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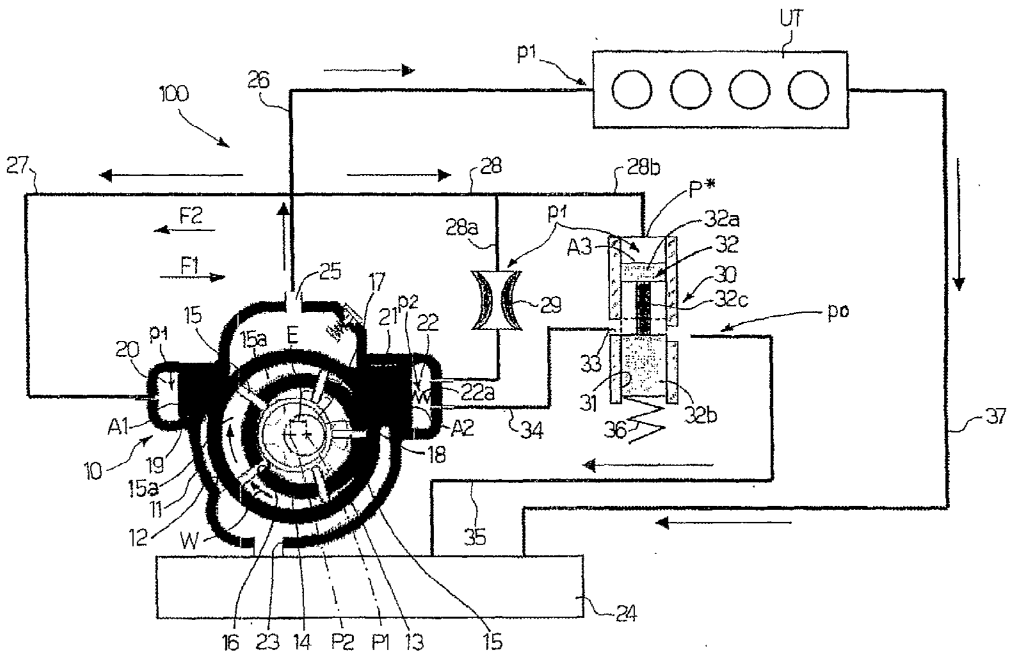
[Continued on next page]

(54) **Title:** PUMPING SYSTEM EMPLOYING A VARIABLE-DISPLACEMENT VANE PUMP



(57) **Abstract:** A pumping system (100) having a variable-delivery vane pump (10). The pump (10) has hydraulic pressure regulating dissipating devices (29, 30) for imparting to the oil in a regulating chamber (22) a pressure (p2) lower than the delivery pressure (p1).

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PUMPING SYSTEM EMPLOYING A VARIABLE-DISPLACEMENT VANE PUMP

TECHNICAL FIELD

The present invention relates to a variable-displacement vane pump comprising a main body having a cavity, in which is movable a ring containing a rotor rotating about a fixed axis. The rotor has a number of vanes, one end of each of which rests on the inner surface of the ring during rotation.

Means are also provided which, depending on a control pressure, move the ring between a centred position with respect to the rotation axis of the rotor, in which no pumping action takes place, and a predetermined eccentric position with respect to the rotation axis of the rotor.

BACKGROUND ART

Vane pumps of the above type are currently used to pump various fluids, such as oil in an internal combustion engine.

As is known, in pumps of the above type, at high rotation speeds of the shaft connected to the rotor, the gaps between adjacent vanes on the pump fail to fill completely, thus resulting in forces impairing operation of the pump.

To counteract the increase in such forces, counteracting springs are traditionally used, but are extremely rigid and therefore do not deform easily.

DISCLOSURE OF INVENTION

It is therefore an object of the present invention to provide for hydraulic control of a variable-delivery vane pump, particularly at high speed.

According to the present invention, there is provided a pumping system employing a variable-displacement vane pump, as claimed in Claim 1.

BRIEF DESCRIPTION OF THE DRAWINGS

A number of non-limiting embodiments of the present invention will be described by way of example with reference to the accompanying drawings, in which:

Figure 1 shows a first embodiment of the present invention;

Figure 2 shows a first configuration of a second embodiment;

Figure 3 shows a second configuration of the second embodiment in Figure 2;

Figure 4 shows a first configuration of a detail of the second embodiment in Figures 2 and 3;

Figure 5 shows a second configuration of the Figure 4 detail;

Figure 6 shows a third embodiment of the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

Number 10 in Figure 1 indicates a variable-delivery vane pump forming part of a pumping system 100 in accordance with the present invention.

Pump 10 comprises, in known manner, a main body 11 having a cavity 12 in which a ring 13 translates as described in detail later on.

