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(54) **RANKINE CYCLE SYSTEM**

(57) A Rankine cycle system includes a refrigerant pump which is mounted on an engine and is configured to feed refrigerant, a heat exchanger which is mounted on the engine and is configured to recover exhaust heat of the engine to the refrigerant, an expander which is mounted on the engine and is configured to convert the exhaust heat recovered to the refrigerant into power by expanding the refrigerant whose temperature has been increased by the heat exchanger, and a condenser which is mounted on a vehicle body and is configured to condense the refrigerant expanded by the expander. The expander and the condenser, and the condenser and the refrigerant pump are connected by flexible pipes having higher flexibility than other pipes.

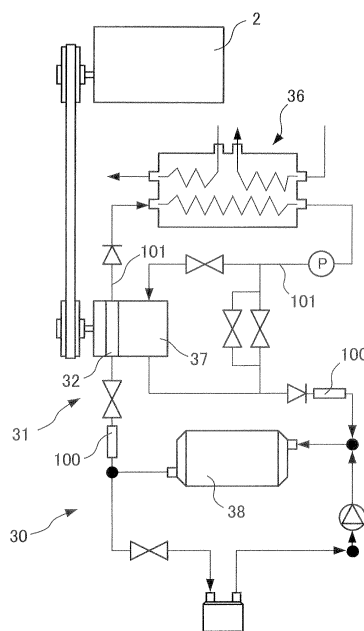


FIG. 8

Description

TECHNICAL FIELD

[0001] The present invention relates to a Rankine cycle system. 5

BACKGROUND ART

[0002] Conventionally, it is disclosed in JP2001-182504A to mount an evaporator and an expander on an engine in an on-vehicle Rankine cycle system. 10

SUMMARY OF INVENTION

[0003] The evaporator and the expander are connected to another member, e.g. a condenser mounted on a vehicle body via pipes. Since a member mounted on an engine and a member mounted on the vehicle body differ in vibration frequency, the member mounted on the engine and that mounted on the vehicle body are connected by a flexible pipe. Since flexible pipes are more expensive than pipes having high rigidity such as stainless steel pipes and aluminum pipes, the usage thereof is preferably reduced. 15 20 25

[0004] However, in the above invention, no consideration is made on such a point and there is a problem of increasing the cost of the Rankine cycle system.

[0005] The present invention was developed to solve the above problem and aims to reduce the cost of a Rankine cycle system by reducing the usage of flexible pipes. 30

[0006] A Rankine cycle system according to one aspect of the present invention includes a refrigerant pump which is mounted on an engine and is configured to feed refrigerant, a heat exchanger which is mounted on the engine and is configured to recover exhaust heat of the engine to the refrigerant, an expander which is mounted on the engine and is configured to convert the exhaust heat recovered to the refrigerant into power by expanding the refrigerant whose temperature has been increased by the heat exchanger, and a condenser which is mounted on a vehicle body and is configured to condense the refrigerant expanded by the expander. In the Rankine cycle system, the expander and the condenser, and the condenser and the refrigerant pump are connected by flexible pipes having higher flexibility than other pipes. 35 40 45

[0007] Embodiments of the present invention and advantages thereof are described in detail below with reference to the accompanying drawings. 50

BRIEF DESCRIPTION OF DRAWINGS

[0008]

FIG. 1 is a schematic configuration diagram of an integrated cycle of a first embodiment of the present invention,

FIG. 2A is a schematic sectional view of an expander pump formed by integrating a pump and an expander,

FIG. 2B is a schematic sectional view of a refrigerant pump,

FIG. 2C is a schematic sectional view of an expander,

FIG. 3 is a schematic diagram showing functions of refrigeration system valves,

FIG. 4 is a schematic configuration diagram of a hybrid vehicle,

FIG. 5 is a schematic perspective view of an engine,

FIG. 6 is a schematic diagram showing an arrangement of an exhaust pipe when the vehicle is viewed from below,

FIG. 7A is a characteristic graph of a Rankine cycle operating region,

FIG. 7B is a characteristic graph of a Rankine cycle operating region,

FIG. 8 is a view diagrammatically showing a state of pipes of the integrated cycle of the first embodiment,

FIG. 9 is a schematic configuration diagram of a hybrid vehicle of a second embodiment of the present invention,

FIG. 10 is a schematic configuration diagram of an integrated cycle of the second embodiment of the present invention,

FIG. 11 is a view diagrammatically showing a state of pipes of the integrated cycle of the second embodiment, and

FIG. 12 is a view diagrammatically showing a state of pipes of an integrated cycle of a third embodiment.

DESCRIPTION OF EMBODIMENTS

[0009] FIG. 1 is a schematic configuration diagram showing an entire system of a Rankine cycle 31 which is a premise of the present invention. The Rankine cycle 31 of FIG. 1 is configured to share refrigerant and a condenser 38 with a refrigeration cycle 51 and a Rankine cycle system obtained by integrating the Rankine cycle 31 and the refrigeration cycle 51 is referred to as an integrated cycle 30 hereinafter. FIG. 4 is a schematic configuration diagram of a hybrid vehicle 1 in which the integrated cycle 30 is mounted. It should be noted that the integrated cycle 30 indicates the entire system including a circuit (passages) for cooling water and exhaust air in addition to a circuit (passages) in which the refrigerant of the Rankine cycle 31 and the refrigeration cycle 51 is circulated and constituent elements such as pumps, expanders and condensers provided at intermediate positions of the circuit. 45 50

[0010] In the hybrid vehicle 1, an engine 2, a motor generator 81 and an automatic transmission 82 are coupled in series and an output of the automatic transmission 82 is transmitted to drive wheels 85 via a propeller shaft 83 and a differential gear 84. A first drive shaft clutch 86 is provided between the engine 2 and the motor generator

81. Further, one of frictional engagement elements of the automatic transmission 82 is configured as a second drive shaft clutch 87. The first and second drive shaft clutches 86, 87 are connected to an engine controller 71, and connection and disconnection (connected state) thereof are controlled according to a driving condition of the hybrid vehicle 1. In the hybrid vehicle 1, as shown in FIG. 7B, when a vehicle speed is in an EV running region where the efficiency of the engine 2 is poor, the engine 2 is stopped, the first drive shaft clutch 86 is disengaged and the second drive shaft clutch 87 is connected, whereby the hybrid vehicle 1 is caused to run only by a drive force by the motor generator 81. On the other hand, when the vehicle speed deviates from the EV running region and transitions to a Rankine cycle operating region, the Rankine cycle 31 (to be described later) is operated by driving the engine 2. The engine 2 includes an exhaust passage 3, which is composed of an exhaust manifold 4 and an exhaust pipe 5 connected to a collection part of the exhaust manifold 4. The exhaust pipe 5 is branched off into a bypass exhaust pipe 6 at an intermediate position and an exhaust heat recovery device 22 for heat exchange between exhaust air and cooling water is provided in a section of the exhaust pipe 5 bypassed by the bypass exhaust pipe 6. The exhaust heat recovery device 22 and the bypass exhaust pipe 6 are united into an exhaust heat recovery unit 23 and arranged between an underfloor catalyst 88 and a sub-muffler 89 downstream of the underfloor catalyst 88 as shown in FIG. 6.

[0011] The engine 2 is mounted on the vehicle body by being fixed to a frame member forming a vehicle body skeleton of the hybrid vehicle 1 via an unillustrated engine mount. The engine mount functions to reduce (damp) vibration transmitted between the engine 2 and the vehicle body and makes it difficult to transmit the vibration of the engine 2 to the vehicle body and the vibration of the vehicle body to the engine 2. As a result, the engine 2 and the vehicle body produce different types of vibration, wherefore an engine 2 side component fixed to the engine 2 and a vehicle body side component fixed to the vehicle body also produce different types of vibration. Even components generally connected by a connecting component having high rigidity need to be connected by a connecting component having high flexibility (excellent in flexibility) to absorb relative displacements caused by vibration when they are separately mounted on the engine 2 and the vehicle body.

[0012] First, an engine cooling water circuit is described based on FIG. 1. Cooling water of about 80 to 90°C coming out from the engine 2 separately flows in a cooling water passage 13 passing through a radiator 11 and a bypass cooling water passage 14 bypassing the radiator 11. Thereafter, two flows join again in a thermostat valve 15 for determining an allocation of cooling water flow rates in the both passages 13, 14 and are further returned to the engine 2 by way of a cooling water pump 16. The cooling water pump 16 is driven by the engine 2 and a rotation speed thereof is synchronized with an en-

gine rotation speed. The thermostat valve 15 relatively increases an amount of the cooling water passing through the radiator 11 by increasing a valve opening on the side of the cooling water passage 13 when a cooling water temperature is high, and relatively decreases the amount of the cooling water passing through the radiator 11 by reducing the valve opening on the side of the cooling water passage 13 when the cooling water temperature is low. When the cooling water temperature is particularly low such as before the warm-up of the engine 2, a total amount of the cooling water flows in the bypass cooling water passage 14 while completely bypassing the radiator 11. On the other hand, the valve opening on the side of the bypass cooling water passage 14 is not completely closed, and the thermostat valve 15 is configured not to completely stop the flow although a flow rate of the cooling water flowing in the bypass cooling water passage 14 decreases as compared with the case where the total amount of the cooling water flows in the bypass cooling water passage 14 when a flow rate of the cooling water flowing through the radiator 11 increases. The bypass cooling water passage 14 bypassing the radiator 11 is composed of a first bypass cooling water passage 24 branched off from the cooling water passage 13 and directly connected to a heat exchanger 36 to be described later and a second bypass cooling water passage 25 branched off from the cooling water passage 13 and connected to the heat exchanger 36 by way of the exhaust heat recovery device 22.

[0013] The heat exchanger 36 for performing heat exchange with the refrigerant of the Rankine cycle 31 is provided in the bypass cooling water passage 14. This heat exchanger 36 is formed by integrating an evaporator and a superheater. Specifically, in the heat exchanger 36, two cooling water passages 36a, 36b are arranged substantially in a row and a refrigerant passage 36c in which the refrigerant of the Rankine cycle 31 flows is provided adjacent to the cooling water passages 36a, 36b so as to enable heat exchange between the refrigerant and the cooling water. Further, each passage 36a, 36b, 36c is so configured that the refrigerant of the Rankine cycle 31 and the cooling water flow in opposite directions when the entire heat exchanger 36 is viewed from above.

[0014] In detail, one cooling water passage 36a located on an upstream side (left side of FIG. 1) for the refrigerant of the Rankine cycle 31 is inserted in the first bypass cooling water passage 24. This cooling water passage 36a and a left part of the heat exchanger formed by a refrigerant passage part adjacent to this cooling water passage 36a constitute the evaporator for heating the refrigerant of the Rankine cycle 31 flowing in the refrigerant passage 36c by directly introducing the cooling water coming out from the engine 2 to the cooling water passage 36a.

[0015] The cooling water having passed through the exhaust heat recovery device 22 via the second bypass cooling water passage 25 is introduced to the other cool-

ing water passage 36b on a downstream side (right side of FIG. 1) for the refrigerant of the Rankine cycle 31. This cooling water passage 36b and a right part (downstream side for the refrigerant of the Rankine cycle 31) of the heat exchanger formed by a refrigerant passage part adjacent to this cooling water 36b constitute the superheater for overheating the refrigerant flowing in the refrigerant passage 36c by introducing the cooling water obtained by further heating the cooling water at the exit of the engine 2 by the exhaust air to the cooling water passage 36b.

