(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 512 871 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
09.03.2005 Bulletin 2005/10

(51) Int Cl.[7]: **F04B 27/18**

(21) Application number: **04020189.9**

(22) Date of filing: **25.08.2004**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IT LI LU MC NL PL PT RO SE SI SK TR
Designated Extension States:
AL HR LT LV MK

(30) Priority: **04.09.2003 JP 2003312369**
25.09.2003 JP 2003332652

(71) Applicant: **TGK Co., Ltd.**
Hachioji-shi, Tokyo 193-0942 (JP)

(72) Inventors:
- **Hirota, Hisatoshi**
  Hachioji-shi Tokyo 193-0942 (JP)
- **Kajiwara, Morimitsu**
  Hachioji-shi Tokyo 193-0942 (JP)
- **Yoshihiro, Ryosuke**
  Hachioji-shi Tokyo 193-0942 (JP)

(74) Representative: **Grünecker, Kinkeldey, Stockmair & Schwanhäusser Anwaltssozietät**
Maximilianstrasse 58
80538 München (DE)

(54) **Capacity control valve for variable displacement compressor**

(57) A capacity control valve includes a valve section 1 having a first or Pd-Pc valve 6, 7 and a second or Pc-Ps valve 10, 11 operating in a manner interlocked with the operation of the Pd-Pc valve. A spool valve element 11a is provided on a valve element 11 of the second or Pc-Ps valve. In a stroke region where the Pd-Pc valve is close to the fully-closed position, refrigerant passes through the clearance between the spool valve element 11a and the valve hole of the valve seat 10 of the second or Pc-Ps valve. The second or Pc-Ps valve has a characteristic such that its opening area does not change when the valve element 11 moves. This suppresses sharp changes in the pressure Pc in the crankcase, even if the solenoid current is stepwise sharply changed.

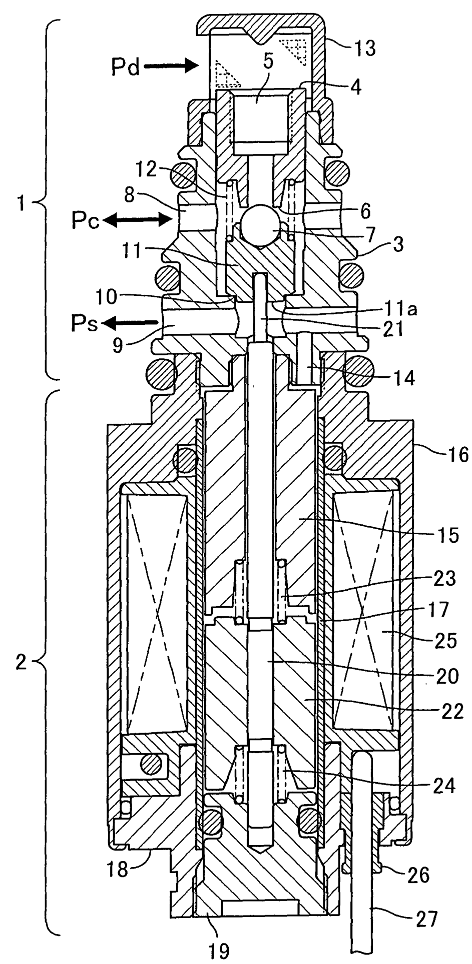

FIG. 1

EP 1 512 871 A1

Description

[0001] The invention relates to a capacity control valve according to the preamble of claim 1, particularly for a variable displacement compressor in a refrigeration cycle of an automotive air conditioner.

[0002] In a known compressor (EP 1 279 831 A2), compression pistons are connected to a wobble plate tiltably fitted on a shaft driven by the engine. The angle of the wobble plate is varied to change the stroke of the pistons for changing the displacement of the compressor. The wobble plate angle is continuously changed by introducing part of the compressed refrigerant into an airtight crankcase and changing the pressure Pc in the crankcase, thereby changing the balance between pressures applied to the opposite ends of each piston. The capacity control valve comprises two control valves disposed in respective refrigerant passages between the discharge chamber and the crankcase and between the crankcase and the suction chamber. Both control valves operate in a manner interlocked with each other. The capacity control valve controls the discharging capacity of the compressor such that the differential pressure (Pd - Ps) between the discharge pressure Pd and the suction pressure Ps of the compressor is held a predetermined value. The first control valve ("the Pd-Pc valve") for high pressure controls the flow rate from the discharge chamber into the crankcase. The second control valve ("the Pc-Ps valve") for low pressure controls the flow rate from the crankcase into the suction chamber in a manner interlocked with the operation of the first or Pd-Pc valve. A solenoid serves to externally set a predetermined differential pressure (Pd - Ps) by a current value.

[0003] Fig. 7 shows characteristics of the capacity control valve of EP 1 279 831 A2, Fig. 8 shows characteristics of the variable displacement compressor of EP 1 278 983 A2.

[0004] When in Fig. 7 the first or Pd-Pc valve leaves the closed state in an opening area-increasing direction, the second or Pc-Ps valve moves from the fully-open state in an opening area-decreasing direction in a manner interlocked with the operation of the first or Pd-Pc valve, and vice versa. When the stroke position is changed by the electric current supplied to the solenoid, the respective opening areas of both valves are changed in opposite directions, which increases the amount of change in the pressure Pc in the crankcase, and which allows to promptly change the variable displacement of the compressor. The known compressor suffers from the problem that when the current is stepwise changed, the pressure Pc in the crankcase is largely changed, which causes a large change in the differential pressure (Pd - Ps), which is to be controlled, causing a large overshoot. This means that the torque momentarily consumed by the compressor is largely changed only at the moment when the solenoid current is changed. This causes a large variation of the load on the engine. More specifically, when the solenoid current is stepwise increased (Fig. 8), the Pd-Pc valve rapidly moves in the valve-closing direction and the Pc-Ps valve as well rapidly moves in the valve-opening direction. A too rapid drop in the pressure Pc in the crankcase is then the result so that the pressure Pc once undergoes a sharp drop and then changes such that it settles to the predetermined pressure. The discharging capacity is excessively increased in response to the sharp drop in the pressure Pc in the crankcase, resulting in a sharp increase of the torque consumed by the compressor, and in an overshoot.

[0005] It is an object of the invention to provide a capacity control valve for a variable displacement compressor, which suppresses a overshoot when the differential pressure between the discharge pressure and the suction pressure is changed in response to a stepwise change in the solenoid current.

