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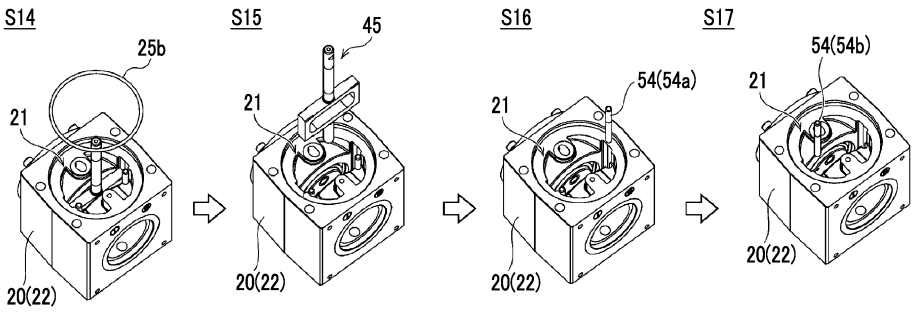
(54) METHOD FOR DISASSEMBLING CRYOGENIC FREEZER

(57) There is provided a method for disassembling a cryocooler including a housing (20) having a lower opening (21), a lower cover that closes the lower opening (21), a scotch yoke shaft (45) that is accommodated in the housing (20) and extends out of the housing (20) by penetrating the lower cover, and a scotch yoke guide (54) that is removably provided in the housing (20) and guides axial movement of the scotch yoke shaft (45), the method including removing the lower cover from the housing (20), and taking the scotch yoke guide (54) out of the housing (20) from the lower opening (21).

FIG. 8



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Description

Technical Field

[0001] The present invention relates to a method for disassembling a cryocooler.

Background Art

[0002] A cryocooler including a drive motor, a scotch yoke that converts rotation of the drive motor into linear reciprocation, a housing to which the drive motor is attached and which accommodates the scotch yoke, and a guide that is provided in the housing to guide linear reciprocation of the scotch yoke and to restrict tilting around a rotation axis of the scotch yoke is known.

Citation List

Patent Literature

[0003] [PTL 1] Japanese Unexamined Patent Publication No. 2015-55374

Summary of Invention

Technical Problem

[0004] As a cryocooler is used in the field for many years, a guide may be gradually abraded by sliding with a scotch yoke. In particular, in a case where the scotch yoke is formed of a metal material and the guide is formed of a synthetic resin material, the abrasion of the guide is likely to proceed. As the abrasion progresses, the guide is difficult to fulfill its role.

[0005] An exemplary object of one aspect of the present invention is to provide a method for disassembling a cryocooler to replace a scotch yoke guide.

Solution to Problem

[0006] According to one aspect of the present invention, there is provided a method for disassembling a cryocooler. The cryocooler includes a housing having a lower opening, a lower cover that closes the lower opening, a scotch yoke shaft that is accommodated in the housing and extends out of the housing by penetrating the lower cover, and a scotch yoke guide that is removably provided in the housing and guides axial movement of the scotch yoke shaft. The present method includes removing the lower cover from the housing, and taking the scotch yoke guide out of the housing from the lower opening.

[0007] Any combination of the components described above and a combination obtained by switching the components and expressions of the present invention between methods, devices, and systems are also effective as an aspect of the present invention.

Advantageous Effects of Invention

[0008] According to the present invention, it is possible to provide a method for disassembling a cryocooler to replace a scotch yoke guide.

Brief Description of Drawings

[0009]

Fig. 1 is a diagram schematically showing a cryocooler according to an embodiment.
Fig. 2 is a diagram schematically showing the cryocooler according to the embodiment.
Fig. 3 is a diagram schematically showing the cryocooler according to the embodiment.
Fig. 4 is a diagram schematically showing a disassembled perspective view of a cold head drive unit of the cryocooler according to the embodiment.
Fig. 5 is a diagram schematically showing a disassembled perspective view of a main part of a motion conversion mechanism of a cold head according to the embodiment.
Figs. 6A and 6B are diagrams schematically showing a scotch yoke guide according to the embodiment.
Fig. 7 is a diagram schematically showing a method for disassembling the cryocooler according to the embodiment.
Fig. 8 is a diagram schematically showing the method for disassembling the cryocooler according to the embodiment.

Description of Embodiments

[0010] Hereinafter, an embodiment for carrying out the present invention will be described in detail with reference to the drawings. In the description and the drawings, the same or equivalent components, members, and processes are denoted by the same reference numerals, and overlapping description is omitted as appropriate. The scale and the shape of each of parts shown in the drawings are set for convenience to make the description easy to understand, and are not to be interpreted as limiting unless stated otherwise. The embodiment is merely an example and does not limit the scope of the present invention. All features described in the embodiment or combinations thereof are not necessarily essential to the present invention.

[0011] Figs. 1 to 3 are diagrams schematically showing a cryocooler 10 according to the embodiment. Fig. 1 shows an appearance of a cold head of the cryocooler 10, and Fig. 2 shows an internal structure of a low-temperature section of the cold head. Fig. 3 shows an internal structure of a drive unit of the cold head. The cryocooler 10 is usually installed in a vacuum container (not shown) such that the low-temperature section is disposed inside the vacuum container and the drive unit is disposed in a surrounding environment (for example, a room temper-

ature atmospheric pressure environment) outside the vacuum container. As an example, the cryocooler 10 is a two-stage Gifford-McMahon (GM) cryocooler.

[0012] The cryocooler 10 includes a compressor 12 and an expander 14. The compressor 12 is configured to collect a working gas of the cryocooler 10 from the expander 14, to pressurize the collected working gas, and to supply the working gas to the expander 14 again. The compressor 12 and the expander 14 constitute a refrigeration cycle of the cryocooler 10, whereby the cryocooler 10 can provide desired cryogenic cooling. The expander 14 is also often referred to as a cold head. The working gas is also referred to as a refrigerant gas, and other suitable gases may be used although a helium gas is typically used. For the sake of understanding, a flow direction of the working gas is shown by an arrow in Fig. 1.

[0013] In general, both a pressure of a working gas supplied from the compressor 12 to the expander 14 and a pressure of a working gas collected from the expander 14 to the compressor 12 are considerably higher than the atmospheric pressure, and can be called a first high pressure and a second high pressure, respectively. For convenience of description, the first high pressure and the second high pressure are also simply called a high pressure and a low pressure, respectively. Typically, the high pressure is, for example, 2 to 3 MPa. The low pressure is, for example, 0.5 to 1.5 MPa and is, for example, about 0.8 MPa. For the sake of understanding, a flow direction of the working gas is shown by an arrow.

[0014] The expander 14 includes a cryocooler cylinder 16, a displacer assembly (hereinafter, also referred to as a displacer) 18, and a cryocooler housing (hereinafter, also referred to as a housing) 20. The cryocooler cylinder 16 guides linear reciprocation of the displacer 18, and forms an expansion chamber (32, 34) as an expansion space for the working gas in a space with the displacer 18. The cryocooler cylinder 16 is fixed to the cryocooler housing 20, whereby a casing of the expander 14 is configured, and an airtight space for accommodating the displacer 18 is formed inside the cryocooler cylinder 16.

[0015] In the present specification, in order to describe a positional relationship between the components of the cryocooler 10, for convenience, a side close to a top dead center of the axial reciprocation of the displacer is described as "upper", and a side close to a bottom dead center is described as "lower". The top dead center is a position of the displacer where a volume of an expansion space is maximized, and the bottom dead center is the position of the displacer where the volume of the expansion space is minimized. Since a temperature gradient is generated in which a temperature drops from the upper side to the lower side in the axial direction during the operation of the cryocooler 10, the upper side can be referred to as a high temperature side and the lower side can be referred to as a low temperature side.