[0016] A cooling water passage 22a of the exhaust heat recovery device 22 is provided adjacent to the exhaust pipe 5. By introducing the cooling water at the exit of the engine 2 to the cooling water passage 22a of the exhaust heat recovery device 22, the cooling water can be heated, for example, up to 110 to 115°C by the high-temperature exhaust air. The cooling water passage 22a is so configured that the exhaust air and the cooling water flow in opposite directions when the entire exhaust heat recovery device 22 is viewed from above.

[0017] A control valve 26 is disposed in the second bypass cooling water passage 25 including the exhaust heat recovery device 22. An opening of this control valve 26 is reduced when a temperature detected by a cooling water temperature sensor 74 at the exit of the engine 2 reaches a predetermined value or higher so that an engine water temperature indicating the temperature of the cooling water in the engine 2 does not exceed a permissible temperature (e.g. 100°C) for preventing, for example, efficiency deterioration of the engine 2 and the occurrence of knocking. When the engine water temperature approaches the permissible temperature, the amount of the cooling water passing through the exhaust heat recovery device 22 is reduced. This can reliably prevent the engine water temperature from exceeding the permissible temperature.

[0018] On the other hand, if the cooling water temperature increased by the exhaust heat recovery device 22 becomes too high and the cooling water evaporates (boils) due to a reduction in the flow rate of the second bypass cooling water passage 25, the flow of the cooling water in the cooling water passage may become poor and component temperatures may excessively increase. To avoid this, the bypass exhaust pipe 6 bypassing the exhaust heat recovery device 22 is provided and a thermostat valve 7 for controlling an amount of the exhaust air passing through the exhaust heat recovery device 22 and an amount of the exhaust air passing through the bypass exhaust pipe 6 is provided in a branched part of the bypass exhaust pipe 6. Specifically, a valve opening of the thermostat valve 7 is adjusted based on the temperature of the cooling water coming out from the exhaust heat recovery device 22 so that the temperature of the cooling water coming out from the exhaust heat recovery device 22 does not exceed a predetermined temperature (e.g. boiling temperature of 120°).

[0019] The heat exchanger 36, the thermostat valve 7

and the exhaust heat recovery device 22 are united into the exhaust heat recovery unit 23 and arranged at intermediate positions of the exhaust pipe under a substantially central part of a floor in a vehicle width direction.

The thermostat valve 7 may be a relatively simple temperature sensitive valve using a bimetal or the like or may be a control valve controlled by a controller to which a temperature sensor output is input. Since an adjustment of a heat exchange amount from the exhaust air into the cooling water by the thermostat valve 7 causes a relatively long delay, it is difficult to prevent the engine water temperature from exceeding the permissible temperature if the thermostat valve 7 is singly adjusted. However, since the control valve 26 in the second bypass cooling water passage 25 is controlled based on the engine water temperature (exit temperature), a heat recovery amount can be quickly reduced to reliably prevent the engine water temperature from exceeding the permissible temperature. Further, if there is a margin between the engine water temperature and the permissible temperature, an exhaust heat recovery amount can be increased by performing heat exchange until the temperature of the cooling water coming out from the exhaust heat recovery device 22 reaches a high temperature (e.g. 110 to 115°C) exceeding the permissible temperature of the engine water temperature. The cooling water coming out from the cooling water passage 36b joins the first bypass cooling water passage 24 via the second bypass cooling water passage 25.

[0020] If the temperature of the cooling water flowing from the bypass cooling water passage 14 toward the thermostat valve 15 is sufficiently reduced, for example, by heat exchange with the refrigerant of the Rankine cycle 31 in the heat exchanger 36, the valve opening of the thermostat valve 15 on the side of the cooling water passage 13 is reduced and the amount of the cooling water passing through the radiator 11 is relatively reduced. Conversely, if the temperature of the cooling water flowing from the bypass cooling water passage 14 toward the thermostat valve 15 is increased such as because the Rankine cycle 31 is not operated, the valve opening of the thermostat valve 15 on the side of the cooling water passage 13 is increased and the amount of the cooling water passing through the radiator 11 is relatively increased. Based on such an operation of the thermostat valve 15, the cooling water temperature of the engine 2 is appropriately maintained and heat is appropriately supplied (recovered) to the Rankine cycle 31.

[0021] Next, the Rankine cycle 31 is described. Here, the Rankine cycle 31 is configured not as a simple Rankine cycle, but as a part of the integrated cycle 30 integrated with the refrigeration cycle 51. The Rankine cycle 31 as a basis is described first and the refrigeration cycle 51 is then mentioned.

[0022] The Rankine cycle 31 is a system for recovering the exhaust heat of the engine 2 by the refrigerant using the cooling water of the engine 2 and regenerating the recovered exhaust heat as power. The Rankine cycle 31

includes a refrigerant pump 32, the heat exchanger 36 as a superheater, an expander 37 and the condenser 38 and each constituent element is connected by refrigerant passages 41 to 44 in which the refrigerant (R134a, etc.) is circulated. The refrigerant passages 41 to 44 are generally formed by ordinary metal pipes (steel pipes) which easily ensure refrigerant sealability and have relatively high rigidity, but flexible pipes having high flexibility are used as some of them in the present embodiment. This is described in detail later.

[0023] A shaft of the refrigerant pump 32 is arranged to be coupled to an output shaft of the expander 37 on the same axis, the refrigerant pump 32 is driven by an output (power) generated by the expander 37 and the generated power is supplied to an output shaft (crankshaft) of the engine 2 (see FIG. 2A). The shaft of the refrigerant pump 32 and the output shaft of the expander 37 are arranged in parallel with the output shaft of the engine 2, and a belt 34 is mounted between a pump pulley 33 provided on the tip of the shaft of the refrigerant pump 32 and a crank pulley 2a (see FIG. 1). Specifically, the output shaft of the expander 37 and that of the engine 2 are configured to be able to transmit power. It should be noted that, in the present embodiment, a gear-type pump is used as the refrigerant pump 32 and a scroll type expander is used as the expander 37 (see FIGS. 2B, 2C). The refrigerant pump 32 and the expander 37 are mounted on the engine 2 as shown in FIG. 5.

[0024] An electromagnetic clutch (hereinafter, this clutch is referred to as an "expander clutch") 35 (first clutch) is provided between the pump pulley 33 and the refrigerant pump 32 to make the refrigerant pump 32 and the expander 37 connectable to and disconnectable from the engine 2 (see FIG. 2A). Thus, by connecting the expander clutch 35 when the output generated by the expander 37 exceeds a drive force of the refrigerant pump 32 and the friction of a rotating body (predicted expander torque is positive), the rotation of the engine output shaft can be assisted by the output generated by the expander 37. By assisting the rotation of the engine output shaft using energy obtained by exhaust heat recovery in this way, fuel economy can be improved. Further, energy for driving the refrigerant pump 32 for circulating the refrigerant can also be generated using the recovered exhaust heat. It should be noted that the expander clutch 35 may be provided at any intermediate position of a power transmission path from the engine 2 to the refrigerant pump 32 and the expander 37.

[0025] The refrigerant from the refrigerant pump 32 is supplied to the heat exchanger 36 via the refrigerant passage 41. The heat exchanger 36 is a heat exchanger for performing heat exchange between the cooling water of the engine 2 and the refrigerant and evaporating and overheating the refrigerant.

[0026] The refrigerant from the heat exchanger 36 is supplied to the expander 37 via the refrigerant passage 42. The expander 37 is a steam turbine for converging heat into rotational energy by expanding the evaporated

and overheated refrigerant. The power recovered by the expander 37 drives the refrigerant pump 32 and is transmitted to the engine 2 via a belt transmission mechanism to assist the rotation of the engine 2.

[0027] The refrigerant from the expander 37 is supplied to the condenser 38 via refrigerant passages 43a, 43b. The condenser 38 is a heat exchanger for performing heat exchange between outside air and the refrigerant and cooling and liquefying the refrigerant. Thus, the condenser 38 is arranged in parallel with the radiator 11 and cooled by a radiator fan 12. The condenser 38 is mounted on the vehicle body.

[0028] The refrigerant passage 43a is connected to the expander 37. The refrigerant passage 43b connects the refrigerant passage 43a and the condenser 38. The refrigerant passages 43a, 43b are connected at a refrigeration cycle junction 46 to be described later.

[0029] The refrigerant passage 43a connecting the engine 2 side component and the vehicle body side component is a flexible pipe for refrigerant having higher flexibility than the refrigerant passage 43b to absorb a relative displacement caused by vibration. High flexibility means low rigidity and being freely deformable. To provide flexibility, the flexible pipe has a bellows-like shape or is made of a material which is soft and excellent in flexibility. Thus, the refrigerant passage 43a can be freely bent at any intermediate position and can absorb vibration if the vibration is transmitted. A part of the refrigerant passage 43a on the side of the expander 37 mounted on the engine 2 vibrates together with the engine 2 and the expander 37.

[0030] The refrigerant passage 43b is a pipe connected to the condenser 38 and having lower flexibility, i.e. higher rigidity than the refrigerant passage 43a such as a stainless steel pipe or an aluminum pipe. The refrigerant passage 43b vibrates together with the condenser 38 mounted on the vehicle body.

[0031] The refrigerant passage 43a is connected to the expander 37 mounted on the engine 2. Further, the refrigerant passage 43b is connected to the condenser 38 mounted on the vehicle body. Thus, when the vehicle is driven, a vibration frequency of the refrigerant passage 43a and that of the refrigerant passage 43b differ. In the present embodiment, the refrigerant passage 43a is formed by a flexible pipe for refrigerant, whereby a vibrational difference between the part of the refrigerant passage 43a on the side of the engine 2 and the refrigerant passage 43b is absorbed by the refrigerant passage 43a.

[0032] The refrigerant liquefied by the condenser 38 is returned to the refrigerant pump 32 via refrigerant passages 44a, 44b. The refrigerant returned to the refrigerant pump 32 is fed to the heat exchanger 36 again by the refrigerant pump 32 and circulates through each constituent element of the Rankine cycle 31.

[0033] The refrigerant passage 44a is connected to the condenser 38. The refrigerant passage 44b connects the refrigerant passage 43a and the refrigerant pump 32. The refrigerant passages 44a, 44b are connected at a refrigeration cycle junction 46 to be described later.

eration cycle junction 45 to be described later.

[0034] The refrigerant passage 44a is, for example, a stainless steel pipe or an aluminum pipe having lower flexibility than the refrigerant passage 44b. The refrigerant passage 44a vibrates together with the condenser 38.

[0035] The refrigerant passage 44b connecting the engine 2 side component and the vehicle body side component is a flexible pipe for refrigerant having higher flexibility than the refrigerant passage 44a to absorb a relative displacement caused by vibration. A part of the refrigerant passage 44b on the side of the engine 2 vibrates together with the engine 2 by having the vibration of the engine 2 transmitted thereto.

[0036] By forming the refrigerant passage 44b by the flexible pipe for refrigerant, a vibrational difference between the refrigerant passages 44a, 44b can be absorbed by the refrigerant passage 44b.

