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(54) Hydraulic servo device

(57) A cylinder houses an angularly movable pilot shaft and a piston axially movably mounted on the pilot shaft. When the pilot shaft is angularly moved, a communication passage defined in an outer circumferential surface of the pilot shaft is brought into communication with an oil supply passage or an oil drain passage for axially moving the piston. The pilot shaft has a pair of communication passages defined in the outer circumferential surface thereof, and the piston has a pair of oil passages defined therein.

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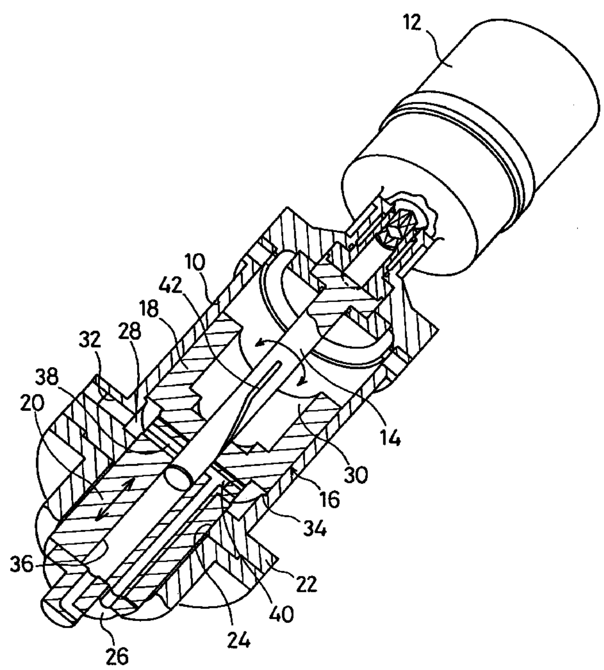

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Description

BACKGROUND OF THE INVENTION

Field of the Invention:

[0001] The present invention relates to a hydraulic servo device for converting a small-torque angular displacement into a large-load linear displacement, and more particularly to a hydraulic servo device for use in controlling the operation of a scoop tube as a speed control mechanism for a variable-speed fluid coupling.

Description of the Prior Art:

[0002] Figure 11 shows an actuator for a water feeding device for supplying water to a high-capacity boiler. As shown in Figure 11, the rotation of an input shaft 121 is accelerated and transmitted through a large-diameter gear 122 and a small-diameter gear 124 to a drive shaft 123, from which the rotation is transmitted through a fluid coupling C to a driven shaft 125. The rotation is then accelerated and transmitted from the driven shaft 125 through a large-diameter gear 131 and a small-diameter gear 133 to an output shaft 132. The fluid coupling C comprises an impeller 126 and an impeller casing 128 which are mounted on the drive shaft 123, and a runner 127 mounted on the driven shaft 125. When working oil is introduced into a working chamber defined in the impeller casing 128, the impeller 126 and the runner 127 interlockingly rotate due to the viscosity of the working oil so as to transmit the rotation from the drive shaft 123 to the driven shaft 125.

[0003] A scoop tube 130 for regulating the rate of the working oil is disposed in the working chamber. The torque transmitted by the fluid coupling C can be controlled by moving the scoop tube 130 into and out of the working chamber. The fluid coupling C, which is of a simple structure, is capable of continuously changing the rotational speed of the load side shaft (output shaft) from a minimum level to a maximum level.

[0004] The scoop tube needs to resist against forces applied by the working oil thereby to be positioned accurately. One actuating device for the scoop tube comprises, for example, a hydraulic servo device for amplifying and transmitting a displacement produced under a small force by an electric actuator, as disclosed in Japanese laid-open patent publication No. 7-208499, for example. The disclosed hydraulic servo device has a piston slidably mounted on a pilot shaft disposed in a cylinder, with oil passages defined in a surface of the pilot shaft and inside the piston. A rotation of the pilot shaft is converted into a displacement of the piston, which is outputted from the hydraulic servo device. The scoop tube is positionally controlled under feedback control based on a signal from a displacement sensor located in a predetermined position.

[0005] It is necessary that the above hydraulic servo device be reduced in size for an overall balance, and to meet such a requirement, the pilot shaft needs to be reduced in diameter. If the diameter of the pilot shaft is reduced, however, the width of the oil passage defined as a groove in the surface of the pilot shaft is also reduced. When the rotational speed of the pilot shaft is increased, the oil passage in the surface of the pilot shaft is displaced out of alignment in the oil passage in the piston, tending to cause a control failure. Consequently, the control response of the hydraulic servo device is limited.

SUMMARY OF THE INVENTION

[0006] It is therefore an object of the present invention to provide a hydraulic servo device which will keep oil passages in alignment with each other even though its pilot shaft is of a small diameter, and which has a sufficient control response even though the overall size is relatively small.

[0007] According to an aspect of the present invention, there is provided a hydraulic servo device comprising a cylinder, a pilot shaft disposed angularly movably and extending axially in the cylinder, the pilot shaft having a pair of communication passages defined in an outer circumferential surface thereof, a piston movably mounted on the pilot shaft for axial movement in the cylinder, the piston having a pair of oil passages defined therein, and an actuator for angularly moving the pilot shaft about its own axis to bring at least one of the communication passages into communication with at least one of the oil passages to apply a fluid under pressure to the piston for axially moving the piston in the cylinder. The communication passages and the oil passages are relatively small in diameter and width, and can be held in communication with each other in a relatively large angular range of the pilot shaft, so that the hydraulic servo device can be controlled with a high response.

[0008] The communication passages and the oil passages are relatively positioned such that the communication passages and the oil passages are brought into communication with each other in different angular ranges of the pilot shaft.

[0009] Each of the communication passages is angularly nonlinear in a configuration thereof.

[0010] The oil passages include an oil supply passage for supplying a working oil under pressure and an oil drain passage connected to a drain.

[0011] According to another aspect of the present invention, there is provided a hydraulic servo device comprising a cylinder, a pilot shaft disposed angularly movably and extending axially in the cylinder, the pilot shaft having a communication passage defined in an outer circumferential surface thereof, a piston movably mounted on the pilot shaft for axial movement in the cylinder, the piston having an oil passage defined therein, an actuator for angularly moving the pilot shaft about its own axis to bring the communication passage into communication with the oil passage to apply a fluid under pressure to the piston for axially moving the piston in the cylinder, the cylinder having an interior space compartmented by the piston into a first space communicating with a pressurized oil hole and a second space which can selectively be brought into and out of communication with the oil passage by the communication passage, and an air bleeder pipe connected to an upper region of the cylinder in communication with the second space. Highly compressible air which has been trapped in the second space can be discharged through the air bleeder pipe for thereby allowing the hydraulic servo device to have a high response.

[0012] The air bleeder pipe has an orifice and vented to the atmosphere therethrough.

[0013] The air bleeder pipe has a check valve and vented to the atmosphere therethrough.

[0014] According to still another aspect of the present invention, there is provided a hydraulic servo device comprising a cylinder, a pilot shaft disposed angularly movably and extending axially in the cylinder, the pilot shaft having a communication passage defined in an outer circumferential surface thereof, a piston movably mounted on the pilot shaft for axial movement in the cylinder, the piston having an oil passage defined therein, and an actuator for angularly moving the pilot shaft about its own axis to bring the communication passage into communication with the oil passage to apply a fluid under pressure to the piston for axially moving the piston in the cylinder, the cylinder having an interior space compartmented by the piston into a first space communicating with a pressurized oil hole and a second space which can selectively be brought into and out of communication with the oil passage by the communication passage, the cylinder having a recess for collecting particles therein, the recess being defined in a lower region of an inner cylindrical surface thereof respectively in the first space and/or the second space. Since particles produced upon sliding movement of the piston against the cylinder are collected in the recess, they are prevented from being caught between the piston and the cylinder, so that the hydraulic servo device can operate stably.

[0015] The cylinder has a discharge hole defined in a cylindrical wall thereof for discharging particles collected in the recess.

[0016] According to yet still another aspect of the present invention, there is provided a hydraulic servo device comprising a cylinder, a pilot shaft disposed angularly movably and extending axially in the cylinder, the pilot shaft having a communication passage defined in an outer circumferential surface thereof, a piston movably mounted on the pilot shaft for axial movement in the cylinder, the piston having an oil passage defined therein, an actuator for angularly moving the pilot shaft about its own axis to bring the communication passage into communication with the oil passage to apply a fluid under pressure to the piston for axially moving the piston in the cylinder, the cylinder having an interior space compartmented by the piston into a first space communicating with a pressurized oil hole and a second space which can selectively be brought into and out of communication with the oil passage by the communication passage, and an oil reservoir disposed in covering relation to an end wall of the cylinder which defines the first space.

[0017] According to a further aspect of the present invention, there is provided a hydraulic servo device comprising a cylinder, a pilot shaft disposed angularly movably and extending axially in the cylinder, the pilot shaft having a communication passage defined in an outer circumferential surface thereof, a piston movably mounted on the pilot shaft for axial movement in the cylinder, the piston having an oil passage defined therein, and an actuator for angularly moving the pilot shaft about its own axis to bring the communication passage into communication with the oil passage to apply a fluid under pressure to the piston for axially moving the piston in the cylinder, the piston having engaging means on an end face thereof for engaging a piston remover for pulling out the piston from the cylinder. The piston can easily be removed from the cylinder by the piston remover which is engaged by the engaging means on the piston. As a result, the piston, the cylinder, and a scoop tube mounted on the piston can easily be inspected, service, for maintenance, or can easily be replaced.

[0018] According to a still further aspect of the present invention, there is provided a fluid coupling comprising an impeller and an impeller casing which are adapted to be mounted on a drive shaft, the impeller casing defining a working chamber therein, a runner adapted to be mounted on a driven shaft, a scoop tube disposed for movement into and out of the working chamber for generating the rate of a working oil introduced into the working chamber, and any of the hydraulic servo devices described above for positionally controlling the scoop tube.

