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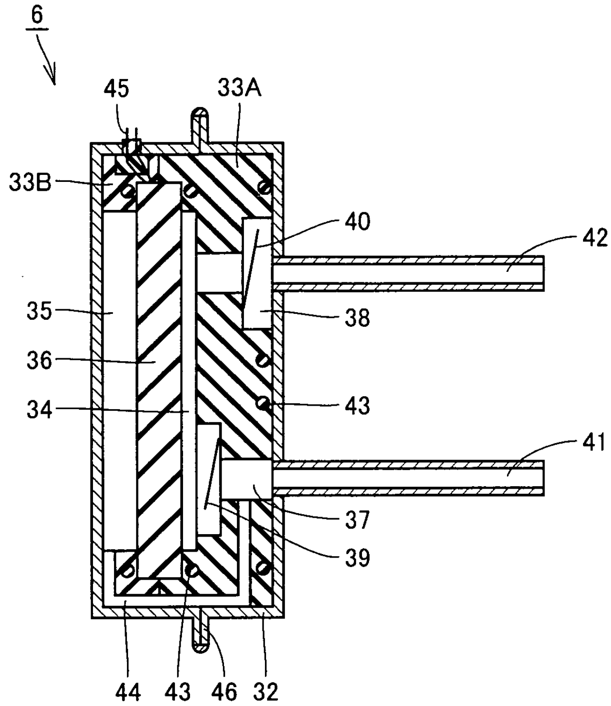
(54) PIEZOELECTRIC PUMP AND STIRLING REFRIGERATOR

(57) A piezoelectric pump (6) includes a casing (32) formed of a plurality of metallic members welded and thus joined together, a piezoelectric element (36) dividing an internal space of the casing (32) into a working space (34) and a back pressure space (35), and internal components (33A, 33B) formed of resin, and provided between the casing (32) and the piezoelectric element (36) and holding the piezoelectric element (36). The internal components (33A, 33B) are formed of workable and moldable resin. The internal component (33A) defines a perimeter of the working space (34) and the internal component (33B) defines a perimeter of the back pressure space (35). The internal components (33A, 33B) are arranged opposite each other to form a recess therebetween to receive and thus hold the piezoelectric element (36) therein.

FIG.2



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Description

Technical Field

[0001] The present invention relates piezoelectric pumps and Stirling refrigerators/freezers, and particularly to piezoelectric pumps efficiently circulating fluid in negative and positive pressure states and Stirling refrigerators/freezers equipped with such piezoelectric pumps.

Background Art

[0002] Conventionally a piezoelectric pump employing a piezoelectric element of quartz, lithium niobate and the like has been used as a medium circulating pump.

[0003] Fig. 6 is a cross section of one example of a conventional piezoelectric pump. With reference to Fig. 6, a piezoelectric pump 106 includes a casing 132, and a working space 134 and a back pressure space 135 in casing 132, as shown in Fig. 6. Working space 134 and back pressure space 135 are spaced by a piezoelectric element 136. Furthermore, a portion of the casing that is adjacent to working space 134 is provided with an inlet 137 aspirating a medium and an outlet 138 discharging the medium. A portion of the casing that is adjacent to back pressure space 135 is provided with a back pressure hole 135A for adjusting back pressure space 135 in pressure. Note that inlet 137 and outlet 138 are provided with check valves 139 and 140, respectively, to prevent the medium from flowing backward.

[0004] To operate piezoelectric pump 106, an electrical signal is applied to piezoelectric element 136. This causes piezoelectric element 136 to oscillatorily move in a direction indicated by a broken arrow. Note that piezoelectric element 136 has ends secured to casing 132, and accordingly, deforms in the form of a projected surface and thus oscillatorily moves. As a result, working space 134 varies in volume and has its internal pressure varied with how piezoelectric element 136 deforms. Thus piezoelectric pump 106 aspirates/discharges the medium.

[0005] As piezoelectric element 136 deforms, back pressure space 135 will also vary in volume, and as a result back pressure space 135 varies in pressure. This causes a force in a direction opposite to that in which piezoelectric element 136 moves. Consequently, piezoelectric pump 106 operates inefficiently. This is addressed by providing back pressure hole 135A to casing 132 at a portion adjacent to back pressure space 135 to maintain back pressure space 135 to be constant in pressure regardless of how piezoelectric element 136 deforms.

[0006] Furthermore, heat exchange utilizing an inverted Stirling cycle is applied to a refrigerator/freezer, such as that described in Japanese Patent Laying-Open No. 2003-50073 (hereinafter referred to as Conventional Example 1).

[0007] Conventional Example 1 discloses a Stirling freezing system including a warm portion externally radiating the heat of a working gas compressed in the inverted Stirling cycle, a cold portion externally absorbing the heat of the working gas expanded by the inverted Stirling cycle, and a circulation circuit associated with the cold portion, formed of a closed circuit connecting a condenser associated with the cold portion and thermally coupled with the cold portion and a plurality of evaporators associated with the cold portion together to configure a thermosyphon, characterized in that a cold heat energy transfer medium transferring the cold heat energy of the cold portion is sealed in the circulation circuit associated with the cold portion. The heat of the warm portion is radiated by a heat exchange cycle (or a radiating system) associated with the warm portion. The heat exchange cycle associated with the warm portion includes an evaporator associated with the warm portion and a condenser associated with the warm portion that are connected by a pipe, and transfers and radiates heat by the principle of thermosyphon.

[0008] Japanese Utility Model Registration No. 2505727 (referred to as Conventional Example 2) discloses a piezoelectric pump including a casing, a piezoelectric oscillator provided at an internal region of the casing, and a check valve provided at a pump chamber located at one side of the piezoelectric oscillator for aspiration and discharge. This piezoelectric pump has the pump chamber communicating with an opposite chamber located opposite to the pump chamber with the piezoelectric oscillator interposed therebetween.

Patent Document 1: Japanese Patent Laying-Open No. 2003-50073

Patent Document 2: Japanese Utility Model Registration No. 2505727

Disclosure of the Invention

Problems to be Solved by the Invention

[0009] However, such piezoelectric pump as described above has the following disadvantage:

[0010] Such a piezoelectric pump as shown in Fig. 6 has a casing configured of a plurality of members opposite to form an internal space. Note that the plurality of members are typically sealed together using an O ring or the like. Such configuration allows a working medium to slowly leak and thus cannot be applied over a long period of time to a sealed system having a circuit having an internal pressure lower or higher than atmospheric pressure (in the present specification, also referred to as "negative or positive pressure states"). Such problem cannot be solved by the piezoelectric pump indicated in Conventional Example 2, either.

[0011] Furthermore the piezoelectric element used for a piezoelectric pump is poor in thermal resistance. Accordingly, if the plurality of members are welded and thus joined together to provide better sealability, how the piezoelectric element can be protected as much as possible from exposure to the heat generated in welding the members will be an issue. Reducing the quantity of heat transferred to the piezoelectric element allows the piezoelectric element to be improved in function and as a result a fluid to be circulated more efficiently.

[0012] The present invention has been made to overcome such disadvantage as described above and it contemplates a piezoelectric pump and Stirling refrigerator/freezer capable of efficiently circulating a fluid in negative and positive pressure states.

Means for Solving the Problems

[0013] A piezoelectric pump according to the present invention includes: a casing formed of a plurality of metallic members joined together; a piezoelectric element dividing an internal space of the casing into first and second internal spaces; and non-metallic, first and second internal components provided between the casing and the piezoelectric element and holding the piezoelectric element.