Ring 13 houses a rotor 14 having a number of vanes 15, which move radially inside respective radial slits 16 formed in rotor 14, which is rotated in the direction indicated by arrow W (see below).

Main body 11 is closed by a cover not shown in the drawings.

In known manner, rotor 14 houses a shaft 17 connected mechanically to rotor 14; and a floating ring 18 surrounding shaft 17, and on which the other ends of vanes 15 rest.

Shaft 17 therefore has a centre P1 which is fixed at all times; and ring 13 has a centre P2.

The distance P1P2 represents the eccentricity E of pump 10.

As is known, by varying eccentricity E, the delivery of pump 10 can be varied as required by a user device UT downstream from pump 10 (see below).

User device UT may be defined, for example, by an internal combustion engine (not shown).

As shown in Figure 1, ring 13 has a projection 19 housed partly in a chamber 20; and a projection 21 housed partly in a chamber 22. Projections 19 and 21 are located on opposite sides of centre P2 of ring 13, and have respective front surfaces A1 and A2 facing chambers 20 and 22 respectively. For reasons explained in detail later on, surface A2 is larger than surface A1. More specifically, tests and calculations have shown surface A2 must be 1.4 to 1.7 times larger than surface A1.

A spring 22a inside chamber 22 exerts a small force on surface A2 to restore the system to a condition of maximum eccentricity E when system 100 is idle.

In the Figure 1 embodiment, chambers 20 and 22 are formed in main body 11 of pump 10.

Main body 11 also comprises an intake port 23 for drawing oil from a tank 24; and a delivery port 25 for feeding oil to user device UT.

A delivery conduit 26 extends from delivery port 25 to feed user device UT.

As shown in Figure 1, a first portion of the oil supplied to user device UT is diverted to chamber 20 by a conduit 27, and a second portion of the oil is fed to chamber 22 by a conduit 28.

More specifically, the second portion of the oil in conduit 28 is almost all fed to chamber 22 by a conduit 28a via a dissipating device 29, in which a calibrated pressure loss occurs as the oil actually flows through it.

Conduit 28 is connected to a valve 30 by a conduit

28b.

Valve 30 comprises a cylinder 31 housing a piston 32.

More specifically, as shown in Figure 1, piston 32 comprises a first portion 32a and a second portion 32b connected to each other by a rod 32c.

Portions 32a and 32b are equal in cross section to cylinder 31, whereas rod 32c is smaller in cross section than cylinder 31.

Cylinder 31 has a port 33 connected hydraulically to chamber 22 by a conduit 34.

Conduit 28b substantially provides for picking up a delivery pressure signal in conduit 28, so as to act on the front surface A3 of portion 32a of piston 32.

The dash line in Figure 1 shows the situation in which port 33 is closed by second portion 32b.

As described in more detail later on, as the delivery pressure (p1) increases alongside an increase in the operating speed of pump 10, greater force is exerted on surface A3 and, on reaching the preload value of a spring 36, moves piston 32 to allow oil flow from conduit 34 through port 33 and along a conduit 35 into tank 24.

At the start of conduit 35, the oil is at atmospheric pressure (po).

Piston 32 is stressed elastically by a suitably sized spring 36 designed to generate a force which only permits movement of piston 32 when the delivery pressure (p1) on surface A3 reaches a given value.

A return conduit 37 from user device UT to tank 24 completes pumping system 100.

In the known art, eccentricity E is normally regulated by diverting a portion of the oil supply into a chamber, in which the delivery pressure acts directly on the ring; and an elastic counteracting force, generated by a spring, acts on the opposite side of the ring, so that the pump is set to an eccentricity E value ensuring the oil pressure and flow requested by the user device.

As stated, however, at high rotation speed of the shaft, and therefore of the rotor and vanes, the gaps between adjacent vanes fail to fill completely, thus resulting in undesired forces which, in addition to high rotation speed of the rotor, also depend on the temperature and chemical-physical characteristics of the oil.

Incomplete fill has the side effect of generating a force acting in the direction indicated by arrow F1 in Figure 1.

Consequently, the user device fails to obtain the required delivery pressure, on account of this undesired force which, as stated, is substantially caused by incomplete oil fill of the gaps between the vanes.

By way of a solution to the problem, an attempt has been made to disassociate control from the above negative internal forces by providing for so-called "hydraulic control".

With reference to Figure 1, since, as stated, surface A2 is larger (preferably 1.4 to 1.7 times larger) than surface A1, it follows that, if the delivery pressure (p1) were present in both chambers 20 and 22, a force would be generated in the direction indicated by arrow F2 to compensate the force produced by incomplete fill of gaps 15a, thus resulting in maximum eccentricity E.

