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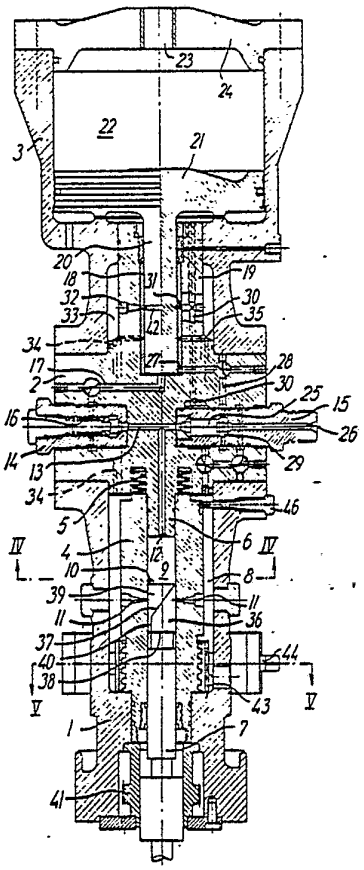
(57) Abstract

The plunger pump (7) having leading and trailing cut off edges (37, 38) delivers fuel to a spring loaded accumulator through a first valve (16) which is opened by the pump pressure. During the pumping stroke of the plunger (7) a second valve (25) in the outlet from the accumulator to the injectors of the engine cylinder is kept closed by the pump pressure, and at the moment when the trailing cut-off edge (38) in cooperation with apertures (10, 11) relieves the pump pressure, that other valve is opened under the influence of the accumulator pressure and the fuel is delivered to the injectors.



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A Fuel Pump for Diesel Engines.

BACKGROUND OF THE INVENTION

This invention relates to a fuel pump for Diesel engines of the type in which each engine cylinder is associated with a pump, the pump plunger of which has leading and trailing cut-off edges cooperating with apertures in the wall of the pump cylinder for determining the effective stroke volume of the pump, and including means for changing the stroke volume by a relative rotation of the pump cylinder and plunger. In this context the terms "leading" and "trailing" refer to the location of the cut-off edges relative to the direction in which the pump plunger moves during the pump stroke.

In engines of type referred to it has till now been common practice to connect the pump chamber directly to the injector or injectors of the engine cylinder. In this way the leading edge on the pump plunger determines, by its passage of the relevant aperture or apertures in the cylinder wall, the moment when the fuel injection in the engine cylinder commences, while the trailing edge determines the termination of the injection by connecting the pump chamber to the suction side of the pump. The latter edge extends along a more or less approximate helix on the surface of the plunger so that the measured amount of fuel and the duration of the injection period can be varied by rotating the piston relative to the cylinder.

In an article in the periodical The Motor Ship, February 1980, pages 37 to 38 there is mentioned a modification of the system referred to in which each fuel pump delivers the fuel to the injector or injectors through an accumulator having a spring-loaded plunger. It is then possible, irrespective of the

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engine load and rpm, to maintain the maximum injection pressure at a predetermined value which is determined solely by the accumulator spring, and thus ensure optimum atomization of the fuel at any operating conditions.

SUMMARY OF THE INVENTION

According to the present invention a fuel pump of the last mentioned kind is characterized in that in an inlet duct leading from the pump chamber to the accumulator there is a first valve which is biased towards open position by the pressure in the pump chamber and towards closed position by the accumulator pressure, and in that in an outlet duct from the accumulator there is a second valve which is biased towards open position by the accumulator pressure and biased towards closed position by the pressure in the pump chamber, and in that the leading cut-off edge of the pump plunger extends exactly or substantially along a helix.

