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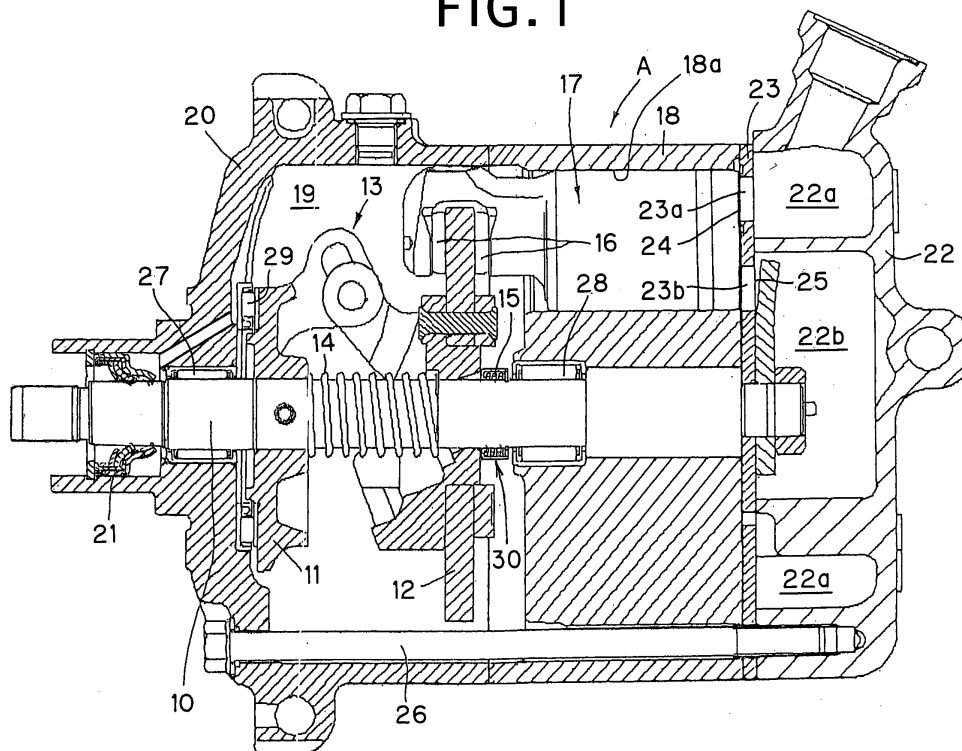
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(54) **Variable displacement swash plate compressor**

(57) A variable displacement swash plate compressor comprises a rotating shaft, a swash plate fitted on the rotating shaft to engage the rotating shaft slidably and to be variable in inclination relative to the rotating shaft, thereby rotating synchronously with the rotating shaft, a first spring for forcing the swash plate in the direction decreasing the inclination of the swash plate, a second spring for forcing the swash plate inclined to near the minimum inclination in the direction increasing the inclination of the swash plate, and a damper for countering the short period variation of the inclination of the swash plate inclined to near the minimum inclination.

**FIG. 1**



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**Description**

## BACKGROUND OF THE INVENTION

5   **[0001]** The present invention relates to a variable displacement swash plate compressor.

**[0002]** Japanese Patent Laid-Open Publication No. 2000-002180 teaches a variable displacement swash plate compressor comprising a rotating shaft, a swash plate fitted on the rotating shaft to engage the rotating shaft slidably and to be variable in inclination relative to the rotating shaft, thereby rotating synchronously with the rotating shaft, a first spring for forcing the swash plate in the direction decreasing the inclination, and a second spring for forcing the swash plate inclined to near the minimum inclination in the direction increasing the inclination.

10   **[0003]** When the variable displacement swash plate compressor is operated with the swash plate inclined to near the minimum inclination, the load acting on the compressor becomes nearly zero. As a result, the biasing forces of the first spring and the second spring become the primary forces acting on the swash plate, the inclination of the swash plate becomes liable to increase and decrease repeatedly with a short period near the minimum inclination owing to the telescopic motions of the two springs, and the swash plate becomes liable to move unstably. The unstable movement of the swash plate causes wear and fatigue of the elements of the compressor.

