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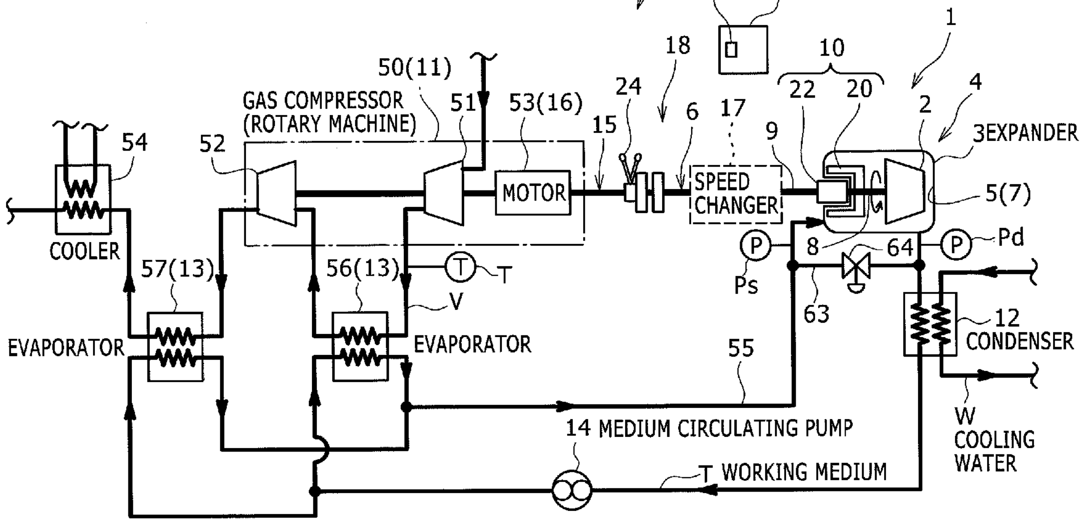
(54) **Power generating apparatus and operation method thereof**

(57) Provided is a power generating apparatus capable of using power generated by a heat engine (4) in combination with power of a driving source (53) provided separately from the heat engine (4). In order to prevent a problem caused when activating and stopping the apparatus, the apparatus of the present invention includes a rotary machine driving source (53) which generates a rotational driving force for a rotary machine (11) and a heat engine (4) which drives the rotary machine (11) in cooperation with the rotary machine driving source (53), wherein the heat engine includes an expander (3) which expands an evaporated working medium so as to generate a rotational driving force, the expander is provided with a bypass pipe (63) which causes a working medium inlet of the expander to communicate with a working medium outlet thereof, and the bypass pipe is provided with an on-off valve (64) which opens and closes the bypass pipe.

FIG.1



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Description

BACKGROUND OF THE INVENTION

(FIELD OF THE INVENTION)

[0001] The present invention relates to a power generating apparatus capable of using power generated by a heat engine in combination with power of a driving source provided separately from the heat engine and an operation method thereof.

(DESCRIPTION OF THE RELATED ART)

[0002] A heat engine such as a binary cycle engine is configured to convert heat into power (convert heat energy into motion energy) by expanding and condensing a working medium of a medium with a low boiling temperature such as ammonia, pentane, Freon, and Hydrochlorofluorocarbon through a thermodynamic cycle such as a Rankine cycle.

[0003] Such a heat engine includes an evaporator which evaporates a liquid working medium, an expander which expands a steam working medium, a condenser which condenses a gas working medium used in the expander into a liquid, and a circulation pump which compresses and circulates the condensed working medium. Further, a rotational driving force which is obtained by a rotational driving operation of the expander is extracted to the outside of a housing accommodating the expander through a rotational driving shaft and is used to rotate a rotary machine (for example, a power generator or the like) connected to a rotational driving shaft.

[0004] As a method of smoothly activating such a heat engine, for example, there is known a method disclosed in JP 2008-175402 A. In the related art, the method is used to operate a refrigerating cycle device, and the refrigerating cycle device includes a compressor, a radiator, an expander, and an evaporator which are sequentially connected to one another so as to circulate refrigerant, and further includes a radiator ability control unit which controls the ability of the radiator or an evaporator ability control unit which controls the ability of the evaporator. Here, the method includes a normal operation step and an activation step of reducing the ability of the radiator ability control unit or the evaporator ability control unit for some time from a normal operation state when activating the compressor.

SUMMARY OF THE INVENTION

[0005] Incidentally, a power generator which is provided in the heat engine (the refrigerating cycle device) of the related art generates power by directly receiving a rotational driving force generated by the expander of the heat engine. That is, the power generator is a "driven rotary machine". Of course, the power generator is maintained in a stop state when the rotational driving force may not be obtained from the expander.

[0006] Meanwhile, there is proposed a method in which a rotational driving force is generated by a heat engine such as a binary cycle engine and the obtained rotational driving force is used as auxiliary power for assisting "power of a driving source provided separately from the heat engine". For example, a gas compressor which is driven by a motor is supposed. The gas compressor is an "active rotary machine" which may be activated and operated independently, and a system is supposed which supplies the rotational driving force of the heat engine to such a gas compressor in order to assist the gas compressor.

[0007] In this case, for example, the following problems may be caused when activating the system.

[0008] That is, the motor of the gas compressor as the active rotary machine is activated along with the heat engine. At this time, since the heat engine is not in a normal operation state, the rotational power generated from the expander may not be applied as the auxiliary power to the motor. Conversely, the motor of the gas compressor rotates the expander. Accordingly, there is a possibility that the activation of the system may be pretty delayed. Further, in such a state, a working medium flowing into the expander is a liquid, and a rotation load of the expander excessively increases. As a result, the expander may be broken in the end.

[0009] Such problems are very severe problems, and may not be solved even by the related art.

[0010] This is because there is a difference in original system configuration in that the heat engine of the related art is not used to generate the auxiliary power for assisting the power of the driving source provided separately from the heat engine. Moreover, the operation method is used to solve the "problem occurring inside the heat engine", that is, a "problem in which the load of the circulation pump increases due to the continuous operation of the circulation pump (described as the compressor) while the expander is not driven". Accordingly, the related art may not solve the problem caused when activating the system including the heat engine and the active rotary machine connected to the heat engine.

[0011] Therefore, the present invention is made in view of the above-described problems, and it is an object of the invention to provide a power generating apparatus capable of using power generated by a heat engine in combination with power of a driving source provided separately from the heat engine. Further, it is an object of the present invention to provide a power generating apparatus capable of reliably preventing a problem caused when activating and stopping the apparatus and an operation method thereof.

[0012] In order to attain the above-described object, the present invention devises the following technical means.

[0013] According to an aspect of the present invention, there is provided a power generating apparatus including: a rotary machine driving source which generates a rotational driving force for a rotary machine; and a heat engine which drives the rotary machine in corporation with the rotary machine driving source, wherein the heat engine includes an expander which expands an evaporated working medium so as to generate a rotational driving force, wherein the expander is provided with a bypass pipe which causes a working medium inlet of the expander to communicate with a working medium outlet thereof, and wherein the bypass pipe is provided with an on-off valve which opens and closes the bypass pipe.

[0014] According to the above-described configuration, it is possible to reliably prevent a problem caused when activating or stopping the apparatus by temporarily opening the on-off valve when activating or stopping the rotary machine.

[0015] In the power generating apparatus with the above-described configuration, the power generating apparatus may further include a control device which controls an opening and closing operation of the on-off valve, wherein when activating the rotary machine driving source and the heat engine, the control device may perform control which opens the on-off valve so that the working medium flows into the bypass pipe, activates the rotary machine driving source, and closes the on-off valve when it is determined that the working medium flowing into the expander is evaporated.

[0016] In the power generating apparatus with the above-described configuration, the power generating apparatus may further include a suction pressure detector which detects a suction pressure of the expander, wherein the control device may determine that the working medium flowing into the expander is evaporated when a pressure value detected by the suction pressure detector becomes a predetermined pressure value or more.

[0017] Alternatively, in the power generating apparatus with the above-described configuration, the power generating apparatus may further include a suction pressure detector which detects a suction pressure of the expander; and an discharge pressure detector which detects an discharge pressure of the expander, wherein the control device may determine that the working medium flowing into the expander is evaporated when a differential pressure between a pressure value detected by the suction pressure detector and a pressure value detected by the discharge pressure detector becomes a predetermined value or more.

[0018] Alternatively, in the power generating apparatus with the above-described configuration, the rotary machine may be a gas compressor, the power generating apparatus may further include a temperature detector which detects an exhaust gas temperature of the gas compressor, and the control device may determine that the working medium flowing into the expander is evaporated when a temperature value detected by the temperature detector becomes a predetermined temperature value or more.

[0019] Alternatively, in the power generating apparatus with the above-described configuration, the control device may include a time measuring unit which measures an elapse time from the activation of the rotary machine driving source, and the control device may determine that the working medium flowing into the expander is evaporated when the elapse time detected by the time measuring unit becomes a predetermined time or more.

[0020] Further, in the power generating apparatus with the above-described configuration, the power generating apparatus may further include a control device which controls an opening and closing operation of the on-off valve, wherein when stopping the rotary machine driving source and the heat engine, the control device may perform control which opens the on-off valve so that the working medium flows into the bypass pipe and the driving operation of the expander is stopped.

[0021] Further, in the power generating apparatus with the above-described configuration, the power generating apparatus may further include a control device which controls an opening and closing operation of the on-off valve, wherein when the rotary machine driving source is stopped under the state where the rotary machine driving source and the heat engine are normally operated, the control device may perform control which opens the on-off valve so that the working medium flows into the bypass pipe and the driving operation of the expander is stopped.

[0022] Further, in the power generating apparatus with the above-described configuration, the rotary machine may be a compressor which compresses a gas supplied thereto in a high pressure state and the rotary machine driving source is a motor, and heat of a high-pressure gas produced by the compressor may be used as a heat source for a working medium in an evaporator of the heat engine.

[0023] Further, in the power generating apparatus with the above-described configuration, the rotary machine driving source may be a second expander which generates power by expanding a heating medium as steam, and an evaporator of the heat engine may heat and evaporate the working medium by the heating medium expanded by the second expander.

[0024] In this aspect, since the heating medium to be introduced into the evaporator is expanded by the second expander, the pressure of the heating medium introduced into the evaporator decreases compared to the related art. For this reason, the stress strain generated in the member constituting the evaporator may be reduced, and hence the burden on the evaporator may be reduced. Moreover, since the second expander is connected to the rotary shaft provided in the rotor portion of the rotary machine, the energy of the heating medium may be extracted as the energy of driving the rotor portion in the second expander. Accordingly, since the energy of the heating medium may be used without waste, the performance of the rotary machine driving system may be improved. That is, the pressure of the heating medium is used in the second expander, and the temperature of the heating medium of which the pressure decreases is used in the evaporator. Accordingly, the energy of the heating medium may be efficiently used compared to the related art.

