



EUROPEAN PATENT APPLICATION
published in accordance with Art. 153(4) EPC

(43) Date of publication:
16.06.2021 Bulletin 2021/24

(51) Int Cl.:
F15B 15/14 ^(2006.01)

(21) Application number: **19859799.9**

(86) International application number:
PCT/JP2019/032236

(22) Date of filing: **19.08.2019**

(87) International publication number:
WO 2020/054322 (19.03.2020 Gazette 2020/12)

(84) Designated Contracting States:
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO
PL PT RO RS SE SI SK SM TR**
Designated Extension States:
**BA ME
KH MA MD TN**

- **TAKAKUWA, Youji**
Tsukubamirai-shi, Ibaraki 300-2493 (JP)
- **MONDEN, Kengo**
Tsukubamirai-shi, Ibaraki 300-2493 (JP)
- **NAGURA, Seiichi**
Tsukubamirai-shi, Ibaraki 300-2493 (JP)
- **SOMEYA, Kazutaka**
Tsukubamirai-shi, Ibaraki 300-2493 (JP)
- **KAZAMA, Akihiro**
Tsukubamirai-shi, Ibaraki 300-2493 (JP)

(30) Priority: **13.09.2018 JP 2018171907**

(71) Applicant: **SMC Corporation**
Tokyo 101-0021 (JP)

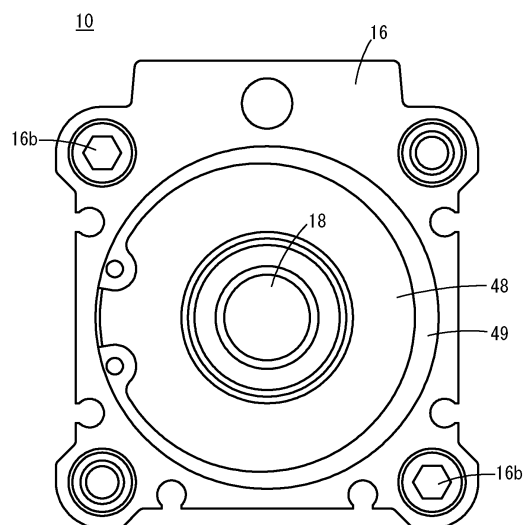
(74) Representative: **Keil & Schaaflhausen**
Patentanwälte PartGmbB
Friedrichstraße 2-6
60323 Frankfurt am Main (DE)

(72) Inventors:
• **TAKADA, Yoshiyuki**
Tokyo 101-0021 (JP)

(54) **HYDRAULIC CYLINDER**

(57) In a hydraulic cylinder (10) in which an operation piston (20) and a boosting piston (22) are disposed in tandem with a partition wall (26) provided therebetween, a high-pressure fluid is sealed in two axially adjacent pressure chambers. In an operation step, the high-pressure fluid is prepared so as to be able to flow between the pressure chambers in which the high-pressure fluid is sealed. Next, when the operation piston (20) has moved to an end side, the flow of the fluid between the two pressure chambers is blocked by a boost switching mechanism (33) such that the high-pressure fluid in one of the pressure chambers is discharged.

FIG. 2



Description

Technical Field

[0001] The present invention relates to a fluid pressure cylinder (hydraulic cylinder).

Background Art

[0002] There are cases in which, in working machines such as clamping devices and locking devices, a large driving force is required in the latter half of a working process while such a large driving force is not required in the first half of the working process. For dealing with such cases, there has been proposed a fluid pressure cylinder with a booster mechanism, which increases thrust force in the latter half of a forward stroke of a piston rod by using the booster mechanism, as a fluid pressure cylinder used in such working machines.

[0003] For example, a fluid pressure cylinder described in Japanese Laid-Open Patent Publication No. 2018-017269 includes a booster piston serving as a booster mechanism, and the booster piston is locked on to a piston rod in the middle of a stroke to thereby increase thrust force.

Summary of Invention

[0004] To reduce energy consumption, a further reduction in the consumption of working fluid is required for the fluid pressure cylinder with the booster mechanism.

[0005] The present invention has been devised taking into consideration the aforementioned problem, and has the object of providing a fluid pressure cylinder with a booster function, which is capable of reducing the consumption of working fluid without complicated structures.

[0006] According to an aspect of the present invention, a fluid pressure cylinder includes a cylinder body including a slide hole extending in an axial direction, a partition wall separating the slide hole into a working cylinder chamber on a head side and a booster cylinder chamber on an end side, a working piston disposed in the working cylinder chamber and partitioning the working cylinder chamber into a first pressure chamber on the head side and a second pressure chamber on the end side, a booster piston disposed in the booster cylinder chamber and partitioning the booster cylinder chamber into a third pressure chamber on the head side and a fourth pressure chamber on the end side, and a piston rod connected to the working piston and the booster piston, the piston rod penetrating through the partition wall and protruding out toward the end side. High-pressure fluid is enclosed in two adjacent pressure chambers among the first pressure chamber, the second pressure chamber, the third pressure chamber, and the fourth pressure chamber. The fluid pressure cylinder further includes a boost switching mechanism configured to allow communication of the high-pressure fluid between the two pressure chambers

while the working piston is located on the head side of a predetermined position, and configured to, when the working piston moves to the end side of the predetermined position, block the communication of the high-pressure fluid between the two pressure chambers and discharge the high-pressure fluid in one of the two pressure chambers.

[0007] In accordance with the fluid pressure cylinder according to the present invention, the high-pressure fluid is enclosed in the two adjacent pressure chambers among the first to fourth pressure chambers. When the working piston is located on the head side of the predetermined position, the fluid pressure cylinder allows the communication of the high-pressure fluid between the two adjacent pressure chambers. In this case, no pressure difference occurs between the two adjacent pressure chambers, resulting in no increase in thrust force. When the working piston moves to the vicinity of an end-of-stroke position, the fluid pressure cylinder blocks the communication between the two adjacent pressure chambers and discharges the high-pressure fluid in one of the pressure chambers. This produces thrust force corresponding to the pressure difference between the two adjacent pressure chambers, increasing the thrust force on the piston rod near the stroke end. Since the high-pressure fluid is discharged when the piston rod is located on the end side of the stroke, the amount of fluid used to increase the thrust force can be reduced.

Brief Description of Drawings

[0008]

FIG. 1 is a cross-sectional view of a fluid pressure cylinder according to a first embodiment, including a partially enlarged cross-sectional view of a third check valve 56;

FIG. 2 is a side view of the fluid pressure cylinder in FIG. 1 viewed from an end side;

FIG. 3A is an enlarged cross-sectional view of a part adjacent to a partition wall of the fluid pressure cylinder in FIG. 1, and FIG. 3B is an enlarged cross-sectional view of a state in which a working piston is disposed adjacent to the partition wall in FIG. 3A;

FIG. 4A is a fluid circuit diagram illustrating a connection state of the fluid pressure cylinder according to the embodiment during a working process, and FIG. 4B is a fluid circuit diagram illustrating a connection state of the fluid pressure cylinder in FIG. 4A during a return process;

FIG. 5 is a cross-sectional view of the fluid pressure cylinder in FIG. 1 during the working process;

FIG. 6 is a cross-sectional view of the fluid pressure cylinder in FIG. 1 during a boosting process;

FIG. 7 is a cross-sectional view (View 1) of the fluid pressure cylinder in FIG. 1 during the return process;

FIG. 8 is a cross-sectional view (View 2) of the fluid pressure cylinder in FIG. 1 during the return process;

FIG. 9A is a plan view of a fluid pressure cylinder according to a second embodiment, and FIG. 9B is a side view of the fluid pressure cylinder in FIG. 9A; FIG. 10 is a cross-sectional view of the fluid pressure cylinder in FIG. 9A at a start-of-stroke position; FIG. 11A is a fluid circuit diagram of a drive device of the fluid pressure cylinder in FIG. 9A illustrating a connection state when a switching valve is in a first position, and FIG. 11B is a fluid circuit diagram illustrating a connection state when the switching valve of the drive device in FIG. 11A is in a second position; and FIG. 12 is a cross-sectional view of the fluid pressure cylinder in FIG. 9A during the boosting process.

Description of Embodiments

[0009] Preferred embodiments of the present invention will be described in detail below with reference to the accompanying drawings. The ratio of the dimensions in the drawings may be exaggerated and differ from the actual ratio for convenience of explanation. In this description, a direction toward an end-of-stroke position is referred to as "end direction" or "end side", and a direction where a start-of-stroke position is located is referred to as "head direction" or "head side". Moreover, in this description, "air" refers to working fluid in gaseous form and is not limited in particular to air.

(First Embodiment)

[0010] As illustrated in FIGS. 4A and 4B, a fluid pressure cylinder 10 according to this embodiment includes a cylinder body 12 and a drive device 120.

[0011] As illustrated in FIG. 1, the fluid pressure cylinder 10 includes the cylinder body 12 extending in the axial direction. The cylinder body 12 may have a rectangular shape as illustrated in FIG. 2 and is composed of, for example, a metal material such as aluminum alloy.

[0012] As illustrated in FIG. 1, the cylinder body 12 contains, formed therein, a circular slide hole 12a (cylinder chamber) extending in the axial direction. The cylinder body 12 includes a head-side body portion 14 disposed on the head side, an end-side body portion 16 disposed on the end side, and a partition wall 26 disposed between the head-side body portion 14 and the end-side body portion 16. As illustrated in FIG. 2, the head-side body portion 14, the partition wall 26, and the end-side body portion 16 are fastened together in the axial direction by connecting rods or bolts 16b.

[0013] As illustrated in FIG. 1, the head-side body portion 14 contains, formed therein, a circular working cylinder chamber 14a, and the end-side body portion 16 contains, formed therein, a circular booster cylinder chamber 16a. The working cylinder chamber 14a and the booster cylinder chamber 16a have an identical inner diameter and constitute the slide hole 12a of the cylinder body 12. The working cylinder chamber 14a and the

booster cylinder chamber 16a are separated by the partition wall 26.

[0014] A working piston 20 is disposed in the working cylinder chamber 14a, and a booster piston 22 is disposed in the booster cylinder chamber 16a. The working piston 20 and the booster piston 22 are connected to a piston rod 18 extending toward the end side and penetrating through the partition wall 26 and the cylinder body 12.

[0015] The head-side body portion 14 is provided with a head-side port 28, a head cover 46, and the working piston 20. The head cover 46 is attached to the head-side end of the working cylinder chamber 14a, and seals the head side of the working cylinder chamber 14a.

[0016] The head-side port 28 is provided adjacent to the head cover 46. The head-side port 28 penetrates through the head-side body portion 14. The head-side port 28 communicates with the working cylinder chamber 14a (first pressure chamber 38) via an opening 28a provided adjacent to the head-side end of the working cylinder chamber 14a.

[0017] The working piston 20 is accommodated inside the working cylinder chamber 14a so as to be slidable in the axial direction. An annular packing receiving groove 21a is formed in the outer circumferential surface of the working piston 20, and a packing 21 is disposed into the packing receiving groove 21a. The packing 21 comes into close contact with the inner circumferential surface of the working cylinder chamber 14a while elastically deforming, and thereby airtightly partitions the working cylinder chamber 14a into the first pressure chamber 38 and a second pressure chamber 40. The first pressure chamber 38 is an empty chamber formed between the working piston 20 and the head cover 46 and is located on the head side of the working piston 20. The second pressure chamber 40 is an empty chamber formed between the working piston 20 and the partition wall 26 and is located on the end side of the working piston 20. The first pressure chamber 38 communicates with the head-side port 28 via the opening 28a.

[0018] The working piston 20 is connected to the piston rod 18 at a head-side connection portion 18a of the piston rod 18 and displaceable integrally with the piston rod 18.

[0019] The end-side body portion 16 is provided with the booster piston 22, a rod cover 48, an end-side port 30, and an auxiliary path 76.

[0020] The booster piston 22 is disposed inside the booster cylinder chamber 16a in the end-side body portion 16 so as to be slidable in the axial direction. An annular packing receiving groove 23a and an annular magnet receiving groove 24a are formed in the outer circumferential surface of the booster piston 22. An annular packing 23 composed of an elastic material such as rubber is mounted into the packing receiving groove 23a. A circular ring-shaped magnet 24 is mounted into the magnet receiving groove 24a. A wear ring (not illustrated) is attached to an outer circumferential portion of the magnet 24.

[0021] The booster piston 22 airtightly partitions the booster cylinder chamber 16a into a third pressure chamber 42 and a fourth pressure chamber 44 via the packing 23. The third pressure chamber 42 is an empty chamber formed between the booster piston 22 and the partition wall 26 and is located on the head side of the booster piston 22. The fourth pressure chamber 44 is an empty chamber formed between the booster piston 22 and the rod cover 48 and is located on the end side of the booster piston 22. The fourth pressure chamber 44 communicates with the end-side port 30.

