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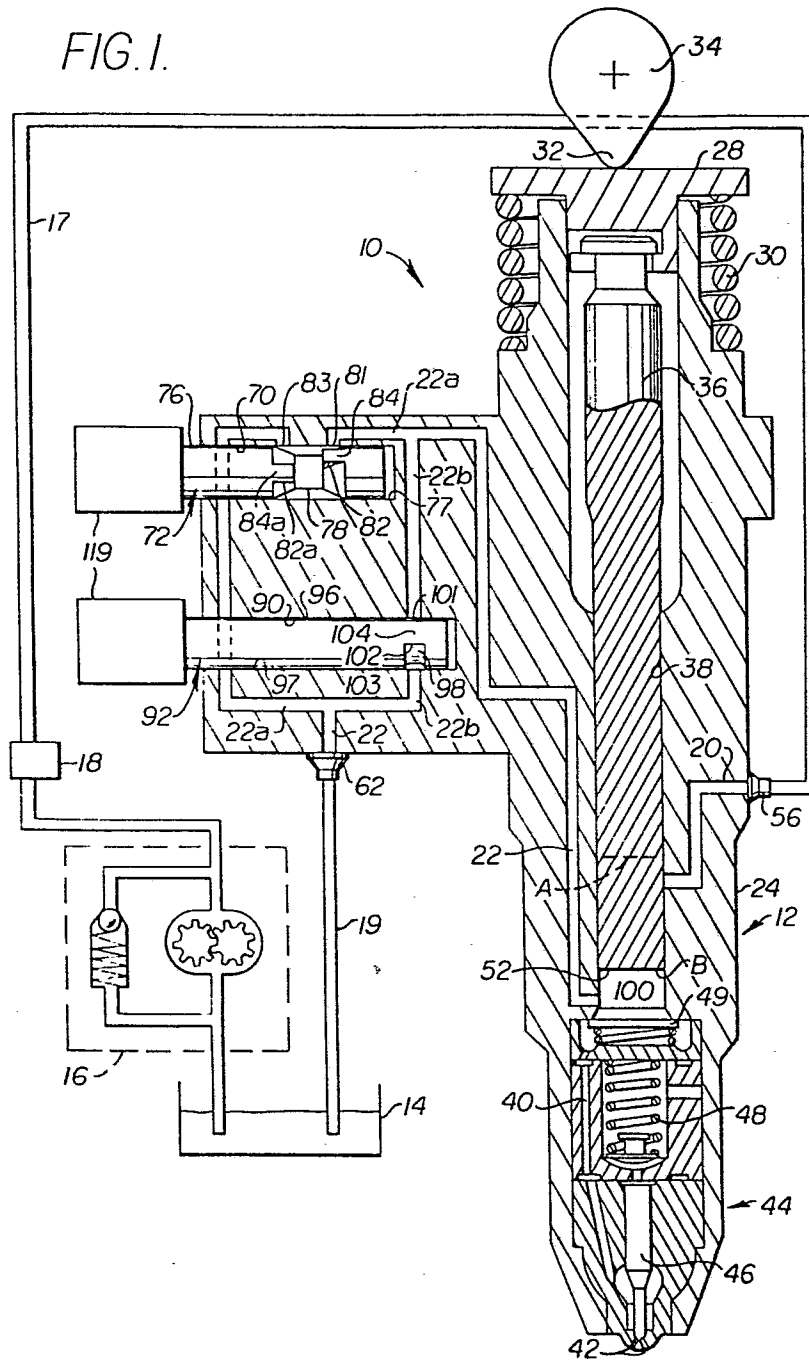
54 **Fuel injection apparatus.**

57 It is some time desired that fuel injection apparatus include pilot injection capabilities in addition to main injection, but undesirable expense, weight and bulk are usually associated with such pilot injection capabilities. To overcome this problem rotary fuel injection apparatus (10) has a plurality of continuously rotating valves (72, 92) for controlling the starting and stopping of both pilot injection and main injection.

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FIG. 1.



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FUEL INJECTION APPARATUS

This invention relates to fuel injection apparatus.

It has been suggested to provide fuel injection apparatus for controlling the amount of fuel injected
5 into an engine, with dual rotary controlled valves, for reducing inertial forces associated with the prior art types of valves used for fuel injection. These are generally electrically controlled. Electrical control of fuel injection is versatile and advantageous, and
10 in general allows accomplishment of several important objectives such as excellent control of exhaust emissions; improved engine response; programming of desired torque characteristics of the engine; programming of desired speed regulations; provision for
15 rapid shutdown of engines; and improved fuel economy.