[0016] The cryocooler cylinder 16 includes a first cylinder 16a and a second cylinder 16b. As an example, the first cylinder 16a and the second cylinder 16b are members having a cylindrical shape, and the second cylinder 16b has a smaller diameter than the first cylinder 16a. The first cylinder 16a and the second cylinder 16b are coaxially disposed, and a lower end of the first cylinder 16a is rigidly connected to an upper end of the second cylinder 16b.

[0017] The displacer assembly 18 includes a first displacer 18a and a second displacer 18b, which are connected to each other, and these move integrally. As an example, the first displacer 18a and the second displacer 18b are members having a cylindrical shape, and the second displacer 18b has a smaller diameter than the first displacer 18a. The first displacer 18a and the second displacer 18b are coaxially disposed.

[0018] The first displacer 18a is accommodated in the first cylinder 16a, and the second displacer 18b is accommodated in the second cylinder 16b. The first displacer 18a can reciprocate in an axial direction along the first cylinder 16a, and the second displacer 18b can reciprocate in the axial direction along the second cylinder 16b.

[0019] As shown in Fig. 2, the first displacer 18a accommodates a first regenerator 26. The first regenerator 26 is formed by filling a tubular main body of the first displacer 18a with a wire mesh such as copper or other appropriate first regenerator material. An upper lid portion and a lower lid portion of the first displacer 18a may be provided as separate members from the main body of the first displacer 18a, and the upper lid portion and the lower lid portion of the first displacer 18a may be fixed to the main body by appropriate means such as fastening or welding, whereby the first regenerator material may be accommodated in the first displacer 18a.

[0020] Similarly, the second displacer 18b accommodates a second regenerator 28. The second regenerator 28 is formed by filling a tubular main body of the second displacer 18b with a non-magnetic regenerator material such as bismuth, a magnetic regenerator material such as $HoCu_2$, or other appropriate second regenerator material. The second regenerator material may be formed in a granular shape. The upper lid portion and the lower lid portion of the second displacer 18b may be provided as separate members from the main body of the second displacer 18b, and the lower lid portion of the upper lid portion of the second displacer 18b may be fixed to the main body by appropriate means such as fastening or welding, whereby the second regenerator material may be accommodated in the second displacer 18b.

[0021] The displacer 18 forms an upper chamber 30, a first expansion chamber 32, and a second expansion chamber 34 inside the cryocooler cylinder 16. The expander 14 includes a first cooling stage 33 and a second cooling stage 35 for heat exchange with a desired object or medium to be cooled by the cryocooler 10. The upper chamber 30 is formed between the upper lid portion of the first displacer 18a and the upper portion of the first cylinder 16a. The first expansion chamber 32 is formed between the lower lid portion of the first displacer 18a

and the first cooling stage 33. The second expansion chamber 34 is formed between the lower lid portion of the second displacer 18b and the second cooling stage 35. The first cooling stage 33 is fixed to the lower portion of the first cylinder 16a to surround the first expansion chamber 32, and the second cooling stage 35 is fixed to the lower portion of the second cylinder 16b to surround the second expansion chamber 34.

[0022] The first regenerator 26 is connected to the upper chamber 30 through a working gas flow path 36a formed in the upper lid portion of the first displacer 18a, and is connected to the first expansion chamber 32 through a working gas flow path 36b formed in the lower lid portion of the first displacer 18a. The second regenerator 28 is connected to the first regenerator 26 through a working gas flow path 36c formed from the lower lid portion of the first displacer 18a to the upper lid portion of the second displacer 18b. In addition, the second regenerator 28 is connected to the second expansion chamber 34 through a working gas flow path 36d formed in the lower lid portion of the second displacer 18b.

[0023] A first seal 38a and a second seal 38b may be provided so that the working gas flow between the first expansion chamber 32, the second expansion chamber 34 and the upper chamber 30 is guided to the first regenerator 26 and the second regenerator 28 rather than to the clearance between the cryocooler cylinder 16 and the displacer 18. The first seal 38a may be mounted to the upper lid portion of the first displacer 18a to be disposed between the first displacer 18a and the first cylinder 16a. The second seal 38b may be mounted to the upper lid portion of the second displacer 18b to be disposed between the second displacer 18b and the second cylinder 16b.

[0024] As shown in Fig. 3, the cryocooler housing 20 includes a housing main body 22 having a lower opening 21 and a lower cover 24 that closes the lower opening 21. The lower opening 21 is formed on a lower surface of the housing main body 22. As shown, a housing internal volume 20a formed by the housing main body 22 and the lower cover 24 may be connected to a low pressure side of the compressor 12 and maintained at a low pressure.

[0025] The lower cover 24 partitions the housing internal volume 20a and a displacer accommodation space (upper chamber 30) in the cryocooler cylinder 16. The lower cover 24 has a disk shape as a whole, and more specifically, has an upper large-diameter portion and a lower small-diameter portion. A first sealing member 25a is provided between the lower cover 24 and the cryocooler cylinder 16 in order to maintain airtightness of an internal volume of the cryocooler cylinder 16, and a second sealing member 25b is provided between the lower cover 24 and the housing main body 22 in order to maintain airtightness of the housing internal volume 20a. As shown, the first sealing member 25a may be mounted to the small-diameter portion of the lower cover 24, and the second sealing member 25b may be mounted to the large-diameter portion of the lower cover 24.

[0026] The lower cover 24 is removably fitted into the lower opening 21, and an upper flange portion of the cryocooler cylinder 16 is fastened to the housing main body 22 with a fastening member such as a bolt. In this way, the lower cover 24 is interposed between the housing main body 22 and the upper flange portion of the cryocooler cylinder 16. The lower cover 24 is not fixed to the housing main body 22 through fastening. Note that a structure may be adopted in which the housing main body 22 and the lower cover 24 are fastened to each other with a fastening member such as a bolt.

[0027] In addition, the expander 14 includes an expander motor 40, a rotary valve 42, and a motion conversion mechanism 43. The expander motor 40 is attached to the cryocooler housing 20, more specifically, to a side surface of the housing main body 22. In order to maintain the airtightness of the housing internal volume 20a, a sealing member (not shown) may be provided on an attachment surface between the expander motor 40 and the housing main body 22.

[0028] The rotary valve 42 and the motion conversion mechanism 43 are accommodated in the cryocooler housing 20.

[0029] The expander motor 40 is provided in the expander 14 as a drive source for the displacer 18 and the rotary valve 42. The expander motor 40 may be an appropriate electric motor, and may be configured to rotate a motor rotary shaft 40a at a constant rotational speed, or may be capable of variably controlling the rotational speed of the motor rotary shaft 40a.

[0030] The rotary valve 42 is configured to alternately connect the high pressure side and the low pressure side of the compressor 12 to the cryocooler cylinder 16 (that is, the upper chamber 30, the first expansion chamber 32, and the second expansion chamber 34) and to periodically switch between the intake and the exhaust of the cryocooler cylinder 16.

[0031] The rotary valve 42 includes a valve rotor 42a and a valve stator 42b, and the valve rotor 42a is in contact with the valve stator 42b so as to rotate while sliding with respect to the valve stator 42b. The valve rotor 42a is supported to be rotatable with respect to the housing main body 22, and the valve stator 42b is supported to be unrotatable with respect to the housing main body 22. An elastic body such as a spring for pressing the valve stator 42b toward the valve rotor 42a in a direction of a rotation axis of the valve rotor 42a may be interposed between the valve stator 42b and the housing main body 22.

[0032] The cryocooler housing 20 is formed with a housing internal flow path 20b for connecting the rotary valve 42 to the upper chamber 30, and the valve rotor 42a and the valve stator 42b of the rotary valve 42 are formed with a valve internal flow path to alternately connect the housing internal flow path 20b to the high pressure side of the compressor 12 and the housing internal volume 20a. Various known forms can be adopted as the

valve internal flow path, and details thereof will not be described herein.