## SUMMARY OF THE INVENTION

20   **[0004]** An object of the present invention is to provide a variable displacement swash plate compressor comprising a rotating shaft, a swash plate fitted on the rotating shaft to engage the rotating shaft slidably and to be variable in inclination relative to the rotating shaft, thereby rotating synchronously with the rotating shaft, a first spring for forcing the swash plate in the direction decreasing the inclination, and a second spring for forcing the swash plate inclined to near the minimum inclination in the direction increasing the inclination, wherein short periodical increase and decrease of the inclination of the swash plate inclined to near the minimum inclination is prevented.

25   **[0005]** In accordance with the present invention, there is provided a variable displacement swash plate compressor comprising a rotating shaft, a swash plate fitted on the rotating shaft to engage the rotating shaft slidably and to be variable in inclination relative to the rotating shaft, thereby rotating synchronously with the rotating shaft, a first spring for forcing the swash plate in the direction decreasing the inclination of the swash plate, a second spring for forcing the swash plate inclined to near the minimum inclination in the direction increasing the inclination of the swash plate, and a damper for countering the short period variation of the inclination of the swash plate inclined to near the minimum inclination.

30   **[0006]** In the variable displacement swash plate compressor of the present invention, the damper counters the short period variation of the inclination of the swash plate inclined to near the minimum inclination to prevent the short periodical increase and decrease of the inclination of the swash plate inclined to near the minimum inclination.

35   **[0007]** In a preferred embodiment of the present invention, the damper forms a case for accommodating the second spring.

**[0008]** When the damper forms a case for accommodating the second spring, the compressor becomes smaller than that wherein the damper is disposed independent of the second spring.

40   **[0009]** In another preferred embodiment of the present invention, the second spring fits on the rotating shaft, the damper comprises a cylindrical body provided with an annular bottom wall opposing the swash plate and slidably fitting on the rotating shaft and a circumferential sidewall, and a cap slidably fitting in the open end of the cylindrical body and fitting on the rotating shaft, the second spring abuts the bottom wall of the cylindrical body at the end adjacent to the swash plate and abuts the cap at the end distanced from the swash plate, and the cap is prevented from moving in the direction away from the swash plate.

45   **[0010]** When the second spring fits on the rotating shaft, the damper provided with the aforementioned simple structure can prevent the short periodical increase and decrease of the inclination of the swash plate inclined to near the minimum inclination.

50   **[0011]** In another preferred embodiment of the present invention, a snap ring fixed to the rotating shaft prevents the cap from moving in the direction away from the swash plate.

**[0012]** In another preferred embodiment of the present invention, the cap is press fitted on the rotating shaft to be prevented from moving in the direction away from the swash plate.

**[0013]** The cap can be prevented from moving in the direction away from the swash plate by snap ring fixed to the rotating shaft or by press fitting on the rotating shaft.

55   **[0014]** In another preferred embodiment of the present invention, the cylindrical body or the cap is provided with a pore.

**[0015]** The damping force of the damper against the short periodical increase and decrease of the inclination of the swash plate can be adjusted by adjusting the size of the pore formed in the cylindrical body or the cap.

**[0016]** In another preferred embodiment of the present invention, the circumferential sidewall of the cylindrical body

is provided with a pore elongated in the longitudinal direction of the cylindrical body, the elongated pore can overlap the cap, and the opening area of the elongated pore decreases as the inclination of the swash plate decreases.

**[0017]** When the inclination of the swash plate becomes minimum, the opening area of the elongated pore becomes minimum to maximize the damping force against the short periodical increase and decrease of the inclination of the swash plate, thereby effectively preventing the short periodical increase and decrease of the inclination of the swash plate inclined to near the minimum inclination.

**[0018]** In another preferred embodiment of the present invention, the cylindrical body is provided with a projection for abutting the end face of the cap distanced from the bottom wall of the cylindrical body at the open end.