[0019] The above and other objects, features, and advantages of the present invention will become apparent from the following description when taken in conjunction with the accompanying drawings which illustrate preferred embodiments of the present invention by way of example.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020]

Figure 1 is a perspective view, partly cut away, of a hydraulic servo device according to a first embodiment of the present invention;

Figure 2A is a transverse cross-sectional view showing a positional relationship between an oil passage and a communication passage when a pilot shaft is in an angular position;

Figure 2B is a transverse cross-sectional view showing a positional relationship between the oil passage and the communication passage when a pilot shaft is in another angular position;

Figure 3A is a transverse cross-sectional view showing a positional relationship between the oil passage and the communication passage when a pilot shaft is in still another angular position;

Figure 3B is a transverse cross-sectional view showing a positional relationship between an oil passage and a communication passage in a conventional hydraulic servo device;

Figure 4 is a diagram showing a two-dimensional shape of the communication passage;

Figure 5 is a graph showing angular ranges in which oil supply and drain passages and communication passages communicate with each other;

Figure 6 is a longitudinal cross-sectional view of a hydraulic servo device according to a second embodiment of the present invention;

Figure 7 is a longitudinal cross-sectional view of a hydraulic servo device according to a third embodiment of the present invention;

Figure 8 is a longitudinal cross-sectional view of a hydraulic servo device according to a fourth embodiment of the present invention;

Figure 9 is a longitudinal cross-sectional view of a hydraulic servo device according to a fifth embodiment of the present invention;

Figure 10 is a longitudinal cross-sectional view of a hydraulic servo device according to a sixth embodiment of the present invention; and

Figure 11 is a cross-sectional view of a fluid coupling for use in combination with a hydraulic servo device.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0021] As shown in Figure 1, a hydraulic servo device according to a first embodiment of the present invention, which is typically used as an actuating device for the scoop tube of the fluid coupling shown in Figure 11, comprises a cylinder 10 as a pressure casing, a pilot actuating device 12 mounted on a proximal end of the cylinder 10 and connected to a controller (not shown), a pilot shaft 14 projecting from the pilot actuating device 12 into the cylinder 10, and a piston 16 disposed in a space defined between the cylinder 10 and the pilot shaft 14. The piston 16 is slidably movable axially along the pilot shaft 14, but is prevented from rotating around the pilot shaft 14. The piston 16 comprises a large-diameter portion 18 closer to the proximal end of the cylinder 10 and a small-diameter portion 20 closer to the distal end of the cylinder 10. The small-diameter portion 20 projects axially out of the cylinder 10 through a slide hole 24 that is defined in an end wall 22 on the distal end of the cylinder 10. The small-diameter portion 20 supports on its projecting end an attachment portion 26 for supporting the scoop tube that is to be actuated by the hydraulic servo device.

[0022] The piston 16 compartments the space within the cylinder 10 into a first space 28 defined around the small-diameter portion 20 and a second space 30 defined in and on the free end of the large-diameter portion 18. A pressurized oil passageway 32 is defined radially in the distal end of the cylinder 10 in communication with the first space 28. The cylinder 10 has an annular step 34 on an inner cylindrical wall thereof which serves as a stop for defining a stop position for the piston 16 on its axial movement towards the distal end of the cylinder 10. With the cylinder 10 being held in the stop position, the first space 28 is still maintained in the distal end of the cylinder 10 while being kept in communication with the first space 28.

[0023] As also shown in Figure 2A, the small-diameter portion 20 of the piston 16 has an axial central hole 36 defined therein which receives the pilot shaft 14 slidably therein, and a pair of oil supply passages 38a, 38b defined radially therein near the large-diameter portion 18 and extending from the first space 28 into the axial central hole 36. The oil supply passages 38a, 38b are positioned substantially symmetrically with respect to the central axis of the small-diameter portion 20. The small-diameter portion 20 also has a pair of oil drain passages 40a, 40b defined therein substantially symmetrically with respect to a plane passing through the central axis of the small-diameter portion 20 parallel to the oil supply passages 38a, 38b. The oil drain passages 40a, 40b are open at the attachment portion 26. The axial central hole 36 and the oil drain passages 40a, 40b are both connected to an external drain (not shown).

[0024] The pilot shaft 14 has a pair of communication passages 42a, 42b defined in an outer circumferential surface thereof for providing communication between the oil supply passages 38a, 38b and the second space 30 depending upon angular location of the pilot shaft 14. The communication passages 42a, 42b are positioned substantially symmetrically with respect to the central axis of the pilot shaft 14. Each of the communication passages 42a, 42b extends substantially axially over a length which corresponds to the stroke of the piston 16, and also extends helically circumferentially over a substantially half the full circumference of the pilot shaft 14. In this embodiment, the oil supply passages 38a, 38b and the oil drain passages 40a, 40b have a diameter equal to the width of the communication passages 42a, 42b. In Figure 1, one of the oil supply passages 38a, 38b is shown as an oil supply passage 38, one of the oil drain passages 40a, 40b as an oil drain passage 40, and one of the communication passages 42a, 42b as a communication passage 42.

[0025] The piston 16 has a pressure bearing area in the first space 28 which is represented by the difference between the cross-sectional area of the large-diameter portion 18 and the cross-sectional area of the small-diameter portion 20. The piston 16 has a pressure bearing area in the second space 30 which is represented by the difference between the cross-sectional area of the large-diameter portion 18 and the cross-sectional area of the pilot shaft 14. Therefore, the pressure bearing area of the piston 16 in the second space 30 is greater than the pressure bearing area of the piston 16 in the first space 28. When an identical working oil pressure acts in both the first space 28 and the second space 30 from the pressurized oil passageway 32 when the communication passages 42 communicates the oil supply passages 38 and the second space 30, the piston 16 moves axially towards the distal end of the cylinder 10, i.e., towards the pilot actuating device 12. When a working oil pressure from the pressurized oil passageway 32 acts only in the first space 28 with the communication passages 42 held in communication with the oil drain passages 40 and the second space 30, the piston 16 moves axially towards the proximal end of the cylinder 10, i.e., towards the end wall 22.

[0026] As shown in Figure 4, each of the communication passages 42 is angularly nonlinear in its configuration for thereby allowing the piston 16 to move axially through a linear stroke in response to an angular displacement of the pilot shaft 14. The large-diameter portion 18 of the piston 16 is hollow so that, even when the piston 16 is axially displaced fully to the proximal end of the cylinder 10, the communication passages 42 are not covered by the piston 16.

[0027] As shown in Figures 2A, 2B and 3A, the oil supply passage 38a and the oil drain passage 40a adjacent thereto are spaced more closely from each other than the oil supply passage 38b and the oil drain passage 40b adjacent thereto are spaced from each other. This angular positional relationship between these passages 38a, 40a and 38b, 40b ensures that when the pilot shaft 14 is angularly moved about its own axis, the communication passage 42a starts to overlap or communicate with the oil supply passage 38a or the oil drain passage 40a earlier than the communication passage 42b starts to overlap or communicate with the oil supply passage 38b or the oil drain passage 40b. Specifically, as shown in Figure 5, the communication passage 42a overlaps or communicates with the oil supply passage 38a or the oil drain passage 40a when the pilot shaft 14 is angularly moved about its own axis through an angular range 2θ where θ corresponds to the diameter of the passages 38a, 38b, 40a, 40b and hence the width of the passages 42a, 42b. The angular range 2θ through which the pilot shaft 14 is angularly moved about its own axis when the communication passage 42b overlaps or communicates with the oil supply passage 38b or the oil drain passage 40b is delayed by an angle α which is not in excess of the angle θ. As a result, the overall angle range through which the pilot shaft 14 is angularly moved about its own axis when the communication passages 42a, 42b overlap or communicate with the oil supply passages 38a, 38b or the oil drain passages 40a, 40b is represented by $(2\theta + \alpha)$. This overall angular range $(2\ \theta + \alpha)$ is greater than the angular range through which the pilot shaft 14 is angularly moved about its own axis when a communication passage 42 overlaps or communicates with one oil supply passage 38 or one oil drain passage 40 in the conventional hydraulic servo device as shown in Figure 3B. Consequently, the possibility for both the communication passages 42a, 42b to be brought out of communication with the oil supply passages 38a, 38b or the oil drain passages 40a, 40b is reduced, and the hydraulic servo device is less likely to suffer a control failure.

[0028] Operation of the hydraulic servo device according to the first embodiment will be described below. When the controller applies a control signal to the pilot actuating device 12, the pilot shaft 14 is angularly moved by the pilot actuating device 12 from the position where the communication passages 42a, 42b are out of communication with the oil supply passages 38a, 38b or the oil drain passages 40a, 40b as shown in Figure 2A, clockwise in the direction indicated by the arrow in Figure 2B. As shown in Figure 2B, the communication passage 42a starts to communicate with the oil supply passage 38a. A working oil starts to be introduced under pressure from the first space 28 through the oil supply passage 38a and the communication passage 42a into the second space 30, and the piston 16 is axially displaced towards the distal end of the cylinder 10 due to the pressure area difference on both directions of the piston 16. Since the communication passage 42a is inclined with respect to the ridge line of the pilot shaft 14, when the piston 16 is axially displaced towards the distal end of the cylinder 10, the communication passage 42a is again brought out of communication with the oil supply passage 38a as shown in Figure 2A so that the axial displacement of the piston 16 is stopped.

[0029] When the pilot shaft 14 is further angularly moved to the position shown in Figure 2B, the piston 16 is also axially displaced towards the distal end of the cylinder 10. In this manner, the pilot shaft 14 is continuously angularly moved under feedback control while the axial position of the piston 16 is being detected, until the piston 16 comes to a desired axial position.