[0025] Further, in the power generating apparatus with the above-described configuration, the power generating apparatus may further include: a first shaft portion which is connected to a rotary shaft of the heat engine; a second shaft portion which is connected to a rotary shaft of the second expander; and a coupling portion which couples the first shaft portion and the second shaft portion to each other so that a driving force is transmitted through the coupled shaft portions, wherein the coupling portion may be configured as a speed increasing and decreasing mechanism which is provided between the first shaft portion and the second shaft portion so as to change a rotation speed.

[0026] Further, in the power generating apparatus with the above-described configuration, water used in a condenser of the heat engine or water condensed from the steam in the evaporator of the heat engine may be supplied as lubricant to a bearing of the rotary shaft of the second expander.

[0027] Further, in the power generating apparatus with the above-described configuration, the power generating apparatus may further include: a first shaft portion which is connected to a rotary shaft of the heat engine; a second shaft portion which is connected to a rotary shaft of the rotary machine driving source; and a coupling portion which couples the first shaft portion and the second shaft portion to each other so that a driving force is transmitted through the coupled shaft portions, wherein at least one of the first shaft portion and the second shaft portion may be accommodated inside a hermetic body, and wherein the coupling portion may be configured as a magnetic coupling which magnetically couples the first shaft portion and the second shaft portion to each other.

[0028] Further, according to another aspect of the present invention, there is provided a method of operating the power generating apparatus with the above-described configuration, wherein when activating the heat engine and the rotary machine driving source, the on-off valve is opened so as to cause the working medium to flow into the bypass pipe, the heat engine and the rotary machine driving source are activated, and the on-off valve of the bypass pipe is closed when it is determined that the working medium flowing into the expander is evaporated, and wherein when stopping the heat engine and the rotary machine driving source, the on-off valve is opened so as to cause the working medium to flow into the bypass pipe and the driving operation of the expander is stopped.

[0029] Alternatively, in the method of operating the power generating apparatus with the above-described configuration, when the rotary machine driving source is stopped under the state where the rotary machine driving source is normally operated, the on-off valve is opened so as to cause the working medium to flow into the bypass pipe and the driving operation of the expander is stopped.

BRIEF DESCRIPTION OF THE DRAWINGS

[0030]

FIG. 1 is a diagram schematically illustrating a configuration of a power generating apparatus according to a first embodiment of the present invention.

FIG. 2 is a perspective view illustrating a magnetic coupling provided in the power generating apparatus of the first embodiment.

FIG. 3 is a flowchart illustrating a method of operating the power generating apparatus of the first embodiment.

FIG. 4 is a diagram schematically illustrating a configuration of a power generating apparatus according to a second embodiment of the present invention.

FIG. 5 is a diagram schematically illustrating a configuration of a power generating apparatus according to a third embodiment of the present invention.

FIG. 6 is a diagram schematically illustrating a configuration of a power generating apparatus of a fourth embodiment of the present invention.

FIG. 7 is a diagram schematically illustrating a configuration of a power generating apparatus of a fifth embodiment of the present invention.

FIG. 8 is a diagram schematically illustrating a configuration of a power generating apparatus of a sixth embodiment of the present invention.

FIG. 9 is a diagram schematically illustrating a configuration of a power generating apparatus of a seventh embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[First Embodiment]

[0031] Hereinafter, a first embodiment of a power generating apparatus 100 according to the present invention will be described by referring to the drawings.

[0032] As illustrated in FIG. 1, the power generating apparatus 100 of the first embodiment includes an auxiliary power generating apparatus 1, a motor 53 which drives a rotary machine 11, and two power generating sources. The auxiliary power generating apparatus 1 includes a heat engine 4 which includes an expander 3 with a driving portion 2 (a screw rotor 2 in this embodiment) rotationally driven by the expansion of steam of a working medium T and a power transmission shaft 6 which extracts a rotational driving force generated by the expander 3 to the outside of a housing 5 accommodating the expander 3.

[0033] The housing 5 accommodates the driving portion 2 of the expander 3 in the inner portion surrounded by a partition wall 7. The power transmission shaft 6 is divided by a partition wall 7 into a driving shaft 8 positioned inside the housing 5 and a driven shaft 9 positioned outside the housing 5. Further, the divided power transmission shafts 6, that is, the driving shaft 8 and the driven shaft 9 are provided with a magnetic coupling 10 which transmits the rotational driving force of the expander 3 to the outside of the housing 5.

[0034] In this way, the auxiliary power generating apparatus 1 includes the magnetic coupling 10 and the power transmission shaft 6 with the driving shaft 8 and the driven shaft 9. Then, the auxiliary power generating apparatus 1 transmits the rotational driving force to the outside of the housing 5 by the power transmission shaft 6 and transmits the rotational driving force to the rotary machine 11 provided separately from the heat engine 4 so that the rotational driving force is used as auxiliary power of the rotary machine 11.

[0035] The present invention relates to a technique capable of preventing a problem caused when activating or stopping the auxiliary power generating apparatus 1. However, the auxiliary power generating apparatus 1 and the rotary machine 11 assisted by the auxiliary power generating apparatus 1 will be described before the description of the technique of the present invention.

[0036] First, the rotary machine 11 as a subject to which the auxiliary power is supplied from the power generating apparatus 1 will be described in detail.

[0037] As the rotary machine 11 of the first embodiment, a "gas compressor" which compresses a supplied gas V in a high pressure state is employed.

[0038] As illustrated in FIG. 1, a gas compressor 50 includes a plurality of compressors (a first-stage compressor 51 and a second-stage compressor 52) which are connected to each other in series in the axial direction and a motor 53 which drives the plurality of compressors, and is configured as an oil-free multi-stage gas compressor which does not use lubricating oil. The motor 53 which generates a driving force is an electric motor. In such a gas compressor 50, the gas V which is introduced from the outside is adiabatically compressed by the first-stage compressor so as to become the high-pressure gas V, and is sent to the second-stage compressor. The sent high-pressure gas V is further adiabatically compressed by the second-stage compressor so as to become the high-pressure gas V. At this time, the produced gas V increases in temperature so that the gas has much heat. The high-pressure gas V which is produced in this way is cooled to a desired temperature according to the use purpose by a cooling device such as a cooler 54.

[0039] The above-described gas compressor 50 (the rotary machine 11) is provided for a user as one component and includes the motor 53. Accordingly, the gas compressor may be operated as a single unit (a main rotary machine). The auxiliary power generating apparatus 1 of this embodiment is additionally attached to the gas compressor 50 and assists the power of the gas compressor 50.

[0040] Meanwhile, the heat engine 4 which is provided in the auxiliary power generating apparatus 1 of the first embodiment will be described in detail.

[0041] A binary cycle engine is exemplified as the heat engine 4 provided in the auxiliary power generating apparatus 1 of the first embodiment.

[0042] As illustrated in FIG. 1, the binary cycle engine 4 is provided on a close-loop-shaped circulation pipe obtained by connecting an evaporator 13 which evaporates the liquid working medium T, the expander 3 which expands the steam of the working medium T evaporated by the evaporator 13 so as to rotationally drive the driving portion 2 (for example, the screw rotor 2 to be described later), a condenser 12 which condenses the steam of the working medium T expanded by the expander 3 so as to be changed into the liquid working medium T, and a medium circulating pump 14 which circulates the working medium T by pressure-feeding the liquid working medium T condensed by the condenser 12 to the evaporator 13.

[0043] The expander 3 includes the screw rotor 2 (the driving portion 2) which is rotationally driven by using a difference in pressure between the non-expanded steam and the expanded steam. The screw rotor 2 is rotatable about the driving shaft 8, and may transmit the generated rotational driving force to the magnetic coupling 10 connected to the driving shaft 8 through the driving shaft 8.

[0044] The housing 5 (the partition wall 7) is provided in the periphery of the screw rotor (the driving portion) 2 of the expander 3, and the inside and the outside may be air-tightly isolated by the housing 5. The housing 5 which is used for the air-tight isolation stores the working medium T as a medium with a low boiling temperature that is used in the binary cycle engine 4 along with the screw rotor 2.

[0045] A power transmission unit which transmits the rotational driving force generated by the screw rotor 2 of the expander 3 to the gas compressor 50 is disposed between the expander 3 and the gas compressor 50.

[0046] The power transmission unit includes the power transmission shaft 6 which is divided by the partition wall 7 into the driving shaft 8 and the driven shaft 9 and the magnetic coupling 10 (see FIG. 2) which magnetically couples both shafts divided by the partition wall 7 to the inside and the outside of the housing 5, and includes a power transmission path 15 with the power transmission shaft 6 and the magnetic coupling 10.

[0047] Then, the rotational driving force which is extracted through the magnetic coupling 10 is transmitted to the gas compressor 50 which is provided separately from the binary cycle engine 4 and is driven by the power of the driving source 16, so that the rotational driving force is used as the auxiliary power for driving the gas compressor 50.

[0048] Further, the power transmission path 15 to which the rotational driving force extracted through the magnetic coupling 10 is provided with a speed changer 17 which changes the rotation speed of the power transmission shaft 6 and transmits the auxiliary power to the downstream side and a clutch mechanism 18 which controls the auxiliary power transmission state to the gas compressor 50.

[0049] Next, the power transmission shaft 6 and the magnetic coupling 10 constituting the auxiliary power generating apparatus 1 will be described.

[0050] As illustrated in FIG. 1, the power transmission shaft 6 is divided by the partition wall 7 of the housing 5 into the driving shaft 8 and the driven shaft 9. One driving shaft 8 of the divided power transmission shafts 6 is a rotary shaft which is disposed along the rotation axis of the screw rotor 2 of the expander 3. One end (the right side of FIG. 1) of the driving shaft 8 is connected to the screw rotor 2 as the driving portion 2 of the expander 3, and the other end (the left side of FIG. 1) thereof extends to the vicinity of the partition wall 7. The front end of the other end side is provided with an outer cylinder body 20 of the magnetic coupling 10 attached to a driving side magnet.

[0051] Meanwhile, one driven shaft 9 of the divided power transmission shafts 6 is a shaft which is rotatably disposed along the coaxial direction with the driving shaft 8. One end (the right side of FIG. 1) of the driven shaft 9 extends toward the expander 3, where one end thereof is provided with an inner insertion body 22 attached to a driven side magnet and the other end (the left side of FIG. 1) thereof is connected to the speed changer 17 to be described later.

[0052] As illustrated in FIGS. 1 and 2, the magnetic coupling 10 includes the outer cylinder body 20 which is provided in the driving shaft 8 and the inner insertion body 22 which is provided in the driven shaft 9.

