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(54) Compact camshaft-phasing drive.

(57) A variable camshaft phaser (VCP) (15) is disclosed in various embodiments having lash take-up drive piston assemblies (43,44) with inner and outer helical splines for phase-changing and return springs (63) mounted in pockets (64) in the pistons (43,44) to shorten overall length for a compact unit and also to relieve lash take-up friction on the piston return strokes. Numerous other features are also included. A three-way feed-discharge valve (59) limits oil flow to that necessary to operate the drive pistons (43,44) for phase-changing.

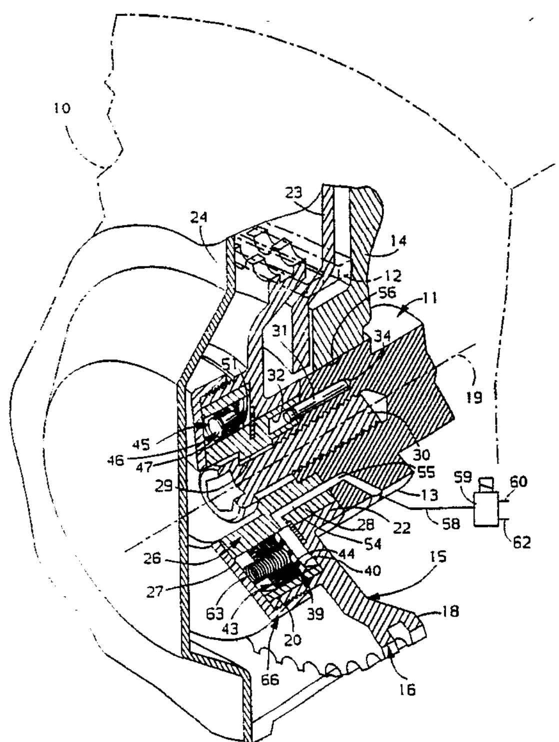

FIG. 1

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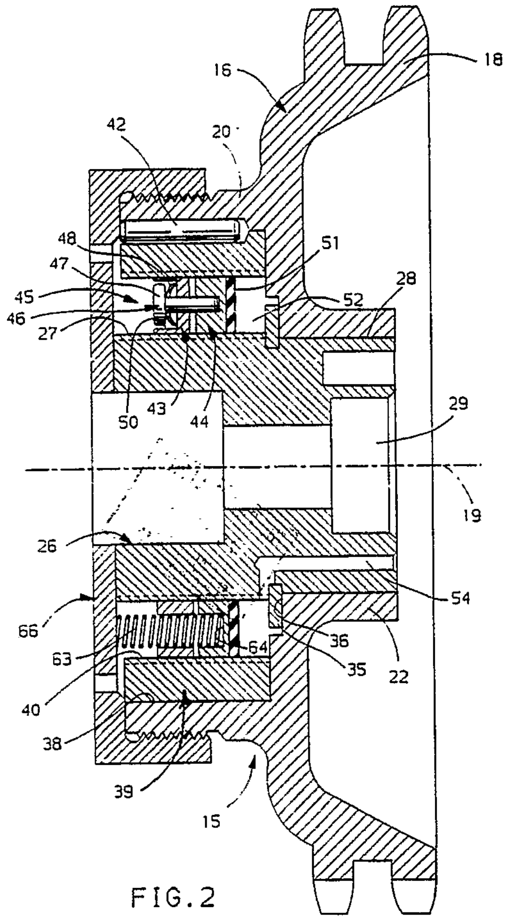
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FIG.2

COMPACT CAMSHAFT-PHASING DRIVE

This invention relates to phase-adjusting drives and especially to camshaft phasing devices for varying the timing of valve actuation by an engine-driven camshaft.

It is known in the art relating to engine valve gear to provide various means for varying valve timing as desired for the control of engine performance and efficiency. Amongst the various types of variable valve timing devices employed have been camshaft phasing devices, often in the form of drive pulleys and the like incorporating phase-changing means for varying the phase between a rotatably-driving input member such as a gear, pulley or sprocket and a rotatably-driven output member such as a camshaft. Amongst the pertinent prior art are mechanisms having splined pistons which are hydraulically actuated against a spring to vary the phasing of outwardly and inwardly engaged drive and driven members. Such arrangements are shown for example in US-A-4,231,330 (Garcea) and US-A-4,811,698 (Akasaka et al).

The present invention extends the concepts of the prior art to provide an especially compact and effective form of phase-adjusting (or hereinafter termed as "phasing") drive. In a preferred embodiment, the invention is used as a variable cam phaser (VCP) applied in an engine camshaft drive to vary the phase or timing of a driven camshaft relative to a driving member, such as a sprocket, pulley or gear, that is driven in timed relation to an engine crankshaft or the like.

A feature of the invention is that multiple return springs engage one of a pair of axially-spaced inwardly-biased (i.e,towards one another) anti-backlash annular drive pistons in such a manner as to minimize anti-backlash friction during return motions of the pistons. An extremely compact assembly results from the arrangement in which the springs extend from a front cover through one of the pistons into engagement with the more distant of the two pistons.

A further feature is that wave spring washers are used with headed pins for biasing of the helically-splined annular drive pistons towards one another to take up the backlash in a limited length assembly.

Still another feature is that a thin sheet oil seal is provided adjacent the inner piston having teeth closely fitted or conformed to a mating hub and shaft to minimize leakage of pressure oil past the drive pistons. The seal may be bonded to the pressure side of the inner drive piston. Additionally or alternatively, sealing may be aided by filling the valleys of the splines with a deformable material such as wax, epoxy resin, metal or plastics material. Either sealing method is consistent with the intent of minimizing the length of the phasing means to provide a compact VCP.