[0033] The motion conversion mechanism 43 is configured to connect the expander motor 40 to the rotary valve 42 and the displacer 18 so as to transmit the rotation of the motor rotary shaft 40a to the rotary valve 42 and convert the rotation into the linear reciprocation of the displacer 18. An example of the motion conversion mechanism 43 will be described below. One rotation of the motor rotary shaft 40a causes one reciprocation of the displacer 18 via the motion conversion mechanism 43, thereby periodically changing the volume of the expansion space for the working gas. Simultaneously, one rotation of the motor rotary shaft 40a causes one rotation of the rotary valve 42 via the motion conversion mechanism 43, thereby periodically changing the pressure of the expansion space for the working gas.

[0034] In this way, the synchronized volume fluctuation and pressure fluctuation are generated in the expansion space to configure the refrigeration cycle of the cryocooler 10, whereby the cryocooler 10 can provide desired cryogenic cooling. The first cooling stage 33 can be cooled to a first cooling temperature, and the second cooling stage 35 can be cooled to a second cooling temperature lower than the first cooling temperature. The first cooling temperature may be, for example, in a range of about 10 K to about 100 K or in a range of about 20 K to about 40 K. The second cooling temperature may be, for example, about 20 K or lower, or about 10 K or lower, or in a range of about 1 K to about 4 K.

[0035] Fig. 4 is a diagram schematically showing a disassembled perspective view of a cold head drive unit of the cryocooler 10 according to the embodiment. Fig. 5 is a diagram schematically showing a disassembled perspective view of a main part of the motion conversion mechanism 43 of the cold head according to the embodiment. An exemplary form of the motion conversion mechanism 43 will be described with reference to Figs. 3 to 5.

[0036] The motion conversion mechanism 43 is a scotch yoke in this embodiment, and includes a crank 44 having a crank pin 44a, a scotch yoke shaft 45, and a crank pin bearing 46. The scotch yoke shaft 45 includes a scotch yoke plate 45a, an upper rod 45b, and a lower rod 45c. The scotch yoke shaft 45 may be formed of a metal material such as stainless steel.

[0037] The crank 44 is fixed to the motor rotary shaft 40a. The crank pin 44a extends parallel to the motor rotary shaft 40a at a position eccentric from the motor rotary shaft 40a. The crank pin 44a extends from the crank 44 toward a side opposite to the motor rotary shaft 40a with respect to the crank 44.

[0038] The scotch yoke plate 45a is a rectangular plate-shaped member having a horizontally elongated window 47.

[0039] The horizontally elongated window 47 extends in the axial direction and in a direction perpendicular to the motor rotary shaft 40a.

[0040] The crank pin bearing 46 is reliably disposed in the horizontally elongated window 47. The crank pin bearing 46 may be, for example, a roller bearing. An engagement hole 46a that engages with the crank pin 44a is formed at the center of the crank pin bearing 46, and the crank pin 44a penetrates the engagement hole 46a.

[0041] On a side opposite to the crank 44 with respect to the scotch yoke plate 45a, the valve rotor 42a of the rotary valve 42 is disposed such that a center axis thereof coincides with the motor rotary shaft 40a, and a tip of the crank pin 44a penetrating the engagement hole 46a is fixed to the valve rotor 42a.

[0042] The upper rod 45b extends upward from the center of an upper frame of the scotch yoke plate 45a, the lower rod 45c extends downward from the center of a lower frame of the scotch yoke plate 45a, and the rods are coaxially disposed. The scotch yoke plate 45a and the upper rod 45b are accommodated in the cryocooler housing 20, and the lower rod 45c extends out of the cryocooler housing 20 by penetrating the lower cover 24. A tip of the lower rod 45c is connected to the displacer 18 inside the cryocooler cylinder 16.

[0043] A first sliding bearing 48a is provided between the upper rod 45b and the housing main body 22, and a second sliding bearing 48b is provided between the lower rod 45c and the lower cover 24. The housing main body 22 has a recessed portion for receiving the upper rod 45b in an upper portion thereof, and the first sliding bearing 48a is disposed in the recessed portion to slidably support the upper rod 45b in the axial direction. The lower cover 24 has a through-hole in a center portion thereof, and the second sliding bearing 48b is disposed in the through-hole to slidably support the lower rod 45c in the axial direction. The second sliding bearing 48b is provided with a seal portion such as a slipper seal or a clearance seal, and is configured to be airtight. Therefore, the housing internal volume 20a is isolated from the upper chamber 30. There is no direct gas flow between the housing internal volume 20a and the upper chamber 30.

[0044] A collar portion 50 is fixed to the tip of the lower rod 45c connected to the displacer 18 by a fixing pin 49. The collar portion 50 is a short tubular member into which a tip of the displacer assembly 18 is inserted. A through-hole is formed in the tip of the lower rod 45c and the collar portion 50 in a direction perpendicular to the axial direction, and the collar portion 50 is fixed to the lower rod 45c by fitting the fixing pin 49 into the through-hole.

[0045] The first displacer 18a has a lid portion 52a and a main body 52b. The lid portion 52a is an upper lid of the first displacer 18a, and has a disk shape. The lid portion 52a is formed of a metal material such as an alumite-treated aluminum alloy, or other material. The main body 52b has a cylindrical shape, and includes a regenerator therein. The main body 52b is formed of a synthetic resin material or other material, and may be formed of, for example, a phenolic resin such as Bakelite. The above-described working gas flow path 36a is formed by penetrating the lid portion 52a and an upper end portion

of the main body 52b in the axial direction. The above-described first seal 38a may be interposed between outermost peripheral portions of the lid portion 52a and the main body 52b. The lid portion 52a and the main body 52b are fixed to each other by using, for example, a fastening member such as a bolt, or by using, for example, other methods such as adhesion.

[0046] A through-hole for receiving the tip of the lower rod 45c and the collar portion 50 is formed in a center portion of the lid portion 52a. The collar portion 50 has a flange portion that expands outward in a radial direction at a lower end portion thereof, and the flange portion is interposed between the lid portion 52a and the main body 52b of the first displacer 18a, so that the lower rod 45c and the collar portion 50 are connected to the first displacer 18a. In this way, the displacer 18 is attached to the scotch yoke shaft 45.

[0047] Therefore, when the expander motor 40 is driven and the motor rotary shaft 40a is rotated, the crank pin bearing 46 engaged with the crank pin 44a rotates in a circular motion. In this case, the crank pin bearing 46 reciprocates in the horizontally elongated window 47 of the scotch yoke plate 45a, and the scotch yoke shaft 45 and the displacer 18 reciprocate in the axial direction. In this way, the expander motor 40 drives the axial movement of the scotch yoke shaft 45.

[0048] Figs. 6A and 6B are diagrams schematically showing the scotch yoke guide 54 according to the embodiment. Fig. 6A schematically shows a cross section of the housing main body 22 according to a cross section taken along line A-A in Fig. 3, and Fig. 3B schematically shows a part of a cross section taken along line B-B in Fig. 6A.

[0049] In this embodiment, as shown, the scotch yoke guide 54 is provided. The scotch yoke guide 54 is configured to guide the axial movement of the scotch yoke shaft 45 and to restrict the rotation around the axis of the scotch yoke shaft 45.