**[0019]** The projection prevents the cylindrical body from leaving the cap.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0020]** In the drawings:

Figure 1 is a sectional view of a variable displacement swash plate compressor in accordance with the first preferred embodiment of the present invention.

Figure 2 is an enlarged sectional view of the damper of the variable displacement swash plate compressor in accordance with the first preferred embodiment of the present invention.

Figure 3 is an enlarged sectional view of the damper of a variable displacement swash plate compressor in accordance with the second preferred embodiment of the present invention.

Figure 4 is a set of structural views of the damper of a variable displacement swash plate compressor in accordance with the third preferred embodiment of the present invention. Figures 4(a) and 4(c) are enlarged sectional views, and Figures 4(b) and 4(d) are perspective views.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

**[0021]** A variable displacement swash plate compressor in accordance with the first preferred embodiment of the present invention will be described.

**[0022]** As shown in Figure 1, a variable displacement swash plate compressor A is provided with a rotating shaft 10, a rotor 11 fixed to the rotating shaft 10, and a swash plate 12 fitted on the rotating shaft 10 to engage the rotating shaft 10 slidably and to be variable in inclination relative to the rotating shaft 10. The swash plate 12 is connected to the rotor 11 through a linkage 13 to be variable in inclination relative to the driving shaft 10, thereby rotating synchronously with the rotating shaft 10.

**[0023]** A first spring 14 is disposed between the rotor 11 and the swash plate 12 and fits on the rotating shaft 10 to force the swash plate 12 in the direction decreasing the inclination of the swash plate 12. A second spring 15 fits on the rotating shaft 10 to force the swash plate 12 in the direction increasing the inclination of the swash plate 12. The first spring 14 and the second spring 15 are disposed to face opposite surfaces of the swash plate 12.

**[0024]** A plurality of pistons 17 engage the swash plate 12 through a plurality of pairs of shoes 16 that slidably engage the outer peripheral portion of the swash plate 12. The pistons 17 are inserted into cylinder bores 18a formed in a cylinder block 18.

**[0025]** The plurality of pairs of shoes 16, the pistons 17 and the cylinder bores 18a are distanced from each other in the circumferential direction.

**[0026]** The rotor 11, the swash plate 12, the linkage 13, the shoes 16 and the pistons 17 form a compressing mechanism driven by the rotating shaft 10.

**[0027]** A cylindrical front housing 20 provided with a bottom wall forms a crank chamber 19 for accommodating the rotating shaft 10, the rotor 11 and the swash plate 12. The fore end portion of the rotating shaft 10 passes through the bottom wall of the front housing 20 to extend out of the front housing 20.

**[0028]** A seal member 21 is disposed in the annular space between the bottom wall of the front housing 20 and the rotating shaft 10.

**[0029]** A rotating force is transferred from a power source not shown in the figures to the fore end portion of the rotating shaft 10.

**[0030]** A cylinder head 22 is installed to form an inlet chamber 22a and an outlet chamber 22b.

**[0031]** A valve plate 23 is disposed between the cylinder block 18 and the cylinder head 22. The valve plate 23 is provided with inlet holes 23a and outlet holes 23b communicating with the cylinder bores 18a. Inlet valves 24 and outlet valves 25 are fitted to the valve plate 23.

**[0032]** The front housing 20, the cylinder block 18, the valve plate 23 and the cylinder head 22 are assembled as a unitary body by a plurality of through bolts 26 circumferentially distanced from each other.

**[0033]** The rotating shaft 10 is rotatably supported by radial bearings 27 and 28 disposed in the front housing 20 and

the cylinder block 18. The rotor 11 is rotatably supported by a thrust bearing 29 disposed in the front housing 20.

**[0034]** A damper 30 is disposed to accommodate the second spring 15.

**[0035]** As shown in Figure 2, the damper 30 comprises a cylindrical body 31 provided with an annular bottom wall 31a opposing the swash plate 12 and slidably fitting on the rotating shaft 10 and a circumferential sidewall 31b, and a cap 32 slidably fitting in the cylindrical body 31 and slidably fitting on the rotating shaft 10. The second spring 15 abuts the bottom wall 31a of the cylindrical body 31 at the end adjacent to the swash plate 12 and abuts the cap 32 at the end distanced from the swash plate 12. The cap 32 is restricted from moving in the direction away from the swash plate 12 by a snap ring 33 fixed to the rotating shaft 10.