[0037] Next, the refrigeration cycle 51 is described. Since the refrigeration cycle 51 shares the refrigerant circulating in the Rankine cycle 31, the refrigeration cycle 51 is integrated with the Rankine cycle 31 and the configuration thereof is simple. Specifically, the refrigeration cycle 51 includes a compressor 52, the condenser 38 and an evaporator 55.

[0038] The compressor 52 is a fluid machine for compressing the refrigerant of the refrigeration cycle 51 at high temperature and high pressure. The compressor 52 is mounted on the vehicle body. The compressor 52 is an electric compressor and power is supplied thereto from an unillustrated battery or the like.

[0039] The refrigerant from the compressor 52 is supplied to the condenser 38 via the refrigerant passage 43b after joining the refrigerant passage 43a at the refrigeration cycle junction 46 via a refrigerant passage 56. The refrigerant passage 56 is formed by a general metal pipe (steel pipe) having relatively high rigidity. The condenser 38 is a heat exchanger for condensing and liquefying the refrigerant by heat exchange with outside air. The liquid refrigerant from the condenser 38 is supplied to the evaporator 55 via a refrigerant passage 57 branched off from the refrigerant passage 44a at the refrigeration cycle junction 45. The refrigerant passage 57 is also formed by a general metal pipe (steel pipe) having relatively high rigidity. The evaporator 55 is arranged in a case of an air conditioning unit in the same manner as an unillustrated heater core. The evaporator 55 is a heat exchanger for evaporating the liquid refrigerant from the condenser 38 and cooling air conditioning air from a blower fan by latent heat of evaporation.

[0040] The refrigerant evaporated by the evaporator 55 is returned to the compressor 52 via a refrigerant passage 58. It should be noted that a mixing ratio of the air conditioning air cooled by the evaporator 55 and that heated by the heater core is changed according to an opening of an air mix door to adjust the temperature to a temperature set by a passenger.

[0041] The integrated cycle 30 composed of the Rankine cycle 31 and the refrigeration cycle 51 appropriately

includes various valves at intermediate positions of the circuit to control the refrigerant flowing in the cycle. For example, to control the refrigerant circulating in the Rankine cycle 31, a pump upstream valve 61 is provided in the refrigerant passage 44b allowing communication between the refrigeration cycle junction 45 and the refrigerant pump 32 and an expander upstream valve 62 is provided in the refrigerant passage 42 allowing communication between the heat exchanger 36 and the expander 37. Further, a check valve 63 for preventing a reverse flow of the refrigerant from the heat exchanger 36 to the refrigerant pump 32 is provided in the refrigerant passage 41 allowing communication between the refrigerant pump 32 and the heat exchanger 36. A check valve 64 for preventing a reverse flow of the refrigerant from the refrigeration cycle junction 46 to the expander 37 is also provided in the refrigerant passage 43a allowing communication between the expander 37 and the refrigeration cycle junction 46. Further, an expander bypass passage 65 is provided which bypasses the expander 37 from a side upstream of the expander upstream valve 62 and joins at a side upstream of the check valve 64, and a bypass valve 66 is provided in this expander bypass passage 65. Furthermore, a pressure regulating valve 68 is provided in a passage 67 bypassing the bypass valve 66. Also in the refrigeration cycle 51, an air conditioning circuit valve 69 is provided in the refrigerant passage 57 connecting the refrigeration cycle junction 45 and the evaporator 55.

[0042] Any of the above four valves 61, 62, 66 and 69 is an electromagnetic on-off valve. To the engine controller 71 are input a signal indicating a pressure upstream of the expander detected by a pressure sensor 72, a signal indicating a refrigerant pressure P_d at the exit of the condenser 38 detected by a pressure sensor 73, a rotation speed signal of the expander 37, etc. In the engine controller 71, the compressor 52 of the refrigeration cycle 51 and the radiator fan 12 are controlled and the opening and closing of the above four electromagnetic on-off valves 61, 62, 66 and 69 are controlled based on each of these input signals according to a predetermined driving condition.

[0043] For example, an expander torque (regenerative power) is predicted based on the pressure upstream of the expander detected by the pressure sensor 72 and the expander rotation speed, and the expander clutch 35 is engaged when this predicted expander torque is positive (the rotation of the engine output shaft can be assisted) and released when the predicted expander torque is zero or negative. The expander torque can be predicted with high accuracy based on the sensor detected pressure and the expander rotation speed as compared with the case where the expander torque (regenerative power) is predicted from the exhaust temperature, and the expander clutch 35 can be properly engaged/released according to a generation state of the expander torque (for further details, see JP2010-190185A).

[0044] The above four on-off valves 61, 62, 66 and 69

and two check valves 63, 64 are refrigeration system valves. Functions of these refrigeration system valves are shown anew in FIG. 3.

[0045] In FIG. 3, the pump upstream valve 61 is for preventing an uneven distribution of the refrigerant (containing a lubricant component) to the Rankine cycle 31 by being closed under a predetermined condition that makes the refrigerant easily unevenly distributed to the circuit of the Rankine cycle 31 as compared with the circuit of the refrigeration cycle 51 such as during the stop of the Rankine cycle 31, and closes the circuit of the Rankine cycle 31 in cooperation with the check valve 64 downstream of the expander 37 as described later. The expander upstream valve 62 cuts off the refrigerant passage 42 when a refrigerant pressure from the heat exchanger 36 is relatively low, so that the refrigerant from the heat exchanger 36 can be maintained until a high pressure is reached. This can prompt the heating of the refrigerant even if the expander torque cannot be sufficiently obtained and can shorten a time, for example, until the Rankine cycle 31 is restarted (regeneration comes to be actually performed). The bypass valve 66 is for shortening a start-up time of the Rankine cycle 31 by being opened to actuate the refrigerant pump 32 after the expander 37 is bypassed such as when an amount of the refrigerant present on the side of the Rankine cycle 31 is insufficient such as at the start-up of the Rankine cycle 31. If a state where the refrigerant temperature at the exit of the condenser 38 or at the entrance of the refrigerant pump 32 is reduced from a boiling point in consideration of a pressure at that location by a predetermined temperature difference (subcool temperature SC) or more is realized by actuating the refrigerant pump 32 after the expander 37 is bypassed, a state is prepared where the liquid refrigerant can be sufficiently supplied to the Rankine cycle 31.

[0046] The check valve 63 upstream of the heat exchanger 36 is for maintaining the refrigerant supplied to the expander 37 at a high pressure in cooperation with the bypass valve 66, the pressure regulating valve 68 and the expander upstream valve 62. Under a condition that the regeneration efficiency of the Rankine cycle is low, the operation of the Rankine cycle is stopped and the circuit is closed in a section before and after the heat exchanger, whereby the refrigerant pressure during the stop is increased so that the Rankine cycle can be quickly restarted utilizing the high-pressure refrigerant. The pressure regulating valve 68 functions as a relief valve for allowing the refrigerant having reached an excessively high pressure to escape by being opened when the pressure of the refrigerant supplied to the expander 37 becomes excessively high.

[0047] The check valve 64 downstream of the expander 37 is for preventing an uneven distribution of the refrigerant to the Rankine cycle 31 in cooperation with the aforementioned pump upstream valve 61. If the engine 2 is not warm yet immediately after the operation of the hybrid vehicle 1 is started, the temperature of the Rankine

cycle 31 is lower than that of the refrigeration cycle 51 and the refrigerant may be unevenly distributed toward the Rankine cycle 31. Although a probability of uneven distribution toward the Rankine cycle 31 is not very high, there is a request to resolve even a slightly uneven distribution of the refrigerant to secure the refrigerant of the refrigeration cycle 51, for example, immediately after the start of the vehicle operation in summer since it is wished to quickly cool vehicle interior and cooling capacity is required most. Accordingly, the check valve 64 is provided to prevent the uneven distribution of the refrigerant toward the Rankine cycle 31.

[0048] The compressor 52 is not so structured that the refrigerant can freely pass when the drive is stopped, and can prevent an uneven distribution of the refrigerant to the refrigeration cycle 51 in cooperation with the air conditioning circuit valve 69. This is described. When the operation of the refrigeration cycle 51 is stopped, the refrigerant moves from the Rankine cycle 31 that is in steady operation and has a relatively high temperature to the refrigeration cycle 51, whereby the refrigerant circulating in the Rankine cycle 31 may become insufficient. In the refrigeration cycle 51, the temperature of the evaporator 55 is low immediately after the cooling is stopped and the refrigerant tends to stay in the evaporator 55 that has a relatively large volume and a low temperature. In this case, the uneven distribution of the refrigerant to the refrigeration cycle 51 is prevented by stopping the drive of the compressor 52 to block a movement of the refrigerant from the condenser 38 to the evaporator 55 and closing the air conditioning circuit valve 69.

[0049] Next, FIG. 5 is a schematic perspective view of the engine 2 showing an entire package of the engine 2. What is characteristic in FIG. 5 is that the heat exchanger 36 is arranged vertically above the exhaust manifold 4. That is, the heat exchanger 36 is mounted on the engine 2. By arranging the heat exchanger 36 in a space vertically above the exhaust manifold 4, the mountability of the Rankine cycle 31 on the engine 2 is improved. Further, a tension pulley 8 is provided on the engine 2.

[0050] Next, a basic operation method of the Rankine cycle 31 is described with reference to FIGS. 7A and 7B.

[0051] First, FIGS. 7A and 7B are graphs showing operating regions of the Rankine cycle 31. FIG. 7A shows the operating region of the Rankine cycle 31 when a horizontal axis represents outside air temperature and a vertical axis represents engine water temperature (cooling water temperature) and FIG. 7B shows the operating region of the Rankine cycle 31 when a horizontal axis represents engine rotation speed and a vertical axis represents engine torque (engine load).

[0052] In both FIGS. 7A and 7B, the Rankine cycle 31 is operated when a predetermined condition is satisfied. The Rankine cycle 31 is operated when both of these conditions are satisfied. In FIG. 7A, the operation of the Rankine cycle 31 is stopped in a region on a low water temperature side where the warm-up of the engine 2 is prioritized and a region on a high outside temperature

side where a load of the compressor 52 increases. During the warm-up in which exhaust temperature is low and recovery efficiency is poor, the cooling water temperature is quickly increased rather by not operating the Rankine cycle 31. During a high outside temperature period in which high cooling capacity is required, the Rankine cycle 31 is stopped to provide the refrigeration cycle 51 with sufficient refrigerant and the cooling capacity of the condenser 38. In FIG. 7B, the operation of the Rankine cycle 31 is stopped in the EV running region and a region on a high rotation speed side where the friction of the expander 37 increases since the vehicle is the hybrid vehicle 1. Since it is difficult to provide the expander 37 with a highly efficient structure having little friction at all the rotation speeds, the expander 37 is so configured (dimensions and the like of each part of the expander 37 are set) in the case of FIG. 7B as to realize small friction and high efficiency in an engine rotation speed region where an operation frequency is high.

[0053] Effects of the first embodiment of the present invention are described.

