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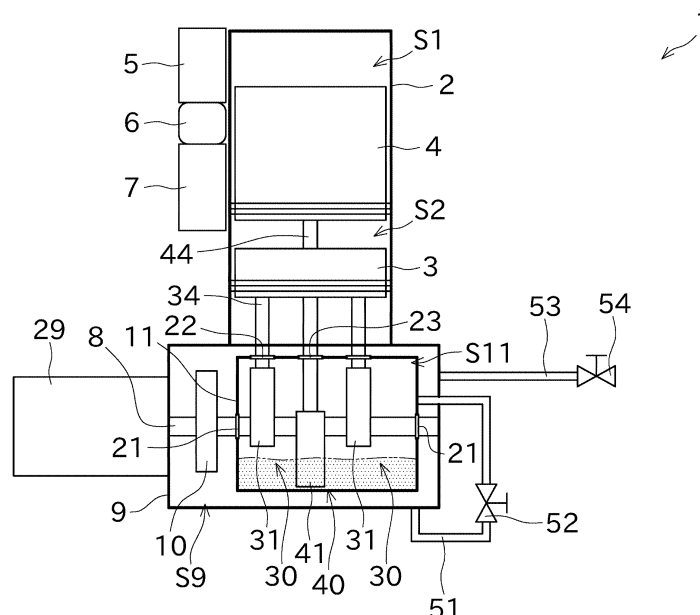
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(54) **STIRLING ENGINE**

(57) A stirling engine (1) includes a crankcase (9), a crank box (11), and a path (51). A crankshaft (8) for taking power to outside is bridged across the crankcase (9). The crank box (11) is disposed in the crankcase (9). The crank box (11) accommodates a power conversion member (30) that converts reciprocating movement of a piston

(3) to rotation movement of the crankshaft (8). A connection route (51) takes a balance between a pressure of a first space (S11) in the crank box (11) and a pressure of a second space (S9) inside the crankcase (9) and outside the crank box (11).

Fig.1



Description

Citation List

Technical Field

Patent Literature

[0001] The present invention relates to a stirling engine. Specifically, the present invention relates to a stirling engine having a configuration in which a crank box accommodating a power conversion member is disposed in a crankcase.

5 **[0006]**

PTL1: Japanese Unexamined Patent Application Publication (Translation of PCT Application) No. 2003-522879

Background Art

10 PTL 2: Japanese Patent Application Publication No. 2009-62906

[0002] Stirling engines have been known to date. Patent Literature 1 (PTL 1) discloses a stirling engine of this type. The stirling engine described in PTL 1 is configured such that operating fluid filling a cylinder is heated and cooled from the outside of the cylinder, and by utilizing a pressure change of the operating fluid, a piston is caused to reciprocate, and this reciprocating movement of the piston is converted to rotation movement of a crankshaft by a power conversion member and is taken out. In the stirling engine of PTL 1, a space accommodating the piston and the power conversion member (Helium chamber) is filled with operating fluid, and spaces at the sides thereof (air chambers) are filled with air. The Helium chamber and the air chamber are kept substantially at the same pressure in order to make a simple low-pressure seal usable as a member for sealing a gap between the Helium chamber and the air chamber.

Summary of Invention

15 Technical Problem

[0007] As described above, the configurations of PTL 1 and PTL 2 have a room for improvement in terms of the necessity for a relatively long period in filling with operating fluid or discharging operating fluid used for the filling.

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[0008] The present invention has been made in view of the circumstances described above. It is an object of the present invention to provide a stirling engine capable of filling a space with operating fluid or discharging the operating fluid in a short period.

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Solution to Problem and Advantageous Effects

[0003] In the stirling engine of PTL 1, supposing that the Helium chamber and the air chamber are filled with helium as operating fluid and air, respectively, from outside, the filling needs to be performed little by little in a sufficiently long period with the Helium chamber and the air chamber being adjusted to substantially the same pressure in order to prevent or reduce damage of the low-pressure seal by the atmospheric pressure difference.

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[0009] Problems to be solved by the invention are as described above, and next, means for solving the problems and effects thereof will be described.

[0004] Patent Literature 2 (PTL 2) also discloses an example of the stirling engine. The stirling engine described in PTL 2 is configured such that a crank box accommodating a power conversion member, which is a member different from a crankcase kept under a high-pressure atmosphere, is disposed inside the crankcase. In the stirling engine of PTL 2, it is not clearly described which one of a wet sump lubrication method or a built-in lubrication method is employed as a method for lubricating the power conversion member as a sliding member. Even in the case of employing the wet sump lubrication method, however, an oil seal is disposed in a gap as appropriate in order to keep the crank box in a state sealed with respect to the crankcase.

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[0010] In an aspect of the present invention, a stirling engine having the following configuration is provided. Specifically, the stirling engine includes a crankcase, a crank box, and a path. A crankshaft for taking power to outside is bridged across the crankcase. The crank box is disposed in the crankcase and accommodates a power conversion member, and the power conversion member is configured to convert reciprocating movement of a piston to rotation movement of the crankshaft. The path is configured to take a balance between a pressure of a first space in the crank box and a pressure of a second space inside the crankcase and outside the crank box.

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[0011] As described above, since the path for taking a balance between the pressure in the crankcase and the pressure in the crank box is provided, it is possible to reduce occurrence of a difference between the pressure in the crankcase and the pressure in the crank box in filling the crankcase or the crank box with operating fluid or in discharging operating fluid from the crankcase or the crank box. Accordingly, it does not take a long time to fill the crankcase and the crank box with operating fluid or to discharge the operating fluid from the crankcase and the crank box.

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[0005] In such a case, supposing that the crankcase is filled with a high-pressure gas, some measures for preventing or reducing damage of the oil seal is needed by, for example, performing the filling in a sufficiently long period at a lower supply rate of the gas.

[0012] In the stirling engine, the path preferably includes a channel through which the first space and the second space communicate with each other.

[0013] Accordingly, it is possible to take a balance between the pressure in the crankcase and the pressure in the crank box with a simple structure.

[0014] The stirling engine preferably has the following configuration. Specifically, the path includes a first end and a second end. The first end is open to the first space. The second end is open to the second space. At least a part of an intermediate portion of the path between the first end and the second end is located outside the crankcase.

[0015] Accordingly, it is possible to take a balance between the pressure in the crankcase and the pressure in the crank box with a very simple structure. In addition, for example, when a valve capable of opening and closing a channel in the path is disposed in the intermediate portion of the path, the valve can be operated by an operator from outside the crankcase so that the inside of the crankcase and the inside of the crank box can communicate with each other only when necessary.

[0016] The stirling engine preferably has the following configuration. Specifically, the path includes a first path and a second path. The first path has one end open to the first space and another end located outside the crankcase. The second path has one end open to the second space and another end located outside the crankcase.

[0017] Thus, operating fluid can be supplied from each of the other end of the first path and the other end of the second path at an appropriate flow rate when necessary in consideration of the ratio between the volume of the portion filled with operating fluid by supplying the operating fluid to the first space and the volume of the portion filled with operating fluid by supplying the operating fluid to the second space, for example. Accordingly, the first and second spaces can be filled with operating fluid with a balance kept between the pressure of the first space and the pressure of the second space.

[0018] In the stirling engine, a ratio between a channel area of the first path and a channel area of the second path is preferably set in consideration of a ratio between a volume of a portion filled with operating fluid by supplying the operating fluid to the first space and a volume of a portion filled with operating fluid by supplying the operating fluid to the second space.

[0019] Accordingly, a balance can be easily kept between the pressure of the first space and the pressure of the second space so that the first and second spaces can be quickly filled with operating fluid easily.

[0020] In the stirling engine, at least one of the first path and the second path is preferably provided with a valve or a throttle, and each of the valve and the throttle is configured to restrict a channel area of a channel in the at least one of the first path and the second path.

[0021] Accordingly, by providing an appropriate valve or throttle, operating fluid can be quickly supplied and discharged to/from the first and second spaces quickly with a substantial balance kept between the pressure of the first space and the pressure of the second space.

[0022] In the stirling engine, each of the valve and the

throttle is preferably configured to adjust the channel area of the channel.

[0023] Accordingly, pressure adjustment can be flexibly performed in accordance with various situations.

[0024] The stirling engine preferably has the following configuration. Specifically, the stirling engine further includes a pressure difference sensor and a control device. The pressure difference sensor detects a difference between a pressure of the first space and a pressure of the second space. The control device controls a state of the valve or the throttle in accordance with a detection result of the pressure difference sensor.

[0025] Accordingly, automatic pressure adjustment for preventing or reducing occurrence of a pressure difference between the first space and the second space can be achieved.

Brief Description of Drawings

[0026]

[Fig. 1] A schematic view illustrating an overall configuration of a stirling engine according to one embodiment of the present invention.

[Fig. 2] A schematic view illustrating a partial configuration of a stirling engine according to a first embodiment.

[Fig. 3] A schematic view illustrating a partial configuration of a stirling engine according to a variation of the first embodiment.

[Fig. 4] A schematic view illustrating a partial configuration of a stirling engine according to a second embodiment.

[Fig. 5] A schematic view illustrating a partial configuration of a stirling engine according to a third embodiment.

[Fig. 6] A schematic view illustrating a partial configuration of a stirling engine according to a fourth embodiment.

[Fig. 7] A schematic view illustrating a configuration of a stirling engine according to a typical example.

Description of Embodiments

<First Embodiment>

[0027] An overall configuration of a stirling engine 1 according to a first embodiment of the present invention will be described with reference to Fig. 1. Fig. 1 is a schematic view illustrating an overall configuration of the stirling engine 1 according to one embodiment of the present invention.

[0028] The stirling engine 1 of this embodiment illustrated in Fig. 1 is a type of an external combustion engine. The stirling engine 1 is configured to expand and contract operating fluid filling a cylinder 2 by using heat taken from the outside to thereby cause a power piston 3 to reciprocate, and this reciprocating movement is converted to

rotation movement of a crankshaft 8 so that power is taken out.

[0029] The stirling engine 1 according to this embodiment mainly includes a cylinder 2, the power piston 3, a displacer piston 4, a heater 5, a regenerator 6, a cooler 7, a crankshaft 8, a crankcase 9, a flywheel 10, a crank box 11, first power conversion members (power conversion member) 30, and a second power conversion member 40. The stirling engine 1 of this embodiment is a so-called β type stirling engine in which the power piston 3 and the displacer piston 4 are accommodated in the same cylinder 2.