[0022] An annular damper receiving groove 25a is formed in the head-side end face of the booster piston 22, and a damper 25 is mounted into the damper receiving groove 25a. The damper 25 is composed of an elastic material such as rubber and is configured to prevent collision of the booster piston 22 with the partition wall 26. The booster piston 22 is connected to a piston attachment portion 18b located in the midsection of the piston rod 18 and is displaceable in the axial direction integrally with the piston rod 18.

[0023] The rod cover 48 is attached to an end-side part of the booster cylinder chamber 16a. The rod cover 48 has a disk shape and includes an annular packing receiving groove 48d formed in an outer circumferential part thereof. A circular ring-shaped packing 48c is mounted into the packing receiving groove 48d. The packing 48c airtightly seals the packing receiving groove 48d.

[0024] The rod cover 48 has an insertion hole 48a in the vicinity of the radial center. The insertion hole 48a extends in the axial direction, and the piston rod 18 passes therethrough. A rod packing 48b is disposed in the insertion hole 48a to prevent leakage of air along the piston rod 18. An annular damper receiving groove 47a is formed in the head-side end face of the rod cover 48, and a damper 47 is mounted into the damper receiving groove 47a. The damper 47 is composed of an elastic member having a circular ring shape. The damper 47 protrudes toward the interior of the booster cylinder chamber 16a to prevent collision of the rod cover 48 with the booster piston 22.

[0025] A retaining clip 49 is attached to an end-side part of the rod cover 48 to secure the rod cover 48. The retaining clip 49 is a plate member engaged into an engaging groove 49a formed in the end-side body portion 16 along the inner circumferential surface of the end-side body portion 16. The retaining clip 49 is an annular plate member having a gap at a circumferential position. The retaining clip is engaged into the engaging groove 49a by the elastic restoring force and is in contact with the end-side end face of the rod cover 48, thereby preventing the rod cover 48 from coming off.

[0026] The end-side port 30 is formed in the end-side body portion 16 adjacent to the end-side end. The end-side port 30 penetrates through the end-side body portion 16 from the outer circumference to the booster cylinder chamber 16a and communicates with the fourth pressure chamber 44 at an end-side end part of the booster cyl-

inder chamber 16a.

[0027] The auxiliary path 76 is a flow path formed inside the end-side body portion 16 and extends in the axial direction. A first end of the auxiliary path 76 communicates with the end-side port 30, and a second end thereof communicates with an adjustment port 32 (described below) in the partition wall 26.

[0028] A third check valve 56 is disposed at a position on the auxiliary path 76. The third check valve 56 includes a hollow portion 56a having a larger diameter than the auxiliary path 76 and a valve element 56b inserted into the hollow portion 56a. The valve element 56b is a cup-shaped member having a cylindrical shape with a bottom, and the bottom 56c is disposed downstream in an airflow that is to be blocked. The bottom 56c of the valve element 56b includes an annular protrusion 56d which is brought into contact with an end face of the hollow portion 56a to thereby block the auxiliary path 76 communicating with the hollow portion 56a.

[0029] A cutout portion 56e is formed in a side part of the valve element 56b to allow air to pass. When air flows from the bottom 56c side into the hollow portion, the annular protrusion 56d of the valve element 56b is configured to be separated from the end face of the hollow portion 56a to thereby pass the air via the cutout portion 56e. When air flows in the opposite direction, the bottom 56c of the valve element 56b is configured to receive the pressure of the air to thereby bring the annular protrusion 56d into contact with the end face of the hollow portion 56a and block the auxiliary path 76, so that the airflow is stopped.

[0030] To cause the third check valve 56 to operate smoothly, a biasing member 56f such as a spring may be disposed inside the hollow portion 56a to bias the annular protrusion 56d of the valve element 56b toward the end face of the hollow portion 56a. Note that a first check valve 52 and a second check valve 54 described below have structures similar to that of the third check valve 56.

[0031] As illustrated in FIG. 3A, the partition wall 26 includes a plate-shaped body 60. The body 60 includes a first connection part 63 protruding toward the head side so as to be inserted into the working cylinder chamber 14a and a second connection part 64 protruding toward the end side so as to be inserted into the booster cylinder chamber 16a. The first connection part 63 has a circular cylindrical shape having an outer diameter substantially equal to the inner diameter of the working cylinder chamber 14a. A packing 63a is attached to an outer circumferential part of the first connection part 63. The second connection part 64 has a circular cylindrical shape having an outer diameter substantially equal to the inner diameter of the booster cylinder chamber 16a. A packing 64a is attached to an outer circumferential part of the second connection part 64. The packing 63a seals the gap between the working cylinder chamber 14a and the first connection part 63. The packing 64a seals the gap between the booster cylinder chamber 16a and the second

connection part 64.

[0032] The partition wall 26 includes a through-hole part 61 in the vicinity of the radial center. The through-hole part 61 extends in the axial direction, and the piston rod 18 passes therethrough. A packing 62 is disposed in the through-hole part 61 to prevent leakage of air along the piston rod 18.

[0033] The partition wall 26 further includes a communication path 34, a communication switching valve 35 disposed in the communication path 34, an exhaust path 36, and an exhaust switching valve 37 disposed in the exhaust path 36, which form a boost switching mechanism 33.

[0034] The communication path 34 is a flow path that allows air to flow between the second pressure chamber 40 and the third pressure chamber 42. The communication path 34 includes a through-hole 65 penetrating through the partition wall 26 in the axial direction, an inner channel 35e of a communication switching pin 35a inserted into the through-hole 65, and a hole 66b of a stopper 66.

[0035] The through-hole 65 penetrates through the partition wall 26 in the axial direction and includes a large-diameter part 65a disposed on the head side, a small-diameter part 65b disposed in the middle in the axial direction, and a stopper insertion hole 65c disposed on the end side. The large-diameter part 65a and the stopper insertion hole 65c have larger inner diameters than the small-diameter part 65b. The communication switching pin 35a is disposed inside the large-diameter part 65a and the small-diameter part 65b. The stopper 66 is inserted into the stopper insertion hole 65c. The stopper 66 is connected to an end-side part of the communication switching pin 35a of the communication switching valve 35 and is displaced integrally with the communication switching pin 35a. Movement of the communication switching pin 35a toward the head side is restricted when the stopper 66 stops inside the stopper insertion hole 65c.

[0036] The communication switching valve 35 includes the communication switching pin 35a. The communication switching pin 35a includes a closing part 35c disposed on the head side and a rod part 35d extending in the axial direction toward the end side. The rod part 35d has a diameter substantially equal to the inner diameter of the small-diameter part 65b of the through-hole 65, and the rod part is inserted into the small-diameter part 65b so as to be slidable in the axial direction. The closing part 35c has a diameter substantially equal to the inner diameter of the large-diameter part 65a of the through-hole 65 so as to be insertable into the large-diameter part 65a. A ring-shaped packing 35b is attached to an outer circumferential part of the closing part 35c. When the closing part 35c is pushed into the large-diameter part 65a, the packing 35b comes into close contact with the large-diameter part 65a and thereby seals the communication path 34.

[0037] A biasing member 35f is attached to the end side of the closing part 35c of the communication switch-

ing pin 35a. The biasing member 35f is formed by, for example, a spring, and disposed in the gap between the large-diameter part 65a and the communication switching pin 35a. The biasing member 35f biases the communication switching pin 35a toward the head side such that the closing part 35c is separated from the through-hole 65 and protrudes into the second pressure chamber 40. That is, the communication switching valve 35 does not block the communication path 34 in a state that the communication switching pin 35a is not pushed, by the working piston 20, toward the head side.

[0038] The exhaust path 36 has an opening on an end face of the partition wall 26 on the first connection part 63 side. The exhaust path 36 includes a detection-pin accommodating hole 67 extending in the axial direction and a connecting channel 71 communicating with both the detection-pin accommodating hole 67 and the adjustment port 32. The detection-pin accommodating hole 67 includes a large-diameter part 67a disposed on the head side, a small-diameter part 67b disposed on the end side of the large-diameter part 67a, and a stopper insertion hole 67c. A stopper 68 is inserted into the stopper insertion hole 67c. The stopper 68 is connected to a detection pin 37a and is displaced integrally with the detection pin 37a. The moving range of the detection pin 37a toward the head side is limited when the stopper 68 stops at the end-side end of the small-diameter part 67b.

[0039] The connecting channel 71 communicates with the detection-pin accommodating hole 67 at an opening part 71a formed in a side part of the small-diameter part 67b. The diameter of the small-diameter part 67b is increased in a predetermined region around the opening part 71a, so that a gap is left between the small-diameter part 67b and the exhaust switching valve 37.

[0040] The first check valve 52, which allows air to flow only in a direction from the opening part 71a toward the adjustment port 32, is disposed in the connecting channel 71. The first check valve 52 is disposed in a direction so as to allow air from the second pressure chamber 40 to be discharged.

[0041] The exhaust switching valve 37 includes the detection pin 37a. The detection pin 37a includes a pin body part 37b having a circular cylindrical shape extending in the axial direction and a flange part 37c extending radially outward from the head-side end of the pin body part 37b. The flange part 37c has a diameter slightly smaller than the inner diameter of the large-diameter part 67a and is formed so as to be insertable into the large-diameter part 67a. A biasing member 37f formed by, for example, a spring is disposed in the large-diameter part 67a. The biasing member 37f is in contact with the flange part 37c and biases the detection pin 37a toward the head side, so that the flange part 37c protrudes into the second pressure chamber 40.

[0042] The pin body part 37b has a diameter slightly smaller than the inner diameter of the small-diameter part 67b and is configured to be slidable in the axial direction along the small-diameter part 67b. A packing 37d and a

packing 37e are disposed on an outer circumferential part of the pin body part 37b at a distance from each other in the axial direction. In a state that the detection pin 37a is not pushed by the working piston 20, the packing 37d and the packing 37e are placed at positions where the packings are in close contact with the small-diameter part 67b to thereby block the communication between the detection-pin accommodating hole 67 and the connecting channel 71. That is, the exhaust switching valve 37 blocks the exhaust path 36 in the state that the exhaust switching valve 37 is not pushed by the working piston 20.

[0043] A supplementary channel 78 and the second check valve 54 are provided in the head-side body portion 14 adjacent to the adjustment port 32. The supplementary channel 78 communicates with the adjustment port 32 and the second pressure chamber 40. The second check valve 54 is disposed in the supplementary channel 78. A first end of the second check valve 54 communicates with the adjustment port 32 via the supplementary channel 78. A second end of the second check valve 54 communicates with the second pressure chamber 40 via the supplementary channel 78. The second check valve 54 allows air to flow only in a direction from the adjustment port 32 toward the second pressure chamber 40 and blocks flow of air in the opposite direction. That is, the second check valve 54 allows air for supplement to the second pressure chamber 40 to flow and blocks air flowing in the opposite direction.

[0044] The fluid pressure cylinder 10 of this embodiment is configured as above and operated by the drive device 120 as illustrated in FIG. 4A.

[0045] The drive device 120 includes a fourth check valve 86, a throttle valve 88, a switching valve 102, a high-pressure-air supply source (high-pressure-fluid supply source) 104, and an exhaust port 106. The drive device 120 is configured to supply high-pressure air to the first pressure chamber 38 in the working cylinder chamber 14a during the working process. Moreover, as illustrated in FIG. 4B, the drive device 120 is configured to supply high-pressure air to the second pressure chamber 40 while supplying part of air accumulated in the first pressure chamber 38 to the fourth pressure chamber 44 during the return process.

[0046] The switching valve 102 is, for example, a 5-port, 2-position valve including a first port 102a to a fifth port 102e and is switchable between a first position (see FIG. 4A) and a second position (see FIG. 4B). As illustrated in FIGS. 4A and 4B, the first port 102a is connected to the head-side port 28 by pipes. The second port 102b is connected to the adjustment port 32 by pipes. The third port 102c is connected to the exhaust port 106 by pipes. The fourth port 102d is connected to the high-pressure-air supply source 104 by pipes. The fifth port 102e is connected to the exhaust port 106 via the throttle valve 88 and to the end-side port 30 via the fourth check valve 86 by pipes.

[0047] As illustrated in FIG. 4A, when the switching

valve 102 is in the first position, the first port 102a is connected to the fourth port 102d, and the second port 102b is connected to the third port 102c.

[0048] Moreover, as illustrated in FIG. 4B, when the switching valve 102 is in the second position, the first port 102a is connected to the fifth port 102e, and the second port 102b is connected to the fourth port 102d. The switching valve 102 is switched between the first position and the second position by pilot pressure from the high-pressure-air supply source 104 or by a solenoid valve.

[0049] When the switching valve 102 is in the second position, the fourth check valve 86 allows air to flow from the head-side port 28 to the end-side port 30 and blocks air flowing from the end-side port 30 toward the head-side port 28.

[0050] The throttle valve 88, which is an adjustable throttle valve of which path area can be changed to adjust the exhaust flow rate, limits the amount of air discharged from the first pressure chamber 38 through the exhaust port 106.

