



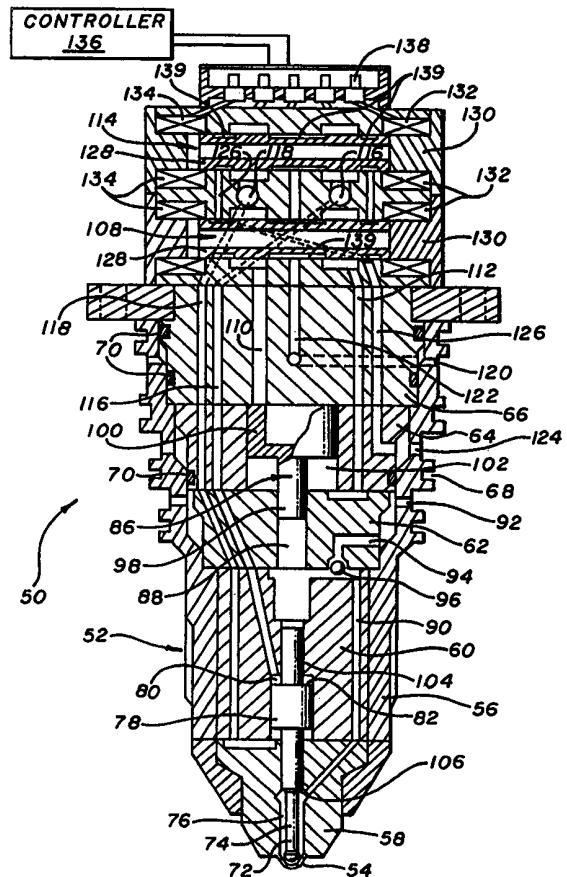
INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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<p>(21) International Application Number: PCT/US99/09669 (22) International Filing Date: 3 May 1999 (03.05.99) (30) Priority Data: 09/072,318 4 May 1998 (04.05.98) US (71)(72) Applicant and Inventor: STURMAN, Oded, E. [US/US]; One Innovation Way, Woodland Parks, CO 80863 (US). (74) Agents: BLAKELY, Roger, W. et al.; Blakely, Sokoloff, Taylor &amp; Zafman, 7th floor, 12400 Wilshire Boulevard, Los Angeles, CA 90025-1026 (US).</p>	<p>(81) Designated States: AE, AL, AM, AT, AT (Utility model), AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, CZ (Utility model), DE, DE (Utility model), DK, DK (Utility model), EE, EE (Utility model), ES, FI, FI (Utility model), GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (Utility model), SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).</p> <p><b>Published</b> <i>With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i></p>	

(54) Title: A HYDRAULICALLY DRIVEN SPRINGLESS FUEL INJECTOR

(57) Abstract

A fuel injector which has a check valve (72) that is hydraulically controlled by a control fluid. A volume of fuel is pressurized within a fuel chamber (88) of the injector by an intensifier (86). The check valve (72) controls the flow of fuel from the fuel chamber through at least one nozzle opening (54) of a valve body. The flow of control fluid is controlled by a control valve (108) which can move between a first position and a second position. When the control valve is at its first position, the control fluid creates an hydraulic force which moves the check valve (72) to a closed position. When the control valve (108) is at its second position, the control fluid moves the check valve (72) to an open position to allow the pressurized fuel to be ejected or sprayed from the nozzle opening(s). The intensifier (86) can also be hydraulically controlled by a control valve (114).



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**A HYDRAULICALLY DRIVEN SPRINGLESS FUEL INJECTOR**BACKGROUND OF THE INVENTIONCROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of Application No. 08/743,858, filed November 5, 1996, pending, which is a continuation of Application No. 08/425,602, filed April 20, 1995, abandoned, which in turn is a continuation of Application No. 08/254,271, filed June 6, 1994, now U.S. Patent No. 5,460,329.

1. FIELD OF THE INVENTION

The present invention relates to a fuel injector for internal combustion engines.

2. BACKGROUND INFORMATION

Fuel injectors are used to introduce pressurized fuel into the combustion chamber of an internal combustion engine. Figure 1 shows a fuel injection system 10 of the prior art. The injection system includes a nozzle 12 that communicates with a fuel inlet port 14 through an intensifier chamber 16. The intensifier chamber 16 contains an intensifier piston 18 which reduces the volume of the chamber 16 and increases the pressure of the fuel therein. The pressurized fuel is released into a combustion chamber of an engine through the nozzle 12.

The intensifier piston 18 is moved by a working fluid that is controlled by a poppet valve 20. The working fluid enters the fuel injector through inlet port 22. The poppet valve 20 is coupled to a solenoid

24 which can be selectively energized to pull the valve 20 into an open position. As shown in Figure 2, when the solenoid 24 opens the poppet valve 20, the working fluid applies a pressure to the intensifier piston 18. The pressure of the working fluid moves the piston 18 and pressurizes the fuel. When the solenoid 24 is de-energized, mechanical springs 26 and 28 return the poppet valve 20 and the intensifier piston 18 back to their original positions. Spring 30 returns a needle valve 32 to a closed position to close the nozzle 12.

