 is a turbine regenerative pump that supplies liquid refrigerant to the evaporator 28 with relatively low net pump suction head (NPSH). This design, combined with the relatively low system pressure difference, allows the feed pump 26 and condenser 24 to be mounted at the same elevation and obviates the need for separate condensate and feed pumps. In alternative embodiments, the refrigerant feed pump 26 may be a side channel centrifugal pump or an axial inlet centrifugal pump. The refrigerant feed pump 26 is equipped with an inverter to allow fully proportional variable speed operation across the full range of exhaust conditions. Other pump controls may be used alternatively. Applications using two or more refrigerant feed pumps 26 offer the advantage of redundancy.

In some embodiments, the piping 74 disposed immediately aft of each of the feed pumps 26 are connected to one another by a cross-over piping segment 76. Multiple refrigerant feed pumps 26 and the cross-over segment 76 enhance the ability of the ORC device 20 to accommodate a marine environment having significant pitch and roll by collecting working medium at different locations in the condenser 24. ORC configurations having more than one turbo-generator 22 and more than one refrigerant feed pump 26 are provided with valves 66 (see FIGS. 7 - 10) that enable each turbo-generator 22 or feed pump 26 to be selectively removed from the working medium flow pattern. Alternatively, a feed pump 26 may be associated with each turbo-generator 22, and selective actuation of the associated feed pump 26 can be used to engage / disengage the associated turbo-generator 22.

[0035] The ORC device 20 configurations shown in FIGS 7 - 10 each includes a cooling circuit 68 used in marine applications, wherein a cooling medium (e.g., seawater) is accessed from a cooling medium source 70 (e.g., the body of water in the environment surrounding the marine vessel) and circuitously passed through the condenser 24 (via the coolant inlet and exit ports 50,52) and returned to the cooling medium source 70. In alternative embodiments, the cooling circuit 68 includes a heat exchanger (e.g., a cooling tower) to remove thermal energy from the cooling medium.

[0036] ORC device 20 configurations are shown schematically in FIGS. 7 - 10. These configurations represent examples of ORC device 20 configurations and should not be interpreted as the only configurations possible within the present invention. Arrows indicate the working medium flow pattern within each configuration.

[0037] Referring to a first configuration shown in FIG. 7, beginning at a pair of refrigerant feed pumps 26, working medium is pumped toward an evaporator 28. In the embodiment shown in FIG. 7, prior to entering the evaporator 28, the working medium passes through a recuperator 60, wherein the working medium is preheated. In a marine application, the evaporator 28 is disposed within an exhaust duct that receives exhaust products from the vessel's power plant. Working medium exiting the evaporator 28 subsequently travels toward the turbo-generator 22. A bypass valve 72, disposed between the evaporator 28 and the turbo-generator 22, enables the selective diversion of working medium around the turbo-generator 22 and toward the condenser 24. An orifice 73 is disposed downstream of the bypass valve 72 to produce a flow restriction. As will be discussed below, the bypass valve 72 is operable to fully bypass working medium around the turbo-generator 22. Alternatively, the bypass valve 72 can operate to selectively vary the amount of working

medium that is introduced into the turbo-generator 22. Assuming some, or all, of the working medium has not been diverted around the turbo-generator 22, the working medium enters the turbine 30 portion of the turbo-generator 22 and provides the energy necessary to power the turbo-generator 22. Once through the turbo-generator 22, the working medium travels toward the condenser 24. Working medium that is diverted around the turbo-generator 22 also travels toward the condenser 24. A perspective view of this configuration of the ORC device 20 is shown in FIG. 1, less the evaporator 28.

[0038] A second ORC device 20 configuration is schematically shown in FIG. 8 that includes a pair of turbo-generators 22. The turbine inlets are connected to a feed conduit from the evaporator 28. A turbine inlet valve 66a is disposed immediately upstream of each turbo-generator 22. In some embodiments, a turbine exit valve 66b is disposed immediately downstream of each turbo-generator 22. In those embodiments, a safety pressure bleed is provided connected to the low pressure side of the ORC device. The second ORC device 20 configuration also includes a plurality of evaporators 28. An evaporator inlet valve 78 is disposed immediately upstream of each evaporator 28. In some embodiments, an evaporator exit valve 80 is disposed immediately downstream of each evaporator 28. A perspective view of this configuration of the ORC device 20 is shown in FIG. 2, less the evaporator 28.

[0039] A third ORC device 20 configuration is schematically shown in FIG. 9 that includes three turbo-generators 22. A perspective view of a portion of this configuration of the ORC device 20 is shown in FIG. 3, less the evaporator 28.

[0040] A fourth ORC device 20 configuration is schematically shown in FIG. 10 that includes three turbo-generators 22 and a pair of condensers 24. A perspective view of a portion of this configuration of the ORC device 20 is shown in FIG. 4, less the evaporator 28.

[0041] In all of the configurations, the ORC controls maintain the ORC device 20 along a highly predictable programmed turbine inlet superheat / pressure curve through the use of the variable speed feed pump 26 in a closed hermetic environment. An example of such a curve is shown in FIG. 11.

[0042] The condenser load is regulated via the feed pump(s) 26 to maintain condensing pressure as the system load changes. In addition to the primary feed pump speed / superheat control loop, the ORC controls can also be used to control: 1) net exported power generation by controlling either hot gas blower speed or bypass valve 72 position depending on the application; 2) selective staging of the generator 34 and gearbox 32 oil flow; and 3) actuation

of the purge unit 58. The ORC controls can also be used to monitor all ORC system sensors and evaluate if any system operational set point ranges are exceeded. Alerts and alarms can be generated and logged in a manner analogous to the operation of a commercially available chillers, with the control system initiating a protective shutdown sequence (and potentially a restart lockout) in the event of an alarm. The specific details of the ORC controls will depend upon the specific configuration involved and the application at hand. The present invention ORC device 20 can be designed for fully automated unattended operation with appropriate levels of prognostics and diagnostics.

[0043] The ORC device 20 can be equipped with a system enable relay that can be triggered from the ORC controls or can be self-initiating using a hot gas temperature sensor. After the ORC device 20 is activated, the system will await the enable signal to begin the autostart sequence. Once the autostart sequence is triggered, fluid supply to the evaporator 28 is ramped up at a controlled rate to begin building pressure across the bypass valve 72 while the condenser load is matched to the system load. When the control system determines that turbine superheat is under control, the turbine oil pump is activated and the generator 34 is energized as an induction motor. The turbine speed is thus locked to the grid frequency with no requirement for frequency synchronization. With the turbine at speed, the valve 66a immediately upstream of the turbine 30 opens automatically and power inflow to the generator 34 seamlessly transitions into electrical power generation.