By means of the invention it is obtained that the moment when the fuel injection begins is determined, not as with the known pump by the leading cut-off edge of the pump plunger, but by its trailing edge, viz. when during the pump stroke this edges uncovers the relevant aperture or apertures in the cylinder wall. At this moment the pressure in the pump chamber drops whereby the above mentioned second valve, under the influence of the pressure in the accumulator, opens to permit outflow of the fuel amount, which during a preceding part of the plunger stroke has been pumped into the accumulator. The pressure relief in the pump chamber also results in the closing of the first valve so that the fuel can only flow from the accumulator to the injector or injectors of the engine cylinder through the outlet duct. The

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setting of the effective stroke volume of the pump can be effected exactly as in the known pumps, but because the entire pump stroke, irrespective of the magnitude of the stroke volume, occurs during the compression stroke of the engine piston and has been terminated before that piston reaches its top dead centre, each fuel pump of a reversible engine can be actuated by the same cam at either direction of rotation without the necessity of rotating the cam relative to the engine crankshaft preparatory to the reversal.

According to a feature of the invention a duct may extend from the outlet duct downstream of the second valve and open into an aperture in the sidewall of the accumulator cylinder, while in the accumulator plunger there is a relief duct which in the bottom position of that plunger provides a communication between said aperture and the suction side of the pump through a chamber surrounding the accumulator cylinder. This feature ensures, in a simple way, an abrupt relief of the pressure in the fuel duct leading to the injectors and, hence, a precise closing of the injectors and an instantaneous termination of the injection period analogous to the instantaneous initiation thereof when the pump plunger relieves the pressure in the pump chamber.

The relief duct may comprise an annular groove in the accumulator plunger. The connection to the suction side of the pump may then comprise a transverse bore through the wall of the accumulator cylinder.

There may be provided a further transverse bore through the sidewall of the accumulator cylinder intermediate the bottom of the accumulator chamber and the first aperture in the cylinder wall. This bore

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safeguards against mechanical overload of the pump or the accumulator due to over-filling of the accumulator cylinder, e.g. as a result of failing passage through the outlet duct to the injectors, because in that case the delivery from the pump will flow back to the suction side as soon as the end of the accumulator plunger has uncovered the bore.

That area of the second valve, which is subjected to the pressure in the pump chamber, is preferably larger than the area subjected to the accumulator pressure. The second valve will then, without a built-in closing spring, be moved to its closed position at the moment when the accumulator pressure is relieved to the same low value as the pressure in the pump chamber so that the valve has closed in advance when next time the pump plunger starts delivering fuel to the accumulator.

In an embodiment of the invention the trailing edge of the pump plunger is, at least on a part of its length, slightly inclined relative to a plane normal to the centre line of the plunger. In the corresponding part of the setting range of the pump delivery the moment when the pressure in the pump chamber is relieved and, hence, the moment when the injection period begins, will vary dependent on the set delivery which permits an optimum adaptation of that moment to the engine load.

In order to permit, during operation, an individual fine setting of the moment when the injections commences in the individual engine cylinders, the pump cylinder may be axially adjustable from the exterior by means of a nut rotatably supported in the pump housing and engaging with a thread on the pump cylinder. In a pump known from Danish patent specification No. 114 873 such adjustment is effected

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by means of an adjusting spindle protruding through the end face of the pump housing. In a pump according to the present invention this arrangement is not possible because the pressure accumulator is built together with the pump housing, and instead one may provide a worm or helical gearing externally on the nut and meshing with an adjustment spindle extending transversely of the cylinder axis.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described in more detail with reference to the accompanying schematical drawings, in which

Fig. 1 is a longitudinal section through a fuel pump embodying the invention,

Fig. 2 is a developed view, on a substantially larger scale, of the active portion of the pump plunger with the leading and trailing cut-off edges when the pump is set to minimum delivery, the so-called zero delivery,

Fig. 3 is a developed view, corresponding to Fig. 2, but with the pump set to maximum delivery,

Fig. 4 is a section through the pump cylinder along line IV-IV in Fig. 1, and on the same scale as that figure, and

Fig. 5 is a section along line V-V in Fig. 1.