[0030] The cylinder 2 is a cylindrical member accommodating the power piston 3 and the displacer piston 4. The cylinder 2 is filled with operating fluid. As operating fluid, various types of fluid such as a helium gas, a hydrogen gas, and air may be used, and a helium gas having a high thermal conductivity is used in this embodiment. One axial end of the cylinder 2 is connected to the heater 5 above the displacer piston 4, and the other axial end of the cylinder 2 is connected to the crankcase 9. As described later, operating fluid changes its pressure in the cylinder 2 by heating and cooling the operating fluid.

[0031] The displacer piston 4 is an approximately columnar member that is accommodated in the cylinder 2 to be slidable in the axial direction. In the cylinder 2, an expansion space S1 at a relatively high temperature is formed at a side closer to a portion where the cylinder 2 and the heater 5 are connected than the displacer piston 4 (i.e., above the displacer piston 4 in the drawing). A compression space S2 at a relatively low temperature is formed in the cylinder 2 at a side closer to the crankcase 9 than the displacer piston 4 (i.e., below the displacer piston 4 in the drawing). The displacer piston 4 changes a volume ratio between the high-temperature expansion space S1 and the low-temperature compression space S2.

[0032] The power piston 3 is a short columnar member that is housed in the cylinder 2 to be slidable in the axial direction. The power piston 3 is located closer to the crankcase 9 than the displacer piston 4. The compression space S2 is disposed between the displacer piston 4 and the power piston 3. The power piston 3 is displaced in the axial direction by a pressure change of operating fluid between the expansion space S1 and the compression space S2 (a high-temperature region and a low-temperature region), that is, a force caused by a pressure difference between an upper portion and a lower portion of the power piston 3.

[0033] The heater 5, the regenerator 6, and the cooler 7 are arranged in this order from the connection side between the cylinder 2 and the heater 5 toward the portion where the crankcase 9 is disposed, immediately outside the cylinder 2. Operating fluid is allowed to flow from the expansion space S1 into the compression space S2 through the heater 5, the regenerator 6, and the cooler 7 in this order. The operating fluid is also allowed to flow from the compression space S2 into the expansion space

S1 through the cooler 7, the regenerator 6, and the heater 5 in this order.

[0034] The heater 5 is a heat exchanger for heating operating fluid. The heater 5 may have various known configurations, and in this embodiment, has a configuration in which operating fluid flows in a large number of fine tubes arranged to obtain a large heat-transfer area. A heating medium is, for example, an exhaust gas generated by a power plant or other places, and flows outside the fine tubes of the heater 5. In this manner, the temperature of the operating fluid is increased (the operating fluid is heated) by receiving heat from the heating medium.

[0035] The cooler 7 is a heat exchanger for cooling operating fluid. The cooler 7 may have various known configurations, and in this embodiment, employs a configuration including a large number of fine tubes, in a manner similar to the heater 5. A cooling medium cooled by some method flows outside the fine tubes of the cooler 7 so that heat is taken by the cooling medium from operating fluid flowing in the fine tubes and the temperature is reduced (cooling).

[0036] The regenerator 6 is a heat exchanger for thermal storage. The regenerator 6 may have various known configurations, and in this embodiment, has a configuration in which metal meshes are stacked. In a case where high-temperature operating fluid in the expansion space S1 flows from the heater 5 to the cooler 7 through the regenerator 6, the regenerator 6 takes heat from the operating fluid and stores the heat. On the other hand, in a case where low-temperature operating fluid in the compression space S2 flows to the heater 5 from the cooler 7 through the regenerator 6, the regenerator 6 transfers the heat thus stored to the operating fluid.

[0037] The crankshaft 8 is configured to convert power generated in the cylinder 2 (specifically, power caused by the reciprocating movement of the power piston 3) to rotation movement. The crankshaft 8 is rotatably supported by the crankcase 9. One end of the crankshaft 8 projects to the outside of the crankcase 9, and an electric generator 29 is attached to this end. This electric generator 29 converts the rotation movement of the crankshaft 8 to electric power.

[0038] The crankcase 9 is a case across which the crankshaft 8 is bridged, and accommodates the flywheel 10 and the crank box 11 therein. The cylinder 2 and the crankcase 9 communicate with each other through an unillustrated hole. Thus, in this embodiment, not only the cylinder 2 but also the crankcase 9 is filled with operating fluid.

[0039] The flywheel 10 is a disk-shaped member, and is disposed in a region inside the crankcase 9 and outside the crank box 11 while being penetrated by the crankshaft 8. The flywheel 10 serves as a flywheel for smoothly rotating the crankshaft 8 with a reduced variation in rotation speed while maintaining a momentum of rotation of the crankshaft 8.

[0040] The crank box 11 accommodates the first power

conversion members 30 for converting reciprocating movement of the power piston 3 to rotation movement of the crankshaft 8. The crank box 11 accommodates the second power conversion member 40 for converting rotation movement of the crankshaft 8 to reciprocating movement of the displacer piston 4. These power conversion members 30 and 40 are sliding members (more strictly, include sliding members), and thus, need lubrication. The stirling engine 1 of this embodiment employs a wet sump lubrication method that lubricates the power conversion members 30 and 40 with lubricating oil stored in the crank box 11.

[0041] Here, if the lubricating oil intrudes into the cylinder 2, this lubricating oil might adversely affect performance of the heat exchangers 5, 6, and 7, for example. Specifically, if lubricating oil adheres to the metal meshes of the regenerator 6 described above or the like, for example, the regenerator 6 might be blocked and a flow of operating fluid might be hindered. Thus, in the stirling engine 1, it is desirable to prevent or reduce intrusion of the lubricating oil into the cylinder 2. In view of this, in this embodiment, lubricating oil is stored only in the crank box 11 accommodating the power conversion members 30 and 40 that need lubrication, and leakage of lubricating oil to a region in the crankcase 9 located outside the crank box 11 (i.e., a region inside the crankcase 9 and outside the crank box 11) is prevented or reduced. In other words, the crankcase 9 has a double structure and lubricating oil is enclosed in the crank box 11 corresponding to the innermost space of the double structure to thereby prevent or reduce intrusion of lubricating oil in the cylinder 2.

[0042] Oil seals 21, 22, and 23 are provided to keep the inside of the crank box 11 sealed (closed) with respect to the outer space. In other words, the oil seals 21, 22, and 23 are sealing members for keeping the inner space of the crank box 11 in a substantially hermetic state with respect to a space inside the crankcase 9 and outside the crank box 11.

[0043] As illustrated in Fig. 1, the crankshaft 8 penetrates the crank box 11. A portion in which the crankshaft 8 penetrates the crank box 11 is provided with the oil seal 21 for filling a gap between the outer peripheral surface of the crankshaft 8 and a through hole formed in the crank box 11. This structure prevents or reduces leakage of lubricating oil in the crank box 11 through the gap between the outer peripheral surface of the crankshaft 8 and the through hole in the crank box 11.

[0044] The first power conversion members 30 are configured to convert reciprocating movement of the power piston 3 to rotation movement of the crankshaft 8, and provided as a pair to sandwich the second power conversion member 40 described later. In a β type stirling engine, various mechanisms such as a crosshead mechanism, a rhombic mechanism, and a Scotch yoke mechanism can be used as a mechanism for converting reciprocating movement to rotation movement. In this embodiment, a Scotch yoke mechanism having a reduced size and a relatively simple structure is employed as the first

power conversion members 30. Specifically, as illustrated in Fig. 2, each of the first power conversion members 30 of this embodiment includes, for example, a power piston yoke 31, guide shafts 32, a first eccentric crankpin (not shown), and a rod 34.

[0045] The power piston yoke 31 is a plate-shape member capable of sliding (reciprocating). The power piston yoke 31 has a pair of through holes penetrating the power piston yoke 31.

[0046] The pair of through holes extends in parallel with the axial direction of the cylinder 2. The power piston yoke 31 has a guide groove penetrating the plate surface thereof. As will be described later, this guide groove accommodates the first eccentric crankpin.

[0047] The guide shafts 32 are axial members extending in parallel with the axial direction of the cylinder 2, and each of the guide shafts 32 has one end fixed to the crank box 11 (see Fig. 2). The guide shafts 32 are provided as a pair sandwiching the crankshaft 8. The guide shafts 32 are inserted in the through holes of the power piston yoke 31. Accordingly, the guide shafts 32 slidably support the power piston yoke 31. A linear motion bearing such as a rotary bushing is disposed in a sliding portion between the through holes of the power piston yoke 31 and the guide shafts 32.

[0048] The first eccentric crankpin is a crankpin that is eccentrically attached to the crankshaft 8. The first eccentric crankpin is fixed to the crankshaft 8 or integrally formed with the crankshaft 8, while penetrating the crankshaft 8. The first eccentric crankpin is accommodated in the guide groove of the power piston yoke 31 such that the first eccentric crankpin can move while rolling in the guide groove. A rotation bearing such as a rolling bearing is provided in a sliding portion between the guide groove of the power piston yoke 31 and the first eccentric crankpin.

[0049] The rod 34 is configured to link reciprocating movement of the power piston yoke 31 and reciprocating movement of the power piston 3 to each other. The rod 34 has a long axial shape, and has one end connected to the power piston 3 and the other end connected to the power piston yoke 31. A portion in which the rod 34 penetrates the crank box 11 is provided with the oil seal 22 for filling a gap between the outer peripheral surface of the rod 34 and a through hole formed in the crank box 11. Accordingly, leakage of lubricating oil in the crank box 11 through the gap between the outer peripheral surface of the rod 34 and the through hole in the crank box 11 is prevented or reduced.

[0050] In the first power conversion members 30 having such a configuration, when the power piston 3 is displaced in the cylinder 2, the power piston yoke 31 coupled to the power piston 3 through the rod 34 slides along the guide shafts 32, and accordingly, the first eccentric crankpin moves in the guide groove while rolling. Accordingly, the crankshaft 8 is displaced by rotation. In this manner, reciprocating movement of the power piston 3 is converted to rotation movement of the crankshaft 8, and the ro-

tation movement is transferred to the electric generator 29.

