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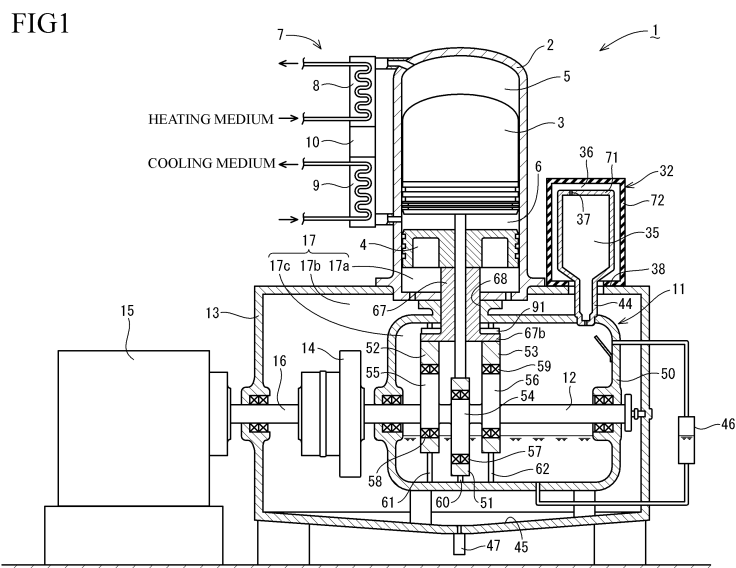
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STIRLING ENGINE

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A Stirling engine 1 includes: a piston 4 that reciprocates in a cylinder 2; a heat exchanger 7 that promotes contraction and expansion of an operating fluid in the cylinder 2; and a power takeout device 11 that converts a reciprocation driving force by the piston 4 to a rotative force. The power takeout device 11 is disposed

in a crank box 50 incorporated in a crankcase 13 so that a first buffer chamber 17b is defined outside the crank box 50 and a second buffer chamber 17c is defined inside the crank box 50 in the crankcase 13. The first and second buffer chambers 17b and 17c communicate with each other through a breather 32.



Description

Technical Field

[0001] The present invention relates to a Stirling engine that is an external combustion engine.

Background Art

[0002] A Stirling engine, for example, has been known as an external combustion engine that outputs a driving force by contraction and expansion of an operating fluid based on a temperature difference by heat from the outside. The Stirling engine moves an operating fluid between a compression chamber and an expansion chamber alternately and repeats expansion and contraction of the operating fluid by a heat exchanger to thereby drive a piston so that heat from the outside is converted to a driving force (see Patent Literatures 1 and 2: PTLs 1 and 2). Examples of such known Stirling engines include an alpha type in which a compression chamber and an expansion chamber are defined in different cylinders, a beta type in which a displacer piston and a power piston are housed in the same cylinder, and a gamma type in which a displacer piston and a power piston are housed in different cylinders.

[0003] The Stirling engine includes a power takeout device such as a crank mechanism for converting reciprocating movement of a power piston to rotation movement, and outputs a rotative force to the outside. A Stirling engine described in PTL 1 is configured such that a power takeout device constituted by a crosshead mechanism is disposed below the piston, a cylinder (operating chamber) incorporating a displacer piston and a power piston and a crank chamber (buffer chamber) on which a crankshaft of the crank mechanism is pivotally supported are separated vertically in the same case. A Stirling engine described in PTL 2 is configured such that a power takeout device constituted by a Scotch yoke mechanism is disposed inside a crankcase (buffer chamber) below a cylinder (operating chamber) incorporating a displacer piston and a power piston.

Citation List

Patent Literatures

[0004]

PTL 1: Japanese Patent Application Laid-Open No. S63-243574 (1988)

PTL 2: Japanese Patent No. 4873647

Summary of Invention

Technical Problem

[0005] The Stirling engine of PTL 1 employs a wet

sump lubrication system that supplies lubricating oil to a sliding portion such as a bearing. The Stirling engine of PTL 2 employs a built-in lubrication system in which a sliding portion is constituted by a grease-enclosed part or an oil-impregnated part, for example. In the wet sump lubrication system in PTL 1, a spray of lubricating oil in the buffer chamber might enter the operating chamber to cause, for example, clogging in a heat exchanger that exchanges heat with an operating fluid. On the other hand, in the built-in lubrication system in PTL 2, when power is increased, a withstand load in the sliding portion such as the bearing needs to be increased, and the size of the power takeout device increases in order to reduce a contact pressure in the sliding portion accordingly. Thus, it is difficult to reduce the size of the entire engine.

[0006] Some aspects of the present invention have a technical object of providing a Stirling engine improved in view of circumstances as described above.

Solution to Problem

[0007] An aspect of the present invention provides a Stirling engine including: a piston that reciprocates in a cylinder; a heat exchanger that promotes contraction and expansion of an operating fluid in the cylinder; and a power takeout device that converts a reciprocation driving force by the piston to a rotative force, wherein the heat exchanger alternately repeats contraction and expansion of the operating fluid in the cylinder to cause the piston to reciprocate, the power takeout device is disposed in a crank box incorporated in a crankcase so that a first buffer chamber is defined outside the crank box and a second buffer chamber is defined inside the crank box in the crankcase, the first buffer chamber and the second buffer chamber communicate with each other through a breather, and an orifice is formed in a box coupled portion that causes the breather to communicate with the second buffer chamber.

[0008] In the Stirling engine, the breather may be divided into a first compartment communicating with the second buffer chamber and a second compartment communicating with the first buffer chamber, the first and second compartments may communicate with each other through a communication port that forms an orifice, and in the breather, the box coupled portion may be disposed at a lowest portion and is located at a position above an oil level of lubricating oil enclosed in the crank box, and the first compartment may have a volume larger than an amount of volume change by piston reciprocation.

[0009] In the Stirling engine, the first compartment may be divided, by a separator including a communication hole, into at least two processing rooms including a final processing room communicating with the second compartment, and a total volume of the processing rooms excluding the final processing room may be greater than or equal to the amount of volume change.

[0010] In the Stirling engine, the number of processing rooms excluding the final processing room may be two

or more.

[0011] In the Stirling engine, the first compartment may be divided, by a separator including a communication hole, into an initial processing room communicating with the box coupled portion, a final processing room communicating with the second compartment, and an intermediate processing room between the initial processing room and the final processing room, and a volume of each of the initial processing room, the intermediate processing room, and the final processing room may be greater than or equal to a half of the amount of volume change.

[0012] In the Stirling engine, the breather may have a double pipe structure in which an inner case coupled to the crank box by the box coupled portion is covered with an outer case coupled to the crankcase by a case coupled portion that is open at an outer periphery of the box coupled portion, the box coupled portion may project from a coupling portion between the case coupled portion and the crankcase toward inside of the crankcase and may be coupled to the crank box, and the inner case may have a communication port through which the first and second compartments communicate with each other, in a highest portion opposite to the box coupled portion.

Advantageous Effects of Invention

[0013] According to an aspect of the present invention, the crankcase has the double structure incorporating the crank box, and lubricating oil is enclosed in the crank box. Accordingly, mixture of lubricating oil into the buffer chamber outside the crank box in the crankcase can be avoided. Accordingly, it is possible to further reliably prevent or reduce entering of lubricating oil into an operating chamber in the cylinder so that failures and problems in driving caused by, for example, adhesion of lubricating oil to the operating chamber in the cylinder, the heat exchanger, and other parts can be reduced.

[0014] According to an aspect of the present invention, in the breather located at a position higher than the oil level of lubricating oil, since the first compartment has a volume larger than the amount of volume change by piston reciprocation, lubricating oil can be separated from an operating fluid flowing into the first compartment, and sent to the second compartment. Thus, entering of lubricating oil into the first buffer chamber communicating with the second compartment can be suppressed so that entering of lubricating oil into an operating chamber in the cylinder and the heat exchanger can be reliably prevented or reduced. Consequently, problems in driving the Stirling engine and mechanical damage can be avoided.

[0015] According to an aspect of the present invention, when the piston moves toward the crankcase and an operating fluid in the second buffer chamber in the crank box is purged, the total volume of the processing rooms excluding the final processing room in the first compartment becomes greater than or equal to a purge amount of the operating fluid. Thus, the operating fluid from the

second buffer chamber tends to remain in the processing rooms before the final processing room. Accordingly, lubricating oil mixed in the operating fluid is easily separated from the operating fluid in the processing rooms before the final processing room, and thus, the amount of lubricating oil flowing into the final processing room is reduced so that mixing of lubricating oil into the operating fluid flowing from the breather into the first buffer chamber can be prevented or reduced.

[0016] According to an aspect of the present invention, in the first compartment, the separator constituting the processing rooms before the final processing room serves as a baffle so that the amount of lubricating oil that reaches the final processing room can be reduced. In addition, when an operating fluid flows from the second buffer chamber into the first compartment, the operating fluid passes through the initial processing room and the intermediate processing room each having a volume greater than or equal to the purge amount of the operating fluid so that the separator blocks the lubricating oil and the amount of lubricating oil flowing into the final processing room can be sufficiently reduced.

[0017] According to an aspect of the present invention, the first compartment in the inner case functions as the lubricating oil separating room that separates mist lubricating oil entering from the second buffer chamber together with an operating fluid, and the communication port is disposed away from the box coupled portion. Accordingly, lubricating oil that has flowed into the first compartment does not easily reach the communication port, and mixture of lubricating oil into the operating fluid flowing to the second compartment can be reduced. Accordingly, entering of lubricating oil into the operating chamber in the cylinder and the heat exchanger can be reliably prevented or reduced so that problems in driving and mechanical damage in the Stirling engine can be avoided.

Brief Description of Drawings

[0018]

[FIG. 1] A cross-sectional side view schematically illustrating a Stirling engine in an embodiment of the present invention.

[FIG. 2] A cross-sectional front view schematically illustrating the Stirling engine.

[FIG. 3] A cross-sectional side view of a power takeout device in the Stirling engine.

[FIG. 4] An explanatory drawing illustrating a connection structure to a displacer piston in the power takeout device.

[FIG. 5] An explanatory drawing illustrating a connection structure to a power piston in the power takeout device.

[FIG. 6] A cross-sectional view illustrating a configuration of a first example of a breather in the Stirling engine.

[FIG. 7] A cross-sectional view illustrating a configuration of a second example of the breather.

[FIG. 8] (a)(b) are cross-sectional views illustrating another configuration of the second example of the breather.

[FIG. 9] A cross-sectional view illustrating a configuration of a third example of the breather.

[FIG. 10] A cross-sectional view illustrating a configuration of a fourth example of the breather.

[FIG. 11] A view illustrating another configuration of an oil level gauge.

[FIG. 12] A schematic view for describing a second example of an oil leakage detecting part.

[FIG. 13] A control flowchart while the Stirling engine is stopped.

[FIG. 14] A schematic view for describing a third example of the oil leakage detecting part.

[FIG. 15] A schematic cross-sectional view of a Stirling engine according to another embodiment of the present invention.

Description of Embodiments

1. Overall configuration of Stirling engine

[0019] An overall configuration of a Stirling engine embodying an aspect of the present invention will be described with reference to the drawings. FIG. 1 is a cross-sectional side view schematically illustrating the Stirling engine. FIG. 2 is a cross-sectional front view schematically illustrating the Stirling engine. In the following description, a beta-type Stirling engine will be described as an example.

[0020] As illustrated in FIGs. 1 and 2, in the Stirling engine 1, a cylinder 2 enclosing an operating fluid such as air, a helium gas, or hydrogen incorporates a displacer piston 3 and a power piston 4. The cylinder 2 is configured to be open at one end and closed at the other end. The displacer piston 3 is disposed at the closed end, whereas the power piston 4 is disposed at the open end. In the cylinder 2, an expansion chamber 5 is formed between the closed end and the displacer piston 3, and the compression chamber 6 is formed between the displacer piston 3 and the power piston 4. The expansion chamber 5 and the compression chamber 6 in the cylinder 2 will be referred to collectively as an operating chamber.

[0021] The Stirling engine 1 includes a heat exchanger 7 that increases and reduces the temperature of an operating fluid in the operating chamber in the cylinder 2. The heat exchanger 7 is configured such that a heater 8 that communicates with the expansion chamber 5 and heats an operating fluid by heat entering from the outside and a cooler 9 that communicates with the compression chamber 6 and cools an operating fluid by dissipating heat to the outside are coupled to each other through a regenerator 10 incorporating a matrix that is a porous thermal storage material. When the displacer piston 3 moves toward the open end of the cylinder 2, the oper-

ating fluid heated by the heater 8 enters the expansion chamber 5 so that the temperature of the operating fluid increases accordingly. On the other hand, when the displacer piston 3 moves toward the closed end of the cylinder 2, the operating fluid cooled by the cooler 9 enters the compression chamber 6 so that the temperature of the operating fluid decreases, accordingly. Thus, the operating fluid flows in opposite directions between the heat exchanger 7 and the operating chamber in the cylinder 2 so that the internal pressure in the operating chamber of the cylinder 2 changes to promote reciprocation movement of the power piston 4.