DETAILED DESCRIPTION

The fuel pump illustrated in the drawings comprises a pump housing 1, which on one end face thereof is secured to a valve block 2 to the opposed end face of which an accumulator housing 3 is secured. A pump cylinder 4, which is axially displaceable within housing 1, is centred in the housing at its lowermost end and is spring-biased downwardly by means of a set of Belleville springs 5 between the end face of the cylinder and the valve block 2. The upper end of the pump cylinder is guided on a central

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hub 6 extending downwardly from valve block 2.

The pump plunger 7, which is axially movable within cylinder 4, extends, in a known manner, through the lower end of housing 1 for cooperating, in a conventional manner, with an actuating cam (not shown), and the engagement between the plunger and the cam is ensured by means of a spring. Intermediate pump cylinder 4 and housing 1 there is an annular suction chamber 8 having means (not shown in detail) for the supply of fuel oil. Suction chamber 8 communicates with pump chamber 9 defined within cylinder 4 by means of two sets of axially staggered apertures 10 and 11 in the cylinder wall. Apertures 10 serve for the inflow of fuel to chamber 9, while the substantially smaller apertures 11 serve for relieving the pressure in chamber 9, as described in more detail below.

A central bore 12 through hub 6 of the valve block opens at its lower end in pump chamber 9 and at its upper end in a transverse bore 13 which at either end opens into an enlargement in which a valve insert 14 and 15, respectively, has been screwed in. Insert 14 contains a hollow slide valve 16, the interior of which communicates, through transverse bores in the slide valve proper and in the insert 14, with a duct 17 in valve block 2, which duct opens at the bottom of an accumulator chamber defined between a cylinder liner 18 secured in an upwardly extending boss 19 on valve block 2 and an accumulator plunger 20. Thus, the pressure in the accumulator chamber acts on the slide valve to effect engagement between a conical sealing surface on the forward, right-hand end of the slide valve and an opposed conical seat surface in insert 14.

At its upper end the accumulator plunger is integral with a substantially larger piston 21, which

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is axially displaceable within a cylinder chamber 22 formed within accumulator housing 3. Through an aperture 23 in a cover 24 of cylinder chamber 22 the chamber is connected to a source of pressurized air (not shown) which e.g. may be a reservoir common to all fuel pumps of an engine, which reservoir may be supplied from the starting air system of the engine.

A slide valve 25 is axially displaceable within valve insert 15 and at its ends it is formed with conical sealing surfaces cooperating with opposed seats in insert 15. The left-hand valve seat, as shown in Fig. 1, surrounds the opening of transverse bore 13 while the right-hand valve seat surrounds a bore 26 in the valve insert through which fuel is delivered to the engine cylinder through a high pressure duct (not shown), which is connected to insert 15.

A transverse bore 27 in cylinder liner 18 closely adjacent the bottom of the accumulator chamber communicates, through a duct 28 in the valve block and transverse bores through insert 15, with an annular chamber 29 in the insert intermediate the valve seat surrounding bore 26 and the annular end face of slide valve 25 at the left of the associated sealing surface. Through other transverse bores in insert 15 and a duct 30 in valve block 2 bore 26 communicates permanently with a transverse bore 31 extending through cylinder liner 18. At the same axial level as bore 31 there is a second bore extending through the cylinder liner and through a a transverse bore 32 in boss 19, said bore communicates with an annular chamber 33 located between accumulator housing 3 and boss 19. Through one or more bores 34 extending through valve block 2 parallel

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to its axis, chamber 33 communicates with the suction chamber 8 of the pump housing.

Intermediate bore 31 and the bottom of the accumulator chamber one or more further transverse bores extend through cylinder liner 18 and continue in transverse bores 35 through boss 19 to the annular chamber 33.

The upper end, as shown in Fig. 1, of pump plunger 7 has two separate sealing surfaces 36 in sealing againstment against the inner wall of pump cylinder 4 and each surface 36 is defined above and below by a leading and trailing cut-off edge 37 and 38, respectively, which edges cooperate with apertures 10 and 11 in the cylinder wall. In the surface of the plunger there is a milled recess 39 above each edge 37, and this recess continues in a groove 40 extending parallel to the plunger axis between the two sealing surfaces and opening into the annular space which is formed below the trailing cut-off edge 38 between the cylinder wall and a reduced portion of the pump plunger.