These and other features and advantages of the invention will be more fully understood from the following description of certain specific embodiments of the invention taken together with the accompanying drawings, in which:

Figure 1 is a pictorial view in partial cross-section of an engine with installed variable cam phaser (VCP) according to the invention, for use with a chain drive;

Figure 2 is a cross-sectional view of the VCP of Figure 1;

Figure 3 is an exploded pictorial view of the VCP of Figure 2;

Figure 4 is a cross-sectional view of an alternative embodiment of VCP applied in a timing belt drive; and

Figure 5 is a cross-sectional view of a third embodiment of VCP incorporating an internal three-way control valve.

Detailed Description

Referring first to Figures 1-3 of the drawings in detail, numeral 10 generally indicates an internal combustion engine of a type having a camshaft 11 driven by a crankshaft, not shown, through a chain 12 or other suitable drive means. The camshaft 11 carries a plurality of cams (not shown) for actuating cylinder intake and/or exhaust valves (not shown) of the engine in known manner. It is supported in part by an enlarged front bearing journal 13 that is carried in a suitable bearing within a front wall 14 of an engine cylinder head or camshaft carrier.

On the front, driven, end of the camshaft there is a phase adjuster or variable cam phaser (VCP) 15 that includes a sprocket 16. The sprocket comprises a drive member with a peripheral drive portion, i.e., wheel 18, that is toothed and is drivably engaged by the chain 12 for rotatably driving the sprocket 16 on an axis 19 that is co-axial with the camshaft 11. Within the wheel 18 is a forwardly-extending large front hub 20 and a rearwardly-extending smaller rear hub 22. The rear hub 22 abuts the front end of the camshaft front journal 13 and the VCP assembly is enclosed within a housing 23 and cover 24 mounted on the engine front wall 14.

The VCP assembly 15 further includes a stub-shaft in the form of a spline shaft 26 having an external helical spline 27 at one end and a finished journal 28 at the other. The journal end is secured through a central opening 29 to the front end of the camshaft by a screw 30, with a dowel pin 31 received in openings 32, 34 of the spline shaft 26 and camshaft 11 to maintain a fixed drive relationship between the two shafts.

A bowed retaining ring 35, engaging a groove 36 between the spline and journal ends of the spline shaft 26, bears against the sprocket wall adjacent the smaller hub 22 to hold the sprocket hub in position against the camshaft. The axial spring force applied by the bowed ring 35 prevents axial displacement of the sprocket that would otherwise occur when torque reversals on the camshaft are transmitted through the helical splines.

The journal end of the hub 22 is carried for oscillating motion on the journal 28. The splined end of the spline shaft 26 extends forward within the front hub 20 concentric with the inner diameter 38 thereof. A sleeve 39 having an internal helical spline 40 is fitted within the hub 20 and is maintained in fixed driving relation by a drive pin 42 or any other suitable means such as shrink-fitting or an adhesive. Use of the splined sleeve insert 39 simplifies manufacturing and shortens the axial length by avoiding the need for an undercut at the inner end of the internal spline. The facing splines 27, 40 have opposite and, preferably, equal leads (or helix angles) to provide for the phasing action to be later described.

Between and engaging both splines are two axially-spaced annular drive pistons, called, for convenience, an outer piston 43 and an inner piston 44, the latter being closer to the inner sprocket wall. Both pistons have inner and outer helical splines drivingly mated with the splines 27, 40 of the spline shaft 26 and sleeve 39 respectively.

The splines are mis-aligned so that, when the pistons are urged inwardly towards one another, they engage opposite sides of the mated splines 27, 40 and thus take up the lash that would otherwise occur in transferring drive torque between the sprocket 16 and spline shaft 26. The pistons 43, 44 are urged, i.e., biased, towards one another and are maintained in a drive piston assembly 45 by annularly spaced pins 46 press-fitted in the inner pistons 44 and having heads 47 compressing wave spring washers 48 in recesses 50 on the far side of the outer pistons 43. The short axial length of the spring washers contributes to the compactness of the VCP 15.

An oil seal 51 formed of a thin sheet of preferably formable material such as an elastomer or oil-resistant plastics is mounted against and preferably bonded, or otherwise secured, to the inside face of the inner piston 44 of assembly 45. The seal 51 may be made with teeth originally mating with the splines 27, 40 with a close or slight interference fit. The teeth are worn or deformed upon installation to closely fitting conformity with their mating splines. In this way a highly effective seal against oil loss through the splines is provided.

As an additional seal, the valleys of the splines of the inner piston 44 and its mating external and internal splines 27, 40 may be filled with a deformable or shearable material such as wax, plastics or soft metal to minimize the leak paths therethrough. Alternatively, the deformable material on the splines could be used instead of the thin seal 51. Both means avoid axial extension of the unit in order to provide an oil seal.

The seal 51 together with the splines 27, 40 and the adjacent wall of the sprocket define an annular chamber 52. Engine oil pressure may be supplied to or discharged from this chamber through connecting oil passages 54 in the spline shaft 26 and 55 in the camshaft journal 13 that leads to an annular groove 56. The groove is connected through schematically-illustrated passage means 58 with any suitable form of three-way valve such as solenoid valve 59 which operates to supply pressure oil from an oil gallery 60 or to drain oil to a discharge line 62 whilst blocking the flow from the gallery 60.