[0022] To increase a heat transfer area with an external heating medium, the heater 8 is constituted by small tubes, heat collecting fins, and other parts, for example, and increases its temperature when the operating fluid passing through the inside of the heater 8 receives heat from the heating medium. Similarly, the cooler 9 is also constituted by small tubes, heat dissipation fins, and other parts, for example, in order to increase a heat transfer area with an external cooling medium, and reduces its temperature when an operating fluid passing through the cooler 9 dissipates heat to the cooling medium. The regenerator 10 is constituted by, for example, a stack of metal fibers or metal meshes, operating fluid channels arranged in, for example, a honeycomb pattern, or a material incorporating flocculent metal fibers, and functions as a regenerative heat exchanger. That is, while a high-temperature operating fluid flows from the heater 8 to the cooler 9, the regenerator 10 stores heat of the operating fluid, whereas while a low-temperature operating fluid flows from the cooler 9 to the heater 8, the regenerator 10 dissipates stored heat to the operating fluid.

[0023] The Stirling engine 1 includes, at the open end of the cylinder 2, a power takeout device 11 that converts a reciprocation operation of the power piston 4 to a rotation operation and outputs a rotative force. The power takeout device 11 pivotally supports, in a crankcase 13, a crankshaft 12 coupled to each of the displacer piston 3 and the power piston 4. An end of the crankshaft 12 serves as an output shaft and is coupled to an input shaft 16 of an electric generator 15 through a flywheel 14 in the crankcase 13. A chamber 17a closer to the open end than the power piston 4 in the cylinder 2 and chambers 17b and 17c in the crankcase 13 define a buffer chamber (rear chamber of the power piston 4) 17.

[0024] The displacer piston 3 and the power piston 4 are connected to the crankshaft 12 of the power takeout device 11 to thereby reciprocate in the cylinder 2 with a predetermined phase difference. In this embodiment, the phase difference in reciprocation operation of the displacer piston 3 and the power piston 4 is 90°.

2. Example configuration of power takeout device

[0025] A configuration of the power takeout device 11 in the Stirling engine 1 will be described hereinafter with reference to FIGs. 1 through 5. As illustrated in FIGs. 1

through 5, the power takeout device 11 is disposed in a crank box 50 fixed inside the crankcase 13. The power takeout device 11 is constituted by a Scotch yoke mechanism in which crankpins 54 through 56 of the crankshaft 12 are respectively fitted, through bearings 57 through 59, in a plate 51c fixed to a crankshaft guide groove (through groove) 51a of a displacer yoke (reciprocating part) 51 that reciprocates in conjunction with the displacer piston 3 and plates 52c and 53c fixed to crankshaft guide grooves (through grooves) 52a and 53a of power piston yokes (reciprocating parts) 52 and 53 that reciprocate in conjunction with the power piston 4.

[0026] As illustrated in FIGs. 1 through 5, the crank box 50 is coupled and supported in the crankcase 13, is coupled to the cylinder 2 inserted in the crankcase 13, and pivotally supports the crankshaft 12. A part of the cylinder 2 is inserted in the crankcase 13, and the crankcase 13 is coupled to the inserted portion of the cylinder 2 to cover the entire crank box 50. That is, the power takeout device 11 is disposed inside the casing having the double structure of the crankcase 13 and the crank box 50. The crankshaft 12 penetrates the crank box 50 to be coupled to the flywheel 14 in the crankcase 13.

[0027] As illustrated in FIG. 4, a center portion of the displacer yoke 51 has the crankshaft guide groove 51a elongated in a direction (lateral direction) intersecting the axial directions of the crankshaft 12 and the displacer piston 3. A reciprocation guide hole (through hole) 51b is formed in each of side portions of the displacer yoke 51 sandwiching the crankshaft guide groove 51a, in a direction (longitudinal direction) along the axial direction of the displacer piston 3. A guide shaft 60 fixed to the crank box 50 is inserted in the reciprocation guide hole 51b of the displacer yoke 51 with a linear motion bearing 63 such as a rotary bushing interposed therebetween. The displacer yoke 51 is coupled to one end of a rod 66 that is coupled to the displacer piston 3 at the other end, and reciprocates in the same directions (longitudinal direction) as the reciprocation direction of the displacer piston 3 in conjunction with reciprocation of the displacer piston 3.

[0028] As illustrated in FIG. 5, a center portion of the power piston yoke 52 (53) has the crankshaft guide groove 52a (53a) elongated in the lateral direction, and the reciprocation guide hole (through hole) 52b (53b) penetrates each of the side portions sandwiching the crankshaft guide groove 52a (53a) in the longitudinal direction. The guide shaft 61 (62) fixed to the crank box 50 is inserted in the reciprocation guide hole 52b (53b) of the power piston yoke 52 (53) with the linear motion bearing 64 (65) interposed therebetween. The power piston yoke 52 (53) is coupled to one end of a bridge 67 that is coupled to the power piston 4 at the other end, and reciprocates in the longitudinal direction in conjunction with reciprocation of the power piston 4.

[0029] As illustrated in FIGs. 3 through 5, through holes 4a and 67a are formed in a direction along the axial direction of the power piston 4 (longitudinal direction) at

the centers of the power piston 4 and the bridge 67, and the rod 66 coupled to the displacer piston 3 penetrates the through holes 4a and 67a. The rod 66 is movable relative to the power piston 4 and the bridge 67, and a dynamic sealing mechanism (not shown) of, for example, a mechanical seal, is constituted in a portion of the power piston 4 in which the rod 66 is inserted.

[0030] As illustrated in FIGs. 2 through 5, the crankshaft 12 is provided with the crankpin 54 coupled to the rod 66 through the displacer yoke 51, between the crankpins 55 and 56 coupled to the bridge 67 through the power piston yokes 52 and 53. The crankpin 54 is attached to the crankpins 55 and 56 of the same phase with a predetermined phase difference (e.g., 90°). A portion of the crank box 50 coupled to the cylinder 2 has a bridge insertion hole 68 in which the bridge 67 is inserted and fitted. The bridge insertion hole 68 of the crank box 50 is formed in a coupling portion between the cylinder 2 and the crank box 50. The bridge 67 reciprocates in conjunction with the power piston 4 in such a manner that a portion of the bridge 67 toward the cylinder 2 is inserted and extracted into/from the bridge insertion hole 68. To reduce variations of the internal pressure caused by volume change with reciprocation of the power piston 4 in the third buffer chamber 17a closer to the open end than the power piston 4 in the cylinder 2, a communication port 17d is disposed between the third buffer chamber 17a and the first buffer chamber 17b.

[0031] The displacer piston 3 reciprocates by a rotative force of the crankshaft 12, and an operating fluid moves toward and rearward between the expansion chamber 5 and the compression chamber 6 so that the internal pressure of the operating chamber changes. This pressure change causes the power piston 4 to reciprocate, and this reciprocation driving force is transferred to the power piston yokes 52 and 53 through the bridge 67. Accordingly, the power piston yokes 52 and 53 reciprocate in the longitudinal direction along the guide shafts 61 and 62, respectively. The reciprocation movement of the power piston yokes 52 and 53 causes the crankpins 55 and 56 to reciprocate in the lateral direction in the crankshaft guide grooves 52a and 53a, respectively, while rotating so that the crankshaft 12 rotates. Thus, the power takeout device 11 that has received the reciprocation driving force of the power piston 4 converts the driving force to a rotative force with the Scotch yoke mechanism and outputs the rotative force from the crankshaft 12 to rotate the electric generator 15 through the flywheel 14 and the input shaft 16.

[0032] As illustrated in FIGs. 1 through 5, the Stirling engine 1 according to this embodiment employs a wet sump lubrication system in which lubricating oil is supplied to a sliding portion of the power takeout device 11. The crank box 50 is configured as an oil tank for storing lubricating oil, and an oil seal (not shown) is provided not only in a portion in which the crankshaft 12 penetrates but also portions of the coupling portion between the cylinder 2 and the crank box 50 where the bridge 67 is in-

serted in the bridge insertion hole 68 and the rod 66 is inserted in the through hole 67a. That is, the crank box 50 has a hermetic structure for preventing stored lubricating oil from leaking to the outside. The crankcase 13 includes the first buffer chamber 17b located outside the crank box 50 and the second buffer chamber 17c located inside the crank box 50.

[0033] That is, the crankcase 13 has a double structure incorporating the crank box 50, and the crank box 50 encloses lubricating oil. Accordingly, mixing of lubricating oil into the first buffer chamber 17b in the crankcase 13 can be avoided. Accordingly, it is possible to more reliably prevent or reduce entering of lubricating oil into the third buffer chamber 17a, that is, the cylinder 2, from the first buffer chamber 17b through the communication port 17d so that failures and problems in driving caused by, for example, adhesion of lubricating oil to the operating chamber in the cylinder 2, the heat exchanger 7, and other parts can be reduced.

[0034] As illustrated in FIGs. 1 and 3, the first buffer chamber 17b in the crankcase 13 communicates with the second buffer chamber 17c in the crank box 50 through a breather 32. The breather 32 is fixed to the crankcase 13 at a position above the oil level of lubricating oil stored in the crank box 50. The breather 32 is divided into a first compartment 35 communicating with the second buffer chamber 17c and a second compartment 36 communicating with the first buffer chamber 17b, and the first compartment 35 and the second compartment 36 communicate with each other through the communication port 37.

[0035] With this structure, lubricating oil that has entered the breather 32 is separated from an operating fluid in the first compartment 35, and only the operating fluid flows into the first buffer chamber 17b in the crankcase 13 through the second compartment 36. Accordingly, it is possible to reliably prevent or reduce entering of lubricating oil into the first buffer chamber 17b, and problems in driving caused by, for example, clogging due to adhesion of lubricating oil to the operating chamber in the cylinder 2, the heat exchanger 7, and other parts and mechanical damage can be avoided. The breather 32 has a configuration in which an orifice is formed by reducing the opening area of a box coupled portion 44 coupled to the crank box 50 to reduce entering of lubricating oil from the crank box 50. In addition, the communication port 37 between the first compartment 35 and the second compartment 36 is also constituted by an orifice having a small opening area.

[0036] The breather 32 has a double pipe structure in which an inner case 71 coupled to the crank box 50 by the box coupled portion 44 constituting the orifice is covered with an outer case 72 coupled to the crankcase 13 by a case coupled portion 38 that is open at the outer periphery of the box coupled portion 44. In the breather 32, a double opening portion by the case coupled portion 38 and the box coupled portion 44 is disposed at the lowest portion, and the breather 32 is coupled to the crankcase 13 and the crank box 50. The box coupled

portion 44 projects from the coupling portion between the case coupled portion 38 and the crankcase 13 toward the inside of the crankcase 13, and is coupled to the crank box 50. The inner case 71 has a communication port 37 in the highest portion opposite to the box coupled portion 44, and causes the first compartment 35 inside the inner case 71 and the second compartment 36 between the inner case 71 and the outer case 72 to communicate with each other.

[0037] The inner case 71 (first compartment 35) in the breather 32 is configured such that the volume of the inner case 71 is larger than the amount of volume change in the buffer chamber 17 by reciprocation movement of the power piston 4. The inner case 71 is also configured such that the uppermost portion of the inner case 71 having the communication port 37 is sufficiently higher than the box coupled portion 44. Accordingly, when an operating fluid including lubricating oil flows into the first compartment 35 from the second buffer chamber 17c in the crank box 50 through the box coupled portion 44, lubricating oil is separated from the operating fluid before reaching the communication port 37. Thus, only the operating fluid flows into the first buffer chamber 17b in the crankcase 13 through the second compartment 36 and the case coupled portion 38.

[0038] As illustrated in FIGs. 1 through 3, an oil level gauge 46 is disposed outside the crankcase 13 in order to determine the amount of lubricating oil in the crank box 50. Thus, while the Stirling engine 1 is stopped, the oil level of lubricating oil in the oil level gauge 46 is determined so that the amount of lubricating oil in the crank box 50 inside the crankcase 13 can be determined. At this time, if the oil level of the oil level gauge 46 is lower than a predetermined level, it can be determined not only that the amount of lubricating oil in the crank box 50 is insufficient relative to a necessary minimum amount, but also that a part of lubricating oil in the crank box 50 is dropped in the crankcase 13.

[0039] As illustrated in FIGs. 1 through 3, to detect lubricating oil dropped from the crank box 50 into the crankcase 13, an oil leakage detecting part 47 is disposed at the lowest position of a bottom portion 45 of the crankcase 13. The bottom portion 45 of the crankcase 13 is shaped such that the bottom portion 45 tilts toward the lowest portion at which the oil leakage detecting part 47 is disposed in order to cause lubricating oil dropped from the crank box 50 to flow toward the location of the oil leakage detecting part 47. Accordingly, in driving of the Stirling engine 1, lubricating oil that has flowed into the oil leakage detecting part 47 can be detected, and a drop of a part of lubricating oil in the crank box 50 into the crankcase 13 can be detected.

[0040] As illustrated in FIGs. 1 through 3, an anti-deformation member 91 for preventing deformation of the power piston yokes 52 and 53 and the bridge 67 is disposed in a coupling portion between the power piston yokes 52 and 53 and the bridge 67. Each of the displacer piston 3, the power piston 4, the displacer yoke 51, the

power piston yokes 52 and 53, the rod 66, and the bridge 67, for example, is made of a light metal material or a light-metal alloy material having a light specific gravity, such as aluminium, in order to reduce a load on each part of the Stirling engine 1 by an inertial force of reciprocating movement thereof. On the other hand, the anti-deformation member 91 is made of a metal material, such as iron, having a specific gravity heavier than that of metal materials constituting the power piston yokes 52 and 53 and the bridge 67.