Below pump cylinder 4 piston 7 is, in a known manner, connected with a sleeve 41 so as to rotate therewith, and on its periphery sleeve 41 has teeth meshing with a toothed rack (not shown) which, as known in the art, serves for adjusting or setting the effective stroke volume of the pump by a rotation of plunger 7.

When the pump plunger starts moving upwardly, from the bottom position shown in Fig. 1, under the influence of the actuating cam (not shown), the two inflow apertures 10 will, at a certain point of the pump stroke, be covered by the leading cut-off edges 37. In the left-hand part of Figs. 2 and 3 this plunger position is shown in full lines at zero

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delivery and maximum delivery, respectively. It will be seen from these figures that in this position sealing surfaces 36 also cover apertures 11. The pump thus builds up a pressure in the amount of oil present in chamber 9 and in ducts 12 and 13 ending at the two slide valves 16 and 25, and due to this pressure slide valve 16 is displaced towards the left to open position whereas slide valve 25 is displaced towards the right to close the connection between annular chamber 29 and bore 26 in case the slide valve does not already assume that position. Fuel flows through slide valve 16 and duct 17 into the accumulator chamber thereby lifting accumulator plunger 20. At the moment when the trailing cut-off edges 38 uncover apertures 11, a communication is established between pump chamber 9 and suction chamber 8 whereby the pressure in the pump chamber is relieved, and slide valve 16 closes. The amount of fuel delivered to accumulator chamber is subjected to the high pressure determined by the pneumatic pressure on piston 21 and in chamber 29 the fuel pressure acts on the right-hand end surface of slide valve 25 while at the same time the pressure at the left-hand end surface of the slide valve has dropped. Slide valve 25 is, therefore, displaced towards the left to the position shown in Fig. 1 in which bore 26 communicates with the accumulator chamber whereby the pneumatic pressure in cylinder 22 presses accumulator plunger 20 downward to deliver the measured amount of pressurized fuel through the outlet duct (not shown) to the injectors of the engine cylinder.

Shortly before plunger 20 assumes its bottom position, it obturates bore 27 in cylinder liner 18 whereby the delivery of fuel from the accumulator

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chamber ceases. At the same time a circumferential groove 42 in the surface of piston 20 establishes a flow path from duct 30 through bores 31 and 32 to annular chamber 33 and thus to the relatively low pressure prevailing in suction chamber 8. In this way the pressure in bore 26 and chamber 29 is relieved to the same value as the pressure acting on the left-hand end of slide 25.

It will be seen from Figs. 2 and 3, in which the cut-off edges 37 and 38 on one sealing surface 36 have been shown in full lines at the beginning of the effective pump stroke and in dot-and-dash lines at the termination of the pump stroke, that the effective stroke of the plunger and, thus, the effective stroke volume of the pump is changed when the pump plunger is rotated relative to cylinder 4 in a per se conventional manner. It will also be seen that the effective pump stroke starts earlier, the larger the set delivery is, and that the beginning of the injection period is determined by the trailing cut-off edges 38 uncovering the relief apertures 11. If it is desired to operate with a constant fuel pump lead at all motor loads, cut-off edges 38 extend perpendicular to the axis of the pump plunger. By slightly inclining these edges, either as shown in Figs. 2 and 3 or in the opposite direction, it is possible to cause the fuel injection to start, with increasing motor load, at an earlier or later point, respectively, of the movement of the engine piston towards top dead centre.