**[0036]** The cylindrical body 31 is provided with projections 31c at the open end. The projections 31c can abut the end face of the cap 32 distanced from the bottom wall 31a of the cylindrical body 31.

**[0037]** The operation of the variable displacement swash plate compressor A is as follows. Rotating force is transferred to the rotating shaft 10 from the external power source not shown in the figures, and rotation of the rotating shaft 10 is transferred to the swash plate 12 through the rotor 11 and the linkage 13. The rotation of the swash plate 12 causes reciprocal movement of the peripheral portion of the swash plate 12 in the longitudinal direction of the rotating shaft 10. The reciprocal movement of the peripheral portion of the swash plate 12 is transferred to the pistons 17 through the shoes 16, and the pistons 17 move reciprocally in the cylinder bores 18a. Refrigerant gas enters into the inlet chamber 22a from an external refrigerant circuit through an inlet port formed in the cylinder head 22. The refrigerant gas is sucked into the cylinder bores 18a through the inlet holes 23a and the inlet valves 24 to be pressurized in the cylinder bores 18a. The pressurized refrigerant gas in the cylinder bores 18a discharges into the outlet chamber 22b through the outlet holes 23b and the outlet valves 25, and then discharges from the outlet chamber 22b into the external refrigerant circuit through an outlet port formed in the cylinder head 22.

**[0038]** A displacement control valve not shown in the figures controls the introduction of the pressurized refrigerant gas in the outlet chamber 22b into the crank chamber 19 to control the internal pressure in the crank chamber 19 and the inclination of the swash plate 12, thereby controlling displacement of the variable displacement compressor A.

**[0039]** When the inclination of the swash plate 12 decreases, the first spring 14 extends to force the swash plate 12 toward the cylinder block 18. The swash plate 12 moves toward the cylinder block 18 and the inclination of the swash plate 12 decreases. When the inclination of the swash plate 12 decreases to a predetermined angle near the minimum inclination angle, the swash plate 12 abuts the bottom wall 31a of the damper 30. When the inclination of the swash plate 12 further decreases, the swash plate 12 further moves toward the cylinder block 18 and forces the cylindrical body 31 toward the cap 32. The cylindrical body 31 slides toward the cap 32 and contracts the second spring 15 that abuts the cap 32 prevented from moving in the direction away from the swash plate 12 by the snap ring 33 and is prevented from rigid body movement.

**[0040]** When the inclination of the swash plate 12 increases, the second spring 15 extends to force the swash plate 12 toward the front housing 20. The projections 31c prevent the cylindrical body 31 from leaving the cap 32.

**[0041]** When the variable displacement swash plate compressor A is operated with the swash plate 12 inclined to near the minimum inclination, the load acting on the compressor A becomes nearly zero. As a result, the biasing forces of the first spring 14 and the second spring 15 become the primary forces acting on the swash plate 12. Therefore, generally speaking, the inclination of the swash plate 12 becomes liable to increase and decrease repeatedly with a short period near the minimum inclination owing to the telescopic motions of the springs 14 and 15, and the swash plate 12 becomes liable to move unstably. The unstable movement of the swash plate 12 causes wear and fatigue of the elements of the compressor A.