Fuel injectors having mechanical return springs are relatively slow because of the slow response time of the return springs. Additionally, the spring rate of the poppet spring generates an additional force which must be overcome by the solenoid. Consequently the solenoid must be provided with enough current to overcome the spring force and the inertia of the valve. Higher currents generate additional heat which degrades the life and performance of the solenoid. Furthermore, the spring rate of the springs may change over time because of creep and fatigue. The change in spring rate will create varying results over the life of the injector. It would be desirable to provide a fuel injector which does not have any mechanical return springs.

#### SUMMARY OF THE INVENTION

One embodiment of the present invention is a fuel injector which has check valve that is hydraulically controlled by a control fluid. A volume of fuel is pressurized within a fuel chamber of the injector by an intensifier. The check valve controls the flow of fuel from the fuel chamber through a nozzle opening of a valve body. The flow of control fluid is controlled by

a control valve which can move between a first position and a second position. When the control valve is at its first position, the control fluid creates an hydraulic force which moves the check valve to a closed position. When the control valve is at the second position, the control fluid moves the check valve to an open position.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a cross-sectional view of a fuel injector of the prior art;

Figure 2 is a cross-sectional view of the prior art fuel injector ejecting fuel;

Figure 3 is a cross-sectional view of an embodiment of a fuel injector of the present invention;

Figure 4 is a view similar to Fig. 3 showing the fuel injector drawing in fuel;

Figure 5 is a view similar to Fig. 3 showing the fuel injector ejecting the fuel;

Figure 6 is a cross-sectional view of an alternate embodiment of the fuel injector.

#### DETAILED DESCRIPTION OF THE INVENTION

One embodiment of the present invention is a fuel injector which has check or needle valve that is hydraulically controlled by a control fluid. A volume of fuel is pressurized within a fuel chamber of the injector by an intensifier. The check valve controls the flow of fuel from the fuel chamber through one or

more nozzle openings of a valve body. The flow of control fluid is controlled by a control valve which can move between a first position and a second position. When the control valve is at its first position, the control fluid creates an hydraulic force which moves the check valve to a closed position. When the control valve is at its second position, the control fluid moves the check valve to an open position to allow the pressurized fuel to be ejected from the nozzle opening(s). The intensifier can also be hydraulically controlled by a control valve. The fuel injector does not contain or utilize any mechanical return springs. The absence of such springs increases the durability and performance repeatability of the injector. Additionally, the positions of the check valve and the intensifier can be rapidly changed by the hydraulic forces of the control fluid to provide a high speed fuel injector.

Referring to the drawings more particularly by reference numbers, Figure 3 shows an embodiment of a fuel injector 50 of the present invention. The injector 50 may include a valve body 52 which has at least one nozzle opening or fuel spring orifice 54. The valve body 52 may include an outer shell 56 which supports a nozzle tip 58, a piston block or spacer 60, a pair of intensifier blocks or spacers 62 and 64 and a manifold block 66. The valve body 52 may be attached to an engine cylinder head (not shown) and extend directly into an internal combustion chamber (not shown). The shell 56 may have a number of outer circumferential grooves 68 that retain O-rings (not shown) which seal the injector 50 to the engine cylinder head. Additionally, the injector 50 may contain a number of internal O-rings 70 that seal the blocks 62, 64 and 66 to the shell 56.

The injector 50 may include a check or needle valve 72 that controls the flow of a fuel through the nozzle openings 54. The check valve 72 may have a needle portion 74 located within a nozzle chamber 76 of block 58 and a piston portion 78 located within a piston chamber 80 of block 60. The piston 78 and needle 74 may be two separate pieces or one integral piece.

The piston chamber 80 may receive a control fluid which exerts an hydraulic force on either a first surface 82 of the piston 78 or a second surface 84 of the piston 78. An hydraulic force exerted on the first surface 82 moves the check valve 72 to a closed position where it seats against the nozzle tip 58 and prevents fuel from being ejected from the injector 50. An hydraulic force exerted on the second surface 84 moves the check valve 72 to an open position and allows fuel to flow through the nozzle openings 54.

The injector 50 may include an intensifier 86 which pressurizes a fuel located within a fuel chamber 88. The fuel chamber 88 communicates with the nozzle chamber 76 by a passage 90. The fuel chamber 88 may also communicate with a fuel inlet port 92 by passage 94. The passage 94 may contain a inlet check valve 96 which prevents a reverse flow of fuel out through the inlet port 92.