By means of the setting mechanism illustrated in Figs. 1 and 5 it is, furthermore, possible to adjust the fuel pump lead at running engine, either for the engine as a whole or individually in each cylinder. This is effected by an axial displacement

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of pump cylinder 4 relative to plunger 7 whereby cut-off edges 37 and 38, with unchanged angular position of plunger 7, uncover and cover apertures 10 and 11 at correspondingly changed moments of the cyclical movement of the engine piston. This mechanism comprises a worm wheel 43 located at the bottom of suction chamber 8 and having an internal thread engaging with an external thread on cylinder 4, and a transverse adjustment spindle 44 having a worm gear 45 meashing with worm wheel 43. The Belleville springs 5 mentioned above provide an axial preload on the threaded connection between the pump cylinder and worm wheel 43, whereby the latter is always maintained in abutment against the bottom of chamber 8, and because cylinder 4 is prevented from rotating relative to pump housing 1 by means of a guide pin 46 engaging in a groove in cylinder 4 parallel to the cylinder axis, a rotation of spindle 44 and, hence, of worm wheel 43 results in the stated, purely axial displacement of pump cylinder 4.

If it is found expedient for the operation of the engine to be able to vary the maximum pressure at which the fuel is injected in the engine cylinder, e.g. to reduce that pressure at low engine load, this is easily possible by a corresponding adjustment of the pneumatic pressure in the air cylinder chamber 22 of the accumulator.

As already briefly mentioned above bores 35 safeguard against overload of the component parts of the pump in case the outflow of fuel is hindered in any way because in that case the pump only provides an internal circulation flow of fuel to the accumulator chamber and through bores 35 back to suction chamber 8 as soon as accumulator plunger 20 has been lifted sufficiently to uncover the bores.

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If the fuel is delivered at a certain pressure to suction chamber 8 by means of a primary pump, a circulating flow through the pump and through the fuel injector or injectors connected thereto can be maintained during standstill of the pump in that from chamber 8 oil then flows through ducts 34, chamber 33, bore 32, groove 42, and duct 30 to bore 26 from which the fuel can flow to the injectors.

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PATENT CLAIMS

1. A fuel pump for Diesel engines of the type in which each engine cylinder is associated with a pump, the pump plunger (7) of which has leading and trailing cut-off edges (37, 38) cooperating with apertures (10, 11) in the wall of the pump cylinder (4) for determining the effective stroke volume of the pump, and including means (41) for changing the stroke volume by a relative rotation of the pump cylinder and plunger, and in which an accumulator having a spring-loaded plunger (20) is provided downstream of the pump chamber (9), characterized in that in an inlet duct (13, 17) leading from the pump chamber (9) to the accumulator there is a first valve (16) which is biased towards open position by the pressure in the pump chamber and towards closed position by the accumulator pressure,

and in that in an outlet duct (26, 28) from the accumulator there is a second valve (25) which is biased towards open position by the accumulator pressure and biased towards closed position by the pressure in the pump chamber,

and in that the leading cut-off edge (37) of the pump plunger extends exactly or substantially along a helix.

2. A fuel pump as claimed in claim 1, characterized in that a duct (30) extends from the outlet duct downstream of the second valve (25) and opens into an aperture (31) in the sidewall of the accumulator cylinder (18), and that in the accumulator plunger (20) there is a relief duct (42) which in the bottom position of that plunger provides a communication between said aperture and the suction side of the pump through a chamber (33) surrounding the accumulator cylinder.

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3. A fuel pump as claimed in claim 2, characterized in that the relief duct (42) is an annular groove in the accumulator plunger (20).

4. A fuel pump as claimed in claim 2, characterized by a transverse bore (35) extending through the side-wall of the accumulator cylinder intermediate the bottom of the accumulator chamber and the first aperture (31) in the cylinder wall.

5. A fuel pump as claimed in claim 2, characterized in that the area of the second valve (25) subjected to the pressure in the pump chamber is larger than the area subjected to the accumulator pressure.

6. A fuel pump as claimed in claim 1, characterized in that at least on a part of its length the trailing cut-off edge (38) of the pump plunger is slightly inclined relative to a plane normal to the centre line of the plunger.

