

(12)

EUROPEAN PATENT APPLICATION

(21) Application number: 80302427.2

(51) Int. Cl.³: **F 02 M 43/00**
F 02 M 59/36

(22) Date of filing: 18.07.80

(30) Priority: 22.10.79 PC T/US79/00883

(43) Date of publication of application:
29.04.81 Bulletin 81/17

(84) Designated Contracting States:
BE DE FR GB IT SE

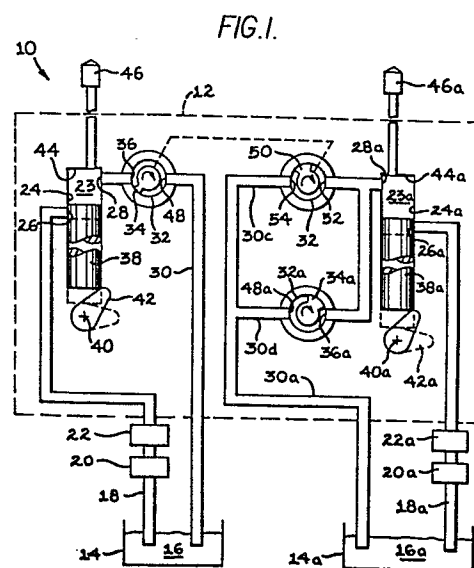
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(54) **Fuel injection apparatus.**

(57) Pilot injection of a high cetane fuel (16) and main injection of a relatively lower cetane fuel (16a) is accomplished by providing dual fuel, rotary controlled, pilot and main injection apparatus. The apparatus has a first rotating valve (32) for starting and stopping pilot injection of the high cetane fuel (16) through a first nozzle (46) and for starting main injection of the lower cetane fuel (16a) through a second nozzle (46a), and a second rotating valve (32a) for stopping main injection of the lower cetane fuel (16a)



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FUEL INJECTION APPARATUS

This invention relates generally to fuel injection apparatus for internal combustion engines and more particularly to apparatus for injecting firstly a pilot fuel and secondly a main fuel.

5. Pilot injection, in an engine using a main liquid fuel such as diesel fuel, has been used in so-called dual-fuel engines to ignite a pilot charge of natural gas, and the use of two separate and different fuels in a given engine is well known.
10. Another example of a dual fuel engine uses alcohol sprayed into the manifold of a supercharged engine providing aftercooling by evaporating the alcohol.

- A rotary electrically controlled fuel injection apparatus has been provided with dual rotary valves for
15. controlling the amount of fuel injected into an engine in order to reduce inertia forces associated with the prior art valves used for fuel injection. These dual rotary valves have been applied to provide pilot and main injection of the same fuel. The prior art discloses
 20. electrical means for continuously rotating the dual valves. This electrical means is also disclosed as being capable of independent adjustment of one or both of the valves. In this manner, timing of pilot injection is controlled and both timing and duration of main injection
 25. is controlled. The so-called universal fuel injection system, UFIS, which reads and interprets vehicle data

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such as engine speed, boost or manifold pressure, engine temperature, ambient temperature, altitude, load etc. and is powered by the vehicular power system, can provide the appropriate adjustment to

5. the dual rotors for controlling timing and duration of pilot and main injection in response to interpretation of the vehicle data.

- According to the present invention fuel injection apparatus for injecting first and second fuels into an engine, the apparatus comprising a first injector for injection of a first fuel through a first nozzle; a second injector for injection of a second fuel through a second nozzle; means for controlling starting and
10. stopping of injection of the first fuel by the first injector; and means for controlling starting and stopping of injection of the second fuel by the second injector; is characterized in that the means for controlling starting and stopping of pilot injection
15. of the first fuel includes a first rotatable valve, that the means for controlling starting of main injection of the second fuel includes said first valve; and that the means for controlling stopping of main injection of the second fuel, includes a second rotatable valve.
20. 25.