[0053] The outer cylinder body 20 is a bottomed cylindrical member that is opened to the side of the gas compressor 50 (the opposite side to the screw rotor 2), and is formed of a non-magnetic material. The driving shaft 8 is coaxially connected to the outer cylinder body 20, and the cylindrical portion is provided with two driving side magnets which are disposed in the circumferential direction so as to face each other.

[0054] The inner insertion body 22 is a columnar body, and is formed of a non-magnetic material as in the outer cylinder body 20. The inner insertion body 22 is loosely insertable into the outer cylinder body 20, and driven side magnets 26 corresponding to the number the driving side magnets 25 are attached to the outer peripheral surface of the inner insertion body 22 (the outer peripheral surface of the portion inserted into the outer cylinder body 20). Further, the number of the driving side magnets 25 and the number of the driven side magnets 26 of the magnetic coupling are not limited to two, and may be two or more.

[0055] The driving side magnets 25 and the driven side magnets 26 are disposed so that different magnetic poles face each other, and a magnetic attracting force is generated between both magnets 25 and 26 so as to permeate the partition wall 7. Accordingly, the rotational driving force of the driving shaft 8 may be transmitted to the driven shaft 9.

[0056] Incidentally, the configuration of the auxiliary power generating apparatus 1 of the present invention has been sequentially described, and then the evaporator 13 provided in the binary cycle engine 4 will be described.

[0057] The evaporator 13 which is provided in the binary cycle engine 4 of the first embodiment is provided as two or more evaporators (a first evaporator 56 and a second evaporator 57 in FIG. 1) at the downstream side of the medium circulating pump 14 so as to use the heat generated by the gas compressor 50 as a heat source which evaporates the working medium T.

[0058] The first evaporator 56 and the second evaporator 57 are disposed in parallel on a circulation pipe 55. The inlets of the first evaporator 56 and the second evaporator 57 are respectively connected with pipes which are branched in parallel from the circulation pipe 55 connected to the downstream side of the medium circulating pump 14. The pipes which extend from the outlets of the first evaporator 56 and the second evaporator 57 are respectively connected to the circulation pipe 55 at the upstream side of the expander 3.

[0059] The high-pressure gas V which is adiabatically compressed by the first-stage compressor 51 of the gas compressor 50 flows into the first evaporator 56 so that the high-pressure gas V exchanges heat with the working medium T. The high-pressure gas V which is subjected to the heat exchange operation is sent to the second-stage compressor 52.

[0060] The high-pressure gas V which is adiabatically compressed by the second-stage compressor 52 flows into the second evaporator 57 so that the high-pressure gas V exchanges heat with the working medium T. The high-pressure gas V which is subjected to the heat exchange operation is sent to the cooler 54 (the cooling device) and is cooled to a desired temperature in accordance with the use purpose.

[0061] The gas working medium T which is provided in this way is sent to the expander 3 through the circulation pipe 55 connected to the outlets of the first evaporator 56 and the second evaporator 57.

[0062] Incidentally, a bypass pipe 63 (bypass passage) is disposed between the expander 3 and the circulation pipe 55 connected to the outlets of the first evaporator 56 and the second evaporator 57.

[0063] The bypass pipe 63 is disposed so as to connect the inlet of the expander 3 to the outlet of the expander 3. The bypass pipe 63 is provided with an on-off valve 64 which changes the circulation state inside the bypass pipe 63. The on-off valve 64 is turned on or off by the operation state of the auxiliary power generating apparatus 1 so as to permit the circulation of the working medium T or interrupt the circulation of the working medium T.

[0064] The problem which is caused by activating or stopping the auxiliary power generating apparatus 1 may be prevented by using the bypass pipe 63, and the detailed description thereof will made below.

[0065] Hereinafter, the operation manner of the auxiliary power generating apparatus 1 according to the first embodiment, that is, the operation in a normal operation state will be described by referring to the drawings.

[0066] As illustrated in FIG. 1, in the first evaporator 56, the steam working medium T is produced by evaporating the liquid working medium T using (exchanging) the heat of the high-pressure gas V produced by the first-stage compressor 51. Further, in the second evaporator 57, the steam working medium T is produced by evaporating the liquid working medium T using (exchanging) the heat of the high-pressure gas V produced by the second-stage compressor 52 as in the first evaporator 56. The steam working medium T which is produced in this way is sent to the expander 3 through the circulation pipe 55 connected to the outlets of the first evaporator 56 and the second evaporator 57.

[0067] In the expander 3, the steam of the working medium T produced by the first evaporator 56 and the second evaporator 57 is expanded, and the driving portion 2 is rotationally driven by using a difference in pressure between the non-expanded working medium T and the expanded working medium T.

[0068] The steam of the low-pressure working medium T used in the expander 3 is sent to the condenser 12 through the outlet-side circulation pipe 55 of the expander 3. In the condenser 12, the steam of the working medium T sent from the expander 3 exchanges heat with the cooling water W so as to be condensed into the liquid working medium T.

[0069] The working medium T which becomes a liquid by the condenser is sent to the medium circulating pump 14. The liquid working medium T is boosted by the medium circulating pump 14, and is pressure-fed to both evaporators 56 and 57 again through the circulation pipe 55.

[0070] Meanwhile, the rotational driving force which is generated by the expander 3 and the rotational driving force which is extracted to the outside of the housing 5 through the magnetic coupling 10 are first transmitted to the speed changer 17 through the driven shaft 9 connected to the magnetic coupling 10.

[0071] After the rotation speed is changed to the rotation speed best suitable for driving the gas compressor 50 by the speed changer 17, the rotational driving force obtained after the speed changing operation is transmitted to the motor 53 of the gas compressor 50 through the clutch mechanism 18 so as to assist the power thereof.

[0072] Incidentally, the following problems are supposed when operating the auxiliary power generating apparatus 1.

[0073] For example, there is a concern that the following situation may occur when starting (activating) the gas compressor 50 again by supplying power to the stopped gas compressor 50.

[0074] When power is supplied to the stopped gas compressor 50 so that the motor 53 starts to rotate, the motor 53 drives the compressors 51 and 52. At this time, in the auxiliary power generating apparatus 1, that is, the binary cycle, the heat for driving the expander 3 is not supplied to the evaporator 13, and the liquid working medium T circulates through the circulation pipe 55. The liquid working medium T may not drive the expander 3, and the motor 53 of the gas compressor 50 rotates the expander 3 (serving as a load) into which the liquid working medium T flows. That is, since the motor 53 of the gas compressor 50 tries to rotate both the compressors 51 and 52 and the expander 3, a large load is applied to the motor 53, and hence the start of the entire apparatus is delayed.

[0075] However, in this embodiment, this problem is prevented by employing the operation method illustrated in FIG. 3.

[0076] That is, in the auxiliary power generating apparatus 1 according to the first embodiment, the on-off valve 64 is opened when activating the gas compressor 50 (S101, S102 of FIG. 3). In this way, since the working medium may circulate through the bypass pipe 63, the liquid working medium T may be branched at the inlet side of the expander 3, so that the liquid working medium substantially does not flow into the expander 3. Then, the expander 3 may idly rotate, and hence the above-described problem may be prevented.

[0077] Subsequently, the gas compressor 50 is normally operated so that the high-pressure gas V is discharged. The heat of the high-pressure gas V evaporates the working medium T through the evaporator 13. When the suction pressure of the expander 3, the differential pressure between the suction side and the discharge side of the expander 3, or the exhaust heat temperature of the gas compressor 50 is measured and it is determined that the measurement value is a predetermined value or more (S103 of FIG. 3), the on-off valve 64 of the bypass pipe 63 is closed (S104 of FIG. 3). All evaporated working medium flows into the expander 3, so that the auxiliary power generating apparatus 1 is normally operated. Furthermore, in S103, it is determined whether the operation time of the gas compressor 50 becomes a predetermined time or more. When the operation time becomes a predetermined time or more, the routine may proceed to S104. Here, the predetermined value and the predetermined time are set as a value which may be used to check the evaporation state of the working medium flowing into the expander.

[0078] As illustrated in FIG. 1, as the apparatus configuration for realizing the above-described operation method, the power generating apparatus 100 according to the first embodiment includes a control device 70. Further, the suction pressure detector Ps is provided for the case where the suction pressure of the expander 3 is used in S103, the suction pressure detector Ps and the discharge pressure detector Pd are provided for the case where the differential pressure between the suction side and the discharge side of the expander 3 is used in S103, and the temperature detector T is provided for the case where the exhaust heat temperature of the gas compressor 50 is used in S103. In the embodiment of FIG. 1, the discharge gas temperature of the first-stage compressor 51 of the gas compressor 50 is measured, but instead of this, the discharge gas temperature of the second-stage compressor 52 may be measured.

[0079] In a case of the operation in which the on-off valve 64 is automatically opened when activating the gas compressor 50 and the on-off valve 64 is automatically closed after a predetermined time, the control device 70 includes a time measuring unit 71 which measures the elapse time from the activation of the gas compressor 50.

[0080] As the determination in S103, only one of the four determination methods may be used. Alternatively, a control may be performed in which the on-off valve 64 is opened when the determination method used in combination with the plurality of determination methods becomes the condition of opening the on-off valve 64.

[0081] The opening and closing operation of the on-off valve 64 may be performed by the manual operation of the operator without using the control device 70.

[0082] Next, the operation of the auxiliary power generating apparatus 1 when stopping the gas compressor 50 will be described. Immediately after stopping the gas compressor 50, the steam working medium T continuously flows into the expander 3 of the auxiliary power generating apparatus 1 through the circulation pipe 55. In this state, the expander 3 becomes an overload state since the expander needs to drive the motor 53 in addition to the compressors 51 and 52 of the gas compressor 50. When an excessive overload is applied to the expander, the magnetic coupling 10 which is present between the expander 3 and the motor 53 may not transmit power and idly rotate, and hence there is a concern that the expander 3 may excessively rotate in a non-load state.

[0083] However, in such a stop case, the auxiliary power generating apparatus 1 according to the first embodiment opens the on-off valve 64 (S201 of FIG. 3) so that the working medium may pass through the bypass pipe 63. Accordingly, the inflow of the working medium into the expander 3 is suppressed. As a result, the driving operation of the expander 3 is stopped. Then, the driving operation of the compressors 51 and 52 is stopped along with the stop of the driving operation of the motor 53 of the gas compressor 50 (S202 of FIG. 3). Then, the above-described problem is reliably prevented. Furthermore, the operation of opening the on-off valve 64 and the operation of stopping the driving operation of the motor 53 may be performed at the same time. The same applies to the operation of the auxiliary power generating apparatus 1 in case of power outage below.

[0084] In the gas compressor 50, there is a case in which power is not supplied to the gas compressor in a normal operation state due to abrupt power outage or the like. Since the steam working medium T continuously flows into the expander 3 of the auxiliary power generating apparatus 1 through the circulation pipe 55, the expander 3 drives the motor 53 and the compressors 51 and 52 of the gas compressor 50 which is stopped due to the power outage, and hence becomes an overload state. When an excessive overload is applied to the expander, the magnetic coupling 10 which is present between the expander 3 and the motor 53 may not transmit power and idly rotates. Conversely, there is a concern that the expander 3 may excessively rotate in a non-load state.