The intensifier 86 has a piston portion 98 located within the fuel chamber 88 and a head portion 100 located within an intensifier chamber 102. The head portion 100 has an effective surface area that is larger than an effective surface area of the piston 98. The differential area provides a mechanical gain so that an hydraulic force exerted on the head 100 will move the intensifier 86 from a first position to a second

position and pressurize the fuel within the fuel chamber 88.

The injector 50 may include a balance pin 104 that communicates with the fuel chamber 88 and the piston 78 of the check valve 72. The pressure of the fuel on the pin 104 offsets the hydraulic force exerted by the fuel onto a shoulder 106 of the needle 74 to balance the check valve 72 so that movement of the check valve 72 is controlled by the net hydraulic force on the piston 78.

The movement of the intensifier 86 may be controlled by a first control valve 108 that communicates with the intensifier chamber 102 by passages 110 and 112. The movement of the check valve 72 may be controlled by a second control valve 114 that communicates with the piston chamber 80 by passages 116 and 118. The control valves 108 and 114 may both communicate with a supply port 120 by a passage 122 and a return port 124 by a passage 126. The supply port 120 may communicate with a rail line (not shown) of an engine which has a pressurized control fluid. The rail line typically communicates with the output of a pump. The control fluid may be the fuel or a separate hydraulic fluid. The return port 124 typically communicates with a drain line which has a relatively low pressure.

Each valve 108 and 114 may have a spool 128 that reciprocally moves within a valve housing 130 between a first position and a second position. Each valve 108 and 114 may also have coils 132 and 134 that are coupled to an electrical controller 136 through terminals 138. The controller 136 selectively provides an electrical current to one of the coils 132 and 134. The current creates a magnetic field which pulls the spool 128 towards one of the positions.

The spool 128 and housing 130 are preferably constructed from 4140 steel which will retain a residual magnetism that is strong enough to maintain the position of the spool 128 even when electrical current is no longer provided to the coils 132 and 134. In this manner, the controller 136 can switch the state of the valves 108 and 114 with a digital pulse. The control valves 108 and 114 may be similar to the valves disclosed in U.S. Patent No. 5,640,987 issued to Sturman, which is hereby incorporated by reference.

The spools 128 preferably have outer grooves 139 which create a four-way valve. When the spool 128 of the first valve 108 is at its the first (e.g. rightward) position, the outer grooves 139 provide fluid communication between passage 112 and the supply port 120, and fluid communication between the passage 110 and the return port 124 to force the intensifier 86 to its first position. When the spool 128 of the first valve 108 is at its second (e.g. leftward) position, the passage 110 is in fluid communication with the supply port 120 and the passage 112 is in fluid communication with the return port 124 so that the intensifier 86 is moved to its second position to pressurize the fuel.

When the spool 128 of the second control valve 114 is at its first position, the passage 116 is in fluid communication with the supply port 120 and the passage 118 is in fluid communication with the return port 120 so that the check valve 72 is pushed into the closed position. When the spool 128 of the second control valve 114 is at its second position the passage 116 is in fluid communication with the return port 124 and the passage 118 is in fluid communication with the supply port 120 so that the check valve 72 is moved to its open position.

As shown in Figure 4, in operation, the spool 128 of the first control valve 108 is switched from its second position to its first position to move the intensifier 86 from its second position to its first position. The (e.g. upward) movement of the intensifier 86 expands the fuel chamber 88 and draws in fuel through the inlet port 92 and the check valve 96. The spool 128 of the first control valve 108 is typically maintained at its closed position to prevent fuel from flowing through the nozzle opening 54.

As shown in Figure 5, to eject or sprayed fuel from the injector 50, the spool 128 of the second control valve 114 is switched from its first position to its second position. The intensifier 86 is moved to its second (e.g. downward) position to pressurize the fuel within the fuel chamber 88. The check valve 72 is moved to its open position to allow the pressurized fuel to flow through the nozzle opening(s) 54. The spool 128 of the respective control valves 108 and 114 are then switched to their respective first positions and the cycle is repeated.

Figure 6 shows an alternate embodiment of a fuel injector 50'. In this embodiment the supply passage 122 communicates with the piston chamber 80 by passage 122'. The check valve 72 is biased towards its closed position by the effective pressure of the control fluid in the piston chamber 80. When the intensifier 86 is moved to its second position, the pressure of the fuel is much greater than the pressure of the control fluid, so that the fuel pressure pushes the check valve 72 away from the nozzle opening(s) 54. When the intensifier 86 returns to its first position (e.g. upward), the pressure of the fuel drops and the pressure of the

working fluid within the passage 122' moves the check valve 78 and closes the nozzle 54.

While certain exemplary embodiments have been described and shown in the accompanying drawings, it is to be understood that such embodiments are merely illustrative of and not restrictive on the broad invention, and that this invention not be limited to the specific constructions and arrangements shown and described, since various other modifications may occur to those ordinarily skilled in the art.