[0044] Shutdown of the ORC device 20 is equally straightforward. When the temperature of the exhaust products passing through the evaporator(s) 28 falls below the operational limit, or if superheat cannot be maintained at minimum power, the ORC controls system begins an auto-shutdown sequence. With the generator 34 still connected to the grid, the valve 66a immediately upstream of the turbine 30 closes and the turbine bypass valve 72 opens. The generator 34 once again becomes a motor (as opposed to a generator) and draws power momentarily before power is removed and the unit coasts to a stop. The refrigerant feed pump 26 continues to run to cool the evaporator 28 while the condenser 24 continues to reject load, eventually resulting in a continuous small liquid circulation through the system. Once system temperature and pressure are adequate for shutdown, the refrigerant feed pump 26, turbine oil pump, and condenser 24 are secured and the system is ready for the next enable signal.

[0045] When the autostart sequence is complete, the control system begins continuous superheat control and alarm monitoring. The control system will track all hot gas load changes within a specified turndown ratio. Very rapid load changes can be tracked. During load increases, significant superheat overshoot can be accommodated until the system reaches a new equilibrium. During load decreases, the system can briefly transition to turbine bypass until superheat control is re-established. If the supplied heat load becomes too high or low, superheat will move outside qualified limits and the system will (currently) shutdown. From this state, the ORC device 20 will again initiate the autostart sequence after a short delay if evaporator high temperature is present.

[0046] The ORC device 20 can be run according to different modes of operation for the purpose of reducing the temperature of the power plant exhaust. In one mode of operation, the ORC device 20 is run with all working medium passing through the bypass valve 72, thereby bypassing the turbo-generator 22. In this mode, the valve 66 disposed adjacent and upstream of the turbo-generator 22 is closed. Working medium passing through the bypass valve 72 is expanded by passing through the orifice 73 disposed downstream of the bypass valve 72. This mode enables exhaust temperature suppression if the turbo-generator 22 is inoperable, or if it is desirable to not operate the turbo-generator 22. In a second mode of operation, the bypass valve 72 is closed and the valve 66 upstream of the turbo-generator 22 is open. Consequently, all of the working medium passes through the turbo-generator(s) 22. This mode of operation will accommodate operating conditions where the thermal energy produced by the power plant exhaust is not enough to drive the high-side pressure over the pressure limit of the ORC device 20. In a third mode of operation, the bypass valve 72 and the valve 66 upstream of the turbo-generator 22 are selectively opened/closed enough to create a desire flow rate of working medium through the turbo-generator(s) 22. The bypass valve 72 is adjustable in this mode to enable the operator to create a desired high-side pressure within the ORC device 20.

[0047] Although this invention has been shown and described with respect to the detailed embodiments thereof, it will be understood by those skilled in the art that various changes in form and detail thereof may be made without departing from the spirit and the scope of the invention.

What is claimed is:

1. An apparatus for decreasing the temperature of exhaust from a marine power plant, the apparatus comprising:
 - at least one evaporator operable to be disposed within the exhaust from the marine power plant;
 - at least one condenser having a plurality of tubes disposed within a housing, wherein the tubes form a closed circuit within the housing that is sized to permit a flow of coolant into and out of the condenser; and
 - at least one refrigerant feed pump operable to pump refrigerant within a circuitous path between the evaporator and the condenser.
2. The apparatus of claim 1, further comprising a turbo-generator that includes a turbine coupled with an electrical generator.
3. The apparatus of claim 1 wherein the refrigerant pump has an operating speed that is selectively controllable.
4. The apparatus of claim 1, further comprising a coolant source that provides the coolant flow into and out of the condenser.
5. The apparatus of claim 4, wherein the coolant source is environmental water.
6. The apparatus of claim 2, further comprising a selectively operable bypass valve disposed within the apparatus and positioned to provide a path between the evaporator and the condenser, so that refrigerant may be selectively bypassed around the turbo-generator.
7. The apparatus of claim 6, further comprising a flow orifice disposed downstream of the bypass valve.
8. The apparatus of claim 1, further comprising a recuperator disposed within the condenser, and the recuperator is positioned within the apparatus such that refrigerant from the refrigerant feed pump enters the recuperator and refrigerant exiting the recuperator passes into the evaporator.

9. The apparatus of claim 1, further comprising a pair of the refrigerant feed pumps operable to pump refrigerant, wherein one of the feed pumps is connected to the condenser adjacent a first lengthwise end of the condenser, and the other of the feed pumps is connected to the condenser adjacent a second lengthwise end of the condenser, opposite the first lengthwise end.
10. A method for decreasing the exhaust temperature of a marine vessel power plant, comprising the steps of:
- providing a Rankine Cycle device that includes at least one of each of an evaporator, a condenser, and a refrigerant feed pump;
 - disposing the evaporator within an exhaust duct of a power plant of the marine vessel;
 - operating the power plant; and
 - selectively pumping refrigerant through the Rankine Cycle device.
11. The method of claim 9, further comprising the step of controlling the refrigerant feed pump in response to the temperature and mass flow of the power plant.
12. The method of claim 9, wherein the Rankine Cycle device further comprises a turbo-generator that includes a turbine coupled with an electrical generator.
13. The method of claim 11, further comprising the steps of:
- disposing a selectively operable bypass valve within the device, positioned to provide a path between the evaporator and the condenser; and
 - selectively operating the bypass valve to bypass at least a portion of the refrigerant flow around the turbo-generator.
14. The method of claim 12, wherein the bypass valve is selectively operated to bypass refrigerant around the turbo-generator during start-up of the Rankine Cycle device and during shut-down of the Rankine Cycle device.
15. The method of claim 12, wherein the bypass valve is selectively operated to bypass refrigerant around the turbo-generator when the turbo-generator is inoperable.

16. A method for decreasing the exhaust temperature of a marine vessel power plant, comprising the steps of:

- providing a Rankine Cycle device that includes a first evaporator, a second evaporator, and at least one of each of a condenser, a turbo-generator, and a refrigerant feed pump;

- disposing the first and second evaporators within at least one exhaust duct of a power plant of the marine vessel;

- operating the power plant;

- selectively pumping refrigerant through the Rankine Cycle device; and

- selectively passing refrigerant through the second evaporator, or diverting refrigerant around the second evaporator, to accommodate a change in the temperature and/or mass flow of the refrigerant.