[0014] Preferably the casing is configured of the plurality of metallic components that are welded and thus joined together. The plurality of metallic components welded and thus joined together can provide enhanced durability against leakage of a working medium. As a result there can be provided a piezoelectric pump usable for a long period of time in a sealed system operated at a pressure higher or lower than atmospheric pressure. Furthermore the non metallic internal components disposed between the metallic casing and the piezoelectric element can space the piezoelectric element apart from the casing. Thus, while welding and thus joining the metallic members together causes heat, the internal components can reduce or prevent transfer of the heat to the piezoelectric element.

[0015] Herein, preferably, the first and second internal components are formed of resin. The first and second internal components define perimeters of the first and second internal spaces respectively. The piezoelectric element is sandwiched to be held between the first and second internal components.

[0016] Using moldable resin and employing a simple structure to hold the piezoelectric element allows the piezoelectric pump to be fabricated at low cost.

[0017] The above piezoelectric pump in one aspect further includes: an inlet provided on the first internal component and passing a working medium flowing from an aspiration pipe external to the casing toward the first internal space serving as a working space; an outlet provided on the first internal component and passing the working medium flowing from the first internal space toward a discharge pipe external to the casing; a first check valve provided between the inlet and the first internal space; a second check valve provided between the outlet and the first internal space; and a plurality of O rings sealing a gap formed between the first and second internal spaces and the piezoelectric element and a gap formed between the inlet and the outlet and the casing, respectively. Herein preferably the first internal component has portions at which the first and second check valves are set, respectively, and a plurality of grooves accommodating the plurality of O rings, respectively.

[0018] This configuration can provide the internal components of resin with a recess, a groove or the like to facilitate forming a mount, a groove and/or the like for mounting or accommodating a check valve, an O ring, and the like.

[0019] Herein preferably the piezoelectric pump further includes a communication portion allowing the second internal space serving as a back pressure space to communicate with one of the inlet and the outlet, and the communication portion is defined by one of a bore and a groove formed in the first and second internal components.

[0020] The communication portion allows the working space (or the first internal space) and the back pressure space (or the second internal space) to be substantially equal in pressure. Furthermore, providing the internal components of resin with a groove, a bore or the like can eliminate the necessity of providing a communication pipe external to the casing and thus facilitate forming the communication portion. Consequently a compact piezoelectric pump allowing a fluid to be circulated efficiently can be fabricated at low cost.

[0021] Furthermore, preferably the communication portion communicates with such portions of the plurality of metallic members that are joined together. This allows the communication portion to be used as a leak check bore of the casing.

[0022] The piezoelectric pump in another aspect further includes: a first inlet provided on the first internal component and passing the working medium flowing from a first aspiration pipe external to the casing toward the first internal space serving as a working space; a second inlet provided on the second internal component and passing the working medium flowing from a second aspiration pipe external to the casing toward the second internal space serving as a working space; a first outlet provided on the first internal component and passing the working medium flowing from the first internal space toward a first discharge pipe external to the casing; a second outlet provided on the second internal component and passing the working medium flowing from the second internal space toward a second discharge pipe external to the casing; first and second check valves provided between the first and second inlets and the first and second internal spaces, respectively; third and fourth check valves provided between the first and second outlets and the first and second internal spaces, respectively; and a plurality of O rings sealing a gap formed between the first and second internal spaces and the piezoelectric element and a gap formed between the first and second inlets and the first and second outlets and the casing, respectively. Herein preferably the first and second internal components have portions at which the first to fourth check valves are set, respectively, and a plurality of grooves accommodating the plurality of O rings, respectively.

[0023] This configuration allows opposite spaces adjacent to the piezoelectric element to be utilized as a working space. Furthermore this configuration can provide the internal components of resin with a recess, a groove or the like to facilitate forming a mount, a groove and/or the like for mounting or accommodating a check valve, an O ring, and the like. Consequently a piezoelectric pump allowing a fluid to be circulated efficiently can be fabricated at low cost.

[0024] Preferably a communication bore is provided to allow one of the first and second inlets and the first and second outlets to communicate with such portions of the metallic members that are joined together.

[0025] This communication bore can be employed as a leak check bore of the casing.

[0026] The piezoelectric pump in still another aspect further includes: a first inlet provided on the first internal component and passing the working medium flowing from an aspiration pipe external to the casing toward the first internal space serving as a working space; a second inlet provided on the second internal component and passing the working medium flowing from the first inlet toward the second internal space; a first outlet provided on the first internal component and passing the working medium flowing from the first internal space toward a discharge pipe external to the casing; a second outlet provided on the second internal component and passing the working medium flowing from the second internal space toward the first outlet; a first communication portion defined by one of a bore and a groove formed in the first and second internal components to allow the first and second inlets to communicate with each other; a second communication portion defined by one of a bore and a groove formed in the first and second internal components to allow the first and second outlets to communicate with each other; first and second check valves provided between the first and second inlets and the first and second internal spaces, respectively; third and fourth check valves provided between the first and second outlets and the first and second internal spaces, respectively; and a plurality of O rings sealing a gap formed between the first and second internal spaces and the piezoelectric element and a gap formed between the first and second inlets and the first and second outlets and the casing, respectively. Herein preferably the first and second internal components have portions at which the first to fourth check valves are set, respectively, and a plurality of grooves accommodating the plurality of O rings, respectively.

[0027] This configuration allows opposite spaces adjacent to the piezoelectric element to be utilized as a working space. Furthermore the configuration can eliminate the necessity of providing a communication pipe external to the casing to form the first and second communication portions. Furthermore the configuration can provide the internal components of resin with a recess, a groove or the like to facilitate forming a mount, a groove and/or the like for mounting or accommodating a check valve, an O ring, and the like. Consequently a compact piezoelectric pump allowing a fluid to be circulated efficiently can be fabricated at low cost.

[0028] Herein one of the first and second communication portions may be communicated with such portions of the plurality of metallic members of the casing that are joined together. This allows the communication portion to be utilized as a leak check bore of the casing.

[0029] Furthermore there may be provided another O ring sealing the first or second communication portion at those surfaces of the first and second internal components which are joined together. This ensures that the first and second communication portions serving as a path of the working medium are closely sealed.

[0030] Note that the plurality of metallic members forming the casing may have flanges, respectively, and the flanges may have their respective ends welded together to form the casing. This allows the piezoelectric element to be father away from the welded portions to more effectively reduce the heat that enters the piezoelectric element.

[0031] A Stirling refrigerator/freezer according to the present invention has the above described piezoelectric pump provided at a working-medium circulation circuit associated with a warm portion.

Effects of the Invention

[0032] The present invention can thus provide a piezoelectric pump that can be used in a sealed system of negative and positive pressure states for a long period of time without causing slow leakage.

Brief Description of the Drawings

[0033]

Fig: 1 shows one example of a diagram of a piping system of a Stirling refrigerator/freezer.

Fig. 2 is a cross section of a piezoelectric pump of the present invention in first embodiment.

Fig. 3 is a cross section of a piezoelectric pump of the present invention in second embodiment.

Fig. 4 is a cross section of a piezoelectric pump of the present invention in third embodiment.

Fig. 5 shows one example of a side cross section of a Stirling refrigerating machine in a Stirling refrigerator/freezer.

Fig. 6 is a cross section of a conventional piezoelectric pump.