In this case, however, there would be no adjustment. To achieve the desired adjustment, therefore, the oil pressure in chamber 22 must be made lower than in chamber 20.

Consequently, when the delivery pressure (p1) reaches a value capable of generating sufficient force on surface A3 of portion 32a to overcome the elastic force of spring 36, piston 32 moves into the configuration shown by the continuous line in Figure 1, in which rod 32c of piston 32 is located at port 33, and so permits oil flow from chamber 22 to conduit 34, and along conduit 35 into tank 24.

Oil therefore also flows along conduit 28a and through dissipating device 29, so that, as opposed to the delivery pressure (p1), a lower pressure (p2) is present in chamber 22.

In other words, the pressure (p2) in chamber 22 is lower than the pressure (p1) in chamber 20, thus disassociating the two pressures to enable ring 13 to move in the direction indicated by arrow F1 to establish a balanced eccentricity E value producing the desired oil flow to user deice UT.

More specifically, as delivery pressure increases to a value (p*) determined by the characteristics of spring 36, piston 32 begins moving so that part of the oil leaks through port 33. In other words, valve 30 also acts as a pressure dissipating device to assist in creating the desired pressure (p2) in chamber 22.

(p1) and (p*) are equal at the end of the transient state

The system has also proved stable.

That is, adjustment continues for as long as permitted by piston 32, i.e. control is taken over by valve 30, which is regulated solely by delivery pressure (p1) and totally unaffected by undesired internal forces.

Conversely, in known regulating systems, when delivery pressure (p1) increases, it remains constant for a while, and then decreases.

With the system employed in system 100, on the other hand, on reaching the value required by user device UT, pressure (p1) remains constant, even at extremely high rotation speeds of rotor 14.

When delivery pressure reaches pressure value (p*), substantially determined by the characteristics of spring 36, generation of pressure (p2) commences, and ring 13 begins moving in the direction of arrow F1 to reduce eccentricity E and therefore the displacement of pump 10. Consequently, delivery pressure falls, and tends to assume a value below (p*), so that piston 32 moves into an intermediate balance position reducing the size of port 33.

Displacement remains fixed up to a given pressure value and, as pump speed increases, tends to increase delivery. When a given pressure value (p*) is reached, valve 30 opens, and oil flows along conduit 34, through port 33, and along conduit 35 to tank 24, so that the pressure (p2) in chamber 22 is lower than (p1), and ring 13 moves in the direction of arrow F1 to reduce displacement and therefore oil flow to user device UT.

In a second embodiment shown in Figures 2 to 5, dissipating device 29 and valve 30 are replaced by a three-way slide valve 50.

Valve 50 comprises a cylinder 51 housing a slide 52 stressed by a spring 53.

As shown more clearly in Figures 4 and 5, slide 52 comprises a first portion 52a, a second portion 52b, and a third portion 52c. Portions 52a and 52b are connected by a rod 52d, and portions 52b and 52c are connected by a rod 52e.

Cylinder 51 comprises four ports 54, 55, 56, 57. More specifically, port 54 defines the first way of three-way valve 50, ports 56 and 57 together define the second way, and port 55 defines the third way.

Slide 52 is controlled by delivery pressure (p1).

As shown in Figure 4, the value of ε1, which represents the size of port 56, must be greater than ε2, i.e. the size of the closed area covered by portion 52b of slide 52.

As shown in Figures 2 and 4, when delivery pressure (p1) is below a given value (p*), the oil pressure in chamber 22 assumes the delivery pressure (p1) value, pump 10 is set to maximum eccentricity, and no pumping action occurs.

As delivery pressure (p1) increases, slide 52 begins moving in the direction of arrow F3, so that oil flows from port 54 to port 56, and from port 57 to port 55 and into tank 24 maintained at atmospheric pressure (p0) (Figures 3, 5).

In other words, oil leaks from valve 50, thus resulting in a load loss, so that the pressure (p2) of the oil in chamber 22 assumes an intermediate value between delivery pressure (p1) and the atmospheric pressure (p0) of tank 24.

Figure 6 shows a third embodiment of the present invention.

Unlike the two embodiments described above, in this case, pressure is regulated in chamber 20 as opposed to chamber 22.

Chamber 22 in fact houses a spring 60 for opposing the force produced in chamber 20, and is at atmospheric pressure (p0).

As shown in Figure 6, oil is diverted from delivery conduit 26 to a valve 70 which, as before, opens as soon as delivery pressure (p1) exceeds the calibration value (p*) of valve 70 defined by the resistance of a calibration spring 72a.