[0006] This object is achieved by the features of claim 1.

[0007] Since there is a flow rate-restricting means associated to the second control valve when the solenoid current is stepwise changed, the flow rate-restricting means suppresses a resulting sharp change in the pressure in the crankcase such that an excessive rise or excessive drop in the pressure cannot occur. This prevents overshooting of the differential pressure between the discharge pressure and the suction pressure, and reduces variations of the torque consumed by the compressor. As a result, it is possible to reduce variation of the load on the engine that drives the compressor.

[0008] Embodiments of the invention will be described with reference to the drawings. In the drawings is:

Fig. 1 a central longitudinal cross-section of a capacity control valve (first embodiment),

Fig. 2 a diagram showing characteristics of the capacity control valve of Fig. 1,

Fig. 3 a diagram showing characteristics of the variable displacement compressor using the capacity control valve of Fig. 1,

Fig. 4 a central longitudinal cross-section of a second embodiment of the capacity control valve,

Fig. 5 a central longitudinal cross-section of a third embodiment of the capacity control valve,

Fig. 6 a central longitudinal cross-section of a fourth embodiment of the capacity control valve,

Fig. 7 a diagram of characteristics of a conventional capacity control valve, and

Fig. 8 a diagram of characteristics of a variable displacement compressor using the conventional capacity control valve of Fig. 7.

[0009] The capacity control valve in Fig. 1 has a valve section 1 and a solenoid section 2. The valve section 1 includes a body 3 having a top opening receiving an open plug 4. The plug 4 has an axial hole forming a port 5 for receiving refrigerant at a discharge pressure Pd from a not shown discharge chamber of a variable displacement compressor, and forming a valve seat 6. Opposed to the valve seat 6, a ball valve element 7 is disposed axially movable A space receiving the ball valve element 7 communicates with the not shown crankcase of the variable displacement compressor via a port 8 formed in the body 3. The ball valve element 7 and the valve seat 6 form a Pd-Pc valve (first control valve) that controls the flow rate of refrigerant at the discharge pressure Pd to fill the crankcase with a pressure Pc.

[0010] The body 3 has a port 9 communicating with a not shown suction chamber of the variable displacement compressor. A valve seat 10 is integrally formed with the body 3 in a passage between the ports 8, 9. A valve element 11 which also holds the ball valve element 7 of the Pd-Pc valve is axially disposed opposed to the valve seat 10. Interposed between the valve element 11 and the plug 4 is a spring 12 urging the ball valve element 7 in valve-opening direction and the valve element 11 in valve-closing direction. The valve element 11 and the valve seat 10 form a Pc-Ps valve (second control valve) which controls the flow rate of refrigerant at pressure Pc in the crankcase to fill the suction chamber with refrigerant at suction pressure Ps.

[0011] The capacity control valve in Fig. 1 is characterized in that the second control valve includes a spool valve structure whose opening area does not change at least as long as the valve element 7 of the Pd-Pc valve is open but is not fully open. For this function, a spool valve element 11 a disposed within a valve hole of the valve seat 10 of the second or Pc-Ps valve is integrally formed with the valve element 11 at an end face of the valve element 11 opposed to the valve seat 10. The second or Pc-Ps valve forms a spool valve for which in a stroke region where the valve element 11 moves axially to start to open the first or Pd-Pc valve, the dimension of the opening area of the second or Pc-Ps valve solely will be defined by a clearance between the spool valve element 11 a and the valve hole. The dimension of the clearance first does not change. Only in a stroke region in which the first or Pd-Pc valve is close to or in the fully-open position, the dimension of the opening area between the valve element 11 and the valve seat 10 changes until the second or Pc-Ps valve closes, i.e. the dimension of the opening area provided by the valve element 11 and the valve seat 10 then will become smaller than the dimension of the opening area provided by the flow restricting areas. The clearance which first does not change its opening area forms flow rate-restricting means.

[0012] The body 3 has a strainer 13 on the upper end. The port 9 is connected with a passage 14 in the body 3 transmitting the suction pressure Ps to the inside of the solenoid 2. It should be noted that in the valve section 1 in Fig. 1, the diameter of the valve hole of the valve seat 10 is larger than that of the valve hole of the valve seat 6 of the Pd-Pc valve, allowing refrigerant to instantly flow at a large flow rate.

[0013] The solenoid section 2 has a central core 15. An upper end of the core 15 is screwed into a lower end of the body 3. A yoke 16 encloses the core 15. An upper end of the yolk 16 is screwed onto the body 3. A sleeve 17 is disposed in the yoke 16. A hollow cylindrical holder 18 is provided on the lower ends of the yoke 16 and of the sleeve 17. The holder 18 receives an adjustment screw 19.

[0014] The core 15 has a central through hole receiving a shaft 20. The shaft 20 has one end supported in a through hole formed in the body 3, and another end supported in a recess in the adjustment screw 19. The shaft 20 has a shaft 21 integrally formed at the one end. The shaft 21 is reduced in diameter and is inserted into the valve element 11 for centering both the valve element 11 and the ball valve element 7. The shaft 20 has the same diameter as the valve hole of the valve seat 6 of the Pd-Pc valve. A pressure-receiving area of the ball valve element 7 where the discharge pressure Pd is received and a pressure-receiving area of the lower end of the shaft 20 where the suction pressure Ps introduced into the solenoid section 2 via the passage 14 is received are equal.

[0015] The solenoid section 2 further includes a plunger 22 fixed to the shaft 20 at a location between the core 15 and the adjustment screw 19. A spring 23 is disposed between the core 15 and the plunger 22. Another spring 24 is disposed between the plunger 22 and the adjustment screw 19. A coil 25 is disposed between the sleeve 17 and the yoke 16. The coil 25 is electrically connected to a harness 27 extending out of the solenoid section 2 via a waterproof coupler 26.