Description of the Reference Signs

[0034] 1: Stirling refrigerator/freezer, 2: radiating portion, 2A-2F: pipe (a circulation circuit associated with a warm portion), 3: endothermic portion, 3A, 3B: pipe (circulation circuit associated with a cold portion), 4: Stirling refrigerating machine, 5: evaporator associated with the warm portion, 6: circulation pump, 7: condenser associated with the warm portion, 8: fan, 9: dew prevention pipe, 10: condenser associated with the cold portion, 11: evaporator associated with the cold portion, 12: fan, 13: cylinder, 14: piston, 15: displacer, 16: regenerator, 17: working space, 17A: compression space, 17B: expansion space, 18, 19: heat exchanger, 18A: tube, 20: inner yoke, 21: movable magnet, 22: outer yoke, 23: linear motor, 24: piston spring, 25: displacer spring, 26: displacer rod, 27: back pressure space, 28: leaf spring, 29: balance mass, 30, 32: casing, 33A, 33B: internal component, 34, 34A, 34B: working space, 35: back pressure space, 36: piezoelectric element, 37, 37A, 37B: inlet, 38, 38A, 38B: outlet, 39, 39A, 39B, 40, 40A, 40B: check valve, 41, 41A, 41B: inlet pipe, 42, 42A, 42B: outlet pipe, 43: O ring, 44: communication portion, 44A: leak check bore, 44B: inlet communication portion, 44C: outlet communication portion, 45: power supply terminal, 46: flange

Best Mode for Carrying Out the Invention

[0035] Hereinafter reference will be made to Figs. 1-5 to describe an embodiment of a piezoelectric pump and Stirling refrigerator/freezer in accordance with the present invention.

[0036] Note that in the present specification, a "refrigerator/freezer" represents a concept including all of a "refrigerator", a "freezer" and a "refrigerator and freezer".

[0037] Furthermore in the present specification will be described a Stirling refrigerator/freezer serving as Stirling engine-mounted equipment equipped with a Stirling refrigerating machine. However, Stirling engine-mounted equipment provided with the piezoelectric pump in accordance with the present invention is not limited to a Stirling refrigerator/freezer. The Stirling engine is also used for example as a power generator.

Description of Stirling Refrigerator/Freezer

[0038] Fig. 1 shows one example of a diagram of a piping system of a Stirling refrigerator/freezer having a piezoelectric pump of first to third embodiments of the present invention, as will be described later, provided at a working-medium circulation circuit associated with a warm portion.

[0039] As shown in Fig. 1, Stirling refrigerator/freezer 1 includes: a Stirling refrigerating machine 4 (or a Stirling engine) having a radiating portion 2 and an endothermic portion 3; a first circulation circuit associated with a warm portion (hereinafter also simply referred to as the first circulation circuit) and including an evaporator 5 associated with the warm portion and attached to radiating portion 2, a condenser 7 associated with the warm portion, and pipes 2A and 2B; a second circulation circuit associated with the warm portion (hereinafter also simply referred to as the second circulation circuit) and including evaporator 5 associated with the warm portion, a circulation pump 6, a dew prevention pipe 9, and pipes 2C, 2D, 2E and 2F; and a circulation circuit associated with a cold portion and including a condenser 10 associated with the cold portion and attached to endothermic portion 3, an evaporator 11 associated with the cold portion, and pipes 3A and 3B. The first circulation circuit associated with the warm portion cools radiating portion 2 of Stirling refrigerating machine 4 and the second circulation circuit associated with the warm portion supplies dew prevention pipe 9 with heat. Furthermore the circulation circuit associated with the cold portion allows the refrigerator/freezer's internal air and endothermic portion 3 of Stirling refrigerating machine 4 to exchange heat.

[0040] The first and second circulation circuits associated with the warm portion have water (H_2O) or the like sealed therein as a coolant. Evaporator 5 associated with the warm portion evaporates the coolant, which is transferred through pipe 2A (a conduit associated with the warm portion) to condenser 7 associated with the warm portion, as indicated in Fig. 1 by a broken arrow. Condenser 7 associated with the warm portion allows heat exchange with external air to condense the coolant. To facilitate this heat exchange, a fan 8 is provided to cause a stream of air in a vicinity of condenser 7 associated with the warm portion. The condensed coolant returns through pipe 2B (or a return pipe associated with the warm portion) to evaporator 5 associated with the warm portion. To thus allow the coolant's evaporation and condensation and resultant natural circulation to be utilized to transfer heat generated at radiating portion 2, the first circulation circuit associated with the warm portion has condenser 7 associated with the warm portion, arranged to be upper than evaporator 5 associated with the warm portion. Furthermore, to adjust the coolant's boiling point, circulation circuitry has an internal pressure adjusted (or reduced to substantially provide vacuum).

[0041] Evaporator 5 associated with the warm portion has a lower portion connected to pipe 2C. From evaporator 5 associated with the warm portion to pipe 2C the coolant flows in liquid phase. The coolant flowing into pipe 2C flows through pipe 2D to circulation pump 6 provided lower than Stirling refrigerating machine 4. Circulation pump 6 discharges the coolant, which is delivered through pipe 2E to dew prevention pipe 9. Dew prevention pipe 9 passes the coolant, which is held at a relatively high temperature by the heat provided from radiating portion 2 of Stirling refrigerating machine 4. Accordingly, arranging dew prevention pipe 9 at a front side of the refrigerator/freezer can reduce dew formed at a door of the refrigerator/freezer and the like. The coolant having passed through dew prevention pipe 9 flows through pipe 2F back to evaporator 5 associated with the warm portion. Thus, in the second circulation circuit associated with the warm portion, forced circulation is performed by circulation pump 6.

[0042] The circulation circuit associated with the cold portion has carbon dioxide, hydrocarbon or the like sealed therein as a coolant. Condenser 10 associated with the cold portion condenses the coolant, which is transferred through pipe 3A (a conduit associated with the cold portion) to evaporator 11 associated with the cold portion. Evaporator 11 associated with the cold portion evaporates the coolant to exchange heat. To facilitate this heat exchange, a fan 12 is provided to cause a stream of air in a vicinity of evaporator 11 associated with the cold portion. After the heat exchange, the gasified coolant returns through pipe 3B (or a return pipe associated with the cold portion) to condenser 10 associated with the cold portion. To thus allow the coolant's evaporation and condensation and resultant natural circulation to be utilized to transfer cold heat energy generated at endothermic portion 3, the circulation circuit associated with the cold portion has evaporator 11 associated with the cold portion, arranged to be lower than condenser 10 associated with the cold portion. Furthermore, to adjust the coolant's boiling point, circulation circuitry has an internal pressure adjusted (or reduced to substantially provide vacuum).

[0043] When Stirling refrigerating machine 4 is activated, radiating portion 2 of Stirling refrigerating machine 4 generates heat, which is subjected to heat exchange with air through condenser 7 associated with the warm portion. In contrast, endothermic portion 3 of Stirling refrigerating machine 4 generates cold heat energy, which is subjected to heat exchange with the internal air of the refrigerator/freezer through evaporator 11 associated with the cold portion. The refrigerator/freezer internally has a warm stream of air, which is again sent to a vicinity of evaporator 11 associated with the cold portion, and repeatedly cooled.

First Embodiment

[0044] Fig. 2 is a cross section of a piezoelectric pump in a first embodiment.

[0045] The present embodiment provides a piezoelectric pump 6 including a casing 32 formed of a plurality of metallic members welded together, a piezoelectric element 36 dividing an internal space of casing 32 into a working space 34 (or a first internal space) and a back pressure space 35 (or a second internal space), and nonmetallic, internal component 33A and 33B (or first and second internal components) provided between casing 32 and piezoelectric element 36 and holding piezoelectric element 36.

[0046] Internal components 33A and 33B are formed of workable and moldable resin. Internal component 33A defines a perimeter of working space 34 (or a pump chamber) and internal component 33B defines a perimeter of back pressure space 35. Internal components 33A and 33B are arranged opposite to each other to form a recess therebetween to receive and thus hold piezoelectric element 36 therein. In other words, internal components 33A and 33B sandwich and thus hold piezoelectric element 36.