Valve 70 comprises a cylinder 71 housing a piston 72 stressed elastically by spring 72a. When delivery pressure (p1) exceeds value (p*) (defined by spring 72a), piston 72 moves to uncover a port 73 in cylinder 71.

Oil therefore flows into a conduit 74 fitted with a dissipating device 75 connected to tank 24 by a conduit 76.

The pressure (p2) of the oil in chamber 20 is therefore lower than delivery pressure (p1), so that a force is produced which is opposed by the reaction force produced by spring 60 in chamber 22.

The mechanism by which equilibrium is established in vane pump 10 is the same as described for the other two embodiments.

CLAIMS

1) A pumping system (100) comprising a variable-delivery vane pump (10); the system (100) also comprising a user device (UT) connected to said pump (10) by a delivery conduit (26), and pressure regulating means for adjusting the eccentricity (E) of a ring (13) with respect to a rotor (14), both forming part of said pump (10), so that said pump (10) assumes a balanced configuration such as to supply the oil flow requested by said user device (UT);

the system (100) being characterized in that said pressure regulating means comprise hydraulic dissipating means (29, 30; 50; 70, 75) for imparting to the oil inside a regulating chamber (20, 22) forming part of said pump (10) a pressure (p2) lower than a control pressure (p1).

2) A system (100) as claimed in Claim 1, characterized in that said hydraulic dissipating means comprise a valve (30; 70) and a dissipating device (29; 75).

3) A system (100) as claimed in Claim 1, characterized in that said hydraulic dissipating means comprise a three-way slide valve (50).

4) A system (100) as claimed in any one of the foregoing Claims, characterized in that said pump (10) comprises a hollow main body (11) having at least one chamber (20, 22); and in that said chamber (20, 22)

houses a respective projection (19, 21) integral with said ring (13).

5) A system (100) as claimed in Claim 4, characterized in that said projection (21) has a first front surface (A2) greater than a second front surface (A1) of said projection (19).

6) A system (100) as claimed in Claim 4, characterized in that the size of said first front surface (A2) is 1.4 to 1.7 times said second front surface (A1).