[0016] When no current is supplied to the coil 25 (e.g. when the automotive air conditioner is not in operation, or when the refrigerating load is the minimum), the plunger 22 is urged by the spring 23 away from the core 15, and the ball valve element 7 and the valve element 11 are urged by the spring 12 in a direction toward the solenoid section 2. The first or Pd-Pc valve for high pressure is in the fully-open position. The second or Pc-Ps valve for low pressure is in the fully-closed position. Introduced discharge pressure Pd is introduced into the crankcase via the first or Pd-Pc valve. Since the refrigerant passage between the crankcase and the suction chamber is closed by the second or Pc-Ps valve, the pressure Pc in the crankcase becomes closer to the discharge pressure Pd, minimizing the differential pressure between the pressures applied to the opposite end faces of the pistons of the compressor. This brings the wobble plate to an inclination angle which minimizes the stroke of the pistons. The compressor is controlled to the minimum displacement operation.

[0017] When no current is supplied to the coil 25 increases, the plunger 22 is attracted by the core 15 to move upward, and the shaft 20 fixed to the plunger 22 moves as well. As shown in Fig. 2, the opening area of the first or Pd-Pc valve decreases from a maximum as the ball valve element 7 moves toward the valve seat 6. The opening area of the second or Pc-Ps valve increases from zero as the valve element 11 moves away from the valve seat 10. Accordingly, the pressure Pc in the crankcase progressively decreases, so that the variable displacement compressor is controlled to operation with a displacement dependent on the value of the solenoid current.

[0018] When the solenoid current continues to be increased, the opening area of the first or Pd-Pc valve continues to decrease but the increase of the opening area of the second or Pc-Ps valve stops at a time point when the opening area between the valve element 11 and the valve seat 10 becomes larger than the opening area defined by the dimension of the clearance between the spool valve element 11a and the valve hole of the valve seat 10 of the second or Pc-Ps valve. Even if the solenoid current then increases further the Pc-Ps valve will show a flat characteristic such that the opening area does not change relative to the travel or stroke amount of the valve element 11 since the opening area remains restricted by the dimension of the clearance between the spool valve element 11a and the valve hole of the valve seat 10.

[0019] When the capacity control valve is controlled in this fashion by a predetermined solenoid current, the Pd-Pc valve and the Pc-Ps valve are controlled to respective stroke positions dependent on the value of the solenoid current. When the differential pressure between the discharge pressure Pd received by the ball valve element 7 and the suction pressure Ps received by the shaft 20 varies due to a change of the rotational speed of the engine and of the compressor, the capacity control valve accordingly will change the travel or stroke amounts of the valve elements 7, 11 of the Pd-Pc valve and the Pc-Ps valve to vary the displacement of the compressor. This provides a control such that the differential pressure Pd-Ps is held at a predetermined value as determined by the solenoid current.

[0020] As the Pc-Ps valve has the flat characteristic such that the opening area does not change in a region where the opening area of the Pd-Pc valve is small, and when the solenoid current is changed stepwise, the pressure Pc in the crankcase does not largely change relative to the change in the solenoid current, as shown in Fig. 3. If the solenoid current is increased, e.g. stepwise, in a region where the opening area of the Pc-Ps valve changes, the ratio of change of the opening area in opening direction of the Pc-Ps valve with respect to the stroke amount is larger than that of the change of the opening area in closing direction of the Pd-Pc valve with respect to the same stroke amount. The pressure Pc in the crankcase may tend to sharply decrease, but the range of this change is restricted by the flat characteristic of the Pc-Ps valve so that overshooting of the pressure Pc in the crankcase is prevented. As a result, overshooting of the differential pressure (Pd - Ps) between the discharge pressure Pd and the suction pressure Ps does not occur, either, which reduces variation in torque consumed by the compressor and hence reduces variation in load on the engine.

[0021] Similarly, if the solenoid current is increased, e.g. stepwise, in a region where the opening area of the Pc-Ps valve does not change due to the spool valve body 11a, the Pc-Ps valve opening area does not change relative to a stroke amount even though the Pd-Pc valve undergoes a change of opening area in the valve-closing direction relative to the same stroke amount. This reduces the range of variation of the pressure Pc in the crankcase. Therefore, the pressure Pc in the crankcase, the differential pressure (Pd - Ps), and the torque consumed by the compressor are reduced, consequently, this reduces the variations of the load on the engine. Of course, even when the solenoid current is stepwise decreased, an overshooting will be suppressed in the same manner.

[0022] The capacity control valve of Fig. 4 attains the same flat characteristic by an orifice 28 as the flow rate-restricting means whose opening area does not change.

[0023] In Fig. 4 the second or Pc-Ps valve has on the valve element 11 a surface with a tapered shape opposed to the valve seat 10. The orifice 28 is provided between the downstream side of the valve element 11, and the port 9 and the passage 14. The orifice 28 is disposed in series with the second or Pc-Ps valve. When the opening area of the Pc-Ps valve becomes larger between the valve element 11 and the valve seat 10 than the opening area of the orifice 28 because the valve element 11 travels further in opening direction, the opening area of the second or Pc-Ps valve will remain limited by the orifice 28 whose opening area does not change. The capacity control valve of Fig. 4 has the same characteristics as shown in Fig. 2.

[0024] Compared with the capacity control valve of Fig. 1 the capacity control valve in Fig. 5 is configured such that the operation of the second or Pc-Ps valve is not adversely affected by the pressure Pc in the crankcase.

[0025] The capacity control valve in Fig. 5 is provided with a passage 14' which connects a space 11b between the Pd-Pc valve and the Pc-Ps valve, with the inside 2a of the solenoid section 2. The pressure Pc is transmitted to the inside 2a of the solenoid section 2. The valve element 11 receives the pressure Pc in the space 11b in valve-closing direction, and also receives the pressure Pc from the solenoid section 2 via the shaft 20 in valve-opening direction. Therefore, the influence of the pressure Pc on the valve element 11 is cancelled. Even when the pressure Pc in the crankcase changes, the change does not adversely affect the operation of the second or Pc-Ps valve.

[0026] The pressure received by the valve element 11 in valve-opening direction is the sum of the pressure Pc in the crankcase received from the solenoid section 2 and the suction pressure Ps. At this time, the area where the pressure Pc is received is equal to the cross-sectional area of the shaft 20, and the area where the suction pressure Ps is received is equal to an area obtained by subtracting the cross-sectional area of the shaft 20 from the opening area of the valve hole of the valve seat 10 of the Pc-Ps valve, and is equal to the area where the discharge pressure Pd is received by the first or Pd-Pc valve, i.e. the opening area of the valve hole of the valve set 6 of the first or Pd-Pc valve.

[0027] The capacity control valve of Fig. 5 also has the valve characteristic shown in Fig. 2.