**[0042]** However, in the variable displacement swash plate compressor A, the swash plate 12 abuts the bottom wall 31a of the damper 30 when the inclination of the swash plate decreases to near the minimum inclination. When the inclination of the swash plate 12 repeats the increase and decrease near the minimum inclination, and the swash plate 12 repeats reciprocally the movement toward the cylinder block 18 and the movement toward the front housing 20, while abutting the bottom wall 31a of the damper 30, the cylindrical body 31 repeats reciprocally the movement toward the cap 32 and the movement away from the cap 32 under the biasing force of the second spring 15. The space enclosed by the rotating shaft 10, the cylindrical body 31 and the cap 32 is filled with the refrigerant gas and lubrication oil. When the cylindrical body 31 repeats reciprocally the movement toward the cap 32 and the movement away from the cap 32, discharging of the refrigerant gas and the lubrication oil from the aforementioned space and sucking of the refrigerant gas and the lubrication oil into the aforementioned space are repeated reciprocally through the clearances formed in the slidable abutments between the rotating shaft 10 and the bottom wall 31a of the cylindrical body 31, the rotating shaft 10 and the cap 32, and the cap 32 and the circumferential wall 31b of the cylindrical body 31. When the refrigerant gas and the lubrication oil are discharged from and sucked into the aforementioned space through the aforementioned clearances formed in the slidable abutments, resistance force proportional to the flow velocity of the refrigerant gas and the lubrication oil is generated due to the viscosities of the refrigerant gas and the lubrication oil. The resistance force prevents the short period discharging of the refrigerant gas and the lubrication oil from the aforementioned space and the short period sucking of the refrigerant gas and the lubrication oil into the aforementioned space, the short period

reciprocal movement of the cylindrical body 31 and the swash plate 12, the short period increase and decrease of the inclination of the swash plate 12, and the unstable movement of the swash plate 12.

**[0043]** The damper 30 forms a case for accommodating the second spring 15. Therefore, the compressor A becomes smaller than that wherein the damper 30 is disposed independent of the second spring 15.

**[0044]** When the second spring 15 fits on the rotating shaft 10, the damper 30 can be provided with the aforementioned simple structure to prevent the short period increase and decrease of the inclination of the swash plate 12 inclined to near the minimum inclination.

**[0045]** As shown in Figure 3, the cap 32 can be press fitted on the rotating shaft 10. The cap 32 is prevented from moving in the direction away from the swash plate 12. Thus, the snap spring 33 can be removed and the number of elements decreases.

**[0046]** The bottom wall 31a of the cylindrical body 31 can be provided with small pores 31d as shown in Figures 4(a) and 4(b). The circumferential sidewall 31b of the cylindrical body 31 can be provided with small pores 31e as shown in Figures 4(c) and 4(d).

**[0047]** The resistance force against the flow of the refrigerant gas and the lubricating oil through the small pores 31d and 31e can be adjusted and the damping force of the damper 30 against the short period increase and decrease of the inclination of the swash plate 12 inclined to near the minimum inclination can be adjusted by adjusting the opening areas of the small pores 31d and 31e.

**[0048]** The small pores 31e can be elongated in the longitudinal direction of the cylindrical body 31 to form elongated pores 31e' as shown in Figure 4(c). The elongated pores 31e' can overlap the cap 32 and the opening areas thereof decrease as the inclination of the swash plate decreases. When the inclination of the swash plate 12 becomes minimum, the opening areas of the elongated pores 31e' become minimum to maximize the damping force against the short period increase and decrease of the inclination of the swash plate 12, thereby effectively preventing the short period increase and decrease of the inclination of the swash plate 12 inclined to near the minimum inclination.

**[0049]** The cap 32 can be provided with small pores 31f as shown in Figures 4(a). The resistance force against the flow of the refrigerant gas and the lubricating oil through the small pores 31f can be adjusted and the damping force of the damper 30 against the short period increase and decrease of the inclination of the swash plate 12 inclined to near the minimum inclination can be adjusted by adjusting the opening area of the pore small pores 31f.

**[0050]** While the present invention has been described with reference to preferred embodiments, one of ordinary skill in the art will recognize that modifications and improvements may be made while remaining within the spirit and scope of the present invention. The scope of the invention is determined solely by the attached claims.