[0051] An air tank may be disposed at a position along a pipe connecting the fourth check valve 86 and the fourth pressure chamber 44 to thereby accumulate air supplied from the head-side port 28 to the end-side port 30 during the return process. The air tank can accumulate air sufficient to fill the fourth pressure chamber 44 during the return operation, resulting in a stable return operation. In this case, the volume of the air tank may be set to, for example, about half the maximum volume of the first pressure chamber 38. The air tank is unnecessary in a case where the pipes have sufficient volume.

[0052] The fluid pressure cylinder 10 and the drive device 120 are configured as above. Next, the effects and operations thereof will be described.

(Startup Process)

[0053] Before the fluid pressure cylinder 10 starts to be used, during a startup process, the second pressure chamber 40 and the third pressure chamber 42 are filled with high-pressure air. The high-pressure air refers to air at a pressure higher than atmospheric pressure. Here, the fluid pressure cylinder 10 is set in the start-of-stroke position as illustrated in FIG. 1. Moreover, the switching valve 102 of the drive device 120 is in the second position (see FIG. 4B). The high-pressure-air supply source 104 is thus connected to the adjustment port 32. As illustrated in FIG. 4B, high-pressure air is introduced from the high-pressure-air supply source 104 into the second pressure chamber 40 via the second check valve 54. Moreover, the high-pressure air introduced into the second pressure chamber 40 is also introduced into the third pressure chamber 42 via the communication path 34. In this manner, the second pressure chamber 40 and the third pressure chamber 42 are filled with high-pressure air. The startup process may be performed only once before the first stroke of the fluid pressure cylinder 10.

(Working Process)

[0054] During the working process of the fluid pressure cylinder 10, the switching valve 102 of the drive device 120 is set in the first position as illustrated in FIG. 4A. High-pressure air is supplied from the high-pressure-air supply source 104 to the head-side port 28 via the first port 102a of the switching valve 102. High-pressure air does not flow toward the fourth check valve 86 since the fourth check valve 86 is connected to the fifth port 102e. The fourth pressure chamber 44 is connected to the exhaust port 106 via the third check valve 56, the adjustment port 32, and the second port 102b.

[0055] As illustrated in FIG. 5, during the working process, high-pressure air from the high-pressure-air supply source 104 flows into the first pressure chamber 38 as indicated by an arrow B. Force exerted on the working piston by the high-pressure air in the second pressure chamber 40 and force exerted on the booster piston 22 by the high-pressure air that fills the third pressure chamber 42 are equal in magnitude and balanced in the opposite direction. Thus, the forces do not contribute to thrust force. As a result, thrust force corresponding to a difference between the pressure in the first pressure chamber 38 adjoining the working piston 20 and the pressure in the fourth pressure chamber 44 adjoining the booster piston 22 acts on the piston rod 18, and the piston rod 18 moves toward the end side.

[0056] As the working piston 20 moves, high-pressure air of an amount equal to the volume of the first pressure chamber 38 is supplied from the high-pressure-air supply source 104 (see FIG. 4A) to the fluid pressure cylinder 10. As the working piston 20 and the booster piston 22 move, the high-pressure air inside the second pressure chamber 40 moves to the third pressure chamber 42 via the communication path 34. During the working process, the pressure of the high-pressure air stored in the second pressure chamber 40 and the pressure of the high-pressure air stored in the third pressure chamber 42 are kept constant. Moreover, air in the fourth pressure chamber 44 is discharged from the fourth pressure chamber 44 as the booster piston 22 moves. In this case, the air in the fourth pressure chamber 44 passes through the adjustment port 32 via the third check valve 56 and the auxiliary path 76, and is discharged from the exhaust port 106 through the second port 102b of the switching valve 102 as illustrated in FIG. 4A.

(Boosting Process)

[0057] As illustrated in FIG. 6, as the working piston 20 moves, the communication switching pin 35a (see FIG. 3B) of the communication switching valve 35 is pushed toward the end side, and the detection pin 37a (see FIG. 3B) of the exhaust switching valve 37 is also pushed toward the end side.

[0058] As a result, as illustrated in FIG. 3B, the closing part 35c of the communication switching pin 35a is in-

serted into the large-diameter part 65a of the through-hole 65. The packing 35b on the closing part 35c seals the gap between the large-diameter part 65a and the closing part 35c, thereby blocking the communication path 34. That is, the communication switching valve 35 blocks the communication of air between the second pressure chamber 40 and the third pressure chamber 42 via the communication path 34.

[0059] Moreover, as the detection pin 37a of the exhaust switching valve 37 is displaced toward the end side, the packing 37d that has sealed the gap between the detection pin 37a and the detection-pin accommodating hole 67 moves to the recessed opening part 71a. This movement opens the exhaust path 36, and the adjustment port 32 and the second pressure chamber 40 communicate with each other via the exhaust path 36. The high-pressure air stored in the second pressure chamber 40 is discharged from the exhaust port 106 via the first check valve 52 and the adjustment port 32. As a result, the internal pressure in the second pressure chamber 40 drops, and thrust force corresponding to a difference between the internal pressure in the second pressure chamber 40 and the internal pressure in the first pressure chamber 38 acts on the working piston 20.

[0060] Moreover, thrust force corresponding to a difference between the pressure of the high-pressure air stored in the third pressure chamber 42 and the pressure in the fourth pressure chamber 44 acts on the booster piston 22. In this manner, the fluid pressure cylinder 10 can increase the thrust force near the stroke end. In the fluid pressure cylinder 10, the thrust force is increased by the discharge of the high-pressure air in the second pressure chamber 40 while the communication switching valve 35 and the exhaust switching valve 37 are being actuated.

(Return Process)

[0061] During the return process of the fluid pressure cylinder 10, the switching valve 102 of the drive device 120 is set in the second position as illustrated in FIG. 4B. High-pressure air is supplied from the high-pressure-air supply source 104 to the adjustment port 32 via the second port 102b of the switching valve 102. The first port 102a of the switching valve 102 is connected to the fifth port 102e, and thereby the head-side port 28 is connected to the end-side port 30 via the fourth check valve 86. The head-side port 28 is also connected to the exhaust port 106 via the throttle valve 88. As a result, part of the air stored in the first pressure chamber 38 is supplied to the fourth pressure chamber 44 via the route with the fourth check valve 86. The remaining part of the air stored in the first pressure chamber 38 is discharged from the exhaust port 106.

[0062] As illustrated in FIG. 7, during the return process, high-pressure air from the high-pressure-air supply source 104 is supplied to the adjustment port 32 of the fluid pressure cylinder 10 as indicated by an arrow B.

The high-pressure air supplied to the adjustment port 32 flows into the second pressure chamber 40 through the supplementary channel 78 and the second check valve 54. The volume of the high-pressure air supplied to the second pressure chamber 40 is equal to the volume of the high-pressure air discharged from the second pressure chamber 40 during the boosting process. That is, high-pressure air required for the boosting process is supplemented during the return process. The amount of high-pressure air supplied at this moment is small compared with the volume of the high-pressure air required for movement of the working piston 20, and thus only a small addition of high-pressure air is required.

[0063] During the return process, the internal pressure in the second pressure chamber 40 and the internal pressure in the third pressure chamber 42 become equal to each other. Consequently, the force exerted on the working piston 20 by the second pressure chamber 40 and the force exerted on the booster piston 22 by the third pressure chamber 42 are balanced and canceled.

[0064] On the other hand, part of the high-pressure air discharged from the first pressure chamber 38 flows into the fourth pressure chamber 44 as indicated by an arrow A. As the air inside the first pressure chamber 38 continues to be discharged, the difference between the pressure in the fourth pressure chamber 44 and the pressure in the first pressure chamber 38 increases, and the working piston 20, the booster piston 22, and the piston rod 18 start moving toward the head side. Along with this, the communication switching valve 35 returns to its original position, and the second pressure chamber 40 and the third pressure chamber 42 communicate with each other through the communication path 34. Moreover, the exhaust switching valve 37 seals the exhaust path 36 and blocks the communication between the adjustment port 32 and the second pressure chamber 40.

[0065] Subsequently, as illustrated in FIG. 8, air in the first pressure chamber 38 continues to be discharged while air flows into the fourth pressure chamber 44, and the working piston 20 and the booster piston 22 return to the start-of-stroke position. The return process is then completed.

[0066] The fluid pressure cylinder 10 according to this embodiment produces the following advantageous effects.

[0067] In the fluid pressure cylinder 10, the fluid pressure cylinder 10 includes, as the boost switching mechanism 33, the communication path 34 communicating with the second pressure chamber 40 and the third pressure chamber 42, the exhaust path 36 communicating with the second pressure chamber 40, the communication switching valve 35 configured to open the communication path 34 when the working piston 20 is located on the head side of a predetermined position and configured to close the communication path 34 when the working piston 20 moves to the end side of the predetermined position, and the exhaust switching valve 37 configured to close the exhaust path 36 when the working

piston 20 is located on the head side of the predetermined position and configured to open the exhaust path 36 to discharge high-pressure fluid in the second pressure chamber 40 when the working piston 20 moves to the end side of the predetermined position. This causes the second pressure chamber 40 and the third pressure chamber 42 to be separated near the stroke end and enables the high-pressure air in the second pressure chamber 40 to be discharged while the high-pressure air in the third pressure chamber 42 is maintained. As a result, thrust force of the booster piston 22 is added to the thrust force of the working piston 20, and it is thus possible to increase the thrust force in the latter half of the stroke.

[0068] In the fluid pressure cylinder 10, the partition wall 26 may include the adjustment port 32, and the exhaust path 36 may be configured to discharge the high-pressure fluid in the second pressure chamber 40 via the adjustment port 32.

[0069] In the fluid pressure cylinder 10, the boost switching mechanism 33 may be configured such that the exhaust switching valve 37 opens the exhaust path 36 after the communication switching valve 35 closes the communication path 34. This prevents the outflow of high-pressure air from the third pressure chamber 42 via the second pressure chamber 40, thereby reducing the consumption of high-pressure air.

[0070] In the fluid pressure cylinder 10, the communication switching valve 35 may include the communication switching pin 35a including the first end that protrudes into the second pressure chamber 40 and the second end that is inserted into the communication path 34, and may be configured to block the communication path 34 when the communication switching pin 35a is pushed by the working piston 20 and displaced toward the end side.

This enables the communication switching valve 35 to operate using the stroke movement of the working piston 20, thereby simplifying the device structure.

[0071] In the fluid pressure cylinder 10, the exhaust switching valve 37 may include the detection pin 37a including the first end that protrudes into the second pressure chamber 40 and sealing the exhaust path 36, and may be configured to unseal or open the exhaust path 36 when the detection pin 37a is pushed by the working piston 20 and displaced toward the end side. This enables the air in the second pressure chamber 40 to be discharged via the exhaust path 36 using the stroke movement of the working piston 20, thereby simplifying the device structure.

[0072] In the fluid pressure cylinder 10, the exhaust path 36 may be provided with the first check valve 52 allowing air to flow only in a direction from the second pressure chamber 40 toward the adjustment port 32 and blocking air flowing in the opposite direction. This prevents malfunctions of the exhaust switching valve 37 during the return process.

[0073] The fluid pressure cylinder 10 may further include the supplementary channel 78 communicating with the adjustment port 32 and the second pressure

chamber 40. The supplementary channel 78 may be provided with the second check valve 54 allowing air to flow only in a direction from the adjustment port 32 toward the second pressure chamber 40 and blocking air flowing in the opposite direction. Provision of the second check valve 54 prevents excessive inflow of high-pressure air into the second pressure chamber 40 during the return process.

[0074] The fluid pressure cylinder 10 may further include the auxiliary path 76 communicating with the fourth pressure chamber 44 and the adjustment port 32. This enables the air in the fourth pressure chamber 44 to be discharged through the adjustment port 32 during the working process and the boosting process.

[0075] In the fluid pressure cylinder 10, the auxiliary path 76 may be provided with the third check valve 56 allowing air to flow only in a direction from the fourth pressure chamber 44 toward the adjustment port 32 and blocking air flowing in the opposite direction. This prevents high-pressure air from flowing into the fourth pressure chamber 44 when high-pressure air is supplied to the adjustment port 32 during the return process, thereby reducing the consumption of high-pressure air.

[0076] The fluid pressure cylinder 10 may further include the drive device 120 connected to the first pressure chamber 38, the second pressure chamber 40, and the fourth pressure chamber 44 of the fluid pressure cylinder 10. The drive device 120 may include the switching valve 102, the high-pressure-air supply source 104, the exhaust port 106, and the fourth check valve 86. When the switching valve 102 is in the first position, the first pressure chamber 38 may communicate with the high-pressure-air supply source 104, and the fourth pressure chamber 44 and the adjustment port 32 (boost switching mechanism 33) may communicate with the exhaust port 106. When the switching valve 102 is in the second position, the first pressure chamber 38 may communicate with the fourth pressure chamber 44 via the fourth check valve 86 and with the exhaust port 106, and the second pressure chamber 40 may communicate with the high-pressure-air supply source 104 via the adjustment port 32. This enables the fourth pressure chamber 44 to be supplied with the air accumulated in the first pressure chamber 38 during the return process, thereby reducing the consumption of high-pressure air.