In some cases it may be desired to provide for pilot injection of fuel in addition to main injection. Pilot injection is ordinarily accomplished in one of two ways. Firstly, if one injector is used, then
20 two fuel pumps deliver fuel to one fuel line via check valves. One of the two pumps delivers a short burst of high pressure fuel, the duration of which is determined by any of the conventional ways, such as by use of a scroll on the injector. Then, after a
25 brief pause, the other of the two pumps delivers a main charge of fuel also through a check valve.

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A limitation of pilot injection done this way is that it is expensive because it requires the use of two separate fuel pumps. Some economy is realized, however, because only one fuel injector is used.

5. In situations where pilot injection is done through one nozzle and the main charge is delivered through another nozzle, two fully independent systems are used; each one having a fuel pump and nozzle. Expense and bulk are limitations of pilot injection accomplished this way.

Another limitation of previously known pilot injection systems is that they are not readily adaptable to independently controlling the timing and duration of pilot and main injection.

15. As a result, pilot injection is not a widely used way of injecting fuel. Originally introduced to reduce ignition lag, it has been found to be complex when compared to the benefits received since it required added equipment, cost, bulk, weight and the resultant maintenance.

- According to the present invention fuel injection apparatus comprising a single fuel injector; a path for conducting fuel to and from the injector; and valve means for controlling both pilot and main injection of fuel through the injector, is characterized in that the valve means comprises a plurality of rotary valves disposed in the path.

25. Preferably the valve means comprises a pair of valves, one of which controls the starting and stopping of pilot injection and the starting of main injection, and the other of which controls the stopping of main injection. The two valves may be arranged in parallel with one another.

30. Two examples of apparatus according to the invention will now be described with reference to the accompanying drawings in which:-

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Figure 1 is a diagrammatic view illustrating a fuel system including a fuel injection apparatus;

Figures 2A and 2B of the drawings are isometric views illustrating rotary valves having blocking

5. shoulders;

Figures 3A, 3B and 3C are partial diagrammatic views illustrating sequential steps of rotary controlled fuel injection;

Figure 4 is a diagrammatic view illustrating an adjustment control for use in the fuel system; and

Figure 5 is a fragmentary view illustrating another embodiment utilizing three valves.

In Figure 1 there is shown a fuel injection apparatus 10 which includes a fuel injector pump 12 fed with fuel from a fuel supply tank or reservoir 14, through a conduit 17, by a fuel transfer pump 16 through a filter 18. The fuel enters a housing 24 of the injector pump at an inlet port 56 of a fuel supply passage 20. Fuel exits the pump from a return passage 22 in the housing 24 at an outlet port 62 and is conducted back to the tank 14 through a conduit 19.

The fuel injection pump housing 24 has a tappet 28 resiliently biased by a spring 30 and driven by a lobe 32 on a camshaft 34 as is well known. The tappet is connected to a plunger 36 which reciprocates between a dotted line position "A" and a solid line position "B" in a bore 38 within the housing 24. Fuel, delivered to the bore 38, is injected into an engine cylinder (not shown) past a one-way check valve 49, through an injection passage 40 and injection ports 42 in a tip assembly 44. This well known arrangement functions due to differential areas on a fuel injection valve 46 biased by a spring 48 in the tip assembly 44.

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The fuel is expelled through port 42 due to its substantial pressurization periodically occurring in a cavity 100 of the bore 38 as the plunger 36 reciprocates. Controlling the quantity and timing of the injection of fuel through ports 42 is the subject of much technology due to present trends in enhancing fuel economy and reducing fuel emissions. Such technology is complicated because the control of quantity and timing must be coordinated with other engine functions and conditions. Since the lobe 32 and plunger 36 have a fixed cyclical relationship for pressurizing the fuel in the bore 38, variations in controlling quantity and timing of injection usually involve electrical and/or mechanical control of the admittance of fuel to the bore 38. In the past this has been accomplished by a scroll (helix) on the plunger which is rotated with a rack.

Fuel supply passage 20 extends into the housing 24 from the port 56 and terminates at the bore 38 adjacent an end 52 of the plunger 36, to conduct fuel to the cavity 100. The fuel return passage 22 extends from the cavity 100 through the housing 24 to the port 62 for conducting fuel from plunger bore 38 back to the reservoir 14.