[0047] The Fig. 2 example is provided with an inlet 37 provided on internal component 33A to pass a working medium flowing from an inlet pipe 41 (or an aspiration pipe) external to casing 32 toward working space 34, an outlet 38 provided on internal component 33A to pass the working medium flowing from working space 34 toward an outlet pipe 42 (or a discharging pipe) external to casing 32, a check valve 39 (or a first check valve) provided between inlet 37 and working space 34, a check valve 40 (or a second check valve) provided between outlet 38 and working space 34, and a plurality of O rings 43 sealing a gap formed between working and back pressure spaces 34 and 35 and piezoelectric element 36 and a gap formed between inlet and outlet 37 and 38 and an internal surface of casing 32, respectively. Check valves 39 and 40 are set on mounts (or portions at which the first and second check valves are set, respectively), respectively, and each O ring 43 is attached in a groove. The mounts and the groove are provided by previously working internal components 33A and 33B.

[0048] Piezoelectric pump 6 has a communication portion 44 allowing back pressure space 35 and inlet 37 to communicate with each other. Communication portion 44 is defined by a bore or groove formed in internal components 33A and 33B. Communication portion 44 reaches an internal surface of casing 32 and communicates with such portions of the plurality of metallic members that are welded together. Note that communication portion 44 may be replaced with a communication portion allowing back pressure space 35 and outlet 38 to communicate with each other.

[0049] To actuate piezoelectric pump 6, an electrical signal is applied through a power supply terminal 45 to piezoelectric element 36 to oscillatorily move piezoelectric element 36 rightward and leftward as seen in Fig. 2.

[0050] The above described configuration allows casing 32 to be configured of a plurality of members welded and thus joined together to provide increased durability against leakage of the working medium. As a result there can be provided piezoelectric pump 6 that can be used in a sealed system of negative and positive pressure states for a long period of time. Furthermore, internal components 33A and 33B of resin that are provided between metallic casing 32 and piezoelectric element 36 to space piezoelectric electric element 36 apart from casing 32 can reduce transfer to piezoelectric element 36 of heat generated as the metallic members are welded together. Thus piezoelectric element 36 can operate more efficiently and as a consequence the working medium can be circulated more efficiently.

[0051] Furthermore, employing moldable resin components as internal components 33A and 33B and employing a simple structure as described above to hold piezoelectric element 36 allows piezoelectric element 36 to be fabricated at low cost.

[0052] Furthermore the mounts on which check valves

39 and 40 are set and the grooves accommodating the plurality of O rings 43 can be formed simply by providing internal resin components 33A and 33B with a recess, a groove and the like.

[0053] Furthermore, communication portion 44 allows working space 34 (or the first internal space) and back pressure space 35 (or the second internal space) to be equally maintained in pressure. As a result in negative and positive pressure states the working medium can be circulated more efficiently. Note that communication portion 44 can be formed simply by providing internal resin components 33A and 33B with a groove, a bore and/or the like and thus eliminate the necessity of a communication pipe external to the casing. As a result piezoelectric pump 6 can have a compact structure at a low cost. Furthermore communication portion 44 communicated with such portions of the plurality of metallic members that are welded together can be used as a leak check bore (or a communication bore) of the casing.

[0054] The plurality of metallic members forming casing 32 have flanges 46, respectively, which have their respective ends welded together to form casing 32. Flange 46 allows piezoelectric element 36 to be father away from the welded portions to more effectively reduce the heat that enters piezoelectric element 36.

Second Embodiment

[0055] Fig. 3 is a cross section of a piezoelectric pump in a second embodiment.

[0056] Piezoelectric pump 6 in the present embodiment is an exemplary variation of piezoelectric pump 6 of the first embodiment and is characterized by employing opposite portions adjacent to piezoelectric element 36 as a pump chamber (or working spaces 34A and 34B).

[0057] As shown in Fig. 3, piezoelectric pump 6 is provided with an inlet 37A (or a first inlet) provided on internal component 33A (or a first internal component) to pass a working medium flowing from an inlet pipe 41 A (or a first aspiration pipe) external to casing 32 toward working space 34A (or a first internal space), an inlet 37B (or a second inlet) provided on an internal component 33B (or a second internal component) to pass the working medium flowing from an inlet pipe 41B (or a second aspiration pipe) external to casing 32 toward working space 34B (or a second internal space), an outlet 38A (or a first outlet) provided on internal component 33A to pass the working medium flowing from working space 34A toward an outlet pipe 42A (or a first discharging pipe) external to casing 32, an outlet 38B (or a second outlet) provided on internal component 33B to pass the working medium flowing from working space 34B toward an outlet pipe 42B (or a second discharging pipe) external to casing 32, check valves 39A and 39B (or first and second check valves) provided between inlets 37A and 37B and working spaces 34A and 34B, respectively, check valves 40A and 40B (or third and fourth check valves) provided between outlets 38A and 38B and working spaces 34A and 34B, respectively, and a plurality of O rings 43 sealing a gap formed between working spaces 34A and 34B and piezoelectric element 36 and a gap formed between inlets and outlets 37A and 37B and 38A and 38B and an internal surface of casing 32, respectively. Check valves 39A and 39B and 40A and 40B are set on mounts (or portions at which the first to fourth check valves are set, respectively), respectively, and each 0 ring 43 is attached in a groove. The mounts and the groove are provided by previously working internal components 33A and 33B.

[0058] Piezoelectric pump 6 has a leak check bore 44A (or a communication bore) provided in internal components 33A and 33B and extending from inlets 37A and 37B to reach an internal surface of casing 32 to communicate such portions of the plurality of metallic members that are welded together. Note that leak check bore 44A may be provided only one of internal components 33A and 33B and may be replaced with a leak check bore extending from outlets 38A and 38B to reach an internal surface of casing 32 to communicate such portions of the plurality of metallic members that are welded together.

[0059] The above described configuration as well as the first embodiment can provide piezoelectric pump 6 at low cost that can be used in a sealed system of negative and positive pressure states for a long period of time and provide significantly efficient circulation.

[0060] Furthermore, leak check bore 44A communicated with such portions of the plurality of metallic members that are welded together allows the casing to be checked in whether it has leakage.

[0061] The present embodiment will not be described in detail for matters similar to those of the first embodiment.

Third Embodiment

[0062] Fig. 4 is a cross section of a piezoelectric pump in a third embodiment.

[0063] Piezoelectric pump 6 in the present embodiment is an exemplary variation of piezoelectric pump 6 of the first embodiment and is characterized by employing opposite portions adjacent to piezoelectric element 36 as a pump chamber (or working spaces 34A and 34B).