[0028] Compared with the capacity control valve of Fig. 4, the capacity control valve of Fig. 6 is configured such that the operation of the second or Pc-Ps valve is not adversely affected by the pressure Pc in the crankcase.

[0029] The capacity control valve in Fig. 6 is provided with the passage 14' which connects the space 11b between the Pd-Pc valve and the Pc-Ps with the inside 20 of the solenoid section 2, similar to the capacity control valve according to Fig. 5. The pressure Pc is transmitted to the inside 2a of the solenoid section 2. The influence of the pressure Pc received by the valve element 11 in opposite directions is cancelled.

Claims

1. A capacity control valve for a variable displacement compressor, for controlling pressure (Pc) in a crankcase to vary a discharging capacity such that a predetermined value of a differential pressure (Pd-Ps) between a pressure (Ps) in a suction chamber and pressure (Pd) in a discharge chamber is held, comprising:

a first control valve consisting of an axially moveable valve element (7) and of a stationary valve seat (6) for controlling the flow rate of refrigerant flowing from the discharge chamber into the crank case;

a second control valve consisting of an axially moveable valve element (11) and of a stationary valve seat (10) for controlling the flow rate of refrigerant flowing out of the crankcase into the suction chamber, in a manner interlocked with the operation of the valve element (7) of the first control valve; and

a solenoid section (2) for applying a solenoid force corresponding to the predetermined differential pressure to the valve elements (7, 11) of the first and second control valves,

characterized in that a flow rate-restricting means (11a, 28) is associated to the second control valve, and that the flow rate-restricting means is operable to provide an opening area the dimension of which remains at least essentially constant for a predetermined amount of the valve element stroke of the first and/or the second control valve.

2. Capacity control valve as in claim 1, **characterized in that** the dimension of the opening area of the flow rate-restricting means (11a, 28) remains at least essentially constant for a predetermined amount of the element opening stroke of the valve element (7) of the first control valve.

3. The capacity control valve as in claim 1, **characterized in that** the dimension of the opening area provided by the flow rate-restricting means (11a, 28) remains at least essentially constant and regulates the flow rate of refrigerant flowing out of the crank case into the suction chamber when the dimension of the opening area formed between the valve element (11) and the valve seat (10) of the second control valve exceeds the dimension of the opening area provided by the flow rate-restricting means.

4. Capacity control valve as in claim 1, **characterized in that** the flow rate-restricting means (11a) comprises a spool valve element provided on the valve element (11) of the second control valve to form a clearance of a predetermined dimension between the spool valve element (11a) and a valve hole of the valve seat (10) such that the dimension of the opening area of the clearance does not change.

5. Capacity control valve as in claim 1, **characterized in that** the flow rate-restricting means (28) is an orifice provided on a downstream side of the second control valve between the valve seat (10) and a port (9) connected to the suction chamber.

6. Capacity control valve as in at least one of the preceding claims, **characterized by** a passage (14') communicating between a space (11b) connected to the crank case and an inside (2a) of the solenoid section (2), such that the second control valve causes the pressure from the crank case introduced via the passage (14') into the solenoid section (2) to be received by the valve element (11) of the second control valve in valve opening direction to cancel out the pressure in the crank case received by the valve element (11) in the space (11b) in valve closing direction.

7. Capacity control valve as in claim 6, **characterized in that** a pressure receiving area of the valve element (11) of the second control valve obtained by subtracting an area where the pressure in the crank case is received via the solenoid section (2) from an opening area of a valve hole of the valve seat (10) of the second control valve is set equal to an opening area of a valve hole of the valve seat (6) of the first control valve.

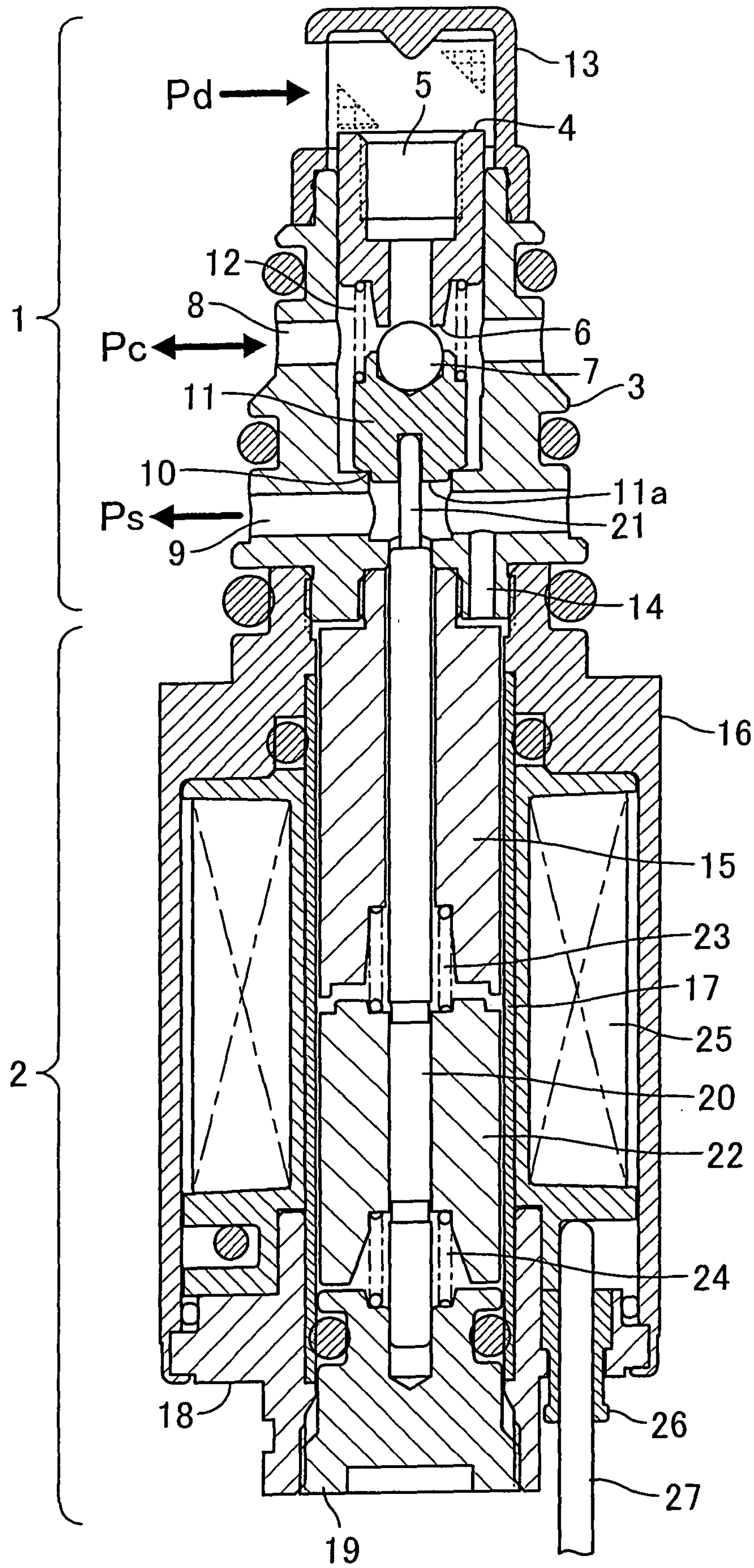
Pd
Pc
Ps
1
2
3
4
5
6
7
8
9
10
11
11a
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27