The passage 20 is in fluid communication with the cavity 100 when the plunger 36 is in position "A" but not when it is in position "B". The passage 22 is in fluid communication with the cavity 100 for any position of the plunger 36 between "A" and "B". The passage 22 separates or diverges to form a first branch 22a and a second separate branch 22b. The branches 22a and 22b converge adjacent the outlet port 62 and are thus in parallel with one another.

A first enlarged bore 70 is transversely disposed across the passage 22a. The bore 70 accommodates a first rotary valve 72 in a lapped fit, which valve

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- rotates to function as a means for starting and stopping pilot injection and for starting main injection. The valve 72 has an outer cylindrical surface 76 for lubricated rotating engagement with
5. the inner cylindrical surface 77 of the bore 70 and a reduced diameter portion 78 adjacent a high pressure inlet 81 and a relatively low pressure outlet 83 at the intersection of the passage 22a and the bore 70. A raised arcuate blocking shoulder 82
10. is formed on the reduced diameter portion 78 of valve 72 and has an outer arcuate surface 84 which engages the inner surface 77 of the bore 70 so as to block the inlet 81 in a given position, thus limiting passage of fuel through passage 22a to port
15. 62. The arcuate surface 84, has a first arcuate length L1 (Figures 2A, 2B, 3A, 3B, 3C) permitting the shoulder 82 to block the inlet 81 for a given brief duration for starting and stopping pilot injection. Blocking shoulder 82 is timed to block inlet 81
20. when plunger 36 is blocking conduit 20 and is moving towards position "B". Injection occurs, as it is well known, only when the fuel is under compression in the cavity 100 and closing of the inlet 81 thus causes injection.
25. The first valve 72 has a second arcuate blocking shoulder 82a, formed on the reduced diameter portion 78, having an outer arcuate surface 84a which also engages the inner surface 77 of the bore 70 so as to block the outlet 83 thus limiting the passage of ,
30. fuel through the passage 22a to the port 62. The arcuate surface 84a has a second arcuate length L2 (Figures "A, 2B, 3A, B, C) greater than length L1 for permitting shoulder 82a to block the outlet 83 for a longer duration to start main fuel injection.
35. Shoulder 82a is located on valve 72 so as to block the outlet 83 shortly after pilot injection ends.

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This blocking also occurs when plunger 36 is blocking conduit 20 and is moving toward position "B" to enable injection to occur.

- A second enlarged bore 90 (Figure 1) is
5. transversely disposed across the passage 22b. The bore 90 accommodates a second rotary valve 92 which functions as a means for stopping main injection. The valve 92 is mounted in housing 24 for rotation in bore 90 in a lapped fit. Valve 92 has an outer
 10. cylindrical surface 96 for lubricated rotating engagement with inner cylindrical surface 97 of bore 90. A reduced diameter portion 98 of valve 92 is provided adjacent a high pressure inlet 101 and a relatively lower pressure outlet 103 at the
 15. intersection of passage 22b and bore 90. A raised arcuate blocking shoulder 102 is formed on the reduced diameter portion 98 of valve 92. The outer arcuate surface 104 of the shoulder 102 rotatably engages the inner surface 97 of the bore 90 so as to
 20. block inlet 101, in a given position thus limiting passage of fuel through passage 22b to port 62. The surface 104, has a second arcuate length L3 (Figures 2A, 2B, 3A, 3B, 3C) greater than first arcuate length L1 and second arcuate length L2,
 25. thus permitting shoulder 102 to block inlet 101 for for a greater duration than the duration which shoulders 82 and 82a block inlet 81 and outlet 83. Shoulder 102 is timed to block inlet the 101 when the plunger 36 is blocking passage 20 and is moving
 30. toward position "B" to enable injection to occur, and blocks the inlet 101 prior to and during the entire time when shoulder 82 blocks inlet 81, to permit shoulder 82 to start and stop pilot injection. Also, the shoulder 102 is still blocking the inlet 101
 35. when shoulder 82a begins to block outlet 83 for starting main injection. However, whilst shoulder

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82a is still blocking outlet 83, shoulder 102 clears or rotates past inlet 101 thus releasing the pressure within cavity 100 and stopping main injection.

5. In Figure 1 it can be seen that the parallel arrangement of the passages 22a, 22b fluidly interconnect the first valve 72 and the second valve 92.