[0077] The fluid pressure cylinder 10 may further include the throttle valve 88 disposed between the first pressure chamber 38 and the exhaust port 106. This allows the amount of air supplied to the fourth pressure chamber 44 to be appropriately adjusted.

(Second Embodiment)

[0078] As illustrated in FIG. 9A, a fluid pressure cylinder 10A according to this embodiment includes a head-side body portion 14A and an end-side body portion 16A. In this embodiment, high-pressure fluid is enclosed in the end-side body portion 16A. To further increase the thrust

force at the stroke end, the size (width and height) of the end-side body portion 16A is made larger than the size of the head-side body portion 14A.

[0079] As illustrated in FIG. 9B, the head-side body portion 14A and the end-side body portion 16A have rectangular cross-sections. The head-side body portion 14A and the end-side body portion 16A are fastened together in the axial direction by connecting rods or bolts.

[0080] As illustrated in FIG. 10, a cylinder body 12A of the fluid pressure cylinder 10A includes the head-side body portion 14A and the end-side body portion 16A connected to each other in the axial direction via a partition wall 126. The head-side body portion 14A includes a head-side port 28A and an end-side port 30A. The end-side body portion 16A includes an adjustment port 32A adjacent to the end-side end.

[0081] A stored-air exhaust port 162 is formed in a portion of the partition wall 126 adjacent to the outer circumference in order to discharge high-pressure air enclosed in a booster cylinder chamber 116a. The stored-air exhaust port 162 communicates with a third pressure chamber 42 via a regulating valve 160. The stored-air exhaust port 162 is used to discharge high-pressure air stored inside the booster cylinder chamber 116a during, for example, the maintenance of the fluid pressure cylinder 10A and to introduce high-pressure air into the booster cylinder chamber 116a at startup.

[0082] An insertion hole 126c into which a piston rod 18A is slidably inserted is formed in a central part of the partition wall 126. A packing 118 is disposed in the insertion hole 126c to prevent leakage of fluid in the axial direction. The partition wall 126 includes a head-side connection part 126a protruding toward the head side and inserted into a working cylinder chamber 14a. The partition wall 126 further includes an end-side connection part 126b protruding toward the end side and inserted into the booster cylinder chamber 116a. An annular cushion member 124 is attached to the end-side connection part 126b to prevent the end-side connection part 126b from colliding with a booster piston 22A.

[0083] The end-side body portion 16A includes a body part 116. The booster cylinder chamber 116a, which is a circular cavity, is formed inside the body part 116. The booster cylinder chamber 116a extends in the axial direction. The booster piston 22A is disposed inside the booster cylinder chamber 116a so as to be slidable in the axial direction. The booster piston 22A is connected to the piston rod 18A. A magnet 24 and a packing 23 are attached to an outer circumferential part of the booster piston 22A. The booster piston 22A divides the booster cylinder chamber 116a into the third pressure chamber 42 on the head side and a fourth pressure chamber 44 on the end side.

[0084] The booster piston 22A is provided with a communication switching valve 35A switching between communication and non-communication of high-pressure fluid between the third pressure chamber 42 and the fourth pressure chamber 44, which are adjacent to each other

in the axial direction. The communication switching valve 35A includes a through-hole 122 penetrating through the booster piston 22A in the axial direction and a communication switching pin 35a inserted into the through-hole 122.

[0085] The through-hole 122 includes an end-side large-diameter part 122a, a small-diameter part 122b, and a head-side large-diameter part 122c. The communication switching pin 35a of the communication switching valve 35A is similar to the communication switching pin 35a, which has been described with reference to FIG. 3A. A rod part 35d of the communication switching pin 35a is inserted into the small-diameter part 122b. A closing part 35c of the communication switching pin 35a is disposed on the end-side large-diameter part 122a side. The communication switching pin 35a protrudes toward the end side by biasing force of a biasing member 35f.

[0086] High-pressure air can flow between the third pressure chamber 42 and the fourth pressure chamber 44 via the through-hole 122 and an inner channel 35e in the communication switching pin 35a. That is, in this embodiment, the through-hole 122 and the inner channel 35e constitute a communication path. When the booster piston 22A moves toward the end side, the communication switching pin 35a is pushed against a rod cover 48A. This causes the closing part 35c and a packing 35b on an outer circumferential part of the closing part 35c to be inserted into the through-hole 122 to thereby close the through-hole 122. As a result, the communication between the third pressure chamber 42 and the fourth pressure chamber 44 is blocked.

[0087] The rod cover 48A is disposed adjacent to the end-side end of the end-side body portion 16A and seals the end-side end of the booster cylinder chamber 116a. The rod cover 48A is provided with an exhaust switching valve 37A switching the discharge state of high-pressure air in the fourth pressure chamber 44. The exhaust switching valve 37A includes a through-hole 139 penetrating through the rod cover 48A in the axial direction and a detection pin 137 inserted into the through-hole 139.

[0088] The end-side end of the through-hole 139 is sealed with a cover member 150, and the detection pin 137 is disposed on the head side of the cover member 150. The detection pin 137 is biased toward the head side by a biasing member 140 such as a spring disposed between the cover member 150 and the detection pin 137. This causes the distal end part of the detection pin 137 on the head side to protrude inside the fourth pressure chamber 44.

[0089] Annular packings 141 and 142 are attached to an outer circumferential part of a basal end part 138 of the detection pin 137 at a distance from each other in the axial direction. The packings 141 and 142 seal the gap between the through-hole 139 and the detection pin 137. A channel 143 is disposed between the packings 141 and 142. The inner end of the channel 143 communicates with the through-hole 139, and the outer end thereof com-

municates with an air channel 144. The air channel 144 is an annular groove formed in an outer circumferential part of the rod cover 48A around the entire circumference and communicates with the adjustment port 32A. A packing 146 is disposed on the head side of the air channel 144, and a packing 148 is disposed on the end side thereof. The packings 146 and 148 keep the air channel 144 airtight. The adjustment port 32A can communicate with the fourth pressure chamber 44 via the air channel 144, the channel 143, and the through-hole 139. That is, in this embodiment, the through-hole 139, the channel 143, and the air channel 144 constitute an exhaust path.

[0090] In a state where the detection pin 137 is in a head-side position, the through-hole 139 is closed by the packings 141 and 142, and high-pressure fluid in the fourth pressure chamber 44 is not discharged. When the booster piston 22A moves to an end-side position, the detection pin 137 is pushed toward the end side, so that the packings 141 and 142 are disposed on the end side of the channel 143. When the packings 141 and 142 are disposed on the end side of the channel 143, the adjustment port 32A communicates with the fourth pressure chamber 44.

[0091] The fluid pressure cylinder 10A of this embodiment configured as above is operated by a drive device 120A illustrated in FIGS. 11A and 11B.

[0092] As illustrated in FIG. 11A, the drive device 120A includes a fourth check valve 86, a throttle valve 88, a switching valve 102, a high-pressure-air supply source 104, an exhaust port 106, and a fifth check valve 108. The drive device 120A is configured to supply high-pressure air to the first pressure chamber 38 in the working cylinder chamber 14a during the working process. Moreover, as illustrated in FIG. 11B, the drive device 120A is configured to supply high-pressure air to the fourth pressure chamber 44 while supplying part of air accumulated in the first pressure chamber 38 to the second pressure chamber 40 during the return process.

[0093] The switching valve 102 is, for example, a 5-port, 2-position valve including a first port 102a to a fifth port 102e and is switchable between a first position (see FIG. 11A) and a second position (see FIG. 11B). As illustrated in FIGS. 11A and 11B, the first port 102a is connected to the head-side port 28A by pipes. The second port 102b is connected to the adjustment port 32A and the downstream side of the fifth check valve 108 by pipes. The third port 102c is connected to the exhaust port 106 by pipes. The fourth port 102d is connected to the high-pressure-air supply source 104 by pipes. The fifth port 102e is connected to the exhaust port 106 via the throttle valve 88 and to the end-side port 30A and the upstream side of the fifth check valve 108 via the fourth check valve 86 by pipes.

[0094] As illustrated in FIG. 11A, when the switching valve 102 is in the first position, the first port 102a is connected to the fourth port 102d, and the second port 102b is connected to the third port 102c.

[0095] Moreover, as illustrated in FIG. 11B, when the

switching valve 102 is in the second position, the first port 102a is connected to the fifth port 102e, and the second port 102b is connected to the fourth port 102d. The switching valve 102 is switched between the first position and the second position by pilot pressure from the high-pressure-air supply source 104 or by a solenoid valve.

[0096] When the switching valve 102 is in the second position, the fourth check valve 86 allows air to flow from the head-side port 28A toward the end-side port 30A and blocks air flowing from the end-side port 30A toward the head-side port 28A. Moreover, when the switching valve 102 is in the second position, the fifth check valve 108 blocks high-pressure air flowing from the second port 102b toward the end-side port 30A.

[0097] The fluid pressure cylinder 10A according to this embodiment and the drive device 120A are configured as above. Next, the effects and operations thereof will be described.

(Working Process)

[0098] During the working process of the fluid pressure cylinder 10A, the switching valve 102 of the drive device 120A is set in the first position as illustrated in FIG. 11A. High-pressure air is supplied from the high-pressure-air supply source 104 to the head-side port 28 via the first port 102a of the switching valve 102. High-pressure air does not flow toward the fourth check valve 86 since the fourth check valve 86 is connected to the fifth port 102e. The second pressure chamber 40 is connected to the exhaust port 106 via the end-side port 30A and the fifth check valve 108. The adjustment port 32A is also connected to the exhaust port 106.

[0099] As illustrated in FIG. 10, during the working process, high-pressure air from the high-pressure-air supply source 104 flows into the first pressure chamber 38 through the head-side port 28A. This produces thrust force toward the end side on a working piston 20. As a result, the piston rod 18A moves toward the end side. Note that no thrust force acts on the booster piston 22A since the high-pressure air enclosed in the third pressure chamber 42 and the fourth pressure chamber 44 flows therebetween through the communication switching valve 35A.

[0100] As the working piston 20 moves, high-pressure air of an amount equal to the volume of the first pressure chamber 38 is supplied from the high-pressure-air supply source 104 (see FIG. 11A) to the fluid pressure cylinder 10A. During the working process, the pressure of the high-pressure air stored in the second pressure chamber 40 and the pressure in the third pressure chamber 42 are kept constant. Moreover, air in the second pressure chamber 40 is discharged from the second pressure chamber 40 as the working piston 20 moves. In this case, the air in the second pressure chamber 40 is discharged from the exhaust port 106 through the end-side port 30A and the fifth check valve 108 as illustrated in FIG. 11A.

(Boosting Process)

[0101] As illustrated in FIG. 12, as the booster piston 22A moves, the communication switching pin 35a of the communication switching valve 35A is pushed toward the head side, while the detection pin 37a of the exhaust switching valve 37A is pushed toward the end side.

[0102] As a result, the closing part 35c of the communication switching pin 35a is inserted into the through-hole 122 and closes the through-hole 122. This blocks the communication of high-pressure air between the third pressure chamber 42 and the fourth pressure chamber 44.

[0103] Moreover, as the detection pin 37a of the exhaust switching valve 37A is displaced toward the end side, the packings 141 and 142 that have sealed the gap between the detection pin 37a and the through-hole 139 are separated from the channel 143, whereby the adjustment port 32A communicates with the fourth pressure chamber 44. As a result, the high-pressure air stored in the fourth pressure chamber 44 is discharged from the exhaust port 106. That is, the internal pressure in the fourth pressure chamber 44 drops while the high-pressure air is kept in the third pressure chamber 42. As a result, thrust force corresponding to a difference between the internal pressure in the fourth pressure chamber 44 and the internal pressure in the third pressure chamber 42 acts on the booster piston 22A. Since this thrust force is added to the thrust force acting on the working piston 20, the thrust force in the fluid pressure cylinder 10A increases near the stroke end. In this manner, in the fluid pressure cylinder 10A, the thrust force is increased by the discharge of the high-pressure air in the fourth pressure chamber 44 while the communication switching valve 35A and the exhaust switching valve 37A are being actuated.

(Return Process)

[0104] During the return process of the fluid pressure cylinder 10A, the switching valve 102 of the drive device 120A is set in the second position as illustrated in FIG. 11B. High-pressure air is supplied from the high-pressure-air supply source 104 to the adjustment port 32A via the second port 102b of the switching valve 102. The first port 102a of the switching valve 102 is connected to the fifth port 102e, and thereby the head-side port 28A is connected to the end-side port 30A via the fourth check valve 86. The head-side port 28A is also connected to the exhaust port 106 via the throttle valve 88. As a result, part of the air stored in the first pressure chamber 38 is supplied to the fourth pressure chamber 44 via the route with the fourth check valve 86. The remaining part of the air stored in the first pressure chamber 38 is discharged from the exhaust port 106.

[0105] During the return process, high-pressure air is supplied from the high-pressure-air supply source 104 to the adjustment port 32A of the fluid pressure cylinder

10A. The high-pressure air supplied to the adjustment port 32A flows into the fourth pressure chamber 44. As a result, high-pressure air discharged during the boosting process is supplemented. As the amount of high-pressure air supplemented at this moment is small compared with the volume of the high-pressure air required for the stroke movement of the working piston, only a small addition of high-pressure air is required.