[0041] The anti-deformation member 91 made of a material having high rigidity can suppress deformation of, for example, the bridge 67 and the power piston yokes 52 and 53 even when the pressure of the compression chamber 6 in the cylinder 2 increases so that loads on the bridge 67 and the power piston yokes 52 and 53 increase through the power piston 4. Thus, abnormal abrasion and peeling (flaking) in the bearings 58 and 59 that are in slidable contact with the crankshaft guide grooves 52a and 53a of the power piston yokes 52 and 53 can be prevented or reduced.

[0042] In addition, since positional displacement of relative positions of the linear motion bearings 64 and 65 relative to the guide shafts 61 and 62 can be reduced, a gap (clearance) between the guide shafts 61 and 62 and the linear motion bearings 64 and 65 can be appropriately maintained so that abnormal abrasion and peeling in the guide shafts 61 and 62 and the linear motion bearings 64 and 65 can be prevented or reduced. In addition, the anti-deformation member 91 is made of a metal material having a linear expansion coefficient (thermal expansion coefficient) smaller than that of a light metal material or a light-metal alloy material, and thus, deformation by heat in the bridge 67 and the power piston yokes 52 and 53 can also be reduced.

3-1. First example of breather

[0043] A first example of the breather 32 disposed in the power takeout device 11 will now be described with reference to FIG. 6. As illustrated in FIG. 6, the breather 32 of this example is divided into the first compartment 35 communicating with the second buffer chamber 17c and the second compartment 36 communicating with the first buffer chamber 17b, and the first and second compartments 35 and 36 communicate with each other through the communication port 37 forming the orifice. In the breather 32, the box coupled portion 44 is disposed at a lowest portion and is located at a position higher than the oil level of lubricating oil enclosed in the crank box 50, and the first compartment 35 has a volume larger than the amount of volume change by piston reciprocation.

[0044] In the breather 32 located at a position higher than the oil level of lubricating oil, since the first compartment 35 has a volume larger than the amount of volume change by piston reciprocation, lubricating oil can be separated from an operating fluid flowing into the first com-

partment 35 and sent to the second compartment 36. Thus, entering of lubricating oil into the first buffer chamber 17b communicating with the second compartment 36 can be suppressed so that entering of lubricating oil into the operating chamber in the cylinder 2 and the heat exchanger 7 can be reliably prevented or reduced. Consequently, problems in driving and mechanical damage in the Stirling engine 1 can be avoided.

[0045] The breather 32 has a double pipe structure in which the inner case 71 coupled to the crank box 50 by the box coupled portion 44 is covered with the outer case 72 coupled to the crankcase 13 by the case coupled portion 38 that is open at the outer periphery of the box coupled portion 44. The box coupled portion 44 projects from the coupling portion between the case coupled portion 38 and the crankcase 13 toward the inside of the crankcase 13, and is coupled to the crank box 50. The inner case 71 has the communication port 37 to the first and second compartments 35 and 36 at the top opposite to the box coupled portion 44.

[0046] With this configuration, the first compartment 35 in the inner case 71 functions as a lubricating oil separating room that separates mist lubricating oil entering together with an operating fluid flowing from the second buffer chamber 17c. In addition, the communication port 37 is disposed at a position away from the box coupled portion 44. Thus, lubricating oil that has flowed into the first compartment 35 does not easily reach the communication port 37, and mixture of lubricating oil into the operating fluid flowing to the second compartment 36 can be reduced.

[0047] The first compartment 35 defined in the inner case 71 is divided into processing rooms 41 and 42 by a separator 73 having a communication hole 74. The volume of the initial processing room 42 communicating with the second buffer chamber 17c is greater than or equal to the amount of volume change by reciprocation of the power piston 4. When the power piston 4 moves toward the crankcase 13 so that an operating fluid in the second buffer chamber 17c of the crank box 50 is purged, since the volume of initial processing room 42 of the first compartment 35 of the breather 32 is greater than or equal to a purge amount of the operating fluid, the operating fluid from the second buffer chamber 17c tends to remain in the initial processing room 42.

[0048] Thus, lubricating oil mixed in an operating fluid is easily separated from the operating fluid in the initial processing room 42, and thus, the amount of lubricating oil flowing into the final processing room 41 is reduced so that mixing of lubricating oil into the operating fluid flowing from the breather 32 into the first buffer chamber 17b can be prevented or reduced. At this time, in a configuration in which the volume of the final processing room 41 communicating with the second compartment 36 is greater than or equal to a half of the amount of volume change by reciprocation of the power piston 4, the amount of lubricating oil flowing into the second compartment 36 can be further reduced.

[0049] The opening area of the box coupled portion 44 coupled to the crank box 50 is reduced to form an orifice, and the communication port 37 between the first compartment 35 and the second compartment 36 and the communication hole 74 of the separator 73 are also formed by orifices having small opening areas. At this time, the opening of the case coupled portion 38 and the communication hole 74 are offset from each other, and the communication port 37 and the communication hole 74 are offset from each other. Then, entering of lubricating oil into the second compartment 36 can be prevented or reduced.

[0050] That is, the communication hole 74 and the communication port 37 constitute orifices, and are arranged in a staggered pattern (offset positions) along a flow of an operating fluid. Thus, the separator 73 and the inner case 71 serve as shielding walls against an operating fluid flowing from the first compartment 35 to the second compartment 36 so that separation of mixed lubricating oil can be promoted. An operating fluid mixed with no lubricating oil can be caused to flow into the first buffer chamber 17b through the breather 32.

3-2. Second example of breather

[0051] Next, a second example of the breather 32 disposed in the power takeout device 11 will now be described with reference to FIG. 7. As illustrated in FIG. 7, in the breather 32 of this example, the first compartment 35 is divided, by the separator 73 including the communication hole 74, into three processing rooms 41 through 43 including the final processing room 41 communicating with the second compartment 36. The total volume of the processing rooms 42 and 43 excluding the final processing room 41 is greater than or equal to the amount of volume change by reciprocation of the power piston 4. With this configuration, the separator 73 defining the processing rooms 42 and 43 before the final processing room 41 serves as a baffle, and the amount of lubricating oil that reaches the final processing room 41 can be reduced.

[0052] That is, the first compartment 35 is divided, by the separator 73 including the communication hole 74, into the initial processing room 42 communicating with the box coupled portion 44, the final processing room 41 communicating with the second compartment 36, and the intermediate processing room 43 between the initial processing room 42 and the final processing room 41. The volume of each of the initial processing room 42, the intermediate processing room 43, and the final processing room 41 is greater than or equal to a half of the amount of volume change by reciprocation of the power piston 4.

[0053] In this manner, when an operating fluid flows from the second buffer chamber 17c into the first compartment 35, the operating fluid passes through the initial processing room 42 and the intermediate processing room 43 each having a volume greater than or equal to a purge amount of the operating fluid so that the separator

73 blocks the lubricating oil and the amount of lubricating oil flowing into the final processing room 41 can be sufficiently reduced. In addition, the initial processing room 42, the intermediate processing room 43, and the final processing room 41 are configured to have substantially the same volumes so that parts constituting the processing rooms 41 through 43 can be shared and the processing rooms 41 through 43 can be easily assembled by stacking the rooms.

[0054] In this example, the communication hole 74 and the communication port 37 constitute orifices, and are arranged in a staggered pattern (offset positions) along a flow of an operating fluid. Accordingly, the separator 73 and the inner case 71 serve as shielding walls against an operating fluid flowing from the first compartment 35 to the second compartment 36 so that separation of mixed lubricating oil can be promoted. That is, the opening of the case coupled portion 38 and the communication hole 74 are offset from each other, the communication port 37 in the final processing room 41 and the communication hole 74 are offset from each other, and the communication holes 74 of the two separators 73 disposed at the sides of the intermediate processing room 43 toward the initial processing room 42 and the final processing room 41 (upper and lower positions) are offset from each other.

[0055] The breather 32 of this example is not limited to the configuration in which the processing rooms 41 through 43 in the first compartment 35 have substantially the same volumes, and as illustrated in FIG. 8(a), the distance of the separators 73 may be reduced along a flow of an operating fluid from the second buffer chamber 17c to the first buffer chamber 17b so that the volumes of the initial processing room 42, the intermediate processing room 43, and the final processing room 41 decrease in this order. In this case, the total volume of the initial processing room 42 and the intermediate processing room 43 is greater than or equal to the amount of volume change by reciprocation of the power piston 4 so that the amount of mixture of lubricating oil in an operating fluid flowing into the final processing room 41 can be sufficiently reduced.

[0056] The breather 32 of this example is not limited to the configuration in which the first compartment 35 is divided into three rooms, and as illustrated in FIG. 8(b), the intermediate processing room 43 may be divided into two or more rooms with the first compartment 35 being divided into four or more rooms. In this case, the total volume of the initial processing room 42 and the plurality of intermediate processing rooms 43 is greater than or equal to the amount of volume change by reciprocation of the power piston 4 so that the number of the separators 73 partitioning the processing rooms 41 through 43 increases, and thus, it is more difficult for lubricating oil to reach the final processing room 41. Thus, the amount of mixture of lubricating oil in the operating fluid flowing into the final processing room 41 can be sufficiently reduced, and even in a case where the volume of the final process-

ing room 41 is reduced, a flow of lubricating oil into the first buffer chamber 17b can be prevented or reduced so that the size of the breather 32 can be reduced.

3-3. Third example of breather

[0057] A third example of the breather 32 disposed in the power takeout device 11 will now be described with reference to FIG. 9. As illustrated in FIG. 9, in the breather 32 of this example, a baffle 76 (lubricating oil trap) for blocking an inflow of lubricating oil is disposed to the opening of the box coupled portion 44 and the communication hole 74 of the separator 73. Accordingly, when an operating fluid from the second buffer chamber 17c flows into the breather 32, the baffle 76 blocks passages of lubricating oil in a flow from the second buffer chamber 17c to the initial processing room 42, a flow from the initial processing room 42 to the intermediate processing room 43, and a flow from the intermediate processing room 43 to the final processing room 41.

[0058] Accordingly, the baffle 76 can be more likely to promote separation of lubricating oil, and thus, the volume of the first compartment 35 can be made smaller than those in the first example and the second example. Accordingly, the breather 32 can be made compact. In this example, the intermediate processing room 43 is disposed in a manner similar to the second example, but may be omitted as in the first example.

3-4. Fourth example of breather

[0059] A fourth example of the breather 32 disposed in the power takeout device 11 will now be described with reference to FIG. 10. As illustrated in FIG. 10, the breather 32 of this example includes a filter screen 77 at the communication port 37 between the first compartment 35 and the second compartment 36. Accordingly, during passage of an operating fluid through the communication port 37, the operating fluid passes through the filter screen 77 so that mist lubricating oil mixed in the operating fluid adheres to the filter screen 77 and is separated from the operating fluid. Accordingly, only the operating fluid can be caused to flow into the second compartment 36. The filter screen 77 in this example may be disposed at the opening of the box coupled portion 44 or the communication hole 74 of the separator 73.

4. Configuration of oil level gauge

[0060] The oil level gauge 46 disposed in the power takeout device 11 will now be described with reference to FIG. 3. As illustrated in FIG. 3, the oil level gauge 46 on channels 81 and 82 connecting both ends of the crank box 50 is disposed outside the crankcase 13. The oil level gauge 46 is connected to the lower channel 81 communicating with the crank box 50 at a position below the oil level of lubricating oil in the crank box 50 and to the upper channel 82 communicating with the crank box 50 at a

position above the oil level of the lubricating oil in the crank box 50.

[0061] A lower port 83 communicating with the lower channel 81 is disposed in a bottom surface of the crank box 50, and an upper port 84 communicating with the upper channel 82 is disposed in a side wall standing from the bottom surface of the crank box 50 at a position above the oil level of lubricating oil. The lower channel 81 and the upper channel 82 are guided to the outside of the crankcase 13 through the crankcase 13 and are connected to the oil level gauge 46 enabling the oil level (oil level while the Stirling engine 1 is stopped) of lubricating oil in the crank box 50 to be visually observed. In this manner, the oil level of lubricating oil in the oil level gauge 46 is visually observed so that the oil level of lubricating oil in the crank box 50 can be thereby visually observed. Accordingly, excess and deficiency of lubricating oil in the crank box 50 can be determined, and in addition, a drop of lubricating oil from the crank box 50 into the crankcase 13 can be determined.

[0062] In the crank box 50, a baffle 85 is disposed in a communication portion with the upper channel 82. That is, the baffle 85 extends from a side wall of the crank box 50 to cover the upper port 84 from below the upper port 84. Accordingly, it is possible to prevent or reduce entering of lubricating oil stirred during driving of the Stirling engine 1 into the oil level gauge 46 through the upper channel 82. Thus, backflow of lubricating oil to the oil level gauge 46 through the upper channel 82 can be prevented or reduced and, for example, failures in measurement of the oil level gauge 46 caused by pipe clogging due to adhesion of lubricating oil in the upper channel 82 can be prevented or reduced. Accordingly, the oil level in the crank box 50 can be normally measured.

[0063] In this embodiment, the baffle 85 is disposed in the crank box 50 so that entering of mist lubricating oil into the upper channel 82 can be prevented or reduced. Alternatively, as illustrated in FIG. 11, the upper channel 82 may communicate with the breather 32. That is, the upper channel 82 may communicate with the second compartment 36 of the breather 32 so that an operating fluid mixed with no lubricating oil flows in the upper channel 82, and failures in measurement of the oil level gauge 46 caused by entering of lubricating oil in the upper channel 82 can be prevented or reduced.