## Claims

1. A variable displacement swash plate compressor comprising a rotating shaft, a swash plate fitted on the rotating shaft to engage the rotating shaft slidably and to be variable in inclination relative to the rotating shaft, thereby rotating synchronously with the rotating shaft, a first spring for forcing the swash plate in the direction decreasing the inclination of the swash plate, a second spring for forcing the swash plate inclined to near the minimum inclination in the direction increasing the inclination of the swash plate, and a damper for countering the short period variation of the inclination of the swash plate inclined to near the minimum inclination.
2. A variable displacement swash plate compressor of claim 1, wherein the damper forms a case for accommodating the second spring.
3. A variable displacement swash plate compressor of claim 1 or 2, wherein the second spring fits on the rotating shaft, the damper comprises a cylindrical body provided with an annular bottom wall opposing the swash plate and slidably fitting on the rotating shaft and a circumferential sidewall, and a cap slidably fitting in the open end of the cylindrical body and fitting on the rotating shaft, the second spring abuts the bottom wall of the cylindrical body at the end adjacent to the swash plate and abuts the cap at the end distanced from the swash plate, and the cap is prevented from moving in the direction away from the swash plate.
4. A variable displacement swash plate compressor of claim 3, wherein a snap ring fixed to the rotating shaft prevents the cap from moving in the direction away from the swash plate.
5. A variable displacement swash plate compressor of claim 3, wherein the cap is press fitted on the rotating shaft to be prevented from moving in the direction away from the swash plate.
6. A variable displacement swash plate compressor of any one of claims 3 to 5, wherein the cylindrical body or the

cap is provided with a pore.

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7. A variable displacement swash plate compressor of any one of claims 3 to 5, wherein the circumferential sidewall of the cylindrical body is provided with a pore elongated in the longitudinal direction of the cylindrical body, and wherein the elongated pore can overlap the cap and the opening area of the elongated pore decreases as the inclination of the swash plate decreases.
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8. A variable displacement swash plate compressor of any one of claims 3 to 7, wherein the cylindrical body is provided with a projection for abutting the end face of the cap distanced from the bottom wall of the cylindrical body at the open end.