10. Figures 3A, 3B, 3C illustrate the relative positions of valves 72, 92 rotating in bores 70, 90, respectively, for starting and stopping pilot and main injection. In Figure 3A, with plunger 36 blocking passage 20, shoulder 102 of valve 92 blocks inlet 101 but since shoulder 82 of valve 72 is not
15. blocking inlet 81, no injection occurs and fuel passes from cavity 100 via conduit 22a and valve 72 and returns to tank 14. In Figure 3B, however, shoulders 82, 102 simultaneously block their respective inlets 81, 101 thus causing fuel to be pilot injected.
20. Pilot injection stops after shoulder 82 rotates past inlet 81. Then, as illustrated in solid line in Figure 3C, shoulder 82a of valve 72 and shoulder 102 of valve 92 simultaneously block inlet 83, 101, respectively, for starting main injection. Thereafter,
25. although shoulder 82a (dotted line) still blocks inlet 83, main injection is stopped when shoulder 102 (also dotted line) of valve 92 no longer blocks inlet 101. Thus, fuel passes from cavity 100 via passage 22b and valve 92 and returns to reservoir 14. It
30. can be seen how shoulder 82 controls pilot injection starting and stopping and shoulder 82a controls main injection starting whereas shoulder 102 controls main injection stopping. Continuous rotation of valves 72, 92, at the same rotational speed causes
35. intermittent blockage of passage 22. Phasing (discussed below) the relative positions of shoulders

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82, 102 for sequential and simultaneous blockage of passage 22 results in control of timing and duration of fuel injection.

- Means are provided for continuously rotating
5. valve 72 and an additional identical means is required to continuously rotate valve 92. However, only one of these means 119 is shown in Figure 4 and described below. Means 119 is electrical, but it is possible to arrange for mechanical rotation
 10. of valves 72, 92. Means 119 includes a control transmitter 120, and a control transformer and servo 122. Control transmitter 120 is driven by camshaft 34 at one-half engine speed (for a 4 cycle engine). Such a control transmitter 120, through suitable
 15. buffering networks which are well known, directly drives the control transformer and servo 122 which rotates the valve 72. By adjusting the position of a stator 124 of the control transmitter 120, the starting of injection is controlled. This is
 20. accomplished by adjusting the timed positioning of the control transmitter relative to camshaft 34 to control precisely the time when shoulder 82 begins to block inlet 81, thus controlling the starting of injection.
 25. In the additional identical means 119, the control transmitter, also driven by camshaft 34, directly drives control transformer and servo 122 for rotating valve 92. By adjusting stator 124 of control transmitter 120, the stopping of injection is
 30. controlled, the duration of main injection depending on the relative positions of the shoulders 82 and 102. Electrical equipment for supplying the above-described functions of means 119 is available from commercial sources such as AEROFLEX and the SINGER INSTRUMENT
 35. COMPANY, both of the United States of America.

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Another electrical means is possible for continuously rotating rotors 72, 92 and will be briefly discussed. Such means comprises a digital system, several types of which have been used successfully

5. for various applications requiring precision drives with adjustable phase angles. Such a digital system may be obtained from stepping motors of the type commercially available from HAWKER-SIDDLEY DYNAMICS of Great Britain, but do not have provisions for

10. feedback corrections. However, feedback loop equipment is commercially available from DISC INSTRUMENT CORP. of the United States of America.

Rotating the valves 72, 92 at one-half engine speed will result in making one injection of fuel

15. per two engine revolutions in a four cycle engine. A two cycle engine would have valves 72, 92, rotating at crank speed since injection frequency is at crank frequency. The arcuate lengths L1, L2 and L3 of shoulders 82, 82a and 102, respectively,

20. may be expressed in rotational degrees. Thus, by controlling the position and dimensions L1, L2, of the blocking shoulders 82, 82a relative to cam 34, the starting and stopping of pilot injection and the starting of main injection can be controlled, and,

25. by controlling the position of shoulder 102 relative to shoulders 82, 82a, the duration of injection can be controlled.

Electrical means are employed to determine the start of injection as well as to determine the quantity

30. of fuel injected. Such means are well known and are not the subject of this invention. These means usually include a power source, sensing devices, actuators, and the like, and take into account inlet manifold pressure and temperature, engine speed and load, and

35. even fuel temperature.

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A well known logic system, for example, the universal fuel injection system, UFIS, developed for the military for use in track type or armored vehicles, may be used for actuating a fuel pump control system.