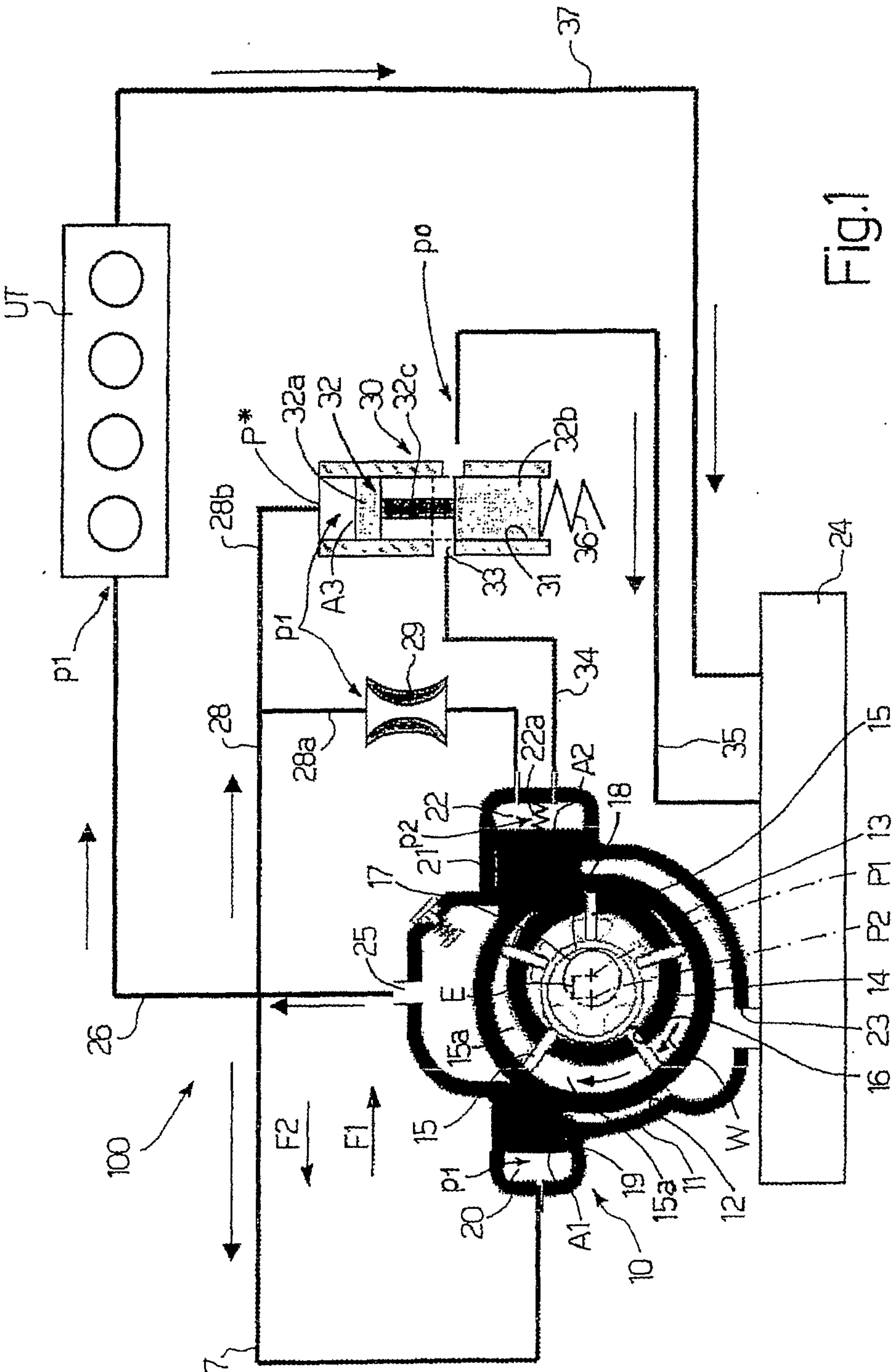
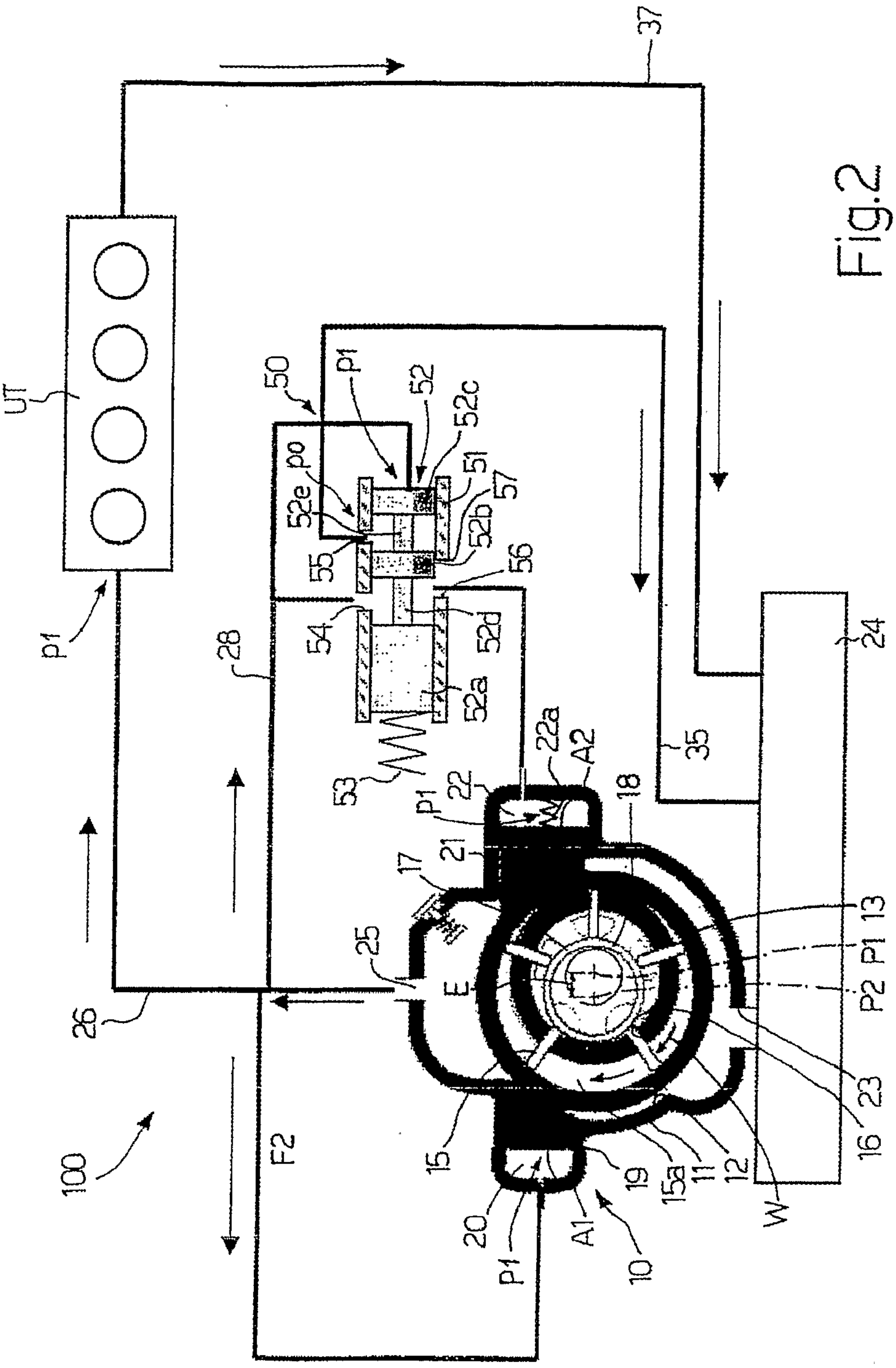