[0106] On the other hand, part of the high-pressure air discharged from the first pressure chamber 38 flows into the second pressure chamber 40. As the air inside the first pressure chamber 38 continues to be discharged, a difference between the pressure in the fourth pressure chamber 44 and the pressure in the first pressure chamber 38 increases, and the working piston 20 starts moving toward the head side. Subsequently, the working piston 20 and the booster piston 22A return to the start-of-stroke position, and the return process is completed. In this manner, the second pressure chamber 40 does not need to be supplied with high-pressure air since air required for the working piston 20 to return to the start-of-stroke position is supplied from the first pressure chamber 38.

[0107] The fluid pressure cylinder 10A according to this embodiment produces the following advantageous effects.

[0108] In the fluid pressure cylinder 10A of this embodiment, high-pressure fluid is enclosed in the third pressure chamber 42 and the fourth pressure chamber 44, and a boost switching mechanism 33A includes the communication switching valve 35A provided in the booster piston 22A and the exhaust switching valve 37A provided in the rod cover 48A. The fluid pressure cylinder 10A can increase the thrust force at the stroke end without any complicated locking mechanisms. Moreover, since a mechanical locking mechanism for connecting the piston and the piston rod is not required, nonconformity is less likely to occur due to an axial impact, resulting in excellent reliability.

[0109] Moreover, in the fluid pressure cylinder 10A of this embodiment, the diameter of the booster piston 22A can be made larger than the diameter of the working piston 20. Due to the booster piston 22A with an increased diameter, it is possible to reduce the diameter of the working piston 20 while maintaining the thrust force at the stroke end, and thus it is possible to further reduce the consumption of high-pressure air.

[0110] The present invention has been described by taking preferred embodiments as examples. However, the present invention is not limited in particular to the above-described embodiments, and various modifications can be made thereto without departing from the scope of the present invention as a matter of course.

[0111] That is, in the above-described embodiments, the drive devices 120 and 120A of the fluid pressure cylinders 10 and 10A, respectively, are disposed outside the fluid pressure cylinders 10 and 10A. However, the present invention is not limited in particular to this. Part or all of the members constituting the drive devices 120

and 120A may be included inside the cylinder body 12.

[0112] Moreover, high-pressure fluid may be enclosed in the first pressure chamber 38 and the second pressure chamber 40 of the fluid pressure cylinder 10, the booster piston 22 may perform the working stroke, and an additional thrust force may be produced from the working piston 20 during the boosting process.

10 Claims

1. A fluid pressure cylinder comprising:

a cylinder body (12) including a slide hole (12a) extending in an axial direction;
a partition wall (26) separating the slide hole into a working cylinder chamber (14a) on a head side and a booster cylinder chamber (16a) on an end side;

a working piston (20) disposed in the working cylinder chamber and partitioning the working cylinder chamber into a first pressure chamber (38) on the head side and a second pressure chamber (40) on the end side;

a booster piston (22) disposed in the booster cylinder chamber and partitioning the booster cylinder chamber into a third pressure chamber (42) on the head side and a fourth pressure chamber (44) on the end side; and

a piston rod (18) connected to the working piston and the booster piston, the piston rod penetrating through the partition wall and protruding out toward the end side;

wherein high-pressure fluid is enclosed in two adjacent pressure chambers among the first pressure chamber, the second pressure chamber, the third pressure chamber, and the fourth pressure chamber; and

wherein the fluid pressure cylinder further comprises:

a boost switching mechanism (33) configured to allow communication of the high-pressure fluid between the two pressure chambers while the working piston is located on the head side of a predetermined position, and configured to, when the working piston moves to the end side of the predetermined position, block the communication of the high-pressure fluid between the two pressure chambers and discharge the high-pressure fluid in one of the two pressure chambers.

2. The fluid pressure cylinder according to claim 1; wherein the high-pressure fluid is enclosed in the second pressure chamber and the third pressure chamber; and wherein the boost switching mechanism includes:

- a communication path (34) communicating with the second pressure chamber and the third pressure chamber;
 an exhaust path (36) communicating with the second pressure chamber;
 a communication switching valve (35) configured to open the communication path while the working piston is located on the head side of the predetermined position, and configured to close the communication path when the working piston moves to the end side of the predetermined position; and
 an exhaust switching valve (37) configured to close the exhaust path while the working piston is located on the head side of the predetermined position, and configured to open the exhaust path to thereby discharge the high-pressure fluid in the second pressure chamber when the working piston moves to the end side of the predetermined position.
3. The fluid pressure cylinder according to claim 2, wherein the communication path, the exhaust path, the communication switching valve, and the exhaust switching valve are provided in the partition wall.
4. The fluid pressure cylinder according to claim 1; wherein the high-pressure fluid is enclosed in the third pressure chamber and the fourth pressure chamber; and wherein the boost switching mechanism includes:
- a communication path (35e) communicating with the third pressure chamber and the fourth pressure chamber;
 an exhaust path communicating with the fourth pressure chamber;
 a communication switching valve configured to open the communication path while the working piston is located on the head side of the predetermined position, and configured to close the communication path when the working piston moves to the end side of the predetermined position; and
 an exhaust switching valve configured to close the exhaust path while the working piston is located on the head side of the predetermined position, and configured to open the exhaust path to thereby discharge the high-pressure fluid in the fourth pressure chamber when the working piston moves to the end side of the predetermined position.
5. The fluid pressure cylinder according to claim 4, wherein the booster piston is provided with the communication path and the communication switching valve.
6. The fluid pressure cylinder according to claim 5, further comprising:
 a rod cover (48) configured to seal an end-side end of the fourth pressure chamber and provided with the exhaust path and the exhaust switching valve.
7. The fluid pressure cylinder according to claim 2 or 4, wherein the cylinder body includes an adjustment port (32) communicating with the exhaust path, and the high-pressure fluid is discharged through the exhaust path via the adjustment port.
8. The fluid pressure cylinder according to claim 2 or 4, wherein, in the boost switching mechanism, the exhaust switching valve opens the exhaust path after the communication switching valve closes the communication path.
9. The fluid pressure cylinder according to any one of claims 2 to 8, wherein the communication switching valve includes a communication switching pin (35a) including a first end that protrudes into one of the two pressure chambers and a second end that is inserted into the communication path, and the communication switching valve is configured to block the communication path when the communication switching pin is pushed in the axial direction as the working piston is displaced.
10. The fluid pressure cylinder according to any one of claims 2 to 8, wherein the exhaust switching valve includes a detection pin (37a) including a basal end part that is inserted into the exhaust path to seal the exhaust path and a distal end part that protrudes toward the head side, and the exhaust switching valve is configured to unseal the exhaust path when the detection pin is pushed by the working piston or the booster piston and displaced toward the end side.
11. The fluid pressure cylinder according to claim 2 or 3, wherein the exhaust path is provided with a first check valve (52) configured to allow fluid to flow only in a direction along which the fluid is discharged and configured to block fluid flowing in an opposite direction thereof.
12. The fluid pressure cylinder according to claim 2 or 3, further comprising:
 a supplementary channel (78) communicating with the second pressure chamber;
 wherein the supplementary channel is provided with a second check valve (54) configured to allow fluid to flow toward the second pressure chamber.
13. The fluid pressure cylinder according to claim 7, fur-

ther comprising:

an auxiliary path (76) communicating with the fourth pressure chamber and the adjustment port;
 wherein the auxiliary path is provided with a third check valve (56) configured to allow fluid to flow only in a direction from the fourth pressure chamber toward the adjustment port and configured to block fluid flowing in an opposite direction thereof.

15, wherein a throttle valve (88) is disposed between the first pressure chamber and the exhaust port.

14. The fluid pressure cylinder according to claim 2, further comprising:

a drive device (120) connected to the first pressure chamber, the second pressure chamber, and the fourth pressure chamber, wherein:

the drive device includes a switching valve (102), a high-pressure-fluid supply source (104), an exhaust port (106), and a fourth check valve (86);
 when the switching valve is in a first position, the first pressure chamber communicates with the high-pressure-fluid supply source, and the fourth pressure chamber and the boost switching mechanism communicate with the exhaust port; and
 when the switching valve is in a second position, the first pressure chamber communicates with the fourth pressure chamber via the fourth check valve and with the exhaust port, and the second pressure chamber communicates with the high-pressure-fluid supply source.

15. The fluid pressure cylinder according to claim 4, further comprising:

a drive device (120A) connected to the first pressure chamber, the second pressure chamber, and the fourth pressure chamber, wherein:

the drive device includes a switching valve, a high-pressure-fluid supply source, an exhaust port, and a fourth check valve;
 when the switching valve is in a first position, the first pressure chamber communicates with the high-pressure-fluid supply source, and the fourth pressure chamber and the second pressure chamber communicate with the exhaust port; and
 when the switching valve is in a second position, the first pressure chamber communicates with the second pressure chamber via the fourth check valve and with the exhaust port, and the fourth pressure chamber communicates with the high-pressure-fluid supply source.