[0064] As shown in Fig. 4, piezoelectric pump 6 is provided with inlet 37A (or the first inlet) provided on internal component 33A (or the first internal component) to pass a working medium flowing from inlet pipe 41 (or an aspiration pipe) external to casing 32 toward working space 34A (or the first internal space), inlet 37B (or the second inlet) provided on internal component 33B (or the second internal component) to pass the working medium flowing from inlet 37A toward working space 34B (or the second internal space), outlet 38A (or the first outlet) provided on internal component 33A to pass the working medium flowing from working space 34A toward an outlet pipe 42 (or a discharging pipe) external to casing 32, outlet 38B (or the second outlet) provided on internal component

33B to pass the working medium flowing from working space 34B toward an outlet 38A, an inlet communication portion 44B (or a first communication portion) defined by a bore or groove formed in internal components 33A and 33B to allow inlets 37A and 37B to communicate with each other, an outlet communication portion 44C (or a second communication portion) defined by a bore or groove formed in internal components 33A and 33B to allow outlets 38A and 38B to communicate with each other, check valves 39A and 39B (or the first and second check valves) provided between inlets 37A and 37B and working spaces 34A and 34B, respectively, check valves 40A and 40B (or the third and fourth check valves) provided between outlets 38A and 38B and working spaces 34A and 34B, respectively, and a plurality of O rings 43 sealing a gap formed between working spaces 34A and 34B and piezoelectric element 36 and a gap formed between inlets and outlets 37A and 37B and 38A and 38B and an internal surface of casing 32, respectively. Check valves 39A and 39B and 40A and 40B are set on mounts (or portions at which the first to fourth check valves are set, respectively), respectively, and each O ring 43 is attached in a groove. The mounts and the groove are provided by previously working internal components 33A and 33B.

[0065] Note that inlet communication portion 44B reaches an internal surface of casing 32 to communicate with such portions of the plurality of metallic members that are welded together. This allows inlet communication portion 44B to be used as a leak check bore. In contrast, outlet communication portion 44C is sealed by providing (another) O ring at such surfaces of internal components 33A and 33B that are joined together, as shown in Fig. 4, and thus does not communicate with such portions of the plurality of metallic components that are welded together. Alternatively, inlet communication portion 44B may be sealed and outlet communication portion 44C may instead be communicated with such welded portions. Thus communicating one of inlet communication portion 44B and outlet communication portion 44C with such welded portions and sealing the other by an O ring can prevent the working medium's path, i.e., inlets 37A and 37B and outlets 38A and 38B from communicating with each other.

[0066] The above described configuration as well as the first embodiment can provide piezoelectric pump 6 at low cost that can be used in a sealed system of negative and positive pressure states for a long period of time and provide significantly efficient circulation.

[0067] Furthermore inlet communication portion 44B and outlet communication portion 44C can be formed simply by providing internal resin components 33A and 33B with a groove, a bore and/or the like and thus eliminate the necessity of providing a communication pipe external to the casing. As a result piezoelectric pump 6 can have a compact structure.

[0068] The present invention will not be described in detail for matters similar to those of the first embodiment.

Description of Stirling Refrigerating Machine

[0069] With reference to Fig. 5, Stirling refrigerating machine 4 is configured, by way of example, and operates, as described hereinafter.

[0070] As shown in Fig. 5, the present embodiment provides Stirling refrigerating machine 4, which is a free piston type Stirling engine including a casing 30, a cylinder 13 assembled to casing 30, a piston 14 and a displacer 15 reciprocating in cylinder 13, a regenerator 16, a working space 17 having a compression space 17A and an expansion space 17B, radiating portion 2, endothermic portion 3, a linear motor 23 serving as piston drive means, a piston spring 24, a displacer spring 25, a displacer rod 26, and a back pressure space 27.

[0071] In the Fig. 5 example Stirling refrigerating machine 4 has a shell (or an external wall) which is not configured in the form of a single container. Rather, it is configured mainly of: a casing 30 (or a vessel) adjacent to back pressure space 27; and radiating portion 2, a tube 18A and endothermic portion 3 adjacent to working space 17. Casing 30 defines back pressure space 27. Casing 30 has cylinder 13, linear motor 23, piston spring 24, displacer spring 25 and other various components assembled thereto. In the shell a working medium such as gaseous helium, gaseous hydrogen, gaseous nitrogen or the like is introduced.

[0072] Cylinder 13 has a generally cylindrical geometry and internally, reciprocatably receives piston 14 and displacer 15 serving as a free piston. In cylinder 13 piston 14 and displacer 15 are coaxially spaced and thus arranged, and section working space 17 located at an internal region of cylinder 13 into compression space 17A and expansion space 17B. More specifically, working space 17 is a space closer to displacer 15 than that end surface of piston 14 which is closer to displacer 15, and between piston 14 and displacer 15 compression space 17A is formed and between displacer 15 and endothermic portion 3 expansion space 17B is formed. Compression space 17A is surrounded mainly by radiating portion 2 and expansion space 17B is surrounded mainly by endothermic portion 3.

[0073] Between compression space 17A and expansion space 17B is arranged regenerator 16 provided by winding a film on an internal circumferential surface of tube 18A such that the film's turns are spaced, as prescribed. Through regenerator 16 compression space 17A and expansion space 17B communicate with each other. Thus in Stirling refrigerating machine 4 a close circuit is formed. The closed circuit has the working medium sealed therein, and as piston 14 and displacer 15 operate, the working medium accordingly flows and thus moves to implement an inverted Stirling cycle, as will be described later.

[0074] In back pressure space 27 at a location outer than cylinder 13 linear motor 23 is arranged. Linear motor 23 has an inner yoke 20, a movable magnet 21 and an outer yoke 22 to drive piston 14 in the axial direction of cylinder 13.

[0075] Piston 14 has an end connected to piston spring 24 configured for example of a leaf spring. Piston spring 24 functions as a means for applying elastic force to piston 14. Applying the elastic force to piston spring 24 allows piston 14 to reciprocate in cylinder 13 more steadily periodically. Displacer 15 has one end connected to displacer spring 25 by displacer rod 26. Displacer rod 26 penetrates piston 14 and displacer spring 25 is configured of a leaf spring or the like. Displacer spring 25 and piston spring 24 have their respective peripheral portions supported by a support member extending from linear motor 23 toward the back pressure space 27 side with respect to piston 24 (hereinafter also referred to as "rearward" or the like).

[0076] Opposite to displacer 15 with respect to piston 14, back pressure space 27 surrounded by casing 30 is provided. Back pressure space 27 includes a circumferential region provided in casing 30 and surrounding piston 14, and a rearward region provided in casing 30 and located on the piston spring 24 side (or a rearward side) with respect to piston 14. Back pressure space 27 also contains the working medium.

[0077] Radiating portion 2 and endothermic portion 3 have inner circumferential surfaces, respectively, on which heat exchangers 18 and 19 are provided, respectively. Heat exchangers 18 and 19 exchange heat between compression and expansion spaces 17A and 17B and radiating and endothermic portions 2 and 3, respectively.

[0078] Rearwardly of casing 30 a balance mass 29 is attached by a leaf spring 28. Balance mass 29 is a mass member absorbing the vibration of casing 30 caused as piston 14, displacer 15 and the like oscillate. More specifically, when piston 14, displacer 15 and the like oscillate and casing 30 accordingly vibrates, balance mass 29 vibrates to follow the vibration of casing 30 to reduce that of Stirling refrigerating machine 4.

[0079] Hereinafter, how Stirling refrigerating machine 4 operates will be described.

[0080] Initially, linear motor 23 is actuated to drive piston 14. Piston 14 driven by linear motor 23 approaches displacer 15 to compress a working medium (or a working gas) in compression space 17A.

[0081] As piston 14 approaches displacer 15, the temperature of the working medium in compression space 17A rises. However, radiating portion 2 liberates externally the heat generated in compression space 17A. Therefore, the working medium in compression space 17A is maintained substantially isothermally. In other words, this process corresponds to an isothermal compression process in an inverted Stirling cycle.

[0082] After piston 14 approaches displacer 15, displacer 15 moves to endothermic portion 3. The working medium compressed in compression space 17A by piston 14 flows into regenerator 16, and further into expansion space 17B. At the time, the heat that the working medium has is accumulated in regenerator 16. In other words, this process corresponds to a constant volume cooling process in the inverted Stirling cycle.