5-1. First example of oil leakage detecting part

[0064] A first example of the oil leakage detecting part 47 disposed in the power takeout device 11 will now be described with reference to FIG. 3. As illustrated in FIG. 3, the oil leakage detecting part 47 of this example is constituted by an oil storage part 86 that stores lubricating oil in the crankcase 13 and is disposed at the lowest position of the bottom portion 45 of the crankcase 13. The oil storage part 86 is configured to be visually observed from the outside, and a drop of lubricating oil from the crank box 50 can be detected by observing the

amount of lubricating oil in the oil storage part 86. Thus, not only a shortage of lubricating oil in the crank box 50 but also abnormality of each part in the Stirling engine 1 including degradation of the oil seal can be detected. Thus, the Stirling engine 1 can be stopped to prevent or reduce damage of the Stirling engine 1.

5-2. Second example of oil leakage detecting part

[0065] A second example of the oil leakage detecting part 47 disposed in the power takeout device 11 will now be described with reference to FIGs. 12 and 13. As illustrated in FIG. 12, the oil leakage detecting part 47 of this example includes an oil leakage amount sensor 87 that detects a drop of lubricating oil in the oil storage part 86, and based on a signal from the oil leakage amount sensor 87, a controller 29 controls opening and closing of an equalizer valve 20 and an operating chamber open valve 22 in an operation stop pipe 18. The oil leakage amount sensor 87 is constituted by, for example, an optical sensor, and measures the oil level of lubricating oil in the oil storage part 86, for example, to measure the amount of lubricating oil in the oil storage part 86.

[0066] The operation stop pipe 18 is provided with the equalizer valve 20 on a bypass channel 19 that allows the operating chamber in the cylinder 2 to communicate with the buffer chamber 17, and the operating chamber open valve 22 is disposed on an operating chamber open channel 21 that communicates with the operating chamber in the cylinder 2 for exposure to the atmosphere. The bypass channel 19 allows the compression chamber 6 in the cylinder 2 to communicate with the first buffer chamber 17b in the crankcase 13. At this time, the bypass channel 19 is connected to the outer case 72 of the breather 32 to thereby communicate with the first buffer chamber 17b through the second compartment 36. The operating chamber open channel 21 branches from a portion of the bypass channel 19 between the equalizer valve 20 and the compression chamber 6.

[0067] As illustrated in FIG. 13, in the case of normally stopping the Stirling engine 1, the controller 29 opens the equalizer valve 20 to cause the compression chamber 6 and the first buffer chamber 17b to communicate with each other through the bypass channel 19. Accordingly, the pressure of the operating chamber in the cylinder 2 and the pressure of the buffer chamber 17 to be made equal so that reciprocation of the displacer piston 3 and the power piston 4 are stopped. In the case of stopping the Stirling engine 1 emergently, the controller 29 first opens the equalizer valve 20 to thereby cause the compression chamber 6 and the first buffer chamber 17b to communicate with each other through the bypass channel 19. Thereafter, when the pressures of the compression chamber 6 and the first buffer chamber 17b approach each other, the controller 29 opens the operating chamber open valve 22 and causes an operating fluid in the compression chamber 6 to be released to the outside through the operating chamber open channel 21 to there-

by stop reciprocation of the displacer piston 3 and the power piston 4.

[0068] The oil leakage amount sensor 87 detects the amount of lubricating oil stored in the oil storage part 86 and transmits a detection signal to the controller 29. Thus, the controller 29 can automatically detect not only a shortage of lubricating oil in the crank box 50 but also abnormality of each part in the Stirling engine including degradation of the oil seal. In addition, when the controller 29 detects that the amount of lubricating oil in the oil storage part 86 exceeds a predetermined amount, based on a detection signal of the oil leakage amount sensor 87, the controller stops the Stirling engine 1 emergently. Thus, in a case where it is determined that the amount of lubricating oil dropped from the crank box 50 is large based on the signal from the oil leakage amount sensor 87, the Stirling engine 1 can be automatically stopped so that damage of the Stirling engine can be prevented or reduced.

5-3. Third example of oil leakage detecting part

[0069] Next, a third example of the oil leakage detecting part 47 disposed in the power takeout device 11 will be described with reference to FIG. 14. As illustrated in FIG. 14, the oil leakage detecting part 47 of this example includes an oil leakage rate sensor 88 that detects an oil leakage rate of lubricating oil from the crankcase 13 to the oil storage part 86, and based on a signal from the oil leakage rate sensor 88, the controller 29 controls opening and closing of the equalizer valve 20 and the operating chamber open valve 22 on the operation stop pipe 18. The oil leakage rate sensor 88 includes a plurality of oil leakage sensors 89a and 89b such as optical sensors disposed at different heights, and measures an oil leakage rate of lubricating oil to the oil storage part 86 based on timings of measurement of lubricating oil in the oil leakage sensors 89a and 89b.

[0070] When the controller 29 of this example detects that the oil leakage rate of lubricating oil in the oil storage part 86 becomes higher than a predetermined rate based on a detection signal of the oil leakage rate sensor 88, the controller 29 first opens the equalizer valve 20 to thereby cause the compression chamber 6 and the first buffer chamber 17b to communicate with each other through the bypass channel 19. Thereafter, when the pressures of the compression chamber 6 and the first buffer chamber 17b approach each other, the controller 29 opens the operating chamber open valve 22 and causes an operating fluid in the compression chamber 6 to be released to the outside through the operating chamber open channel 21 to thereby stop reciprocation of the displacer piston 3 and the power piston 4. Thus, in a case where it is determined that the amount of drop of lubricating oil from the crank box 50 is large based on a signal from the oil leakage rate sensor 88, the Stirling engine 1 can be automatically stopped emergently so that damage of the Stirling engine can be prevented or reduced.

(Other Embodiments)

[0071] The Stirling engine 1 according to the embodiment described above is configured such that the power takeout device 11 is disposed below the cylinder 2 and the reciprocating movement part including the displacer piston 3 and the power piston 4 reciprocates in the vertical direction (longitudinal direction). Alternatively, the power takeout device 11 may be disposed at a side of the cylinder 2 so that the reciprocating movement part including the displacer piston 3 and the power piston 4 reciprocates in the horizontal direction (lateral direction). A Stirling engine 1 according to another embodiment in which a power takeout device 11 is disposed at a side of a cylinder 2 will now be described with reference to FIG. 15.

[0072] As illustrated in FIG. 15, in the Stirling engine 1 according to this embodiment, a crank box 50 incorporating the power takeout device 11 is incorporated in a crankcase 13, and a bottom portion 45 of the crankcase 13 is parallel to piston shafts of a displacer piston 3 and a power piston 4. In this embodiment, a breather 32 is also disposed at a position higher than the oil level of lubricating oil in the crank box 50, and an oil leakage detecting part 47 is disposed on a bottom portion 45 of the crankcase 13. An oil level gauge 46 is disposed outside the crankcase 13, a lower channel 81 communicates with a lower port 83 in the bottom surface of the crank box 50 through the bottom portion 45 of the crankcase 13, and an upper channel 82 communicates with an upper port 84 in a side wall of the crank box 50 through a side wall of the crankcase 13.

[0073] The configurations of parts of some aspects of the present invention are not limited to those of the illustrated embodiments, but can be variously changed without departing from the gist of the invention. Although the embodiments described above are directed to the beta-type Stirling engines, Stirling engines of other types such as an alpha type and a gamma type may be employed. The power takeout device is not limited to the Scotch yoke mechanism as described in the embodiments, and may be another structure such as a crosshead mechanism.

Reference Signs List

[0074]

1	Stirling engine
2	cylinder
3	displacer piston
4	power piston
5	expansion chamber
6	compression chamber
7	heat exchanger
11	power takeout device
12	crankshaft
13	crankcase
17	buffer chamber

17b	first buffer chamber
17c	second buffer chamber
32	breather
35	first compartment
5 36	second compartment
37	communication port
38	case coupled portion
41	final processing room
42	initial processing room
10 43	intermediate processing room
44	box coupled portion
45	bottom portion
46	oil level gauge
47	oil leakage detecting part
15 50	crank box
71	inner case
72	outer case
73	separator
74	communication hole
20 76	baffle
77	filter screen
81	lower channel
82	upper channel
83	lower port
25 84	upper port
85	baffle
86	oil storage part
87	oil leakage amount sensor
88	oil leakage rate sensor
30 89a	oil leakage sensor
89b	oil leakage sensor

Claims

35

1. A Stirling engine comprising:

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a piston that reciprocates in a cylinder;
a heat exchanger that promotes contraction and expansion of an operating fluid in the cylinder; and
a power takeout device that converts a reciprocation driving force by the piston to a rotative force, wherein
45 the heat exchanger alternately repeats contraction and expansion of the operating fluid in the cylinder to cause the piston to reciprocate, the power takeout device is disposed in a crank box incorporated in a crankcase so that a first buffer chamber is defined outside the crank box and a second buffer chamber is defined inside the crank box in the crankcase, the first buffer chamber and the second buffer chamber communicate with each other through a breather, and
55 an orifice is formed in a box coupled portion that causes the breather to communicate with the second buffer chamber.

2. The Stirling engine according to claim 1, wherein the breather is divided into a first compartment communicating with the second buffer chamber and a second compartment communicating with the first buffer chamber, 5
the first and second compartments communicate with each other through a communication port that forms an orifice, and
in the breather, the box coupled portion is disposed at a lowest portion and is located at a position above an oil level of lubricating oil enclosed in the crank box, and the first compartment has a volume larger than an amount of volume change by piston reciprocation. 10
15
3. The Stirling engine according to claim 2, wherein the first compartment is divided, by a separator including a communication hole, into at least two processing rooms including a final processing room communicating with the second compartment, and a total volume of the processing rooms excluding the final processing room is greater than or equal to the amount of volume change. 20
4. The Stirling engine according to claim 3, wherein the number of processing rooms excluding the final processing room is two or more. 25
5. The Stirling engine according to claim 2, wherein the first compartment is divided, by a separator including a communication hole, into an initial processing room communicating with the box coupled portion, a final processing room communicating with the second compartment, and an intermediate processing room between the initial processing room and the final processing room, and 30
a volume of each of the initial processing room, the intermediate processing room, and the final processing room is greater than or equal to a half of the amount of volume change. 35
40
6. The Stirling engine according to claim 2, wherein the breather has a double pipe structure in which an inner case coupled to the crank box by the box coupled portion is covered with an outer case coupled to the crankcase by a case coupled portion that is open at an outer periphery of the box coupled portion, the box coupled portion projects from a coupling portion between the case coupled portion and the crankcase toward inside of the crankcase and is coupled to the crank box, and 45
the inner case has a communication port through which the first and second compartments communicate with each other, in a highest portion opposite to the box coupled portion. 50
55