17. A method for suppressing the infrared signal of a marine vessel power plant, comprising the steps of:

- providing a Rankine Cycle device that includes at least one of each of an evaporator, a condenser, and a refrigerant feed pump;

- sizing the Rankine Cycle device to have the capacity to the marine vessel's power plant exhaust temperature from a first predetermined temperature to a second predetermined temperature;

- disposing the evaporator within an exhaust duct of a power plant of the marine vessel;

- operating the power plant; and

- selectively pumping refrigerant through the Rankine Cycle device.

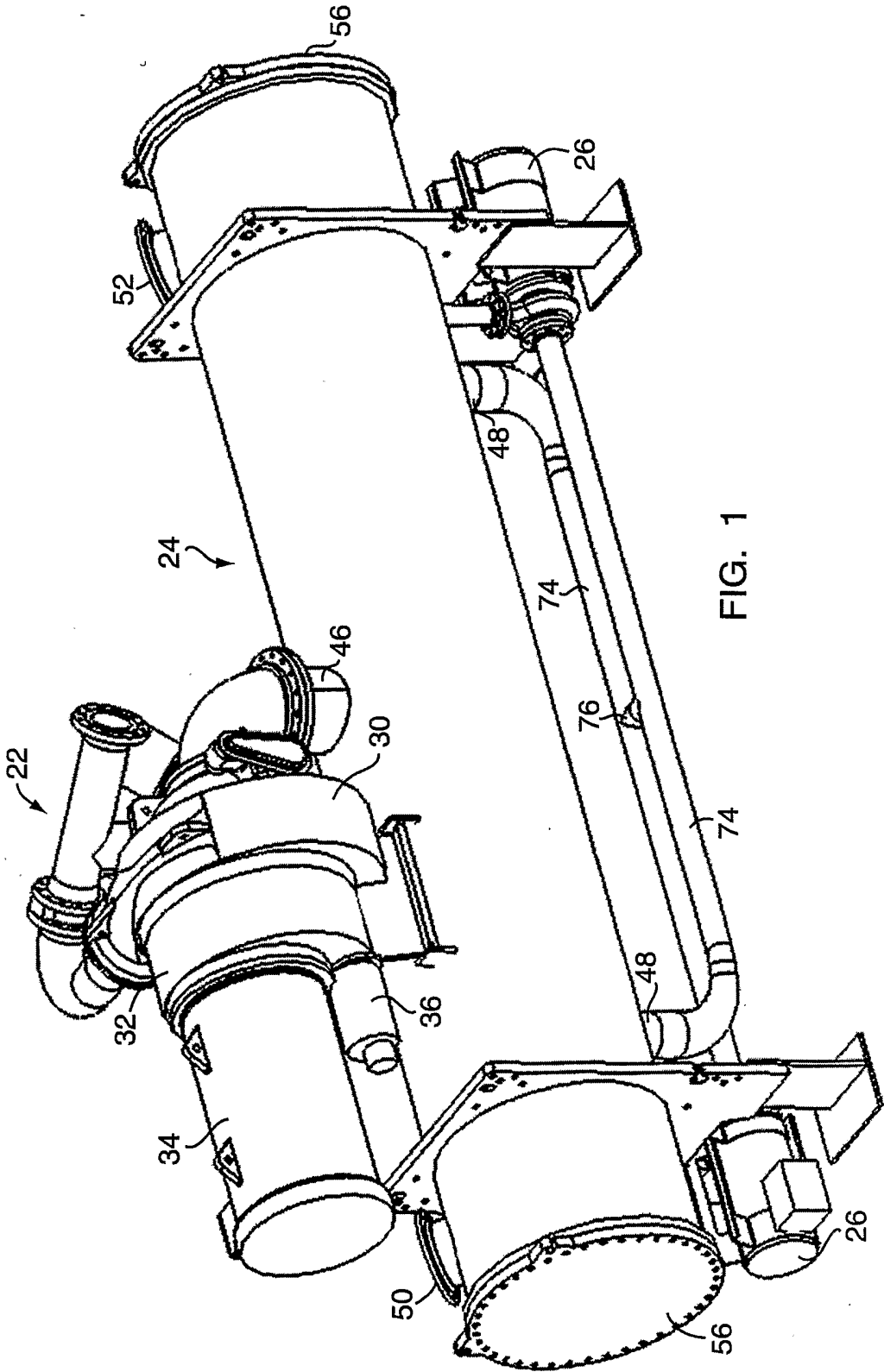