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FIG. 1

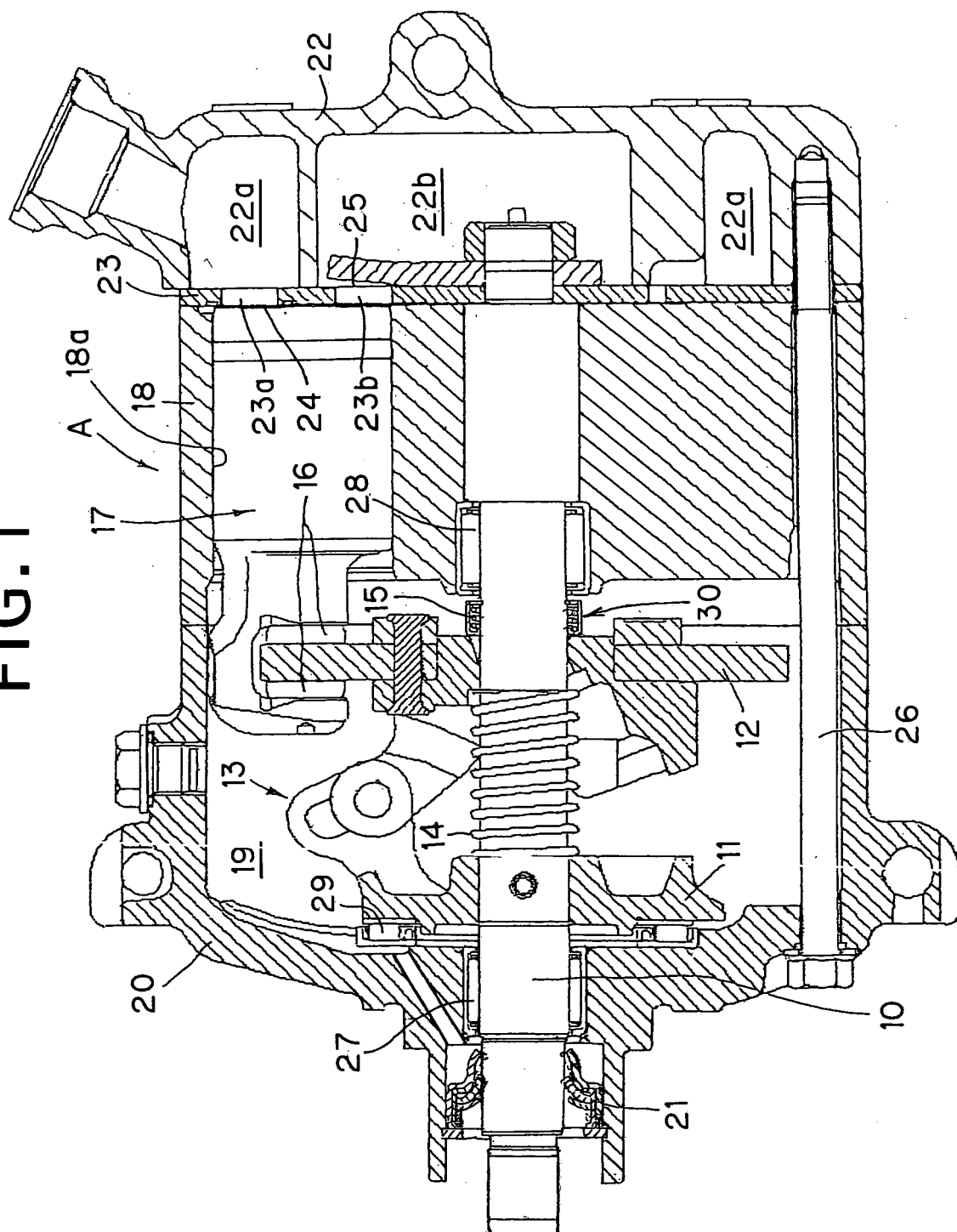


FIG. 2

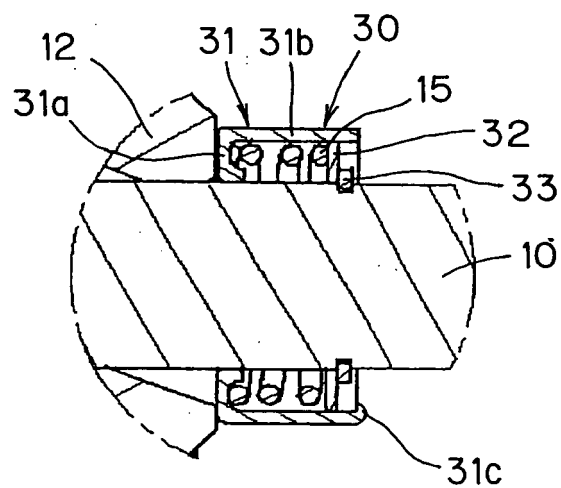


FIG. 3

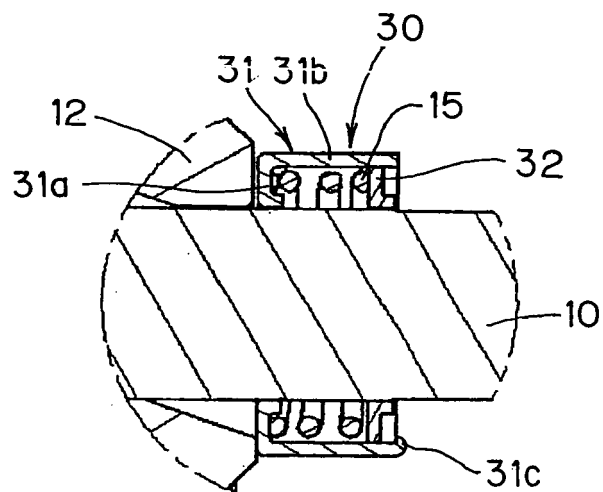


FIG.4(a)