[0085] However, in such a power outage case, the auxiliary power generating apparatus 1 according to the first embodiment opens the on-off valve 64 (S201 of FIG. 3) so that the working medium may pass through the bypass pipe 63. Thus, the inflow of the working medium into the expander 3 is suppressed and hence the driving operation of the expander 3 is stopped. Then, the driving operation of the compressors 51 and 52 is stopped along with the stop of the driving of the motor 53 of the gas compressor 50 (S202 of FIG. 3). Then, the above-described problem is reliably prevented.

[0086] When opening and closing the on-off valve 64, the opening and closing operation may be manually performed by the operator, but a configuration may be employed in which the on-off valve 64 automatically detects power outage and is automatically opened when detecting the power outage.

[Second Embodiment]

[0087] Next, a second embodiment of the power generating apparatus 100 of the present invention will be described by referring to the drawings.

[0088] As illustrated in FIG. 4, the configuration of the auxiliary power generating apparatus 1 according to the second embodiment is different from the configuration of the first embodiment as below.

[0089] That is, the binary cycle engine 4 of the second embodiment has a difference in that the heat source for evaporating the working medium T is supplied from the outside. In other words, the heat generated by the rotary machine 11 is not used (collected) as the heat source for evaporating the working medium T. In this way, the auxiliary power generating apparatus 1 of the second embodiment includes the binary cycle engine 4 with a simple configuration. Furthermore, various rotary machines such as a motor or a compressor may be used in the rotary machine 11.

[0090] However, the second embodiment is substantially the same as the first embodiment in that the bypass pipe 63 causing the inlet and the outlet of the expander 3 to communicate with each other is provided and the bypass pipe 63 is provided with the on-off valve 64 for enabling and disabling the circulation of the working medium T.

[0091] Even in the auxiliary power generating apparatus 1, that is, in the binary cycle engine 4, the problem caused when activating or stopping the apparatus mentioned in the first embodiment may occur.

[0092] Even in this case, it is possible to reliably prevent the problem caused when activating and stopping the apparatus even in the apparatus of the second embodiment that uses the bypass pipe 63 connecting the inlet of the expander 3 and the outlet of the expander 3 to each other and performs an operation based on the flowchart illustrated in FIG. 3.

[0093] Furthermore, since the other configurations and the supposed operation and effect in the second embodiment are substantially the same as those of the first embodiment, the description thereof will not be repeated. Furthermore, in FIG. 4, the control device and various detectors are not illustrated.

[Modified example]

[0094] In the apparatus 100 of the first embodiment and the second embodiment, the configuration may be modified as below.

[0095] For example, in the first embodiment, the heat of the high-pressure gas V produced by the gas compressor 50 is used as the heat source of the binary cycle engine 4. However, when a water cooling type engine (internal combustion engine) is employed in the rotary machine 11, the cooling water for cooling the engine may be used as the heat source of the binary cycle engine 4.

[0096] Further, even when an air clutch is employed as the clutch mechanism 18 disposed in the auxiliary power generating apparatus 1, a problem caused in the case of power outage or activation may be prevented.

[0097] That is, a configuration may be employed in which the air clutch is used as the clutch mechanism 18 and a part of the gas V compressed by the gas compressor 50 is guided to the air clutch.

[0098] For example, when the gas compressor 50 which is normally operated is stopped due to the abrupt power outage or the like, the high-pressure gas V is not supplied (only the low-pressure gas V exists), and the air clutch is not operated. Accordingly, the expander 3 of the auxiliary power generating apparatus 1 is not automatically interlocked with the motor 53 of the gas compressor 50. For this reason, it is possible to reliably prevent the problem caused in the case of power outage. Since the high-pressure gas V is supplied during the normal operation of the gas compressor 50, the air clutch is operated.

[0099] Such an operation of the air clutch occurs in the same way even when starting the gas compressor 50. That is, in the activation state, the high-pressure gas V is not supplied from the gas compressor 50 (only the low-pressure gas V exists), and the air clutch is not operated. Accordingly, the expander 3 of the auxiliary power generating apparatus 1 is not automatically interlocked with the motor 53 of the gas compressor 50 only for some time. For this reason, it is possible to reliably prevent the problem caused when activating the apparatus.

[Third Embodiment]

[0100] FIG. 5 illustrates a configuration of a power generating apparatus of a third embodiment. Specifically, the power generating apparatus includes a circulation circuit 110 that is a binary cycle engine through which the working medium circulates, a power generator 120 as a rotary machine, a heating medium circuit 130, and a control unit 150 which performs various controls. Furthermore, a working medium (for example, HFC245fa) having a boiling temperature lower than that of water circulates through the circulation circuit 110.

[0101] The circulation circuit 110 is a closed circuit which is obtained by serially connecting an evaporator 111 which evaporates a working medium, a first expander 113 which expands a gas working medium, a condenser 114 which condenses a working medium expanded by the first expander 113, and a working medium pump 115 which sends the working medium condensed by the condenser 114 to the evaporator 111.

[0102] The evaporator 111 is used to evaporate the liquid working medium. The evaporator 111 includes a working medium passage 111a through which the working medium flows and a heating medium passage 111b through which the heating medium flows. The heating medium passage 111b is connected to the heating medium circuit 130 as described below, so that the heating medium flows therethrough. The working medium which flows through the working medium passage 111a evaporates by the heat exchange with the heating medium flowing through the heating medium passage 111b.

[0103] The first expander 113 is provided at the downstream side of the evaporator 111 in the circulation circuit 110, and expands the working medium evaporated by the evaporator 111, so that motion energy is extracted from the working medium. In this embodiment, a screw expander is used as the first expander 113. In the screw expander, a pair of male and female screw rotors 113b is accommodated in a rotor chamber (not illustrated) formed inside a casing 113a of the first expander 113. In the screw expander, the screw rotor 113b is rotated by the expanding force of the working medium supplied from the suction port formed in the casing 113a to the rotor chamber. Then, the working medium of which the pressure decreases is discharged from the outlet formed in the casing 113a due to the expansion inside the rotor chamber. Furthermore, the first expander 113 is not limited to the screw expander, but may be other expanders such as a turbine expander.

[0104] The condenser 114 condenses a gas working medium discharged from the first expander 113 so as to be changed into a liquid working medium. The condenser 114 includes a working medium passage 114a through which a gas working medium flows and a cooling medium passage 114b through which a cooling medium flows. The cooling medium passage 114b is connected to a cooling medium circuit 117, and the cooling medium supplied from the outside flows through the cooling medium circuit 117. As the cooling medium, for example, cooling water cooled by a cooling tower may be exemplified. The working medium which flows through the working medium passage 114a is condensed by the heat exchange with the cooling medium flowing through the cooling medium passage 114b.

[0105] The working medium pump 115 is used to circulate the working medium inside the circulation circuit 110, and is provided at the downstream side of the condenser 114 (between the evaporator 111 and the condenser 114) in the circulation circuit 110. The working medium pump 115 pressurizes the liquid working medium condensed by the condenser 114 to a predetermined pressure and sends the liquid working medium to the evaporator 111. As the working medium pump 115, a centrifugal pump which includes an impeller as a rotor or a gear pump which includes a rotor as a pair of gears is used. The working medium pump 115 may be driven at an arbitrary rotation speed.

[0106] The power generator 120 includes a rotor portion 120a, and the rotor portion 120a is provided in an intermediate portion of a rotary shaft 123 connected to one screw rotor 113b of the first expander. When the screw rotor 113b is driven by the expansion of the working medium inside the first expander 113, the rotary shaft 123 rotates. Accordingly, the rotor portion 120a rotates. Since the rotor portion 120a rotates along with the rotation of the rotary shaft 123, the power generator 120 generates power. In this embodiment, an IPM power generator (permanent magnet synchronized power generator) is used as the power generator 120. The power generator 120 may adjust the rotation speed by an inverter (not illustrated). The control unit 150 outputs a rotation speed adjusting signal to an inverter (not illustrated) so as to adjust the rotation speed of the power generator 120 so that the power generation efficiency of the power generator 120 is improved as much as possible. Furthermore, the power generator 120 is not limited to the IPM power generator, but may be other power generators, for example, an induction power generator and the like.

[0107] The circulation circuit 110 is provided with a bypass passage 125. The bypass passage 125 is provided with a bypass valve 125a which is configured as an on-off valve, and the bypass passage 125 opens the bypass valve 125a so that the working medium flows so as to bypass the first expander 113 in the circulation circuit 110. One end of the bypass passage 125 is connected to a pipe between the evaporator 111 and the first expander 113 in the circulation circuit 110, and the other end of the bypass passage 125 is connected to a pipe between the first expander 113 and the condenser 114 in the circulation circuit 110.

[0108] The heating medium circuit 130 may be connected to an external medium passage 135, and a heating medium is introduced from the external medium passage 135 into the heating medium circuit 130. One end (upstream end) of the heating medium circuit 130 is provided with a second expander 140. The heating medium which is supplied through the external medium passage 135 is introduced into the second expander 140, and the second expander 140 extracts motion energy from the heating medium by expanding the heating medium. In this embodiment, the screw expander is used as the second expander 140, but other expanders such as a turbine expander may be used.

[0109] As the heating medium supplied to the heating medium circuit 130, for example, steam sampled from a well (steam well), steam discharged from a factory or the like, steam produced by a solar energy collector using solar heat as a heat source, steam produced by exhaust heat of an engine, a compressor, and the like, and steam produced from a boiler using a biomass or a fossil fuel as a heat source may be exemplified. The heating medium which is introduced into the second expander 140 is, for example, 120°C to 250°C.

[0110] The second expander 140 is connected to the rotary shaft 123. That is, the rotary shaft 123 is connected to one screw rotor 140a of the second expander 140. When the screw rotor 140a is driven by the expansion of the heating medium inside the second expander 140, the rotary shaft 123 rotates.

[0111] The heating medium passage 111b of the evaporator 111 is connected to the heating medium circuit 130. Accordingly, the heating medium which is expanded by the second expander 140 flows through the heating medium passage 111b of the evaporator 111.

[0112] The circulation circuit 110 is provided with an entering side pressure sensor Ps and a back pressure sensor Pd. The entering side pressure sensor Ps is provided in a pipe between the evaporator 111 and the first expander 113 among the pipe constituting the circulation circuit 110. The back pressure sensor Pd is provided in a pipe between the first expander 113 and the condenser 114 among the pipe constituting the circulation circuit 110.

[0113] The control unit 150 includes a ROM, a RAM, a CPU, and the like, and exhibits a predetermined function by executing a program stored in the ROM. The function of the control unit 150 includes the pump control unit 151 and the opening and closing control unit 152.