37
UT
p1
po
P*
32a
32
30
32c
32b
28b
A3
33
31
36
p1
29
34
28
28a
22a
A2
22
p2
21
18
15
13
P1
P2
14
23
16
17
25
E
26
15a
15
100
F2
F1
p1
20
A1
19
15a
11
12
W
10
27
24
35

Fig.1



UT
P1
37
50
P1
52
52c
Po
51
57
52e
52b
55
56
54
52d
28
52a
53
22a
22
A2
P1
35
18
21
17
25
E
13
P1
P2
26
23
16
15
15a
11
12
W
100
F2
19
20
A1
P1
10
24

Fig.2

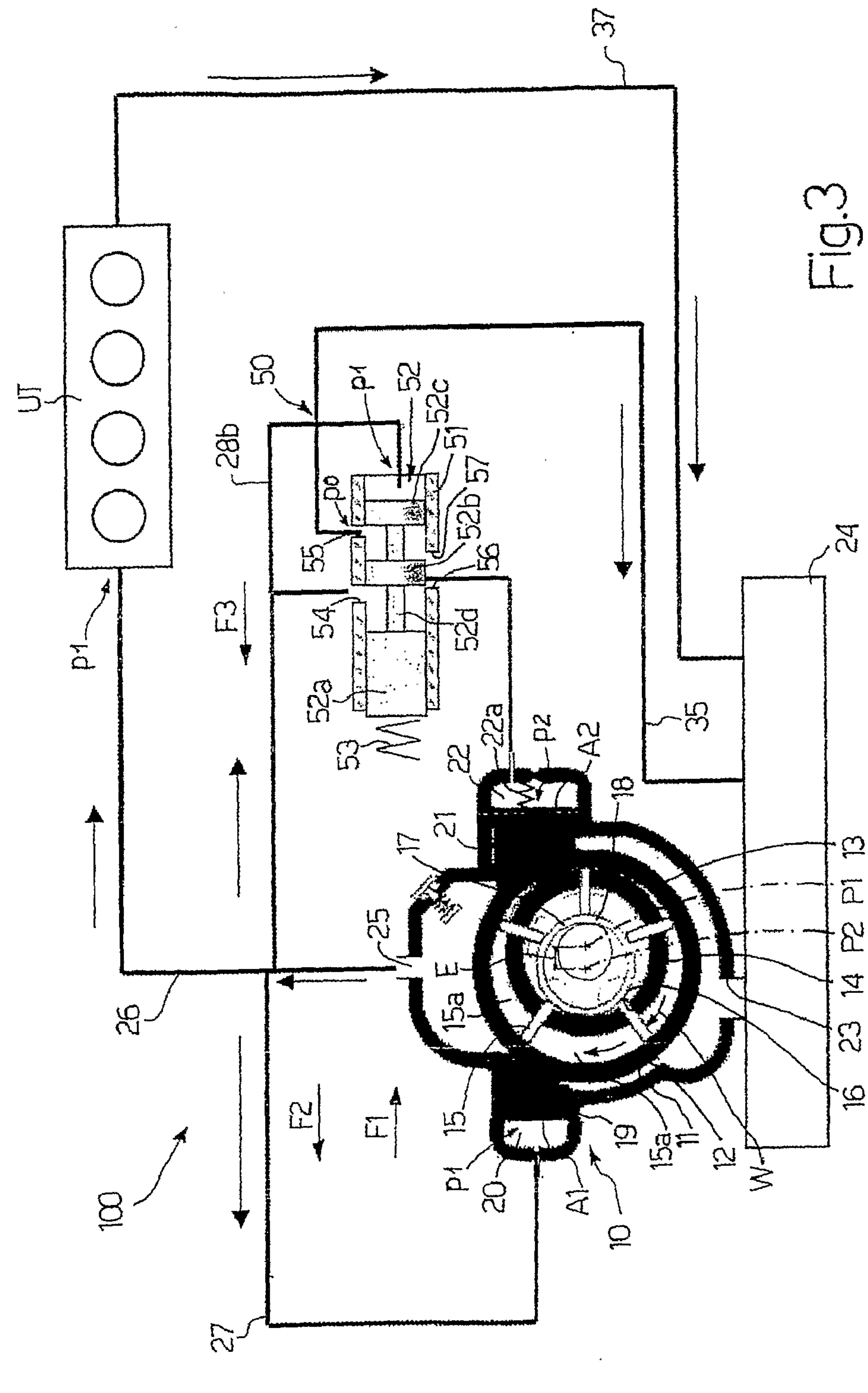