[0051] The second power conversion member 40 is configured to convert rotation movement of the crankshaft 8 to reciprocating movement of the displacer piston 4. As a mechanism for converting rotation movement to reciprocating movement in a β type stirling engine, various mechanisms can be used as described above. In this embodiment, a Scotch yoke mechanism is employed as the second power conversion member 40, in a manner similar to the first power conversion members 30. Specifically, the second power conversion member 40 of this embodiment includes, for example, a displacer yoke 41, a guide shaft 42, a second eccentric crankpin, and a rod 44.

[0052] The configurations of the displacer yoke 41, the guide shaft 42, the second eccentric crankpin, and the rod 44 of the second power conversion member 40 are substantially the same as those of the power piston yoke 31, the guide shafts 32, the first eccentric crankpin, and the rod 34 of the first power conversion members 30, respectively, and thus, will not be described in detail.

[0053] The rod 44 of the second power conversion member 40 is inserted in an unillustrated through hole formed in the power piston 3 in order to couple the displacer yoke 41 and the displacer piston 4 to each other. The power piston 3 is slidably provided to the rod 44, and this sliding portion is provided with an unillustrated seal mechanism for keeping hermeticity. A portion where the rod 44 penetrates the crank box 11 is provided with an oil seal 23 for filling a gap between the outer peripheral surface of the rod 44 and the through hole formed in the crank box 11.

[0054] In the second power conversion member 40 having such a configuration, when rotation movement of the crankshaft 8 occurs, the second eccentric crankpin integrally formed with the crankshaft 8 moves in the guide groove of the displacer yoke 41 while rolling. With this movement, the displacer yoke 41 slides along the guide shaft 42. Accordingly, the displacer piston 4 coupled to the displacer yoke 41 through the rod 44 is displaced in conjunction with the displacer yoke 41. In this manner, the rotation movement of the crankshaft 8 is converted to reciprocating movement of the displacer piston 4, and in cooperation with reciprocating movement of the power piston 3, a volume ratio between the expansion space S1 and the compression space S2 varies periodically.

[0055] The first eccentric crankpin and the second eccentric crankpin are disposed to have a predetermined phase difference (phase difference of 90° in this embodiment) such that a timing at which the power piston 3 reaches a top dead point (a highest point above the cylinder 2 in Fig. 1) and a timing at which the displacer piston 4 reaches the top dead point are shifted from each other.

[0056] An operation principle of the stirling engine 1 will now be described briefly.

[0057] When the displacer piston 4 is near the top dead point, operating fluid in the compression space S2 is

pushed and compressed by the power piston 3 that rises with rotation of the crankshaft 8. When the displacer piston 4 starts descending by rotation of the crankshaft 8, the volume of the compression space S2 decreases and the volume of the expansion space S1 increases. Consequently, operating fluid in the compression space S2 passes through the cooler 7, the regenerator 6, and the heater 5 in this order, and moves into the expansion space S1. In this process, the operating fluid is heated to be at a relatively high temperature, and thus, the operating fluid starts thermal expansion in the expansion space S1 so that the pressure increases.

[0058] The increased pressure in the expansion space S1 immediately propagates to the compression space S2 so that the pressure in the compression space S2 increases similarly to the expansion space S1. In this situation, when the power piston 3 starts descending after having reached the top dead point, the power piston 3 is pushed downward by operating fluid, and accordingly, the power piston 3 slides in the cylinder 2. The displacement of the power piston 3 is transferred to the crankshaft 8, and the crankshaft 8 obtains a drive force to rotate.

[0059] With the rotation of the crankshaft 8, the displacer piston 4 reaches the bottom dead point. Thereafter, when the displacer piston 4 rises, the volume of the expansion space S1 decreases and the volume of the compression space S2 increases. Accordingly, operating fluid in the expansion space S1 passes through the heater 5, the regenerator 6, and the cooler 7 in this order, and moves into the compression space S2. In this process, the operating fluid is cooled to a relatively low temperature, and the pressure thereof decreases.

[0060] The power piston 3 reaches the bottom dead point after the displacer piston 4, and then starts rising. Subsequently, the displacer piston 4 reaches a point near the top dead point.

[0061] The foregoing cycle is repeated so that the pressure changes of operating fluid in the expansion space S1 and the compression space S2 are repeated. By using the repetitive changes, the power piston 3 reciprocates, and this reciprocating movement is converted to rotation movement of the crankshaft 8, and power is taken.

[0062] In the stirling engine 1 having the configuration described above, the expansion space S1 and the compression space S2 are filled with operating fluid in the manner described above. A space in the cylinder 2 closer to the crankshaft 8 than the power piston 3 (hereinafter referred to as a space at the rear of the power piston 3), the crankcase 9, and the crank box 11 are also filled with operating fluid. In this embodiment, these spaces are filled with operating fluid under high pressure (higher than the atmospheric pressure) in order to obtain power efficiently by increasing a pressure change of operating fluid.

[0063] As described above, in the case where a space inside the crank box 11 is kept in a substantially hermetic state with respect to a space outside the crank box 11, the following problems can arise. That is, conventionally, in the case of performing a process of filling the inner

space of the crankcase 9 with operating fluid, the operating fluid is supplied from an operating fluid passage that is open to the crankcase 9. Fig. 7 illustrates an example of a conventional stirling engine having an operating fluid passage. If this filling method is applied to the stirling engine 1 of this embodiment without change, operating fluid that has flowed into a second space S9 through the operating fluid passage flows into the inner space of the crank box 11 through small gaps such as a gap between the rod 34 and the oil seal 22, a gap between the rod 44 and the oil seal 23, and a gap between the crankshaft 8 and the oil seal 21. This structure enables both of a first space S11 and the second space S9 to be filled with operating fluid. However, if the filling with the operating fluid is not performed slowly in a sufficient period, a large pressure difference occurs between the spaces S9 and S11 so that the oil seals 21, 22, and 23 might be damaged. Similarly, in a case where a process of discharging operating fluid in the crankcase 9 through the operating fluid passage, if the operating fluid is not slowly discharged in a sufficient period, a large pressure difference also occurs between the spaces S9 and S11 so that the oil seals 21, 22, and 23 might be damaged.

[0064] In view of this, in this embodiment, to prevent or reduce damage of, for example, the oil seals 21, 22, and 23, there provided is a path for keeping a balance between the pressure of a space inside the crank box 11 and the pressure of a space outside the crank box 11 and inside the crankcase 9. This path will be described in detail hereinafter with reference to Fig. 2. Fig. 2 is a schematic view illustrating a partial configuration of the stirling engine 1 according to the first embodiment. In the following description, the space inside the crank box 11 will be simply referred to as the "first space S11" in some cases. A space located outside the crank box 11 and inside the crankcase 9 will be simply referred to as the "second space S9" in some cases.

[0065] As illustrated in Fig. 2, the stirling engine 1 of this embodiment includes a connection route (path) 51, a valve 52, an operating fluid passage 53, and a valve 54.

[0066] The connection route 51 is a path for keeping a balance between the pressure of the first space S11 and the pressure of the second space S9. The connection route 51 of this embodiment is a pipe member having a circular cross section, and a channel in which operating fluid flows is formed inside the connection path 51. In other words, the connection route 51 includes a channel that communicates the first space S11 and the second space S9 with each other.

[0067] One end (first end) 51a of the connection route 51 is connected to a side surface of the crank box 11 and is open (has an opening) to the first space S11. The end 51a of the connection route 51 is disposed above a liquid level of an oil sump of lubricating oil in the crank box 11. A specific example of the liquid level of the oil sump of lubricating oil is shown by a chain double-dashed line in the drawing. The other end (second end) 51b of the connection route 51 is connected to the bottom surface of

the crankcase 9, and is open (has an opening) to the second space S9.

[0068] A part of an intermediate portion of the connection route 51 between the one end 51a and the other end 51b is disposed outside the crankcase 9.

[0069] The valve 52 is a valve capable of opening and closing a channel in the connection route 51. The valve 52 is disposed in the intermediate portion of the connection route 51. The valve 52 is disposed in a portion of the connection route 51 outside the crankcase 9. In this embodiment, the valve 52 is configured to be opened and closed manually by an operator.

[0070] The operating fluid passage 53 is a passage for distributing operating fluid in filling the first space S11 and the second space S9 with operating fluid and in discharging (releasing) the operating fluid from the first space S11 and the second space S9. The operating fluid passage 53 of this embodiment is a pipe member having a circular cross section, and a channel in which operating fluid flows is formed inside the operating fluid passage 53.

[0071] One end of the operating fluid passage 53 is connected to a side surface of the crankcase 9, and is open to the second space S9. The other end of the operating fluid passage 53 is open to the outside of the crankcase 9.

[0072] The valve 54 is a valve capable of opening and closing a channel in the operating fluid passage 53. The valve 54 is disposed in the operating fluid passage 53. In this embodiment, the valve 54 is configured to be opened and closed manually by an operator.

[0073] In the stirling engine 1 having the configuration described above, filling the first space S11 and the second space S9 with operating fluid is performed in the following manner. That is, before start of filling with the operating fluid, the valve 52 is opened so that the first space S11 and the second space S9 are connected to each other (communicate with each other). The space at the rear of the power piston 3 and the compression space S2 are connected to each other through a communication path (not shown) to communicate with each other. In this state, a vessel (e.g., a cylinder) enclosing operating fluid is connected to the other end of the operating fluid passage 53, and the valve 54 is opened so that the operating fluid is supplied to the crankcase 9 through the operating fluid passage 53 at an appropriate flow rate.

[0074] The operating fluid supplied through the operating fluid passage 53 in the manner described above gradually fills the crankcase 9 (second space S9). A part of the operating fluid filling the crankcase 9 passes through the through hole of the crankcase 9 to fill the space at the rear of the power piston 3. A part of the operating fluid filling the space at the rear of the power piston 3 passes through the communication path to also fill the compression space S2 and the expansion space S1.

[0075] In addition, since the valve 52 is open, a part of operating fluid filling the second space S9 is quickly sup-

plied to the first space S11 through the connection route 51. Consequently, a balance is kept between the pressure of the first space S11 and the pressure of the second space S9. At this time, since the one end 51a of the connection route 51 is located above the liquid level of the oil sump of lubricating oil in the crank box 11, even in a state where the crank box 11 accommodates lubricating oil, a part of operating fluid in the second space S9 can be supplied to the first space S11 through the connection route 51. As described above, in this embodiment, it is possible to reduce occurrence of a difference between the pressure of the first space S11 and the pressure of the second space S9 with a simple structure. Thus, in filling these spaces with operating fluid, even when operating fluid is supplied at a high rate, the oil seals 21, 22, and 23 are not damaged. As a result, the process of filling with the operating fluid can be completed in a short time.