16. The fluid pressure cylinder according to claim 14 or

FIG. 1

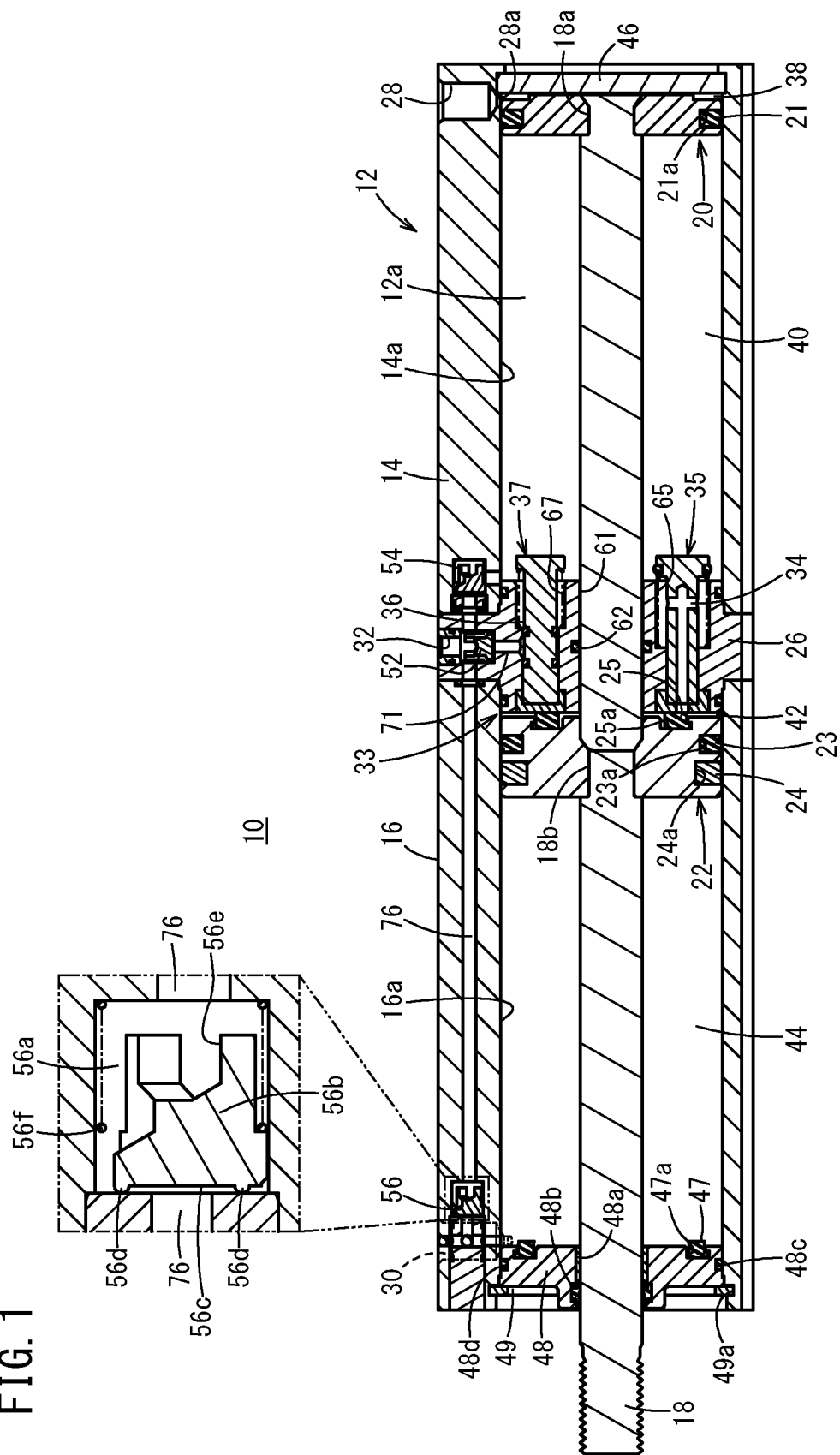


FIG. 2

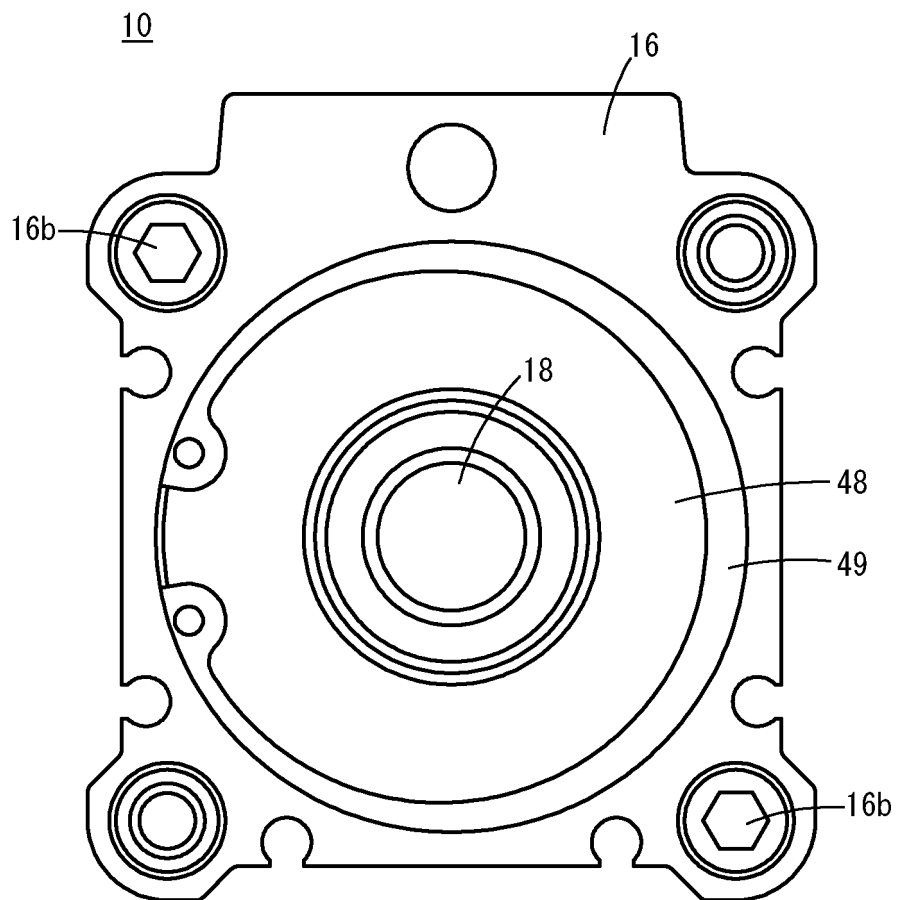


FIG. 3A

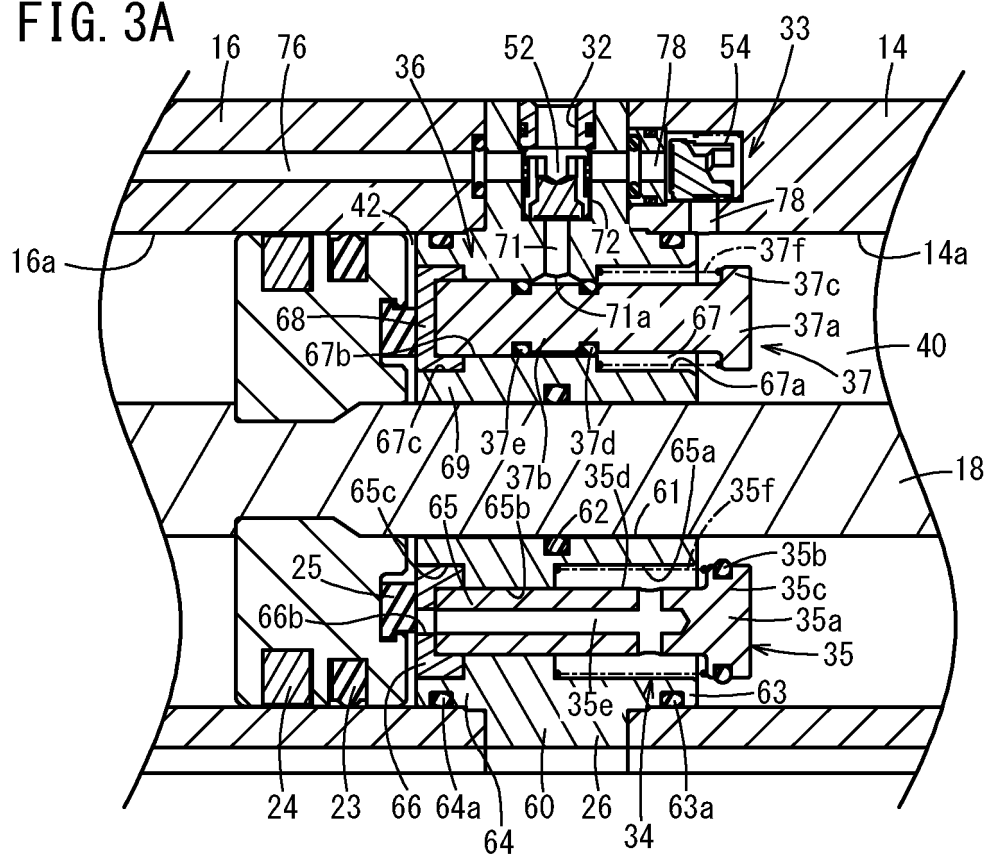


FIG. 3B

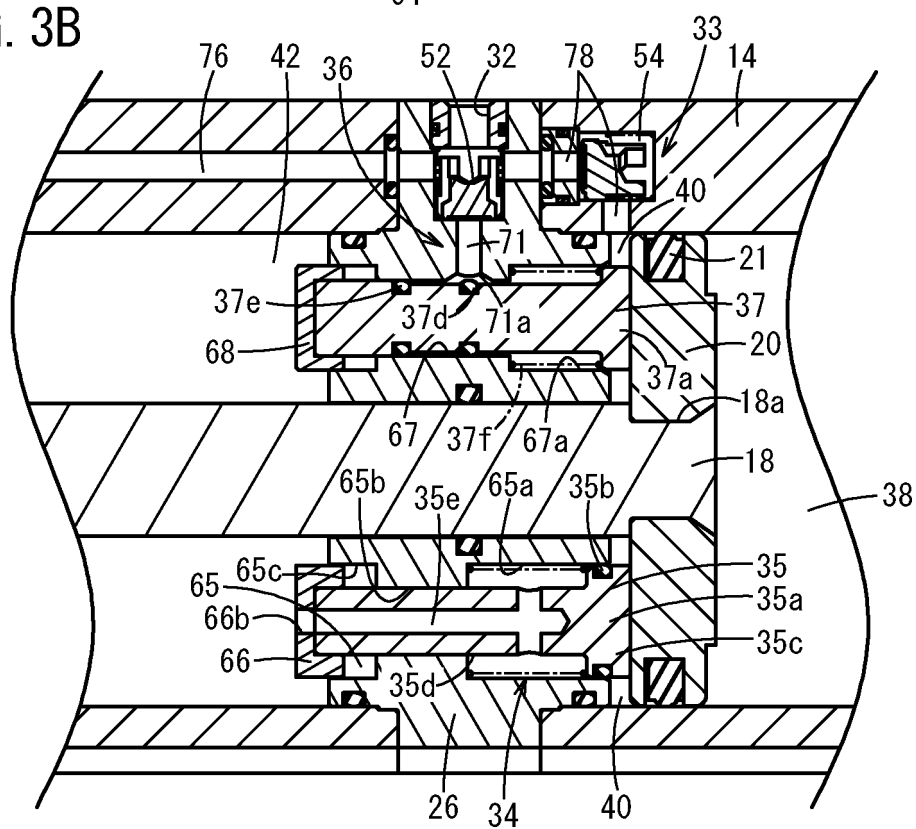