One example of apparatus according to the present invention will now be described with reference to the accompanying drawings in which:-

- Figure 1 is a diagrammatic view of a fuel
30. injection system;

Figure 2 is a diagrammatic view of fluidly interconnected rotary valves;

Figure 3 is an isometric view of the first rotor;

35. Figure 4 is an isometric view of the second rotor; and

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Figures 5 - 8 are partial diagrammatic views illustrating sequential movement of the first and second rotors causing pilot and main fuel injection.

In Figure 1 a fuel injection system 10 is shown to include a fuel injection apparatus 12. System 10 also includes a first reservoir 14 for holding a supply of a first fuel 16, say an easily ignitable or high cetane fuel to be injected as pilot fuel. Fuel 16 is pumped through a conduit 18 by a pump 20, and preferably through a fuel filtering device 22, to the fuel injection apparatus 12 and thence through a passage to the inlet 26 of a chamber 23 formed in a bore 24 between the end 44 of the bore and a reciprocating plunger 38.

The fuel 16 exits the bore 24 through an outlet 28 and returns to the reservoir 14 via a passage 30. A valve 32 which is arranged to rotate generally at a speed proportional to engine speed is interposed across the passage 30 between an inlet 36 and an outlet 48. A blocking shoulder 34 rotates with the valve 32 to close the passage 30 and prevent fuel from returning to the reservoir 14 by blocking the inlet 36.

The plunger 38, reciprocates in bore 24 in response to rotation of a first camshaft 40 having a lobe 42 which urges plunger 38 toward an end 44 of the bore 24 thus closing the inlet 26. Pilot injection through a nozzle 46 occurs when a) the plunger 38 is moving towards the end 44; b) the inlet 26 is closed by plunger 38; and c) the shoulder 34 closes the inlet 36. As a result, fuel 16 is momentarily trapped and thus compressed in the chamber 23 and injected through the nozzle 46. Pilot injection does not occur when shoulder 34 rotates to close the outlet 48 as the plunger 38 is arranged to be moving away from the end

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44 of the bore and fuel 16 is thus no longer being compressed in the chamber 23.

The system 10 also includes a second reservoir 14a for holding a supply of a second fuel 16a, a less easily ignitable, or relatively low cetane fuel for main injection. Fuel 16a is pumped through conduit 18a by a pump 20a, and preferably through a well known fuel filtering device 22a, to the apparatus 12 and thence to an inlet 26a of a chamber 23a formed in a bore 24a between the end 44a of the bore and a plunger 38a.

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- The fuel 16a exits the bore 24a through an outlet 28a and returns to the reservoir 14a via a passage 30a. The passage 30a has two branches 30c, 30d. Within the branch conduit 30c is interposed the valves
5. 32, which has a second blocking shoulder 50 which rotates with the valve 32, to close the passage 30c to prevent fuel 16a from returning to the reservoir 14a when the shoulder 50 closes the inlet 52 to the valve 32. Within branch conduit 30d is a second
 10. valve 32a. This valve 32a has a blocking shoulder 35a which rotates with the valve 32a, to prevent fuel from returning to the reservoir 14a via branch conduit 30d when the shoulder 34a closes an inlet 36a. The plunger 38a, reciprocates in the bore 24a in response
 15. to rotation of a second camshaft 40a having a lobe 42a which urges plunger 38a towards the end 44a of the bore 24a thus closing the inlet 26a. Main injection begins when a) the plunger 38a is moving towards end 44a; b) inlet 26a is closed by plunger 38a; c)
 20. shoulder 34a has closed inlet 36a and d) shoulder 50 has closed off inlet 52. Main injection ends a) when plunger 38a is still moving toward end 44a; b) inlet 26a is still closed by plunger 38a; c) shoulder 50 continues to close off inlet 52; and d) shoulder 34a
 25. has opened inlet 36a. As a result, fuel 16a is trapped for a predetermined time and thus compressed in chamber 23a and injected through a nozzle 46a. Main injection does not occur when shoulders 34c and 50 rotate to close their respective outlets 48a, 54 since, at
 30. that time, plunger 38a is arranged to be moving away from the end 44a and fuel 16a is no longer being compressed in the chamber 23a.

In Figures 2, 3 and 4, rotary valves 32, 32a are illustrated in greater detail. Valves 32, 32a are

35. disposed in a housing 56 in respective bores 58, 58a.