[0076] In addition, in this embodiment, the valve 52 is disposed in an intermediate portion of the connection route 51 outside the crankcase 9, and thus, the valve 52 can be operated by an operator from outside the crankcase 9 so that the first space S11 and the second space S9 can communicate with each other easily only when necessary.

[0077] In discharging the operating fluid from the first space S11 and the second space S9 to the outside through the operating fluid passage 53, the operating fluid can be discharged with a balance being kept between the pressure of the first space S11 and the pressure of the second space S9 by opening the valve 52 while allowing the space at the rear of the power piston 3 and the compression space S2 to communicate with each other through the communication path.

[0078] As described above, the stirling engine 1 of this embodiment includes the crankcase 9, the crank box 11, and the connection route 51. The crankshaft 8 for taking power to the outside is disposed across the crankcase 9. The crank box 11 is disposed in the crankcase 9. The crank box 11 accommodates the first power conversion members 30 of converting reciprocating movement of the power piston 3 to rotation movement of the crankshaft 8, and the second power conversion member 40 for converting rotation movement of the crankshaft 8 to reciprocating movement of the displacer piston 4. The connection route 51 keeps a balance between the pressure of the first space S11 in the crank box 11 and the pressure of the second space S9 located inside the crankcase 9 and outside the crank box 11.

[0079] In the manner described above, since the connection route 51 for keeping a balance between the pressure of the first space S11 in the crank box 11 and the pressure of the second space S9 in the crankcase 9 is provided, in filling the first space S11 and the second space S9 with operating fluid or in discharging the operating fluid from these spaces, occurrence of a pressure difference can be reduced between the pressure of the first space S11 and the pressure of the second space

S9. Thus, it does not take a long time to fill the crankcase 9 and the crank box 11 with operating fluid or to discharge the operating fluid from the crankcase 9 and the crank box 11.

[0080] In the stirling engine 1 of this embodiment, the connection route 51 has a channel for allowing the first space S11 and the second space S9 to communicate with each other.

[0081] Accordingly, it is possible to take a balance between the pressure in the crank box 11 and the pressure in the crankcase 9 with a simple structure.

[0082] In the stirling engine 1 of this embodiment, the connection route 51 includes one end (first end) 51a and the other end 51b (second end). The one end 51a of the connection route 51 is open to the first space S11. The other end 51b of the connection route 51 is open to the second space S9. At least a part of the intermediate portion between the one end 51a and the other end 51b is disposed outside the crankcase 9.

[0083] Accordingly, it is possible to take a balance between the pressure in the crank box 11 and the pressure in the crankcase 9 with a very simple structure. In addition, as in this embodiment, for example, when the valve 52 capable of opening and closing the channel in the connection route 51 is disposed in the intermediate portion of the connection route 51, the valve 52 can be operated by an operator from outside the crankcase 9, and the crank box 11 and the crankcase 9 are allowed to communicate with each other easily only when necessary.

[0084] In the stirling engine 1 of this embodiment, the one end 51a of the connection route 51 is disposed above the liquid level of the oil sump of lubricating oil in the crank box 11.

[0085] Accordingly, operating fluid can be distributed between the first space S11 and the second space S9 through the connection route 51 with lubricating oil stored in the crank box 11. Thus, supply and release of operating fluid to the crankcase 9 and the crank box 11 can be quickly performed with lubricating oil stored in the crank box 11.

<Variation of First Embodiment>

[0086] Subsequently, a stirling engine 1 according to a variation of the first embodiment will be described with reference to Fig. 3. Fig. 3 is a schematic view illustrating a partial configuration of the stirling engine 1 according to the variation of the first embodiment. In the description of the variation, parts that are identical or similar to those of the above-described embodiment are given identical reference numerals in the drawings, and description of these parts may be omitted.

[0087] As illustrated in Fig. 3, the stirling engine 1 of this variation is different from that of the first embodiment in including a dual-purpose path 55 instead of the connection route 51 and the operating fluid passage 53.

[0088] The dual-purpose path 55 is a pipe member

branched into two at an intermediate portion thereof, and an end (first end) 55a of one of the branched passages (branched passage) is connected to a crank box 11. The one end 55a of this branched passage of the dual-purpose path 55 is open to the crank box 11.

[0089] The other end (second end) 55b of the other branched passage (branched passage 55e) of the dual-purpose path 55 is connected to the crankcase 9. This end 55b of the other branched passage 55e of the dual-purpose path 55 is open in the crankcase 9.

[0090] The branched passage 55e of the other dual-purpose path 55 is disposed outside the crankcase 9. An intermediate portion of the branched passage 55e is provided with a valve 52 for opening and closing a channel in the branched passage 55e.

[0091] A valve 54 is disposed at an open-side end (third end) in a non-branched portion of the dual-purpose path 55.

[0092] In the stirling engine 1 having this structure, a passage for allowing the first space S11 and the second space S9 to communicate with each other (corresponding to the connection route 51) and a passage for distributing operating fluid in filling and discharging the operating fluid (corresponding to the operating fluid passage 53) can be constituted by one passage, and thus, the passage can be simplified.

<Second Embodiment>

[0093] A stirling engine 1 according to a second embodiment will now be described with reference to Fig. 4. Fig. 4 is a schematic view illustrating a partial configuration of the stirling engine 1 according to the second embodiment. In the description of this embodiment, parts that are identical or similar to those of the above-described embodiment are given identical reference numerals in the drawings, and description of these parts may be omitted.

[0094] As illustrated in Fig. 4, the stirling engine 1 of this embodiment includes a first filling/discharging path (first path) 61, a second filling/discharging path (second path) 62, a valve 63, and a valve 64.

[0095] The first filling/discharging path 61 is a passage for distributing operating fluid in filling a first space S11 with operating fluid and discharging operating fluid from the first space S11. The first filling/discharging path 61 of this embodiment is a pipe member having a circular cross section, and a channel in which operating fluid flows is formed inside the first filling/discharging path 61.

[0096] One end 61a of the first filling/discharging path 61 is connected to a side surface of a crank box 11 and is open (has an opening) to the first space S11. The first filling/discharging path 61 extends from the side surface of the crank box 11 toward the outside of a crankcase 9. The other end of the first filling/discharging path 61 is disposed outside the crankcase 9, and is open (has an opening) to the outside of the crankcase 9.

[0097] The second filling/discharging path 62 is a pas-

sage for distributing operating fluid in filling a second space S9 with operating fluid and in discharging the operating fluid from the second space S9. The second filling/discharging path 62 of this embodiment is a pipe member having a circular cross section, and a channel in which operating fluid flows is formed inside the second filling/discharging path 62.

[0098] The second filling/discharging path 62 is disposed outside the crankcase 9. One end 62a of the second filling/discharging path 62 is connected to the bottom surface of the crankcase 9, and is open (has an opening) to the second space S9. The other end of the second filling/discharging path 62 is disposed outside the crankcase 9, and is open (has an opening) to the outside of the crankcase 9.

[0099] Here, a ratio between a channel area of the channel of the first filling/discharging path 61 and a channel area of the channel of the second filling/discharging path 62 is set in consideration of a ratio between a volume of a portion filled with operating fluid by supplying the operating fluid to the first space S11 and a volume of a portion filled with operating fluid by supplying the operating fluid to the second space S9. Specifically, the ratio between the channel area of the channel of the first filling/discharging path 61 and the channel area of the channel of the second filling/discharging path 62 can be set to be substantially equal to the ratio described above.

[0100] The valve 63 is a valve capable of opening and closing the channel in the first filling/discharging path 61. The valve 63 is disposed at the other end of the first filling/discharging path 61.

[0101] The valve 64 is a valve capable of opening and closing the channel in the second filling/discharging path 62. The valve 64 is disposed at the other end of the second filling/discharging path 62.

[0102] In the stirling engine 1 having this structure, filling the first space S11 and the second space S9 with operating fluid is performed in the following manner, for example. Specifically, a vessel (e.g., cylinder) enclosing operating fluid is connected to the other end of the first filling/discharging path 61 and the other end of the second filling/discharging path 62, and the valve 63 and the valve 64 are opened substantially at the same time so that the operating fluid is supplied to the first space S11 and the second space S9 at an appropriate flow rate.

[0103] At this time, since the ratio between the channel area of the channel of the first filling/discharging path 61 and the channel area of the channel of the second filling/discharging path 62 is set in consideration of the ratio between the volume of the portion filled with the operating fluid as described above, a balance can be easily kept between the pressure of the first space S11 and the pressure of the second space S9 by appropriately adjusting the flow rate of supply of the operating fluid, for example. Accordingly, these spaces can be quickly filled with the operating fluid without damage of the oil seals 21, 22, and 23.

[0104] As described above, the stirling engine 1 of this

embodiment includes, as the paths described above, the first filling/discharging path 61 and the second filling/discharging path 62.

[0105] Thus, operating fluid can be supplied from each of the other end of the first filling/discharging path 61 and the other end of the second filling/discharging path 62 at an appropriate flow rate when necessary in consideration of the rate of the volume of the portion filled with operating fluid supplying the operating fluid to the first space S11 and the volume of the portion filled with operating fluid by supplying the operating fluid to the second space S9. Accordingly, these spaces can be filled with operating fluid with a balance kept between the pressure of the first space S11 and the pressure of the second space S9.

[0106] To keep a balance between the pressures of these spaces, possible resistances on the inner peripheral surfaces of the first filling/discharging path 61 and the second filling/discharging path 62, the lengths of channels of the first filling/discharging path 61 and the second filling/discharging path 62, and pressures of pushing operating fluid into the other end of the first filling/discharging path 61 and the other end of the second filling/discharging path 62 from the vessel, for example.

[0107] In the stirling engine 1 of this embodiment, setting is made in consideration of the ratio of the volume between the portion filled with operating fluid by supplying the operating fluid to the first space S11 and the volume of the portion filled with operating fluid by supplying the operating fluid to the second space S9.