5. The UFIS reads and interprets vehicle data such as engine speed, boost or manifold pressure, engine temperature, ambient temperature, altitude, load etc. The UFIS is powered by the vehicular power system, e.g., a twelve or twenty-four volt system or the like.
10. The UFIS logic requires relatively low milliamperage. Thus, the signal produced by the UFIS logic must be matched to provide an appropriate UFIS input to control transmitter 102. UFIS type logic can also provide the appropriate adjustment to stator 124 for controlling
15. the position of shoulders 82, 82a, relative to cam 34 and the position of shoulder 102 relative to shoulders 82, 82a as discussed above.

- Figure 5 illustrates an alternative where three valves are utilized as a means for starting and
20. stopping pilot injection and main injection. However, the two valve apparatus is preferred over the three valve apparatus. A first valve 300 includes a first blocking shoulder 301 of a first size for starting and stopping pilot injection. A second valve 302
 25. includes a second blocking shoulder 303 of a second size greater than the first size for starting main injection, and a third valve 304 includes a third blocking shoulder 305 of a third size greater than the first and second sizes for stopping main injection.
 30. All three valves 300, 302, 304 are continuously rotated and function as previously discussed with the sole difference being that shoulder 301 (for starting and stopping pilot injection) and shoulder 303 (for starting main injection) are on separate valves 300,
 35. 302, respectively, whereas in the preferred embodiment,

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- shoulder 82, (for starting and stopping pilot injection) and shoulder 82a, for starting main injection) are on the same valve 72. The reason the three valve concept is not preferred is that it is
5. more expensive and bulky. Of course, the three valves 300, 302, 304 can obviously be independently rotated for adjustment as previously described for the two valve apparatus and has the advantage of including the ability to adjust the timing
10. between the end of pilot injection and the beginning of main injection.

In operation the transfer pump 16 maintains a system pressure at about 30-35 psi. Means 119 rotate valves 72, 92 continuously at the same cyclic

15. rate. Fuel enters housing 24 at port 56 and flows to cavity 100 via conduit 20. The fuel continues through passage 22 and returns to tank 14 via branch passages 22a, 22b which include valves 72, 92 respectively.

20. Camshaft 34 and lobe 32 rotate and cause plunger 36 to reciprocate between positions "A" and "B". When plunger 36 blocks passage 20 and continues toward position "B" pilot injection can occur depending now on the time sequential and simultaneous position-
25. ing of shoulders 82 and 102. First in the sequence, shoulder 102 rotates to block inlet 101 but fuel continues to tank 14 via passage 22a. Second in the sequence, shoulder 82 simultaneously rotates to block inlet 81 as shoulder 102 continues to block inlet
30. 101 and fuel is trapped in housing 24. Further downward movement of plunger 36 greatly compresses fuel in cavity 100 forcing the fuel past check valve 49 to be pilot injected through port 42. Next in the sequence after pilot injection ends, as plunger 36
35. continues toward position "B", shoulder 82a blocks outlet 83 and main injection begins. Subsequently, and a plunger 36 continues toward position "B", shoulder

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102 rotates past inlet 101 and main injection stops as fuel resumes flowing to tank 14 via passage 22b. Finally, shoulder 82a also clears outlet 83 and fuel again flows to tank 14 via conduit 22a as well.

5. Plunger 36 then begins travel from position "B" to position "A", but under these conditions no injection can occur since fuel in cavity 100 is not being compressed. The above-described cycle repeats rapidly.
10. Signals from the logic to means 119 can operate through stator 124 to rotatably drive valves 72, 92 and adjust the relative positions of valve shoulders 82, 82a and 102.
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CLAIMS.

1. Fuel injection apparatus (10) comprising a single fuel injector (12); a path (22) for conducting fuel from the injector (12); and valve means for controlling both pilot and main injection of fuel
5. through the injector (12), characterized in that the valve means comprises a plurality of rotary valves (72, 92) disposed in the path (22).
2. Apparatus according to claim 1, characterized in that the valve means comprises a pair of valves
10. (72, 92).
3. Apparatus according to claim 2, characterized in that a first (72) of the valves is arranged to control the starting and stopping of pilot injection and the starting of main injection, and the second
15. valve (92) is arranged to control the stopping of main injection.
4. Apparatus according to claim 3, characterized in that the first valve (72) has a blocking shoulder (82), having an arcuate length L1, for controlling the
20. starting and stopping of pilot injection, and a second blocking shoulder (82a), having an arcuate length L2 greater than L1, for controlling the start of main injection.
5. Apparatus according to claim 3 or claim 4,
25. characterized in that the second valve (92) has a blocking shoulder (102), having an arcuate length L3

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greater than L1 and L2, for controlling the stopping of main injection.