[0083] The working medium of high pressure that flows into expansion space 17B expands as displacer 15 moves towards piston 14 (or rearward). Thus, as displacer 15 moves rearward, displacer spring 25 has a center portion deformed to protrude rearward.

[0084] Thus, as the working medium expands in expansion space 17B, the working medium in expansion space 17B decreases in temperature. However, endothermic portion 3 transfers external heat to expansion space 17B, and expansion space 17B is internally maintained substantially isothermally. In other words, this process corresponds to an isothermal expansion process in the inverted Stirling cycle.

[0085] Thereafter, displacer 15 starts to move away from piston 14. Accordingly, the working medium in expansion space 17B passes through regenerator 16 and returns to compression space 17A again. At the time, the heat accumulated in regenerator 16 is provided to the working medium, and the temperature of the working medium rises. In other words, this process corresponds to a constant volume heating process in the inverted Stirling cycle.

[0086] By repeating the series of processes (the isothermal compression process-the constant volume cooling process-the isothermal expansion process-the constant volume heating process), an inverted Stirling cycle is formed. As a result, the temperature of endothermic portion 3 is gradually lowered to cryogenic temperature (for example of approximately -50°C). In contrast, radiating portion 2 gradually attains a high temperature (for example of approximately 60°C). As has been described above, the cold heat energy at endothermic portion 3 is fed into the refrigerator/freezer via the circulation circuit associated with the cold portion and the heat at radiating portion 2 is radiated outside the refrigerator/freezer via the first and second circulation circuits associated with the warm portion.

[0087] Thus the embodiments of the present invention have been described. It should be noted that the features of the described embodiments may be combined together as appropriate. Furthermore the disclosed embodiments are by way of illustration and example only and is not to be taken by way of limitation, the spirit and scope of the present invention being limited only by the terms of the appended claims and intended to include any modifications within the scope and meaning equivalent to the terms of the claims.

Industrial Applicability

[0088] Thus the present invention is applicable to piezoelectric pumps and Stirling refrigerators/freezers.

Claims

1. A piezoelectric pump comprising:

   a casing (32) formed of a plurality of metallic members joined together;
   a piezoelectric element (36) dividing an internal space of said casing (32) into first and second internal spaces (34, 34A, 34B, 35); and
   non-metallic, first and second internal components (33A, 33B) provided between said casing (32) and said piezoelectric element (36) and holding said piezoelectric element (36).

2. The piezoelectric pump according to claim 1, wherein:

   said first and second internal components (33A, 33B) are formed of resin;
   said first and second internal components (33A, 33B) define perimeters of said first and second internal spaces (34, 35), respectively; and
   said piezoelectric element (36) is sandwiched to be held between said first and second internal components (33A, 33B).

3. The piezoelectric pump according to claim 1, further comprising:

   an inlet (37) provided on said first internal component (33A) and passing a working medium flowing from an aspiration pipe (41) external to said casing (32) toward said first internal space (34) serving as a working space;
   an outlet (38) provided on said first internal component (33A) and passing the working medium flowing from said first internal space (34) toward a discharge pipe (42) external to said casing (32);
   a first check valve (39) provided between said inlet (37) and said first internal space (34);
   a second check valve (40) provided between said outlet (38) and said first internal space (34); and
   a plurality of O rings (43) sealing a gap formed between said first and second internal spaces (34, 35) and said piezoelectric element (36) and a gap formed between said inlet and said outlet (37 and 38) and said casing (32), respectively, wherein said first internal component (33A) has portions at which said first and second check valves (39, 40) are set, respectively, and a plurality of grooves accommodating said plurality of O rings (43), respectively.

4. The piezoelectric pump according to claim 3, further comprising a communication portion (44) allowing said second internal space (35) serving as a back pressure space to communicate with one of said inlet (37) and said outlet (38), wherein said communication portion (44) is defined by one of a bore and a groove formed in said first and second internal components (33A, 33B).

5. The piezoelectric pump according to claim 3, provided with a communication bore (44) allowing one of said inlet (37) and said outlet (38) to communicate with such portions of said metallic members that are joined together.

6. The piezoelectric pump according to claim 1, comprising:

   a first inlet (37A) provided on said first internal component (33A) and passing the working medium flowing from a first aspiration pipe (4 1 A) external to said casing (32) toward said first internal space (34A) serving as a working space;
   a second inlet (37B) provided on said second internal component (33B) and passing the working medium flowing from a second aspiration pipe (41B) external to said casing (32) toward said second internal space (34B) serving as a working space;
   a first outlet (38A) provided on said first internal component (33A) and passing the working medium flowing from said first internal space (34A) toward a first discharge pipe (42A) external to said casing (32);
   a second outlet (38B) provided on said second internal component (33B) and passing the working medium flowing from said second internal space (34B) toward a second discharge pipe (42B) external to said casing (32);
   first and second check valves (39A, 39B) provided between said first and second inlets (37A, 37B) and said first and second internal spaces (34A, 34B), respectively;
   third and fourth check valves (40A, 40B) provided between said first and second outlets (38A, 38B) and said first and second internal spaces (34A, 34B), respectively; and
   a plurality of O rings (43) sealing a gap formed between said first and second internal spaces (34A, 34B) and said piezoelectric element (36) and a gap formed between said first and second inlets and said first and second outlets (37A, 37B and 38A, 38B) and said casing (32), respectively, wherein
   said first and second internal components (33A, 33B) have portions at which said first to fourth check valves (39A, 39B, 40A, 40B) are set, respectively, and a plurality of grooves accommodating said plurality of O rings (43), respectively.

7. The piezoelectric pump according to claim 6, provid-

ed with a communication bore (44A) allowing one of said first and second inlets and said first and second outlets (37A, 37B and 38A, 38B) to communicate with such portions of said metallic members that are joined together.

8. The piezoelectric pump according to claim 1, comprising:

a first inlet (37A) provided on said first internal component (33A) and passing the working medium flowing from an aspiration pipe (41) external to said casing (32) toward said first internal space (34A) serving as a working space;
a second inlet (37B) provided on said second internal component (33B) and passing the working medium flowing from said first inlet (37A) toward said second internal space (34B);
a first outlet (38A) provided on said first internal component (33A) and passing the working medium flowing from said first internal space (34A) toward a discharge pipe (42) external to said casing (32);
a second outlet (38B) provided on said second internal component (33B) and passing the working medium flowing from said second internal space (34B) toward said first outlet (38A);
a first communication portion (44B) defined by one of a bore and a groove formed in said first and second internal components (33A, 33B) to allow said first and second inlets (37A, 37B) to communicate with each other;
a second communication portion (44C) defined by one of a bore and a groove formed in said first and second internal components (33A, 33B) to allow said first and second outlets (38A, 38B) to communicate with each other;
first and second check valves (39A, 39B) provided between said first and second inlets (37A, 37B) and said first and second internal spaces (34A, 34B), respectively;
third and fourth check valves (40A, 40B) provided between said first and second outlets (38A, 38B) and said first and second internal spaces (34A, 34B), respectively; and
a plurality of O rings (43) sealing a gap formed between said first and second internal spaces (34A, 34B) and said piezoelectric element (36) and a gap formed between said first and second inlets and said first and second outlets (37A, 37B and 38A, 38B) and said casing (32), respectively, wherein
said first and second internal components (33A, 33B) have portions at which said first to fourth check valves (39A, 39B, 40A, 40B) are set, respectively, and a plurality of grooves accommodating said plurality of O rings (43), respectively.

9. A Stirling refrigerator/freezer having the piezoelectric pump (6) of claim 1 at a working-medium circulation circuit associated with a warm portion.