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- The outer peripheral surface 60 of the valve 32 rotates in lubricated contact with the bore 58, and the valve 32 has a first groove 62 recessed from the surface 60. The blocking shoulder 34 is formed in the groove 62 and has an arcuate length L1 which is of sufficient length to completely close off the inlet 36 momentarily as the shoulder 34 rotates past the inlet 36. A second groove 64 is also recessed from the surface 60, and blocking shoulder 50 is formed on the valve 32 in the groove 64. The shoulder 50 has an arcuate length L2 greater than L1. L2 is of more than sufficient length to completely close off the inlet 52 as the shoulder 50 rotates past the inlet 52.

- The position of the shoulder 50 relative to the shoulder 34 is such that there is a fixed timed relationship between the shoulders 34 and 50 reaching the same angular position, so that with properly placed ports 52 and 36, the timing between the end of pilot injection caused by shoulder 34 and the beginning of main injection caused by shoulder 50 is fixed.

- An outer peripheral surface 66 of the valve 32a rotates in lubricated contact with bore 58a and the valve 32a includes a groove 68 recessed from the surface 66. Blocking shoulder 34a is formed on valve 32a in groove 68 and has an arcuate length L3 greater than L1 and L2. L3 is therefore also of more than sufficient length to completely close off the inlet 36a as shoulder 34a rotates past the inlet 36a. The position of the shoulder 34a may be adjusted relative, to the shoulder 50 since, as is known, valves 32, 32a are relatively adjustable. However, the relative positions of shoulders 34a and 50 are such that shoulder 34a blocks inlet 36a prior to shoulder 50 blocking inlet 52. As a result, fuel 16a is first blocked from passage through branch passage 30d and is forced to pass through branch passage 30c. Thus, when shoulder

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50 blocks inlet 52, main injection is begun.

Furthermore, the relative positions of shoulders 34a and 50 are such that shoulder 34a opens inlet 36a prior to shoulder 50 opening inlet 52. As a result,

5. fuel 16a is free to pass through branch passage 30d while shoulder 50 continues to block inlet 52. Thus, when shoulder 34a opens inlet 36a, main injection ends.

Figures 5, 6, 7 and 8 sequentially illustrate pilot and main injection of two fuels 16, 16a. In Figure 5, 10. shoulder 34 momentarily blocks inlet 36 thus limiting passage of first fuel 16 through passage 30 via groove 62 and pilot injection of fuel 16 occurs. At the same time, fuel 16a freely passes through passage 30a via branch 30c and groove 64 and via branch 15. 30d and groove 68, thus no main injection occurs.

In Figure 6, shoulder 34 opens inlet 36 thus permitting passage of first fuel 16 through passage 30 via groove 62 and pilot injection ends. At the same time, fuel 16a is blocked from passing through 20. branch 30d and groove 68 due to shoulder 34a blocking inlet 48a. However, fuel 16a still freely passes through conduit 40a via branch conduit 30c and groove 64, thus no main injection occurs.

In Figure 7, shoulder 34a still blocks inlet 48a 25. thus closing branch 30d and simultaneously, shoulder 50 blocks inlet 52 which also closes the free flow of fuel 16a through passage 30a via branch conduit 30c and groove 64. Thus main injection is begun.

In Figure 8, shoulder 50 continues to block inlet 30. 52 closing the flow of fuel 16a through passage 30a via branch 30c and groove 64. However, shoulder 34a opens inlet 48a and permits free flow of fuel 16a through conduit 30a via branch conduit 30d and groove 68. Thus, main injection is ended.

35. The fuel injection apparatus 12 provides for an

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easily ignitable or high cetane fuel to be pilot injected and a less easily ignitable or relatively low cetane fuel to be main injected afterwards. The purpose is to conserve petroleum based fuel and

5. greatly facilitate usage of other fuels such as syncrude, shale oil, methanol, other alcohols, and mixtures of low cetane fuels etc. The first and second valves 32, 32a, rotate in use at a speed proportional to the engine speed, and are fed from two fuel pumps
10. 20, 20a. The first of the valves 32 provides pilot injection of a fixed duration, the timing of which is adjustable and also starting of main injection, the timing of which is adjustable in fixed relationship with the timing of pilot injection. The second
15. of the rotors 32a provides for stopping main injection, the second rotor 32a being adjustable relative to the first rotor 32 to permit adjustment of the duration and stopping of main injection. With appropriate modifications, it will be obvious to the skilled
20. artisan that this apparatus may be adaptable to various engines.