The piston assembly 45 is urged in a direction compressing the chamber 52 by eight (or any suitable number of) coil return springs 63 that extend between the ends of recesses 64 in the inner piston 44 and through apertures in the outer piston 43 to an inner face of a cover 66 that is threaded or otherwise retained on the outer hub 20. The arrangement significantly contributes to axial compactness of the VCP.

Operation

In operation of the VCP 15 embodiment just described, when the control valve 59 is not energized the valve 59 preferably closes off the gallery 60 and opens the annular chamber 52 to the drain line 62. The springs 63 are thus able to maintain the drive piston assembly 45 to its extreme inner position near the sprocket wall whereby the volume of the annular chamber 52 is held at a minimum. In this position, the camshaft is preferably maintained by the piston assembly 45 in a retarded phase relation with the sprocket for operation of the actuated engine valves under desired retarded timing conditions.

When the engine operating conditions call for advanced valve timing, the solenoid valve is energized, to close off the drain line 62 and to open the gallery 60 to supply pressurized engine oil to the annular chamber 52 in the VCP 15. The oil pressure moves the piston assembly 45 against the bias of springs 63 to the extreme opposite position adjacent the cover 66. Because of the opposite lead of the inner and outer helical splines 27, 40, the outward motion of the piston assembly 45 advances the timing or phase angle of the camshaft relative to the sprocket so that the timing of the associated engine valves is likewise advanced.

A return to retarded timing when called for is accomplished by de-energizing the solenoid valve 59, blocking oil flow from the pressure gallery 60 and allowing the VCP annular chamber 52 to drain to line 62. The springs 63 then return the piston assembly 45 to its initial retarded position adjacent the sprocket inner wall.

The use of the three-way solenoid valve 59 to control oil flow has the advantage that oil flow is used only for the purpose of advancing the camshaft timing and is shut off at other times. In this way the capacity and power requirements of the engine oil pump may be lessened. However, any other suitable type of valve and supply arrangement may be used to control the oil flow to and from the annular chamber 52. Also, the valve and oil passages may be arranged in any desired manner and located in any appropriate location to accomplish the purpose without departing from the invention.

In addition to their phase-changing function, the pistons 43, 44 of the assembly 45 are also the means through which all torque is transferred from the sprocket 16 to the camshaft 11 and vice versa via their helical splines and the mating splines 27, 40. The mis-alignment of the piston splines and their biasing towards one another by the pins 46 and wave washers 48 takes up any clearance lash in the spline connections by urging the pistons 43, 44 into engagement with opposite sides of the engaged splines 27, 40 as was previously described.

Because of this mode of operation, the passing of the return springs 63 through openings, not numbered, in the outer piston 43 to extend between recesses 64 in the inner piston and the inside of the cover 66 has dual benefits. The overall length of the VCP unit 15 is thereby shortened while the length of the return springs remains relatively long to provide for adequate axial motion of the piston assembly 45. In addition, during the return stroke, the pulling of the outer piston 43 behind the inner piston 44 as it is moved inwards by the return springs tends to increase slightly the separation of the pistons from one another and thereby reduce the lash take-up force, thus reducing the friction that opposes the return motion of the piston assembly. The required force of the return springs may thereby be reduced.

Various alternative embodiments of the invention and its various features may be made within the scope of the disclosed concepts and the appended claims. While not intended to be exhaustive, the following discussion pertains to certain such alternative forms utilising the present invention.

Figure 4 discloses an embodiment of the invention for use with a reinforced rubberlike timing belt drive. Such drive belts are in current use and require an environment that is relatively free of oil. Thus, an engine 67 of Figure 4 carries a camshaft 68 with a front bearing journal 70 and an outwardly adjacent seal flange 71. A seal 72 engages the flange outer surface to prevent oil leakage into an adjacent camshaft drive housing 74.

A variable cam phaser (VCP) or phase adjuster 75 is mounted on the front end of camshaft 68. The VCP includes a pulley 76 having an outer toothed wheel 78 driven by a timing belt 79 and connected with an inner hub 80. The hub includes an end wall 82 having a seal-carrying central opening 83 that is journalled on a finished journal end 84 of a spline shaft 86. A screw 87 secures the spline shaft 86 to the camshaft 68 in a manner similar to that shown in Figure 1.

Also in the manner of Figure 1, the hub 80 receives a sleeve 88 having helical internal splines 90 that concentrically oppose helical external splines 91 of opposite lead on the projecting outer end of the spline shaft 86. These splines are engaged by a lash-free piston assembly 45 with oil seal 51 inwardly biased by return springs 63 as in Figure 1. The springs 63 are seated in an annular cover 92 sealingly secured in the hub 80 and sealingly engaging a seal surface 94 near the end of the spline shaft 86.

The VCP 75 defines an annular chamber 52 which is communicated with a source of oil under pressure or drained through passages 54, 55 in the spline shaft 86 and camshaft 68 in the same manner as in Figure 1. The operation of these portions of the VCP 75 is the same as previously described in the embodiment shown in Figures 1-3.

In Figure 4, oil is prevented from escaping onto the timing belt by the sealing contact of the end wall 82 and the cover 92 with the spline shaft 86. Oil that leaks past the piston assembly 45 is drained to a space 95 outwards of the camshaft seal flange 71 by drain passages 96 and 98 in the spline shaft 86 and camshaft seal flange 71 respectively.

Figure 5 illustrates another embodiment of VCP 100 which includes a sprocket 101, spline shaft 102, retaining ring 104, sleeve 105, drive piston assembly 106, return springs 108 and cover 109 which, although of slightly differing form, are the functional equivalents of the corresponding parts of the Figure 1 embodiment. Figure 5 differs in that a screw 110 that secures the spline shaft 102 to the camshaft, not shown, also incorporates a three-way oil control valve.