FIG. 1

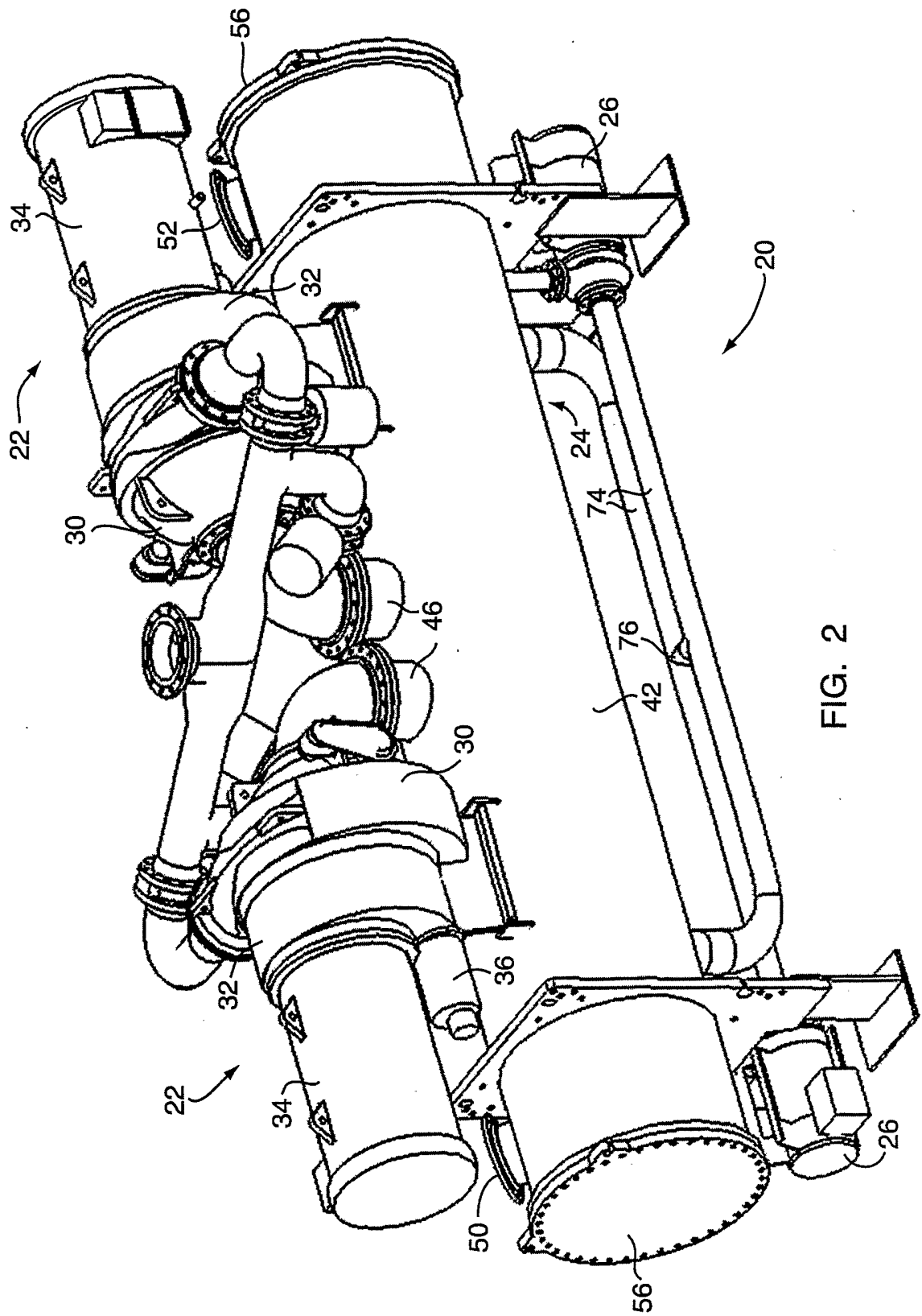


FIG. 2

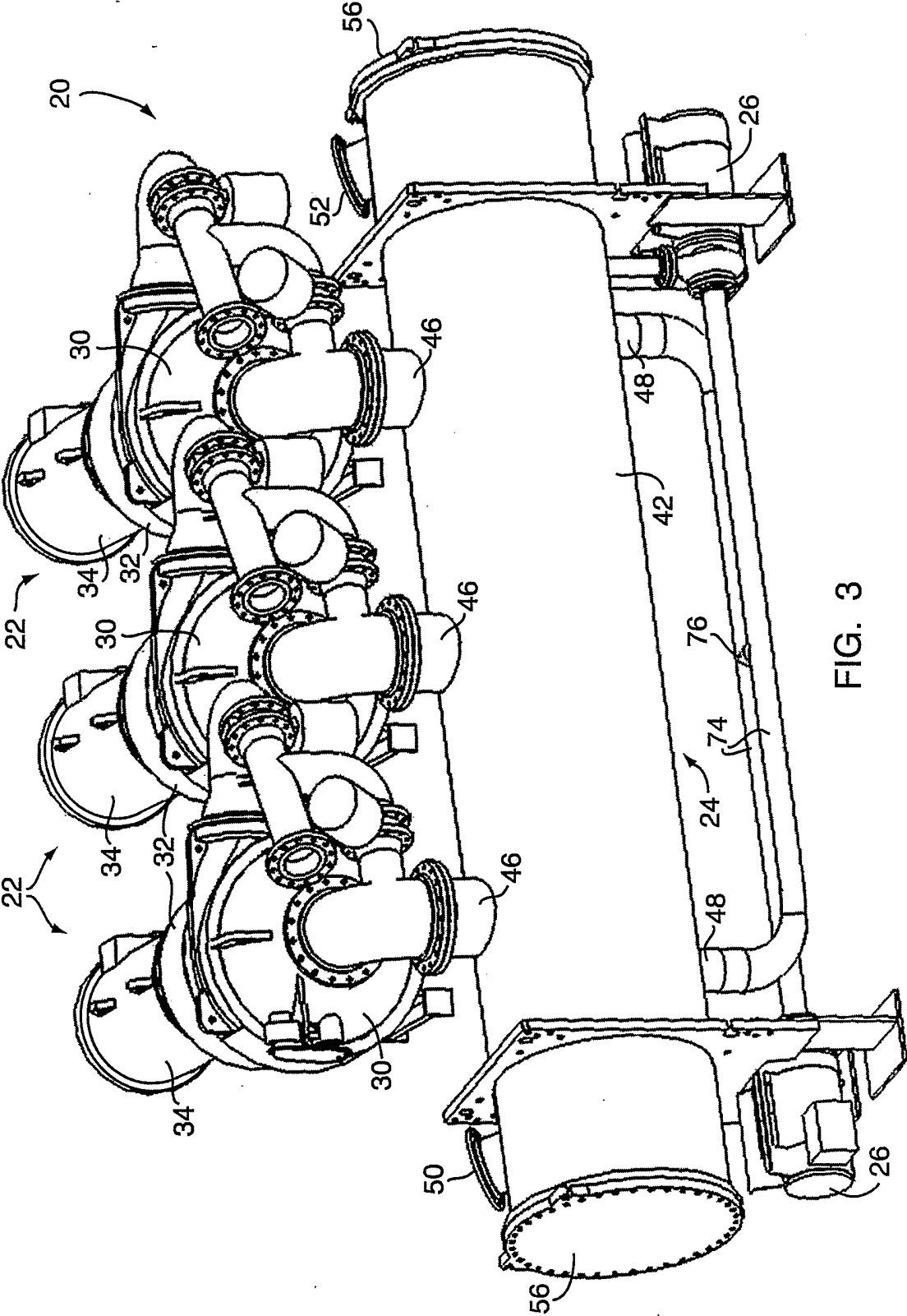


FIG. 3

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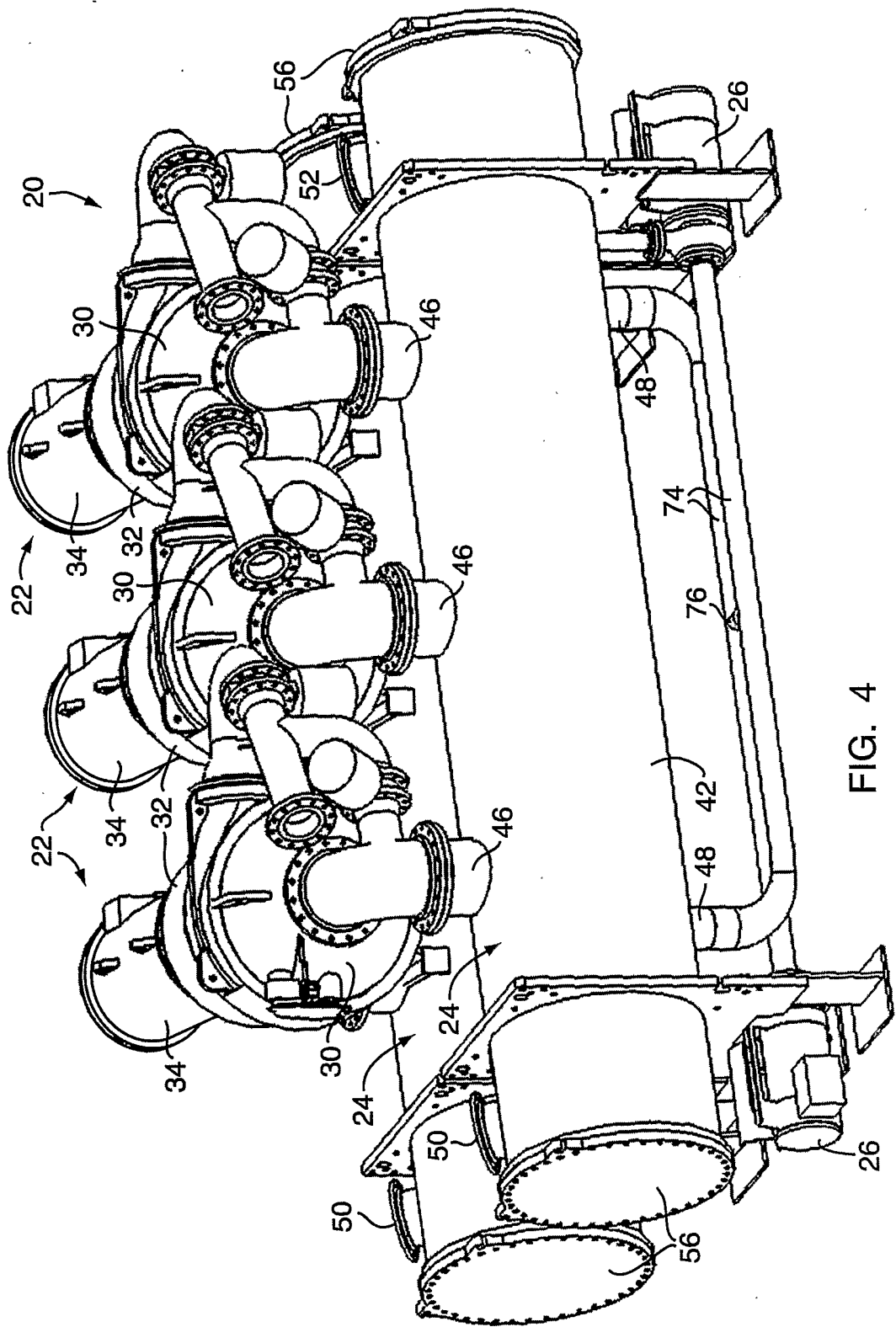


FIG. 4

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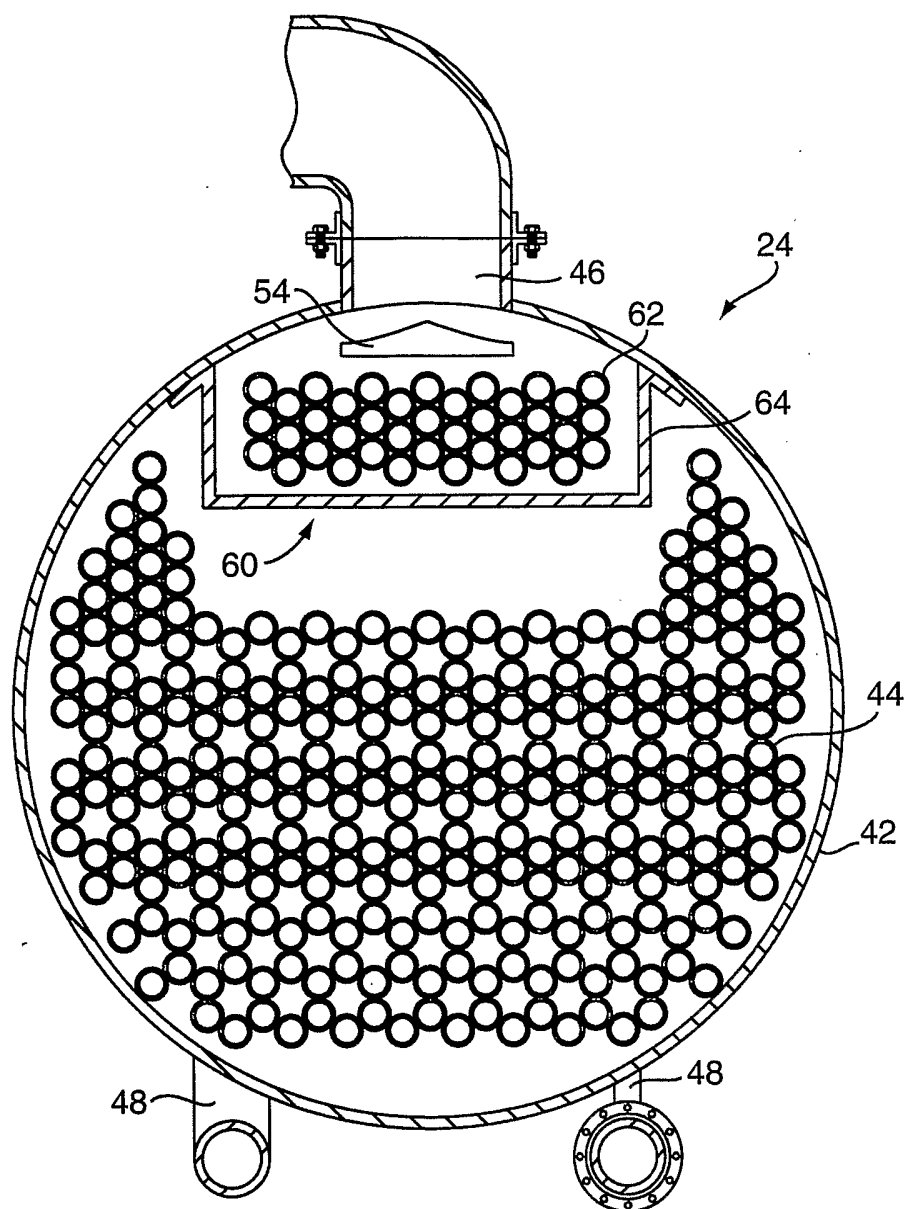