- Preferably, the valves 32, 32a are driven by an electrical servo system coupled to the engine crankshaft by suitable gearing if necessary, to enable
25. easy adjustment of the injection timing, with feedback control if desired. However, it may be possible to drive the valves mechanically.

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CLAIMS

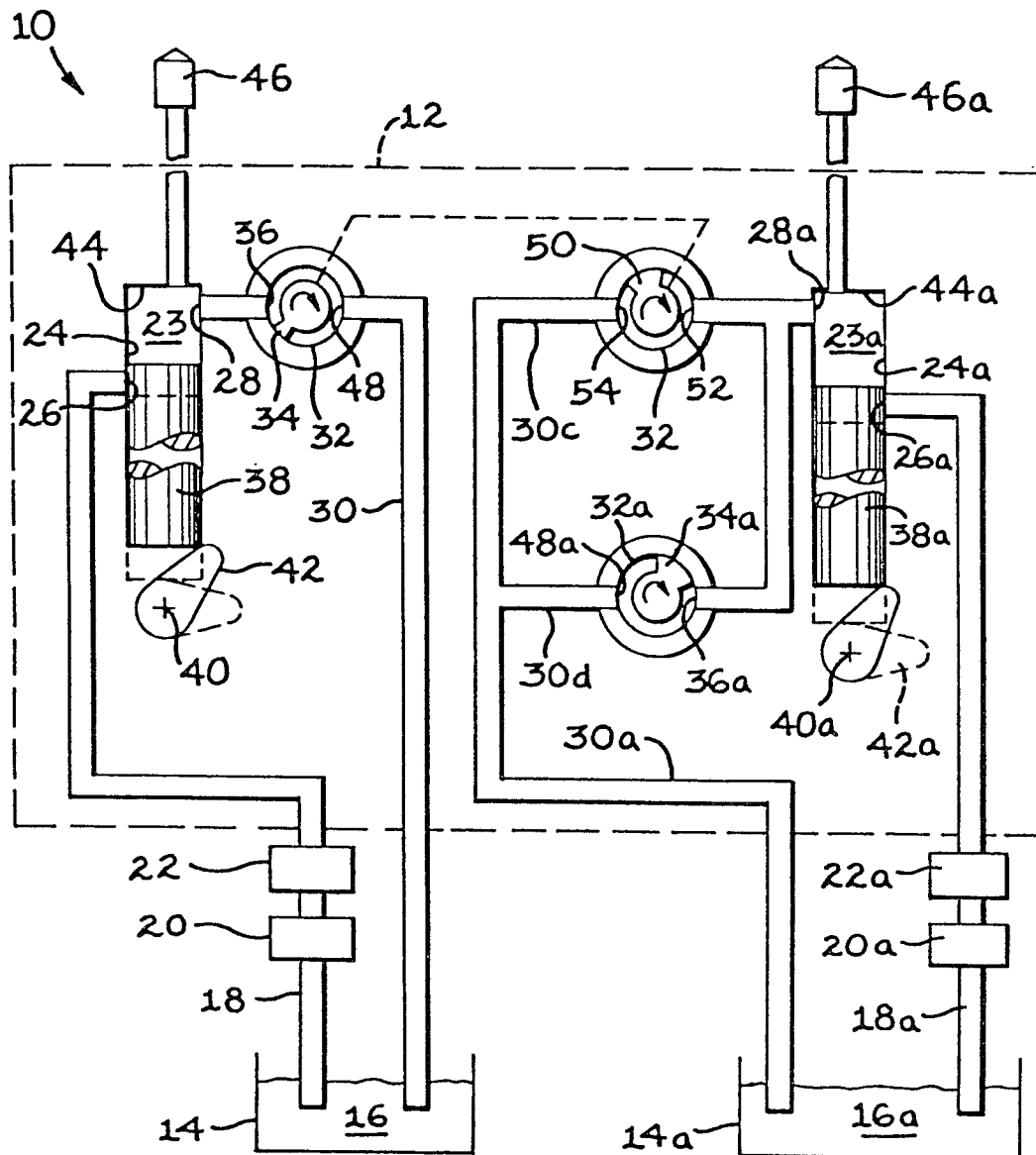
1. Fuel injection apparatus for injecting first and second fuels into an engine; the apparatus comprising a first injector for injection of a first fuel (16) through a first nozzle (46); a second
5. injector for injection of a second fuel (16a) through a second nozzle (46a); means for controlling starting and stopping of injection of the first fuel by the first injector; and means for controlling starting and stopping of injection of the second fuel by the second
10. injector; characterized in that the means for controlling starting and stopping of pilot injection of the first fuel (16) includes a first rotatable valve (32), that the means for controlling starting of main injection of the second fuel (16a) includes said first valve
15. (32); and that the means for controlling stopping of main injection of the second fuel (16a) includes a second rotatable valve (32a).
2. Apparatus according to claim 1, wherein the means for starting and stopping pilot injection of the
20. first fuel (16) includes a first member (34) on the first valve (32).
3. Apparatus according to claim 2, wherein the means for starting main injection of the second fuel (16a) is a second member (50) on the first valve (32).
25. 4. Apparatus according to any of claims 1 to 3, wherein the means for stopping main injection of the second fuel (16a) is a blocking shoulder (34a) on the