[0050] The scotch yoke guide 54 includes a plurality of (two in this example) pins 54a and 54b, and each pin 54a extends in the axial direction of the scotch yoke shaft 45. The pins 54a and 54b have a columnar shape, and may be formed of, for example, a synthetic resin material having excellent abrasion resistance, such as a fluorine-based resin, or other material. The housing main body 22 has a plurality of (two in this example) pin insertion holes 56 into which the plurality of pins 54a and 54b are removably inserted, respectively. Accordingly, the scotch yoke guide 54 is removably provided in the cryocooler housing 20. As will be described below, the scotch yoke shaft 45 and the scotch yoke guide 54 can be taken out from the housing main body 22 through the lower opening 21 of the housing main body 22.

[0051] The scotch yoke guide 54 is disposed at a position different from the position of the lower rod 45c with respect to the direction of the motor rotary shaft 40a that drives the axial movement of the scotch yoke shaft 45, and is adjacent to the scotch yoke plate 45a. In this embodiment, the scotch yoke guide 54 is disposed to be offset to the motor rotary shaft 40a side with respect to the scotch yoke plate 45a and the lower rod 45c, but may be disposed on the rotary valve 42 side.

[0052] A cylindrical side surface of each pin 54a of the scotch yoke guide 54 is in contact with a side surface 58 of the scotch yoke plate 45a in which the horizontally elongated window 47 is formed. One pin 54a is in contact with the side surface 58 at a right frame portion of the scotch yoke plate 45a, and the other pin 54a is in contact with the side surface 58 at a left frame portion of the scotch yoke plate 45a.

[0053] Therefore, the scotch yoke guide 54 can guide the axial movement of the scotch yoke plate 45a on the side surface of each pin 54a. In addition, the scotch yoke guide 54 can restrict the rotation around the axis of the scotch yoke shaft 45 by the pin 54a.

[0054] Figs. 7 and 8 are diagrams schematically showing a method for disassembling the cryocooler 10 according to the embodiment. First, as shown in Fig. 7, the expander motor 40 is removed from the cryocooler housing 20 (S10). A fastening member that fixes the expander motor 40 to the cryocooler housing 20 is removed, and the expander motor 40 is removed from the side surface of the housing main body 22. The crank 44 may be removed together with the expander motor 40. In addition, a high-pressure pipe and a low-pressure pipe that are attached to the cryocooler housing 20 are also removed.

[0055] Subsequently, the fixation between the cryocooler housing 20 and the cryocooler cylinder 16 is released (S11). As described above, the housing main body 22 is attached to the cryocooler cylinder 16 with the fastening member, and the cryocooler housing 20 is removed from the cryocooler cylinder 16 by removing the fastening member. Thereafter, the cryocooler housing 20 is pulled up from the cryocooler cylinder 16. Whereby, the displacer 18 can be pulled out from the cryocooler cylinder 16 together with the cryocooler housing 20.

[0056] Next, the displacer 18 is removed from the scotch yoke shaft 45 (S12). The fixation between the lid portion 52a and the main body 52b of the first displacer 18a is released, and the main body 52b is removed from the lid portion 52a. Further, the fixing pin 49 and the collar portion 50 are removed from the lower rod 45c of the scotch yoke shaft 45, and the lid portion 52a is also removed (S13). In this way, before the lower cover 24 is removed from the cryocooler housing 20, the displacer 18 is removed from the scotch yoke shaft 45. Then, the lower cover 24 is removed from the cryocooler housing 20 (S13).

[0057] As shown in Fig. 8, the second sealing member 25b is removed from the housing main body 22 (S14). For ease of understanding, in Fig. 8, the upper and lower sides are reversed (that is, the lower opening 21 faces upward). As described above, the second sealing member 25b is interposed between the lower cover 24 and the housing main body 22, and is disposed inside the lower opening 21. The second sealing member 25b is

taken out from the lower opening 21 that is opened again by the lower cover 24 being removed from the housing main body 22.

[0058] Subsequently, the scotch yoke shaft 45 is pulled out of the cryocooler housing 20 from the lower opening 21 (S15). By taking out the scotch yoke shaft 45 before taking out the scotch yoke guide 54, a work space for removing the scotch yoke guide 54 can be made wider in the cryocooler housing 20.

[0059] Then, the scotch yoke guide 54 is taken out of the cryocooler housing 20 from the lower opening 21. First, one pin 54a is taken out of the cryocooler housing 20 through the lower opening 21 (S16), and next, and then the other pin 54b is also taken out of the cryocooler housing 20 through the lower opening 21 (S17).

[0060] In this way, after the pins 54a and 54b are removed, new pins 54a and 54b are attached. Thereafter, the expander 14 is reassembled in the reverse order of the above. In this way, the abraded scotch yoke guide 54 can be replaced with a new one. Accordingly, the rotation around the axis of the scotch yoke shaft 45 can be reliably prevented.

[0061] Although the present invention has been described using specific words and phrases based on the embodiment, the embodiment merely shows one aspect of the principle and application of the present invention, and various modifications and improvements can be made within the scope of the present invention described in claims.

Industrial Applicability

[0062] The present invention can be used in the field of a method for disassembling a cryocooler.

Reference Signs List

[0063]

10 Cryocooler
21 Lower opening
24 Lower cover
40a Motor rotary shaft
45 Scotch yoke shaft
45a Scotch yoke plate
54 Scotch yoke guide
54a Pin
56 Pin insertion hole

Claims

1. A method for disassembling a cryocooler including a housing having a lower opening, a lower cover that closes the lower opening, a scotch yoke shaft that is accommodated in the housing and extends out of the housing by penetrating the lower cover, and a scotch yoke guide that is removably provided in the housing and guides axial movement of the scotch yoke shaft, the method comprising:

removing the lower cover from the housing; and
taking the scotch yoke guide out of the housing from the lower opening.

2. The method according to claim 1,
wherein the scotch yoke guide is configured to restrict rotation around an axis of the scotch yoke shaft.

3. The method according to claim 1 or 2,

wherein the scotch yoke shaft includes a scotch yoke plate that is accommodated in the housing, and a rod extending out of the housing by penetrating the lower cover from the scotch yoke plate, and
the scotch yoke guide is disposed at a position different from a position of the rod with respect to a direction of a motor rotary shaft that drives the axial movement of the scotch yoke shaft, and is adjacent to the scotch yoke plate.

4. The method according to any one of claims 1 to 3, wherein the scotch yoke guide includes a plurality of pins extending in an axial direction of the scotch yoke shaft, and the housing has a plurality of pin insertion holes into which the plurality of pins are removably inserted, respectively.

5. The method according to any one of claims 1 to 4, further comprising:
pulling the scotch yoke shaft out of the housing from the lower opening before taking out the scotch yoke guide.

6. The method according to any one of claims 1 to 5, wherein the cryocooler includes a displacer attached to the scotch yoke shaft, and
the method further comprises removing the displacer from the scotch yoke shaft before removing the lower cover from the housing.

7. The method according to claim 6,

wherein the cryocooler includes a cylinder fixed to the housing and accommodating the displacer, and
the method further comprises

releasing the fixation between the housing and the cylinder, and
pulling out the displacer from the cylinder together with the housing.

8. The method according to any one of claims 1 to 7, wherein the cryocooler includes a motor that is at-

tached to the housing and drives the axial movement of the scotch yoke shaft, and
the method further comprises removing the motor from the housing.

