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

(11) Publication number: **0 413 430 A1**

(12) **EUROPEAN PATENT APPLICATION**

(21) Application number: **90307401.1**

(51) Int. Cl.5: **F02M 59/46**

(22) Date of filing: **06.07.90**

(30) Priority: **14.08.89 US 393183**

(43) Date of publication of application: **20.02.91 Bulletin 91/08**

(84) Designated Contracting States: **DE FR GB IT**

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(54) **Fuel-delivery and variable-volume retraction valve assembly for fuel-injection system.**

(57) A fuel-delivery valve assembly (70) with a variable-volume, fuel-retraction collar (96) is operatively mounted in a bore (72) of an engine-driven high-pressure fuel pump rotor (62) fed with fuel through a metering valve (46). The valve assembly operates at speeds proportional to engine speed between an open position, in which a pressure wave of fuel generated by the fuel pump (66) is transmitted to a fuel injector nozzle (22), and a closed position, in which a valve charging chamber (90) is sealed by the retraction collar (96) which has a pair of flats (116,118) ground therein. During low-speed engine operations, the flats (116,118) provide bleed paths to reduce the volume of fuel retracted so that engine shut-down will be immediate when the metering valve (46) is closed. During high-speed operation, valve element operating frequency increases to such a rate that the flats (116,118) are ineffective as bleeds and the volume of fuel retracted is increased. With increased retraction of fuel, secondary fuel injection is eliminated.

FIG.1

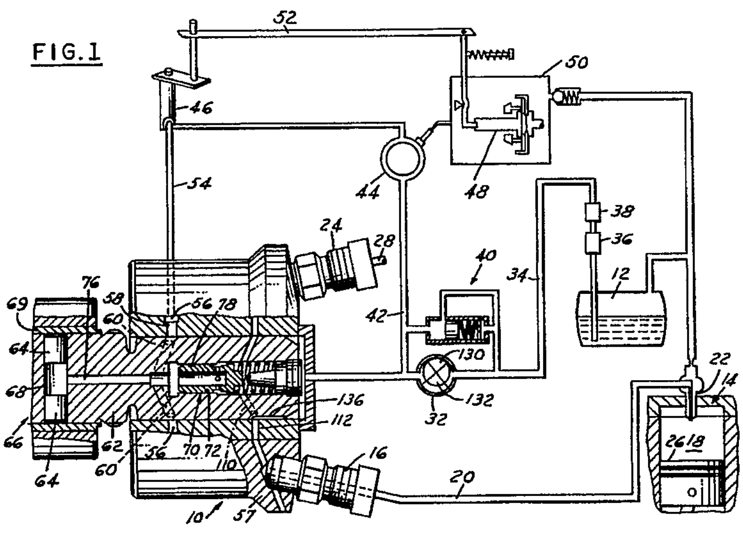
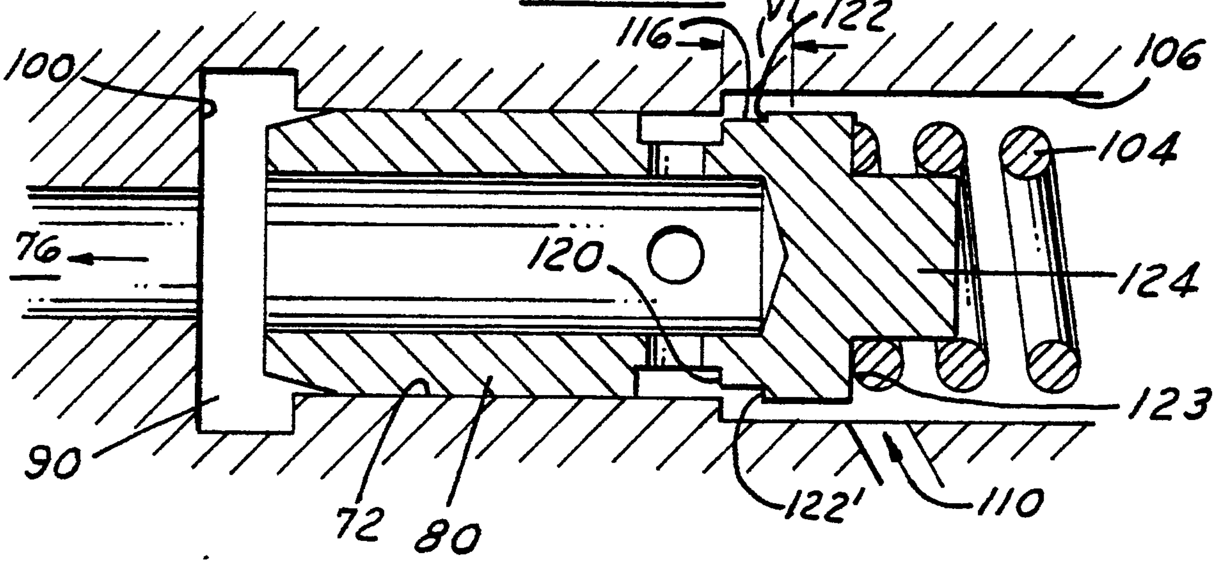