The threaded shank of the screw has an axial feed passage 111 for receiving oil under pressure from a gallery, not shown, in the centre of the camshaft. In the base of the head, passage 111 connects with a valve chamber 112 having opposed first and second valve seats 114, 115. Cross-passages 116 lead transversely from the valve chamber 112 to an annular space 118 that is connected by a duct 119 to an annular chamber 120 that borders on the piston assembly 106. In the valve chamber is a pintle 121 having a head seatable on the valve seats 114, 115 and a stem 122 extending axially into a socket 123 provided for driving the screw 110. Drain grooves 124 in a seat insert around the stem 122 connect the valve chamber 112 to drain.

A solenoid actuator, not shown, or other suitable actuating means may be mounted on the associated engine in a position to engage the stem 122 of the valve pintle 121 when desired. A seal ring 125 around the head of the screw 110 closes a leakage path for oil under pressure from the annular space 118.

In operation, preferably the solenoid actuator would normally be biased against the stem 122 with a force sufficient to seat the pintle 121 against the first valve seat 114, thereby cutting off pressure oil flow and discharging any oil in the annular chamber 119 through the drain grooves 124. Energizing the solenoid actuator would release the force on the stem 122, allowing the pintle 121 to be forced off the first seat 114 and seated on the second seat 115 by the force of engine oil pressure in the feed passage 111. This closes the drain grooves 124 and allows pressure oil to flow to the annular chamber 120 to actuate the drive piston assembly 106 in the manner previously described with the other embodiments. De-energizing the solenoid actuator would return the system to the previous condition.

The arrangement has the advantage of providing a compact internal control valve for use with applications of the variable cam phaser (VCP) of the invention in appropriate engine configurations.

Whilst the invention disclosed in this application is not so limited, it is noted that all of the described embodiments can be assembled prior to installation on an engine and then simply attached (or detached) by use of the single screw which is either left exposed or is covered only by a removable central plug. This allows all the working parts of the VCP unit to be assembled and tested, if desired, at the factory prior to delivery for installation on an engine, rather than having to complete any significant part of the unit during engine assembly.

Although the embodiments described have shown the use of inner and outer helical splines of opposite lead, it should be evident that a combination of straight and helical splines could be substituted if desired. Also inner and outer helical splines of differing lead angles could be used. It would also be possible to substitute other forms of cam-like devices for the splines illustrated whilst incorporating at least some feature or features of the present invention.

Claims

1. A variable cam phaser (15) comprising co-axial drive and driven members (16,11) drivingly connected to one another by annular piston means (43,44) having inner and outer splines of varying lead, said annular piston means (43,44) being axially movable in one direction by force means to vary the phase relationship between said drive and driven members (16,11), <u>characterised in that</u> there is a plurality of springs (63) seated in recesses (64) of the piston means (43,44) so as to compactly bias the piston means (43,44) in a return direction opposite to the direction of actuation by said force means.

2. A variable cam phaser (15) according to claim 1, <u>characterised in that</u> said force means includes oil under pressure, controllably supplied to a chamber (52) on one side of the piston means (43,44).

3. A variable cam phaser (15) according to claim 2, <u>characterised in that</u> the piston means (43,44) coact with seal means (51) adjacent the pressure oil chamber (52) and extending into valleys of the mating splines to restrict the leakage of oil under pressure from the chamber (52).

4. A variable cam phaser (15) according to claim 3, <u>characterised in that</u> the seal means (51) comprises a thin formable member engaging the chamber side of the piston means (43,44).

5. A variable cam phaser (15) according to claim 2, <u>characterised in that</u> the springs (63) are also seated upon a removable cover (66) on an outer side of the cam phaser (15) distant from the pressure oil supply.

6. A variable cam phaser (15) according to claim 1, <u>characterised in that</u> the co-axial drive and driven members (16,11) are drivingly connected by a pair of axially-spaced annular pistons (43,44) with misaligned inner and outer splines of varying lead, which pistons (43,44) are biased one towards the other for lash take-up, the pistons (43,44) being axially movable in said one direction by said force means acting against one (44) of said pistons; and said springs (63) extend through the other (43) of the pistons and are seated in recesses (64) of said one piston (44) so as to reduce the lash take-up

friction of the pistons (43,44) during piston return strokes upon relaxation of the force means acting against said one piston (44).

7. A variable cam phaser (15;100) according to claim 6, characterised in that said force means includes oil under pressure, controllably supplied to an annular chamber (52;120) on a side of said one piston (44) opposite from said other piston (43).

8. A variable cam phaser (15) according to claim 7, characterised in that the springs (63) are also seated upon a removable cover (66) on an outer side of the cam phaser (15) distant from the pressure oil supply.

9. A variable cam phaser (15) according to claim 6, characterised in that the phaser (15) includes biasing means comprising wave spring washers (48) compactly biasing the pistons (43,44) towards one another.

10. A variable cam phaser (15) according to claim 6, characterised in that said driven member comprises a splined shaft (26) fixed to a driven camshaft (11) and said drive member includes a hub (22) oscillatably carried on the splined shaft (26), said cam phaser (15) further including a bowed retaining ring (35) acting between the splined shaft (26) and the hub (22) and resiliently urging the hub (22) into engagement with the camshaft (11) to avoid axial motion of the hub (22).

11. A variable cam phaser (15) according to claim 7, characterised in that said one piston (44) co-acts with seal means (51) adjacent the pressure oil chamber (52) and extending into valleys of the mating splines to restrict the leakage of pressure oil from the chamber (52).