FIG. 5

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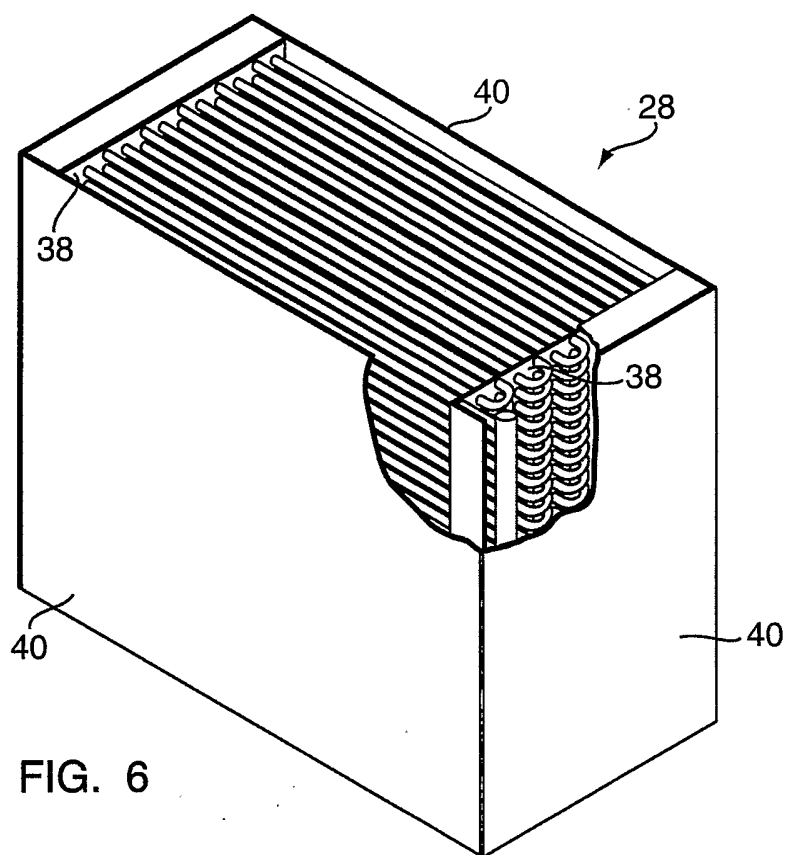


FIG. 6

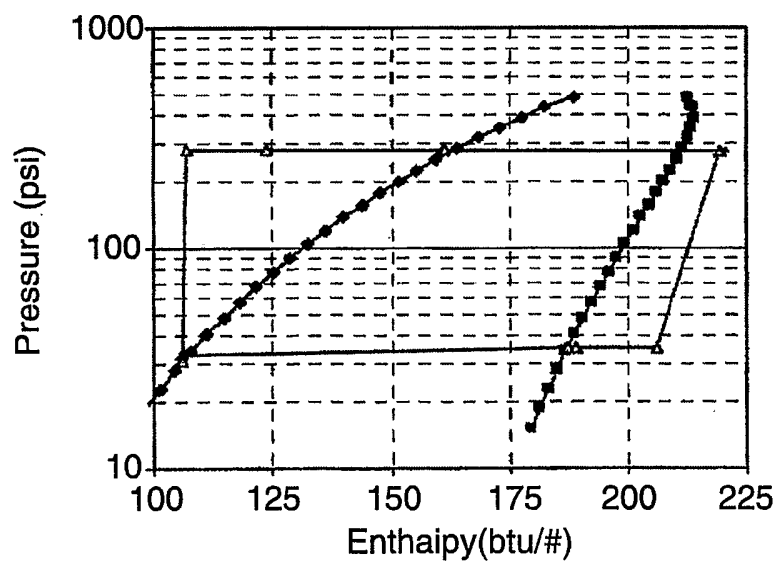


FIG. 11

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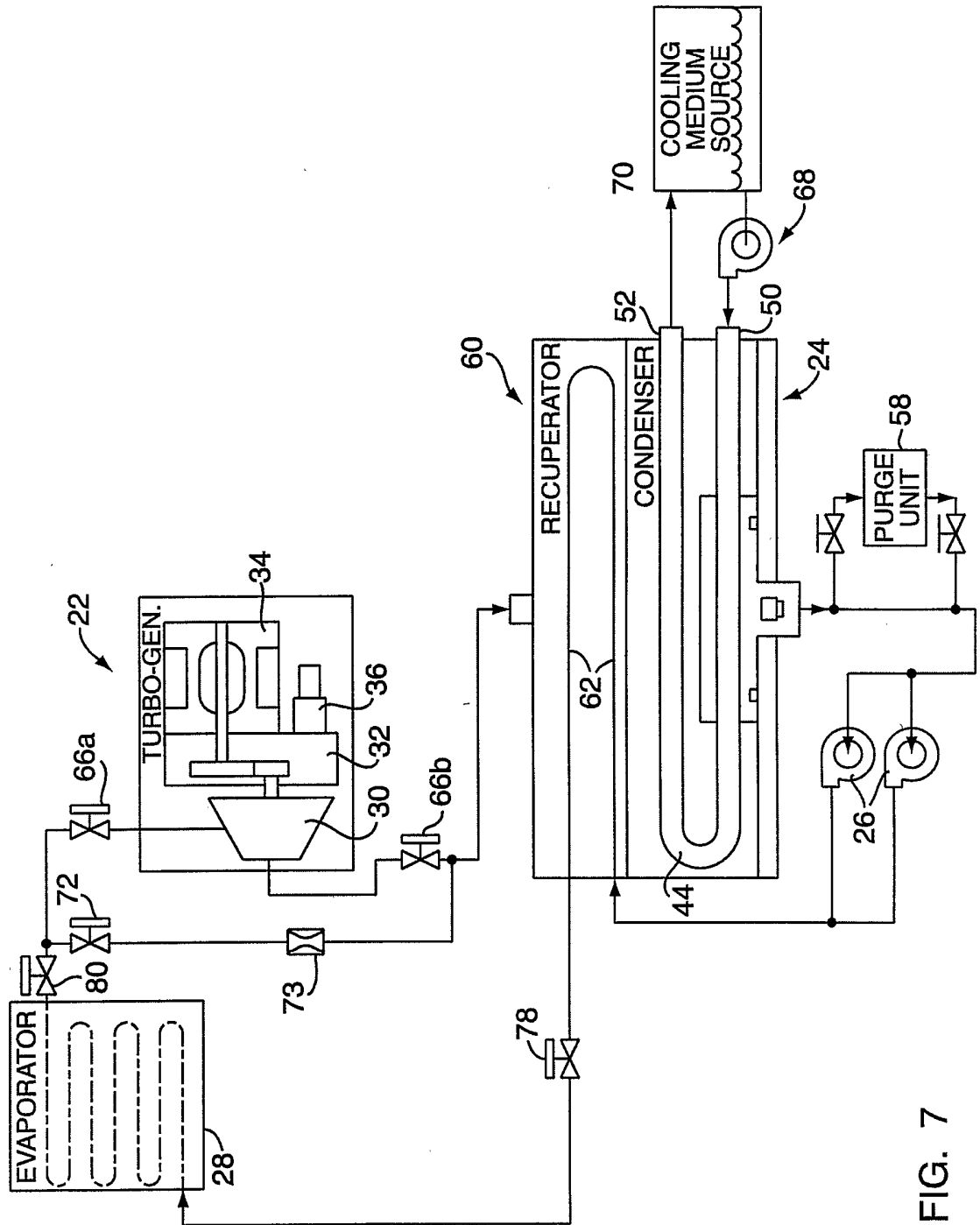