FIG. 1

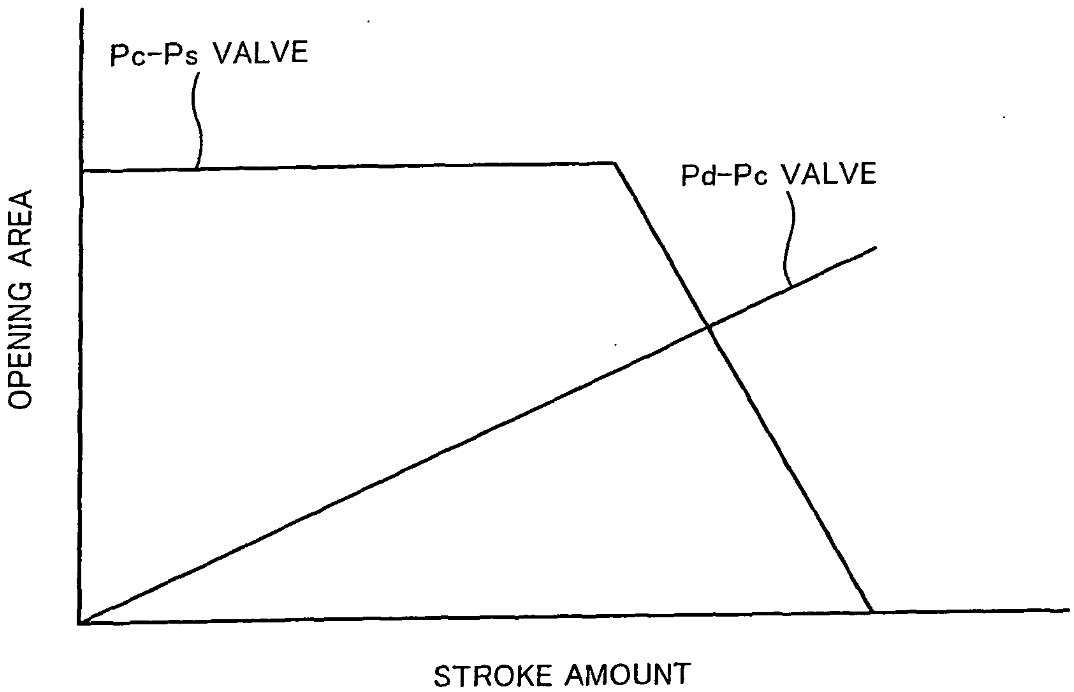

FIG. 2

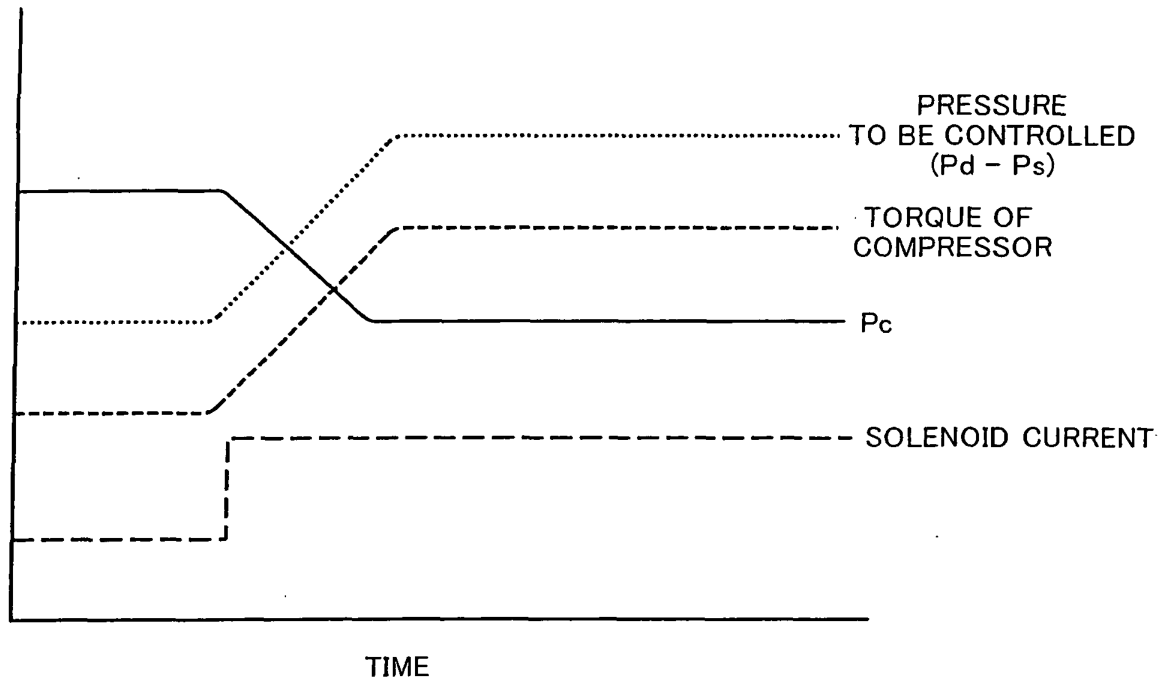
PRESSURE
TO BE CONTROLLED
(Pd - Ps)
TORQUE OF
COMPRESSOR
Pc
SOLENOID CURRENT
TIME