[0054] FIG. 8 diagrammatically shows a state of pipes of the integrated cycle 30 of the first embodiment. As described above, each of the refrigerant pump 32, the heat exchanger 36 and the expander 37 of the Rankine cycle 31 is mounted on the engine 2 and the condenser 38 is mounted on the vehicle body. The refrigerant pump 32 and the heat exchanger 36, and the heat exchanger 36 and the expander 37 are connected by general metal pipes (steel pipes) 101 having relatively high rigidity. The expander 37 and the condenser 38, and the condenser 38 and the refrigerant pump 32 are connected by passages (conduits) having high flexibility and including a flexible pipe 100 at least in an intermediate part. This causes the flexible pipes 100 to absorb vibrational differences (changes in relative positions) between the expander 37 and the refrigerant pump 32 mounted on the engine 2 and the condenser 38 mounted on the vehicle body, thereby enhancing component reliability or suppressing the transmission of unpleasant vibration to passengers.

[0055] Particularly, the present embodiment is not only configured to be able to drive the refrigerant pump 32 by the engine 2 by mounting the refrigerant pump 32 on the engine 2, but also configured to be able to drive the refrigerant pump 32 by a regenerative output of the expander 37 by mounting the expander 37 on the engine 2, and energy efficiency can be improved by enabling the refrigerant pump 32 to be driven also utilizing the regenerative output of the expander 37 while increasing a degree of freedom in the operation of the Rankine cycle 31 by enabling the refrigerant pump 32 to be driven by the power of the engine 2. Since the heat exchanger 36 provided between the refrigerant pump 32 and the expander 37 is mounted on the engine 2 under such an assumption, the refrigerant pump 32 and the heat exchanger 36, and the heat exchanger 36 and the expander 37 can be connected by the passages (conduits) 101

having relatively high rigidity, and only the expander 37 and the condenser 38, and the condenser 38 and the refrigerant pump 32 are connected by the flexible pipes 100 having high flexibility. This can suppress cost by reducing the number of the relatively expensive flexible pipes 100. Specifically, only two flexible pipes 100 are provided at intermediate positions of the circuit of the Rankine cycle 31.

[0056] Specifically, at least a part of the refrigerant passage 43a connected to the expander 37 mounted on the engine 2 is formed by a flexible pipe for refrigerant having higher flexibility than the refrigerant passage 43b connected to the condenser 38 mounted on the vehicle body. This enables the refrigerant passage 43a to absorb a vibrational difference between the part of the refrigerant passage 43a on the side of the engine 2 and the refrigerant passage 43b. Further, the refrigerant passage 43b can be formed by a metal pipe less expensive than the flexible pipe for refrigerant such as a copper pipe, a stainless steel pipe or an aluminum pipe, and the number of the expensive flexible pipes for refrigerant can be reduced. Thus, the cost of the integrated cycle 30 can be reduced.

[0057] By using the flexible pipe for refrigerant at least in a part of the refrigerant passage 43a, the length of the pipe connecting the expander 37 and the condenser 38 can be shortened, a pressure loss in the pipe can be reduced and the efficiency of the integrated cycle 30 can be improved.

[0058] At least a part of the refrigerant passage 44b connected to the refrigerant pump 32 mounted on the engine 2 is formed by a flexible pipe for refrigerant having higher flexibility than the refrigerant passage 44a connected to the condenser 38. This enables the refrigerant passage 44b to absorb a vibrational difference between the refrigerant passage 44a and the part of the refrigerant passage 44b on the side of the engine 2. Further, the refrigerant passage 44a can be formed by a metal pipe less expensive than the flexible pipe for refrigerant, and the number of the expensive flexible pipes for refrigerant can be reduced. Thus, the cost of the integrated cycle 30 can be reduced.

[0059] By using the flexible pipe for refrigerant at least in a part of the refrigerant passage 43a, the length of the pipe connecting the condenser 38 and the refrigerant pump 32 can be shortened, a pressure loss in the pipe can be reduced and the efficiency of the integrated cycle 30 can be improved.

[0060] By forming the refrigerant passage 43a by a flexible pipe for refrigerant and forming the refrigerant passage 43b, for example, by a metal pipe in the integrated cycle 30 in which the output shaft of the expander 37 and that of the engine 2 are configured to be able to transmit power, the above effects can be obtained more.

[0061] Next, a second embodiment of the present invention is described using FIGS. 9 and 10.

[0062] FIG. 9 is a schematic configuration diagram of a hybrid vehicle in the present embodiment. FIG. 10 is a

schematic configuration diagram of an integrated cycle in the present embodiment. The second embodiment is described, centering on parts different from the first embodiment. The same configuration as the first embodiment is denoted by the same reference signs as in the first embodiment and not described here.

[0063] A compressor 59 is mounted on an engine 2 and driven by the engine 2. As shown in FIG. 9, a compressor pulley 53 is fixed to a drive shaft of the compressor 59 and a belt 34 is mounted on this compressor pulley 53 and a crank pulley 2a. A drive force of the engine 2 is transmitted to the compressor pulley 53 via this belt 34 to drive the compressor 59. Further, an electromagnetic clutch 54 is provided between the compressor pulley 53 and the compressor 59 to make the compressor 59 and the compressor pulley 53 connectable to and disconnectable from each other.

[0064] A refrigerant passage 56 connected to the compressor 59 is a flexible pipe for refrigerant having higher flexibility than a refrigerant passage 43b.

[0065] A refrigerant passage 58 provided between the compressor 59 and an evaporator 55 and connected to the compressor 59 is a flexible pipe for refrigerant similarly to the refrigerant passage 56.

[0066] When the compressor 59 is mounted on the engine 2, a vibration frequency of the refrigerant passage 56 connected to the compressor 59 and that of the refrigerant passage 43b connected to a condenser 38 differ when the vehicle is driven. In the present embodiment, a vibrational difference between the refrigerant passages 56 and 43b is absorbed by forming the refrigerant passage 56 by the flexible pipe for refrigerant.

[0067] Effects of the second embodiment of the present invention are described.

[0068] FIG. 11 diagrammatically shows a state of pipes of the integrated cycle 30 of the second embodiment. A difference from the first embodiment is that the refrigerant passages before and after the compressor 59 are formed by flexible pipes 100 since the compressor 59 is mounted on the engine 2. Also according to the second embodiment, cost can be suppressed by reducing the number of relatively expensive flexible pipes 100. Specifically, only two flexible pipes 100 are provided at intermediate positions of a circuit of a Rankine cycle 31 and the number of the flexible pipes 100 is suppressed to four in the entire integrated cycle 30.

[0069] Specifically, at least a part of the refrigerant passage 56 is formed by the flexible pipe for refrigerant and the refrigerant passage 56 is connected to the refrigerant passage 43b at a refrigeration cycle junction 46. This enables the refrigerant passage 43b to absorb a vibrational difference between the refrigerant passages 43b and 56.

[0070] Next, a third embodiment of the present invention is described.

[0071] The third embodiment is described, centering on parts different from the second embodiment.

[0072] In the third embodiment, a refrigerant passage

43b is formed by a flexible pipe having higher flexibility than refrigerant passages 43a and 56. Further, the refrigerant passages 43a and 56 are formed, for example, by stainless steel pipes or aluminum pipes having low flexibility.

[0073] Effects of the third embodiment of the present invention are described.

[0074] FIG. 12 diagrammatically shows a state of pipes of an integrated cycle 30 of the third embodiment. A difference from the second embodiment is that a pipe connecting an expander 37 and a condenser 38 and a pipe connecting a compressor 59 and the condenser 38 join each other at an intermediate position and a part after the junction is formed by a flexible pipe 100. Also according to the third embodiment, cost can be suppressed by reducing the number of relatively expensive flexible pipes 100. Specifically, only two flexible pipes 100 are provided at intermediate positions of a circuit of a Rankine cycle 31 and the number of the flexible pipes 100 is suppressed to three in the entire integrated cycle 30.

[0075] Specifically, a refrigerant passage 43b connected to the condenser 38 is formed by a flexible pipe for refrigerant, and a refrigerant passage 43a connected to the expander 37 and a refrigerant passage 56 connected to the compressor 59 are formed, for example, by stainless pipes or aluminum pipes less expensive than flexible pipes for refrigerant. This enables the absorption of a vibrational difference between the refrigerant passage 43b and the refrigerant passages 43a, 56. Further, the refrigerant passages 43a, 56 can be formed by inexpensive pipes and the cost of the integrated cycle 30 can be reduced.

[0076] It should be noted that a refrigerant passage 44a may be formed by a flexible pipe for refrigerant and a refrigerant passage 44b may be formed by a stainless steel pipe or an aluminum pipe.

[0077] By using flexible pipes for refrigerant at least as some of the refrigerant passages, the length of the pipes connecting the expander 37 or the compressor 59 and the condenser 38 and the pipe connecting the condenser 38 and a refrigerant pump 32 can be shortened, a pressure loss in the pipes can be reduced and the efficiency of the integrated cycle 30 can be improved.

[0078] The present invention is not limited to the above embodiments. For example, a pipe configured to include a flexible pipe for refrigerant having high flexibility in a part (at an intermediate position) of a general metal pipe may be used as a passage pipe having high flexibility to absorb a relative displacement caused by vibration.

[0079] Although the embodiments of the present invention have been described above, the above embodiments are only an illustration of some application examples of the present invention and not intended to limit the technical scope of the present invention to the specific configurations of the above embodiments.

[0080] This application claims a priority of Japanese Patent Application No. 2011-216772 filed with the Japan Patent Office on September 30, 2011, all the contents of

which are hereby incorporated by reference.

Claims

1. A Rankine cycle system, comprising:

a refrigerant pump which is mounted on an engine and is configured to feed refrigerant;
a heat exchanger which is mounted on the engine and is configured to recover exhaust heat of the engine to the refrigerant;
an expander which is mounted on the engine and is configured to convert the exhaust heat recovered to the refrigerant into power by expanding the refrigerant whose temperature has been increased by the heat exchanger; and
a condenser which is mounted on a vehicle body and condenses the refrigerant expanded by the expander; wherein
the expander and the condenser, and the condenser and the refrigerant pump are connected by flexible pipes having higher flexibility than other pipes.

2. The Rankine cycle system according to claim 1, comprising:

a refrigeration cycle which is configured to share the condenser and the refrigerant; wherein
a compressor provided in the refrigeration cycle is mounted on the engine, a pipe between the expander and the condenser and a pipe between the compressor and the condenser are joined in a state where the pipes are supported on the engine, and a junction and the condenser are connected by a flexible pipe.

3. The Rankine cycle system according to claim 1 or 2, wherein an output shaft of the expander and an engine output shaft are configured to be able to transmit power.

4. A Rankine cycle system, comprising:

a heat exchanger which is mounted on an engine and is configured to recover exhaust heat of the engine to refrigerant;
an expander which is mounted on the engine and is configured to convert the exhaust heat recovered to the refrigerant into power by expanding the refrigerant whose temperature has been increased by the heat exchanger;
a condenser which is mounted on a vehicle body and is configured to condense the refrigerant expanded by the expander;
a refrigeration cycle of an air conditioner which is configured to share the condenser and the

refrigerant;

a first pipe which is connected to the expander; and

a third pipe which is connected to the first pipe and a second pipe connected to a compressor of the refrigeration cycle and is configured to introduce the refrigerant to the condenser; wherein

either one of the first and third pipes has higher flexibility than the other.