FIG.5



FUEL-DELIVERY AND VARIABLE-VOLUME RETRACTION VALVE ASSEMBLY FOR FUEL-INJECTION SYSTEM

Technical Field

This invention relates to fuel injection for internal combustion engines and more particularly to a fuel-delivery, variable-volume valve for a pumping system for directing high-pressure waves of fuel to a combustion chamber of an internal combustion engine as specified in the preamble of claim 1, for example as disclosed in SAE Paper No. 790899 (Hess et al).

Background of the Invention

Prior to the present invention, fuel injector pumping systems for internal combustion engines have incorporated a fuel-delivery and retraction valve in the fuel flowing between a high-pressure pump and injector nozzles for combustion chambers of the engines. This valve serves as a one-way check valve to seal the high-pressure pumping chamber from the injector lines when fuel is not being delivered to the nozzle, and to control the residual line pressure with valve retraction and volume unloading. Without appropriate retraction and sealing, difficulties are encountered in shutting the fuel off at both low and high engine speeds.

Various venting constructions have been designed or proposed for such injector systems to vent injection lines after ignition has occurred in the associated combustion chamber to ensure that the lines have uniform residual pressure thereon for the injectors in preparation for subsequent delivery of pressure waves of fuel thereto. This helps to reduce late reflected pressure waves and to ensure that each line has the same balanced pressure after firing. In such systems, the engine may continue to operate for a time after the metering valve has closed-off fuel delivery to the high-pressure pump. This happens because a retraction collar has pulled too much fuel from the injection line at low engine speed causing a negative pressure differential to occur between the injection line and a transfer pump. Accordingly, instead of venting fuel under pressure in the injector line to the transfer pump, the fuel from the transfer pump is delivered to the injector line, bypassing the metering valve and delivery valve element. This may result in continued engine operation after shut-down thereof is desired.

A fuel-delivery, variable-volume valve assembly according to the present invention is characterised by the features specified in the characterising portion of claim 1.

In the present invention, the short-circuiting of fuel from the transfer pump to the injection line which is open to vent is effectively eliminated by providing a variable-volume retraction valve collar on the delivery valve. The retraction halve collar has leak paths provided by small flats extending across only a part of the retraction collar. The flats produce only a small but definite retraction volume of fuel at low speed since there is fuel leakage around the flats as the valve retracts. With this small retraction volume, secondary fuel injection at low speed is eliminated and there are no pressure cavities formed in the line so that engine operation is rapidly terminated when the metering valve is closed. The retraction volume of fuel progressively increases as engine speed increases from a predetermined low speed to a predetermined high speed since the effectiveness of the flats as leak paths decreases with speed. At high speeds, the leakage paths provided by the small flats are ineffective since the time for leakage across the flats is minimal. Therefore, there is full retraction of fuel as the valve closes. Accordingly, with full fuel retraction, pressure waves of fuel reflecting from the injectors are reduced or dissipated so secondary fuel injection is minimized and there is good combustion maintenance for high-speed operation. The length and depth of the leak path can be readily controlled by appropriate sizing of the depth and length of the flats to provide a mechanism for adjusting or tailoring retraction volume, particularly low-speed retraction volume.

A feature, object and advantage of the invention is to provide a new and improved variable-volume retraction valve for a fuel-injector system which retracts varying volumes of fuel from injection lines for optimizing the fuel-handling performance and engine operation. Another feature, object and advantage of this invention is to provide a new and improved variable-volume retraction valve that (1) will retract a definite but small volume of fuel from a fuel-injector line at low engine speeds so that secondary injections are eliminated and engine shut-down can be effectively and rapidly obtained; (2) will retract a definite and large volume of fuel from a fuel-injector line at speeds above a predetermined speed so that secondary injections are eliminated and good fuel combustion at high engine speeds is maintained and (3) will provide a seal between a pumping chamber of the pump and the line when the valve is closed so that further retraction of pumping plungers of the pump does not cause pressure cavities in the fuel in the line.

Another feature, object and advantage of this invention is to provide a new and improved retraction valve that retracts different volumes of fuel from a fuel-injection line as a function of engine speed including retraction volumes that progressively increase from a predetermined low-speed retraction volume to a predetermined high-speed retraction volume.

Another feature, object and advantage of this invention is to provide a variable volume retraction valve for an engine fuel-injector system with a fuel bleed across a portion of a fuel-delivery valve retraction collar, which bleed can be tailored in length and capacity for selective control of retraction volumes of fuel from injection lines to optimize the hydraulic performance of fuel-injection events.