CLAIMS

What is claimed is:

1. A fuel injector, comprising:
  - a valve body having a fuel chamber that is in fluid communication with at least one nozzle opening;
  - an intensifier movable within said valve body between a first position and a second position, said intensifier operable to pressurize fuel within said fuel chamber when moved from its first position to its second position; and,
  - an hydraulically controlled check valve movable within said valve body between an open position and a closed position, said check valve operable to allow the fuel to flow from said fuel chamber through said nozzle opening when in said open position.
  
2. The fuel injector of claim 1, further comprising a control valve movable between a first position and a second position, said control valve operable to allow control fluid to move said check valve into said closed position when in said first position and move said check valve into said open position when in said second position.
  
3. The fuel injector of claim 2, wherein said control valve is a four-way valve.
  
4. The fuel injector of claim 2, wherein said control valve has a pair of opposed electrical coils.

5. The fuel injector of claim 1, further comprising a balance pin that is arranged in third communication with said check valve and said fuel chamber.

6. The fuel injector of claim 2, wherein said position of said control valve is maintained by a residual magnetism of said control valve.

7. A fuel injector, comprising:

a valve body having a fuel chamber that is in fluid communication with at least one nozzle opening;

an intensifier within said valve body between a first position and a second position, said intensifier operable to pressurize fuel within said fuel chamber when moved from said first position to said second position;

a first control valve movable between a first position and a second position, said first control valve operable to allow a control fluid to move said intensifier into said first position when said first control valve is at said first position and move said intensifier into said second position when said first control valve is at said second position;

a check valve movable within said valve body between an open position and a closed position, said check valve operable to allow the fuel to flow from said fuel chamber through said nozzle opening when in said open position; and,

a second control valve movable between a first position and a second position, said second control valve operable to allow control fluid to move said check valve into said closed position when in said first position and move said check valve into said open position when in said second position.

8. The fuel injector of claim 7, wherein said first and second control valves are each a four-way valve.

9. The fuel injector of claim 7, wherein said first and second control valves each have a pair of opposed electrical coils.

10. The fuel injector of claim 7, further comprising a balance pin that is arranged in fluid communication with to said check valve and said fuel chamber.

11. The fuel injector of claim 7, wherein said positions of said first and second control valves are maintained by a residual magnetism of said control valves.

12. A method for selectively moving a check valve of a fuel injector, comprising the steps of:

a) exerting an hydraulic force on a first surface of said check valve to move said check valve towards a closed position; and,

b) exerting an hydraulic force on a second surface of said check valve to move said check valve towards an open position.

13. The method of claim 12, wherein the hydraulic forces are created by a control fluid which is controlled by a control valve.

14. The method of claim 13, wherein the hydraulic force in step (a) is created by moving said control valve to a first position and the hydraulic force in

step (b) is created by moving said control valve to a second position.

15. The method of claim 14, wherein said position of said control valve is maintained by a residual magnetism of said control valve.