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second valve (32a).

5. Apparatus according to claim 2, wherein the first member (34) is a blocking shoulder on the first valve (32).
5. 6. Apparatus according to claim 3, wherein the second member (50) is a second blocking shoulder on the first valve (32).
7. Apparatus according to claim 3, characterized in that second member (50) on the first valve (32)
10. and the second valve (32a) are interposed in respective parallel branches (30c, 30d) of a path (30a) for the second fuel (16a).
8. Apparatus according to claim 2, characterized in that the first member (34) on the first valve (32)
15. is in fluid connection with the first injector which has a bore (24) in which is mounted for reciprocation a first plunger (38) for injecting the first fuel (16) through the first nozzle (46).
9. Apparatus according to claim 3, characterized
20. in that the second member (50) on the first valve (32) and the second valve (32a) are in fluid connection with the second injector which has a bore (24a) in which is mounted for reciprocation a second plunger (38a) for injecting the second fuel (16a) through the
25. second nozzle (46a).

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FIG. 1.



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FIG.2.

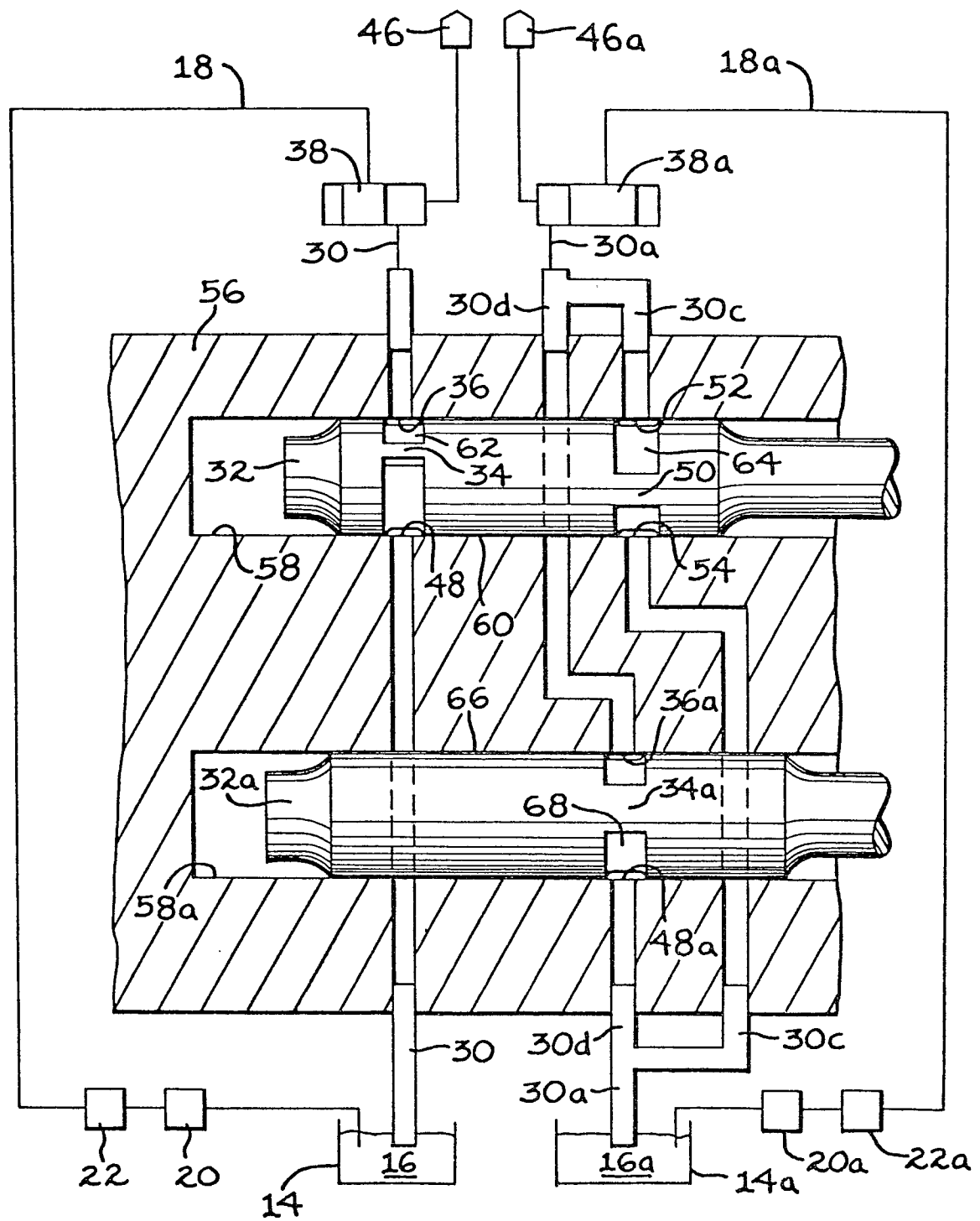


FIG. 4.

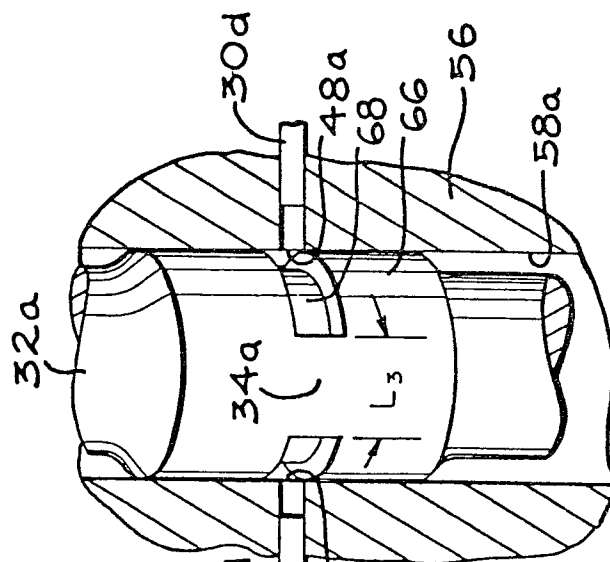
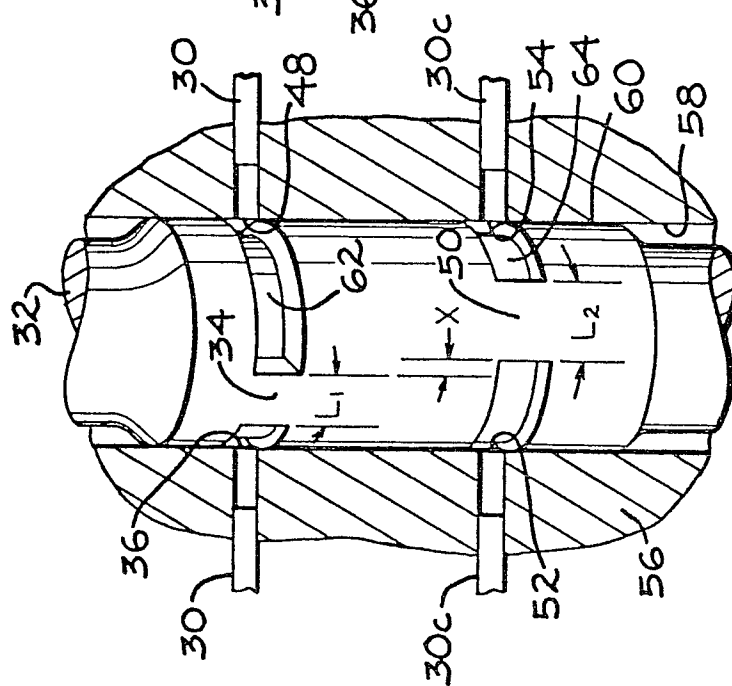