These and other objects, advantages and features of the invention will be more apparent from the following detailed description and the accompanying drawings, in which:

Description of the Drawings

Figure 1 is a schematic diagram of a portion of a fuel flow system for a distributor pump for a fluid-injected internal combustion engine;

Figure 2 is a diagrammatic view in cross-section of a fuel pump rotor and housing illustrating fuel-injection and line-venting;

Figure 2A is a pictorial view of the pump rotor of Figure 2;

Figure 3 is a cross-sectional view of a portion of the distributor pump of the system of Figure 1, showing a variable-volume retraction valve according to the present invention;

Figures 4, 5 and 6 are cross-sectional views of the fuel-delivery and variable-volume retraction valve of this invention in different positions of operation;

Figure 7 is an elevational view of the fuel-delivery and variable-volume retraction valve element of this invention; and

Figure 8 is a graph illustrating the variable retraction volume operation of the retraction valve of this invention.

Detailed Description of the Drawings

Turning now in greater detail to the drawings, there is shown in Figure 1 a hydraulic head assembly 10 of a distributor pump for pumping and distributing pressure waves of liquid fuel from a tank 12 to combustion chambers of an internal combustion engine 14. The head assembly 10 is shown with discharge fitting 16 feeding combustion chamber 18 through high-pressure fuel injector line 20 and nozzle 22. A second discharge fitting 24 of the head assembly feeds a second combustion chamber 26 diagrammatically shown in Fig. 2 through line 28 and nozzle 30.

The head assembly 10 includes a vane-type transfer pump 32 driven by the engine 14 that pumps fuel at low pressure from the fuel tank 12 through line 34 having water separator 36 and fuel filter 38 therein. The output volume and pressure of pump 32 is controlled by a hydraulic pressure regulator 40 connected in parallel therewith. The transfer pump has its output connected to a transfer line 42 that feeds into an annular charging passage 44 which connects to a metering valve 46 whose output is controlled by an engine-driven governor 48 mounted in distributor pump housing 50. Quantities of fuel as metered by the valve 46 are fed by passage 54 to an annular charging passage 56 in a fixed body 57 of the head assembly that has arcuately-spaced and inwardly-extending ports 58 that are fixed for registry with inlet passages 60 of a fuel distributor rotor 62 that is rotatably mounted in the fixed body of the head assembly and driven by the engine so that rotor-mounted pumping plungers 64 of a cam-operated, high-pressure pump 66 can pump high-pressure waves of fuel from a pumping chamber 68 to a delivery and variable-volume retraction valve assembly 70 operatively mounted in a centralized bore 72 in the rotor 62.

The plungers 64 move radially outwards in their associated bores within the rotor 62 a distance proportional to the amount of fuel required for injection on the following stroke. For example, at engine-idle, the metering valve 46 is highly restrictive and a correspondingly small volume of fluid is fed into the pumping chamber 68 so that the plungers move out a proportionally short distance. When the engine is operating at full load, the metering valve fully opens and the plungers are forced to their outermost position by proportionally increased volume of fuel from the metering valve. As the rotor is driven, the pumping plungers are moved inwards by a fixed cam ring 69 to pump pulses (pressure waves) of high-pressure fuel to the delivery and variable-volume retraction valve assembly 70 by way of an axial pump passage 76 of the rotor 62.

As best shown in Figure 3, the valve assembly 70 has a valve element 78 mounted for linear shifting movement within the bore 72 at cycling frequencies that increase with engine speed. The valve element 78 has a main cylindrical body 80 with a centralized axially-drilled bore 82, a blind end of which communicates with diametral cross-bores 84 that extend through the body 80 of the valve element 78 to terminate at an annular fuel-feed groove 86. The entrance end of the blind bore 82 in the valve element communicates with a variable-volume connector chamber 90 that is primarily formed by the valve element 78 as it shifts in bore 72. Chamber 90, being at the end of axial passage 76, communicates with the pumping chamber 68 of the high-pressure pump 66 and receives pressure waves of fuel therefrom when the inlet passages 60 are closed and the plungers 64 are moved inwards.

The outboard end of the valve element 78 has a cylindrical bore closure and retraction collar 96 integral with the main body 80, which collar extends outwards of the annular fuel-feed groove 86. The bore closure and retraction collar 96 is lapped to slidingly and sealingly fit in the bore 72 when the valve element 78 is moved towards the seated position of Figure 4 in which inner end 98 of the valve element 78 contacts valve seat 100 formed by a wall at the inner end of bore 72 and chamber 90.