FIG. 3

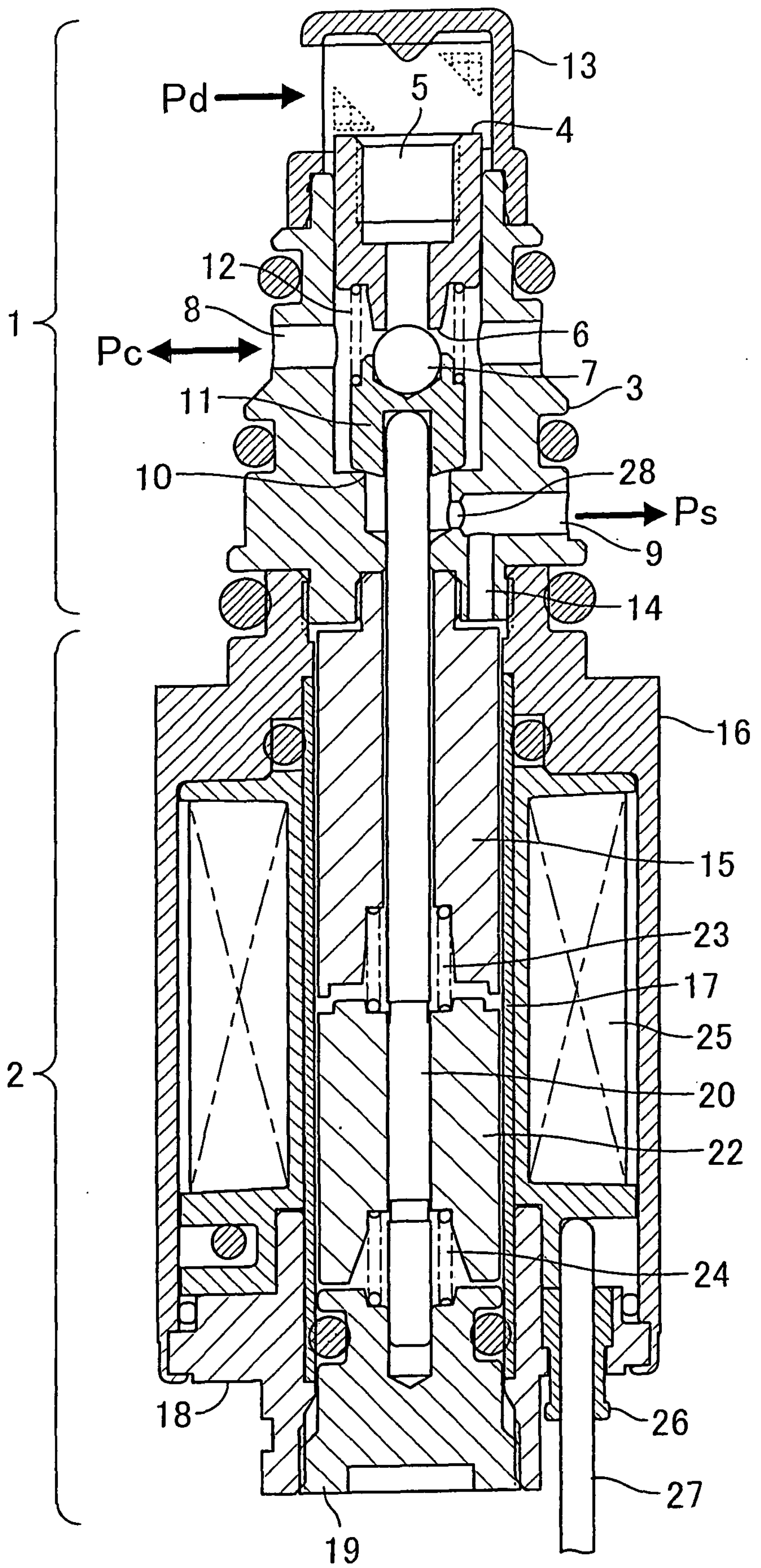
13
Pd
5
4
12
8
6
1
Pc
7
3
11
10
28
Ps
9
14
16
15
23
17
2
25
20
22
24
18
26
27
19

FIG. 4

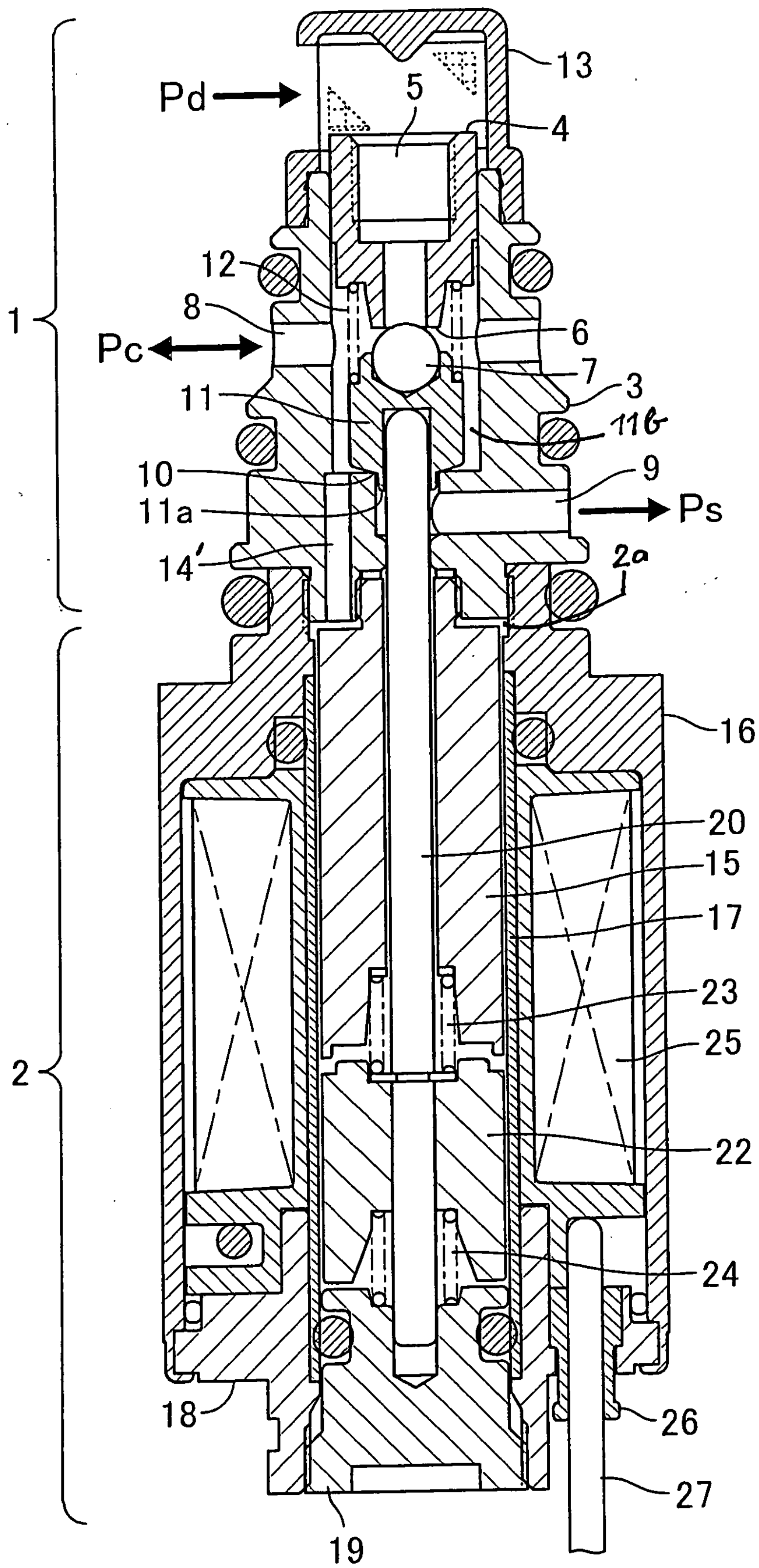
13
Pd
5
4
12
8
1
Pc
6
7
3
11
11b
10
9
11a
Ps
14'
2a
16
20
15
17
23
2
25
22
24
18
26
27
19