7. A fuel pump as claimed in any of claims 1-6, and in which the pump cylinder (4) is axially adjustable from the exterior for adjusting the moment when the injection begins, by means of a nut rotatably supported in the pump housing and engaging with a thread on the pump cylinder, characterized in that the nut has an external worm or helical gearing (43) meshing with an adjustment spindle (44) extending transversely of the cylinder axis.

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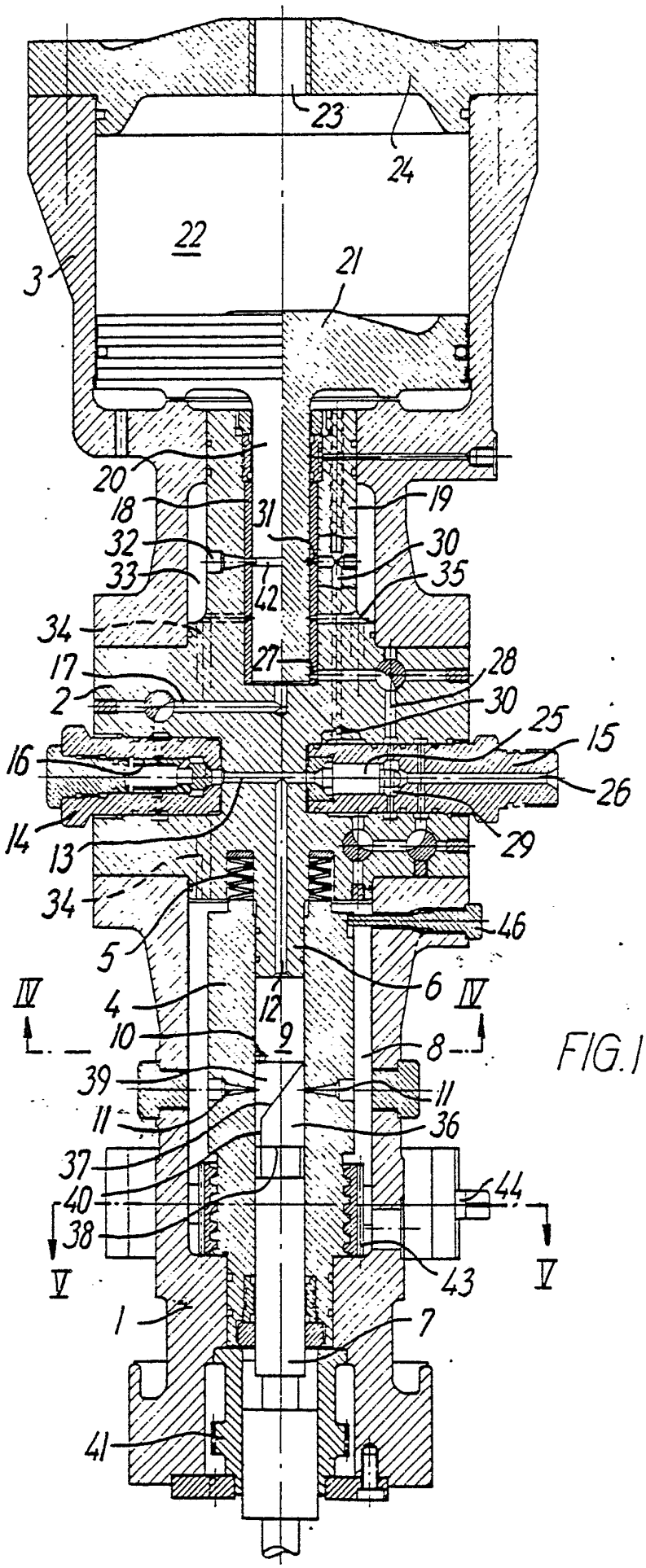