FIG. 7

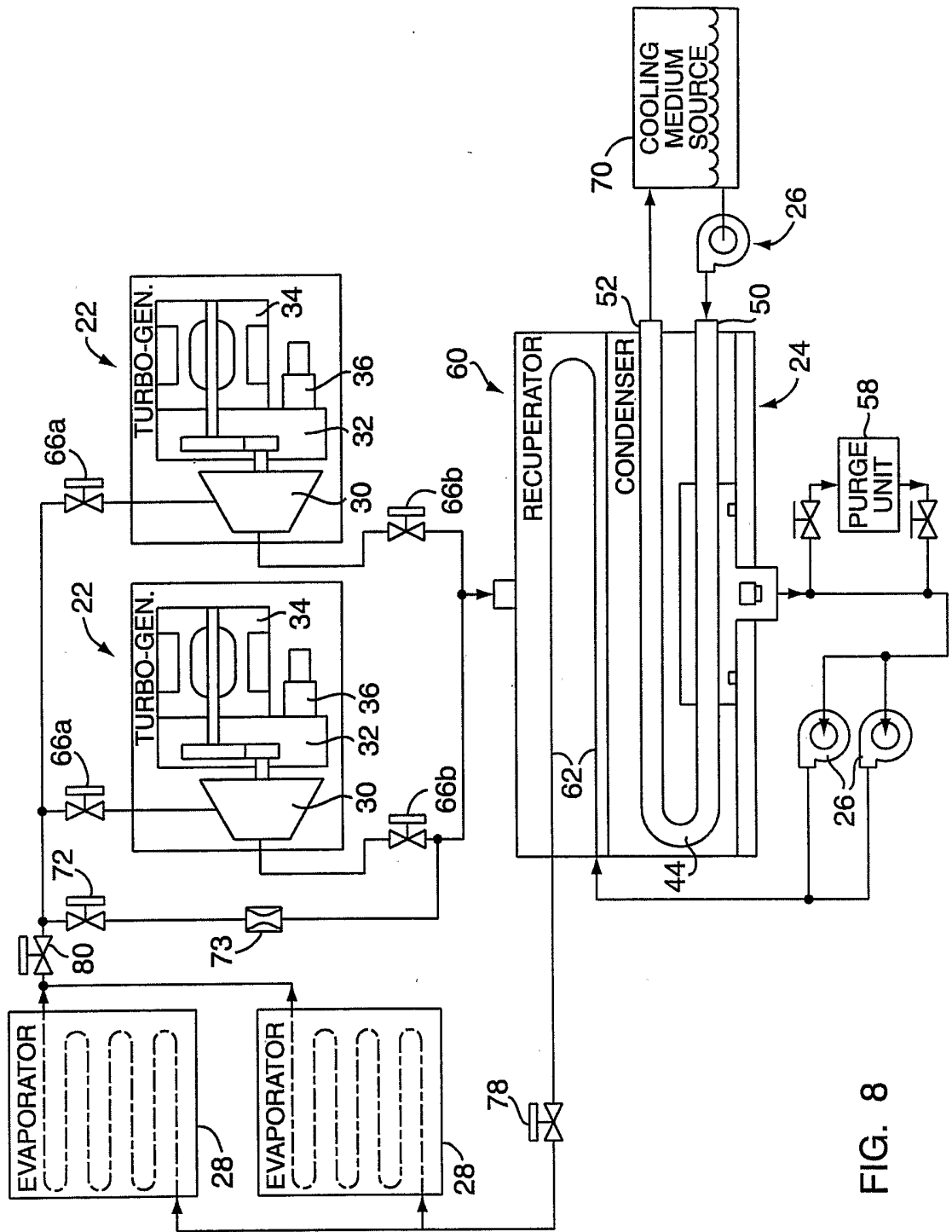


FIG. 8

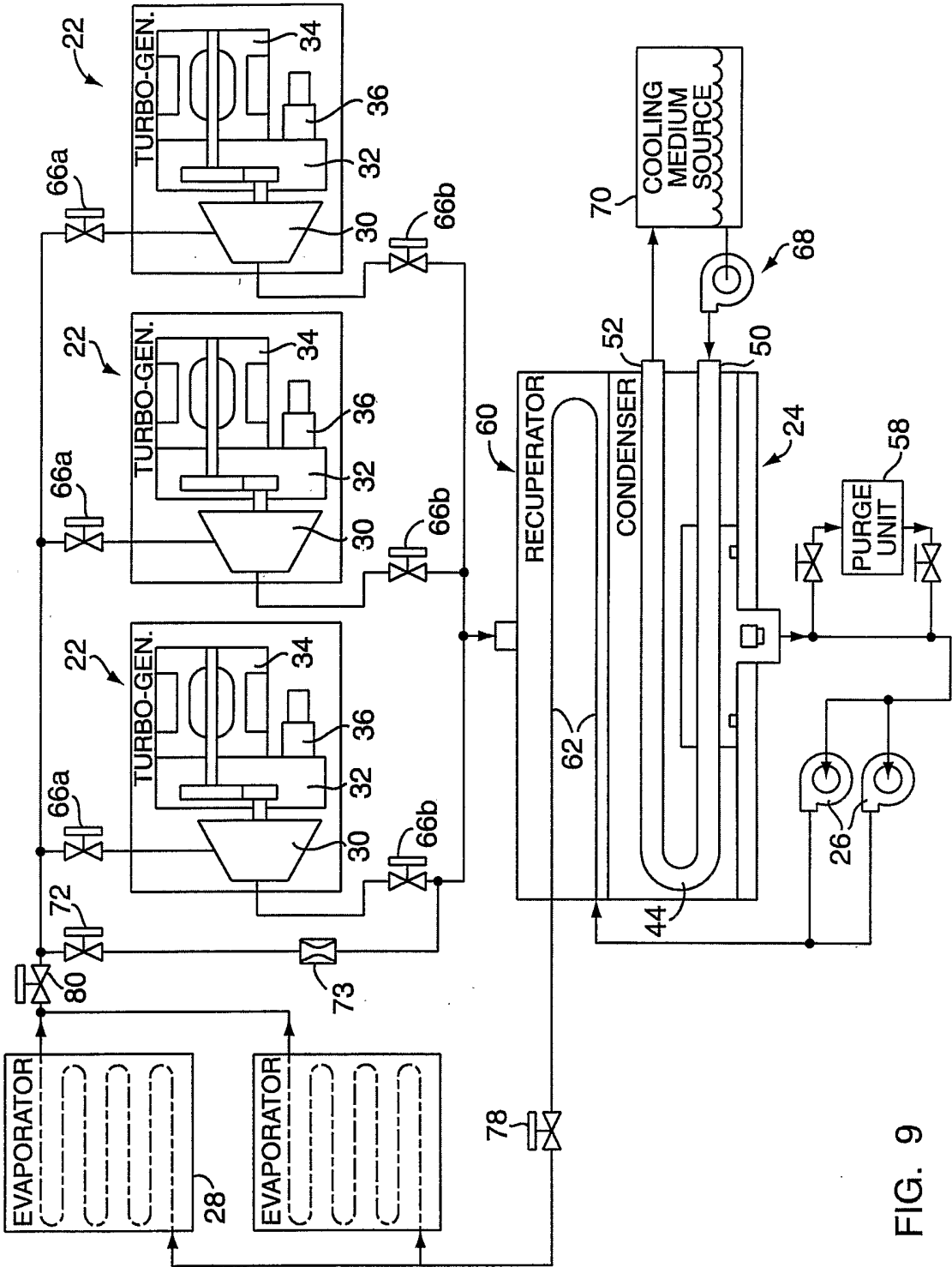
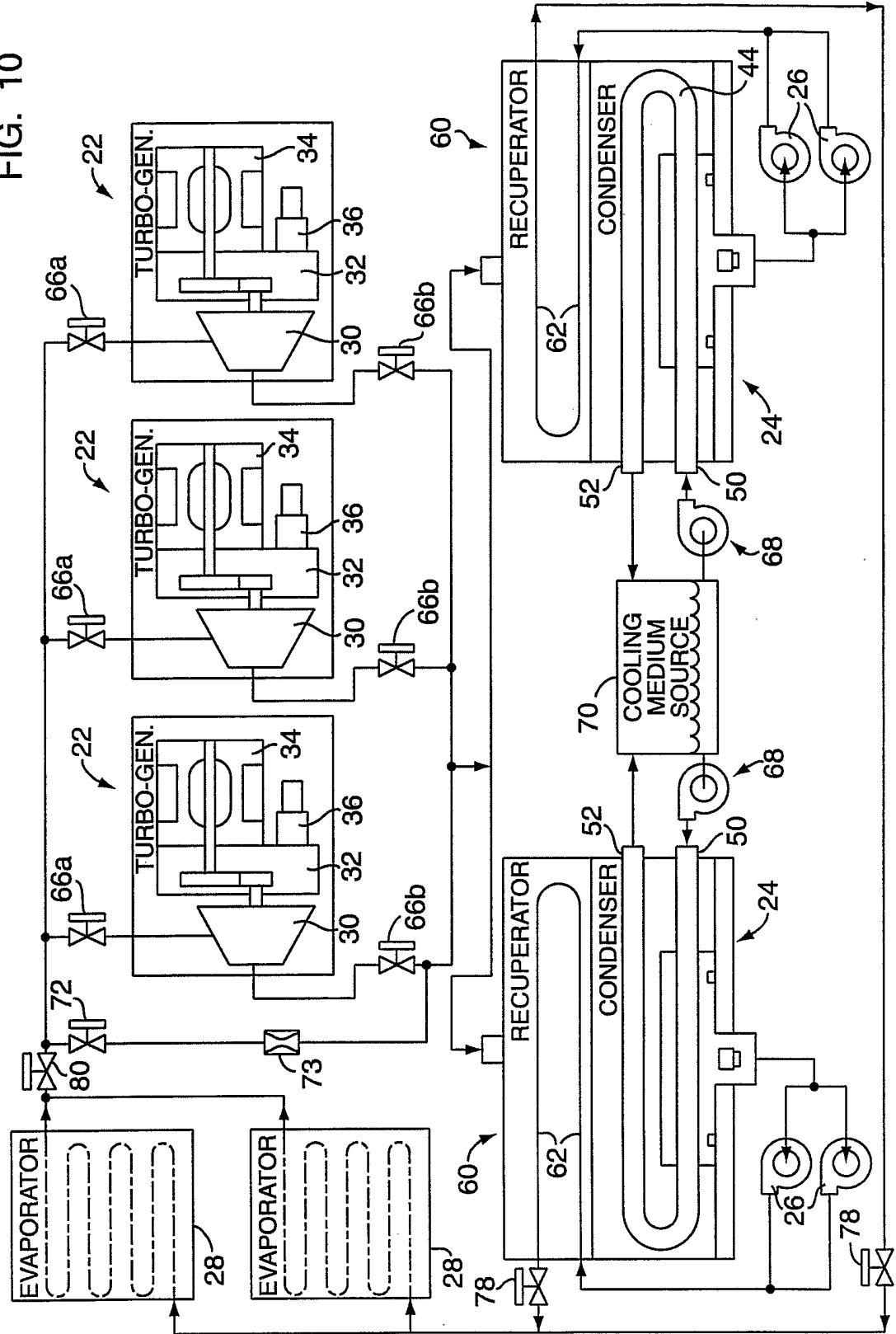


FIG. 9

FIG. 10



INTERNATIONAL SEARCH REPORT

International application No.

PCT/US05/42437

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : B63H 21/32

US CL : 440/89R

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : Please See Continuation Sheet

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

USPAT, US-PGPUB, USOCR, EPO, JPO, DERWENT, IBM_TDB

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4,166,361 A (EARNEST et al.) 04 September 1979 (04.09.1979)	1,2,4,10,12,17
A	US 3,613,368 A (DOERNER) 19 October 1971 (19.10.1971)	

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T"

later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X"

document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y"

document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&"

document member of the same patent family

Date of the actual completion of the international search

08 February 2006 (08.02.2006)

Date of mailing of the international search report

21 FEB 2006

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US05/42437

Continuation of B. FIELDS SEARCHED Item 1:
440/89R, 3, 88HE