FIG1

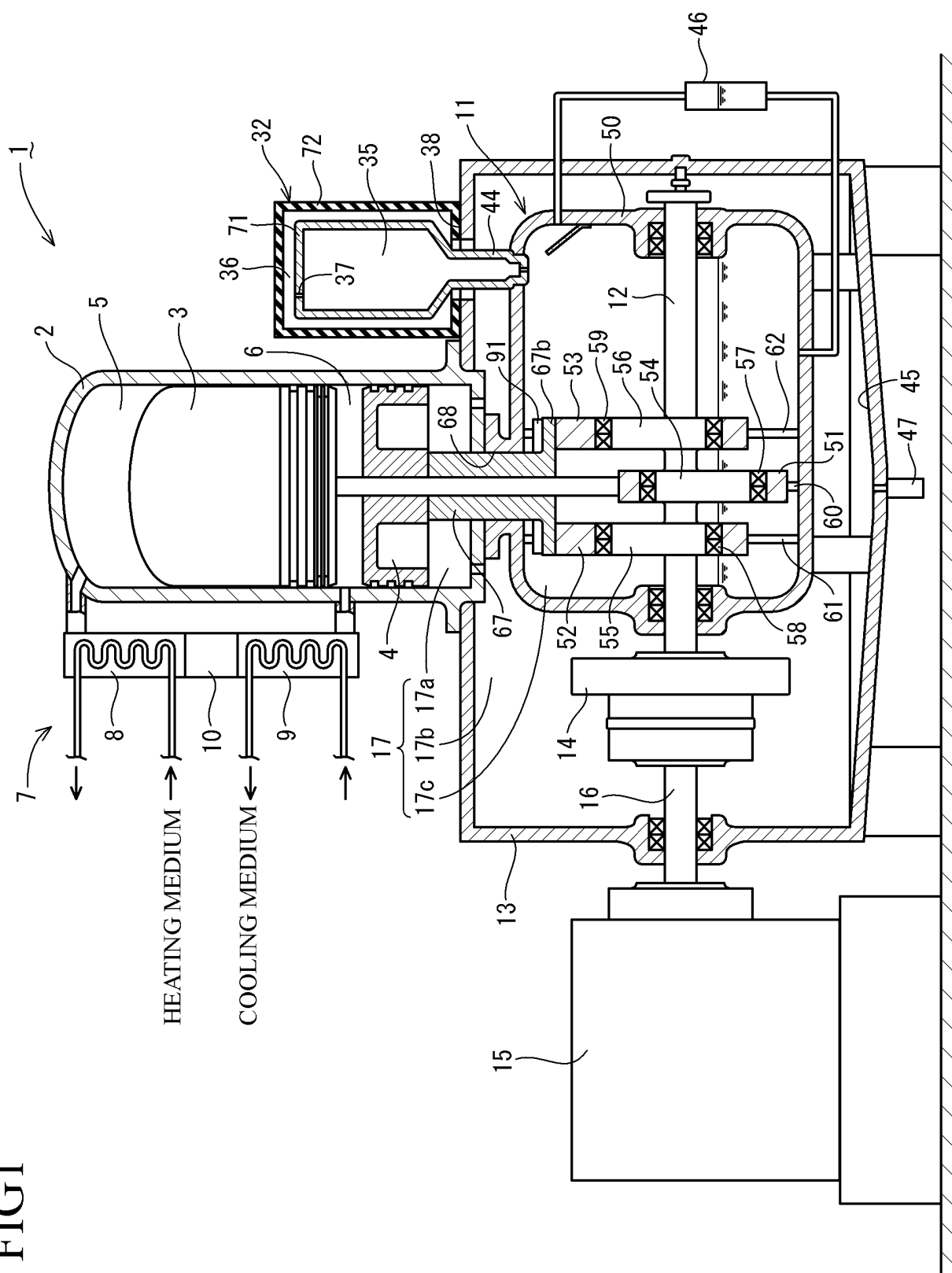


FIG2

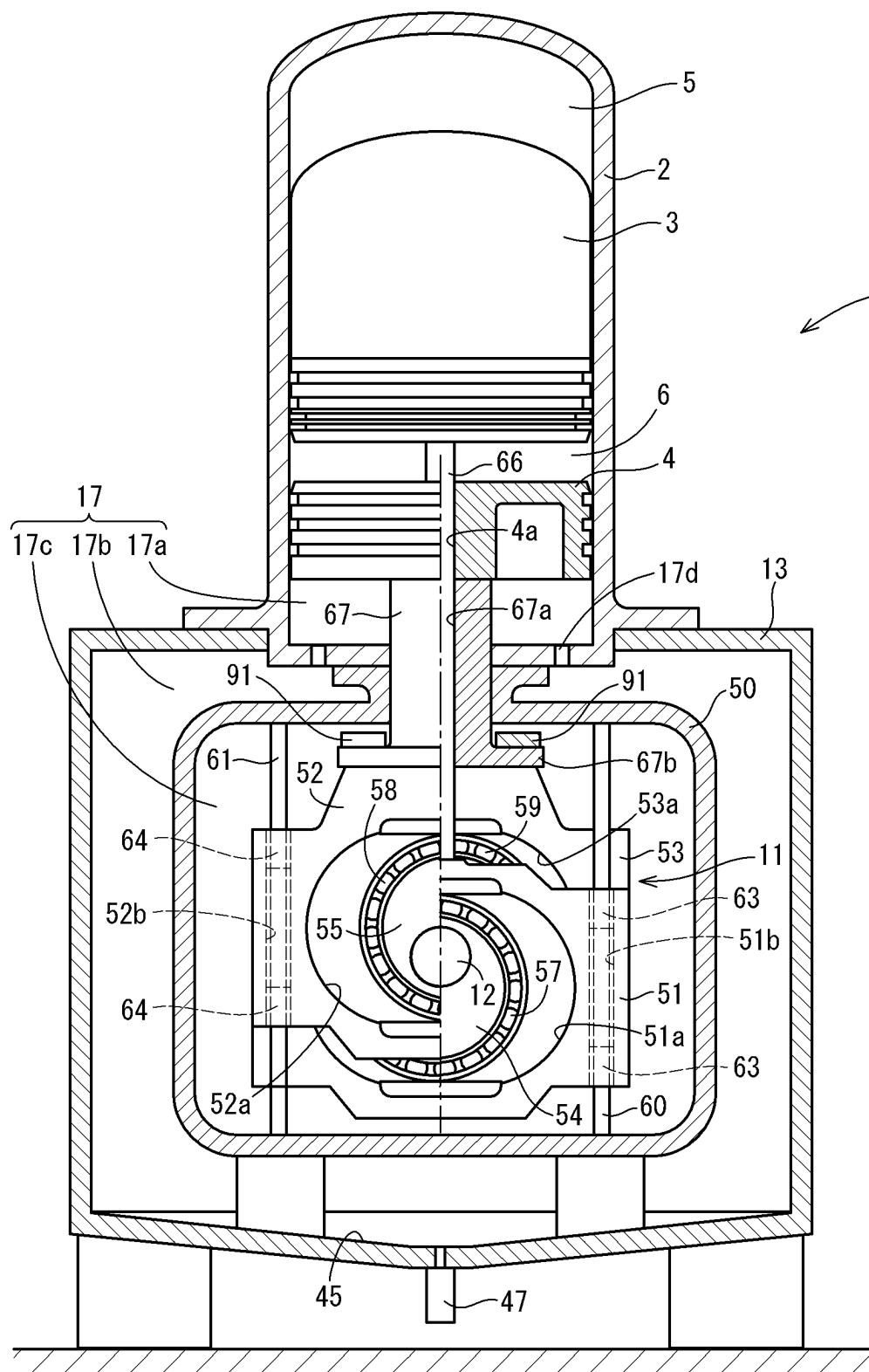


FIG3

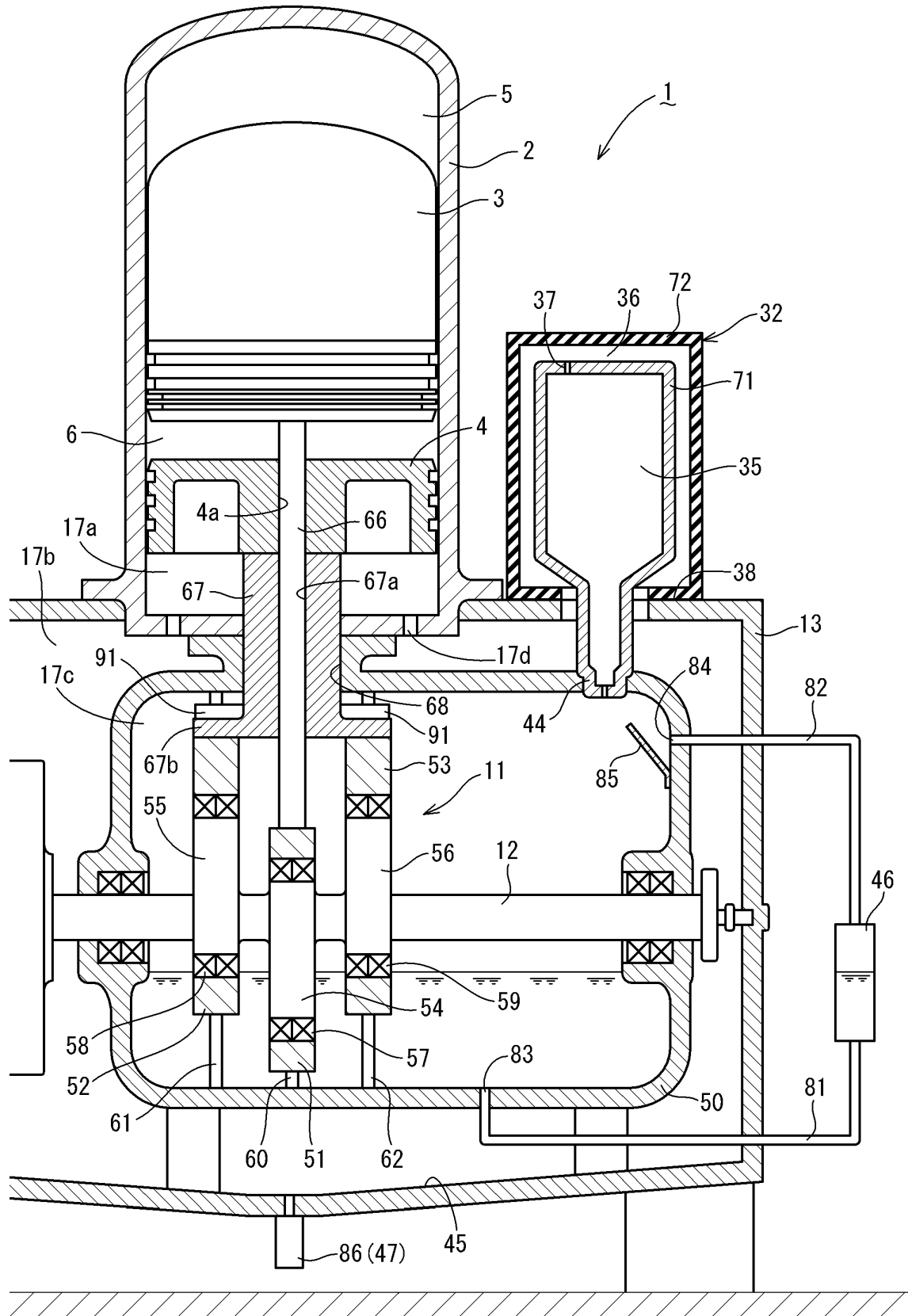


FIG4

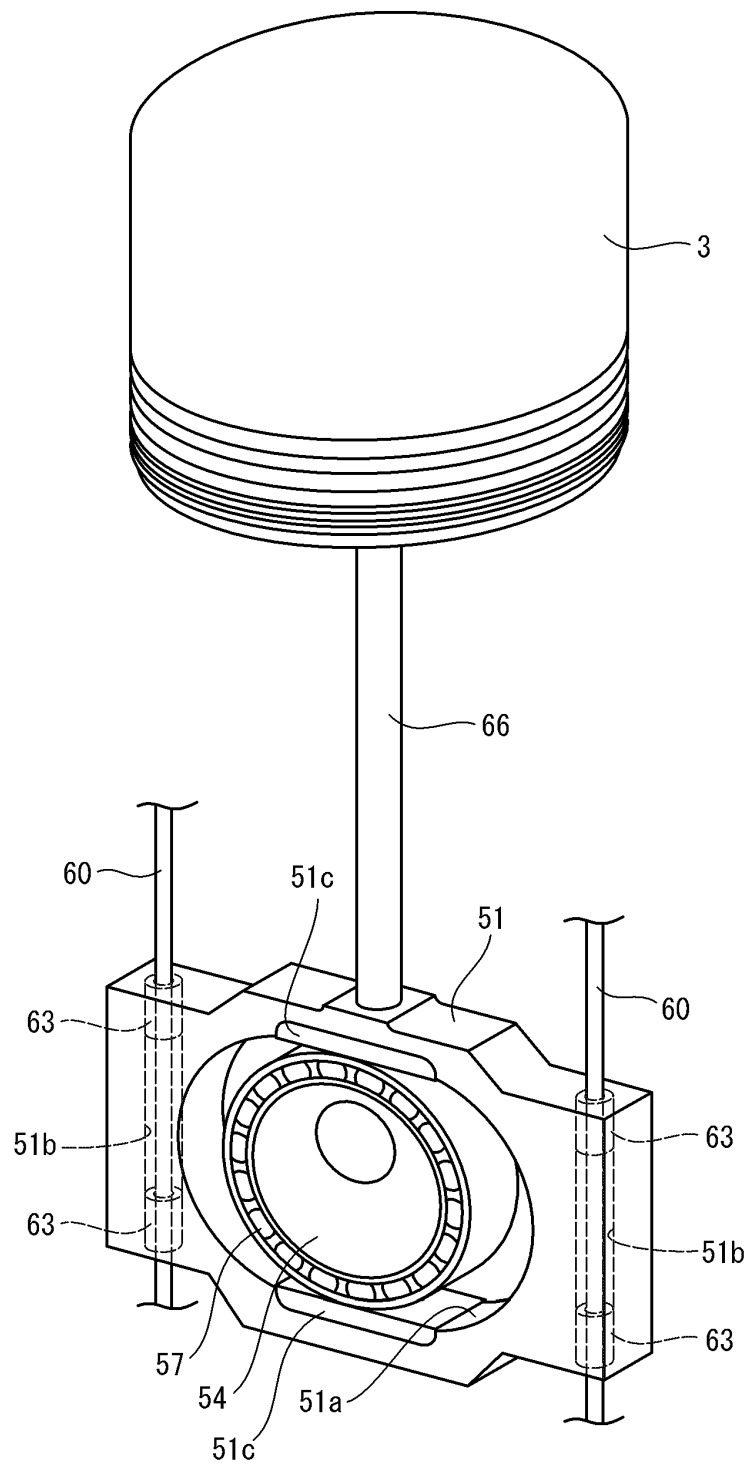