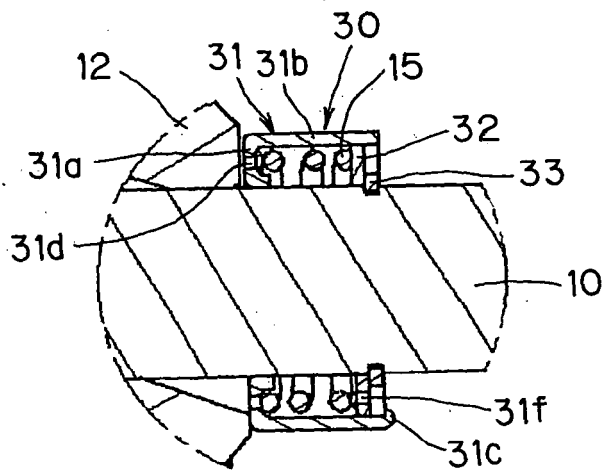


FIG.4(b)

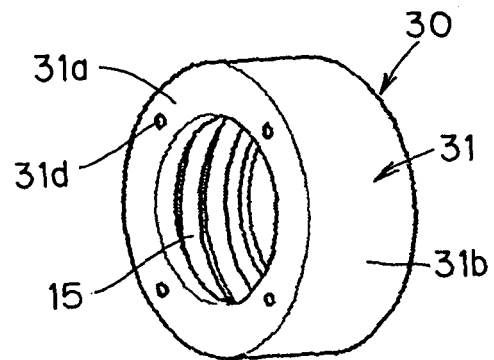


FIG.4(c)

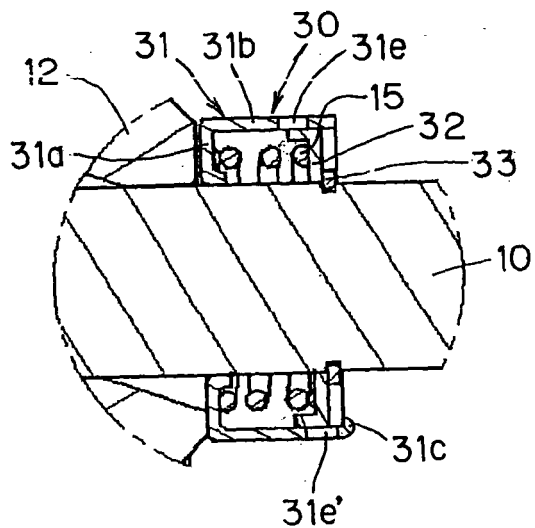
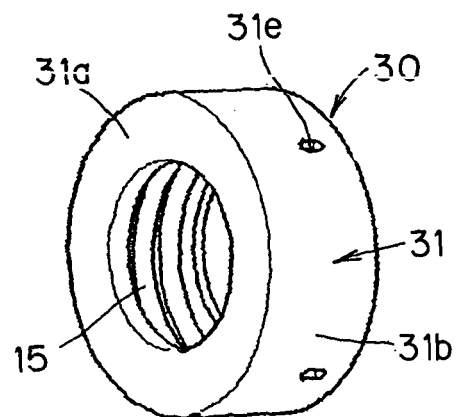


FIG.4(d)





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Application Number  
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| DOCUMENTS CONSIDERED TO BE RELEVANT                                                                                                                                                                                                                       |                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                             |                                         |
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| The present search report has been drawn up for all claims                                                                                                                                                                                                |                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                             |                                         |
| Place of search<br>Munich                                                                                                                                                                                                                                 |                                                                                                                                                                                       | Date of completion of the search<br>12 April 2006                                                                                                                                                                                                                                           | Examiner<br>Pinna, S                    |
| CATEGORY OF CITED DOCUMENTS<br>X : particularly relevant if taken alone<br>Y : particularly relevant if combined with another<br>document of the same category<br>A : technological background<br>O : non-written disclosure<br>P : intermediate document |                                                                                                                                                                                       | T : theory or principle underlying the invention<br>E : earlier patent document, but published on, or<br>after the filing date<br>D : document cited in the application<br>L : document cited for other reasons<br>.....<br>& : member of the same patent family, corresponding<br>document |                                         |

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EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT  
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EP 06 00 4335

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.  
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