[0030] If the load on the piston 16 is so large that the piston 16 cannot be axially displaced or if the axial displacement of the piston 16 is too small even in the position shown in Figure 2B, then the controller issues a control signal to the pilot actuating device 12 which angularly moves the pilot shaft 14 further clockwise into the position shown in Figure 3A. In this position, both the communication passages 42a, 42b communicate with the oil supply passages 38a, 38b, respectively, allowing the working oil to flow under pressure from the first space 28 through the oil supply passages 38a, 38b and the communication passages 42a, 42b into the second space 30. The piston 16 is axially displaced by an increased working oil flow rate to produce an increased drive power with an increased response. Even when the controller further applies a control signal to the pilot actuating device 12, the communication passages 42a, 42b are less liable to be brought out of communication with the oil supply passages 38a, 38b because the angular range of the pilot shaft 14 in which the communication passages 42a, 42b communicate with the oil supply passages 38a, 38b is larger than when only one communication passage 42 and one oil supply passage 38 are provided.

[0031] For axially moving the piston 16 towards the proximal end of the cylinder 10, the pilot shaft 14 is angularly moved from the position shown in Figure 2A counterclockwise in the direction opposite to the direction indicated by the arrow in Figure 2B. The communication passage 42a starts to communicate with the oil drain passage 40a, connecting the second space 30 to the drain. Since the oil pressure in the second space 30 drops, the piston 16 is axially displaced towards the proximal end of the cylinder 10 under the oil pressure in the first space 28 until the communication passage 42a is brought out of communication with the oil drain passage 40a as shown in Figure 2A. The pilot shaft 14 is continuously angularly moved under feedback control while the axial position of the piston 16 is being detected, for thereby controlling the axial position of the piston 16. Since the oil drain passages 40a, 40b are positioned relatively to each other in the same manner as the oil supply passages 38a, 38b, the piston 16 is axially displaced towards the proximal end of the cylinder 10 with an increased response and without the danger of the communication passages 42a, 42b being brought out of communication with the oil drain passages 40a, 40b.

[0032] Figure 6 shows a hydraulic servo device according to a second embodiment of the present invention. In Figure 6, an air bleeder pipe 44 is connected at an upper region of the proximal end of the cylinder 10 in communication with the second space 30. The air bleeder pipe 44 is vented to the atmosphere through an orifice 46. Air contained in the working oil flowing from the pressurized oil passageway 32 and trapped in the second space 30 can be discharged through the air bleeder pipe 44. Therefore, the response of the hydraulic servo device is prevented from being adversely affected by such trapped air. Since the orifice 46 has a small air passage hole, it can discharge the trapped air while keeping the oil pressure in the second space 30.

[0033] Figure 7 shows a hydraulic servo device according to a third embodiment of the present invention. The hydraulic servo device shown in Figure 7 is an improvement in the hydraulic servo device shown in Figure 6. The air bleeder pipe 44 vented to the atmosphere by the orifice 46 is connected to the upper region of the proximal end of the cylinder 10, and the slide hole 24 in the end wall 22 is covered with an oil reservoir 48. The oil reservoir 48 is defined by a bottom plate 50 and a wall 52 which are attached to the end wall 22. The wall 52 has a hole (not shown) defined therein for the passage therethrough of the scoop tube that is to be actuated by the hydraulic servo device. The oil reservoir 48 has a height which is preferably the same as or greater than the height of the lower end of the air bleeder pipe 44 that is connected to the cylinder 10.

[0034] In the embodiment shown in Figure 6, since the air bleeder pipe 44 is vented to the atmosphere through the orifice 46, when no oil pressure acts in the second space 30 while the hydraulic servo device is at rest, the working oil seeps through the gap between the small-diameter portion 20 of the piston 16 and the end wall 22 because of the head of the working oil in the second chamber 30. Therefore, air tends to flow from the air bleeder pipe 44 into the second space 30. Such air is responsible for unstable operation or reduced response of the hydraulic servo device when it starts to operate next time. In the embodiment shown in Figure 7, the oil reservoir 48 covering the slide hole 24 is effective to prevent the working oil from seeping from the second space 30 through the gap between the small-diameter portion 20 and the end wall 22, so that the hydraulic servo device can start to operate stably or with desired response.

[0035] Figure 8 shows a hydraulic servo device according to a fourth embodiment of the present invention. The hydraulic servo device shown in Figure 8 is also an improvement in the hydraulic servo device shown in Figure 6. In Figure 8, the air bleeder pipe 44 has a check valve 50 connected between its end coupled to the cylinder 10 and the orifice 46. The check valve 50 serves to prevent air from flowing into the second space 30 through the air bleeder pipe 44 while the hydraulic servo device is at rest. The check valve 50 may be replaced with a remotely controlled or automatically operated on-off valve, which can be open only when necessary.

[0036] Figure 9 shows a hydraulic servo device according to a fifth embodiment of the present invention. In Figure 9, two recesses 56 are defined in lower regions of an inner cylindrical surface of the cylinder 10 respectively in the first and second spaces 28, 30 near the distal and proximal ends of the cylinder 10. The recesses 56 serve to collect particles that are produced as the piston 16 slides against the inner cylindrical surface of the cylinder 10. The cylinder 10 also has two discharge holes 58 defined in its cylindrical wall in communication with the bottoms of the respective recesses 56, for discharging particles P collected on the bottoms of the respective recesses 56. The discharge holes 58 are normally closed by respective pressure-tight plugs 60. Since particles produced as the piston 16 slides against the inner cylindrical surface of the cylinder 10 are gathered and collected in the recesses 56, they are less likely to remain on the inner cylindrical surface of the cylinder 10, and hence less liable to be caught between the piston 56 and the cylinder 10. The collected particles P can be discharged when the plugs 10 are removed and the interior of the cylinder 10 is cleaned with working oil, etc. while the hydraulic servo device is not in use.

[0037] Figure 10 shows a hydraulic servo device according to a sixth embodiment of the present invention. The hydraulic servo device shown in Figure 10 is designed for easy maintenance. In Figure 10, the large-diameter portion 18 of the piston 16 has threaded holes 64 defined in an end face thereof, and elongate bolts 62 are threaded in the respective threaded holes 64 as piston removers for pulling the piston 10 out of the cylinder 10. After the working oil is drawn out of the cylinder 10, an end wall is detached from the proximal end of the cylinder 10, and the pilot shaft 14 is removed. Thereafter, the elongate bolts 62 are threaded into the respective threaded holes 64, and axially drawn to pull out the piston 16 from the cylinder 10. The elongate bolts 62 can remove the piston 16 from the cylinder 10 without disassembling the cylinder 10, so that the worker can easily inspect and service the piston 16, the cylinder 10, the scoop tube mounted on the piston 16 for maintenance, or easily replace them.

[0038] Although certain preferred embodiments of the present invention have been shown and described in detail, it should be understood that various changes and modifications may be made therein without departing from the scope of the appended claims.

[0039] According to its broadest aspect the invention relates to a hydraulic servo device comprising: a cylinder; a pilot shaft, said pilot shaft having a pair of communication passages; and a piston movably mounted on said pilot shaft for axial movement in said cylinder.

[0040] It should be noted that the objects and advantages of the invention may be attained by means of any compatible combination(s) particularly pointed out in the items of the following summary of the invention and the appended claims.

SUMMARY OF THE INVENTION

[0041]

1. A hydraulic servo device comprising:

    a cylinder;
    a pilot shaft disposed angularly movably and extending axially in said cylinder, said pilot shaft having a pair of communication passages defined in an outer circumferential surface thereof;
    a piston movably mounted on said pilot shaft for axial movement in said cylinder, said piston having a pair of oil passages defined therein; and
    an actuator for angularly moving said pilot shaft about its own axis to bring at least one of said communication passages into communication with at least one of said oil passages to apply a fluid under pressure to said piston for axially moving said piston in said cylinder.

2. A hydraulic servo device
wherein said communication passages and said oil passages are relatively positioned such that said communication passages and said oil passages are brought into communication with each other in different angular ranges of said pilot shaft.
3. A hydraulic servo device
wherein each of said communication passages is angularly nonlinear in a configuration thereof.
4. A hydraulic servo device
wherein said oil passages include an oil supply passage for supplying a working oil under pressure and an oil drain passage connected to a drain.
5. A hydraulic servo device comprising:

    a cylinder;
    a pilot shaft disposed angularly movably and extending axially in said cylinder, said pilot shaft having a communication passage defined in an outer circumferential surface thereof;
    a piston movably mounted on said pilot shaft for axial movement in said cylinder, said piston having an oil passage defined therein;
    an actuator for angularly moving said pilot shaft about its own axis to bring said communication passage into communication with said oil passage to apply a fluid under pressure to said piston for axially moving said piston in said cylinder;
    said cylinder having an interior space compartmented by said piston into a first space communicating with a pressurized oil hole and a second space which can selectively be brought into and out of communication with said oil passage by said communication passage; and
    an air bleeder pipe connected to an upper region of said cylinder in communication with said second space.

6. A hydraulic servo device
wherein said air bleeder pipe has an orifice and vented to the atmosphere therethrough.
7. A hydraulic servo device
wherein said air bleeder pipe has a check valve and vented to the atmosphere therethrough.
8. A hydraulic servo device comprising:

    a cylinder;
    a pilot shaft disposed angularly movably and extending axially in said cylinder, said pilot shaft having a communication passage defined in an outer circumferential surface thereof;
    a piston movably mounted on said pilot shaft for axial movement in said cylinder, said piston

having an oil passage defined therein; and

an actuator for angularly moving said pilot shaft about its own axis to bring said communication passage into communication with said oil passage to apply a fluid under pressure to said piston for axially moving said piston in said cylinder;

said cylinder having an interior space compartmented by said piston into a first space communicating with a pressurized oil hole and a second space which can selectively be brought into and out of communication with said oil passage by said communication passage, said cylinder having a recess for collecting particles therein, said recess being defined in a lower region of an inner cylindrical surface thereof respectively in said first space and/or said second space.

9. A hydraulic servo device wherein said cylinder has a discharge hole defined in a cylindrical wall thereof for discharging particles collected in said recess.