[0114] The pump control unit 151 controls the rotation speed of the working medium pump 115 Since the rotation speed of the working medium pump 115 is controlled by an inverter (not illustrated), the pump control unit 151 performs the rotation speed control of the working medium pump 115 by sending a control signal to the inverter.

[0115] The opening and closing control unit 152 performs control which opens the bypass valve 125a when the second expander 140 is driven at a timing earlier than the driving of the first expander 113 by the working medium. For example, in the activation state, the driving of the second expander 140 by the heating medium is started at a timing earlier than the driving of the first expander 113 by the working medium. That is, in the evaporator 111, the working medium flowing through the working medium passage 111a is heated and evaporated by the heating medium flowing through the heating medium passage 111b. For this reason, the steam working medium may not be introduced into the first expander 113 until a predetermined time is elapsed from the state where the heating medium flows through the heating medium circuit 130. At this time, the power generator 120 and the first expander 113 are driven by the second expander 140 until the undamped steam starts to be introduced into the first expander 113. For this reason, when the liquid working medium is introduced into the first expander 113, the load of the second expander 140 increases. Therefore, the screw rotor 113b of the first expander 113 may idly rotate by opening the bypass valve 125a in the activation state.

[0116] When the opening and closing control unit 152 receives the activation instruction of the working medium pump 115, the opening and closing control unit performs control which opens the bypass valve 125a. Subsequently, when a difference in pressure between the detection value of the entering side pressure sensor Ps and the detection value of the back pressure sensor Pd reaches a predetermined threshold value, the opening and closing control unit performs control which closes the bypass valve 125a. The threshold value of the difference in pressure is set to a pressure which may be determined as a state where the working medium is sufficiently evaporated by the evaporator 111 so that the first expander 113 may be driven.

[0117] Furthermore, the opening and closing control of the bypass valve 125a is not limited thereto. For example, a configuration may be employed in which the back pressure sensor Pd is not provided, the opening and closing control unit performs control which opens the bypass valve 125a when the opening and closing control unit 152 receives the activation instruction of the working medium pump 115, and the opening and closing control unit performs control which closes the bypass valve 125a when the detection value of the entering side pressure sensor Ps reaches a predetermined threshold value. Further, a configuration may be employed in which pressure sensors (a second entering side pressure sensor and a second back pressure sensor) are respectively provided at the inlet side and the outlet side of the second expander 140, the bypass valve 125a is opened when a difference in pressure obtained from the second entering side pressure sensor and the second back pressure sensor becomes equal to or larger than a predetermined threshold value and a difference in pressure obtained from the entering side pressure sensor Ps and the back pressure sensor Pd becomes smaller than a predetermined threshold value, and the bypass valve 125a is closed when a difference in pressure obtained from the entering side pressure sensor Ps and the back pressure sensor Pd becomes equal to or larger than a predetermined threshold value. Further, a configuration may be employed in which the entering side pressure sensor Ps and the back pressure sensor Pd are not provided and the bypass valve 125a is closed when a predetermined time is elapsed from the receiving of the activation instruction of the working medium pump 115.

[0118] Subsequently, a method of controlling an operation when activating the power generating apparatus according to this embodiment will be described. The basic flow is the same as the flow of the first embodiment illustrated in FIG. 3. However, in this embodiment, a method of using a differential pressure between the suction side and the discharge side of the expander is employed.

[0119] In a case of activating the power generating apparatus, first, the control unit 150 receives an activation instruction. When the control unit 150 receives the activation instruction, control is performed which opens the bypass valve 125a. At this time, the heating medium is introduced from the external medium passage 135 into the heating medium circuit 130. The heating medium is introduced into the second expander 140 and is expanded therein, so that the second expander 140 is driven. By the driving of the second expander 140, the rotor portion 120a of the power generator 120 rotates, so that the power generator 120 starts to generate power. The heating medium of which the pressure is decreased by the expansion of the second expander 140 flows into the heating medium passage 111b of the evaporator 111.

[0120] Meanwhile, in the circulation circuit 110, the working medium pump 115 is activated by receiving the activation instruction, so that the working medium starts to flow. In the evaporator 111, the heating medium of the heating medium passage 111b heats the working medium of the working medium passage 111a. In the evaporator 111, the working medium is not sufficiently evaporated, but only a part of the working medium is evaporated in the activation state. For this reason, the liquid working medium also flows out of the evaporator 111, but since the bypass valve 125a is opened, the working medium does not flow into the first expander 113, but is introduced into the condenser 114 so as to bypass the first expander 113. At this time, the screw rotor 113b of the first expander 113 idly rotates by the rotation of the rotary shaft 123.

[0121] Subsequently, when a difference in pressure obtained from the detection value of the entering side pressure sensor Ps and the detection value of the back pressure sensor Pd reaches a predetermined threshold value, the opening and closing control unit 152 performs control which closes the bypass valve 125a. Accordingly, the working medium which is evaporated by the evaporator 111 is introduced into the first expander 113, and the first expander 113 is driven by the working medium. Accordingly, the rotor portion 120a of the power generator 120 is driven by the driving forces of the first expander and the second expander 140. Subsequently, a general operation is performed.

[0122] As described above, in the power generating apparatus of the first embodiment, since the heating medium to be introduced into the evaporator 111 is expanded by the second expander 140, the pressure of the heating medium introduced into the evaporator 111 is lower than that of the related art. For this reason, the stress strain generated in the member constituting the evaporator 111 may be reduced, and hence the burden of the evaporator 111 may be reduced. Moreover, since the second expander 140 is connected to the rotary shaft 123 provided with the rotor portion 120a of the power generator 120, the energy of the heating medium may be extracted as the driving energy of the rotor portion 120a in the second expander 140. Accordingly, since the energy of the heating medium may be used any waste, the performance of the power generating apparatus may be improved. That is, the pressure of the heating medium is used in the second expander 140, and the temperature of the heating medium of which the pressure is decreased is used in the evaporator 111. Accordingly, the energy of the heating medium may be more effectively used compared to the related art.

[0123] Further, in the third embodiment, the bypass valve 25a is opened when the second expander 140 is driven at a timing earlier than that of the driving of the first expander 113 by the working medium. Accordingly, the screw rotor 113b of the first expander 113 may idly rotate. Accordingly, in a case where only the second expander 140 is driven among the first expander 113 and the second expander 140 connected to the power generator 120, the first expander 113 may not serve as a load, and the energy of the heating medium may be effectively extracted in the second expander 140.

[Fourth Embodiment]

[0124] FIG. 6 illustrates a rotary machine driving system according to a fourth embodiment of the present invention. Furthermore, the same reference numerals as those of the third embodiment will be given to the same components, and the description thereof will not be repeated.

[0125] In the third embodiment, the rotary shaft 123 is configured as one shaft member. On the contrary, in the fourth embodiment, the rotary shaft 123 is divided into a first shaft portion 123a and a second shaft portion 123b, and includes a coupling portion 123c which couples the first shaft portion 123a and the second shaft portion 123b to each other so as to transmit a driving force therethrough.

[0126] The coupling portion 123c is configured by a speed increasing and decreasing mechanism 161 which is provided between the first shaft portion 123a and the second shaft portion 123b so as to change the rotation speed. The speed increasing and decreasing mechanism 161 includes a first gear 161a which is connected to the first shaft portion 123a and a second gear 161b which is connected to the second shaft portion 123b and meshes with the first gear 161a. In the example, the number of teeth of the first gear 161a is larger than the number of teeth of the second gear 161b, but instead of this, the opposite configuration may be employed. Further, in the example, the first shaft portion 123a is provided with the power generator 120, but instead of this, the second shaft portion 123b may be provided with the power generator 120.

[0127] One end of the first shaft portion 123a is connected to the first expander 113. The first gear 161a is coupled to the other end of the first shaft portion 123a. The second expander 140 is connected to one end of the second shaft portion 123b. The second gear 161b is coupled to the other end of the second shaft portion 123b.

[0128] In the fourth embodiment, it is possible to easily handle a case where the rotation speed of the first expander 113 is different from the rotation speed of the second expander 140. That is, in a case where the first expander 113 and the second expander 140 are respectively configured as different types of expanders and the stated rotation speeds thereof are different from each other, it is possible to easily handle a difference between both rotation speeds by providing the speed increasing and decreasing mechanism 161 between the first shaft portion 123a and the second shaft portion 123b.

[0129] Furthermore, the other configurations and the other operations and effects are not described, but are the same as those of the third embodiment.

[Fifth Embodiment]

[0130] FIG. 7 illustrates a power generating apparatus according to a fifth embodiment of the present invention. Furthermore, the same reference numerals as those of the third embodiment will be given to the same components, and the description thereof will not be repeated.

[0131] In the fourth embodiment, the coupling portion 123c is configured as the speed increasing and decreasing mechanism 161. On the contrary, in the fifth embodiment, the coupling portion 123c is configured by a magnetic coupling 165 which magnetically couples the first shaft portion 123a and the second shaft portion 123b to each other.

[0132] Since the configuration of the magnetic coupling 165 is the same as the configuration of the first embodiment illustrated in FIG. 2, the detailed description thereof will not be repeated.

[0133] In the fifth embodiment, since the first shaft portion 123a accommodated in the casing 113a is axially supported by a bearing inside the casing 113a, it is possible to prevent a state where a fluid such as lubricating oil and a working medium leaks to the outside through the bearing and to connect the first shaft portion 123a and the second shaft portion 123b in a driven state by the magnetic coupling 165.

[0134] Furthermore, in the fifth embodiment, the second shaft portion 123b and the inner insertion body 165b are not accommodated in a hermetic body, but the second shaft portion 123b and the inner insertion body 165b may be also accommodated in a hermetic body.

[0135] Further, in the fifth embodiment, the outer cylinder body 165a of the magnetic coupling 165 serves as a driving side and the inner insertion body 165b serves as a driven side. However, the inner insertion body 165b may serve as a driving side and the outer cylinder body 165a may serve as a driven side.

[0136] The other configurations and the other operations and effects are not described, but are the same as those of the fourth embodiment.

[Sixth Embodiment]

[0137] FIG. 8 illustrates a power generating apparatus according to a sixth embodiment of the present invention. Furthermore, the same reference numerals as those of the third embodiment will be given to the same components, and the description thereof will not be repeated.

[0138] In the sixth embodiment, the water which is used in the condenser 114 is supplied as lubricant to a bearing 170 of the rotary shaft 123. That is, in the cooling medium circuit 117, the downstream passage of the condenser 114 is connected to the bearing 170 of the rotary shaft 123. Accordingly, the cooling medium which is used to cool the working medium in the cooling medium passage 114b of the condenser 114 may be used as lubricant of the bearing 170. In the example, the cooling medium is introduced into the bearing 170 disposed inside the second expander 140, but the bearing 170 may not be disposed inside the second expander 140.