FIG. 1

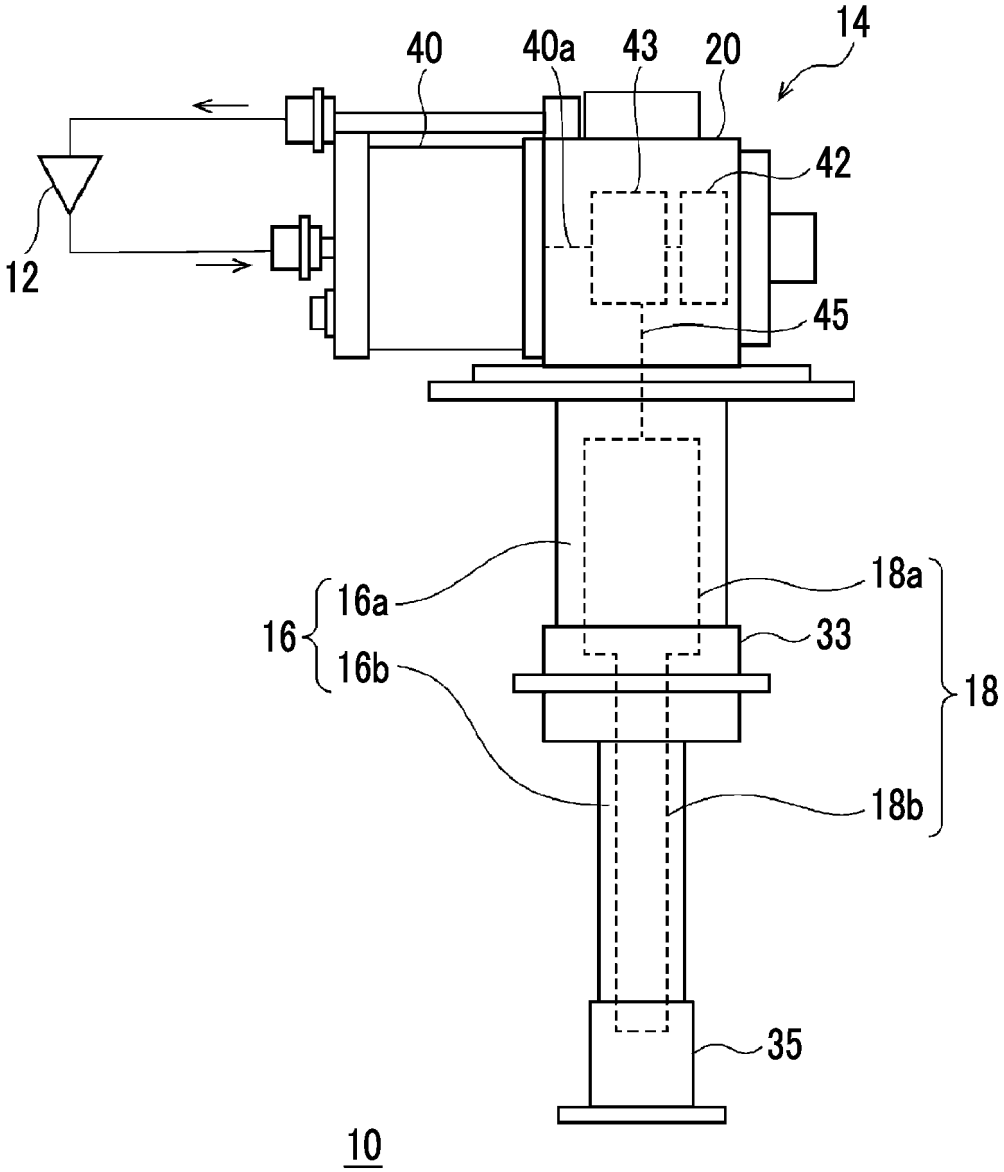
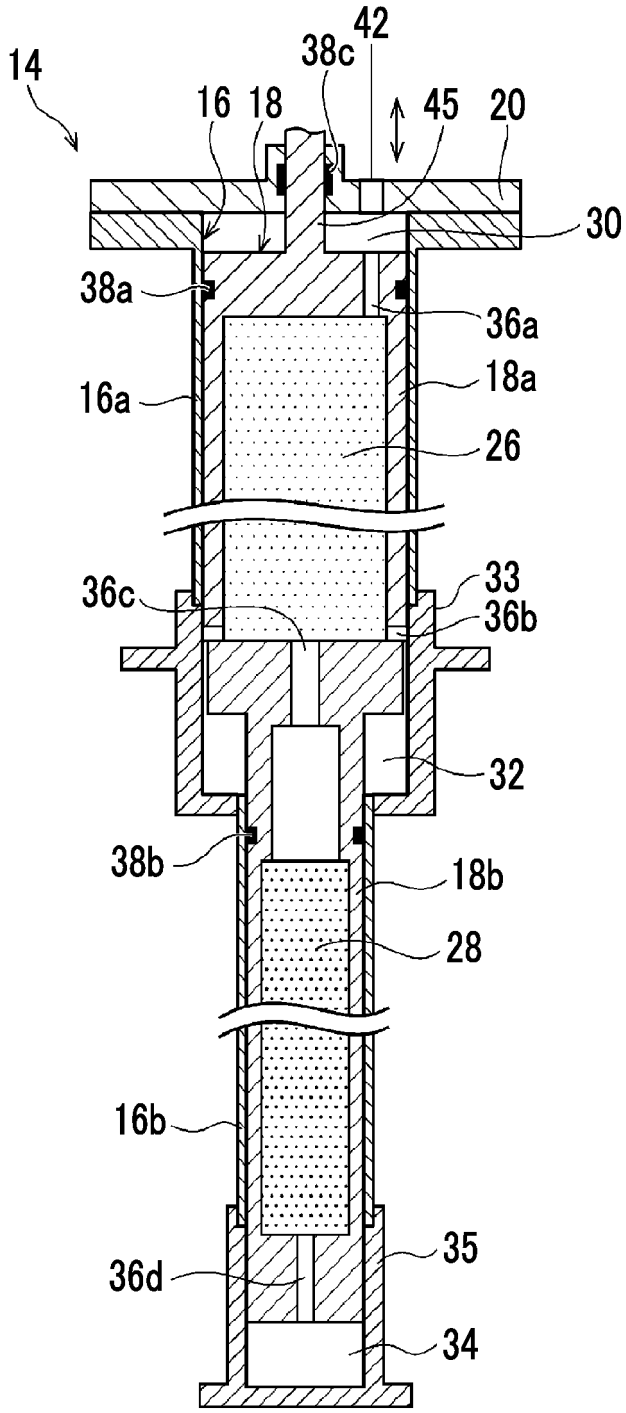