FIG. 3.



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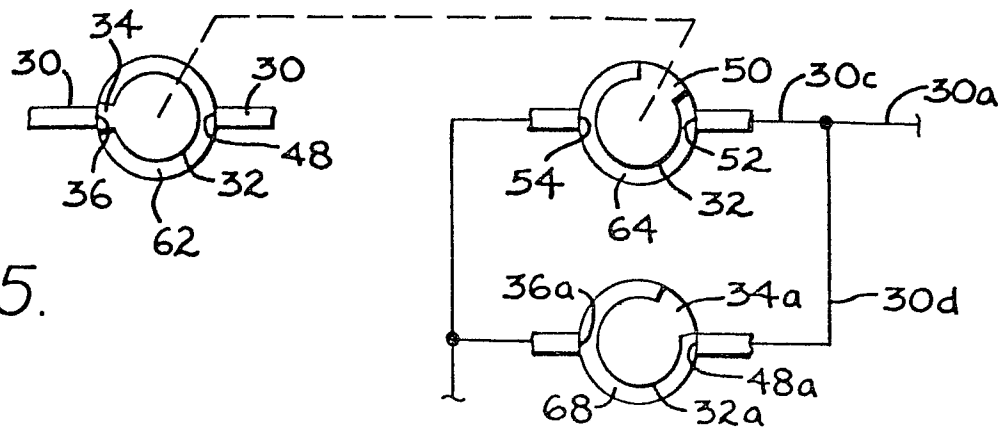


FIG. 5.

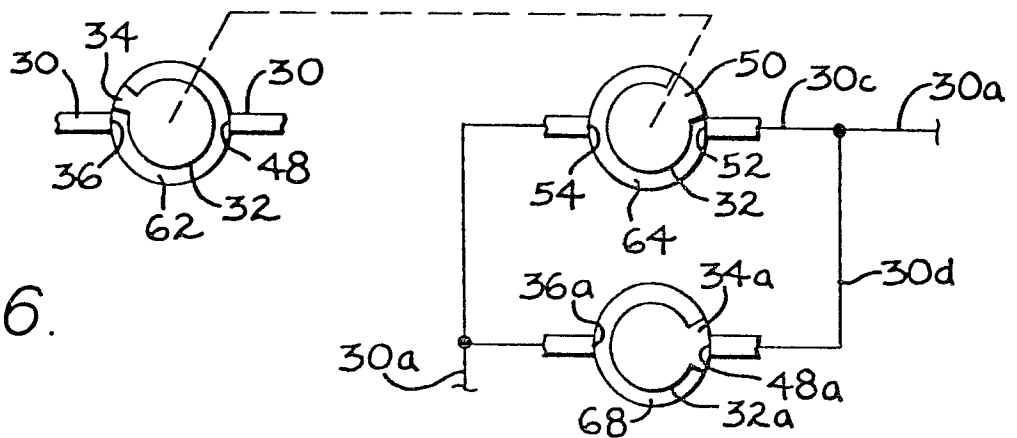


FIG. 6.