5. The Rankine cycle system according to claim 4, wherein the compressor is mounted on the vehicle body; and the first pipe has higher flexibility than the second and third pipes.

6. The Rankine cycle system according to claim 4, wherein the compressor is mounted on the engine; and the first and second pipes have higher flexibility than the third pipe.

7. The Rankine cycle system according to claim 4, wherein the compressor is mounted on the engine; and the third pipe has higher flexibility than the first and second pipes.

8. The Rankine cycle system according to any one of claims 4 to 7, comprising:

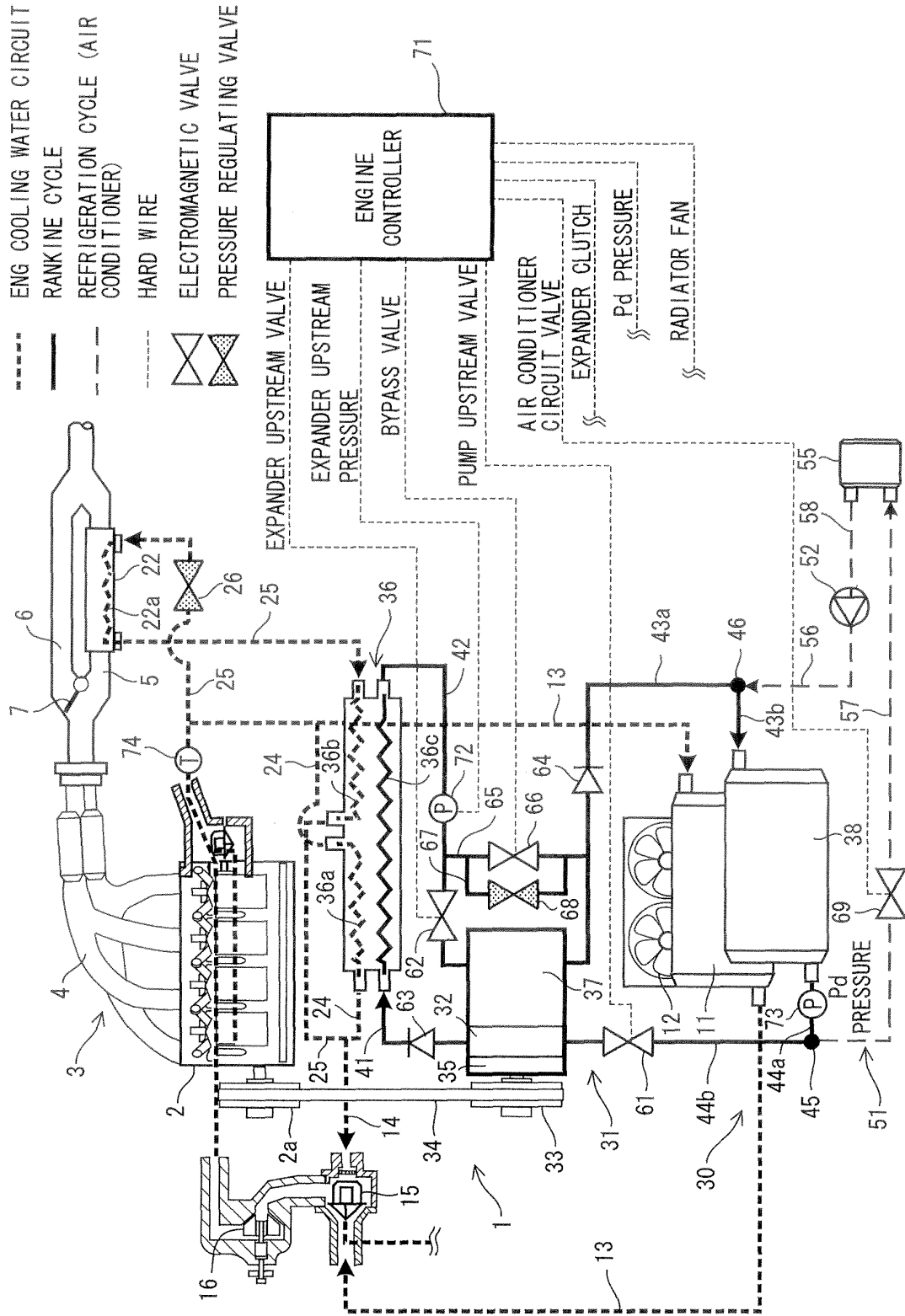
a refrigerant pump which is configured to supply the refrigerant condensed by the condenser to the heat exchanger;

a fourth pipe which is connected to the refrigerant pump; and

a sixth pipe which is connected to the fourth pipe and a fifth pipe connected to an evaporator of the refrigeration cycle and in which the refrigerant discharged from the condenser flows; wherein

either one of the fourth and sixth pipes has higher flexibility than the other.

9. The Rankine cycle system according to any one of claims 4 to 8, wherein an output shaft of the expander and an output shaft of the engine are configured to be able to transmit power.