12. A variable cam phaser (15) according to claim 11, characterised in that the seal means (51) comprises a thin formable member engaging the chamber side of said one piston (44).

13. A variable cam phaser (75) according to claim 7, characterised in that the phaser further comprises means (82,92) containing oil leakage past said pistons (43,44) and return passage means (95,96,98) extending from the containing means to a location external to the cam phaser (75) to avoid discharging oil on to an associated oil-affected drive element (79).

14. A variable cam phaser (15) according to claim 2, characterised in that there is a valve means (59) operable to connect the chamber (52) with one of a supply (60) of oil under pressure and a drain (62) whilst concurrently closing a connection with the other of said supply (60) of oil under pressure and said drain (62).

15. A variable cam phaser (15) according to claim 14, characterised in that the valve means (59) comprises a three-way valve.

16. A variable cam phaser (100) according to claim 7, characterised in that there is a valve means (121) operable to connect the annular chamber (120) with one of a supply (111) of oil under pressure and a drain (124) whilst concurrently closing a connection with the other of said supply (i11) of oil under pressure and said drain (124).

17. A variable cam phaser (100) according to claim 16, characterised in that the valve means (121) comprises a three-way valve.

18. A variable cam phaser (100) according to claim 17, characterised in that said three-way valve (121) is carried in a screw (110) which is threaded into a camshaft and which receives oil under pressure therefrom, said screw (110) also fixing said driven member (102) to said camshaft.

19. A variable cam phaser (100) according to claim 18, characterised in that the three-way valve is a pintle valve (121) reciprocably movable in a valve chamber (112) between two oppositely disposed valve seats (114,115) so as to selectively engage one or the other of said valve seats (114,115) to thereby block either said supply (111) of oil under pressure or said drain (124) from connection with said annular chamber (120) whilst allowing such a connection with either said drain (124) or said supply (111) of oil under pressure.

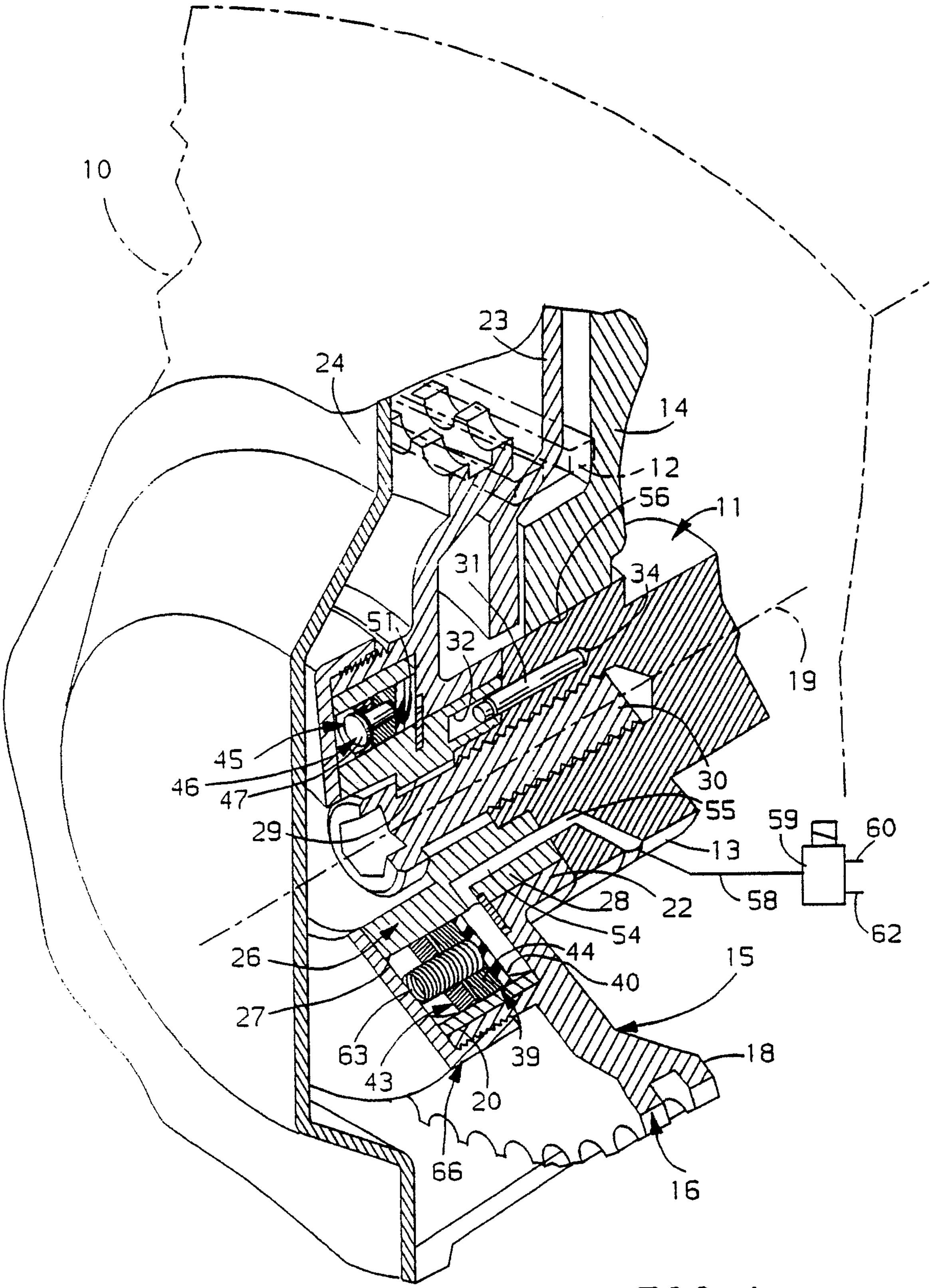
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FIG.1