6. Apparatus according to any of claims 2 to 5, further comprising means (119) for independantly
5. rotatably adjusting the first and second valves (72, 92).
7. Apparatus according to any of claims 2 to 6, characterized in that the first and second valves (72 and 92) are arranged in parallel with one another.
10. 8. Apparatus according to claim 1, characterized in that the valve means comprises first, second and third rotary valves (300, 302, 304).
9. Apparatus according to claim 8, characterized in that the first valve (300) is arranged to control
15. starting and stopping of pilot injection, the second valve (302) is arranged to control starting of main injection, and the third valve (304) is arranged to control stopping of main injection.
10. Apparatus according to claim 9, characterized
20. in that the first valve (300) includes a blocking shoulder (301) for controlling starting and stopping of pilot injection, the second valve (302) includes a blocking shoulder (303) for controlling starting of main injection, and the third valve (304) includes
25. a blocking shoulder (305) for controlling stopping of main injection.
11. Apparatus according to any of claims 8 to 10, wherein the first and second valves (300, 302) are arranged in series and are in parallel with the
30. third valve (304).
12. Apparatus according to any of claims 8 to 11, including means (119) for independently rotatably adjusting the first, second and third valves (300, 302, 304).
- 35.

FIG. 1.

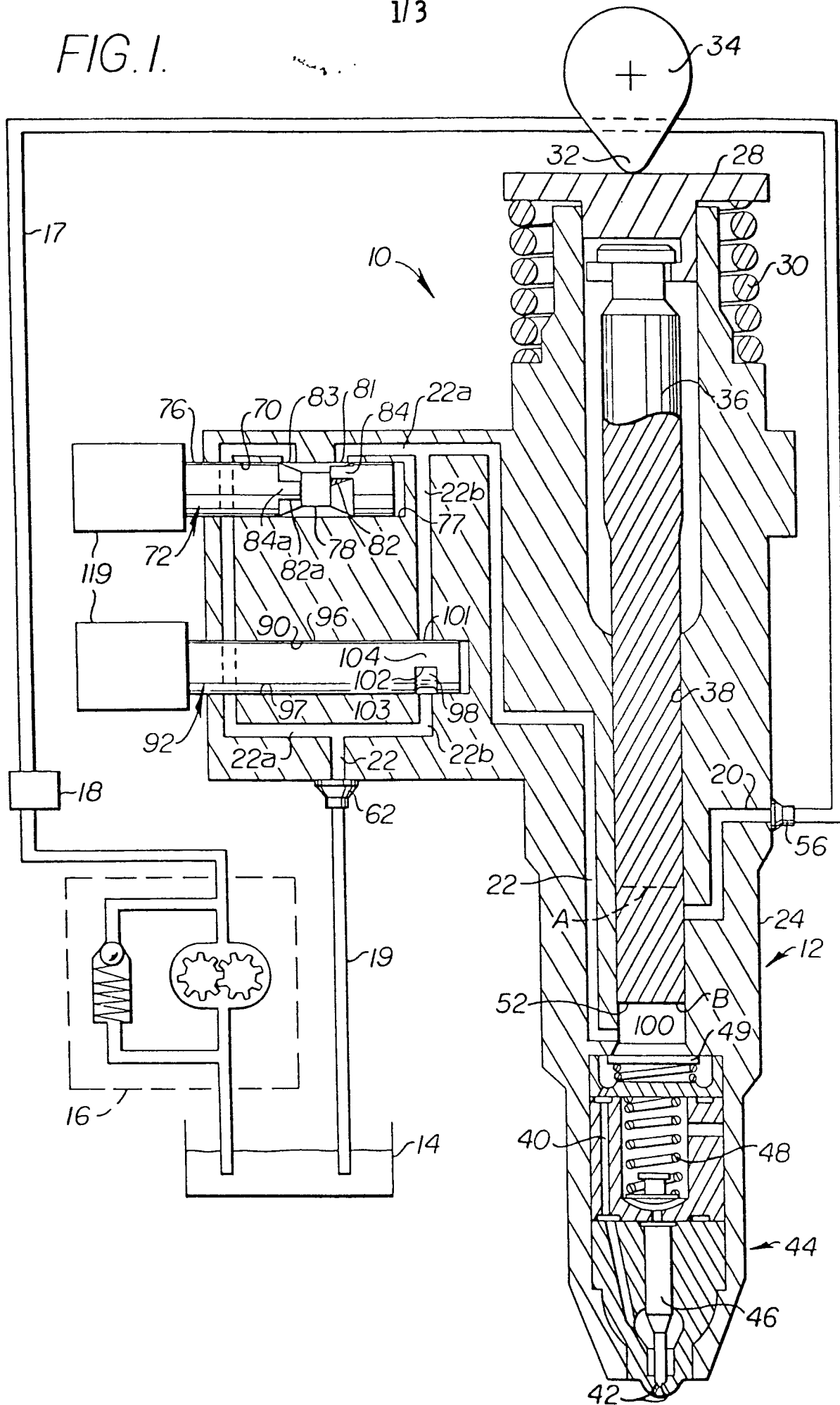


FIG. 3A.

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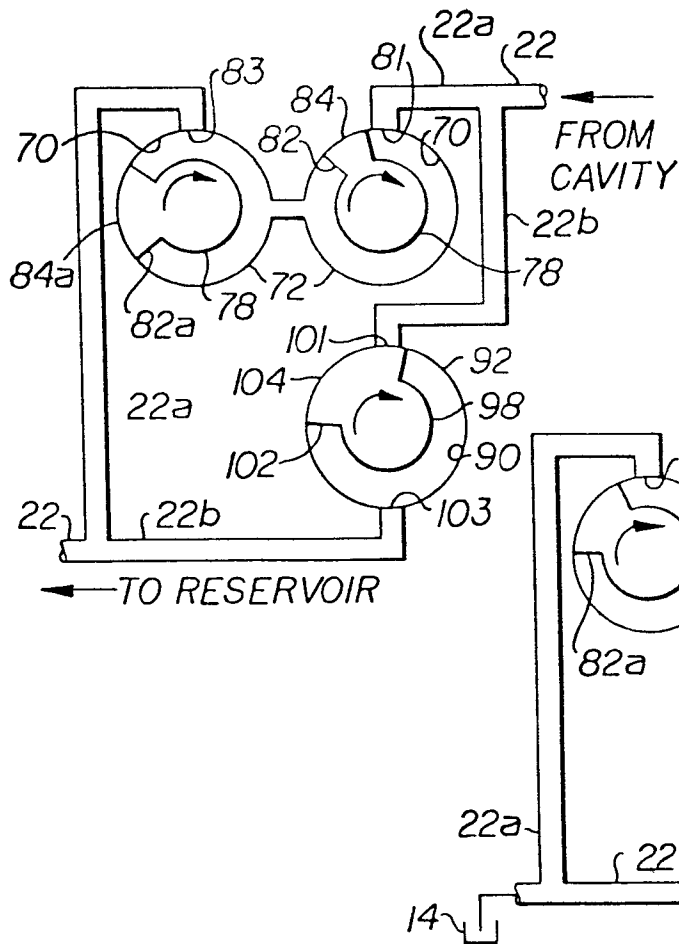


FIG. 3B.