FIG5

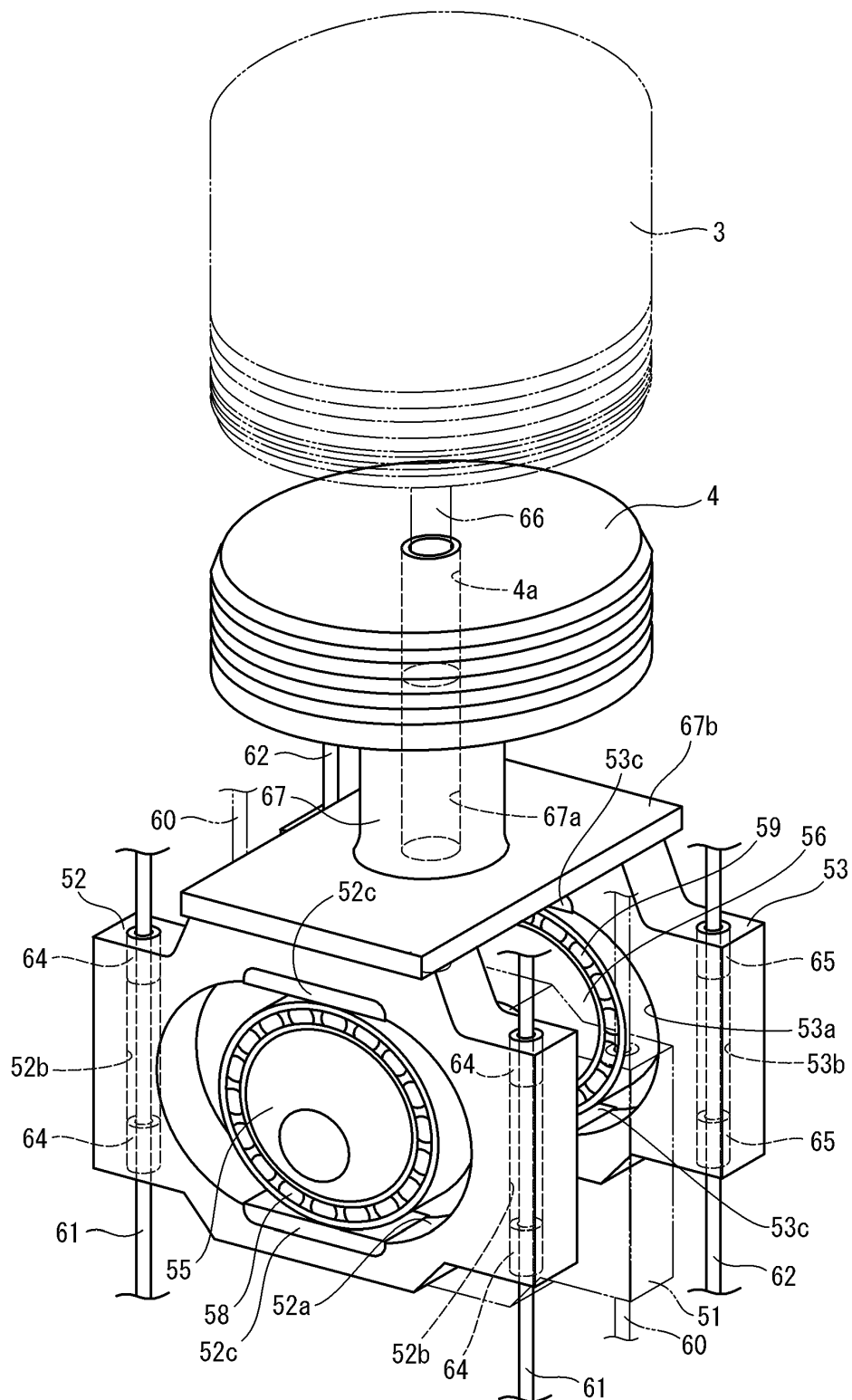


FIG6

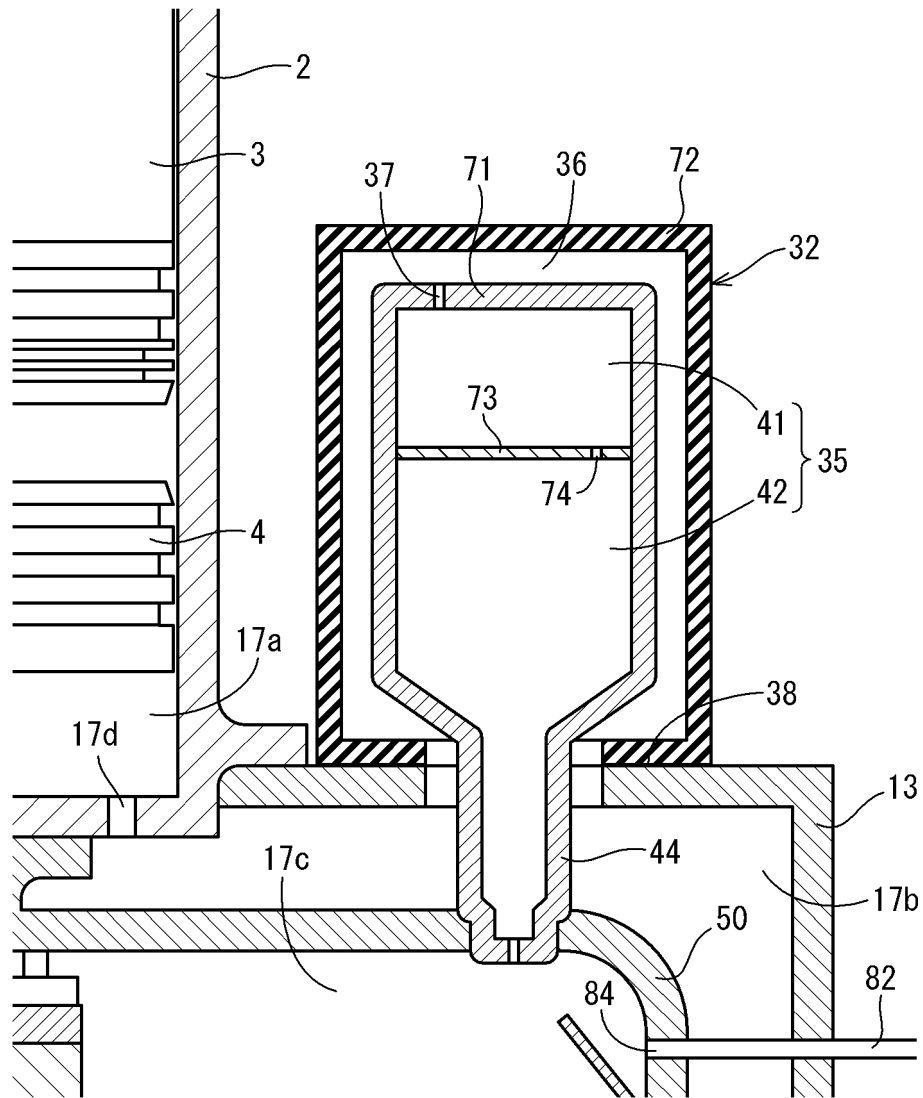


FIG7

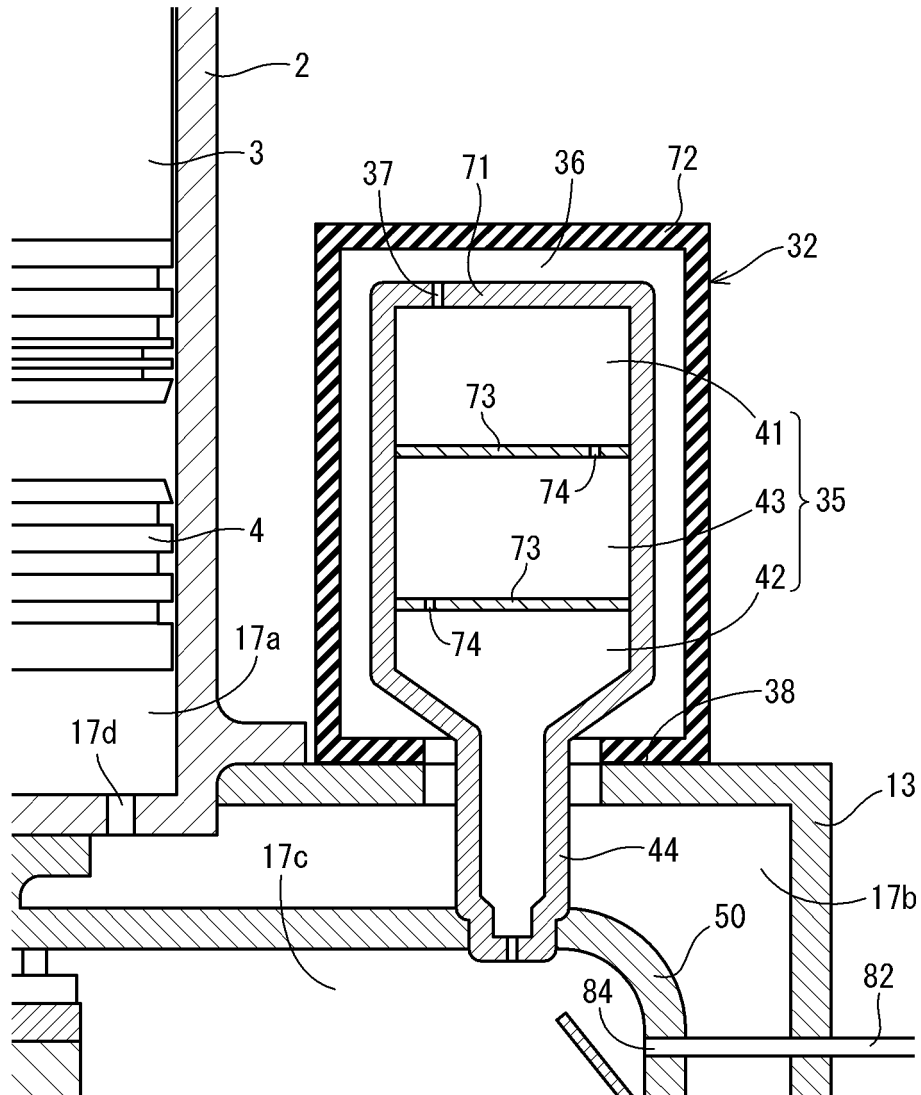
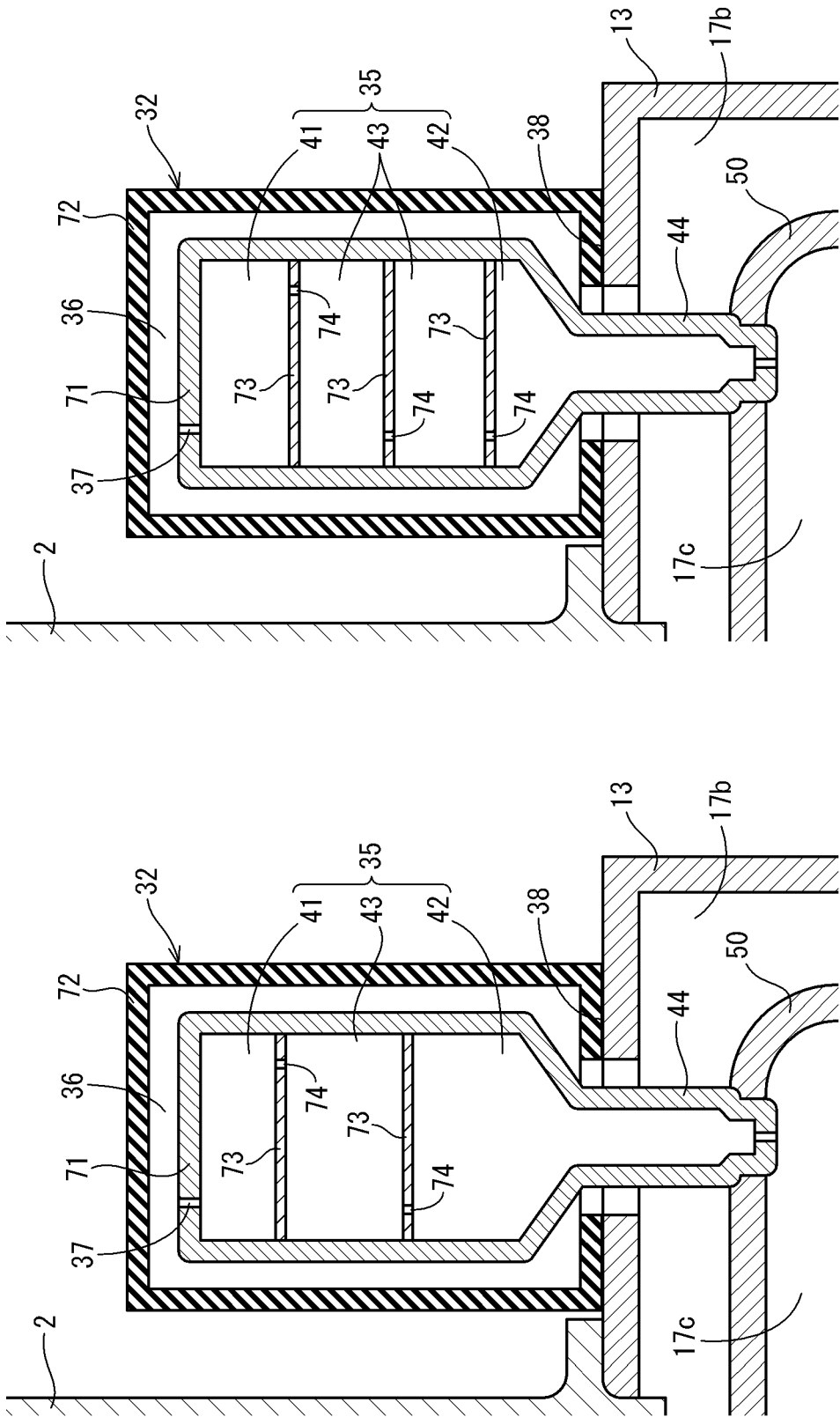