FIG. 2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16a
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36c
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36b
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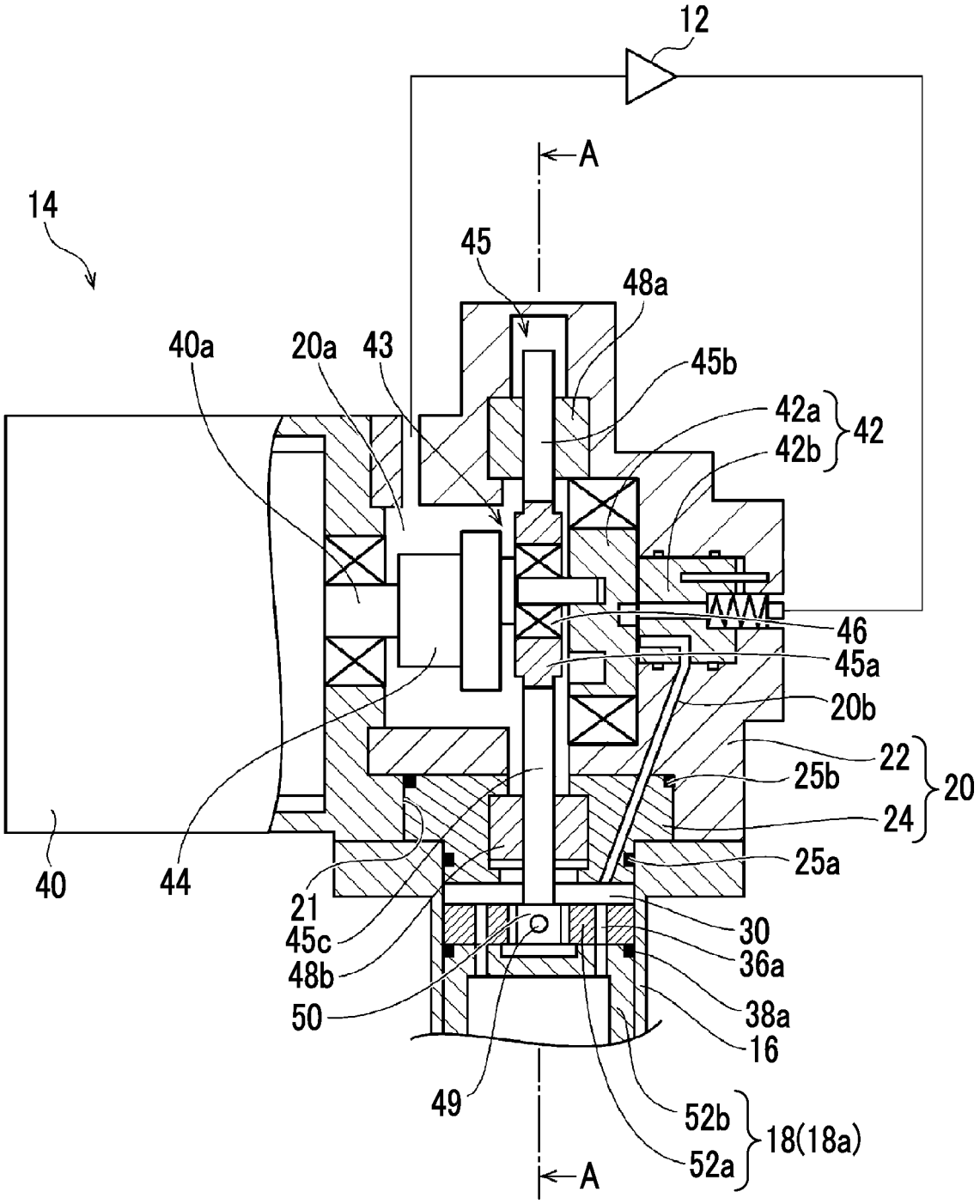
38b
18b
28
16b
35
36d
34

FIG. 3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20b
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24
25a
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45c
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36a
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49
52b
52a
18(18a)
A