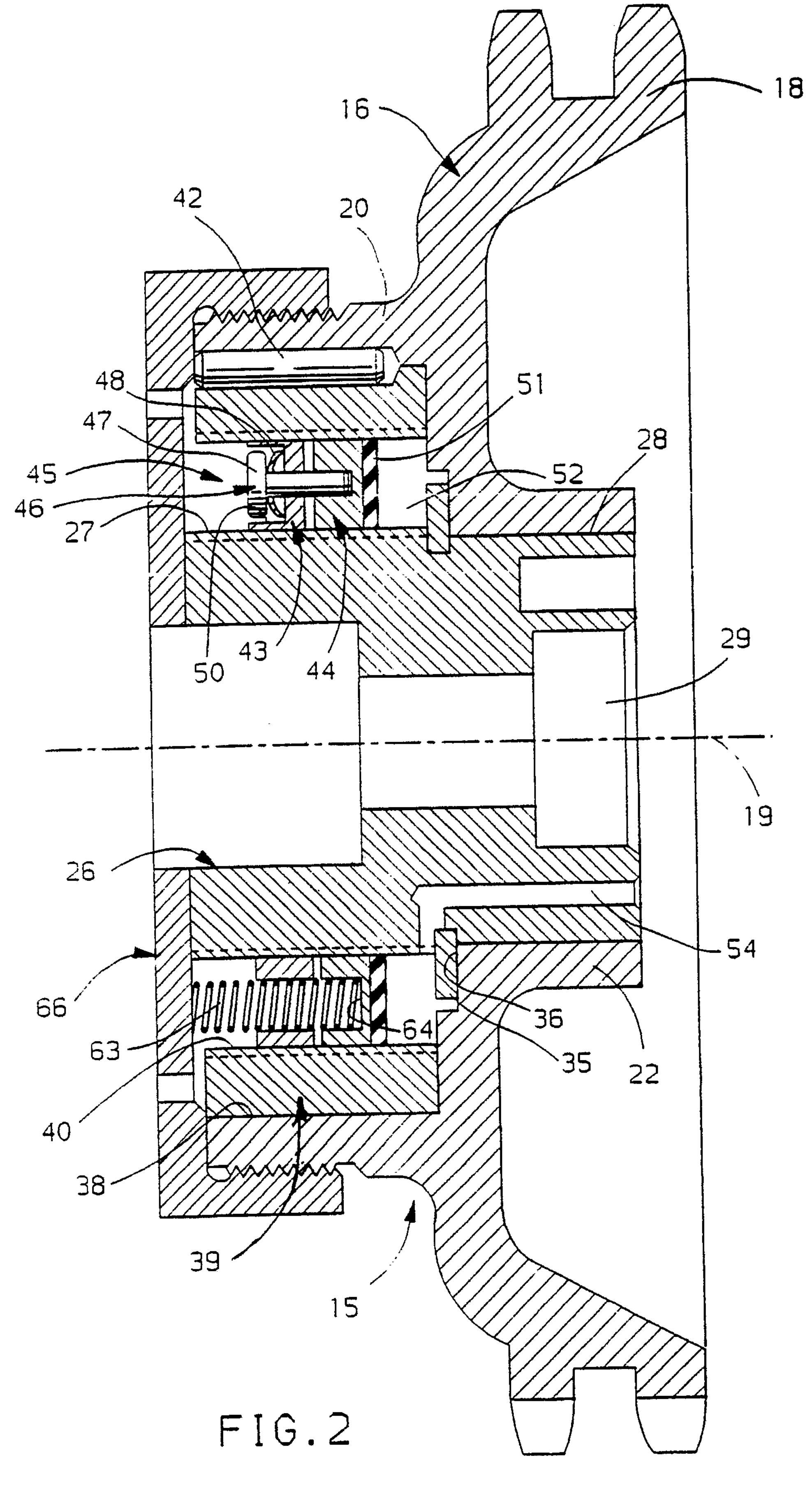
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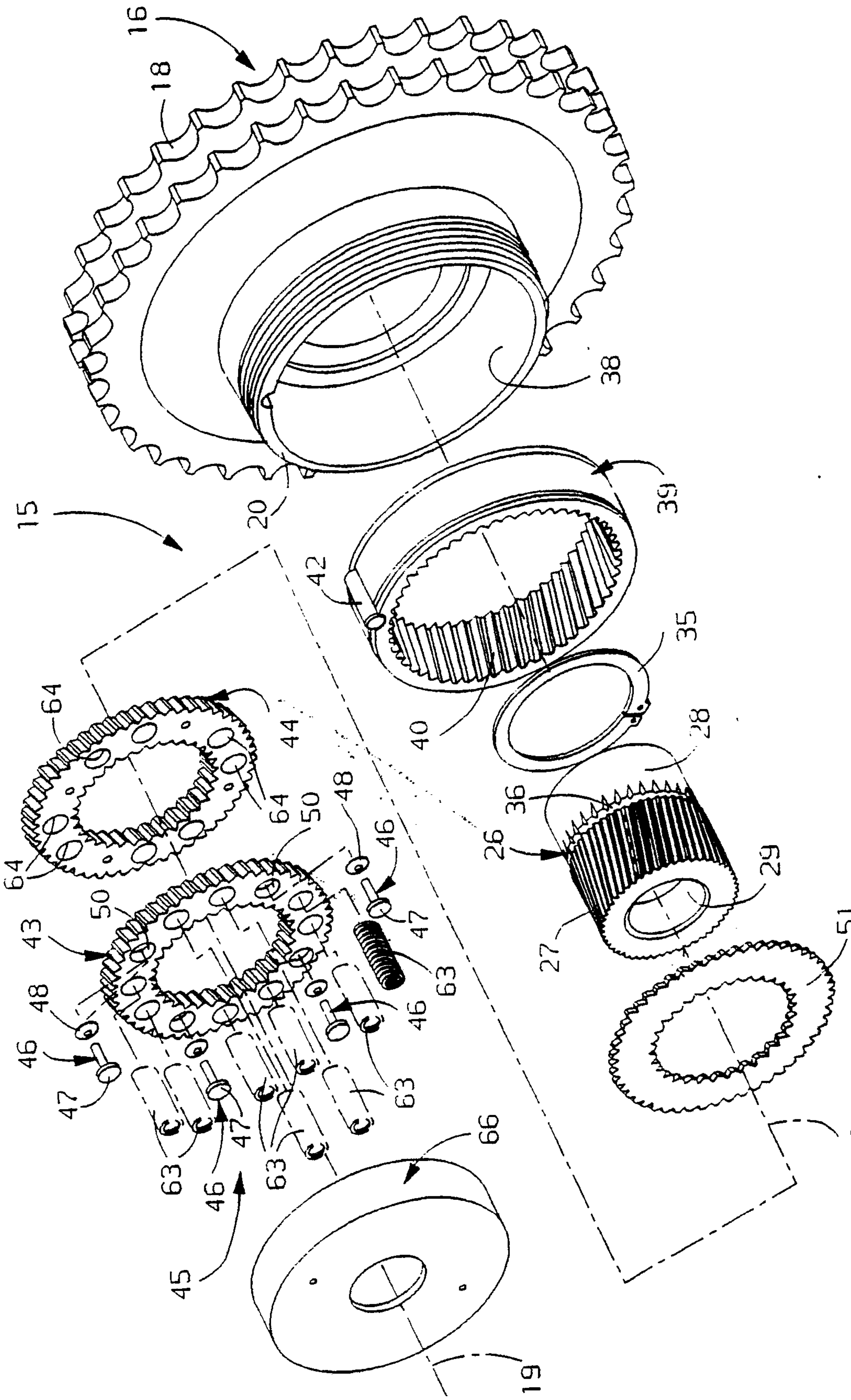