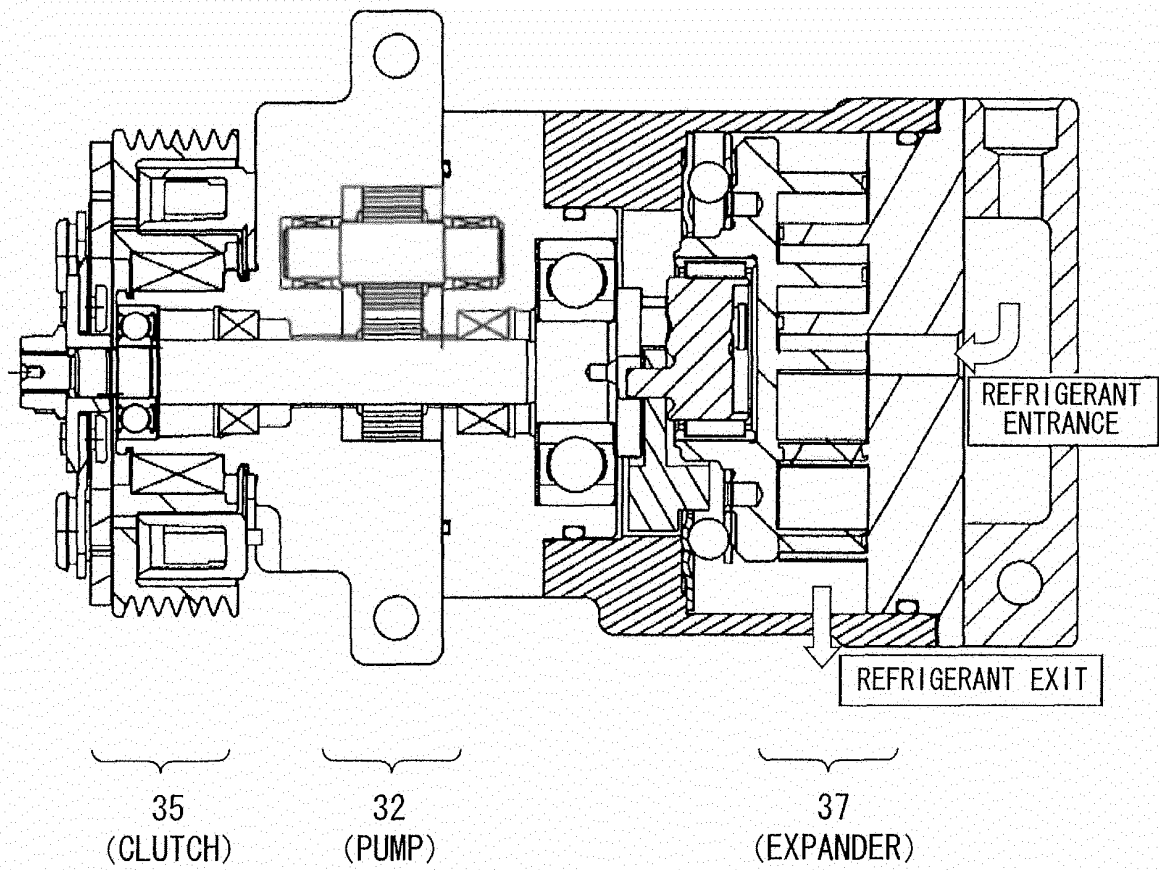


FIG. 2A

FIG. 2B

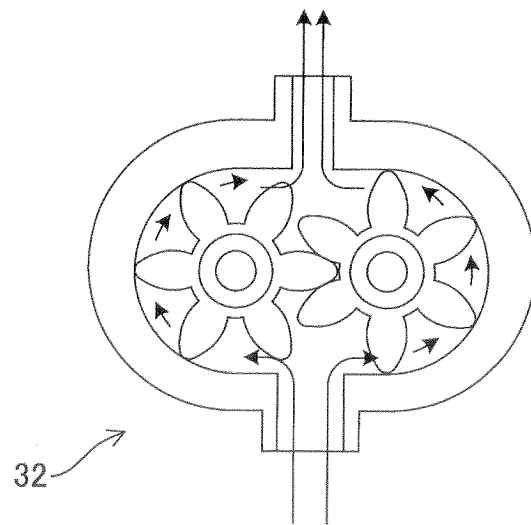
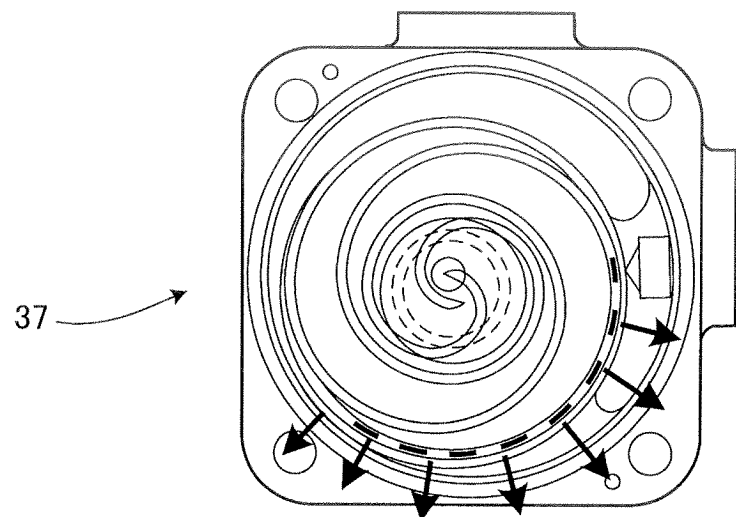
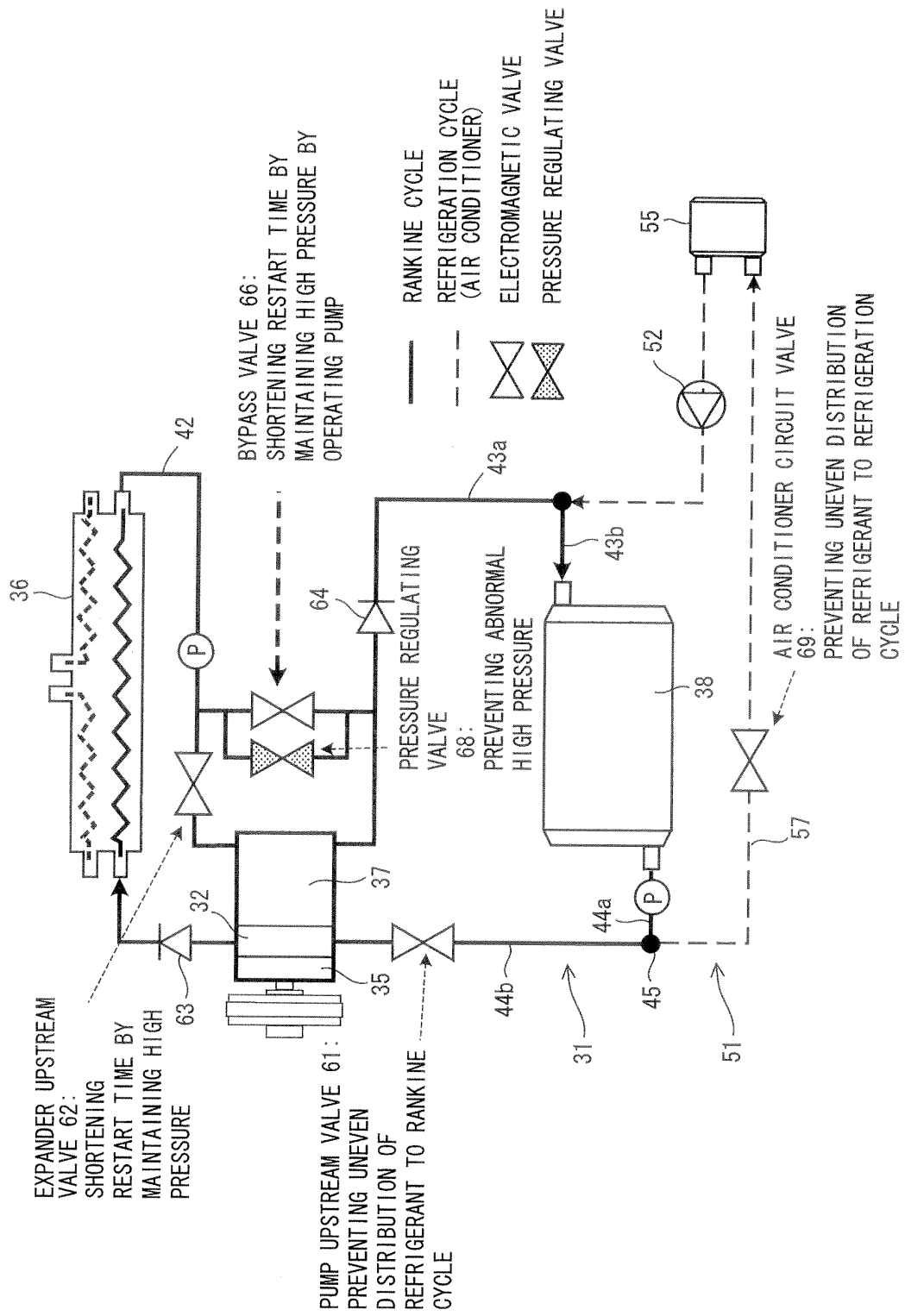