FIG.1

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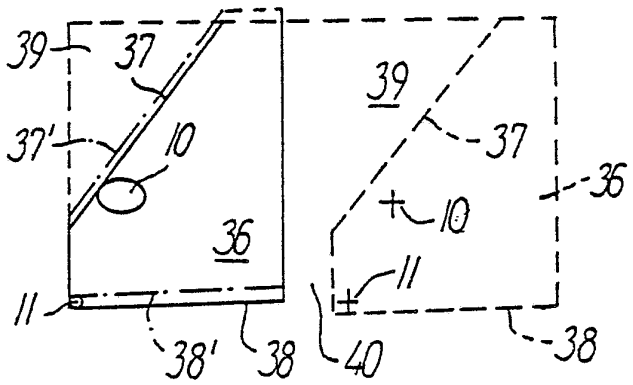

FIG.2

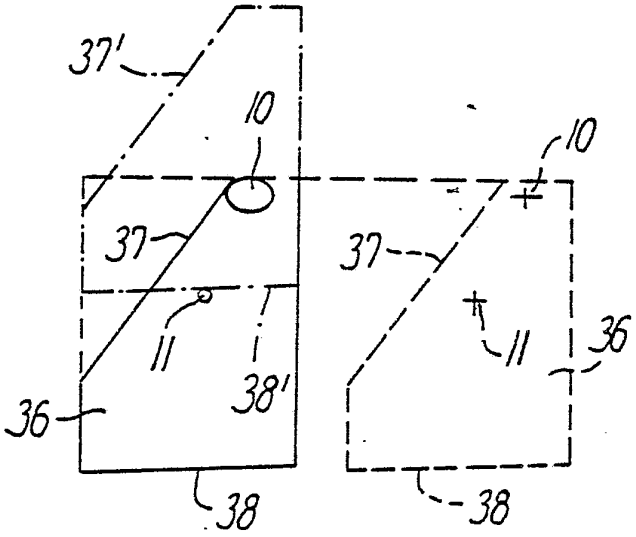

FIG.3

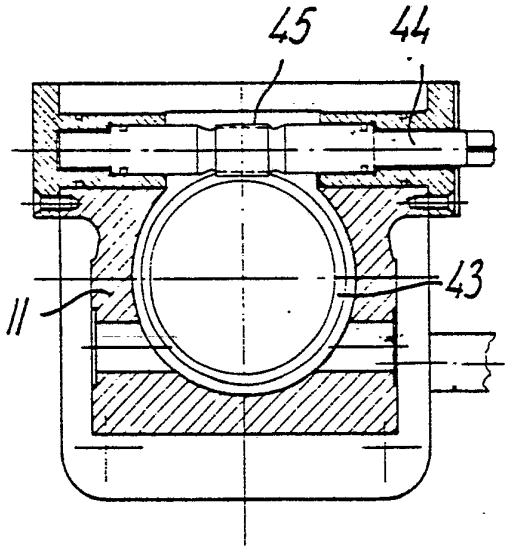

FIG.5

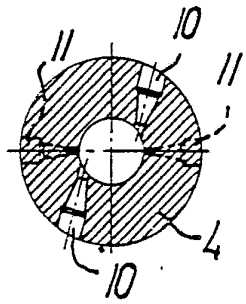

FIG.4

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INTERNATIONAL SEARCH REPOF

International Application No PCT/DK 81/00031

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) 3

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Int.Cl.^{3} F 02 M 59/00

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Classification System	Classification Symbols
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Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched 5

III. DOCUMENTS CONSIDERED TO SE RELEVANT 14

Category *	Citation of Document, 16 with indication, where appropriate, of the relevant passages 17	Relevant to Claim No. 18
A	US, A, 2739643, published March 27, 1956 see column 2, line 21 to column 2, line 70; figure 1, Voit	6
A	The Institute of Marine Engineers, Volume 75, No. 12, published December 1963, (London, GB), Herbert Milne: "The application of free-piston machinery to marine propulsion", see page 432, figure b	
A	SU, A, 179123, published November 3, 1966 Shneyerov	
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IV. CERTIFICATION

Date of the Actual Completion of the International Search 2	Date of Mailing of this International Search Report 2
25th June 1981	7th July 1981

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