FIG. 2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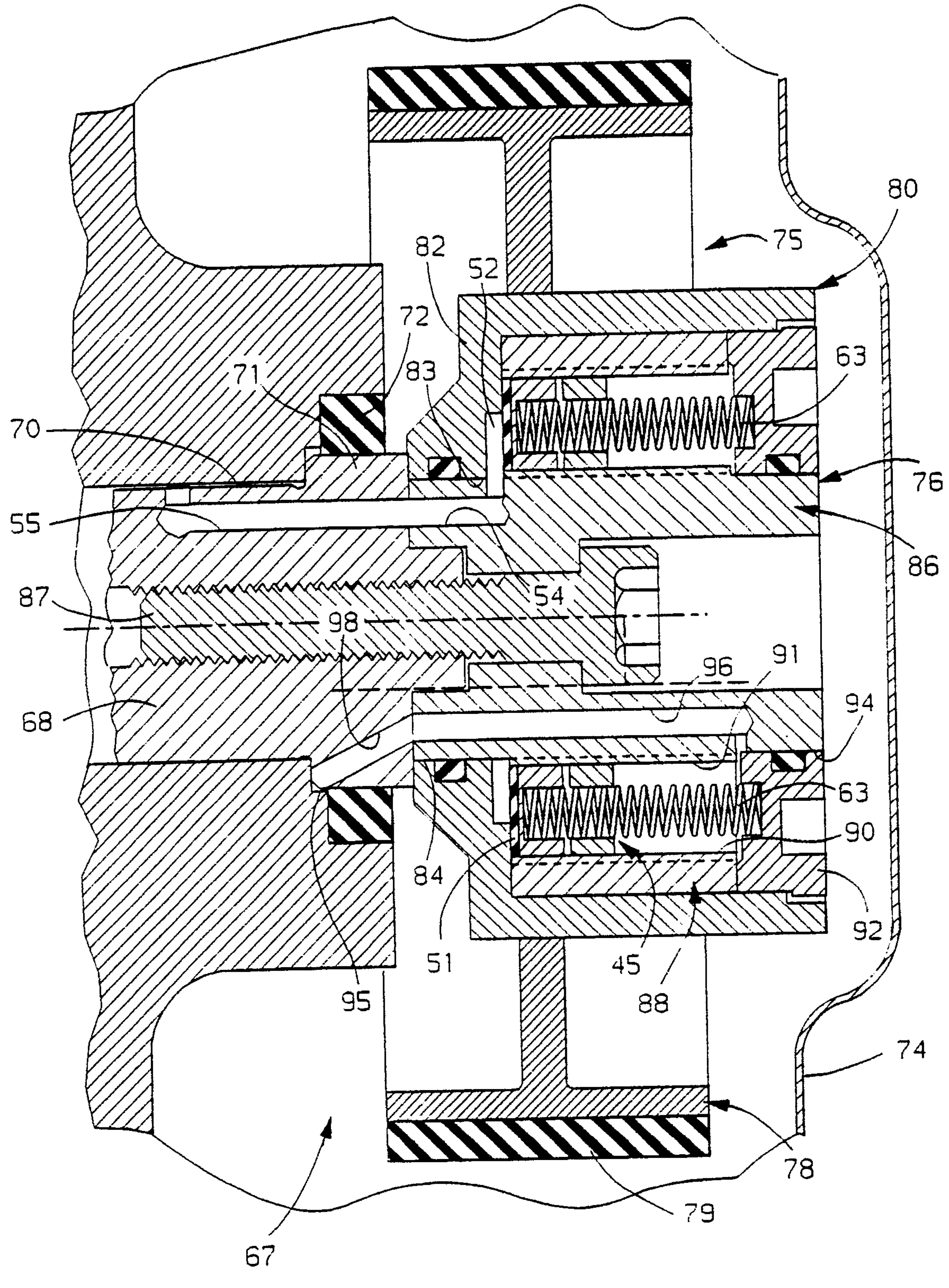
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FIG. 4