FIG.1

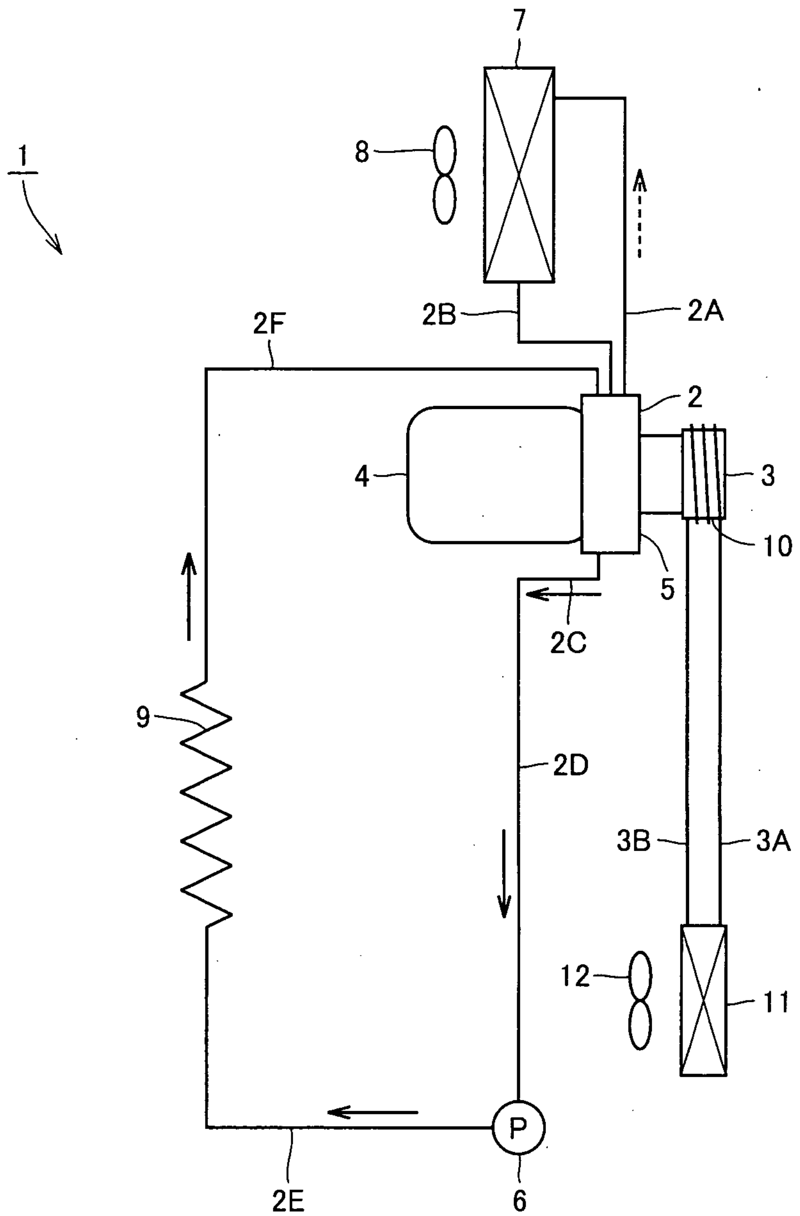
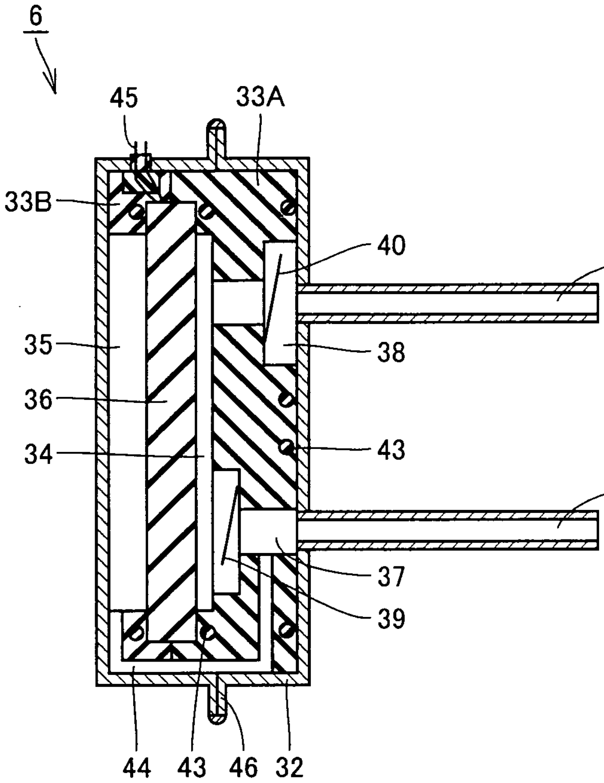


FIG.2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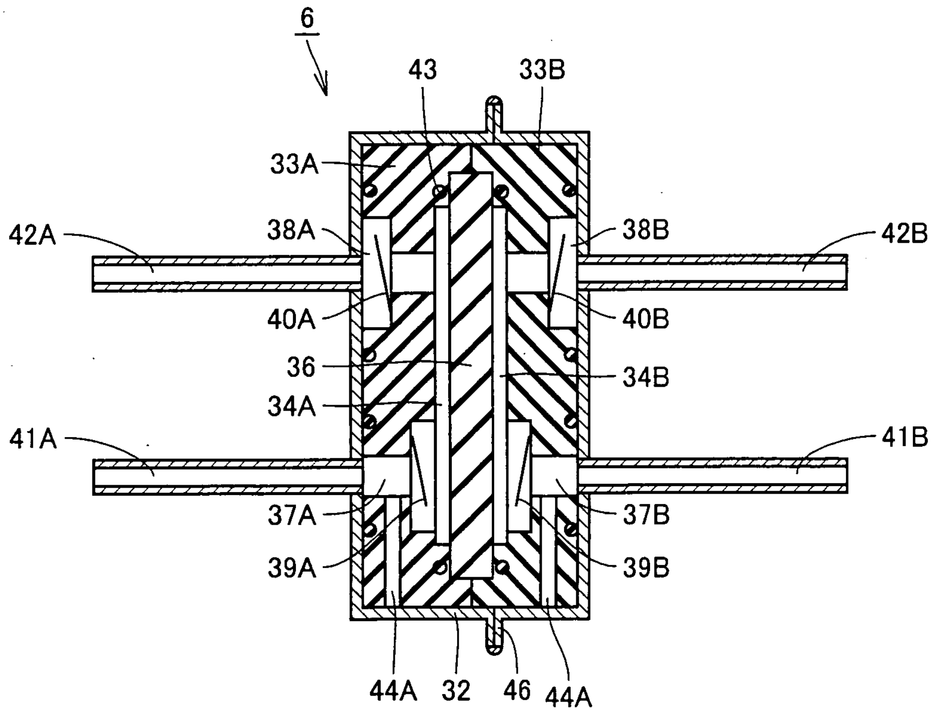
43
46
32