FIG. 4

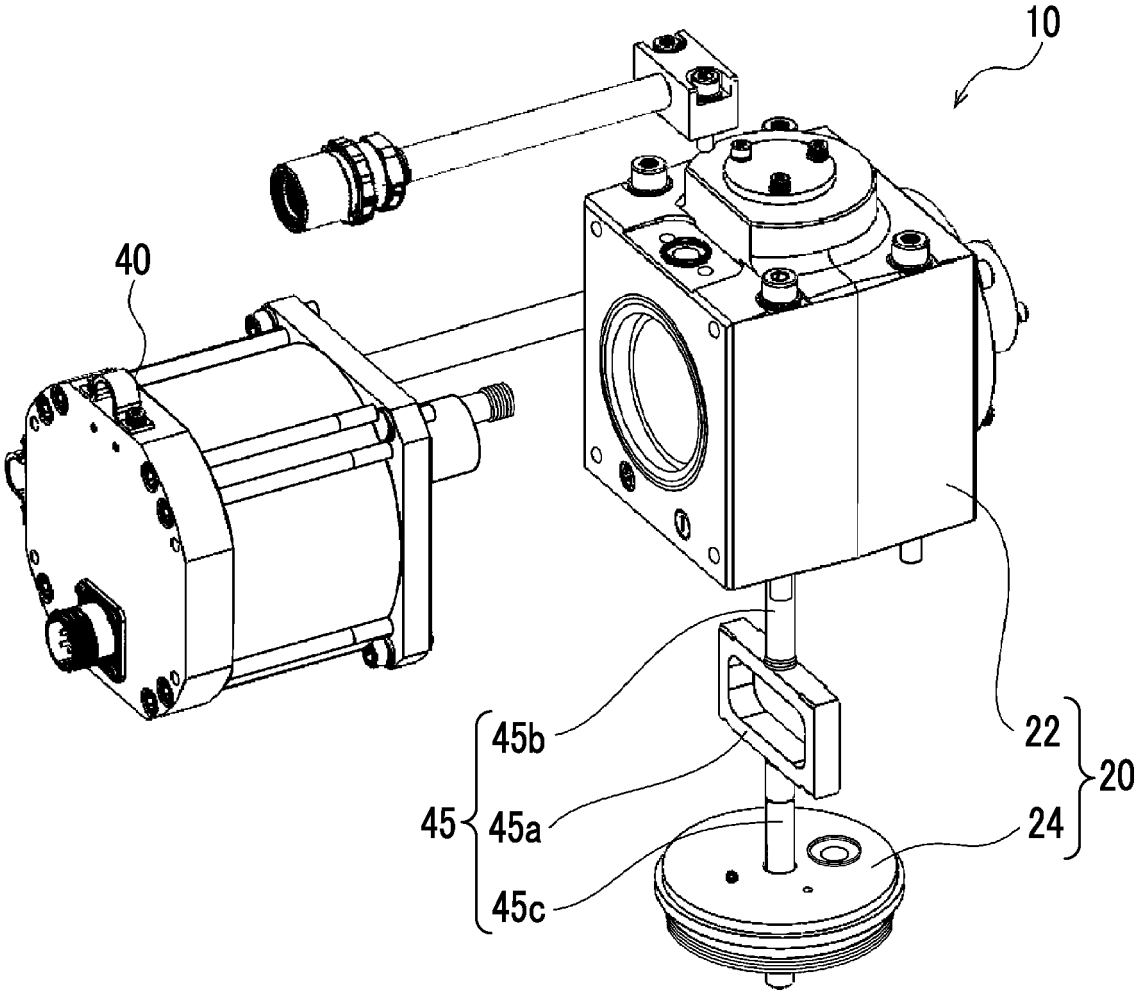


FIG. 5

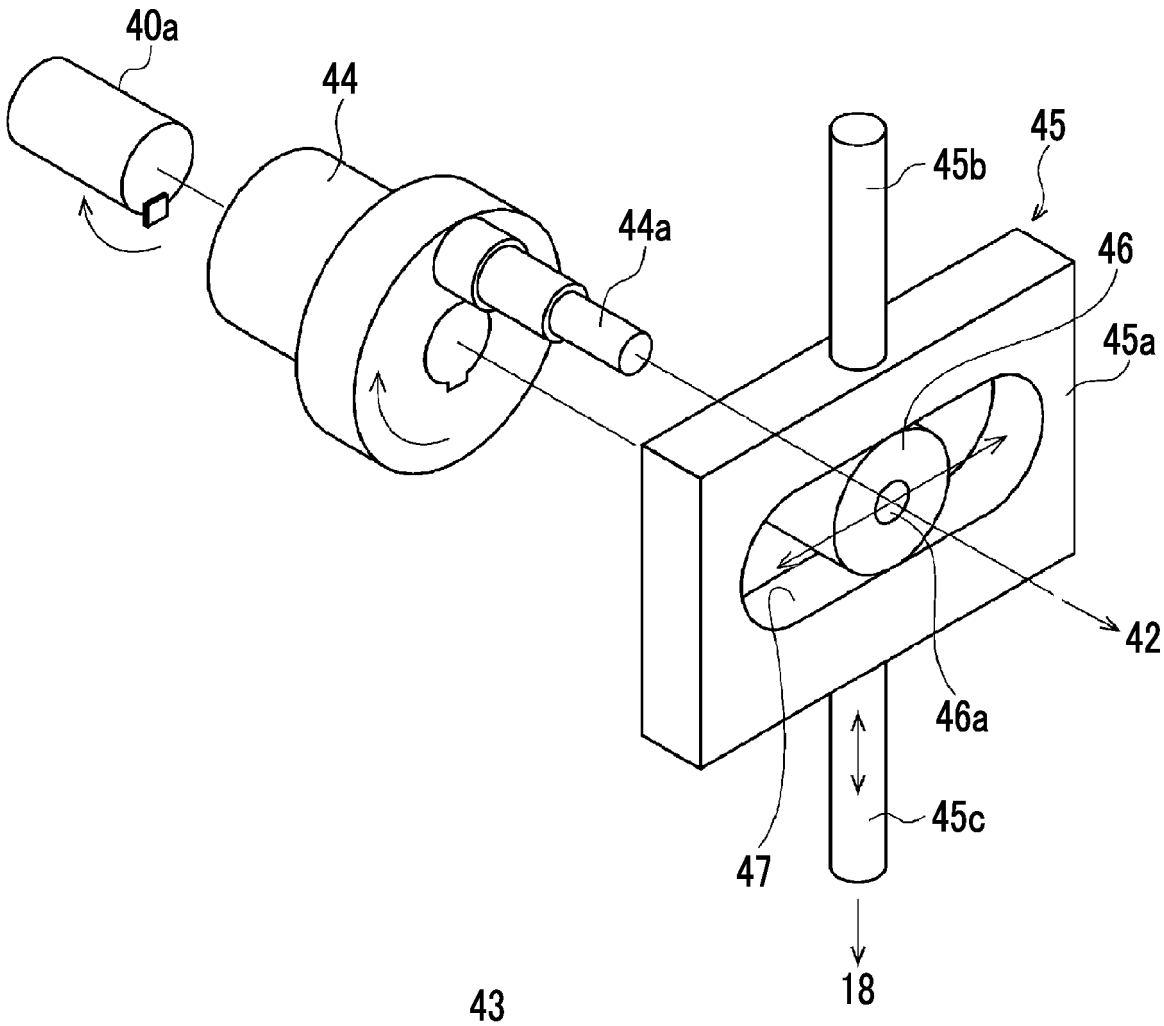
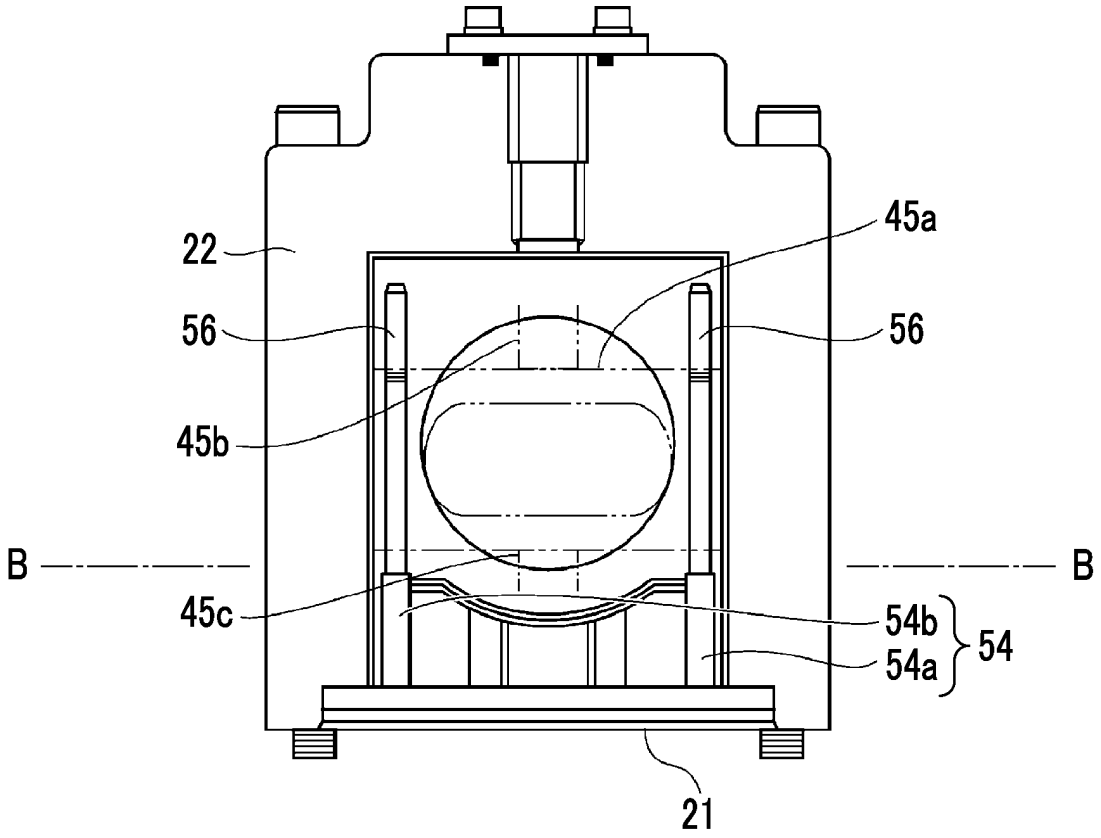


FIG. 6A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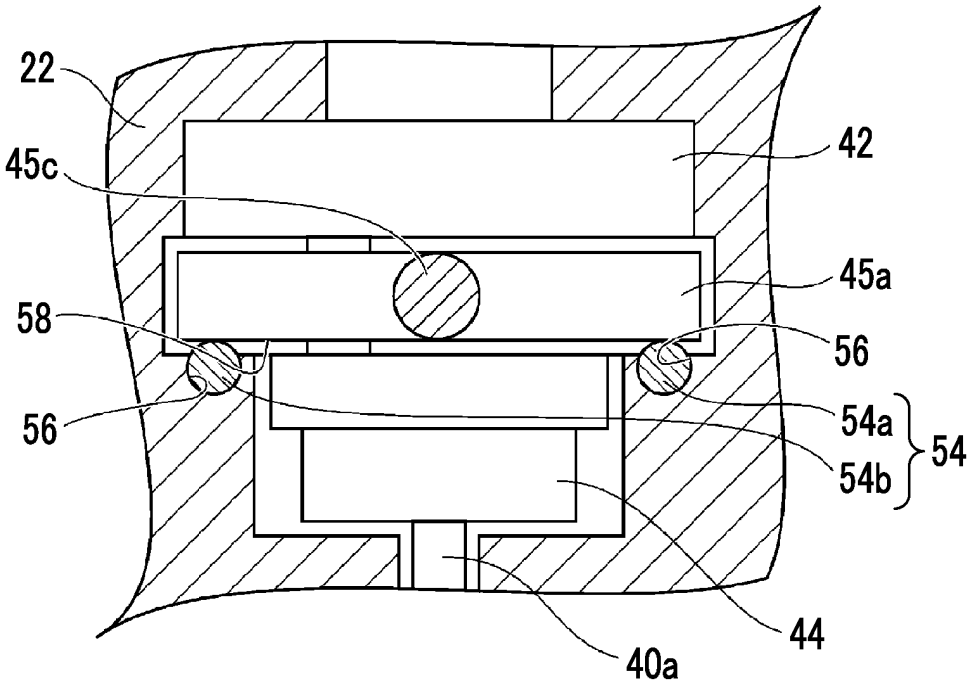
56
45b
B
B
45c
54b
54
54a
21