37
UT
p1
50
52
52c
51
57
28b
p0
55
52b
56
54
52d
52a
53
F3
35
24
22
22a
P2
A2
18
17
21
25
26
E
15a
15
19
20
p1
A1
10
11
12
15a
W
16
23
14
P2
P1
13
F1
F2
100
27

Fig.3

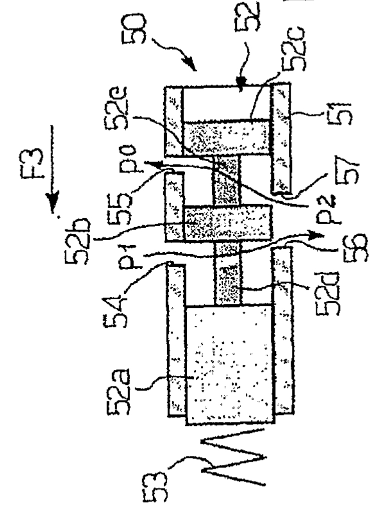

50
52
52c
52e
F3
p0
55
52b
p1
p2
56
57
51
54
52d
52a
53

Fig.5

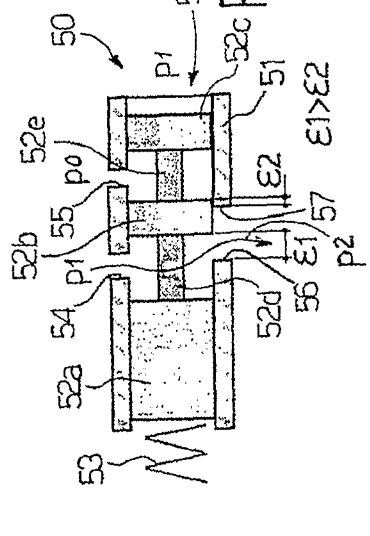
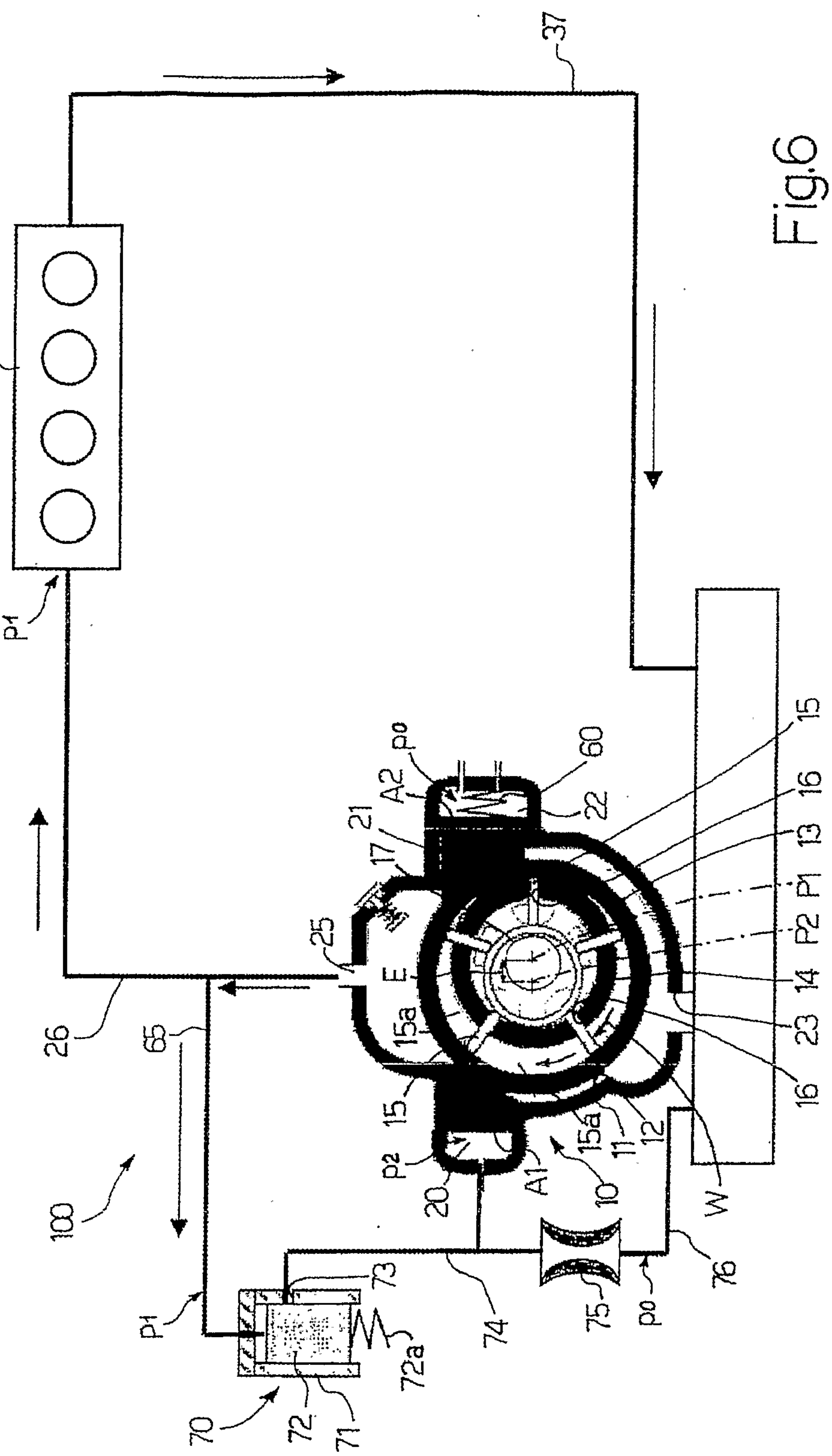