The valve element 78 is urged towards the seated position shown in Figure 4 by a helical return spring 104 located in a large-diameter bore forming a spring pocket 106. This spring pocket 106 is co-axial with and hydraulically communicates with the smaller-diameter bore 72 during certain positions of movement of the valve element 78. A fuel-delivery discharge passage 110 formed in the rotor 62 sequentially feeds, as the rotor 62 rotates, arcuately-spaced fuel-feed passages 112 and 114 in body 57 of the head assembly. The feed passages 112 and 114 respectively connect into the two discharge fittings 16 and 24 that project from the head assembly.

The bore closure and retraction collar 96 is formed with a pair of diametrically-opposed retraction-volume-controlling flats 116 and 118 ground in the outer periphery thereof as best shown in Figures 4-7. Each of these flats 116, 118 extends a predetermined distance from an inner face 120 of retraction collar to a terminal vertical wall 122 or 122′ located at a predetermined distance from the face 120 to provide fluid-leakage passages under certain fue-retraction collar positions and conditions. The number of flats and their location are selected to suit operating requirements. In one preferred embodiment, a single flat has been utilized.

The return spring 104 mounted in the large-diameter spring pocket 106 seats on an outer face 123 of the retraction collar and surrounds an end stop 124 that extends axially from the retraction collar 96 of the valve element 78. The stop 124 is adapted to contact a projecting end of a valve lift stop 126 that is mounted in the large-diameter spring pocket 106, which valve lift stop also provides a seat for the outer end of return spring 104. The valve lift stop 126 is trapped in position between the return spring 104 and a plug 128 threaded into the end of spring pocket 106. Vane holders 130, 132 formed on the end of rotor 62 operatively support the vanes of the transfer pump 32 diagrammatically shown in Figure 1.

As illustrated in Figures 1, 2 and 2A, the rotor 62 has a longitudinally-extending vent groove 136 arcuately spaced from and adjacent to the fuel-delivery passage 110 so that the injection line can be vented immediately after the injection event. For example, Figure 3 shows the rotor in the delivery position in which the delivery passage 110 registers with the fuel-feed passage 112 and a pressure wave of fuel is fed to injector line 20. After injection and combustion in chamber 18, the continuously turning rotor turns, as shown by directional arrow A, to the Figure 1 position so that vent groove 136 registers with the passage 112 so that the injection line 20 will be vented to the transfer pump as diagramatically shown in Figure 1. As the rotor continues to turn, delivery passage 110 will align with feed passage 114 and fuel will be pumped to chamber 26 through line 28, as shown in Figure 2, and then the vent groove 136, arcuately spaced from delivery passage 110, will register with feed passage 114 to vent line 28 after the combustion event in chamber 26.

In fuel delivery operation for high engine speed, the valve assembly 70 is rapidly displaced from its valve seat 100 to the delivery position shown in Figure 3 by a wave of high pressure fuel. This pressure wave is generated by the pumping plungers as they are moved inwards, and is transmitted into fuel-feed groove 86. Since groove 86 is opened to the spring pocket 106, the wave travels through the rotor discharge passage 110 into fuel feed passage 112 and into the fitting 16 for charging line 20 for the measured fuel injection of combustion chamber 18. When the valve element 78 has ended this delivery it moves toward its seat and, as illustrated in Figure 5, high-speed retraction begins. During high-speed retraction, the speed of the valve element is such that the flats 116, 118 have no bleeding effect because of quick closure and only minute amounts of fuel are squeezed through the small bleed openings provided by the flats. Accordingly, a full retraction volume of fuel illustrated by volume V1 in Figures 5 and 8 is produced so that secondary fuel injections are eliminated or reduced and good combustion at high speed can be maintained.

In contrast to high engine speed operation, Figure 6 illustrates the valve element moved to the start of retraction position for low engine speed (from idle up to 2200 rpm). Because the valve element moves toward its seat at a relatively slow speed, the flats 116 and 118 are effective as fluid leak paths. Accordingly, the volume of fuel retracted by the retraction collar 96 as shown in Figures 6 is not as large as that retracted as shown in Figure 5, because of the leakage around the flats 116, 118 from chamber 90 into the spring pocket 106. As the valve moves to the seated Figure 4 position, the small volume V2 represents the small retraction volume of fuel at a low speed. Since there are no pressure cavities formed in the fuel in the feed line, there will be no short-circuit from the transfer pump through the vent groove 136 to the line, and the fuel can be shut off by closure of the delivery valve 46. The feed line is subsequently pressure-balanced by the venting groove 136 with the transfer pump when the groove aligns with feed passage 112 as in Figure 1.

Figure 8 is a graph illustrating operation of this invention. From idle up to a predetermined engine speed N2, such as 2200 rpm, for example, a small volume V2 of fuel will be retracted from the injection lines. At a predetermined high speed N1, a large volume V1 of fuel will be retracted. As engine speed increases from N2 to N1, the retraction volume progressively increases as shown by curve R since the effectiveness of the fuel bleed path decreases with speed.