[0108] Accordingly, the state in which a balance is kept between the pressure of the first space S11 and the pressure of the second space S9 can be easily obtained by appropriately adjusting the rate of supplying operating fluid, for example. Thus, these spaces can be quickly filled with operating fluid easily. Similarly, operating fluid can be easily discharged from the spaces.

<Third Embodiment>

[0109] A stirling engine 1 according to a third embodiment will now be described with reference to Fig. 5. Fig. 5 is a schematic view illustrating a partial configuration of the stirling engine 1 according to the third embodiment. In the description of this embodiment, parts that are identical or similar to those of the above-described embodiments are given identical reference numerals in the drawings, and description of these parts may be omitted.

[0110] As illustrated in Fig. 5, the stirling engine 1 of this embodiment includes a first filling/discharging path (first path) 71, a second filling/discharging path (second path) 72, a valve 73, a valve 74, and a throttle 75.

[0111] The first filling/discharging path 71 is a passage for distributing operating fluid in filling a first space S11 with operating fluid and discharging the operating fluid from the first space S11. The first filling/discharging path 71 of this embodiment is a pipe member having a circular cross section, and a channel in which operating fluid flows is formed inside the first filling/discharging path 71.

[0112] One end 71a of the first filling/discharging path 71 is connected to a side surface of a crank box 11 and is open to the first space S11. The first filling/discharging path 71 extends from a side surface of the crank box 11 toward the outside of a crankcase 9. The other end of the first filling/discharging path 71 is disposed outside the crankcase 9, and is open to the outside of the crankcase 9.

[0113] The second filling/discharging path 72 is a passage for distributing operating fluid in filling a second space S9 with operating fluid and discharging the operating fluid from the second space S9. The second filling/discharging path 72 of this embodiment is a pipe member having a circular cross section, and a channel in which operating fluid flows is formed inside the second filling/discharging path 72.

[0114] The second filling/discharging path 72 is disposed outside the crankcase 9. One end 72a of the second filling/discharging path 72 is connected to the bottom surface of the crankcase 9, and is open to the second space S9. The other end of the second filling/discharging path 72 is disposed outside the crankcase 9, and is open to the outside of the crankcase 9.

[0115] In this embodiment, a channel area of the channel of the first filling/discharging path 71 is substantially equal to a channel area of the channel of the second filling/discharging path 72.

[0116] The valve 73 is a valve capable of opening and closing a channel in the first filling/discharging path 71. The valve 73 is disposed at the other end of the first filling/discharging path 71.

[0117] The valve 74 is a valve capable of opening and closing the channel in the second filling/discharging path 72. The valve 74 is disposed at the other end of the second filling/discharging path 72.

[0118] The throttle 75 restricts a channel area of a channel in which the throttle 75 is disposed. In this embodiment, the throttle 75 is disposed in an intermediate portion of the second filling/discharging path 72. The throttle 75 of this embodiment is configured to set a channel area in the second filling/discharging path 72 at a predetermined channel area. This channel area is appropriately set in consideration of various factors such as a ratio between a volume of a portion filled with operating fluid by supplying the operating fluid to the first space S11 and a volume of a portion filled with operating fluid by supplying the operating fluid to the second space S9, lengths of the first filling/discharging path 71 and the second filling/discharging path 72, and the pressure and temperature, for example, of operating fluid to be supplied. In this embodiment, the throttle 75 is disposed in the second filling/discharging path 72. Alternatively or in addition to the second filling/discharging path 72, the throttle 75 may be disposed in the first filling/discharging path 71.

[0119] In the stirling engine 1 having this structure, filling the first space S11 and the second space S9 with operating fluid is performed in the following manner, for

example. Specifically, a vessel enclosing operating fluid is connected to the other end of the first filling/discharging path 71 and the other end of the second filling/discharging path 72, and the valve 73 and the valve 74 are opened substantially at the same time so that the operating fluid is supplied to the first space S11 and the second space S9 at an appropriate flow rate.

[0120] At this time, since the degree of reducing a channel in the second filling/discharging path 72 by the throttle 75 is set in consideration of various factors as described above, a state in which a balance is easily kept between the pressure of the first space S11 and the pressure of the second space S9 can be obtained by appropriately adjusting the pressure and the temperature, for example, of operating fluid to be supplied. Accordingly, these spaces can be filled with operating fluid without an excessively long period.

[0121] As described above, the stirling engine 1 of this embodiment includes, as the paths described above, the first filling/discharging path 71 and the second filling/discharging path 72. At least one of the first filling/discharging path 71 and the second filling/discharging path 72 is provided with the throttle 75 for restricting a channel area of the channel.

[0122] Thus, by providing the throttle 75 appropriately, operating fluid can be quickly supplied and discharged to/from the spaces with a substantial balance kept between the pressure of the first space S11 and the pressure of the second space S9.

<Fourth Embodiment>

[0123] A stirling engine 1 according to a fourth embodiment will now be described with reference to Fig. 6.

[0124] Fig. 6 is a schematic view illustrating a partial configuration of the stirling engine 1 according to the fourth embodiment. In the description of this embodiment, parts that are identical or similar to those of the above-described embodiments are given identical reference numerals in the drawings, and description of these parts may be omitted.

[0125] As illustrated in Fig. 5, the stirling engine 1 of this embodiment includes a first filling/discharging path 71, a second filling/discharging path 72, a valve 73, a valve 74, a variable throttle 85, a pressure difference sensor 86, and a control device 87.

[0126] The variable throttle 85 is configured to adjust a channel area of a channel in which the variable throttle 85 is disposed. In this embodiment, the variable throttle 85 is disposed in an intermediate portion of the second filling/discharging path 72. The variable throttle 85 changes a channel area of the channel (the degree of the throttle) in a plurality of stages or steplessly in accordance with an instruction signal from the control device 87. In this embodiment, the variable throttle 85 is disposed in the second filling/discharging path 72. Alternatively or in addition to the second filling/discharging path 72, the variable throttle 85 may be provided in the first filling/dis-

charging path 71.

[0127] The pressure difference sensor 86 is a sensor for detecting a difference between the pressure of the first space S11 and the pressure of the second space S9. A detection result of the pressure difference sensor 86 is sent to the control device 87 as a detection signal.

[0128] The control device 87 monitors a detection result of the pressure difference sensor 86 and adjusts the state of the variable throttle 85 automatically in accordance with the detection result to perform control of adjusting a channel area in the second filling/discharging path 72. The control device 87 is configured as a computer, and includes, for example, a CPU, a ROM, and RAM. The ROM records (stores) an appropriate operation program for causing the variable throttle 85 to operate. With cooperation of the software and the hardware, the control device 87 serves as an instruction section for causing the variable throttle 85 to operate appropriately in accordance with a pressure difference between the first space S11 and the second space S9 and to send an instruction for adjusting a channel area.

[0129] The control device 87 receives a detection result of the pressure difference sensor 86, that is, information on a pressure difference between the first space S11 and the second space S9 as a detection signal regularly or irregularly.

[0130] In the case of filling the first space S11 and the second space S9 with operating fluid, if the pressure of the second space S9 is lower than the pressure of the first space S11, the control device 87 of this embodiment outputs an instruction signal for increasing the opening degree of the variable throttle 85 from the current degree to the variable throttle 85, based on the pressure difference acquired from the pressure difference sensor 86. On the other hand, if the pressure of the second space S9 is higher than the pressure of the first space S11, the control device 87 outputs an instruction signal for reducing the opening degree of the variable throttle 85 from the current degree to the variable throttle 85.

[0131] This feedback control is repeated so that the channel area ratio between the first filling/discharging path 71 and the second filling/discharging path 72 to a preferable ratio for sufficiently reducing a difference between the pressure of the first space S11 and the pressure of the second space S9. In this state, operating fluid continues to be supplied through the first filling/discharging path 71 and the second filling/discharging path 72 so that the first space S11 and the second space S9 can be filled with operating fluid with a balance automatically kept between the pressure of the first space S11 and the pressure of the second space S9 without a complicated calculation. As a result, filling with the operating fluid can be quickly performed without damage of the oil seals 21, 22, and 23, for example.

[0132] In the case of discharging operating fluid from the first space S11 and the second space S9, the opening degree of the variable throttle 85 is controlled in the direction opposite to that described above.

[0133] As described above, the stirling engine 1 of this embodiment includes, as the paths described above, the first filling/discharging path 71 and the second filling/discharging path 72. The stirling engine 1 includes the variable throttle 85 as a throttle for restricting the channel area. This variable throttle 85 is configured to enable adjustment of the channel area of this channel.

[0134] Accordingly, pressure adjustment can be flexibly performed in accordance with various situations.

[0135] The stirling engine 1 of this embodiment further includes the pressure difference sensor 86 and the control device 87. The pressure difference sensor 86 detects a difference between the pressure of the first space S11 and the pressure of the second space S9. In accordance with a detection result of the pressure difference sensor 86, the control device 87 controls a state of the variable throttle 85.

[0136] Accordingly, automatic pressure adjustment for preventing or reducing occurrence of a pressure difference between the first space S11 and the second space S9 can be achieved.

[0137] The foregoing description is directed to the preferred embodiments of the present invention and variations thereof, and the configurations described above may be changed, for example, as follows.

[0138] In the first embodiment, one end of the operating fluid passage 53 is open to the second space S9. However, the present invention is not limited to this embodiment. For example, instead of this configuration, one end of the operating fluid passage (corresponding to the operating fluid passage 53) may be open to the first space S11.

[0139] A lubrication passage for use in filling the crank box 11 with lubricating oil may be used as the operating fluid passage 53.

[0140] In this embodiment, for example, the cylinder enclosing operating fluid is connected to the other end of the operating fluid passage 53 or other places to thereby supply the operating fluid to the first space S11 and the second space S9. However, the source of operating fluid is not limited to this. For example, instead of this configuration, operating fluid may be pumped to the first space S11 and the second space S9 with a pump from a vessel (tank) enclosing operating fluid.

[0141] In the second through fourth embodiments, operating fluid may be supplied to the first space S11 and the second space S9 from the same source or different sources.