FIG. 5

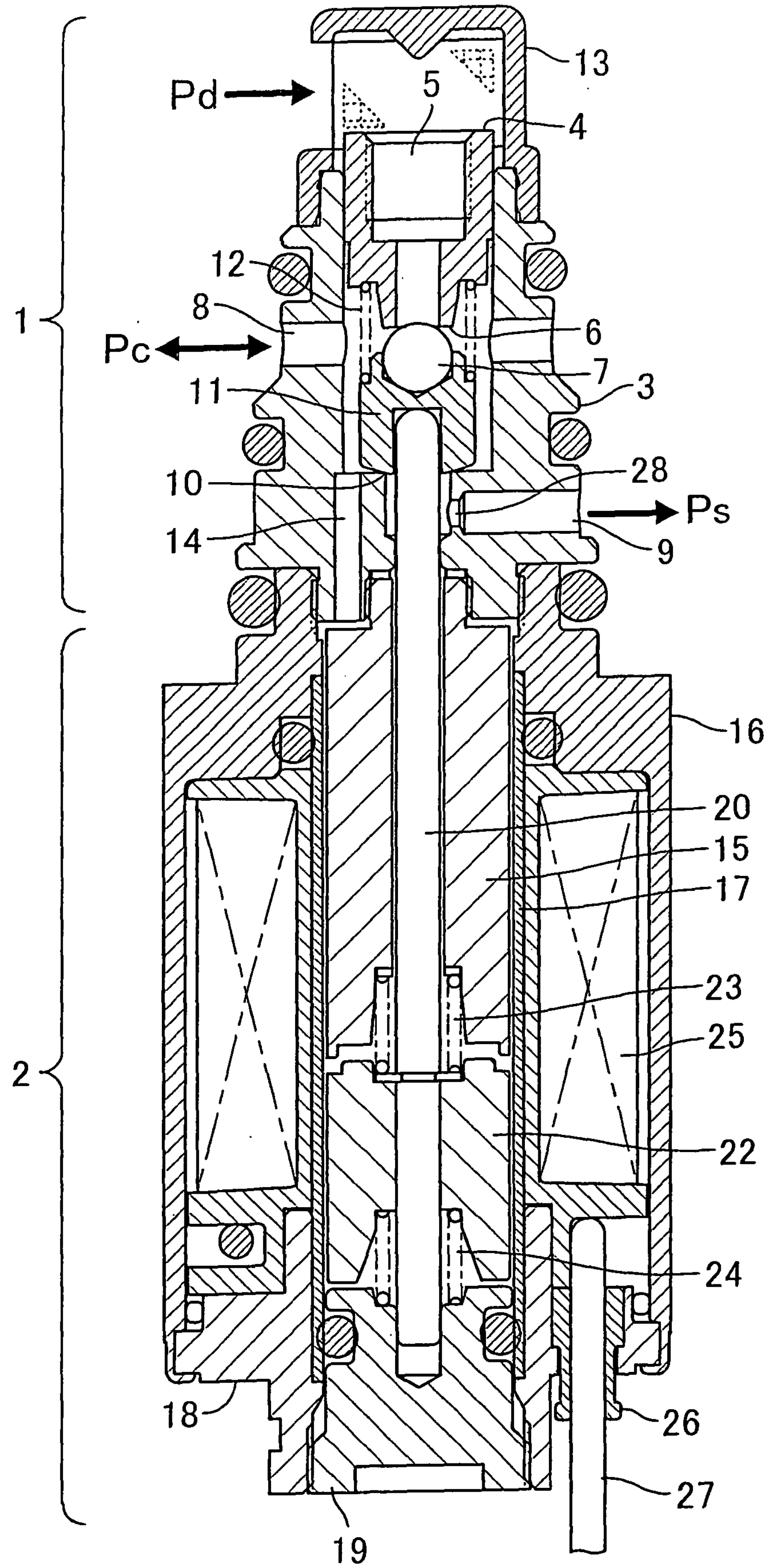
13
Pd
5
4
12
8
1
Pc
6
7
3
11
10
28
14
Ps
9
16
20
15
17
23
2
25
22
24
18
26
27
19