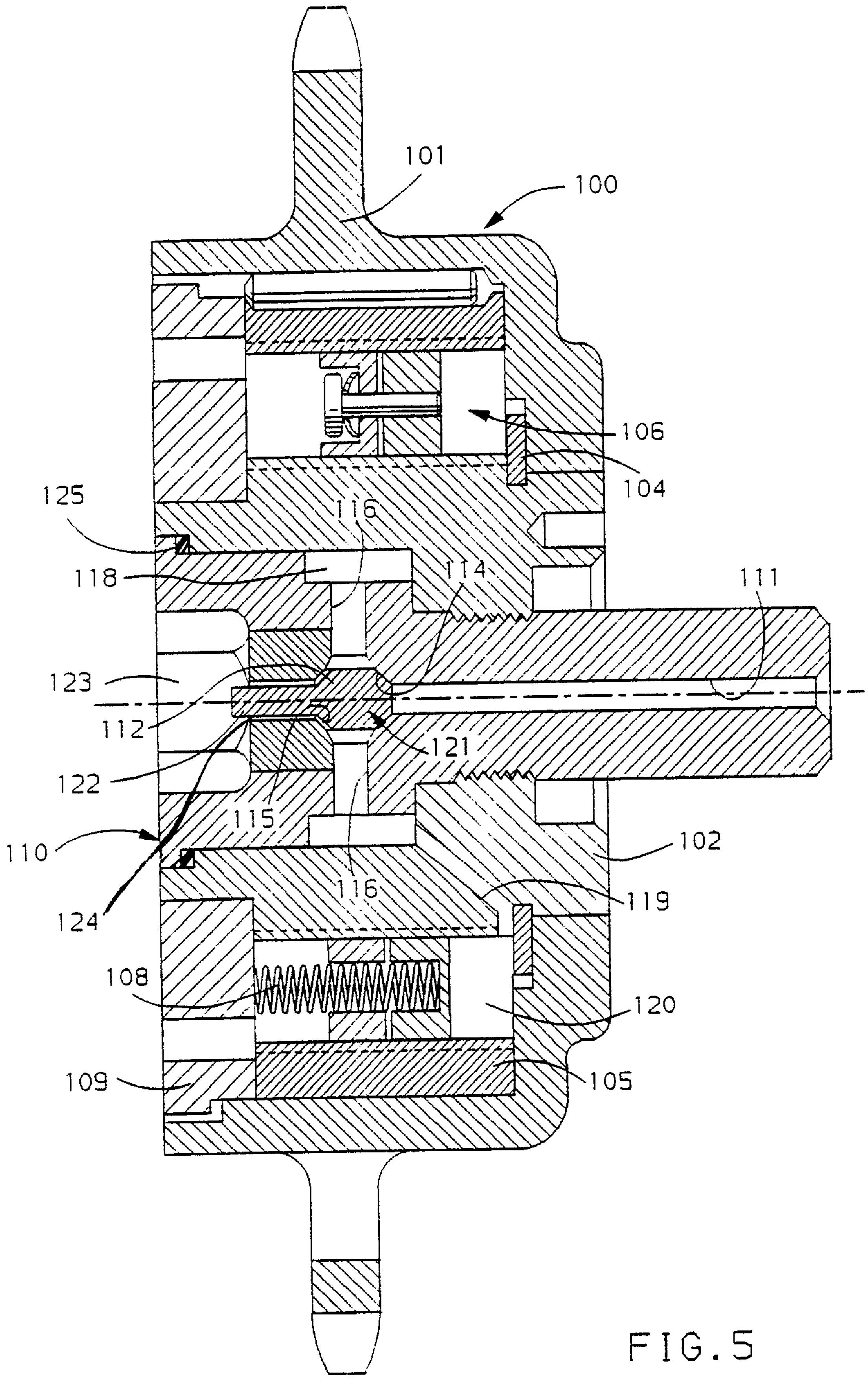
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FIG. 5

European
Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 90 31 0453

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.5)
D,X,D,A	US-A-4 811 698 (AKASAKA) * column 7, line 55 - column 8, line 32; figures 2-10 * - - -	1,2,6,7, 14,15	F 01 L 1/34
A	GB-A-2 157 364 (GRAHAM) * page 1, lines 22 - 26; figure 1 * - - -	14-17	
A	GB-A-2 019 613 (BOSCH) * page 3, lines 31 - 35; figure 1 * - - - - -	1	

TECHNICAL FIELDS SEARCHED (Int. Cl.5)
F 01 L F 16 D F 02 D

The present search report has been drawn up for all claims

Place of search	Date of completion of search	Examiner
The Hague	15 January 91	LEFEBVRE L.J.F.

CATEGORY OF CITED DOCUMENTS

X: particularly relevant if taken alone
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D: document cited in the application
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