Accordingly, with this invention the pump can be shut-off at all speeds, even when rotor vent grooves are utilized since the retraction volume is small enough at low speeds to eliminate voids in the feed lines so the metering valve will not be circumvented. The plungers themselves cannot retract fluid from the lines since the sealing surfaces of the retraction collar outward of flats 116, 118 seal bore 72 when the valve is in the seated position of Figure 4. At high and intermediate speeds, the retraction volume is still large enough to eliminate secondary injections and to provide good combustion.

Claims

1. A fuel-delivery, variable-volume valve assembly (70) for controlling fuel pumped to an injection line (20), said valve assembly comprising a valve housing (62) having a bore (72) of a first diameter and having a pocket (106) extending from and in communication with said bore (72); a valve element (78) having a cylindrical main body (80) sized for fluid-sealing and sliding contact with the walls defining said bore (72), and having a fuel-discharge opening (86) and a bore-closing, fuel-retraction collar (96) disposed adjacent to one end thereof, said collar (96) having inner and outer faces (120,123), and slidably and sealingly fitting said bore (72) and extending into said pocket (106); a seat (100) for said valve element (78) formed at one end of said bore (72); a fuel passage (82) in said valve element (78) having a connection (84) to said fuel-discharge opening (86); a return spring (104) for said valve element (78) mounted in said pocket (106) and contacting said valve element (78); and a fuel-delivery passage (110) in said housing (62) communicating with said pocket (106), characterised in that there are fluid bleed means (116,118) formed in the periphery of said collar (96) which extend from said inner face (120) of said collar (96) to a predetermined point (122,122') between said inner and outer faces (120,123) of said collar (96) and are sized so that said retraction collar (96) effectively seals said bore (72) at said inner face (120) when said valve element (78) moves with high retraction speed toward said seat (100) to effect retraction of a large volume of fuel from said injection line (20), and seals at said predetermined point (122,122') when said valve element (78) moves with low retraction speed towards said valve seat (100) to effect retraction of a low volume of fuel from said injection line (20).

2. A fuel-delivery, variable-volume valve assembly (70) according to claim 1, characterised in that said valve housing is a fuel pump rotor (62), said rotor (62) has a vent passage (136) therein for venting fuel from said injection line (20), and said retraction collar (96) retracts a progressively increasing volume of fuel from said injection line (20) as the retraction speed of said valve element (78) increases from said low retraction speed to said high retraction speed.

3. A fuel-delivery, variable-volume valve assembly (70) according to claim 1 or 2, characterised in that said fluid bleed means comprises two diametrically-opposed flat sections (116,118) formed in the periphery of said collar (96).