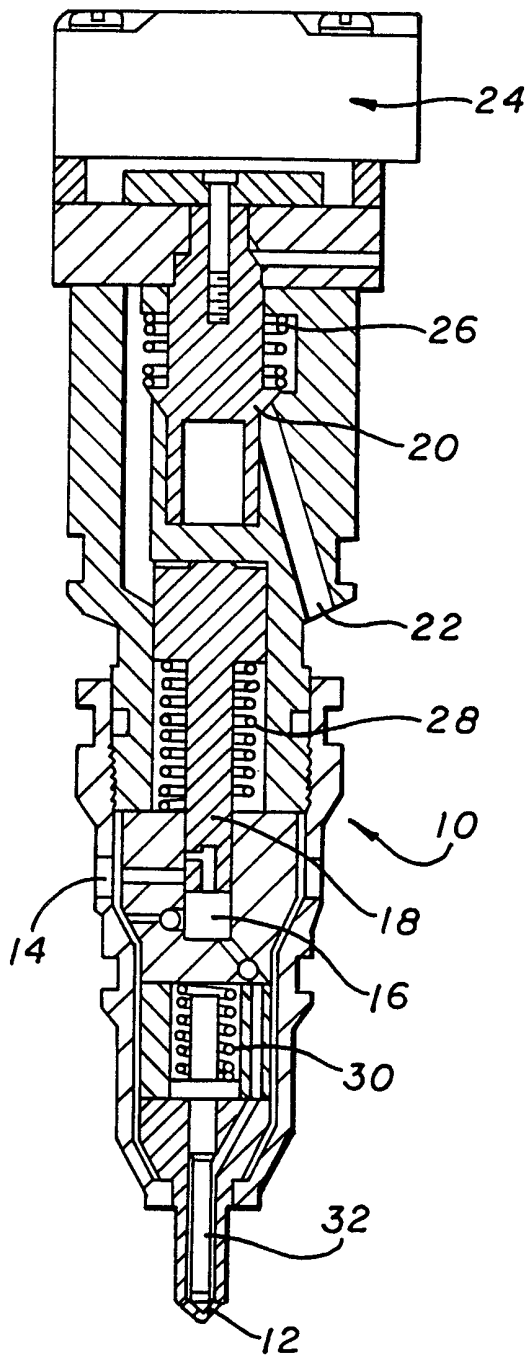


FIG. 1  
PRIOR ART

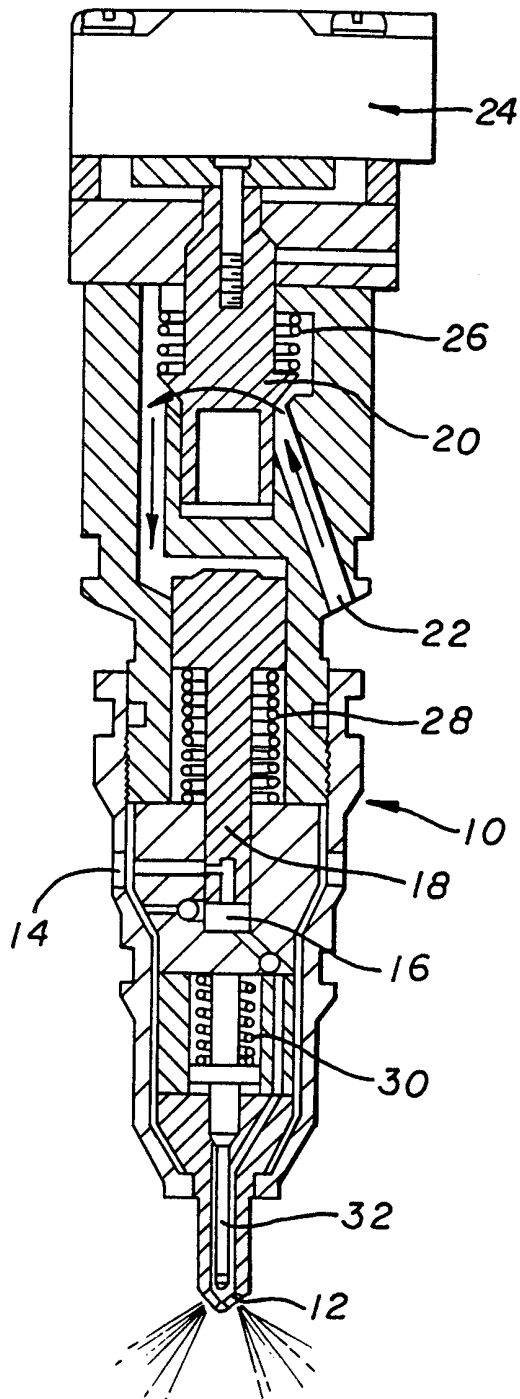


FIG. 2  
PRIOR ART

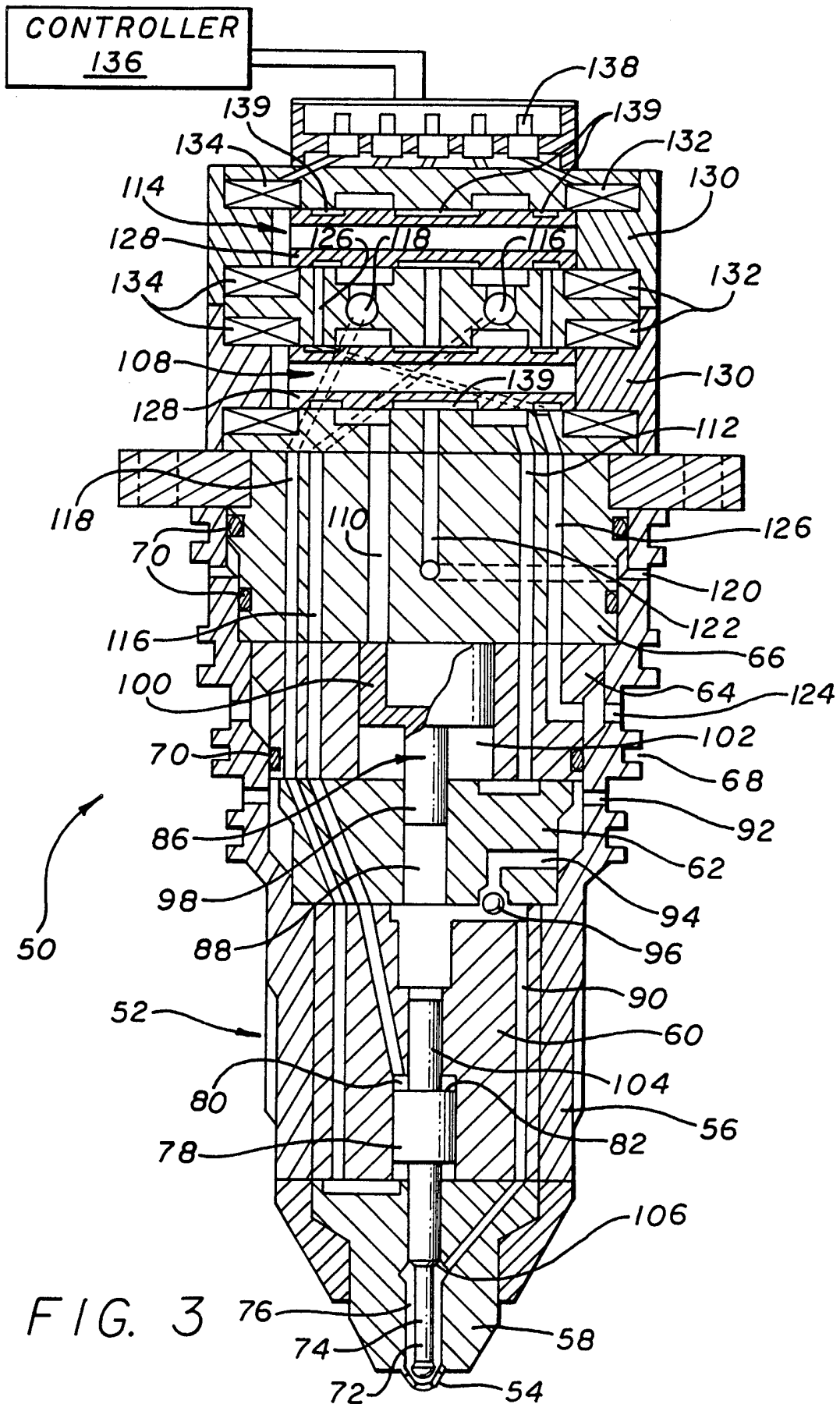


FIG. 3

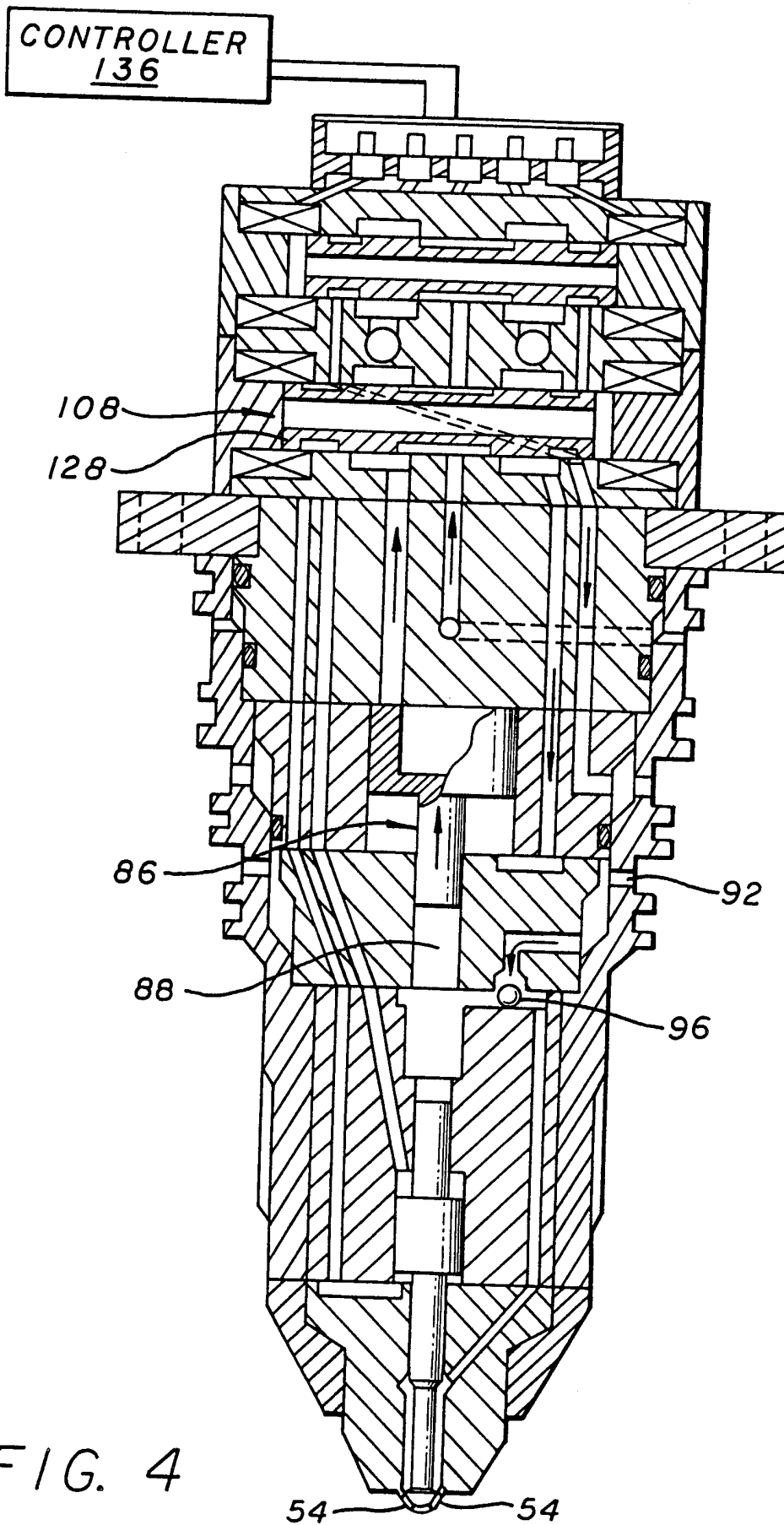


FIG. 4

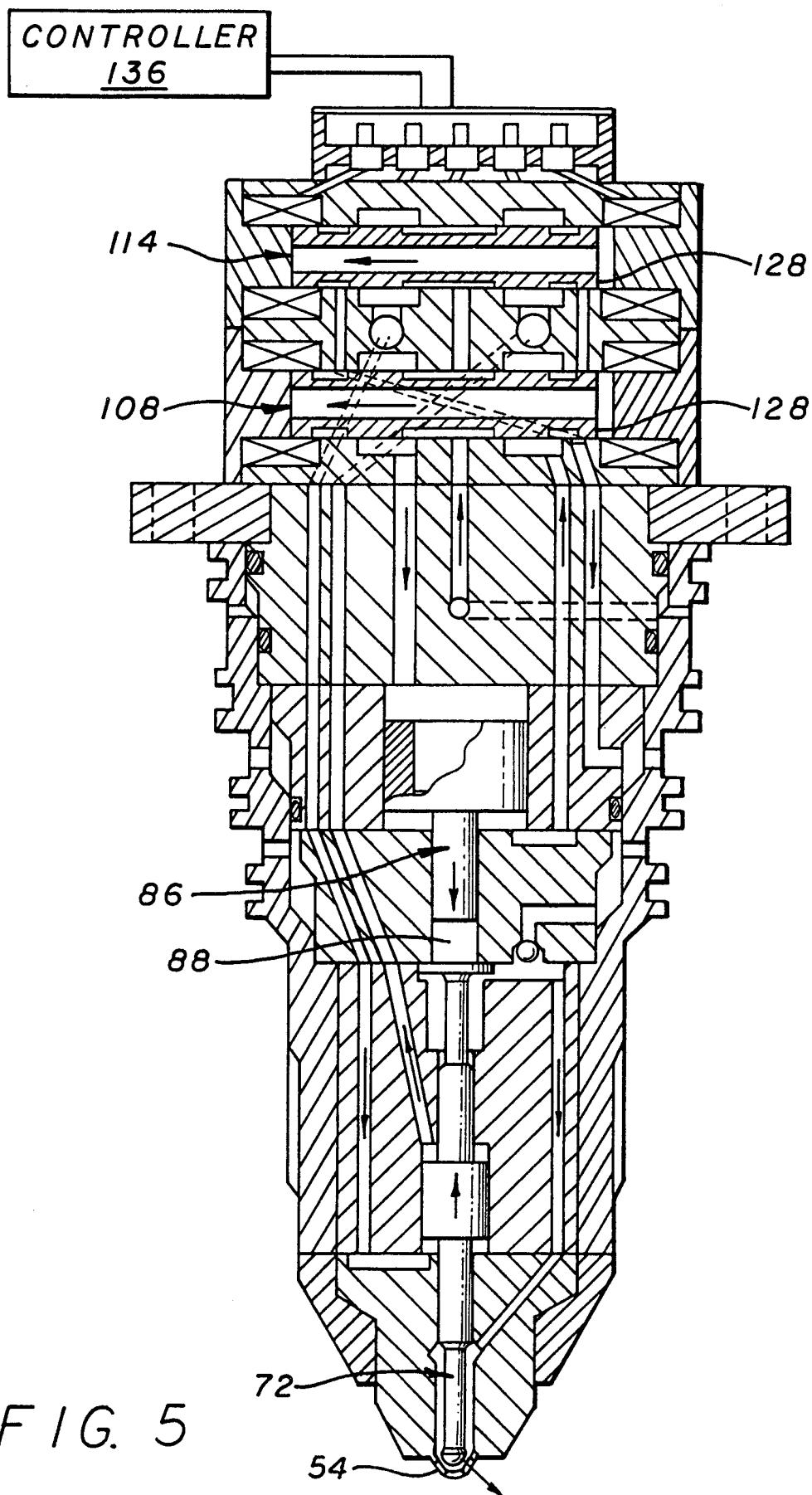


FIG. 5

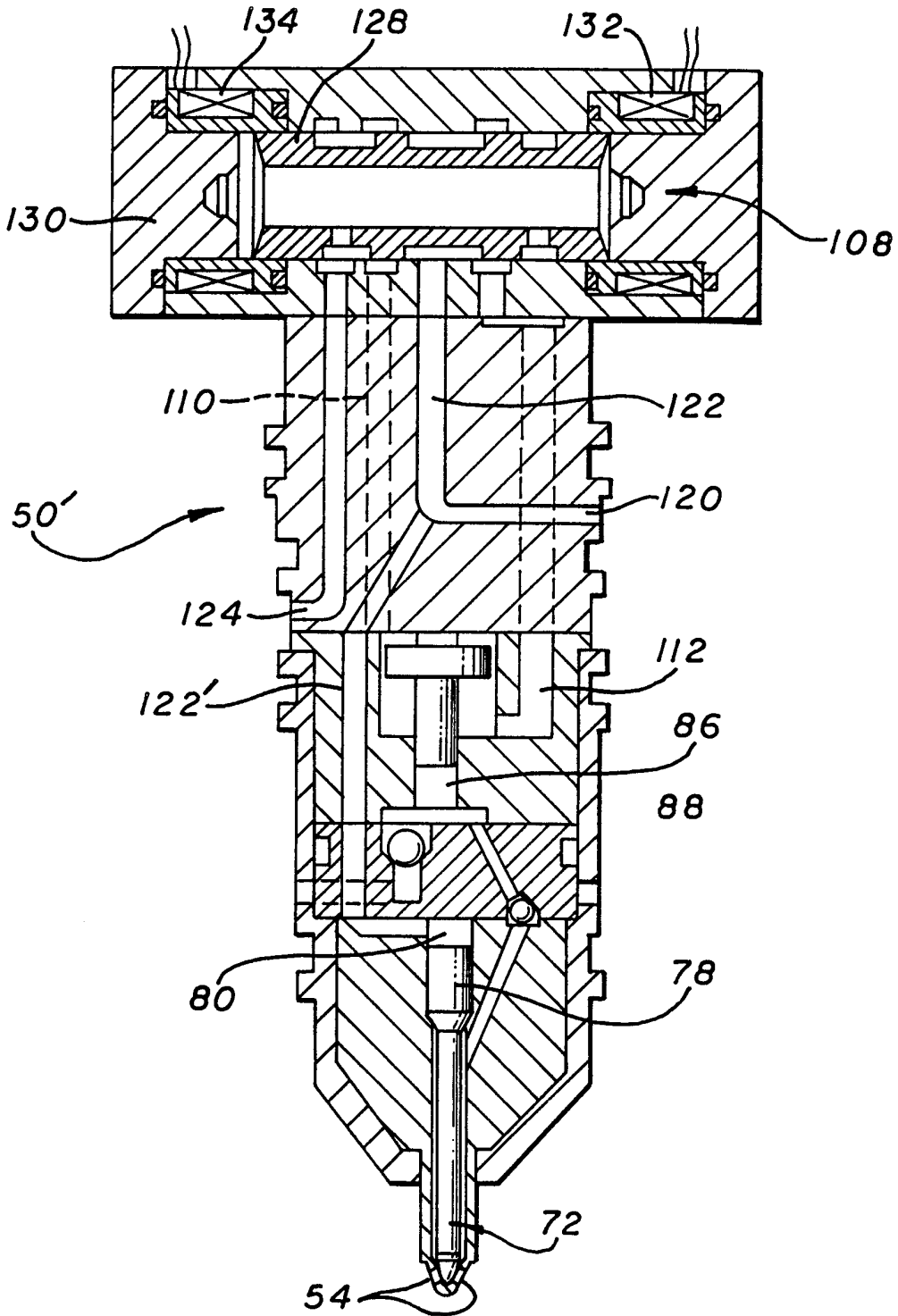


FIG. 6

# INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 99/09669

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC 6 F02M57/02 F02M47/02 F02M47/04 F02M59/46

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**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 F02M

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

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**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 697 342 A (ANDERSON ET AL) 16 December 1997 (1997-12-16) column 5, line 34 - column 6, line 47; figures	1,2,5,7, 10,12-14
X	US 5 669 334 A (SCHOENFELD DIETER ET AL) 23 September 1997 (1997-09-23) abstract	12-14
A	US 5 640 987 A (STURMAN ODED E) 24 June 1997 (1997-06-24) cited in the application abstract	3,4,6,8, 9,11,15
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Date of the actual completion of the international search

6 September 1999

Date of mailing of the international search report

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Torle, E

# INTERNATIONAL SEARCH REPORT

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X  A	US 5 460 329 A (STURMAN ODED E) 24 October 1995 (1995-10-24) cited in the application abstract; figures  -----	1  2-4, 6-9, 11

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