[0139] In the sixth embodiment, lubricating oil does not need to be used, and it does not take time and effort when discarding lubricant (water).

[0140] Furthermore, the other configurations and the other operations and effects are not described, but are the same as those of the third embodiment.

[Seventh Embodiment]

[0141] FIG. 9 illustrates a power generating apparatus according to a seventh embodiment of the present invention. Furthermore, the same reference numerals as those of the third embodiment will be given to the same components, and the description thereof will not be repeated.

[0142] In the seventh embodiment, a rotor portion of a motor 200 is connected to the rotary shaft 123. That is, the rotor portion of the motor 200 is connected to the shaft member as a part of the rotary shaft 123, that is, the shaft member connected to the end (the right side of FIG. 9) opposite to the first expander 113 in the screw rotor 140a of the second expander 140. The motor 200 is exemplified as the rotary machine. The shaft 201 of the motor 200 is connected to a compressor 190, and the compressor 190 is driven by the rotation of the motor 200. The other configurations are the same as those of the third embodiment. When driving the compressor 190, the power of the first and second expanders 113 and 140 is transmitted to the compressor 190 through the rotary shaft 123 and the shaft 201 connected to the rotary shaft 123. As a result, it is possible to reduce power consumption compared to a case where the compressor 190 is driven only by the motor 200.

[Other Embodiments]

[0143] Furthermore, the present invention of the third to seventh embodiments is not limited to the above-described embodiments, and various modifications and improvements may be made without departing from the spirit of the present invention. For example, the evaporator 111 may include an evaporation portion which evaporates the working medium by heating the working medium to a saturation temperature or so and an overheat portion which keeps the working medium heated to the saturation temperature or so in the evaporation portion in an overheat state. In this case, the evaporation and the overheat portion may be separately provided or may be integrally provided. In the sixth embodiment, the water which is condensed from the steam in the evaporator 111 may be used as lubricant of the bearing 170 of the rotary shaft 123. In the seventh embodiment, the compressor 190 may be provided on the rotary shaft 123 so that the compressor 190 is directly driven by the rotary machine driving system.

[0144] Provided is a power generating apparatus capable of using power generated by a heat engine in combination with power of a driving source provided separately from the heat engine. In order to prevent a problem caused when activating and stopping the apparatus, the apparatus of the present invention includes a rotary machine driving source which generates a rotational driving force for a rotary machine and a heat engine which drives the rotary machine in cooperation with the rotary machine driving source, wherein the heat engine includes an expander which expands an evaporated working medium so as to generate a rotational driving force, the expander is provided with a bypass pipe which causes a working medium inlet of the expander to communicate with a working medium outlet thereof, and the bypass pipe is provided with an on-off valve which opens and closes the bypass pipe.

Claims

1. A power generating apparatus comprising:

a rotary machine driving source which generates a rotational driving force for a rotary machine; and
a heat engine which drives the rotary machine in corporation with the rotary machine driving source,
wherein the heat engine includes an expander which expands an evaporated working medium so as to generate a rotational driving force,
wherein the expander is provided with a bypass pipe which causes a working medium inlet of the expander to communicate with a working medium outlet thereof, and
wherein the bypass pipe is provided with an on-off valve which opens and closes the bypass pipe.

2. The power generating apparatus according to claim 1, further comprising:

a control device which controls an opening and closing operation of the on-off valve,
wherein when activating the rotary machine driving source and the heat engine, the control device performs control which opens the on-off valve so that the working medium flows into the bypass pipe, activates the rotary machine driving source, and closes the on-off valve when it is determined that the working medium flowing into the expander is evaporated.

3. The power generating apparatus according to claim 2, further comprising:

a suction pressure detector which detects a suction pressure of the expander,
wherein the control device determines that the working medium flowing into the expander is evaporated when a pressure value detected by the suction pressure detector becomes a predetermined pressure value or more.

4. The power generating apparatus according to claim 2, further comprising:

a suction pressure detector which detects a suction pressure of the expander; and
an discharge pressure detector which detects an discharge pressure of the expander,
wherein the control device determines that the working medium flowing into the expander is evaporated when a differential pressure between a pressure value detected by the suction pressure detector and a pressure value detected by the discharge pressure detector becomes a predetermined value or more.

5. The power generating apparatus according to claim 2,
wherein the rotary machine is a gas compressor,
wherein the power generating apparatus further comprises a temperature detector which detects an exhaust gas temperature of the gas compressor, and
wherein the control device determines that the working medium flowing into the expander is evaporated when a temperature value detected by the temperature detector becomes a predetermined temperature value or more.

6. The power generating apparatus according to claim 2,
wherein the control device includes a time measuring unit which measures an elapse time from the activation of the rotary machine driving source, and
wherein the control device determines that the working medium flowing into the expander is evaporated when the elapse time detected by the time measuring unit becomes a predetermined time or more.

7. The power generating apparatus according to claim 1, further comprising:

a control device which controls an opening and closing operation of the on-off valve,
wherein when stopping the rotary machine driving source and the heat engine, the control device performs control which opens the on-off valve so that the working medium flows into the bypass pipe and the driving operation of the expander is stopped.

8. The power generating apparatus according to claim 1, further comprising:

a control device which controls an opening and closing operation of the on-off valve,
wherein when the rotary machine driving source is stopped under the state where the rotary machine driving source and the heat engine are normally operated, the control device performs control which opens the on-off valve so that the working medium flows into the bypass pipe and the driving operation of the expander is stopped.

9. The power generating apparatus according to claim 1,
wherein the rotary machine is a compressor which compresses a gas supplied thereto in a high pressure state and the rotary machine driving source is a motor, and
wherein heat of a high-pressure gas produced by the compressor is used as a heat source for a working medium in an evaporator of the heat engine.

10. The power generating apparatus according to claim 1,
wherein the rotary machine driving source is a second expander which generates power by expanding a heating medium as steam, and
wherein an evaporator of the heat engine heats and evaporates the working medium by the heating medium expanded by the second expander.

11. The power generating apparatus according to claim 10, further comprising:

a first shaft portion which is connected to a rotary shaft of the heat engine;
a second shaft portion which is connected to a rotary shaft of the second expander; and
a coupling portion which couples the first shaft portion and the second shaft portion to each other so that a driving force is transmitted through the coupled shaft portions,
wherein the coupling portion is configured as a speed increasing and decreasing mechanism which is provided between the first shaft portion

and the second shaft portion so as to change a rotation speed.

12. The power generating apparatus according to claim 10, wherein water used in a condenser of the heat engine or water condensed from the steam in the evaporator of the heat engine is supplied as lubricant to a bearing of the rotary shaft of the second expander.

13. The power generating apparatus according to claim 1, further comprising:

a first shaft portion which is connected to a rotary shaft of the heat engine;
a second shaft portion which is connected to a rotary shaft of the rotary machine driving source; and
a coupling portion which couples the first shaft portion and the second shaft portion to each other so that a driving force is transmitted through the coupled shaft portions,
wherein at least one of the first shaft portion and the second shaft portion is accommodated inside a hermetic body, and
wherein the coupling portion is configured as a magnetic coupling which magnetically couples the first shaft portion and the second shaft portion to each other.

14. A method of operating the power generating apparatus according to claim 1, wherein when activating the heat engine and the rotary machine driving source, the on-off valve is opened so as to cause the working medium to flow into the bypass pipe, the heat engine and the rotary machine driving source are activated, and the on-off valve of the bypass pipe is closed when it is determined that the working medium flowing into the expander is evaporated, and wherein when stopping the heat engine and the rotary machine driving source, the on-off valve is opened so as to cause the working medium to flow into the bypass pipe and the driving operation of the expander is stopped.

15. The method of operating the power generating apparatus according to claim 1, wherein when the rotary machine driving source is stopped under the state where the rotary machine driving source is normally operated, the on-off valve is opened so as to cause the working medium to flow into the bypass pipe and the driving operation of the expander is stopped.

FIG.1

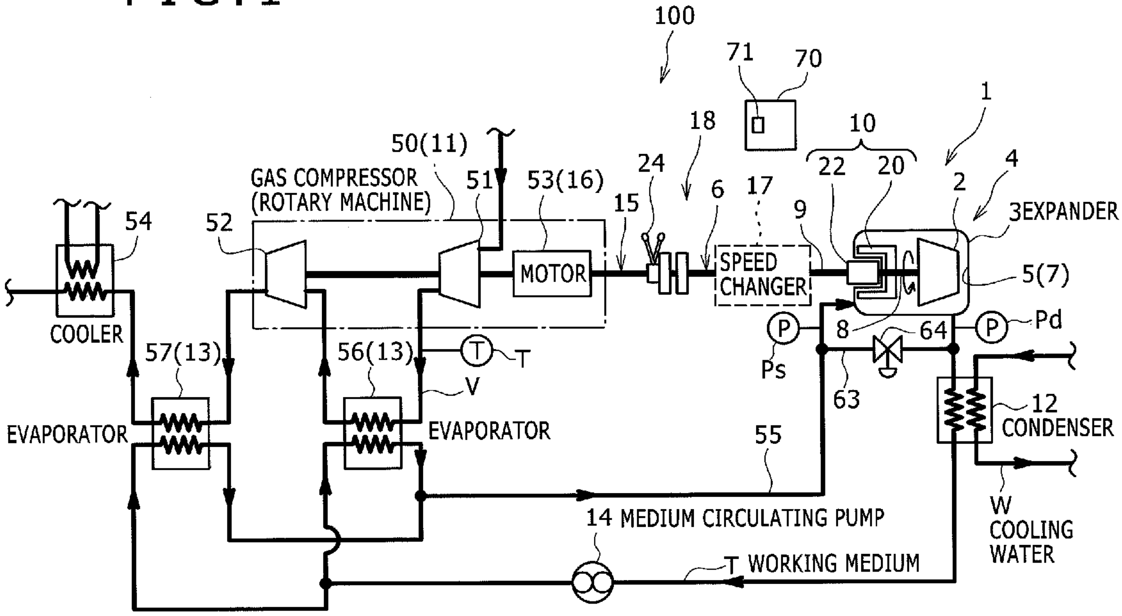

100
71
70
1
18
10
50(11)
24
22
20
4
GAS COMPRESSOR
(ROTARY MACHINE)
51
53(16)
6
17
2
3EXPANDER
54
52
15
9
MOTOR
SPEED
CHANGER
5(7)
COOLER
57(13)
56(13)
T
8
64
Pd
Ps
63
V
12
CONDENSER
EVAPORATOR
EVAPORATOR
55
14 MEDIUM CIRCULATING PUMP
W
COOLING
WATER
T WORKING MEDIUM