FIG. 2C





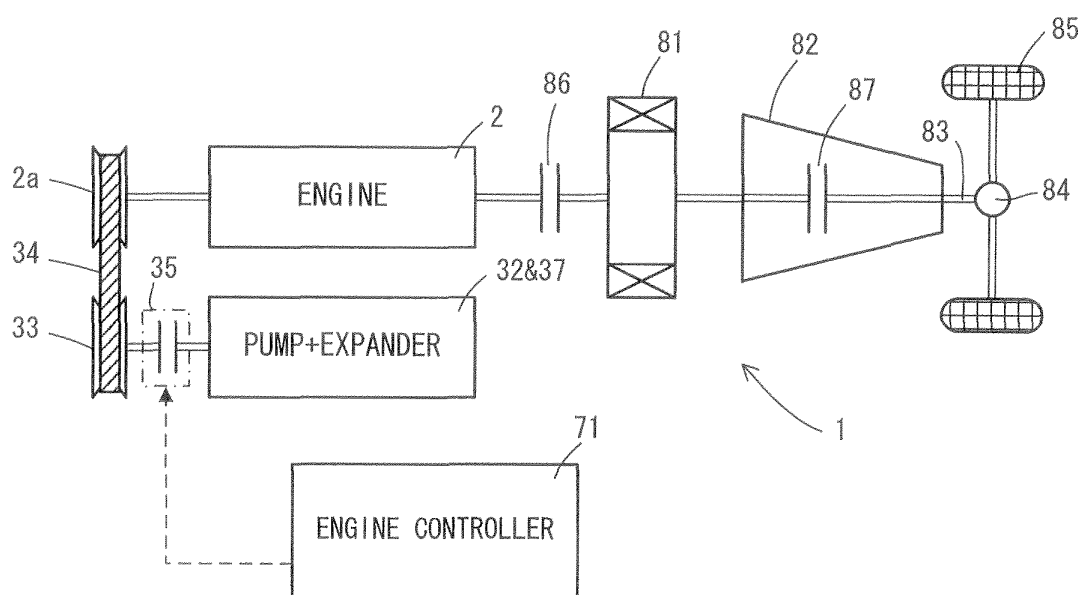


FIG. 4

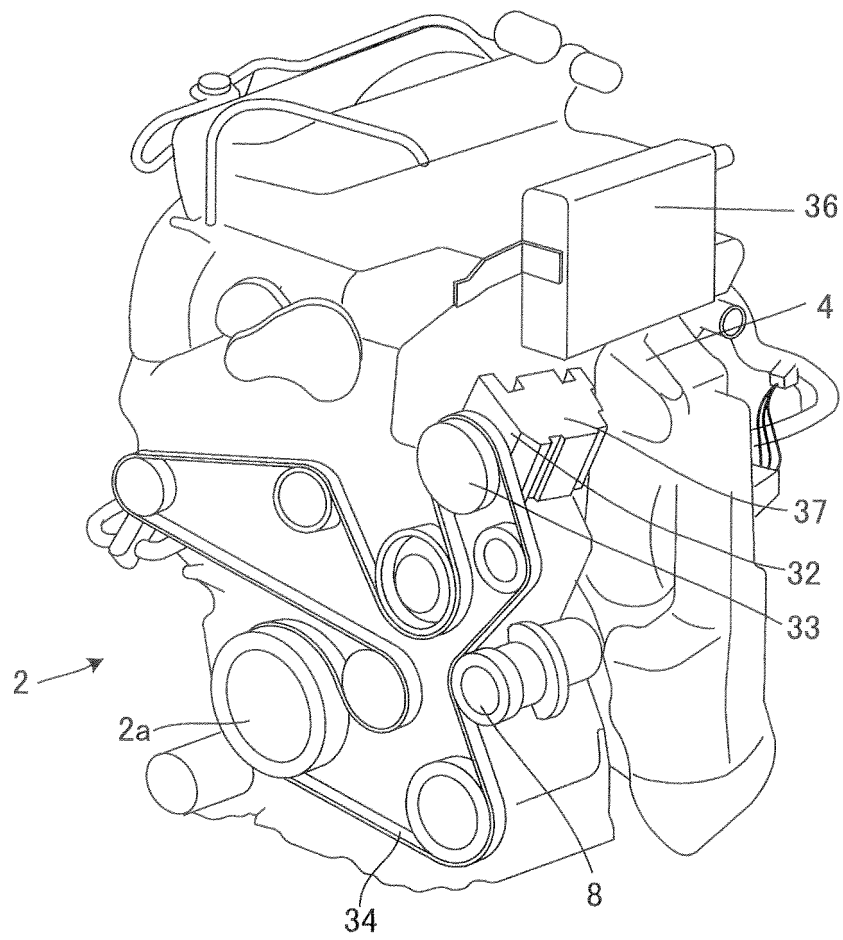


FIG. 5

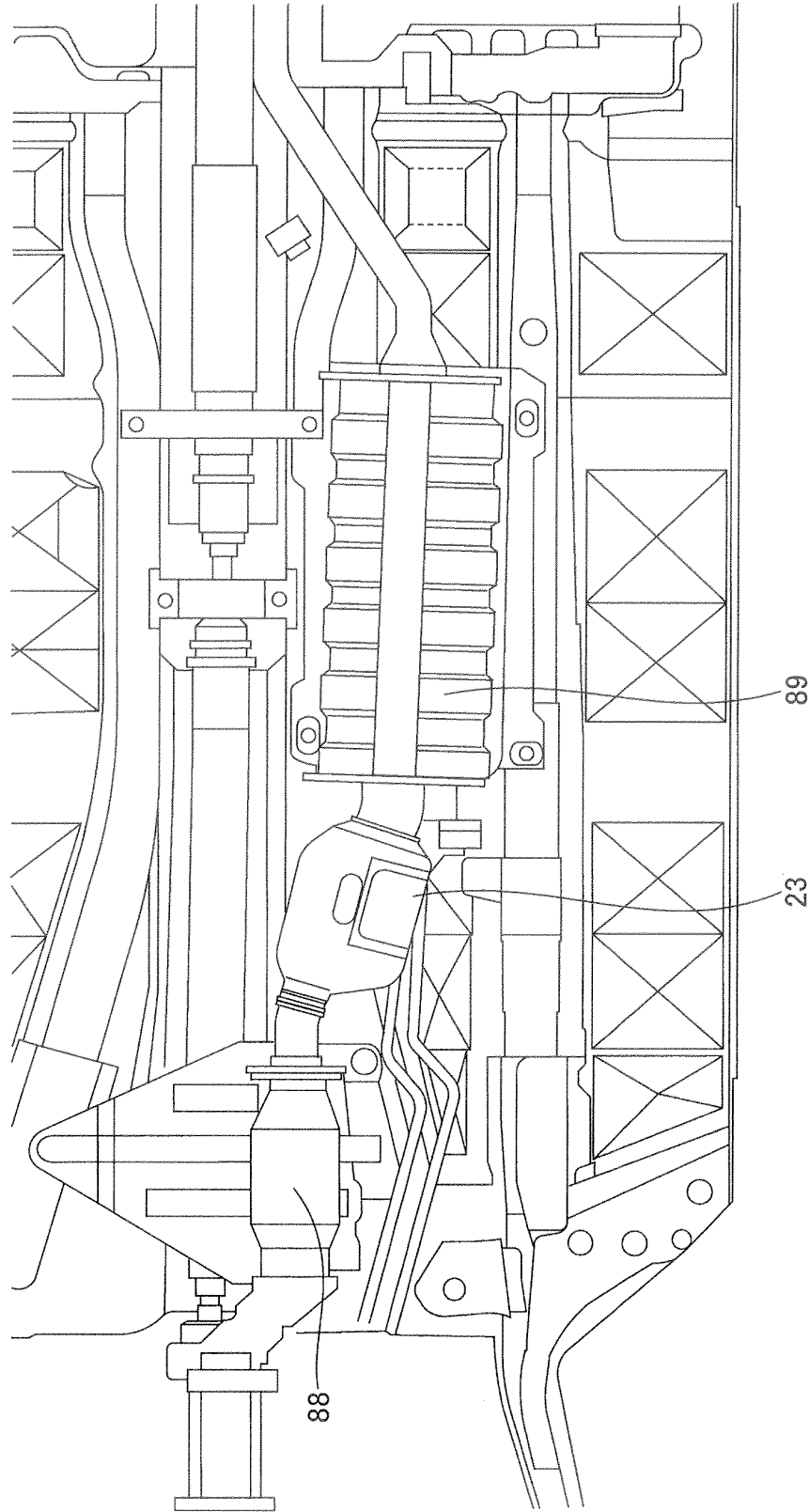


FIG. 6

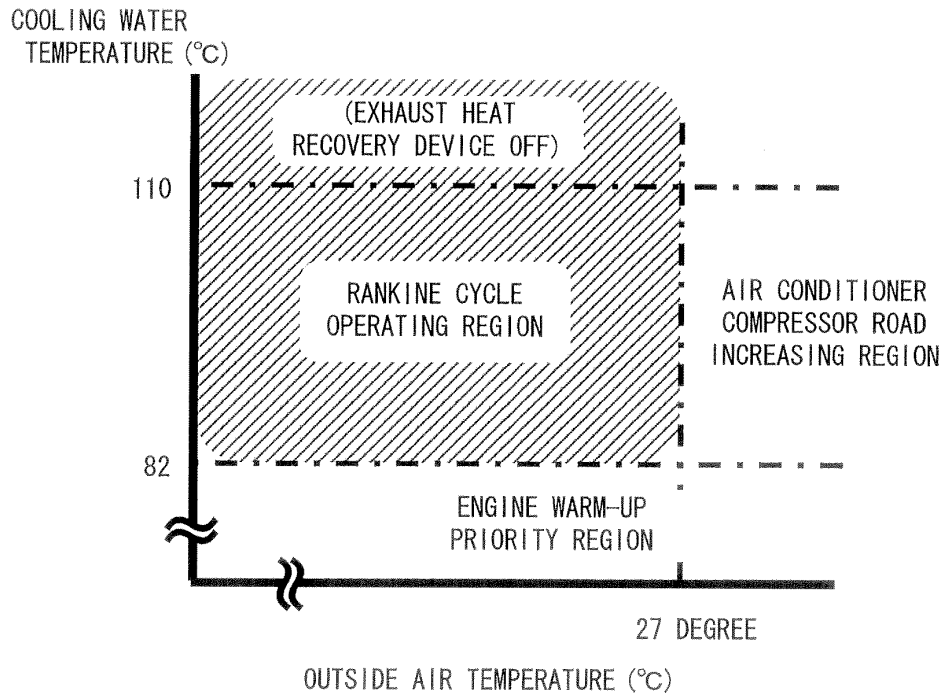


FIG. 7A

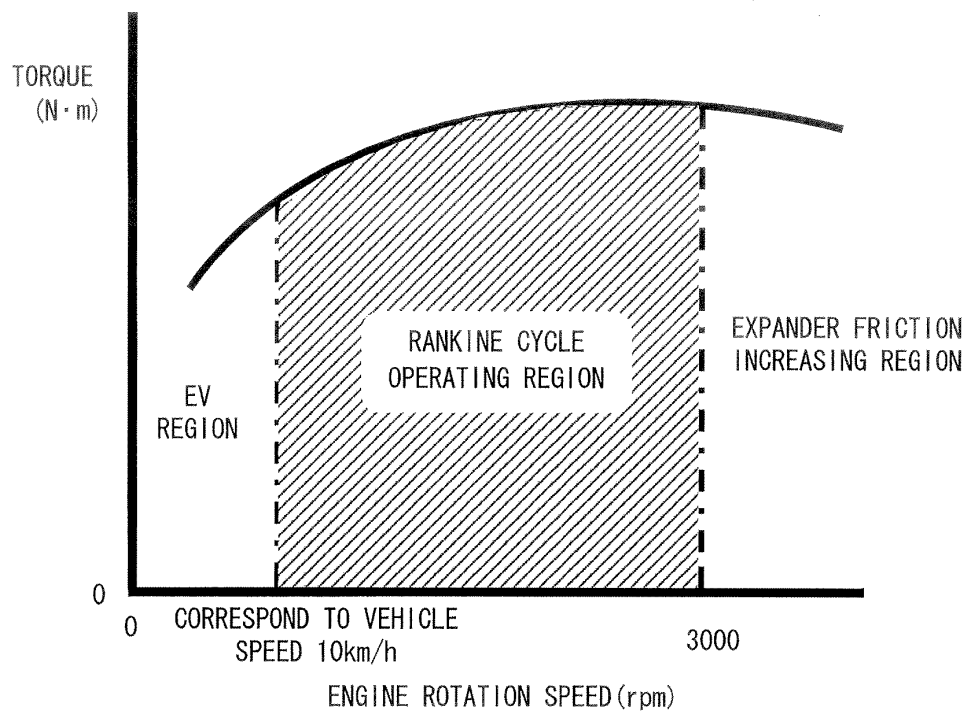


FIG. 7B

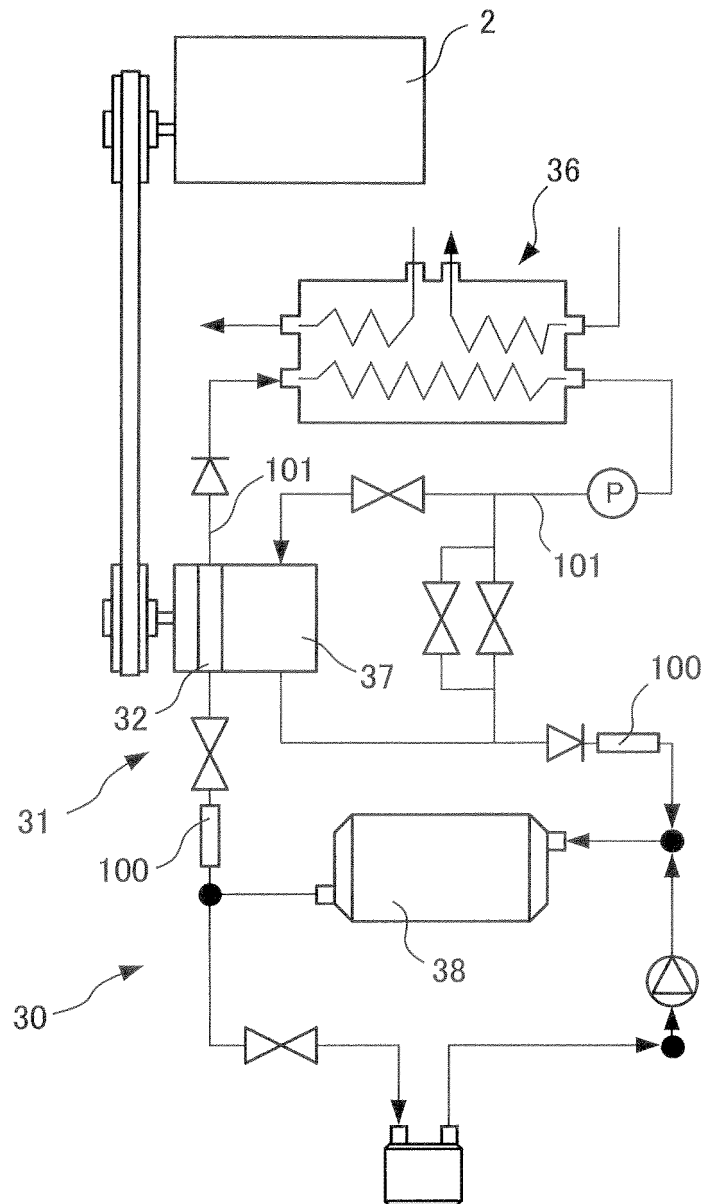


FIG. 8

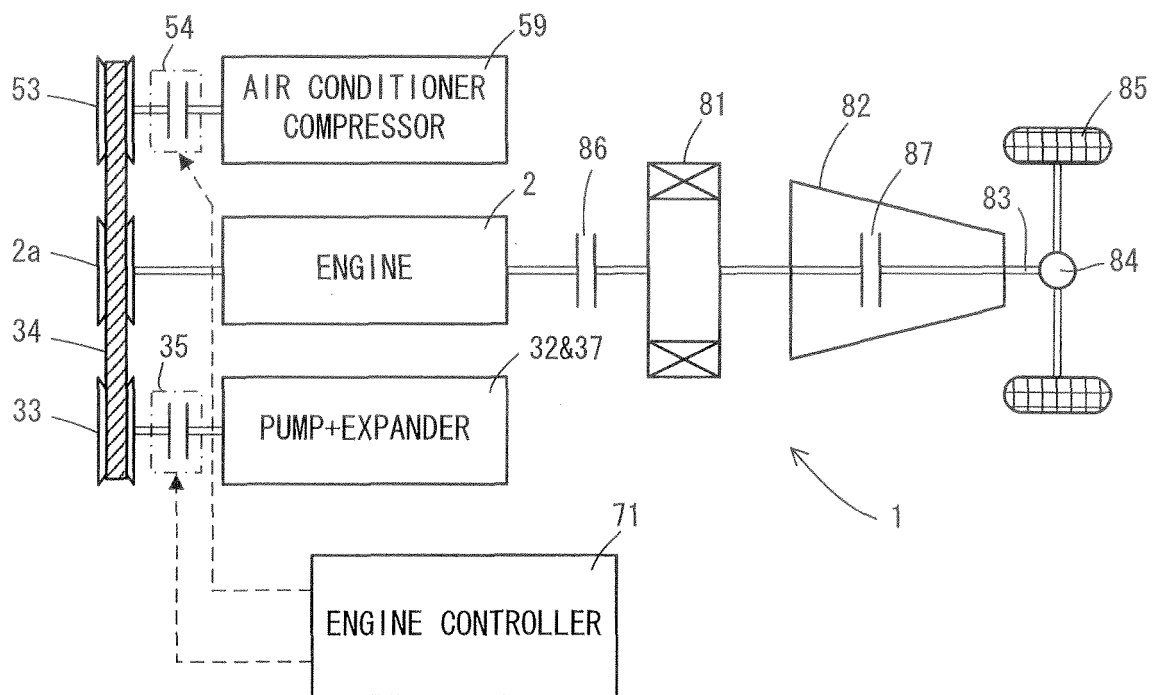


FIG. 9

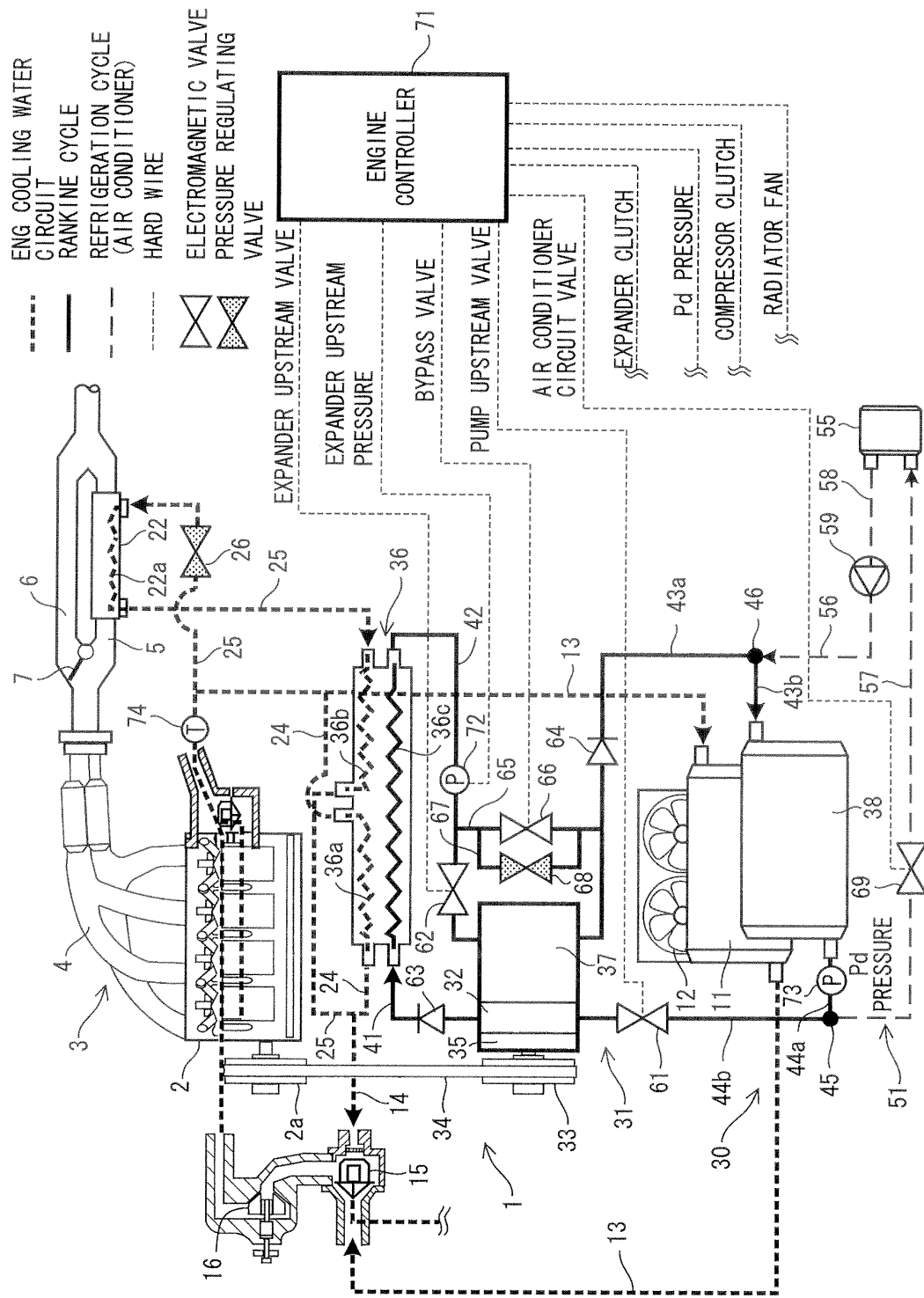


FIG. 10

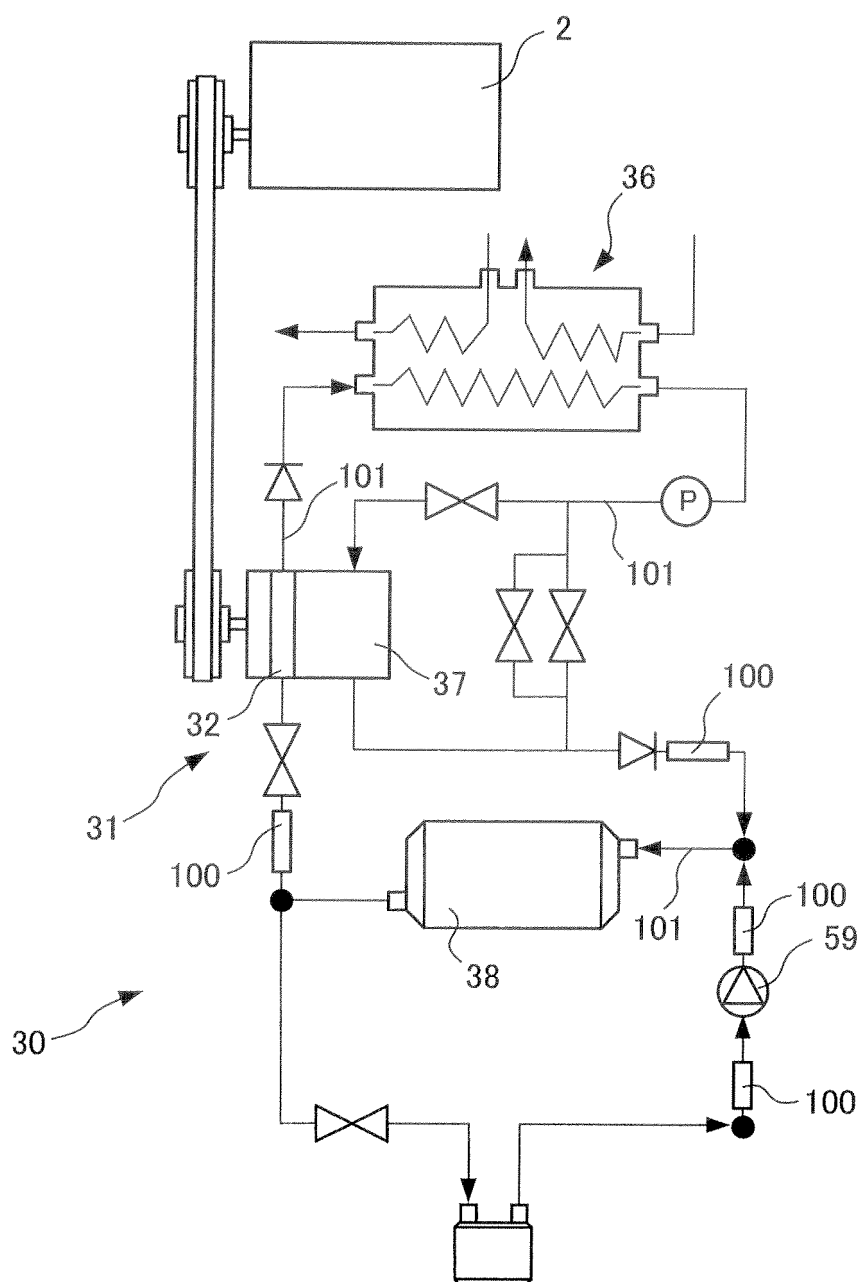


FIG. 11

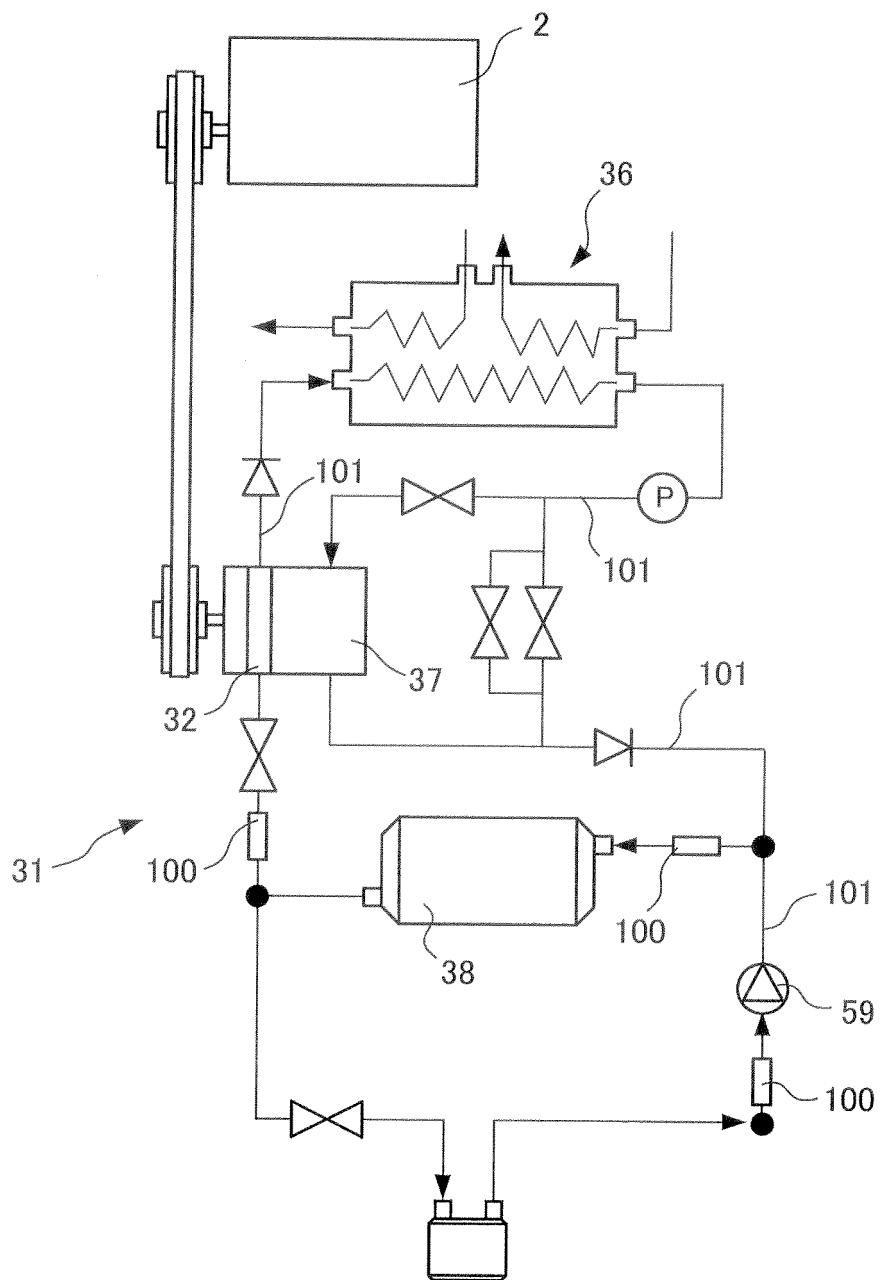


FIG. 12

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/072725

A. CLASSIFICATION OF SUBJECT MATTER

F01D25/00(2006.01)i, F01K13/00(2006.01)i, F01K23/06(2006.01)i, F01K23/10(2006.01)i, F01K25/10(2006.01)i, F25B41/00(2006.01)i

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)

F01D25/00, F01K13/00, F01K23/06, F01K23/10, F01K25/10, F25B41/00

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2012
Kokai Jitsuyo Shinan Koho	1971-2012	Toroku Jitsuyo Shinan Koho	1994-2012

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
E, X E, A	JP 2012-184697 A (Toyota Industries Corp.), 27 September 2012 (27.09.2012), paragraphs [0011] to [0022]; fig. 1 to 2 (Family: none)	1 2-9
A	JP 2001-182504 A (Honda Motor Co., Ltd.), 06 July 2001 (06.07.2001), entire text; all drawings (Family: none)	1-9

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

☐ See patent family annex.

* Special categories of cited documents:

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"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
06 November, 2012 (06.11.12)

Date of mailing of the international search report
20 November, 2012 (20.11.12)

Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

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REFERENCES CITED IN THE DESCRIPTION

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- JP 2011216772 A [0080]