FIG. 4B

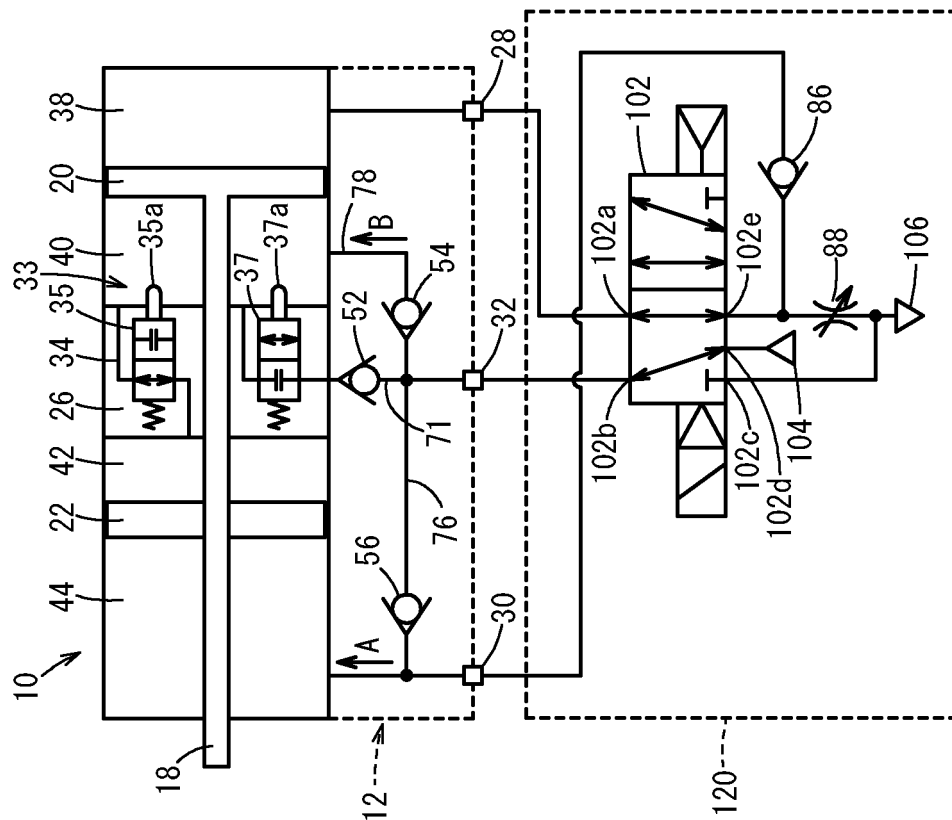


FIG. 4A

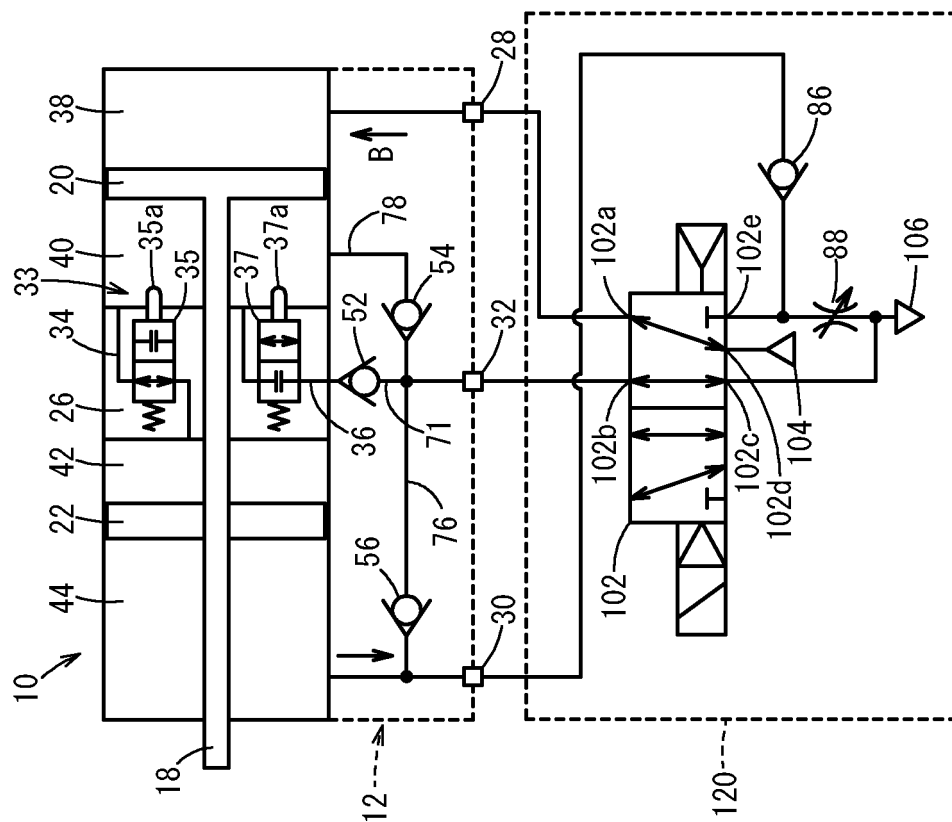


FIG. 5

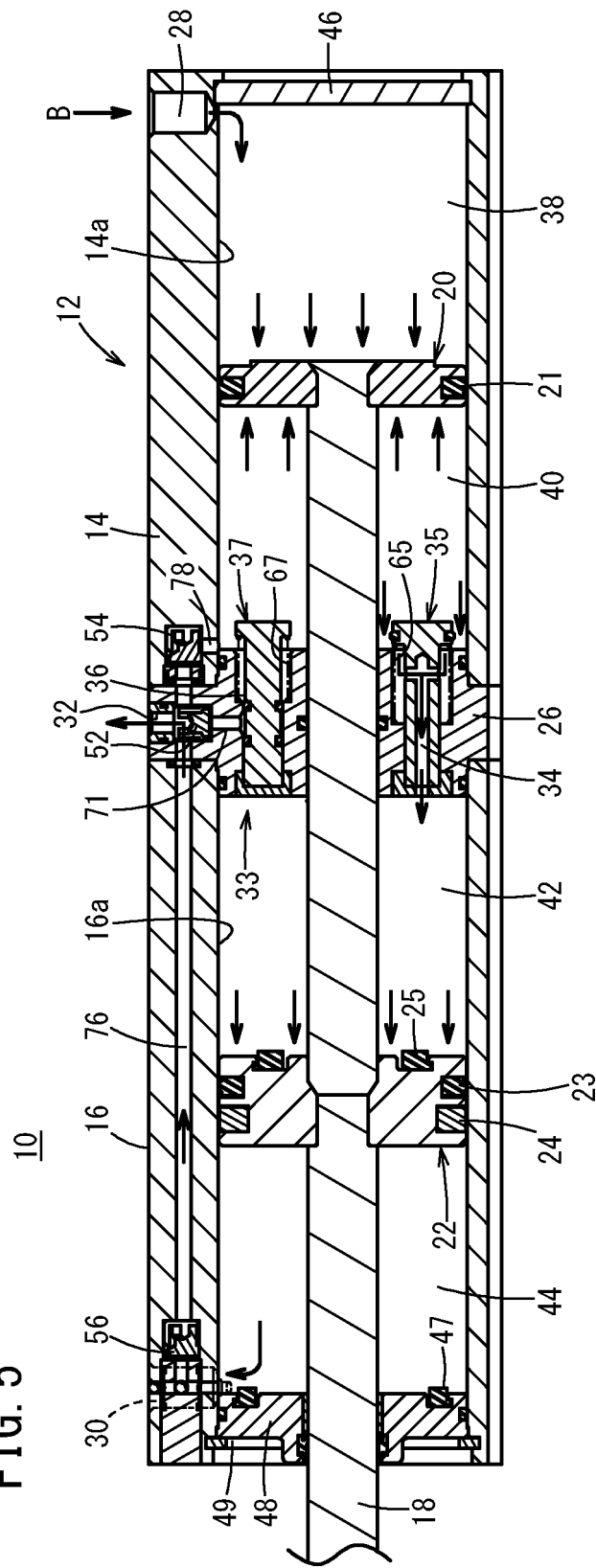


FIG. 6

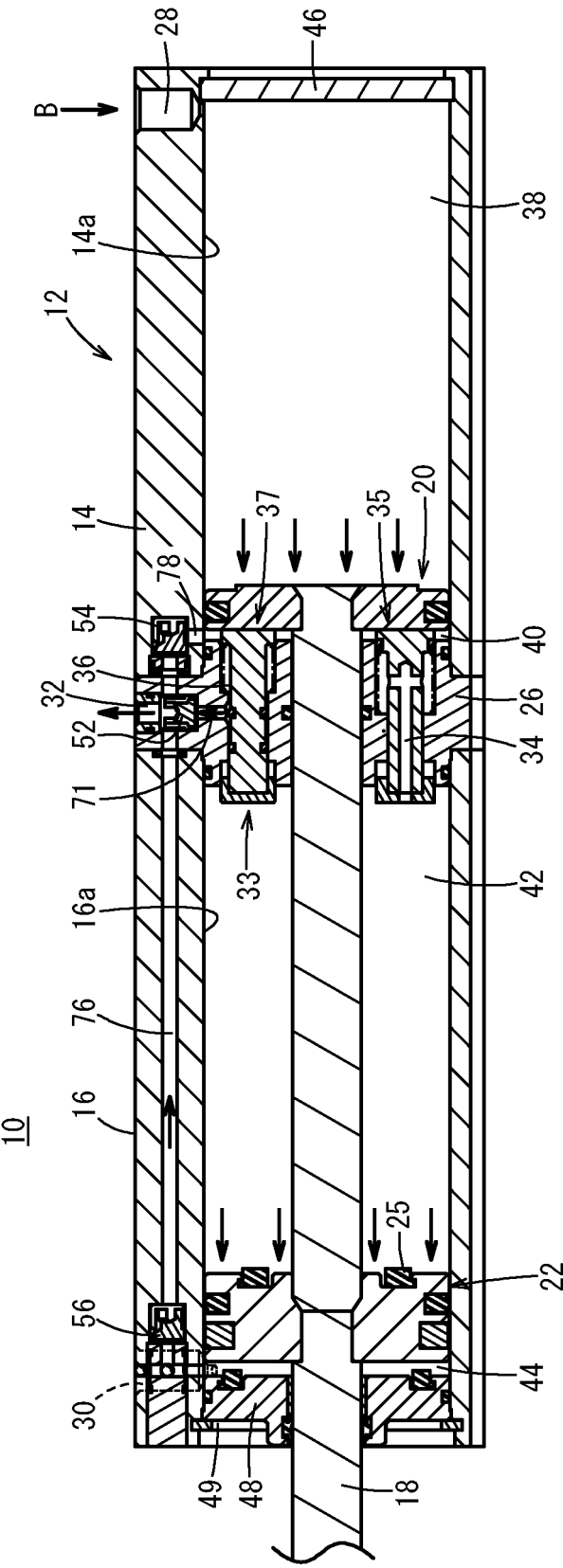
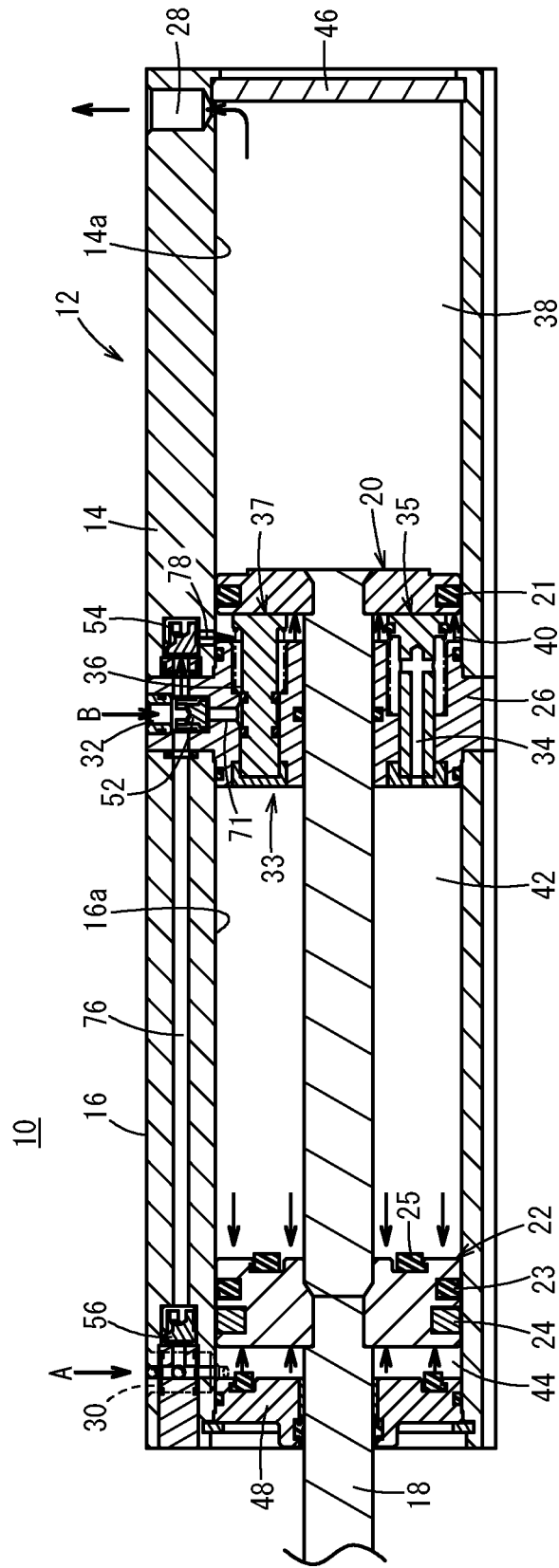