10. A hydraulic servo device comprising:

a cylinder;

a pilot shaft disposed angularly movably and extending axially in said cylinder, said pilot shaft having a communication passage defined in an outer circumferential surface thereof;

a piston movably mounted on said pilot shaft for axial movement in said cylinder, said piston having an oil passage defined therein;

an actuator for angularly moving said pilot shaft about its own axis to bring said communication passage into communication with said oil passage to apply a fluid under pressure to said piston for axially moving said piston in said cylinder;

said cylinder having an interior space compartmented by said piston into a first space communicating with a pressurized oil hole and a second space which can selectively be brought into and out of communication with said oil passage by said communication passage; and

an oil reservoir disposed in covering relation to an end wall of said cylinder which defines said first space.

11. A hydraulic servo device comprising:

a cylinder;

a pilot shaft disposed angularly movably and extending axially in said cylinder, said pilot shaft having a communication passage defined in an outer circumferential surface thereof;

a piston movably mounted on said pilot shaft for axial movement in said cylinder, said piston having an oil passage defined therein; and

an actuator for angularly moving said pilot shaft about its own axis to bring said communication passage into communication with said oil passage to apply a fluid under pressure to said piston for axially moving said piston in said cylinder;

said piston having engaging means on an end face thereof for engaging a piston remover for pulling out the piston from said cylinder.

12. A fluid coupling comprising:

an impeller and an impeller casing which are adapted to be mounted on a drive shaft, said impeller casing defining a working chamber therein;

a runner adapted to be mounted on a driven shaft;

a scoop tube disposed for movement into and out of said working chamber for generating the rate of a working oil introduced into said working chamber; and

a hydraulic servo device for positionally controlling said scoop tube, said hydraulic servo device comprising:

a cylinder;

a pilot shaft disposed angularly movably and extending axially in said cylinder, said pilot shaft having a pair of communication passages defined in an outer circumferential surface thereof;

a piston movably mounted on said pilot shaft for axial movement in said cylinder, said piston having a pair of oil passages defined therein; and

an actuator for angularly moving said pilot shaft about its own axis to bring at least one of said communication passages into communication with at least one of said oil passages to apply a fluid under pressure to said piston for axially moving said piston in said cylinder.

13. A fluid coupling wherein said communication passages and said oil passages are relatively positioned such that said communication passages and said oil passages are brought into communication with each other in different angular ranges of said pilot shaft.

14. A fluid coupling wherein each of said communication passages is angularly nonlinear in a configuration thereof.

15. A fluid coupling wherein said oil passages include an oil supply passage for supplying a working oil under pressure and an oil drain passage connected to a drain.

16. A fluid coupling comprising:

an impeller and an impeller casing which are adapted to be mounted on a drive shaft, said impeller casing defining a working chamber therein;

a runner adapted to be mounted on a driven shaft;

a scoop tube disposed for movement into and out of said working chamber for generating the rate of a working oil introduced into said working chamber; and

a hydraulic servo device for positionally controlling said scoop tube, said hydraulic servo device comprising:

a cylinder;

a pilot shaft disposed angularly movably and extending axially in said cylinder, said pilot shaft having a communication passage defined in an outer circumferential surface thereof;

a piston movably mounted on said pilot shaft for axial movement in said cylinder, said piston having an oil passage defined therein;

an actuator for angularly moving said pilot shaft about its own axis to bring said communication passage into communication with said oil passage to apply a fluid under pressure to said piston for axially moving said piston in said cylinder;

said cylinder having an interior space compartmented by said piston into a first space communicating with a pressurized oil hole and a second space which can selectively be brought into and out of communication with said oil passage by said communication passage; and

an air bleeder pipe connected to an upper region of said cylinder in communication with said second space.

17. A fluid coupling wherein said air bleeder pipe has an orifice and vented to the atmosphere therethrough.

18. A fluid coupling wherein said air bleeder pipe has a check valve and vented to the atmosphere therethrough.

19. A fluid coupling comprising:

an impeller and an impeller casing which are adapted to be mounted on a drive shaft, said impeller casing defining a working chamber therein;

a runner adapted to be mounted on a driven shaft;

a scoop tube disposed for movement into and out of said working chamber for generating the rate of a working oil introduced into said working chamber; and

a hydraulic servo device for positionally controlling said scoop tube, said hydraulic servo device comprising:

a cylinder;

a pilot shaft disposed angularly movably and extending axially in said cylinder, said pilot shaft having a communication passage defined in an outer circumferential surface thereof;

a piston movably mounted on said pilot shaft for axial movement in said cylinder, said piston having an oil passage defined therein; and

an actuator for angularly moving said pilot shaft about its own axis to bring said communication passage into communication with said oil passage to apply a fluid under pressure to said piston for axially moving said piston in said cylinder;

said cylinder having an interior space compartmented by said piston into a first space communicating with a pressurized oil hole and a second space which can selectively be brought into and out of communication with said oil passage by said communication passage, said cylinder having a recess for collecting particles therein, said recess being defined in a lower region of an inner cylindrical surface thereof respectively in said first space and/or said second space.

20. A fluid coupling wherein said cylinder has a discharge hole defined in a cylindrical wall thereof for discharging particles collected in said recess.

21. A fluid coupling comprising:

an impeller and an impeller casing which are adapted to be mounted on a drive shaft, said impeller casing defining a working chamber therein;

a runner adapted to be mounted on a driven shaft;

a scoop tube disposed for movement into and out of said working chamber for generating the rate of a working oil introduced into said working chamber; and

a hydraulic servo device for positionally controlling said scoop tube, said hydraulic servo device comprising:

a cylinder;

a pilot shaft disposed angularly movably and extending axially in said cylinder, said pilot shaft having a communication passage defined in an outer circumferential surface thereof;

a piston movably mounted on said pilot shaft for axial movement in said cylinder, said piston having an oil passage defined therein;

an actuator for angularly moving said pilot shaft about its own axis to bring said communication passage into communication with said oil passage to apply a fluid under pressure to said piston for axially moving said piston in said cylinder;

said cylinder having an interior space compartmented by said piston into a first space communicating with a pressurized oil hole and a second space which can selectively be brought into and out of communication with said oil passage by said communication passage; and

an oil reservoir disposed in covering relation to an end wall of said cylinder which defines said first space.

22. A fluid coupling comprising:

an impeller and an impeller casing which are adapted to be mounted on a drive shaft, said impeller casing defining a working chamber therein;
a runner adapted to be mounted on a driven shaft;
a scoop tube disposed for movement into and out of said working chamber for generating the rate of a working oil introduced into said working chamber; and
a hydraulic servo device for positionally controlling said scoop tube, said hydraulic servo device comprising:
a cylinder;
a pilot shaft disposed angularly movably and extending axially in said cylinder, said pilot shaft having a communication passage defined in an outer circumferential surface thereof;
a piston movably mounted on said pilot shaft for axial movement in said cylinder, said piston having an oil passage defined therein; and
an actuator for angularly moving said pilot shaft about its own axis to bring said communication passage into communication with said oil passage to apply a fluid under pressure to said piston for axially moving said piston in said cylinder;
said piston having engaging means on an end face thereof for engaging a piston remover for pulling out the piston from said cylinder.

Claims

1. A hydraulic servo device comprising:

a cylinder;
a pilot shaft disposed angularly movably and extending axially in said cylinder, said pilot shaft having a pair of communication passages defined in an outer circumferential surface thereof;
a piston movably mounted on said pilot shaft for axial movement in said cylinder, said piston having a pair of oil passages defined therein; and
an actuator for angularly moving said pilot shaft about its own axis to bring at least one of said communication passages into communication with at least one of said oil passages to apply a fluid under pressure to said piston for axially moving said piston in said cylinder.

2. A hydraulic servo device according to claim 1, wherein said communication passages and said oil passages are relatively positioned such that said communication passages and said oil passages are brought into communication with each other in different angular ranges of said pilot shaft,
and/or wherein preferably

each of said communication passages is angularly nonlinear in a configuration thereof,
and/or wherein preferably

said oil passages include an oil supply passage for supplying a working oil under pressure and an oil drain passage connected to a drain.

3. A hydraulic servo device comprising:

a cylinder;
a pilot shaft disposed angularly movably and extending axially in said cylinder, said pilot shaft having a communication passage defined in an outer circumferential surface thereof;
a piston movably mounted on said pilot shaft for axial movement in said cylinder, said piston having an oil passage defined therein;
an actuator for angularly moving said pilot shaft about its own axis to bring said communication passage into communication with said oil passage to apply a fluid under pressure to said piston for axially moving said piston in said cylinder;
said cylinder having an interior space compartmented by said piston into a first space communicating with a pressurized oil hole and a second space which can selectively be brought into and out of communication with said oil passage by said communication passage; and
an air bleeder pipe connected to an upper region of said cylinder in communication with said second space.

4. A hydraulic servo device according to any of the preceding claims wherein said air bleeder pipe has an orifice and vented to the atmosphere therethrough,
and/or wherein preferably

said air bleeder pipe has a check valve and vented to the atmosphere therethrough.

5. A hydraulic servo device comprising:

a cylinder;

a pilot shaft disposed angularly movably and extending axially in said cylinder, said pilot shaft having a communication passage defined in an outer circumferential surface thereof;

a piston movably mounted on said pilot shaft for axial movement in said cylinder, said piston having an oil passage defined therein; and

an actuator for angularly moving said pilot shaft about its own axis to bring said communication passage into communication with said oil passage to apply a fluid under pressure to said piston for axially moving said piston in said cylinder;

said cylinder having an interior space compartmented by said piston into a first space communicating with a pressurized oil hole and a second space which can selectively be brought into and out of communication with said oil passage by said communication passage, said cylinder having a recess for collecting particles therein, said recess being defined in a lower region of an inner cylindrical surface thereof respectively in said first space and/or said second space.