[0142] In the third and fourth embodiments, the throttle 75 and the variable throttle 85 are provided as structures for restricting the channel area of the channel through which operating fluid passes in supplying and discharging the operating fluid, respectively. That is, instead of the throttle, a "valve" capable of restricting a channel area may be provided. In this case, for example, the valves 63 and 64 (valves 73 and 74) may have the function of restricting channel areas and serve as the "valve."

[0143] In the first embodiment, the first space S11 and

the second space S9 are connected to each other with the pipe-like connection route 51. However, the present invention is not limited to this embodiment. For example, instead of this configuration, a columnar plug in which a channel capable of connecting and disconnecting the first space S11 and the second space S9 is formed may be provided to penetrate the crank box 11 and the crankcase 9. In this case, this plug is operated by an operator from outside the crankcase 9 so that the first space S11 and the second space S9 are switched between connection and disconnection.

[0144] In addition, instead of this configuration, a valve capable of connecting and disconnecting the first space S11 and the second space S9 may be provided to penetrate the crank box 11. In this case, in supplying and discharging operating fluid, valve is opened or closed to switch the first space S11 and the second space S9 between connection and disconnection. In a case where this valve is constituted by a first check valve closed to the first space S11 and a second check valve closed to the second space S9, when a pressure difference occurs between the first space S11 and the second space S9, one of these check valves is opened so that the first space S11 and the second space S9 can be switched between connection and disconnection without an operation of the valve from outside the crankcase 9.

[0145] In the embodiments described above, the stirling engine 1 is a so-called β type engine. However, the present invention is not limited to this, and instead, an α type or a γ type engine may be employed.

Reference Signs List

[0146]

1	stirling engine
3	piston
8	crankshaft
9	crankcase
11	crank box
30	power conversion member
51	path
S11	first space
S9	second space

Claims

1. A stirling engine comprising:

a crankcase across which a crankshaft for taking power to outside is bridged;
a crank box disposed in the crankcase and accommodating a power conversion member, the power conversion member being configured to convert reciprocating movement of a piston to rotation movement of the crankshaft; and
a path configured to take a balance between a

pressure of a first space in the crank box and a pressure of a second space inside the crankcase and outside the crank box.

sult of the pressure difference sensor.

2. The stirling engine according to claim 1, wherein the path includes a channel through which the first space and the second space communicate with each other. 5

3. The stirling engine according to claim 2, wherein the path includes
 - a first end that is open to the first space, and
 - a second end that is open to the second space, and 15
 at least a part of an intermediate portion of the path between the first end and the second end is located outside the crankcase. 20

4. The stirling engine according to claim 1, wherein the path includes
 - a first path having one end open to the first space and another end located outside the crankcase, and 25
 - a second path having one end open to the second space and another end located outside the crankcase. 30

5. The stirling engine according to claim 4, wherein a ratio between a channel area of the first path and a channel area of the second path is set in consideration of a ratio between a volume of a portion filled with operating fluid by supplying the operating fluid to the first space and a volume of a portion filled with operating fluid by supplying the operating fluid to the second space. 35

6. The stirling engine according to claim 4 or 5, wherein at least one of the first path and the second path is provided with a valve or a throttle, each of the valve and the throttle being configured to restrict a channel area of a channel in the at least one of the first path and the second path. 40 45

7. The stirling engine according to claim 6, wherein each of the valve and the throttle is configured to adjust the channel area of the channel. 50

8. The stirling engine according to claim 7, further comprising:
 - a pressure difference sensor that detects a difference between a pressure of the first space and a pressure of the second space; and 55
 - a control device that controls a state of the valve or the throttle in accordance with a detection re-

1 ↗

Fig.1

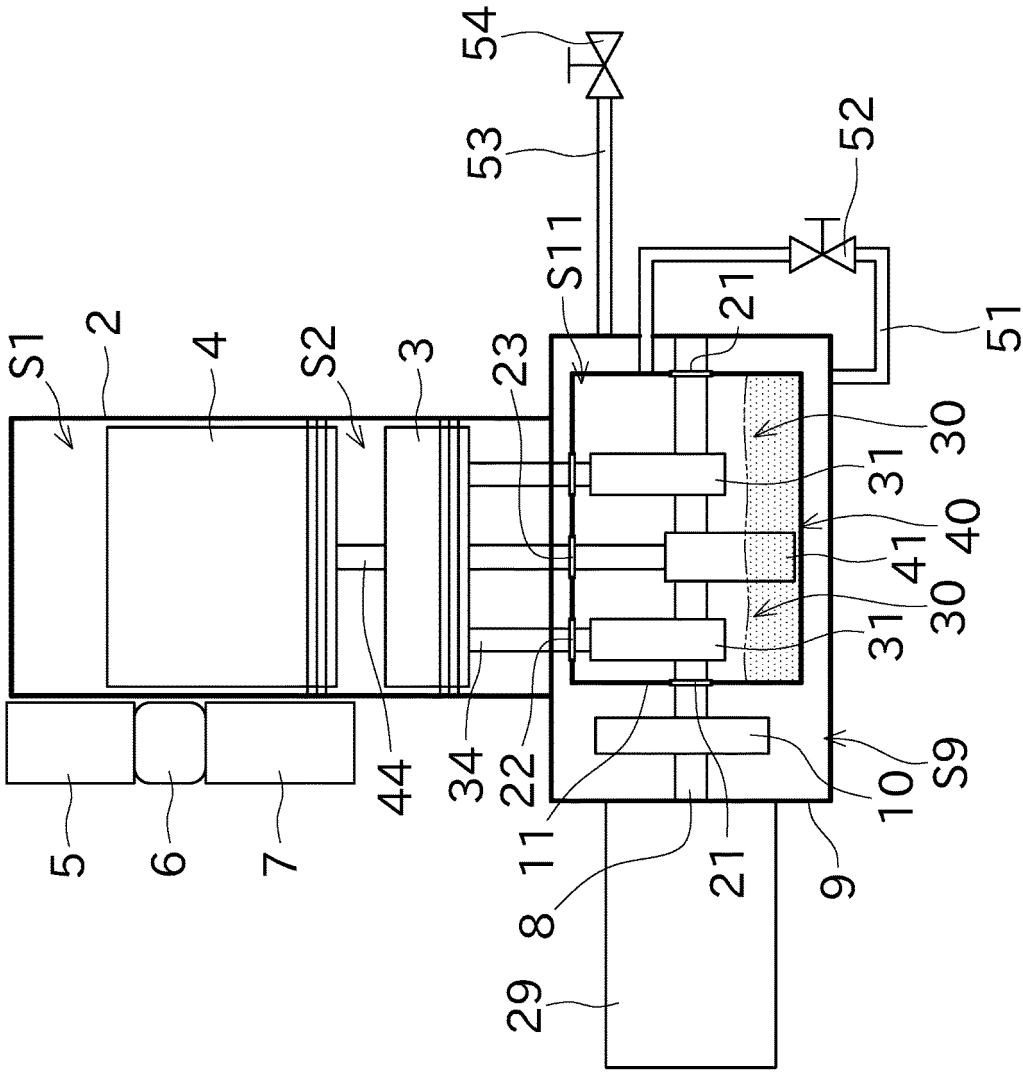
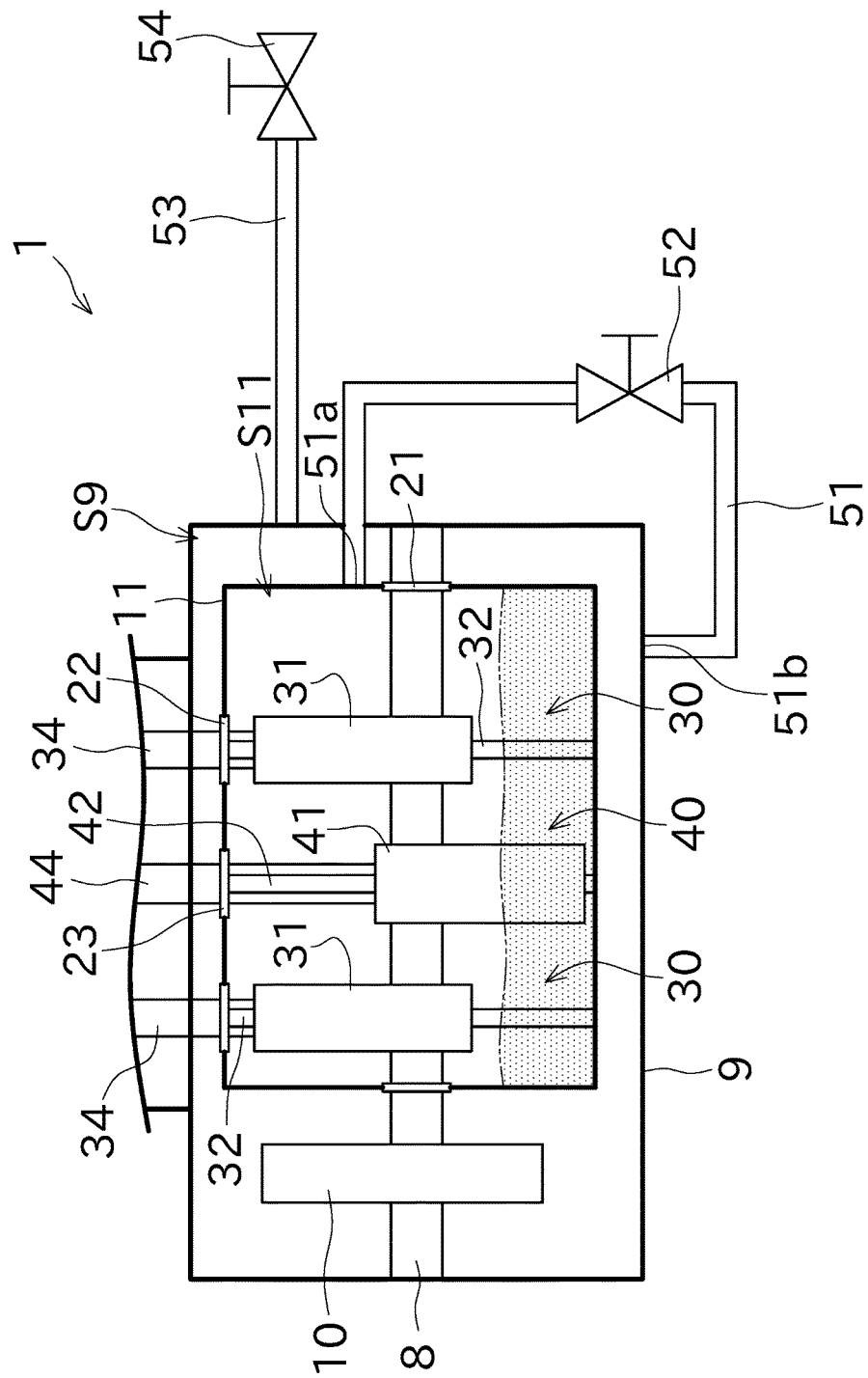