FIG. 2

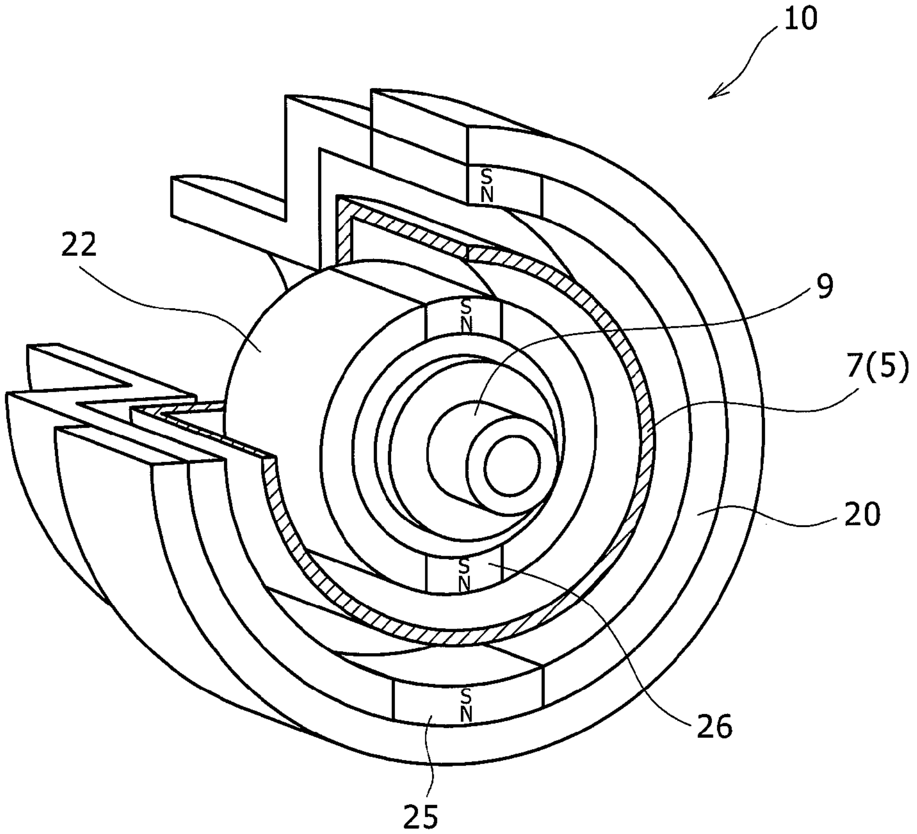


FIG. 3

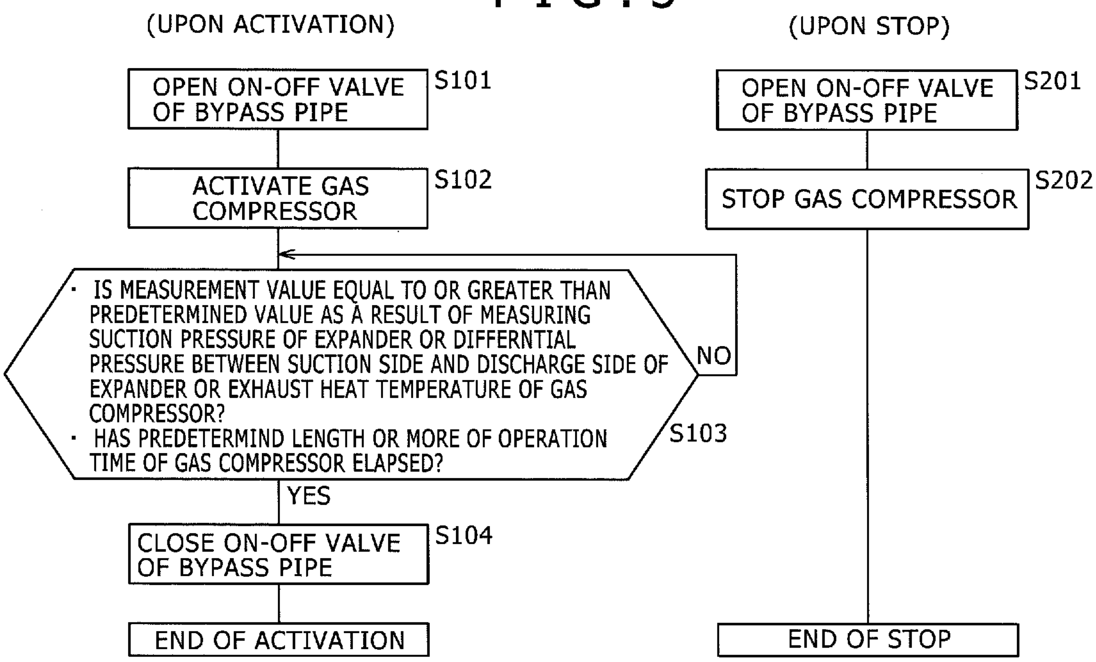

(UPON ACTIVATION)
OPEN ON-OFF VALVE OF BYPASS PIPE
S101
ACTIVATE GAS COMPRESSOR
S102
· IS MEASUREMENT VALUE EQUAL TO OR GREATER THAN PREDETERMINED VALUE AS A RESULT OF MEASURING SUCTION PRESSURE OF EXPANDER OR DIFFERNTIAL PRESSURE BETWEEN SUCTION SIDE AND DISCHARGE SIDE OF EXPANDER OR EXHAUST HEAT TEMPERATURE OF GAS COMPRESSOR?
· HAS PREDETERMIND LENGTH OR MORE OF OPERATION TIME OF GAS COMPRESSOR ELAPSED?
NO
S103
YES
CLOSE ON-OFF VALVE OF BYPASS PIPE
S104
END OF ACTIVATION
(UPON STOP)
OPEN ON-OFF VALVE OF BYPASS PIPE
S201
STOP GAS COMPRESSOR
S202
END OF STOP

FIG.4

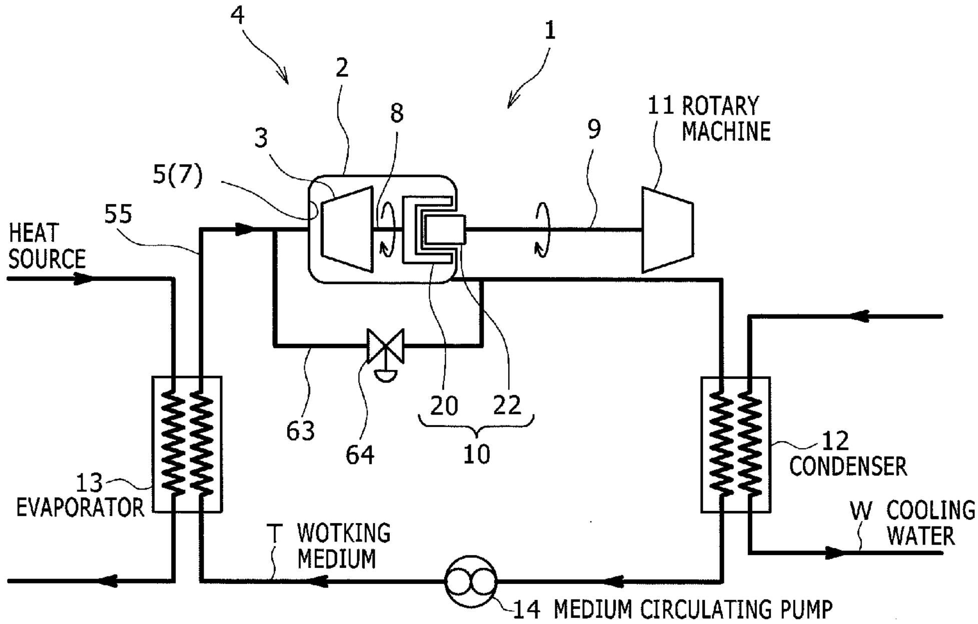

4
1
2
8
11 ROTARY MACHINE
9
3
5(7)
55
HEAT SOURCE
63
64
20
22
10
12
CONDENSER
13
EVAPORATOR
T WOTKING MEDIUM
W COOLING WATER
14 MEDIUM CIRCULATING PUMP

FIG.5

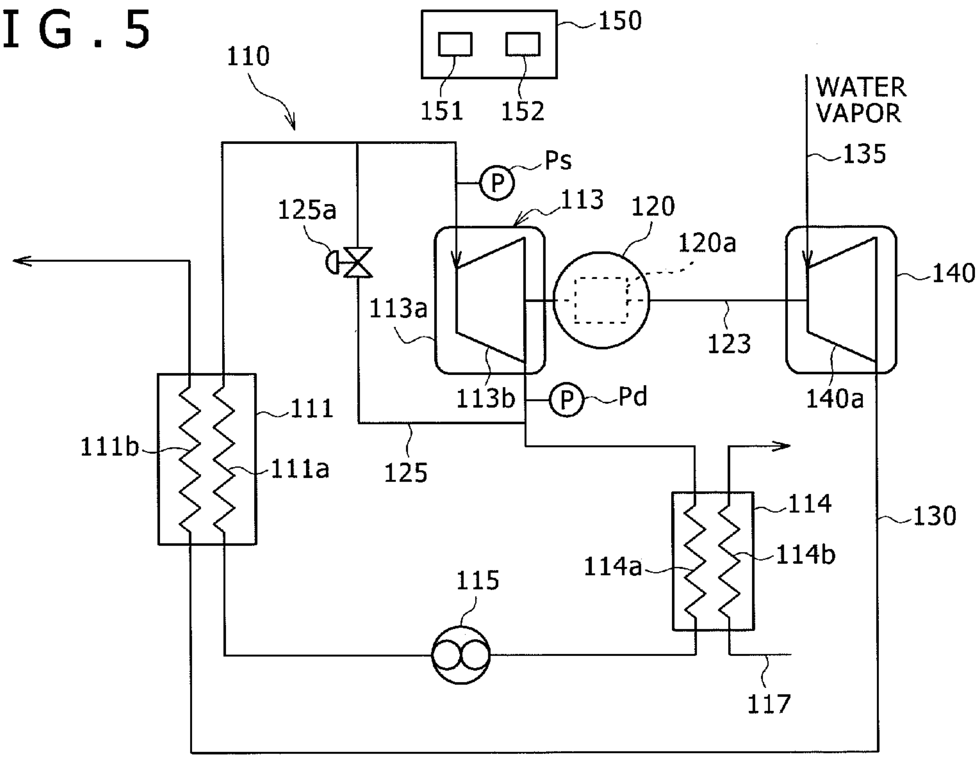
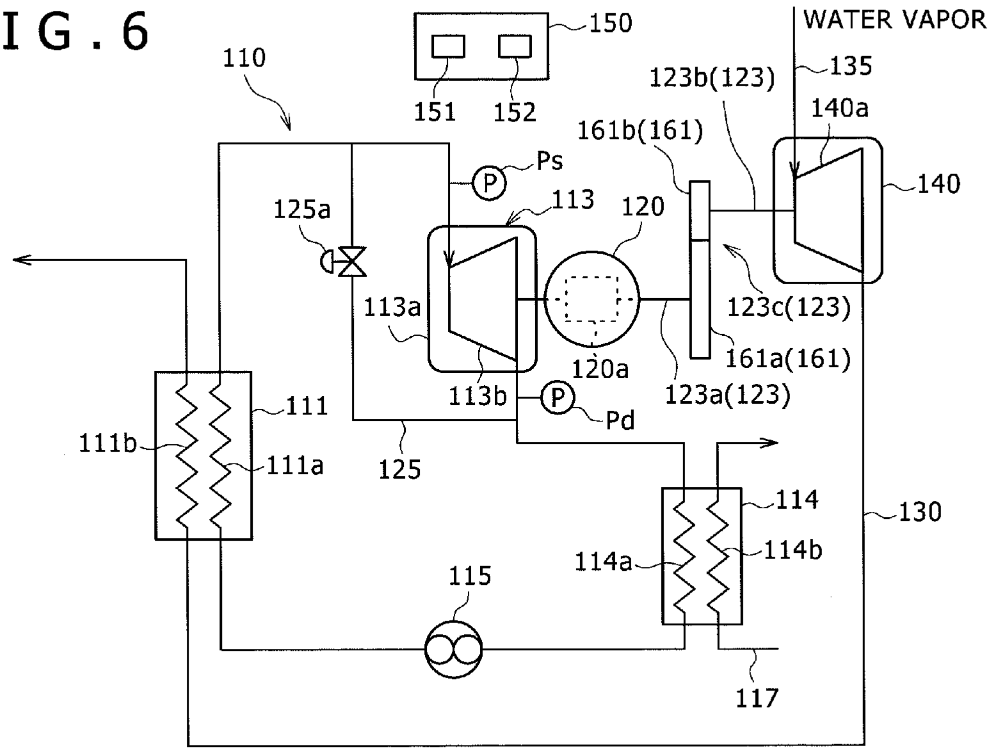