6. A hydraulic servo device according to any of the preceding claims wherein said cylinder has a discharge hole defined in a cylindrical wall thereof for discharging particles collected in said recess.

7. A hydraulic servo device comprising:

a cylinder;

a pilot shaft disposed angularly movably and extending axially in said cylinder, said pilot shaft having a communication passage defined in an outer circumferential surface thereof;

a piston movably mounted on said pilot shaft for axial movement in said cylinder, said piston having an oil passage defined therein;

an actuator for angularly moving said pilot shaft about its own axis to bring said communication passage into communication with said oil passage to apply a fluid under pressure to said piston for axially moving said piston in said cylinder;

said cylinder having an interior space compartmented by said piston into a first space communicating with a pressurized oil hole and a second space which can selectively be brought into and out of communication with said oil passage by said communication passage; and

an oil reservoir disposed in covering relation to an end wall of said cylinder which defines said first space.

8. A hydraulic servo device comprising:

a cylinder;

a pilot shaft disposed angularly movably and extending axially in said cylinder, said pilot shaft having a communication passage defined in an outer circumferential surface thereof;

a piston movably mounted on said pilot shaft for axial movement in said cylinder, said piston having an oil passage defined therein; and

an actuator for angularly moving said pilot shaft about its own axis to bring said communication passage into communication with said oil passage to apply a fluid under pressure to said piston for axially moving said piston in said cylinder;

said piston having engaging means on an end face thereof for engaging a piston remover for pulling out the piston from said cylinder.

9. A fluid coupling comprising:

an impeller and an impeller casing which are adapted to be mounted on a drive shaft, said impeller casing defining a working chamber therein;

a runner adapted to be mounted on a driven shaft;

a scoop tube disposed for movement into and out of said working chamber for generating the rate of a working oil introduced into said working chamber; and

a hydraulic servo device for positionally controlling said scoop tube, said hydraulic servo device comprising:

a cylinder;

a pilot shaft disposed angularly movably and extending axially in said cylinder, said pilot shaft having a pair of communication passages defined in an outer circumferential surface thereof;

a piston movably mounted on said pilot shaft for axial movement in said cylinder, said piston having a pair of oil passages defined therein; and

an actuator for angularly moving said pilot shaft about its own axis to bring at least one of said communication passages into communication with at least one of said oil passages to apply a fluid under pressure to said piston for axially moving said piston in said cylinder.

10. A fluid coupling according to any of the preceding claims wherein said communication passages and said oil passages are relatively positioned such that said communication passages and said oil passages are brought into communication with each other in different angular ranges of said pilot shaft, and/or wherein preferably each of said communication passages is angularly nonlinear in a configuration thereof,

and/or wherein preferably

said oil passages include an oil supply passage for supplying a working oil under pressure and an oil drain passage connected to a drain.

11. A fluid coupling comprising:

an impeller and an impeller casing which are adapted to be mounted on a drive shaft, said impeller casing defining a working chamber therein;
a runner adapted to be mounted on a driven shaft;
a scoop tube disposed for movement into and out of said working chamber for generating the rate of a working oil introduced into said working chamber; and
a hydraulic servo device for positionally controlling said scoop tube, said hydraulic servo device comprising:
a cylinder;
a pilot shaft disposed angularly movably and extending axially in said cylinder, said pilot shaft having a communication passage defined in an outer circumferential surface thereof;
a piston movably mounted on said pilot shaft for axial movement in said cylinder, said piston having an oil passage defined therein;
an actuator for angularly moving said pilot shaft about its own axis to bring said communication passage into communication with said oil passage to apply a fluid under pressure to said piston for axially moving said piston in said cylinder;
said cylinder having an interior space compartmented by said piston into a first space communicating with a pressurized oil hole and a second space which can selectively be brought into and out of communication with said oil passage by said communication passage; and
an air bleeder pipe connected to an upper region of said cylinder in communication with said second space.

12. A fluid coupling according to any of the preceding claims wherein said air bleeder pipe has an orifice and vented to the atmosphere therethrough,

and/or wherein preferably

said air bleeder pipe has a check valve and vented to the atmosphere therethrough.

13. A fluid coupling comprising:

an impeller and an impeller casing which are adapted to be mounted on a drive shaft, said impeller casing defining a working chamber therein;
a runner adapted to be mounted on a driven shaft;
a scoop tube disposed for movement into and out of said working chamber for generating the rate of a working oil introduced into said working chamber; and
a hydraulic servo device for positionally controlling said scoop tube, said hydraulic servo device comprising:
a cylinder;
a pilot shaft disposed angularly movably and extending axially in said cylinder, said pilot shaft having a communication passage defined in an outer circumferential surface thereof;
a piston movably mounted on said pilot shaft for axial movement in said cylinder, said piston having an oil passage defined therein; and
an actuator for angularly moving said pilot shaft about its own axis to bring said communication passage into communication with said oil passage to apply a fluid under pressure to said piston for axially moving said piston in said cylinder;
said cylinder having an interior space compartmented by said piston into a first space communicating with a pressurized oil hole and a second space which can selectively be brought into and out of communication with said oil passage by said communication passage, said cylinder having a recess for collecting particles therein, said recess being defined in a lower region of an inner cylindrical surface thereof respectively in said first space and/or said second space.

14. A fluid coupling according to any of the preceding claims wherein said cylindrical has a discharge hole in a cylindrical wall thereof for discharging particles collected in said recess.

15. A fluid coupling comprising:

an impeller and an impeller casing which are adapted to be mounted on a drive shaft, said impeller casing defining a working chamber therein;
a runner adapted to be mounted on a driven shaft;
a scoop tube disposed for movement into and out of said working chamber for generating the rate of a working oil introduced into said working chamber; and
a hydraulic servo device for positionally controlling said scoop tube, said hydraulic servo device comprising:
a cylinder;

a pilot shaft disposed angularly movably and extending axially in said cylinder, said pilot shaft having a communication passage defined in an outer circumferential surface thereof;

a piston movably mounted on said pilot shaft for axial movement in said cylinder, said piston having an oil passage defined therein;

an actuator for angularly moving said pilot shaft about its own axis to bring said communication passage into communication with said oil passage to apply a fluid under pressure to said piston for axially moving said piston in said cylinder;

said cylinder having an interior space compartmented by said piston into a first space communicating with a pressurized oil hole and a second space which can selectively be brought into and out of communication with said oil passage by said communication passage; and

an oil reservoir disposed in covering relation to an end wall of said cylinder which defines said first space.

16. A fluid coupling comprising:

an impeller and an impeller casing which are adapted to be mounted on a drive shaft, said impeller casing defining a working chamber therein;

a runner adapted to he mounted on a driven shaft;

a scoop tube disposed for movement into and out of said working chamber for generating the rate of a working oil introduced into said working chamber; and

a hydraulic servo device for positionally controlling said scoop tube, said hydraulic servo device comprising:

a cylinder;

a pilot shaft disposed angularly movably and extending axially in said cylinder, said pilot shaft having a communication passage defined in an outer circumferential surface thereof;

a piston movably mounted on said pilot shaft for axial movement in said cylinder, said piston having an oil passage defined therein; and

an actuator for angularly moving said pilot shaft about its own axis to bring said communication passage into communication with said oil passage to apply a fluid under pressure to said piston for axially moving said piston in said cylinder;

said piston having engaging means on an end face thereof for engaging a piston remover for pulling out the piston from said cylinder.

17. A hydraulic servo device comprising:

a cylinder;

a pilot shaft, said pilot shaft having a pair of communication passages; and

a piston movably mounted on said pilot shaft for axial movement in said cylinder.