FIG. 6

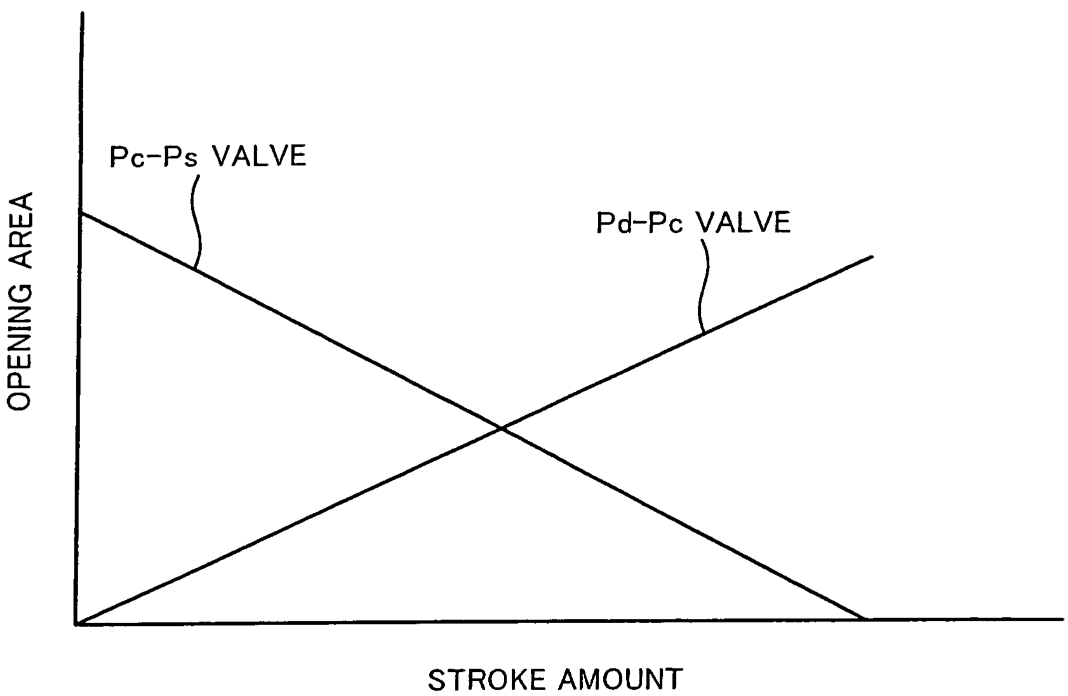

FIG. 7
PRIOR ART

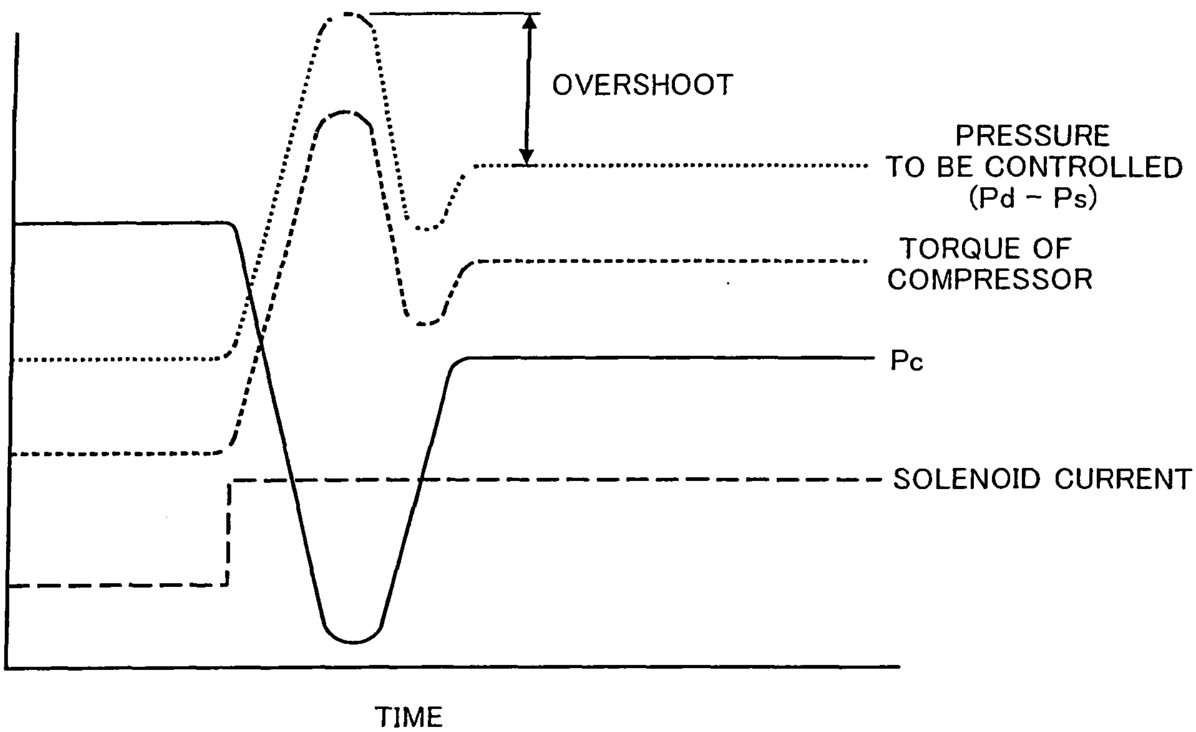

FIG. 8
PRIOR ART

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 04 02 0189

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	EP 1 106 831 A (TOYODA AUTOMATIC LOOM WORKS) 13 June 2001 (2001-06-13) * abstract; figure 2 * * paragraphs [0088] - [0097]; claims; figure 7 *	1-7	F04B27/18
X,D	EP 1 279 831 A (TGK CO LTD) 29 January 2003 (2003-01-29) * abstract; figures 2,4,5,7,8 *	1-7	
X	US 6 010 312 A (NAGAI HIROYUKI ET AL) 4 January 2000 (2000-01-04) * abstract; figure 1 * * claims; figures 2-4,7-11 *	1	

TECHNICAL FIELDS SEARCHED (Int.Cl.7)
F04B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	18 November 2004	Pinna, S

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 04 02 0189

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

18-11-2004

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
EP 1106831	A	13-06-2001	JP	2001165055	A	19-06-2001
			EP	1106831	A2	13-06-2001
			US	2001003573	A1	14-06-2001
EP 1279831	A	29-01-2003	JP	2003035269	A	07-02-2003
			EP	1279831	A2	29-01-2003
			US	2003019226	A1	30-01-2003
US 6010312	A	04-01-2000	DE	19733099	A1	12-02-1998
			FR	2752020	A1	06-02-1998
			JP	10103249	A	21-04-1998

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82