FIG. 6B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40a

FIG. 7

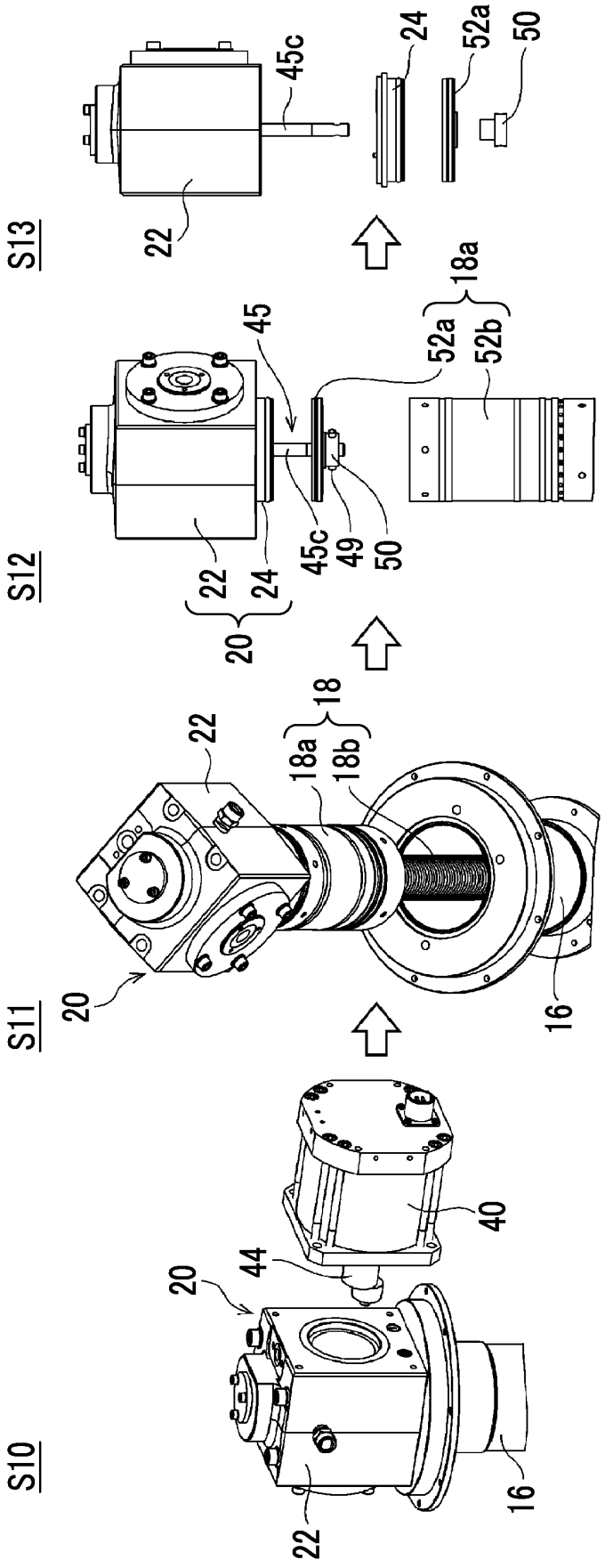
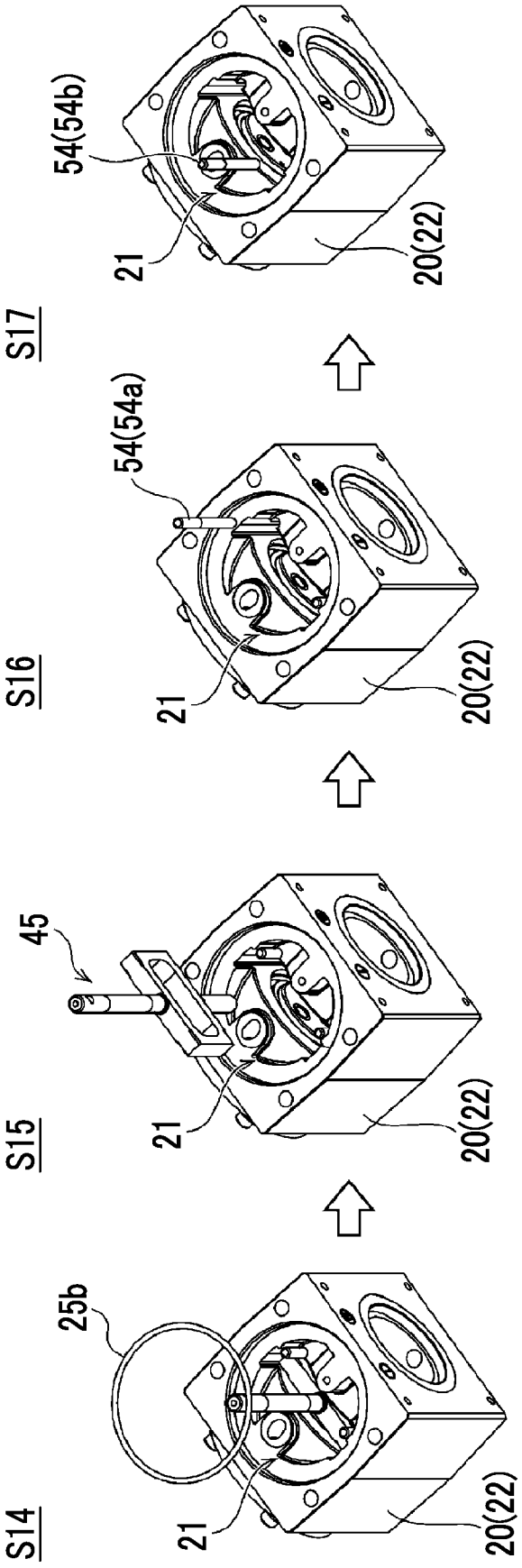


FIG. 8


S14
25b
21
20(22)
S15
45
21
20(22)
S16
54(54a)
21
20(22)
S17
54(54b)
21
20(22)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2022/039683

A. CLASSIFICATION OF SUBJECT MATTER

F25B 9/14(2006.01)i
FI: F25B9/14 530Z

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)

F25B9/00-9/14

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 1971-2022
Registered utility model specifications of Japan 1996-2022
Published registered utility model applications of Japan 1994-2022

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.
Y	JP 4-32302 B2 (OERLIKON-BUHRLE U.S.A. INC.) 28 May 1992 (1992-05-28) column 4, line 43 to column 5, line 11, column 6, line 25 to column 10, line 6, fig. 1, 5	1-2, 4, 6-8
A		3, 5
Y	JP 2015-55374 A (SUMITOMO HEAVY INDUSTRIES, LTD.) 23 March 2015 (2015-03-23) paragraphs [0053]-[0079], fig. 4-6	1-2, 4, 6-8
A		3, 5
Y	JP 2017-142036 A (AISIN SEIKI) 17 August 2017 (2017-08-17) paragraphs [0022]-[0074], fig. 1-5	4
A	JP 2019-95090 A (SUMITOMO HEAVY INDUSTRIES, LTD.) 20 June 2019 (2019-06-20) paragraphs [0091]-[0095], fig. 8	1-8
A	WO 2011/129317 A1 (SUMITOMO HEAVY INDUSTRIES, LTD.) 20 October 2011 (2011-10-20) fig. 6	3-5

☐ 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	Date of mailing of the international search report
22 November 2022	**06 December 2022**
Name and mailing address of the ISA/JP **Japan Patent Office (ISA/JP)** **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2022/039683

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JP 2015-55374 A	23 March 2015	US 2015/0068221 A1 paragraphs [0059]-[0085], fig. 4-6 CN 104422192 A	
JP 2017-142036 A	17 August 2017	(Family: none)	
JP 2019-95090 A	20 June 2019	WO 2019/098128 A1 paragraphs [0091]-[0095], fig. 8	
WO 2011/129317 A1	20 October 2011	US 2013/0031916 A1 fig. 8 CN 102844633 A KR 10-2013-0009840 A	

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2015055374 A **[0003]**