F I G. 1

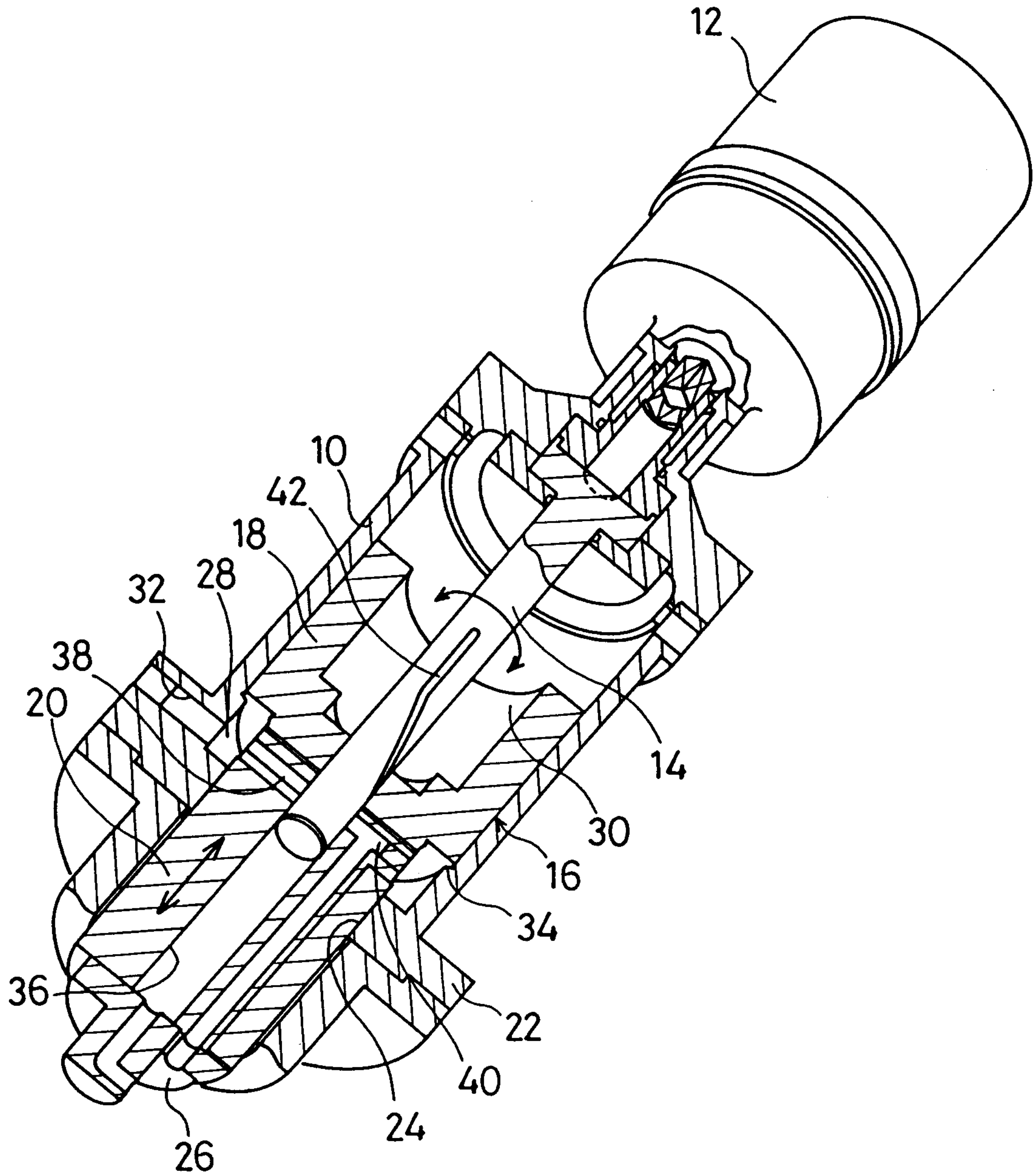


FIG. 2A

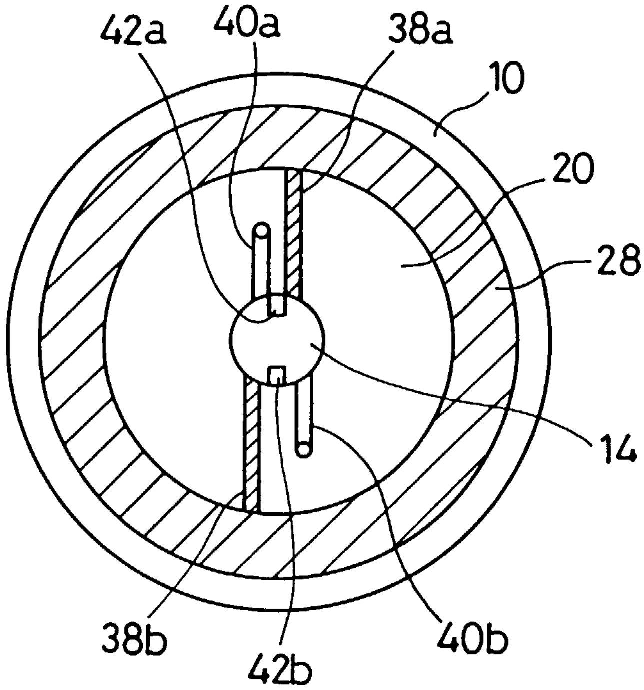
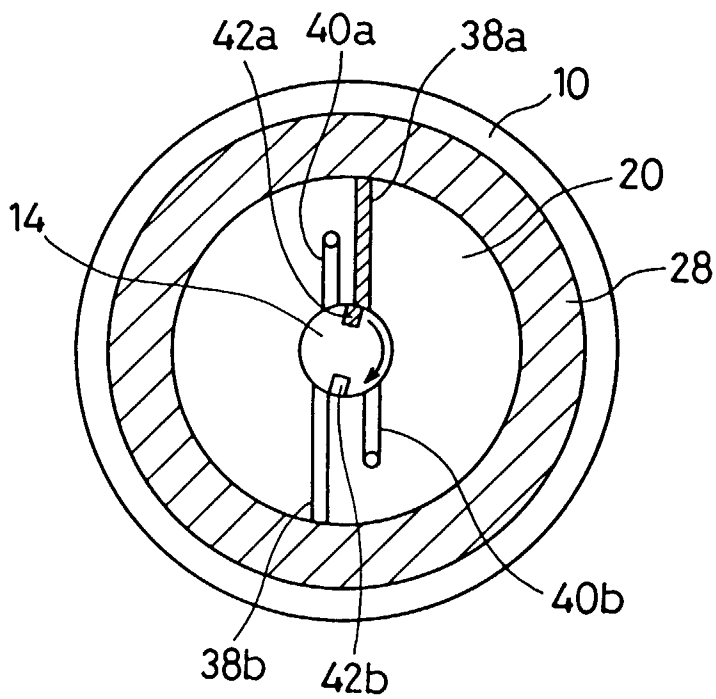
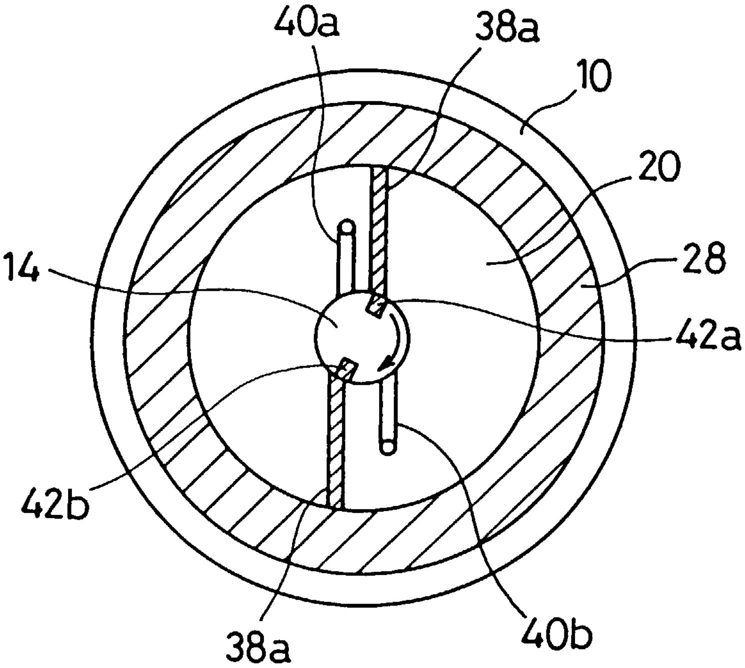