50
52
52c
p1
52e
p0
55
52b
54
52a
53
51
52d
56
57
p2
ε2
ε1
ε1>ε2

Fig.4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UT
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100
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E
17
21
A2
po
60
22
15
16
13
P1
P2
14
23
16
W
12
11
15a
15a
15
10
A1
20
p2
74
73
72a
75
po
76
P1
70
72
71

Fig.6

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP2004/052140

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F04C2/344 F04C15/04

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 F04C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	FR 2 195 271 A (PEUGEOT & RENAULT) 1 March 1974 (1974-03-01)	1,2,4
Y	page 2, line 39 - page 3, line 17; figures 1,2 page 3, line 28 - page 4, line 8	5
X	DE 32 14 212 A (TEVES GMBH ALFRED) 20 October 1983 (1983-10-20)	1,2
Y	page 5, last paragraph - page 7, last line ; figure	5
X	GB 2 151 705 A (TEVES GMBH ALFRED) 24 July 1985 (1985-07-24) page 2, line 36 - page 3, line 6	1,2

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
11 January 2005	18/01/2005

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Descoubes, P

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 02/052155 A (INAGUMA YOSHIHARU ; KATO HIDEYA (JP); IKEDA TSUYOSHI (JP); SUZUKI KEIJ) 4 July 2002 (2002-07-04) abstract; figures 1,4	1-3
X	US 2002/085923 A1 (KONISHI HIDEO) 4 July 2002 (2002-07-04) abstract; figures 1,2	1-3
X	EP 1 043 504 A (BAYERISCHE MOTOREN WERKE AG) 11 October 2000 (2000-10-11) column 2, line 32 - column 4, line 20; figures 2,3	1,2
A	US 4 702 083 A (TAGA YUTAKA ET AL) 27 October 1987 (1987-10-27) abstract; figure 1	1-6

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/EP2004/052140

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
FR 2195271	A	01-03-1974	FR	2195271 A5	01-03-1974
			DE	2307218 A1	14-02-1974
DE 3214212	A	20-10-1983	DE	3214212 A1	20-10-1983
GB 2151705	A	24-07-1985	DE	3347015 A1	04-07-1985
			ES	283592 U	16-05-1985
			FR	2557215 A1	28-06-1985
			IT	1181930 B	30-09-1987
			JP	60153480 A	12-08-1985
WO 02052155	A	04-07-2002	JP	2002168181 A	14-06-2002
			EP	1350957 A1	08-10-2003
			WO	02052155 A1	04-07-2002
			US	2004076536 A1	22-04-2004
US 2002085923	A1	04-07-2002	JP	2002188579 A	05-07-2002
			DE	10161296 A1	12-09-2002
EP 1043504	A	11-10-2000	DE	19915739 A1	12-10-2000
			DE	50003605 D1	16-10-2003
			EP	1043504 A2	11-10-2000
US 4702083	A	27-10-1987	JP	1832976 C	29-03-1994
			JP	5031697 B	13-05-1993
			JP	61105340 A	23-05-1986
			JP	1832977 C	29-03-1994
			JP	5031698 B	13-05-1993
			JP	61105341 A	23-05-1986
			CA	1241214 A1	30-08-1988