FIG. 7



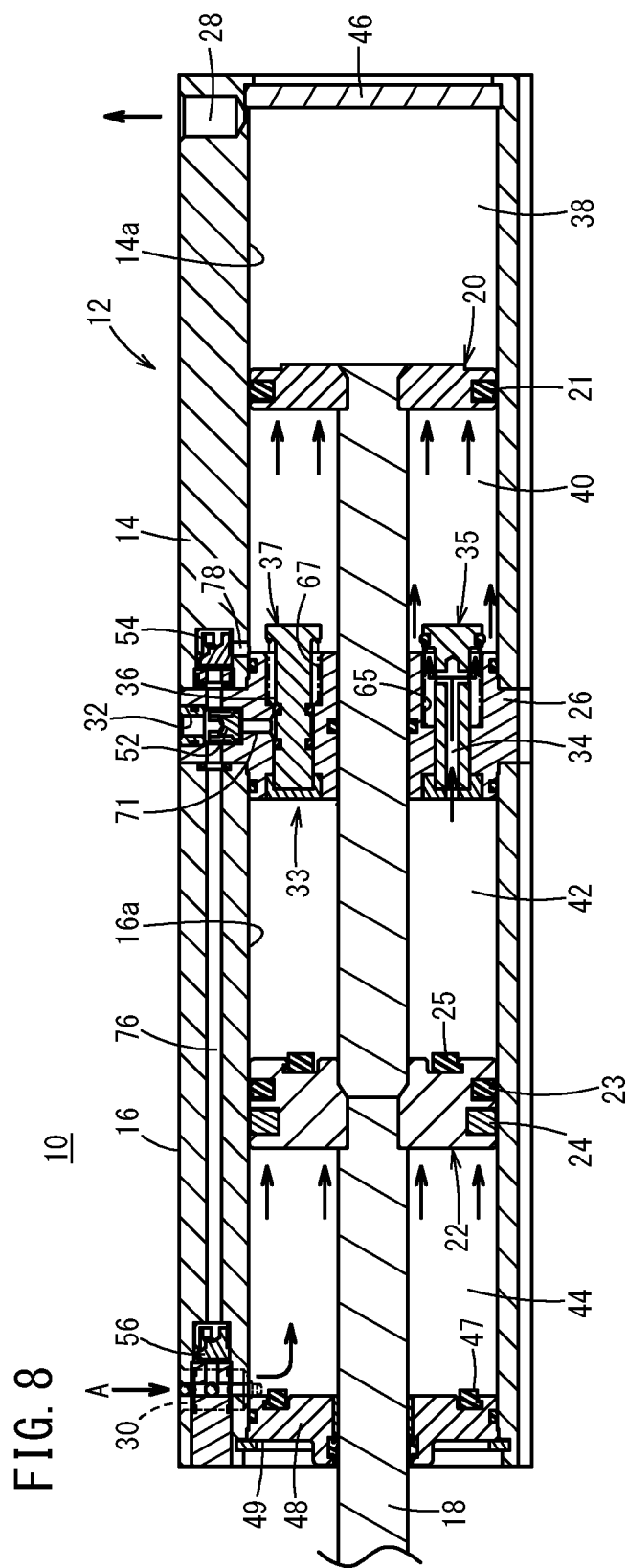


FIG. 9A

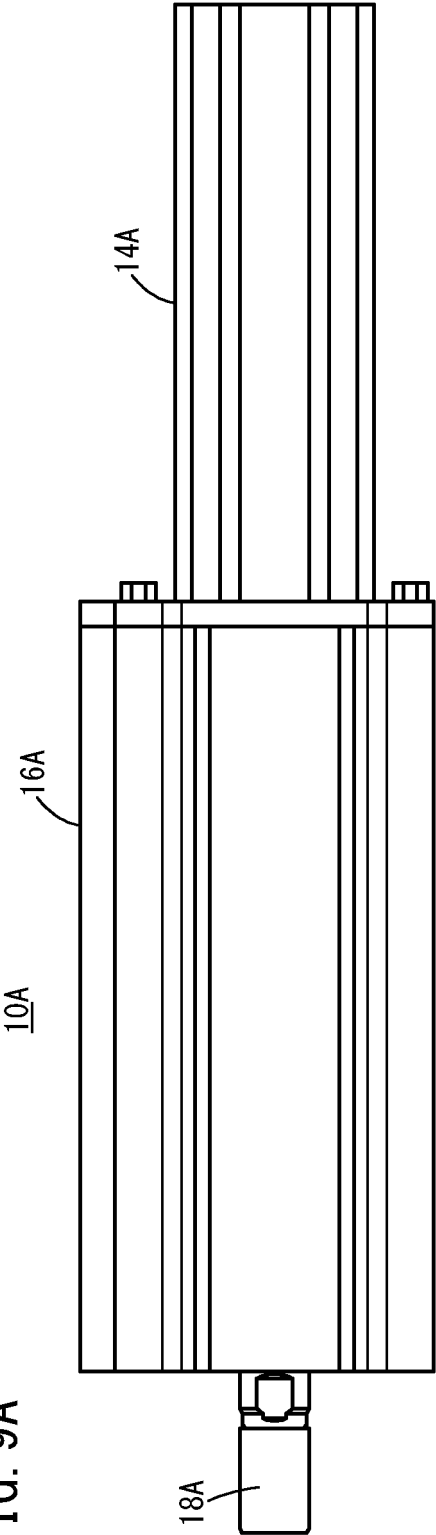


FIG. 9B

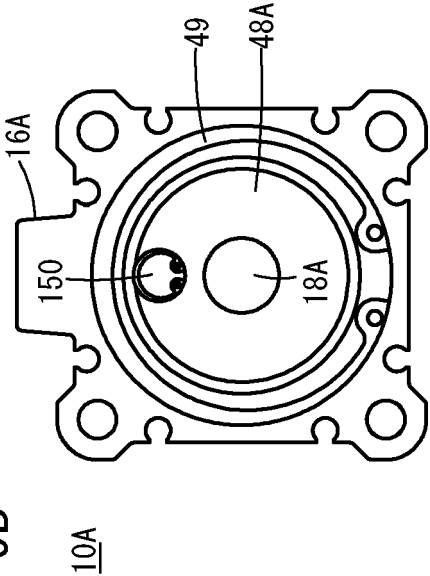


FIG. 10

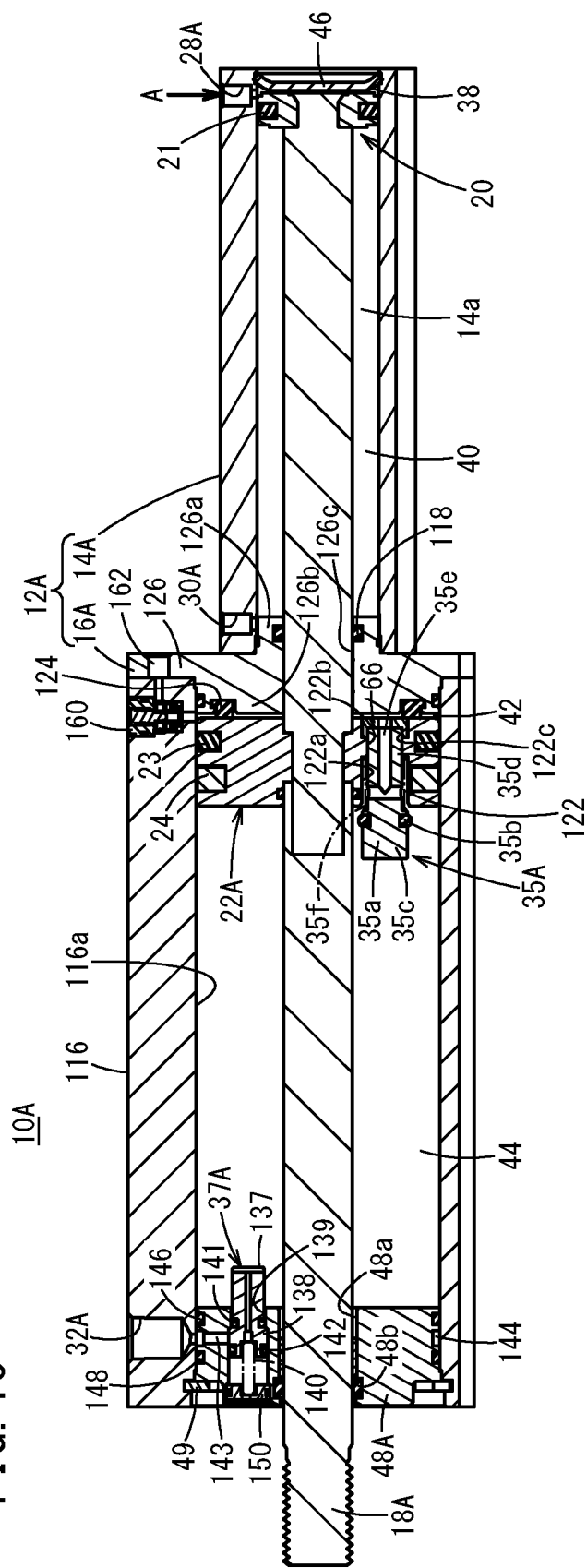


FIG. 11B

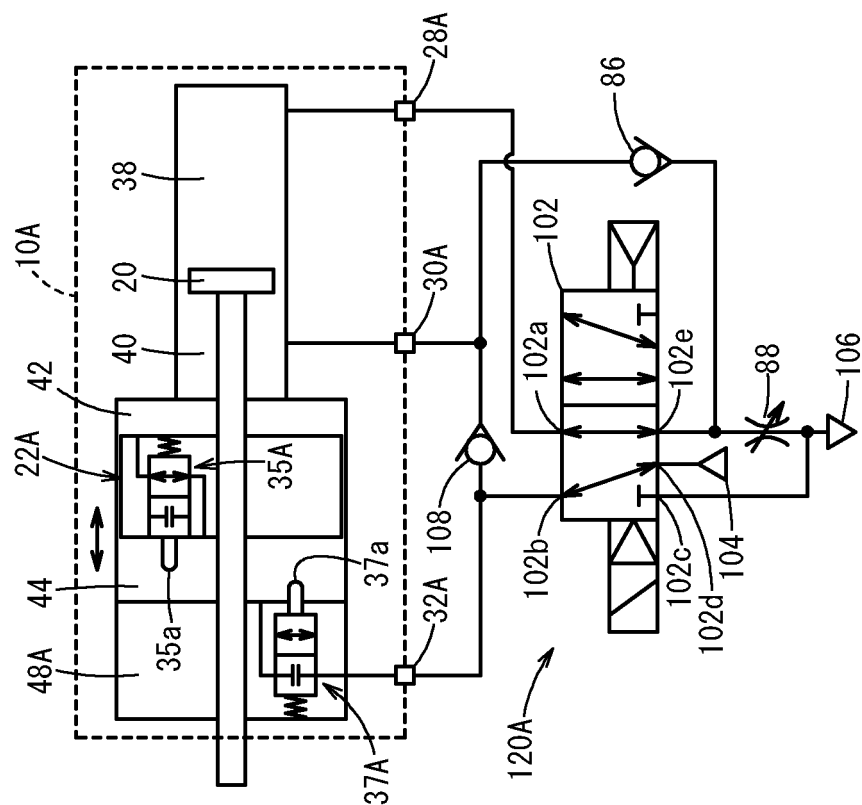


FIG. 11A

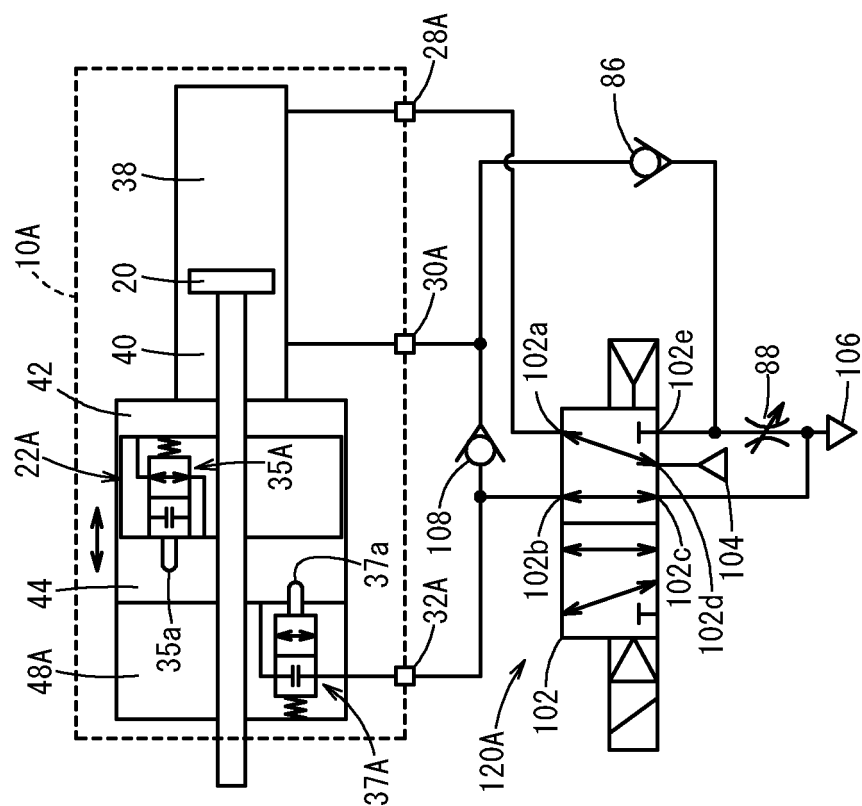
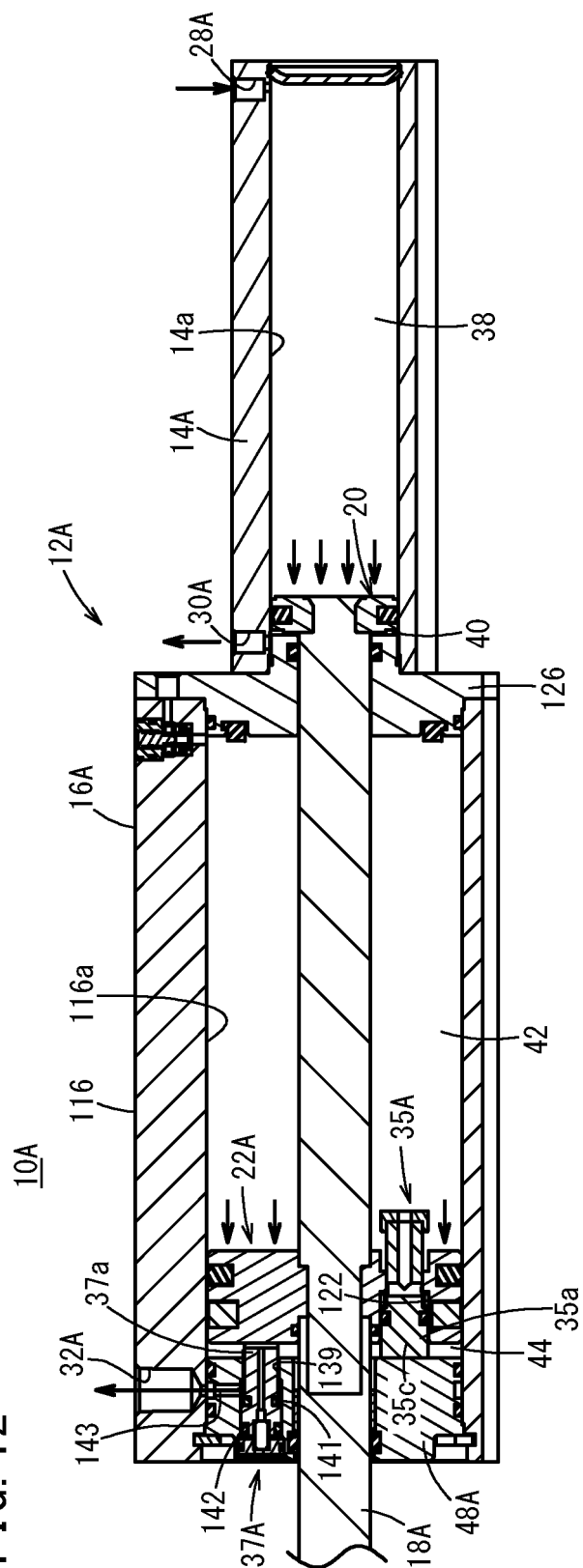


FIG. 12



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2019/032236

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl. F15B15/14 (2006.01) i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl. F15B15/00-15/28, F15B11/00-11/22; 21/14

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	1971-2019
Registered utility model specifications of Japan	1996-2019
Published registered utility model applications of Japan	1994-2019

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.
A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 110489/1975 (Laid-open No. 24192/1977) (HITACHI ZOSEN CORP.) 19 February 1977, entire text, fig. 2 (Family: none)	1-16
A	JP 2018-54117 A (SMC CORPORATION) 05 April 2018, fig. 4 & WO 2018/056036 A1, fig. 4 & CN 109790858 A & KR 10-2019-0052116 A	14-16

☐

Further documents are listed in the continuation of Box C.

☐

See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"I" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search
25 October 2019 (25.10.2019)

Date of mailing of the international search report
05 November 2019 (05.11.2019)

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

Authorized officer

Telephone No.

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

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 2018017269 A [0003]