Fig.2



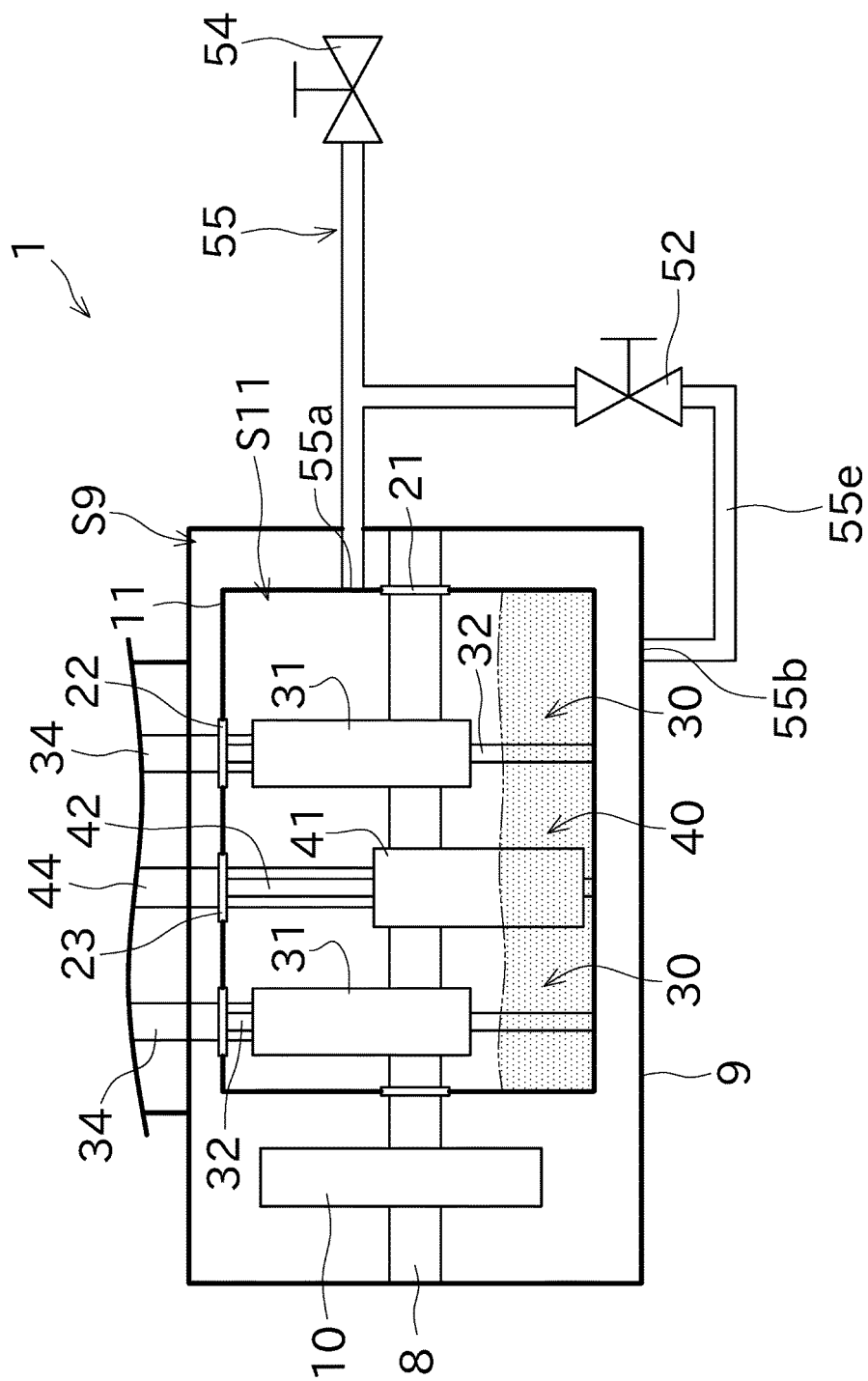


Fig. 3

Fig. 4

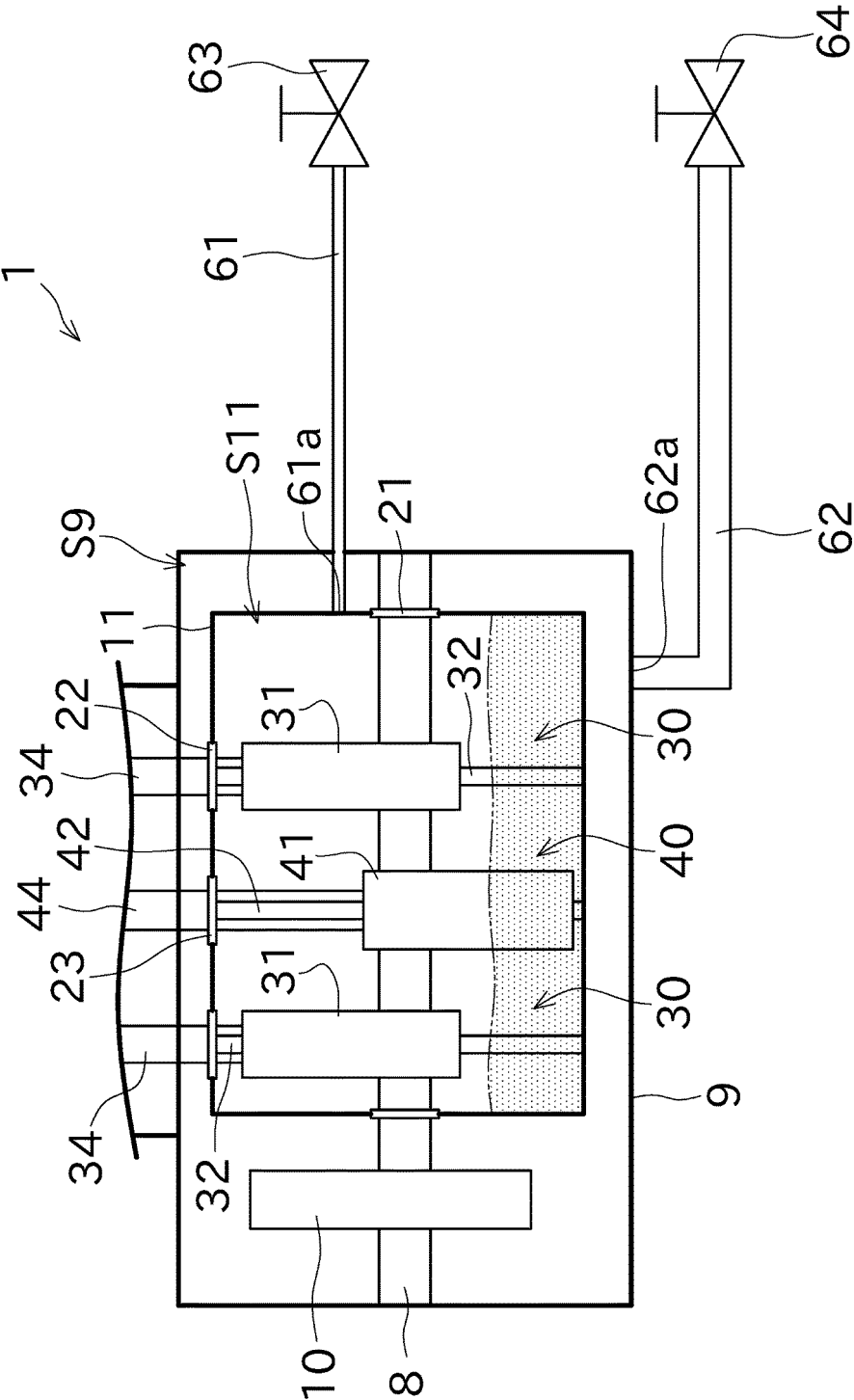


Fig.5

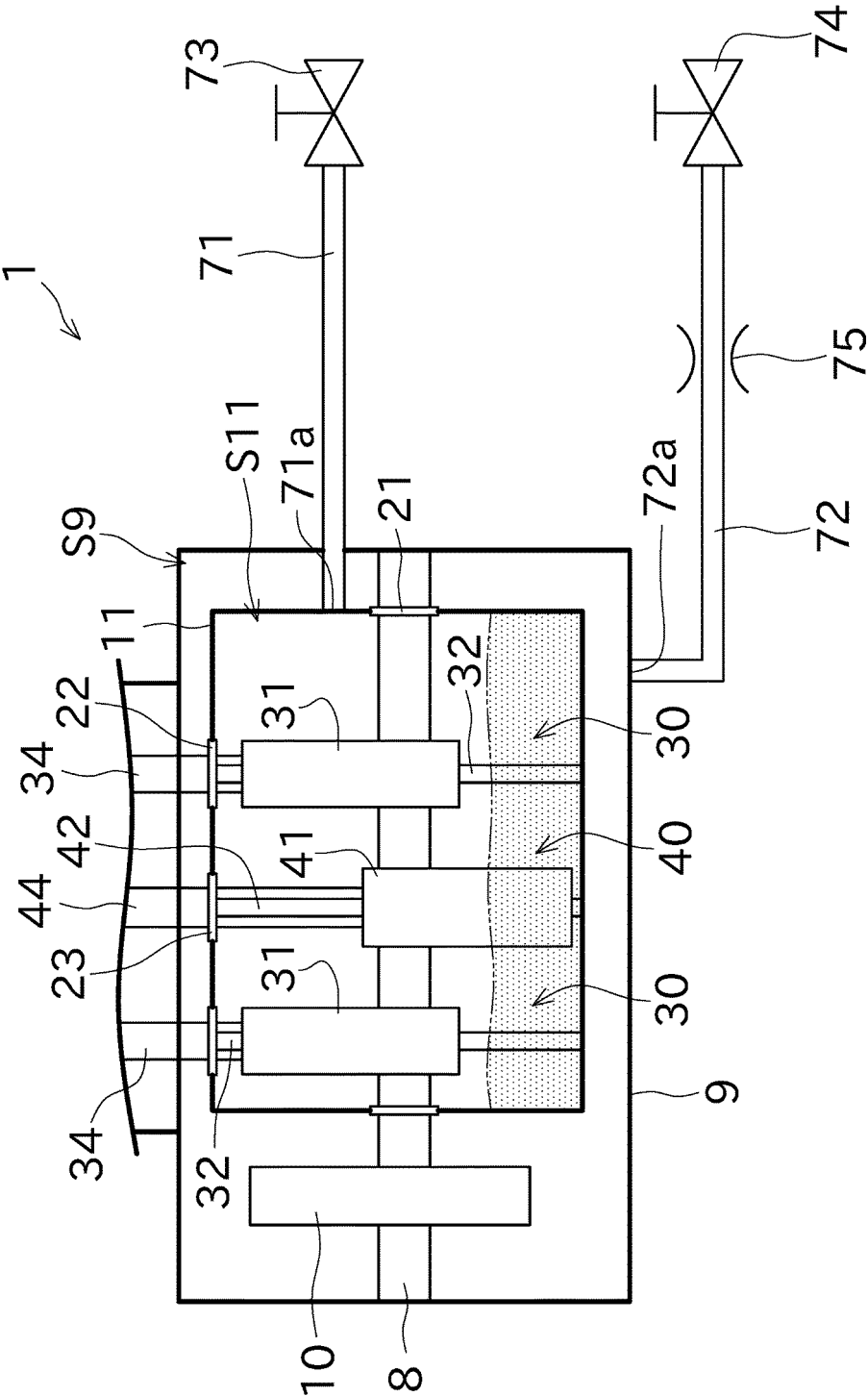


Fig.6

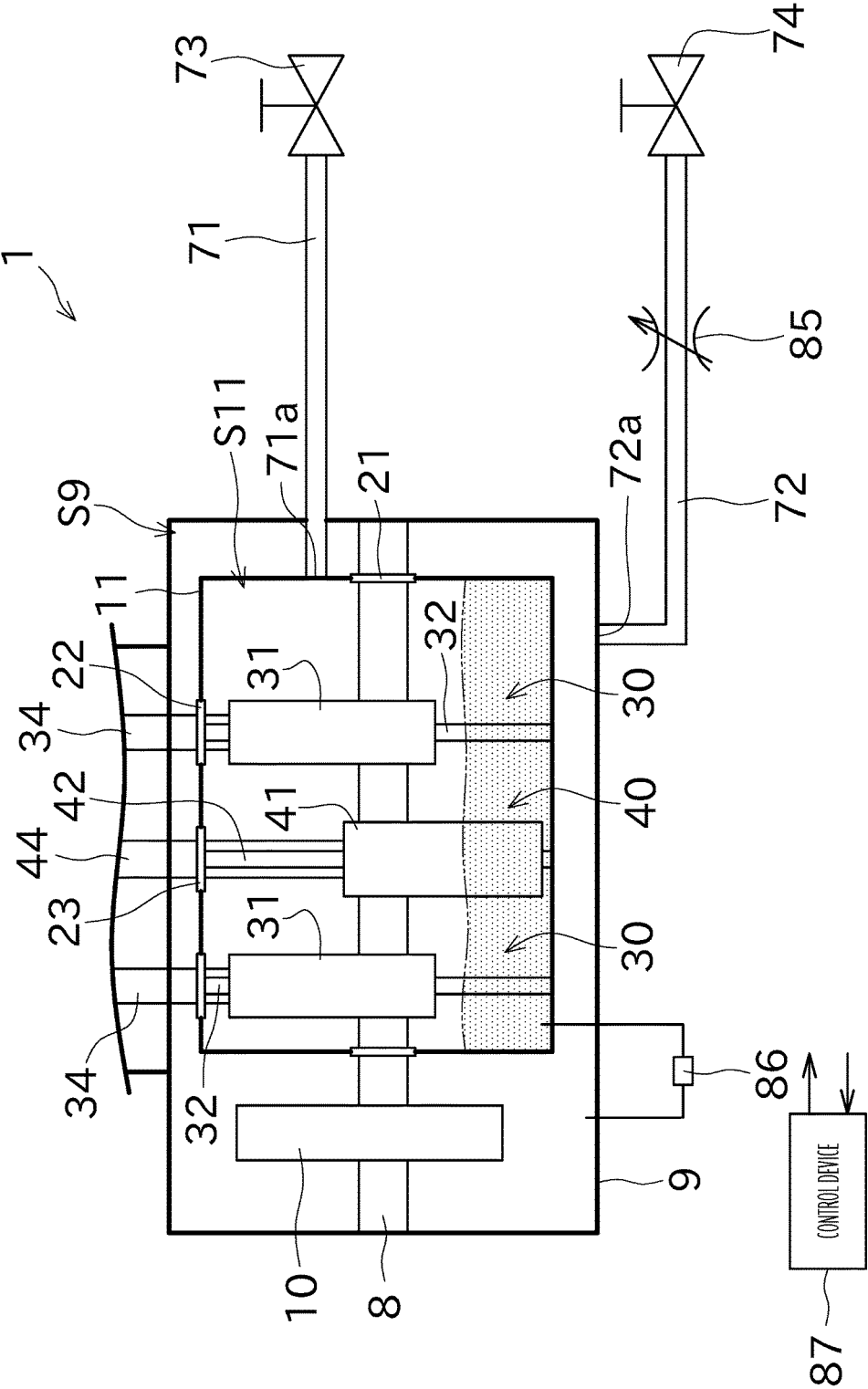
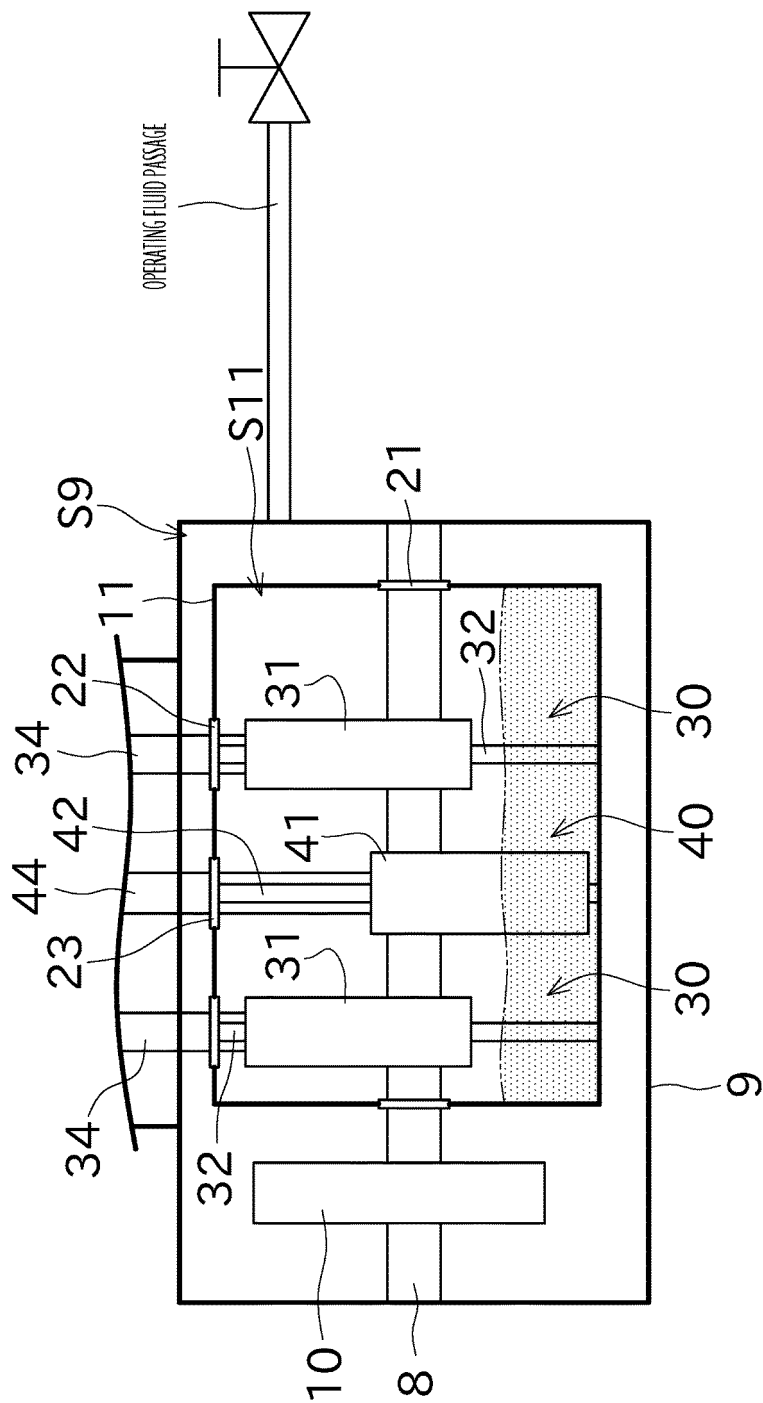


Fig.7

PRIOR ART



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2018/009088

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. F02G1/053(2006.01)i, F02G1/045(2006.01)i, F02G1/05(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)

Int.Cl. F02G1/053, F02G1/045, F02G1/05

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

Published examined utility model applications of Japan 1922-1996

Published unexamined utility model applications of Japan 1971-2018

Registered utility model specifications of Japan 1996-2018

Published registered utility model applications of Japan 1994-2018

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.
X	JP 2009-62906 A (ESTIR KK) 26 March 2009, paragraphs [0008]-[0016], fig. 9	1-2
A	(Family: none)	3-8
A	WO 91/15672 A1 (STIG G. CARLQVIST MOTOR CONSULTANT (C. M. C.) AKTIEBOLAG) 17 October 1991	1-8
	(Family: none)	

☐ Further documents are listed in the continuation of Box C.☐ See patent family annex.

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Date of the actual completion of the international search
26.04.2018Date of mailing of the international search report
15.05.2018Name and mailing address of the ISA/
Japan Patent Office
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Patent documents cited in the description

- JP 2003522879 W [0006]
- JP 2009062906 A [0006]