150
151
152
110
WATER
VAPOR
135
Ps
113
120
120a
125a
140
113a
123
113b
Pd
140a
111
111b
111a
125
114
130
114b
114a
115
117

FIG. 6



150
151
152
WATER VAPOR
110
123b(123)
135
140a
161b(161)
Ps
140
113
120
125a
123c(123)
113a
161a(161)
120a
113b
123a(123)
Pd
111
111b
111a
125
114
130
114b
114a
115
117

FIF.7

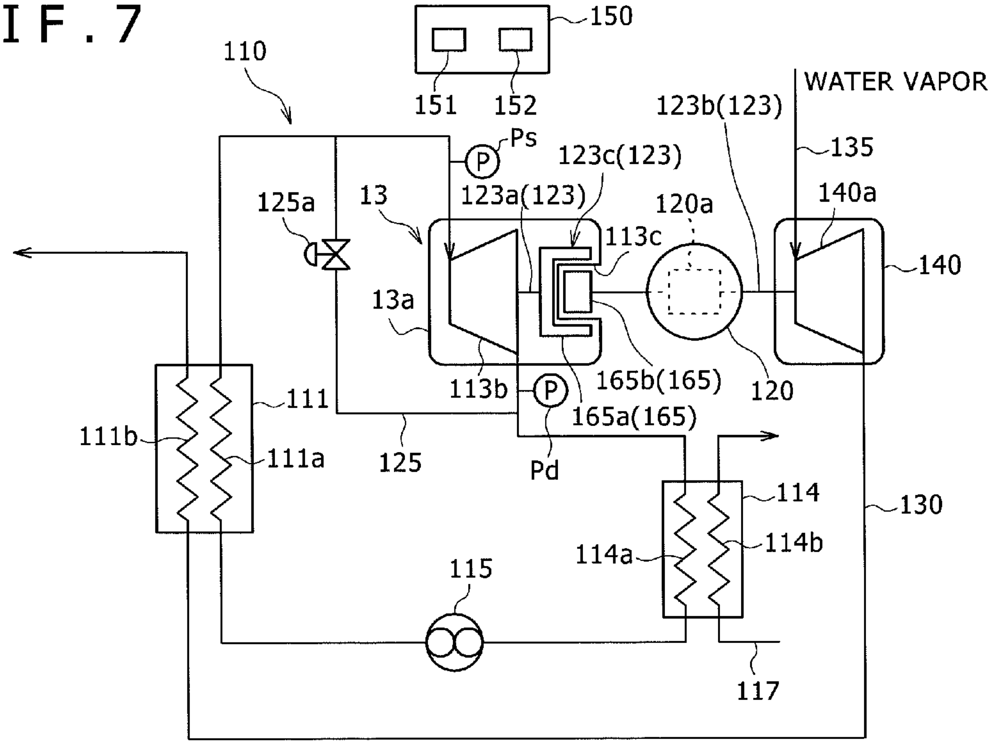

150
151
152
110
WATER VAPOR
123b(123)
Ps
135
123c(123)
125a
13
123a(123)
120a
140a
113c
140
13a
113b
165b(165)
120
111
165a(165)
111b
111a
125
Pd
114
130
114a
114b
115
117

FIG.8

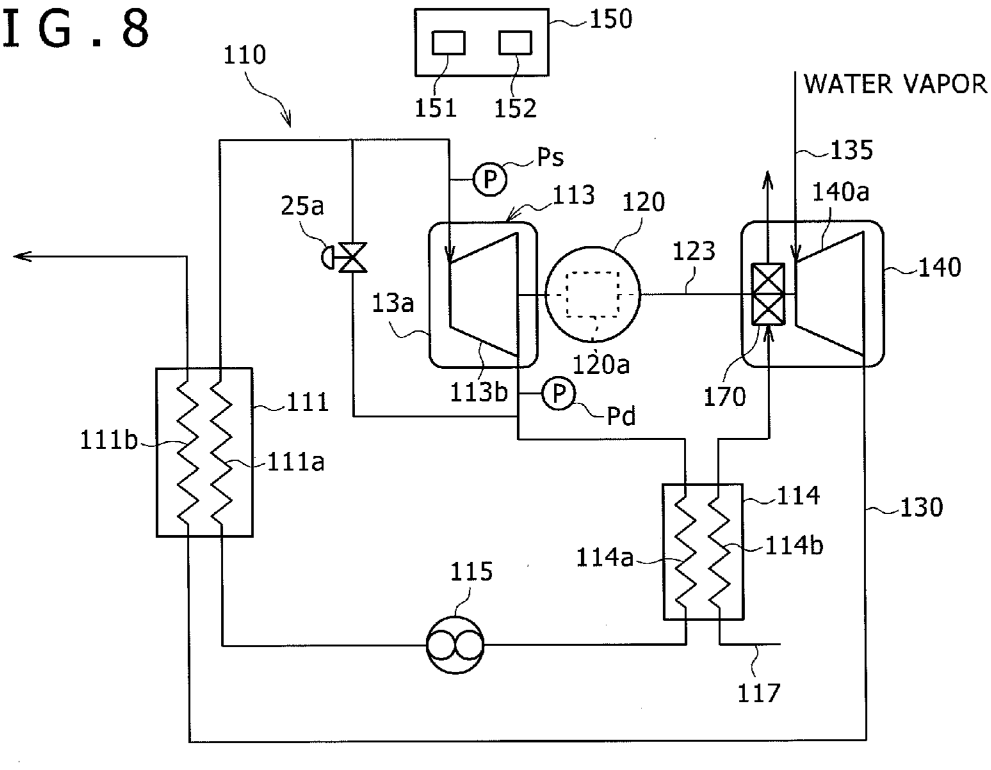
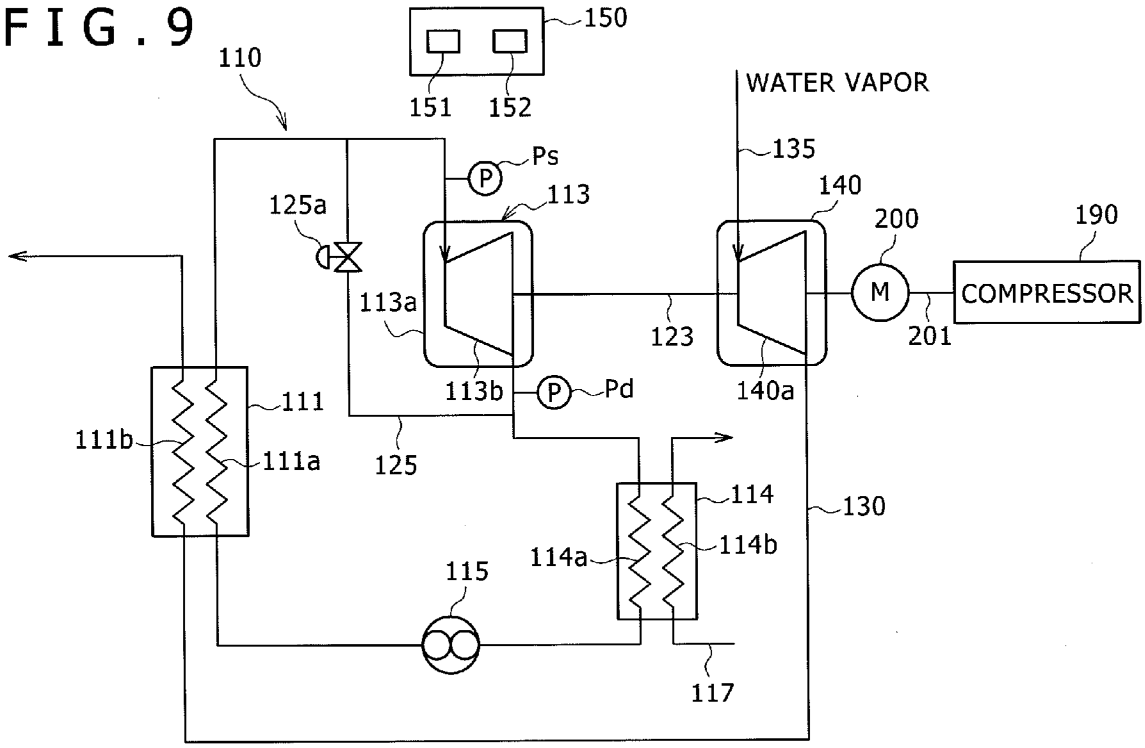

150
151
152
110
WATER VAPOR
135
Ps
113
120
140a
25a
123
140
13a
120a
113b
170
111
Pd
111b
111a
114
130
114a
114b
115
117

FIG. 9



110
150
151
152
WATER VAPOR
135
140
Ps
113
125a
200
190
COMPRESSOR
113a
123
201
113b
Pd
140a
111
111b
111a
125
114
130
114a
114b
115
117

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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