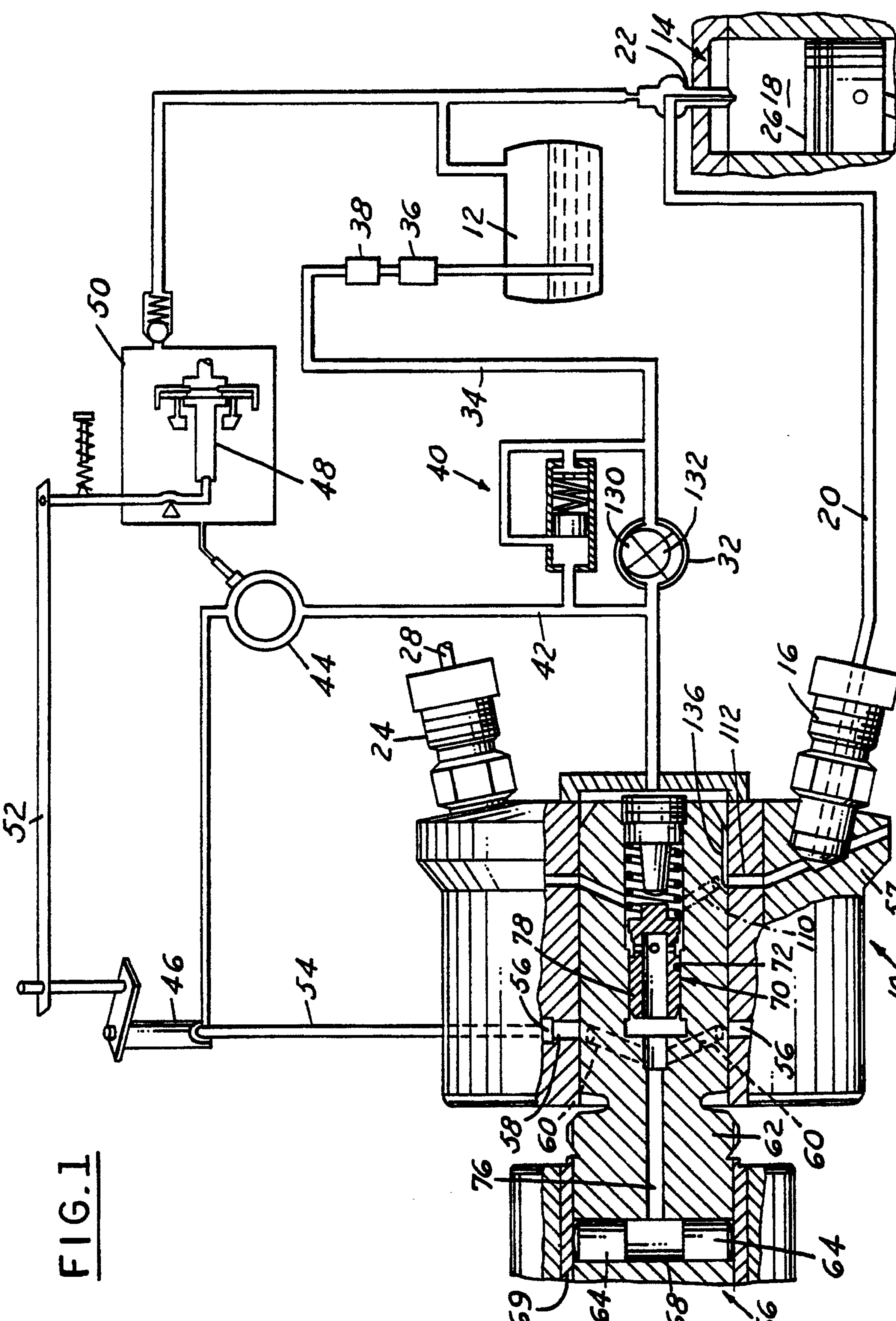

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FIG.1

FIG.2

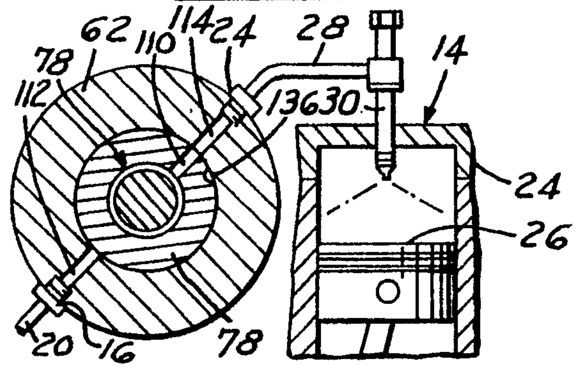


FIG.2A

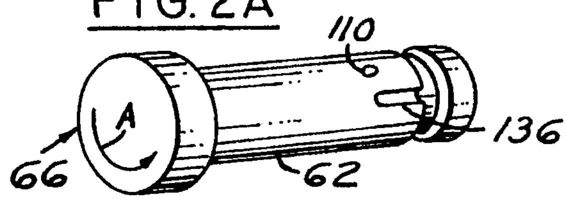
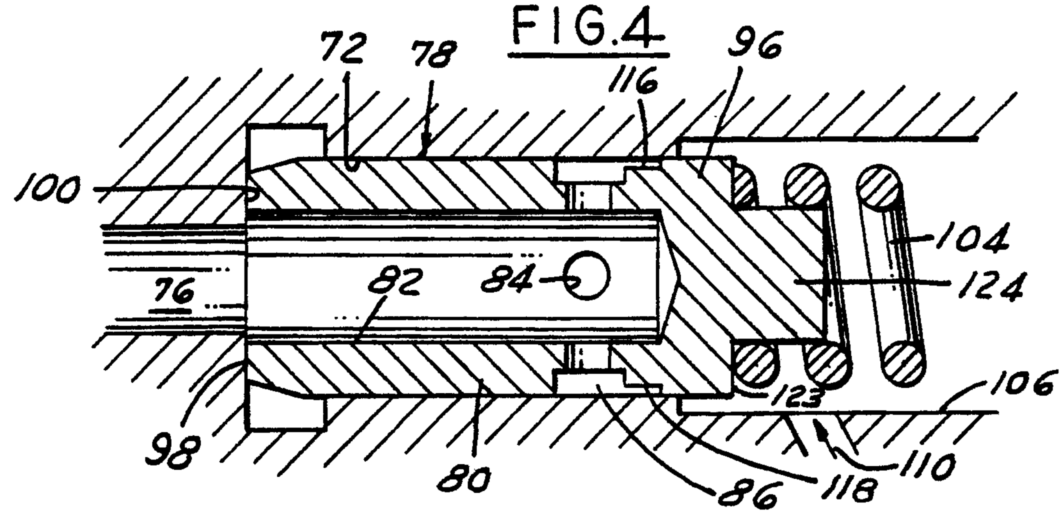