42a
40a
38a
10
20
28
14
38b
42b
40b

FIG. 2B


42a
40a
38a
10
14
20
28
40b
38b
42b

F I G. 3 A



F I G. 3 B

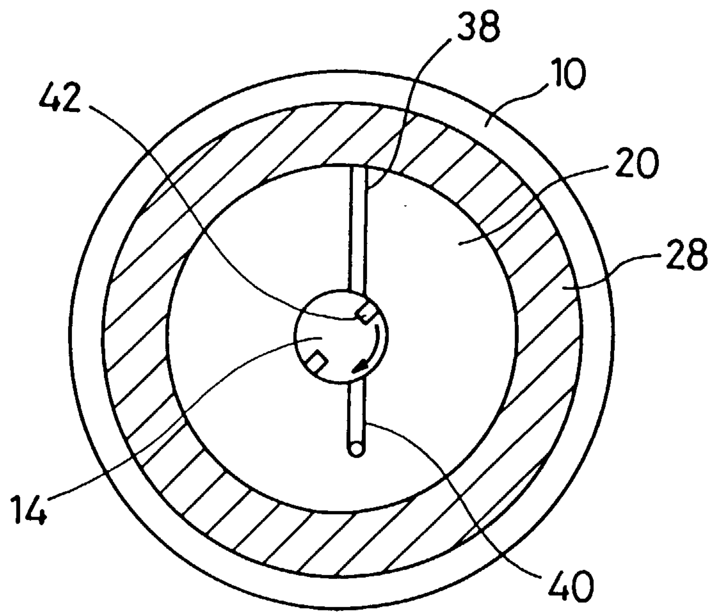


FIG. 4

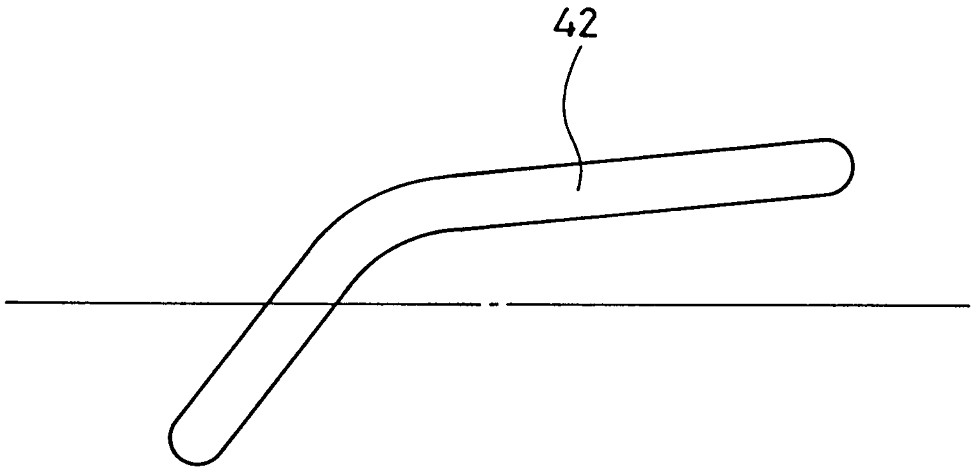


FIG. 5

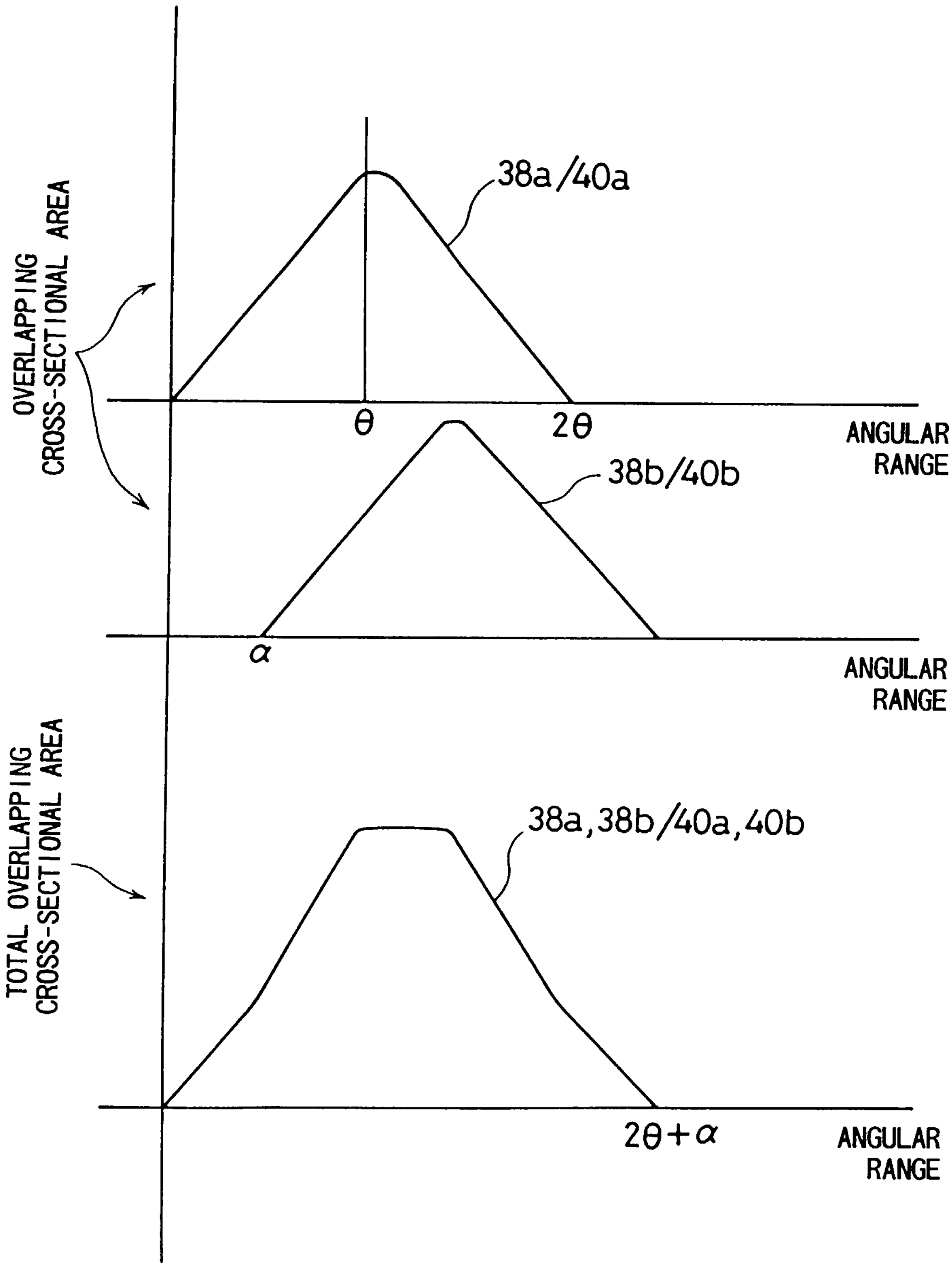

OVERLAPPING CROSS-SECTIONAL AREA
38a/40a
θ
2θ
ANGULAR RANGE
38b/40b
α
ANGULAR RANGE
TOTAL OVERLAPPING CROSS-SECTIONAL AREA
38a,38b/40a,40b
2θ+α
ANGULAR RANGE