FIG8



(b)

(a)

FIG9

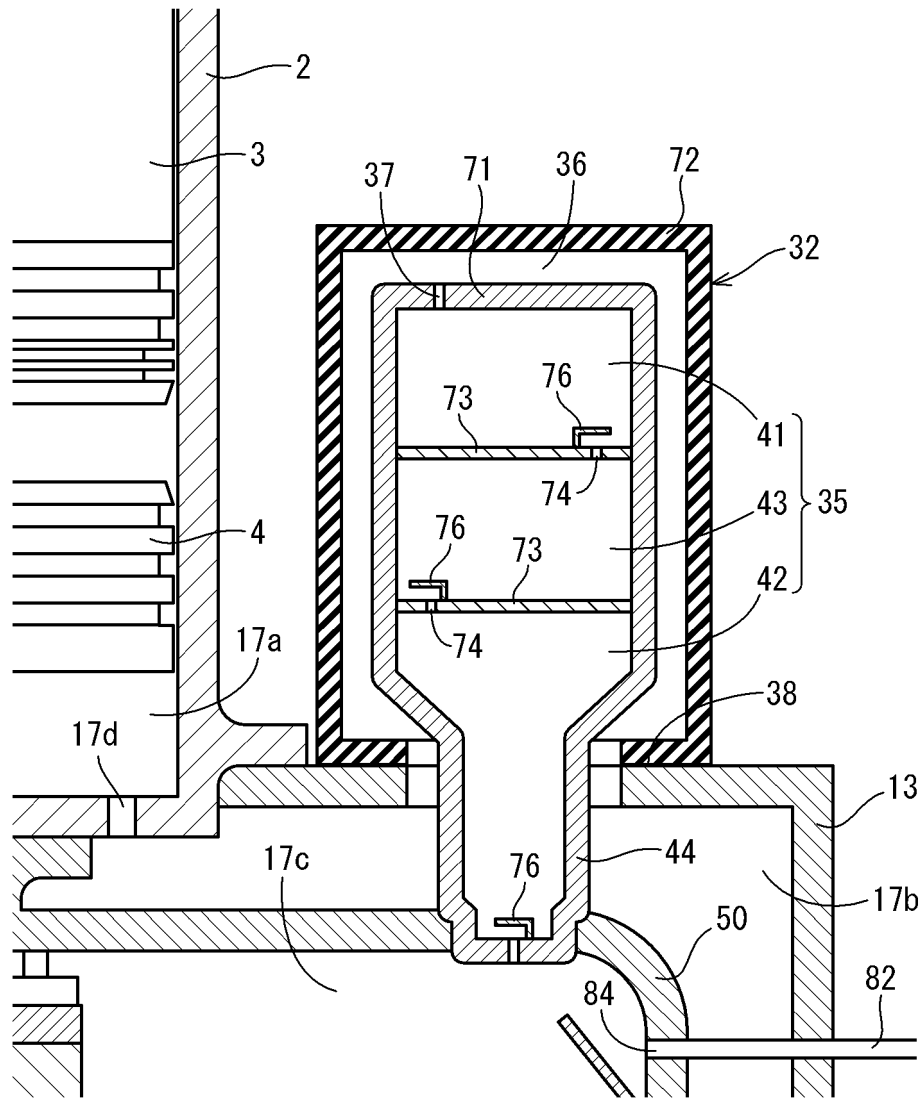


FIG10

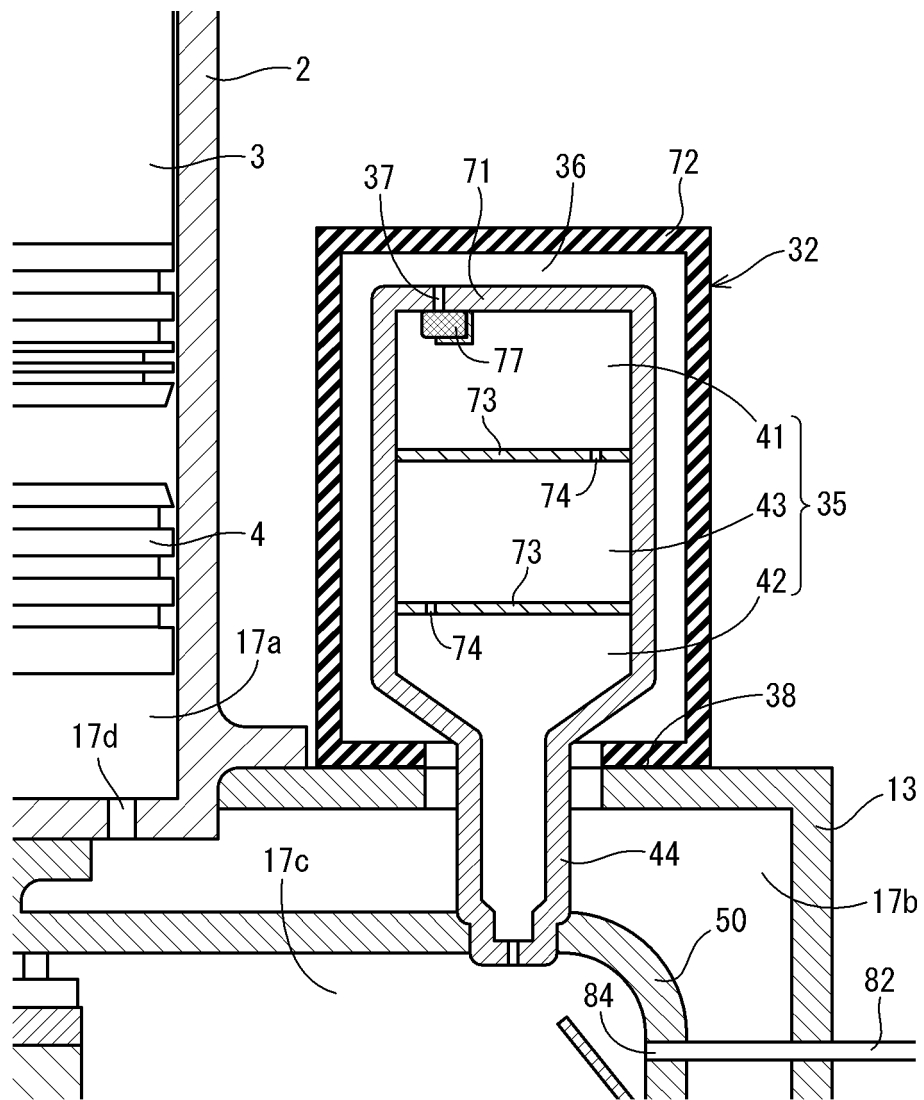


FIG11

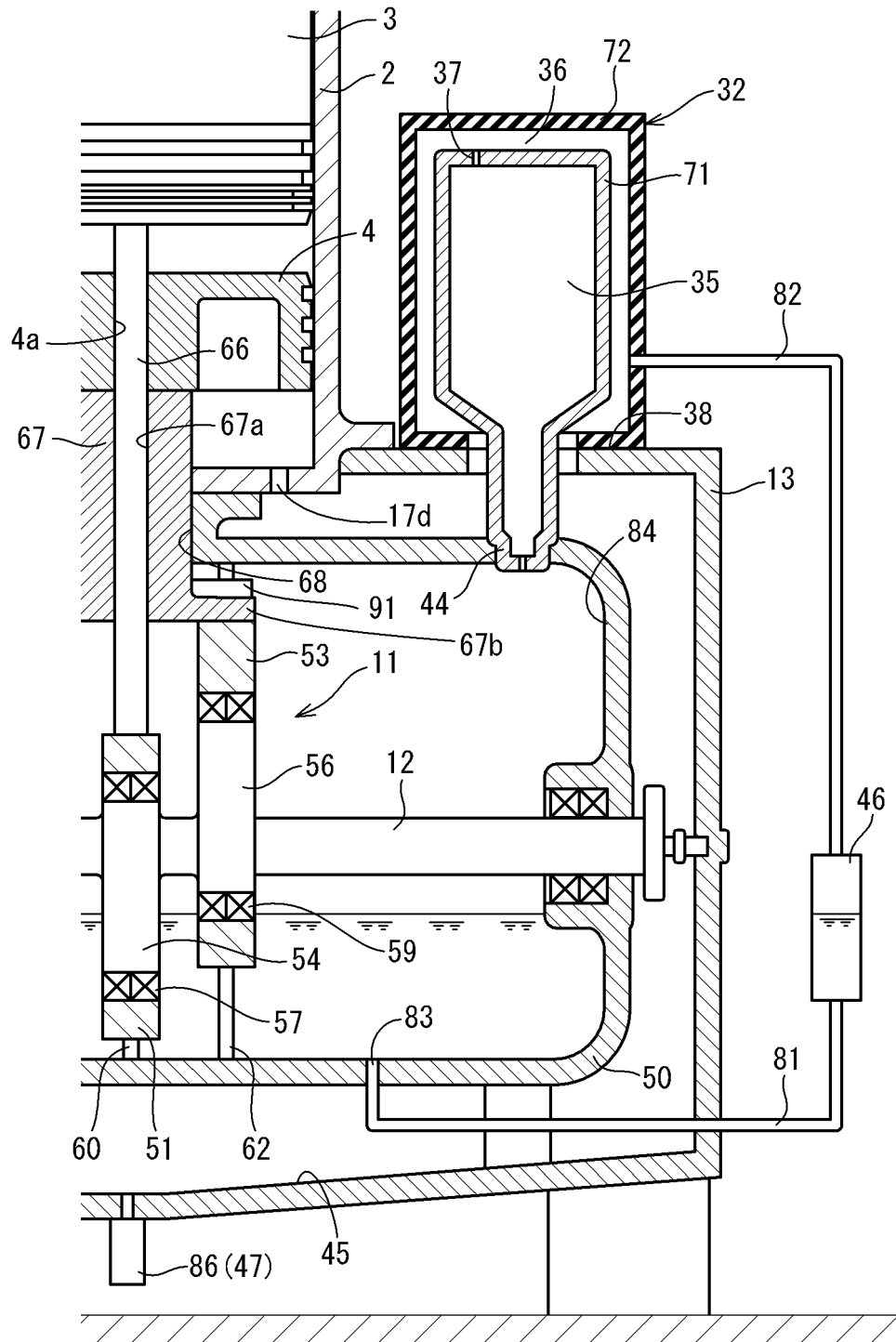


FIG12

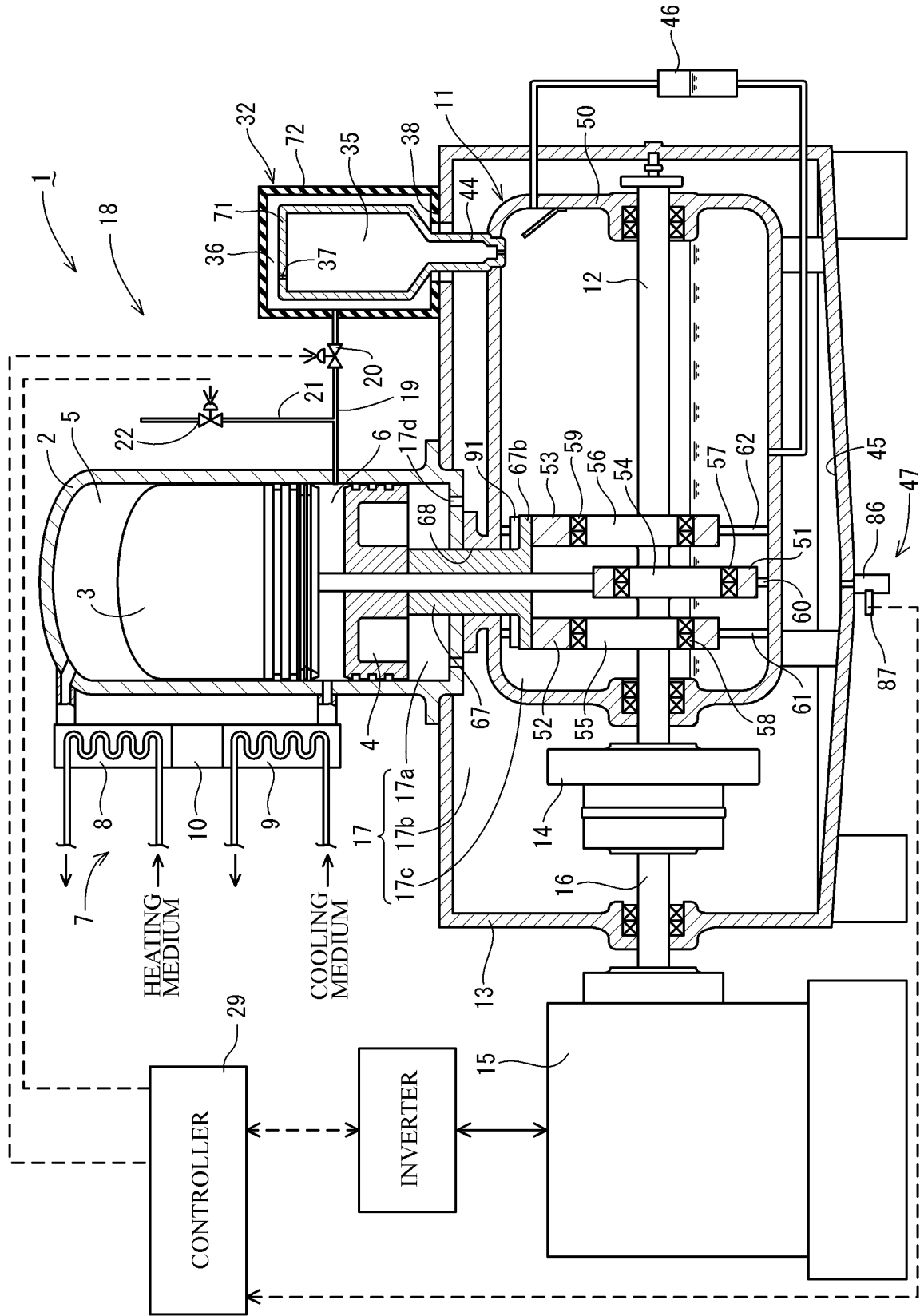


FIG13

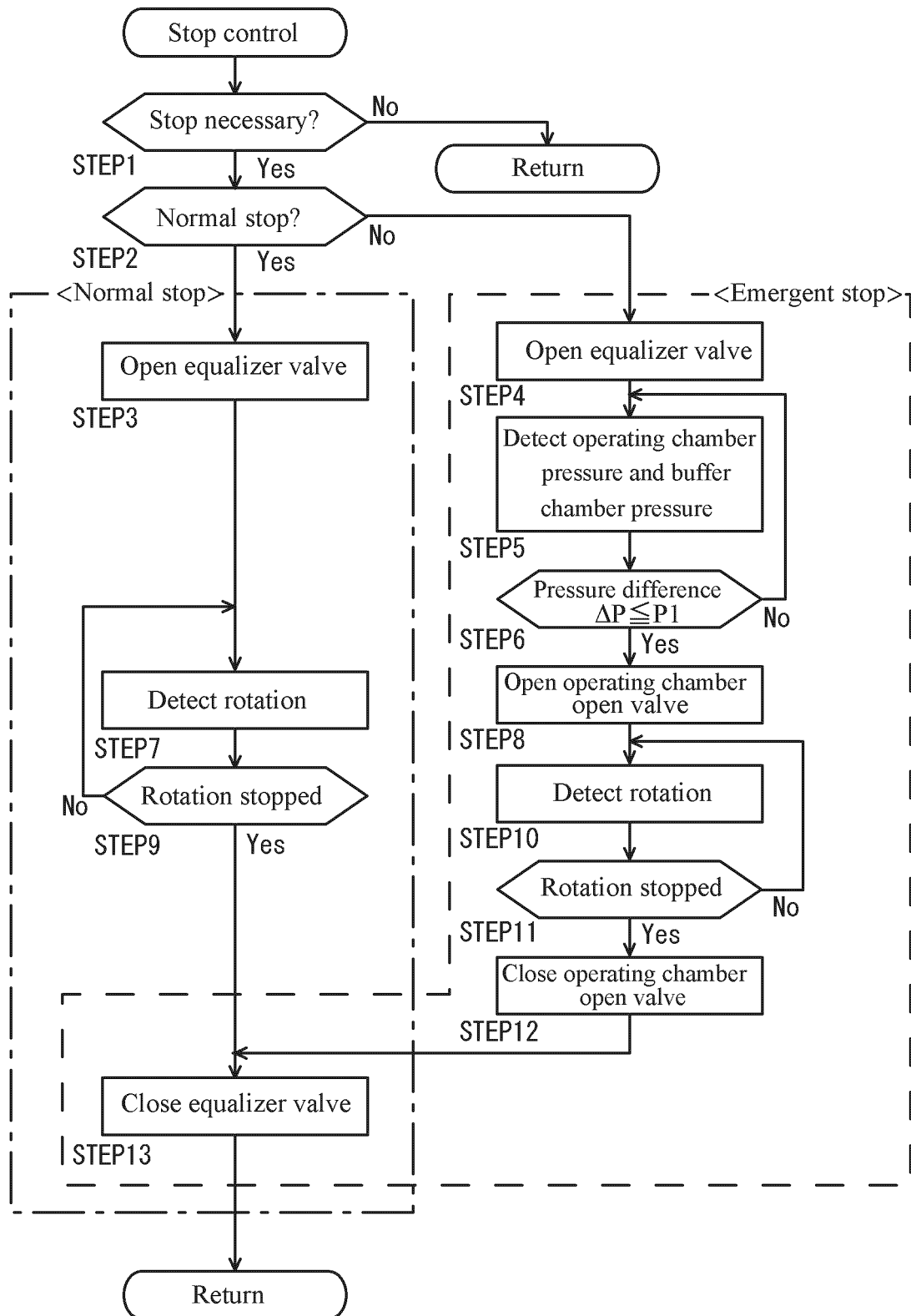


FIG14

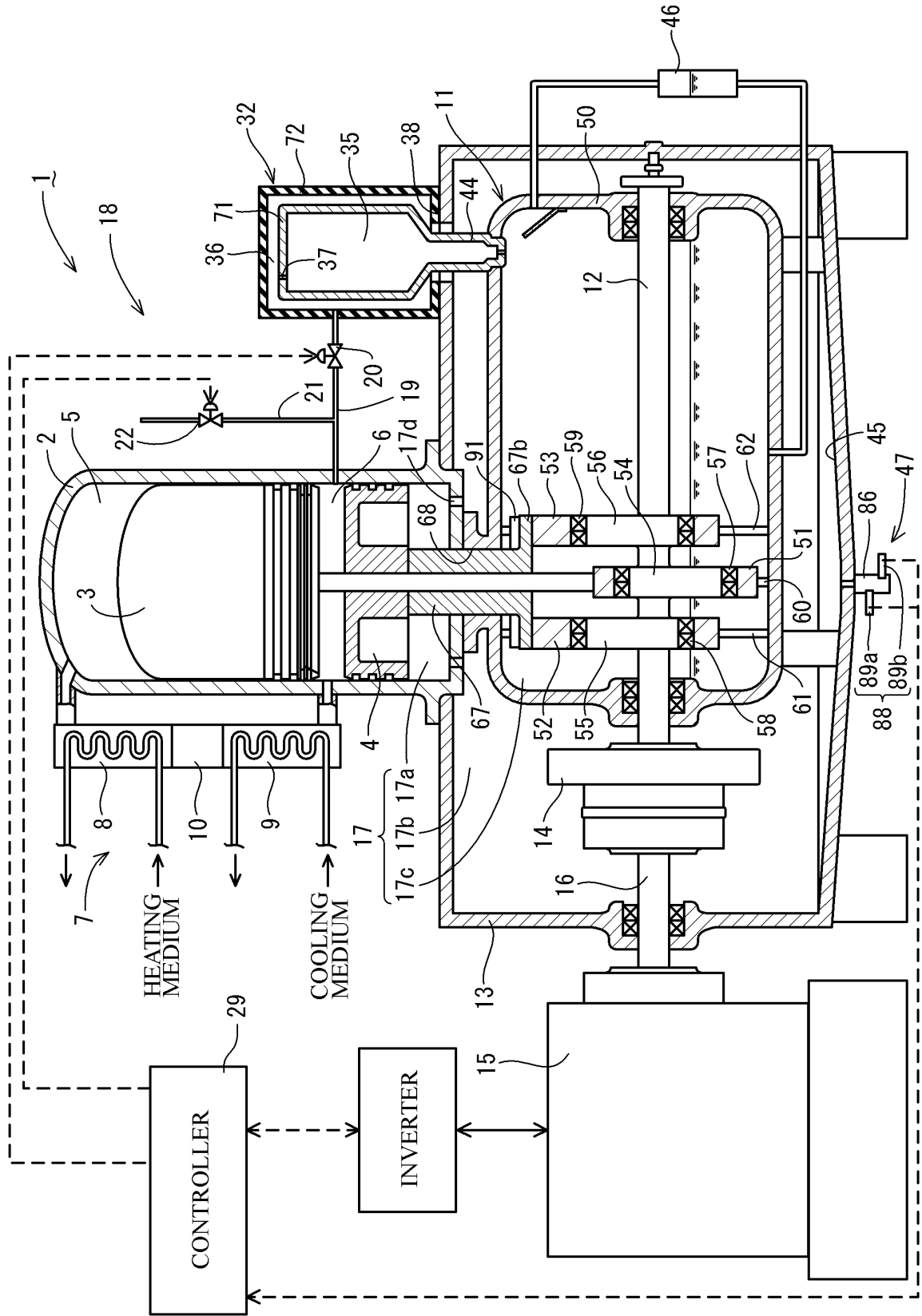
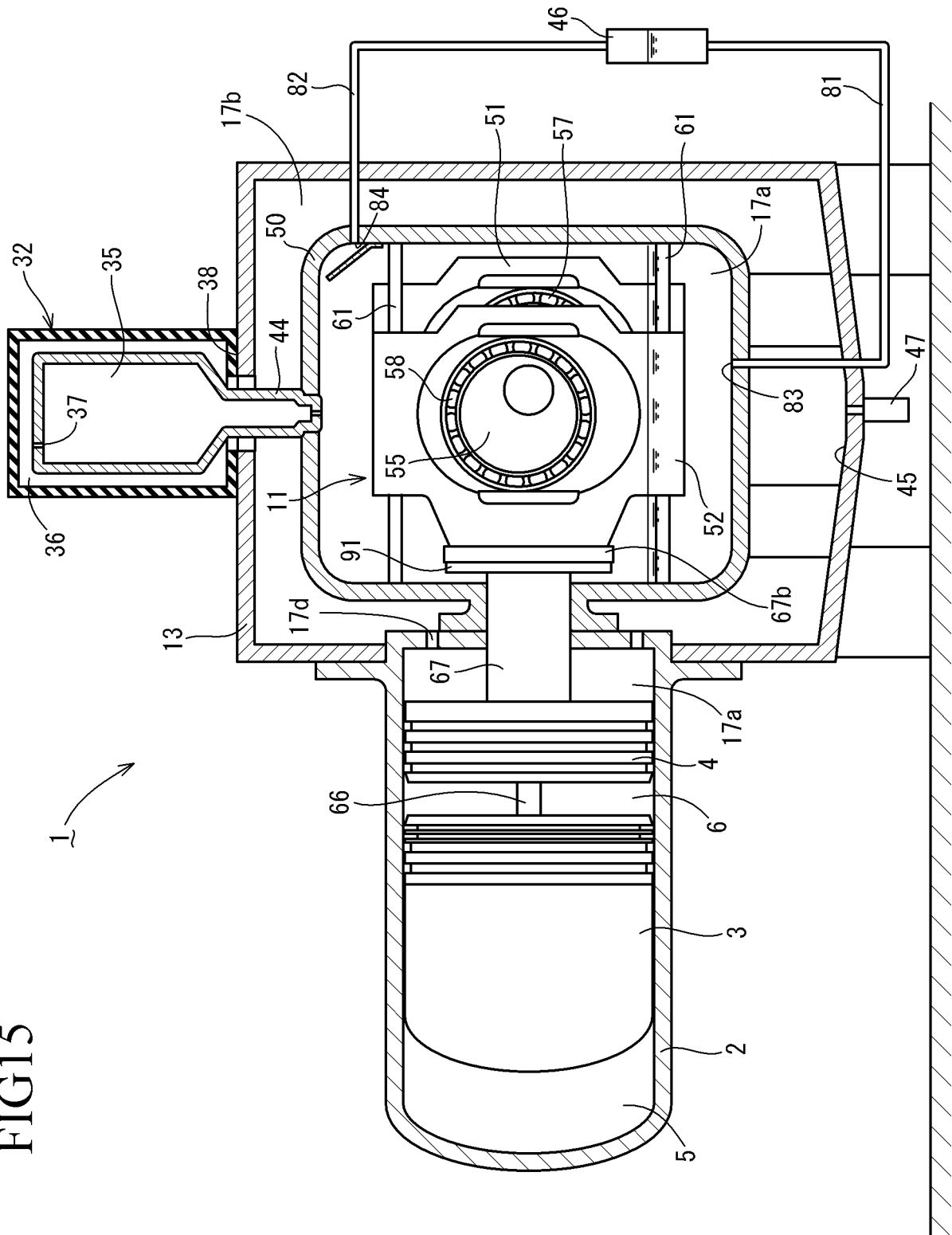


FIG15



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2017/034305

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl. F02G1/053 (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, F01M1/00-13/06, F02F7/00

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	1971-2017
Registered utility model specifications of Japan	1996-2017
Published registered utility model specifications of Japan	1994-2017

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 2-91456 A (AISIN SEIKI CO., LTD.) 30 March 1990, page 2, upper left column, line 18 to lower right column, line 5, page 3, lower right column, line 18 to page 4 upper left column, line 3, fig. 1 (Family:none)	1 2-6
Y A	JP 2008-157193 A (KAWASAKI HEAVY INDUSTRIES, LTD.) 10 July 2008, paragraphs [0002]-[0003] & US 2008/0210206 A1, paragraphs [0004]-[0005]	1 2-6



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
28 November 2017 (28.11.2017)

Date of mailing of the international search report
12 December 2017 (12.12.2017)

Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2017/034305

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	JP 9-209738 A (SUZUKI MOTOR CORPORATION) 12 August 1997, paragraphs [0004]-[0006] (Family: none)	2-6

Form PCT/ISA/210 (continuation of second sheet) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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- JP 4873647 B [0004]