FIG.3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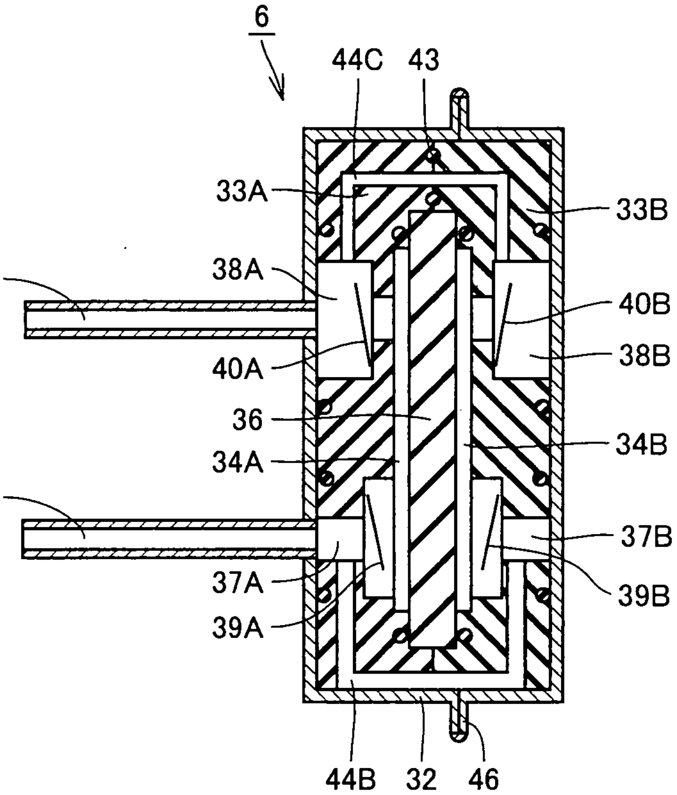
32
46
44A

FIG.4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33B
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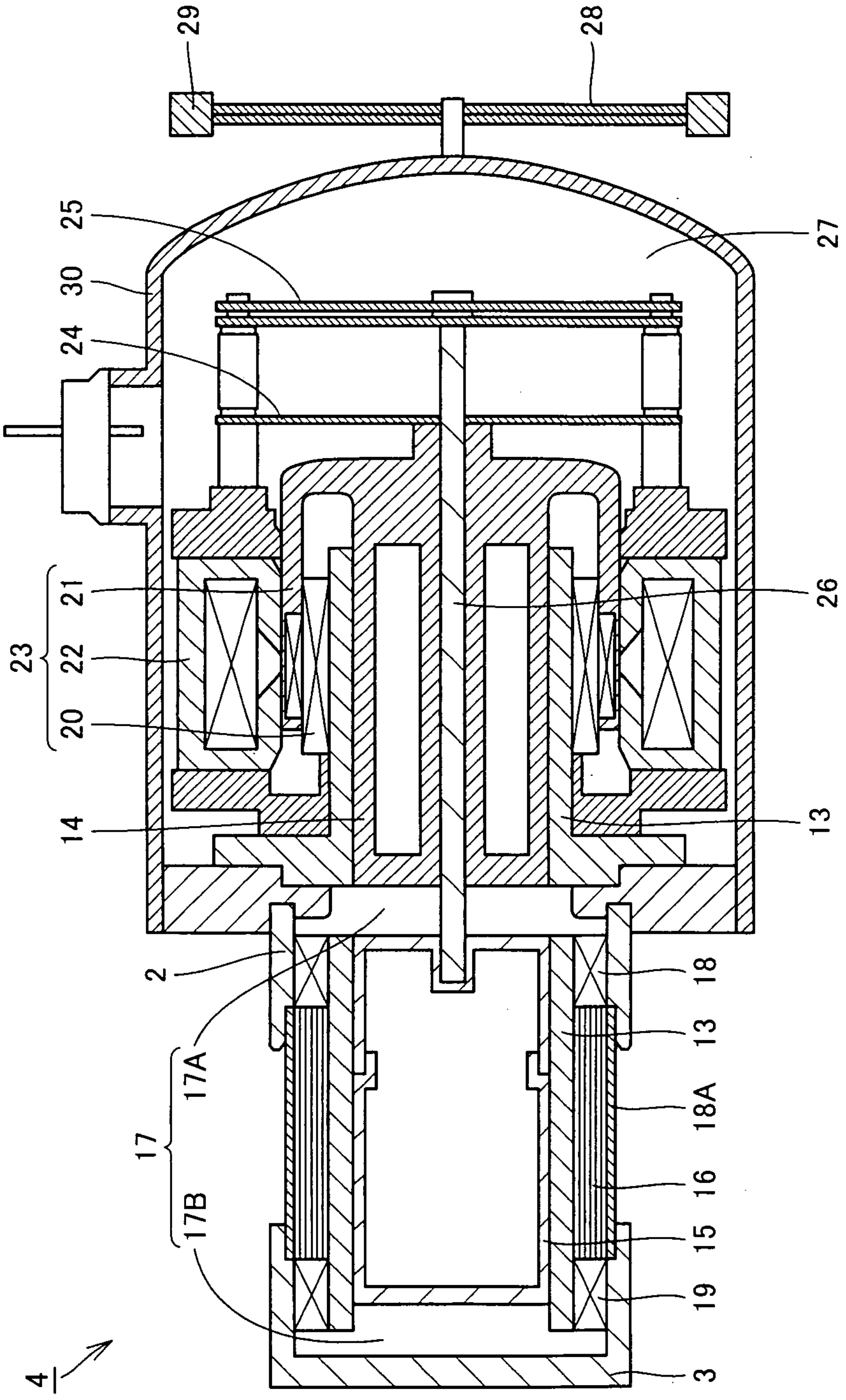
39B
39A
44B
32
46

FIG.5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13
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17A
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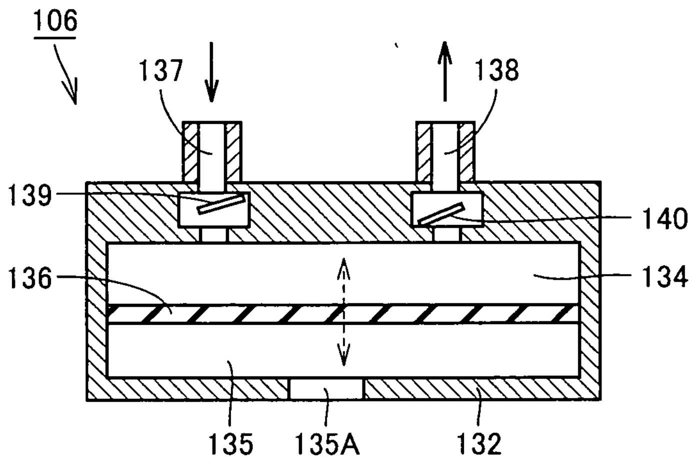
18A
16
17B
15
19
4
3

FIG.6



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2005/020694

A. CLASSIFICATION OF SUBJECT MATTER
F04B43/04(2006.01), ***F25D11/00***(2006.01), ***F25D19/00***(2006.01)

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)
F04B43/04(2006.01), ***F25D11/00***(2006.01), ***F25D19/00***(2006.01)

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2006
Kokai Jitsuyo Shinan Koho	1971-2006	Toroku Jitsuyo Shinan Koho	1994-2006

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 Y A	JP 2004-517240 A (Par Technologies, LLC.), 10 June, 2004 (10.06.04), Par. Nos. [0010], [0012], [0041]; Figs. 1 to 2 & US 2004/0000843 A1 & US 2004/0021398 A1 & GB 2387965 A & GB 2403846 A & WO 2002/22358 A1 & WO 2004/084274 A2 & CA 2431677 A1	1-2 9 3-8
Y	JP 2004-101050 A (Sharp Corp.), 02 April, 2004 (02.04.04), Par. No. [0025]; Fig. 2 (Family: none)	9
A	JP 2000-287468 A (NGK Spark Plug Co., Ltd.), 13 October, 2000 (13.10.00), Par. No. [0014]; Figs. 1 to 5 (Family: none)	1-8

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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 January, 2006 (16.01.06)	24 January, 2006 (24.01.06)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (April 2005)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2003050073 A **[0006] [0008]**
- JP 2505727 B **[0008] [0008]**