FIG. 6

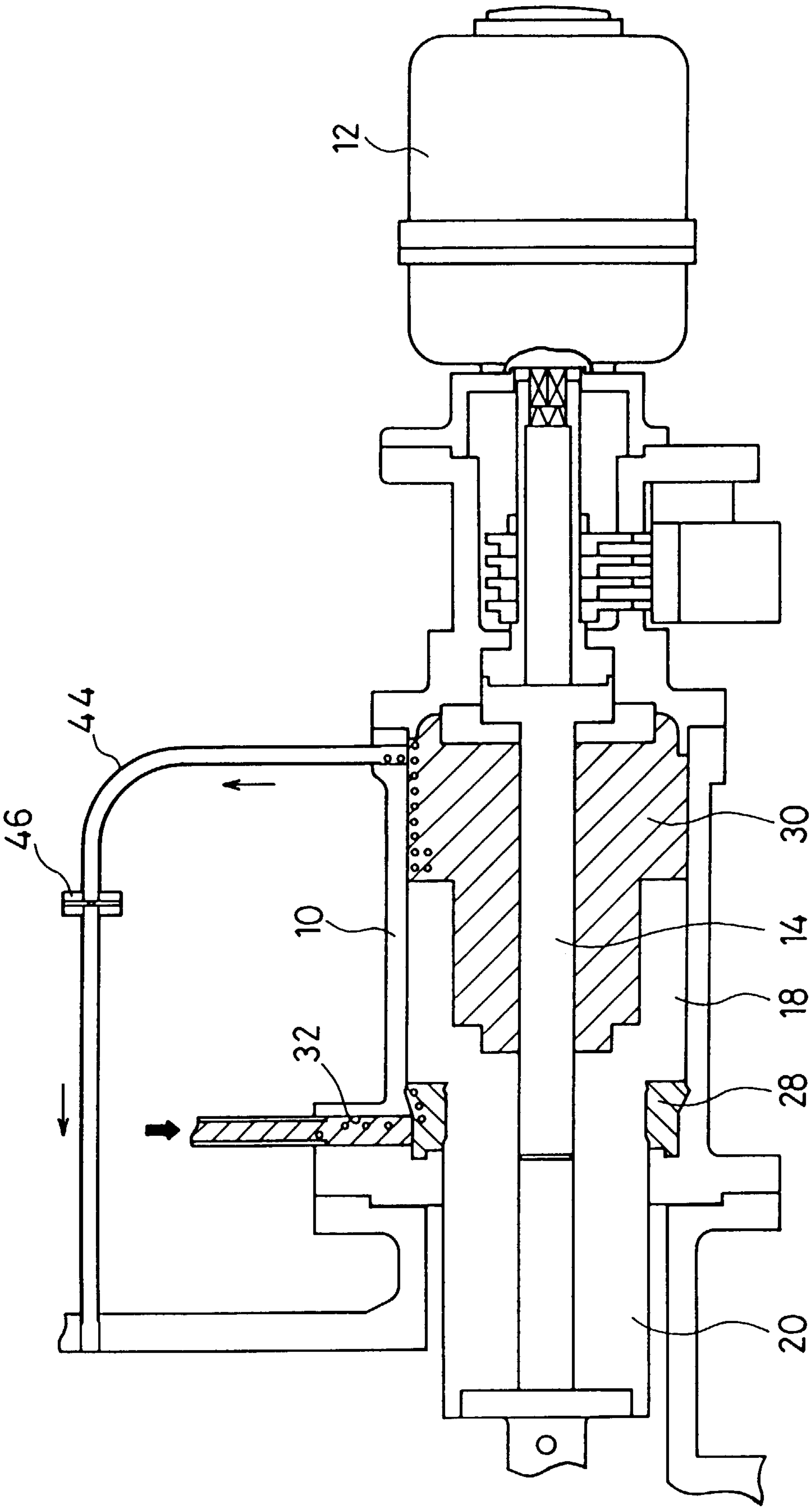


FIG. 7

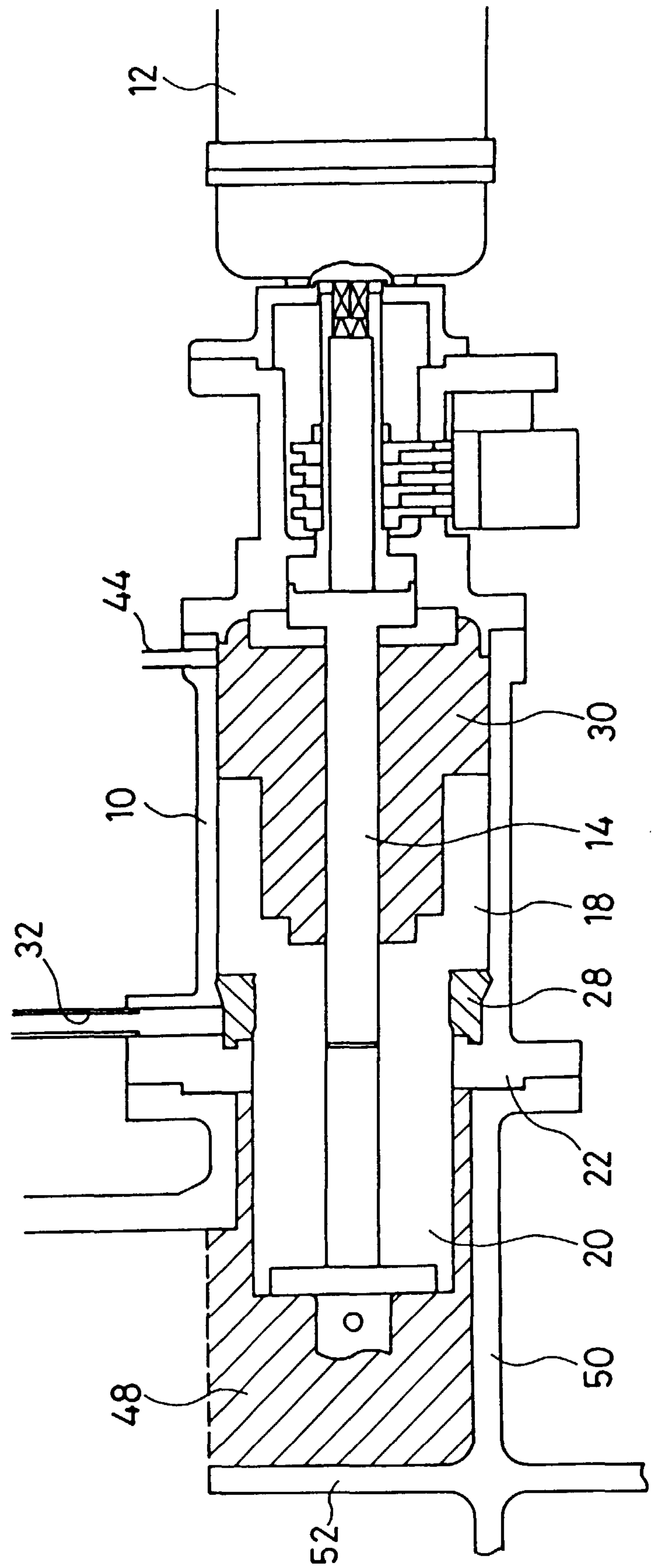
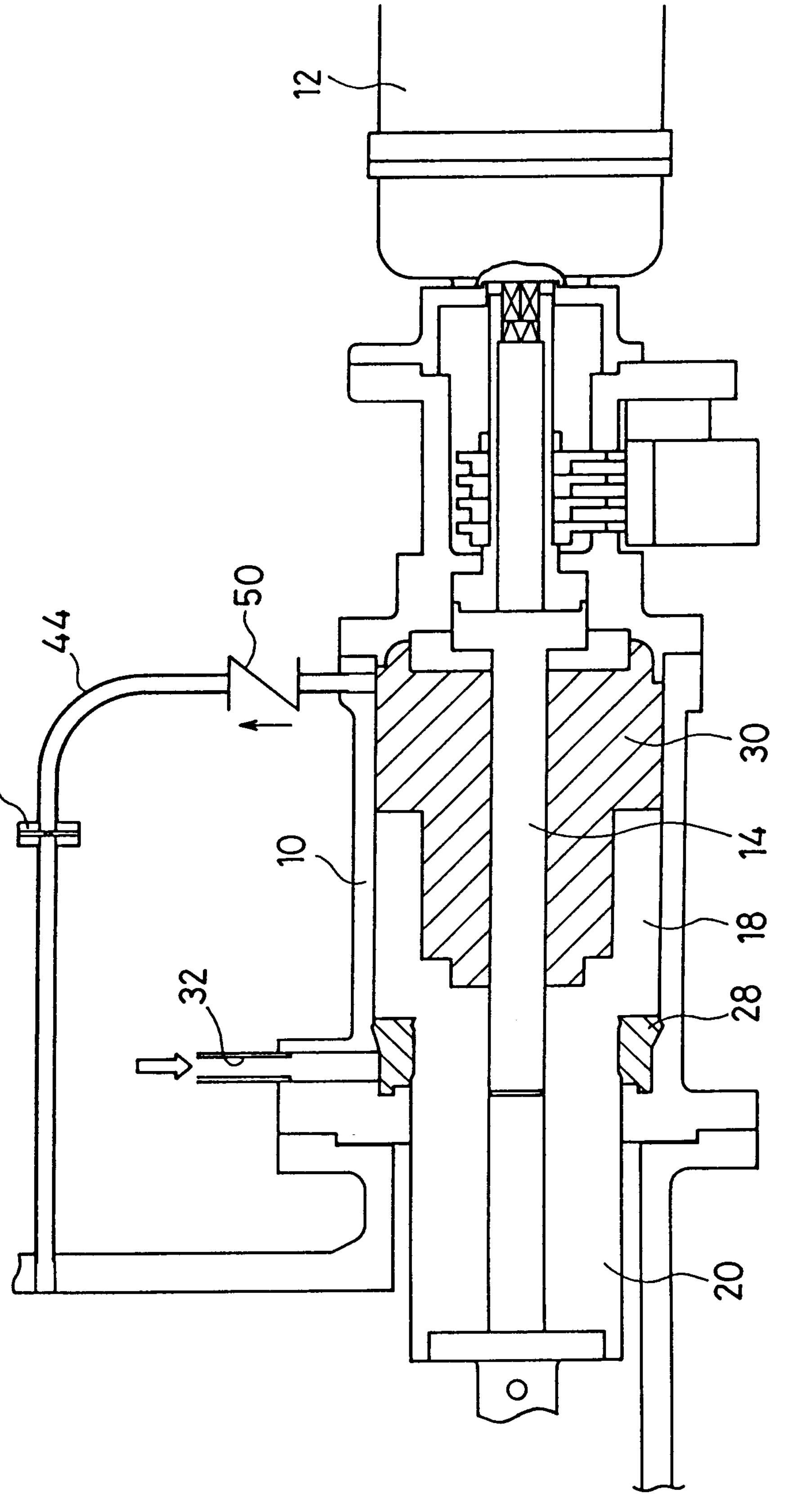


FIG. 8



F I G. 9

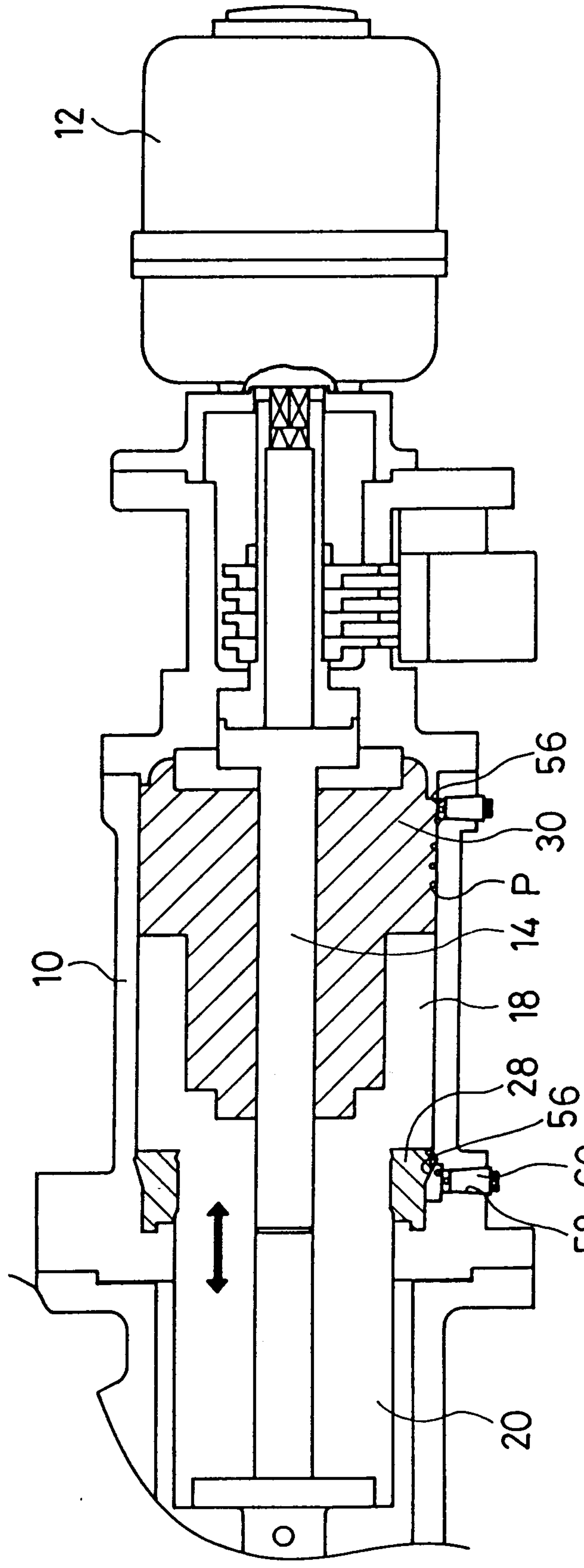


FIG. 10

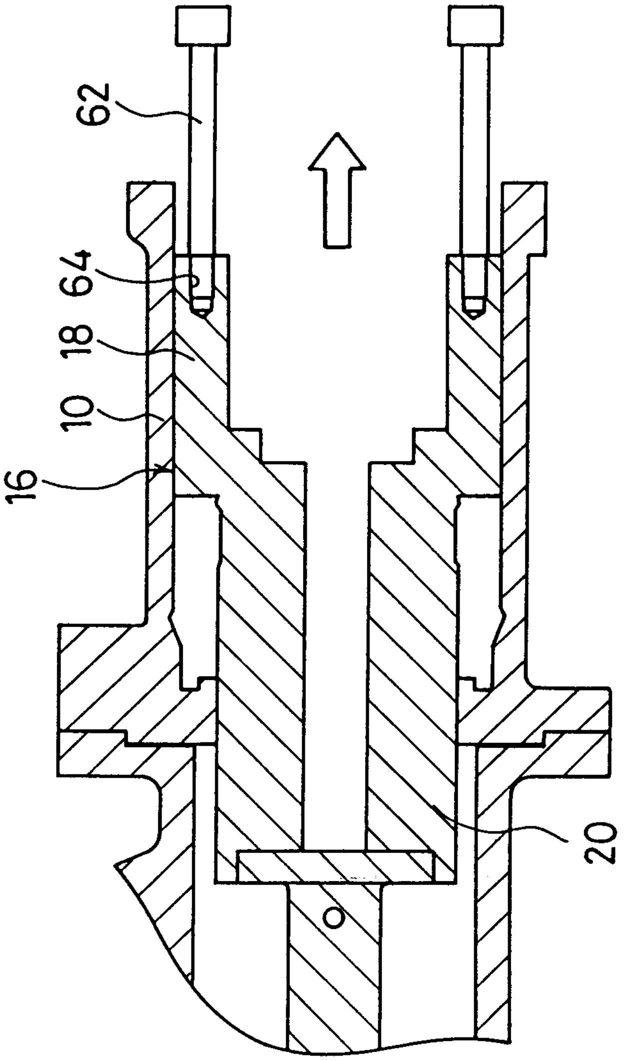


FIG. 11