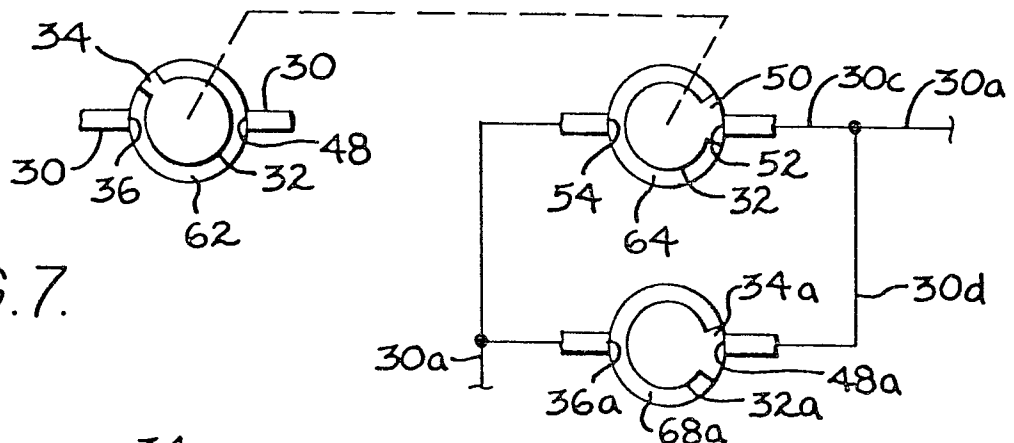


FIG. 7.

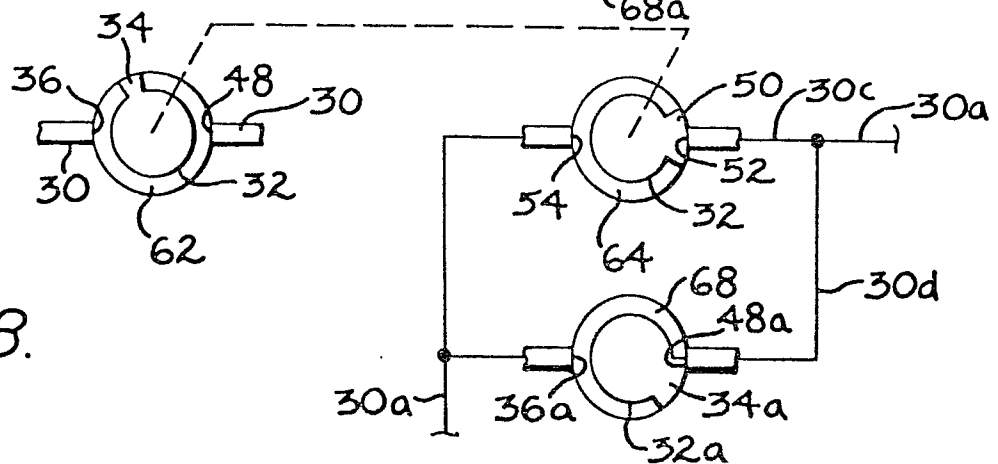


FIG. 8.



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	
A	<u>GB - A - 499 741</u> (DAIMLER-BENZ)		F 02 M 43/00 59/36
A	<u>FR - A - 748 088</u> (KRUPP)		
A	<u>FR - A - 429 021</u> (KOERTING)		
A	<u>DE - C - 914 080</u> (KORNACKER)		
A	<u>US - A - 3 891 151</u> (SHOWALTER)		
A	<u>US - A - 3 068 794</u> (MORRIS)		
-----			TECHNICAL FIELDS SEARCHED (Int.Cl. ³)
			F 02 M F 02 D
			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
☒ The present search report has been drawn up for all claims			&: member of the same patent family, corresponding document
Place of search The Hague		Date of completion of the search October 29, 1980	Examiner HAKHVERDI