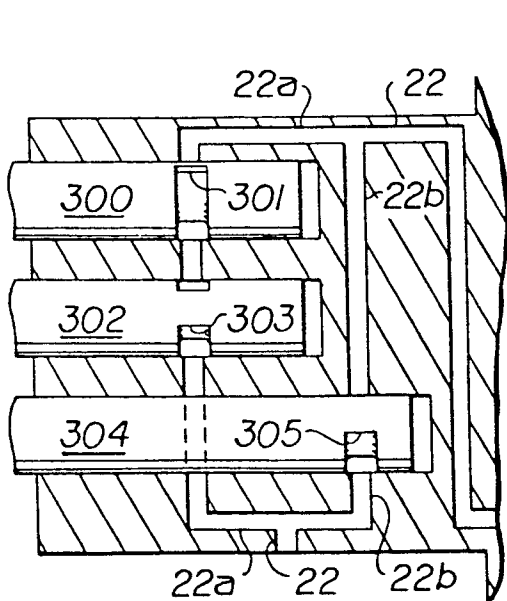
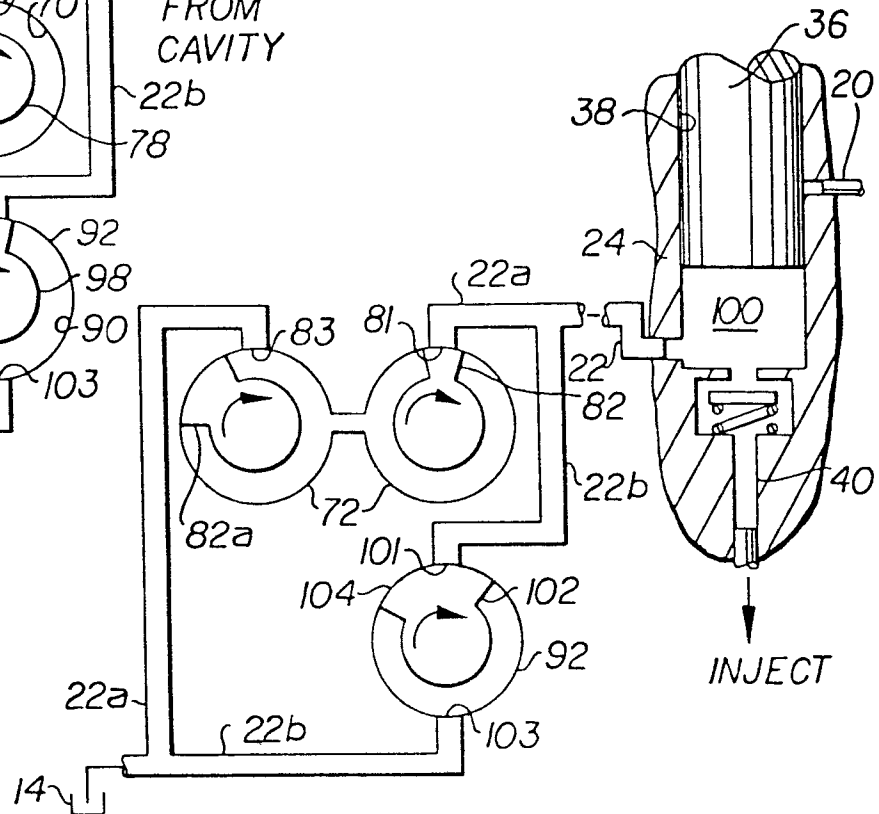


FIG. 5.

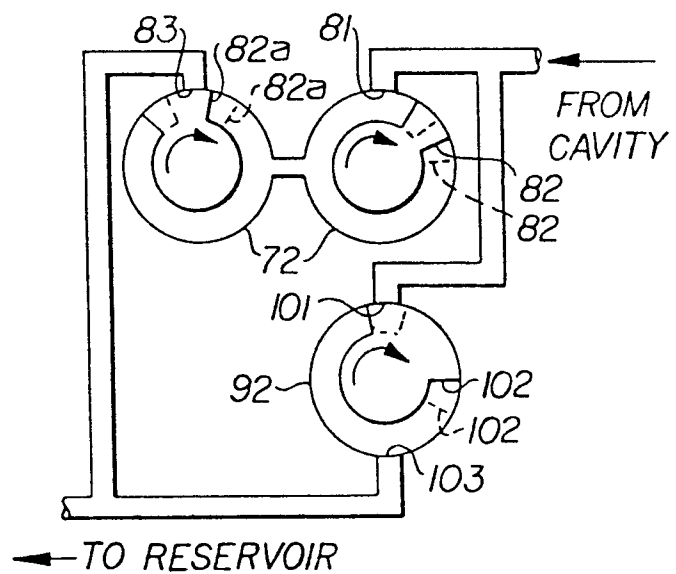


FIG. 3C.



DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	
	<u>DE - C - 914 080</u> (KORNACKER) * Page 2, lines 22-73; figures 1,2 *	1,3,4	F 02 M 45/06 59/36// 57/02
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A	<u>US - A - 4 033 301</u> (WALTON)		
A	<u>FR - A - 2 246 736</u> (EATON)		

			TECHNICAL FIELDS SEARCHED (Int.Cl. 3)
			F 02 M
			CATEGORY OF CITED DOCUMENTS
			X: particularly relevant A: technological background O: non-written disclosure P: intermediate document T: theory or principle underlying the invention E: conflicting application D: document cited in the application L: citation for other reasons
			&: member of the same patent family, corresponding document
☒ The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
The Hague		02-10-1980	HAKHVERDI