FIG.4



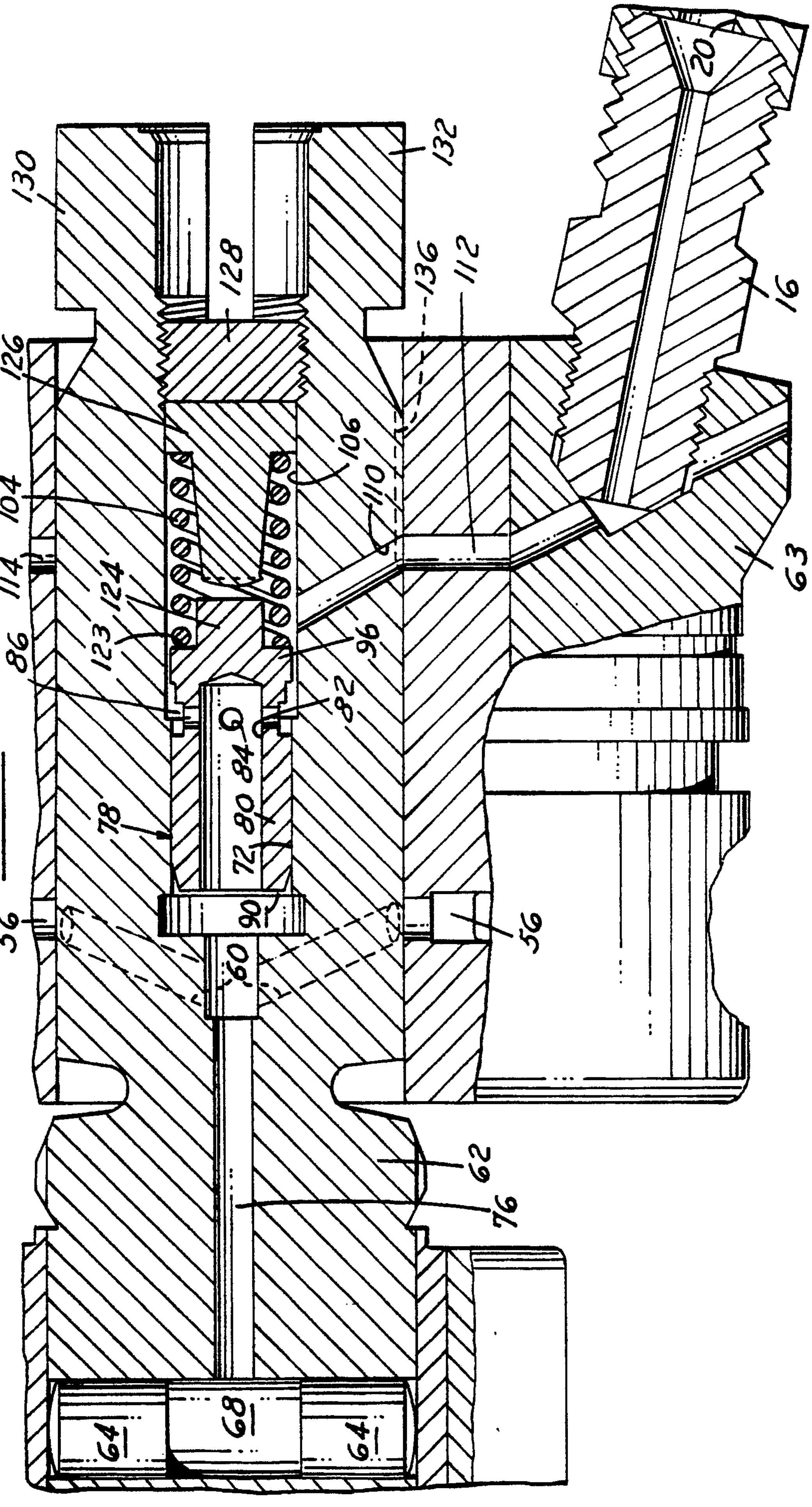

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FIG.3

FIG.5

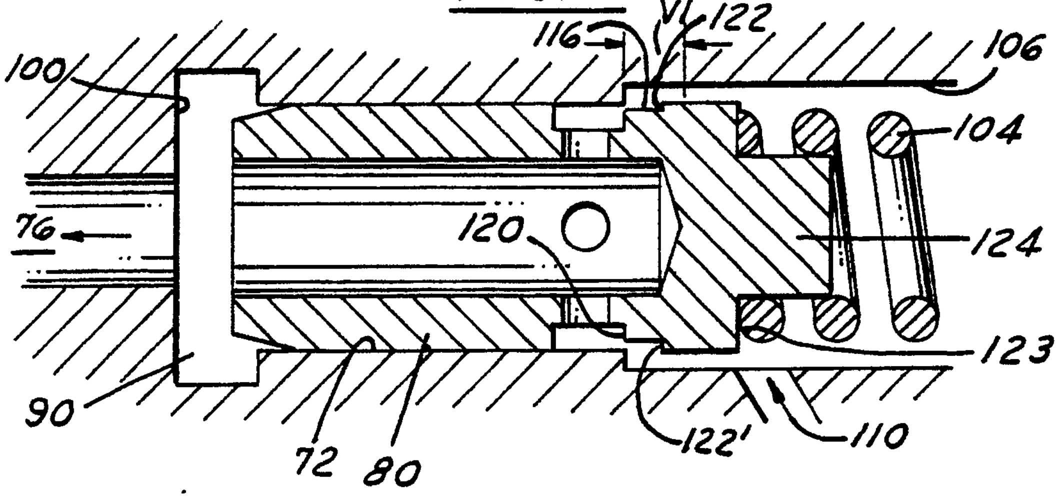


FIG.6

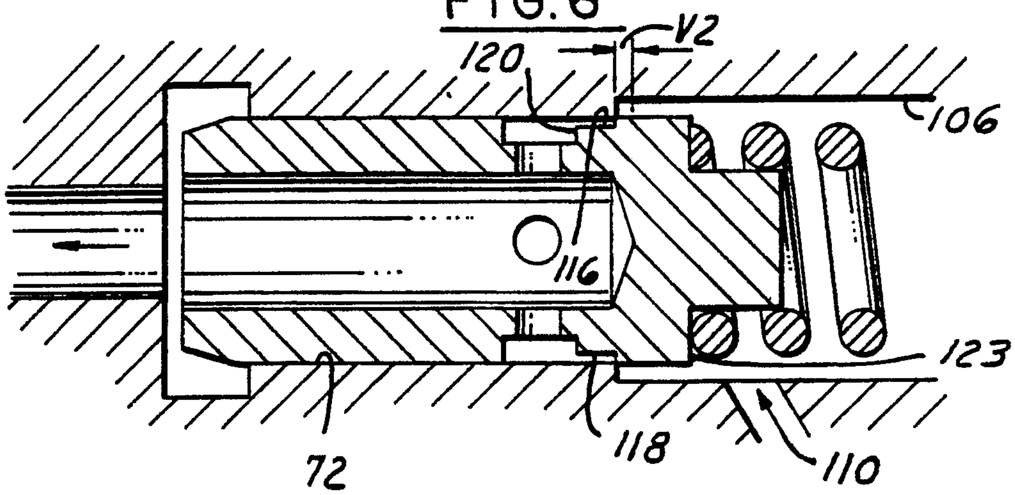


FIG.7

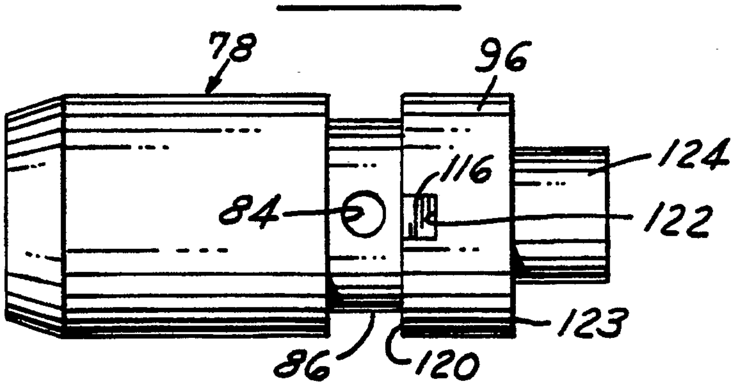
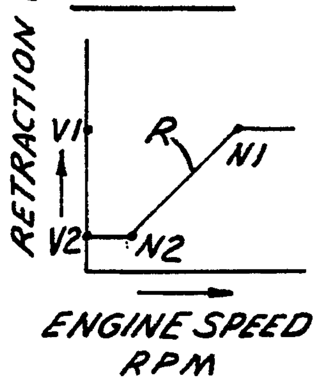


FIG.8



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EUROPEAN SEARCH REPORT

Application Number

EP 90 30 7401

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)
X,A	GB-A-2 026 601 (STANADYNE) * the whole document *	1,3,2	F 02 M 59/46
A	GB-A-2 053 372 (LUCAS) * page 1, line 75 - page 3, line 43; figures *	2	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			F 02 M

The present search report has been drawn up for all claims

Place of search	Date of completion of search	Examiner
The Hague	03 December 90	SIDERIS M.

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