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(71) Applicant: CATERPILLAR TRACTOR CO.
100 Northeast Adams Street
Peoria Illinois 61629(US)

(72) Inventor: Cemenska, Richard A.
RR 1, Box 153W
Edelstein, Illinois 61526(US)

(72) Inventor: Grim, George B.
710, Crestview Drive
Washington, Illinois 61571(US)

(74) Representative: Brunner, Michael John et al,
Gill Jennings & Every 53 to 64, Chancery Lane
London WC2A 1HN(GB)

(54) **Fuel injection apparatus.**

(57) A fuel injection apparatus has a pair of rotary valve spindles (46, 48) which form the necessary valves (20, 22, 24) for starting and stopping both pilot and main injection of fuel into an engine. The first valve spindle (46) also provides means (26) for sequentially controlling the fuel flow through a first nozzle (28) for pilot injection and through a second nozzle (30) for main injection.

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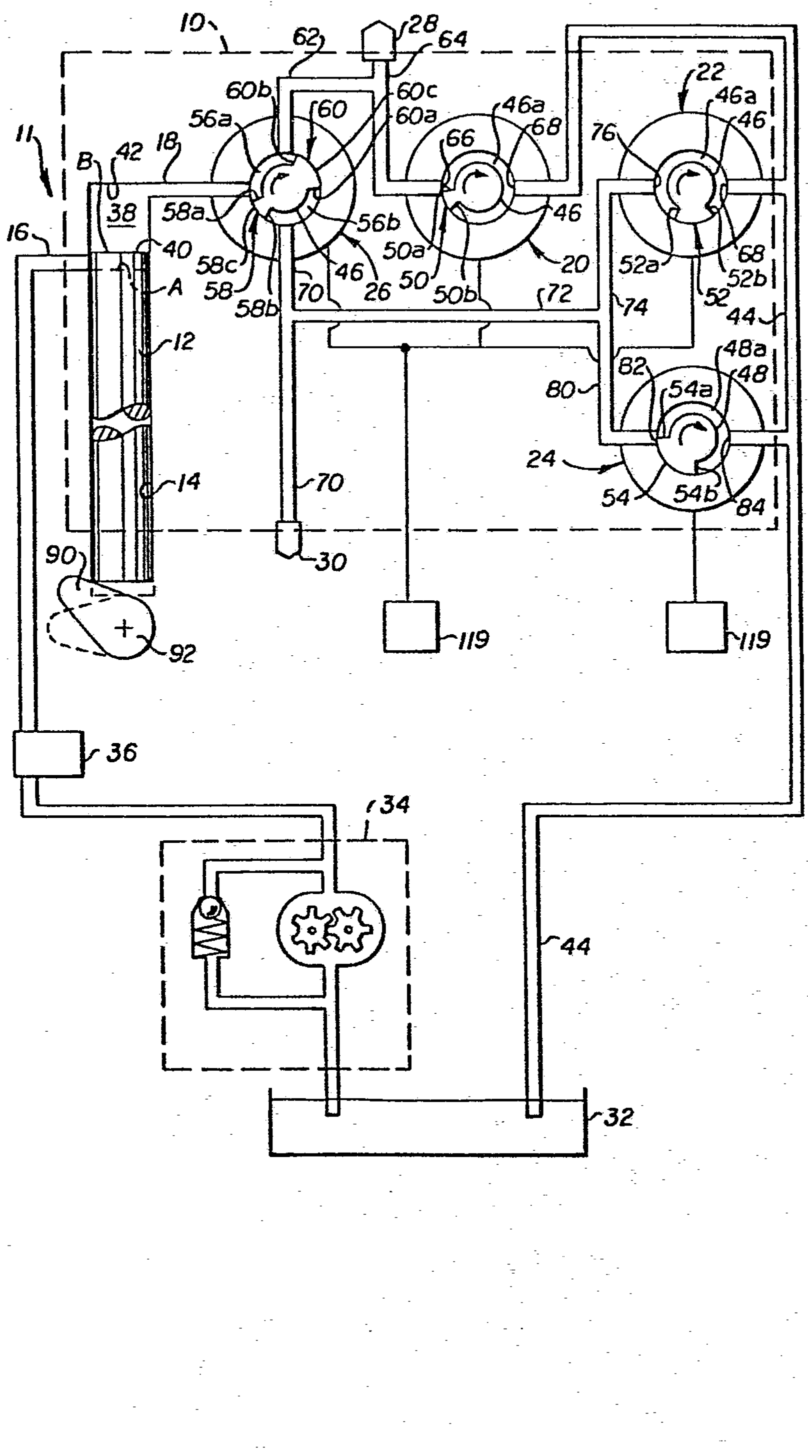
FIG. 2.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FUEL INJECTION APPARATUS.

This invention relates to fuel injection apparatus, and more particularly to such apparatus designed to provide both pilot and main injection of fuel into an engine.

Conventionally, when it is desired to provide pilot injection, two fully independent fuel injection systems have been used. Expense and bulk are obvious limitations of pilot injection accomplished this way.

As an alternative it has been suggested to employ fuel injection apparatus having dual rotary controlled valves which have reduced inertial forces compared with prior art valves used for fuel injection. Where only one injector nozzle is used, dual electrically controlled rotary valves can provide control of both pilotand main fuel injection.

Electrical control of fuel injection is versatile and advantageous, and 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 rapid shutdown of engines; and improved fuel economy.

According to the present invention fuel injection apparatus for providing both pilot and main injection of a fuel, through a first nozzle and a second nozzle; an injector and valve means for starting and stopping pilot injection and main injection of the fuel, the valve means including a plurality of rotary valve spindles fluidly connected to the injector is characterized in that means are provided for sequentially directing fuel from the injector to the first nozzle for pilot injection therethrough and to the second nozzle injection therethrough.

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

Figure 1 is a diagrammatic view of a fuel injection apparatus;

Figure 2 is a diagrammatic view illustrating the fuel injection apparatus in greater detail and embodied in a system;

Figure 3 is an isometric view partially illustrating one rotary valve spindle;

Figure 4 is an isometric view partially illustrating another rotary valve spindle;

Figure 5, 6, 7 and 8 are views illustrating sequential steps of fuel injection using the apparatus of Figures 1 to 4;

Figure 9 is a diagrammatic view illustrating an adjustment control for use with the rotary valves; and

Figure 10 is a diagrammatic view of a second apparatus.

In Figure 1 there is shown diagrammatically a fuel injection apparatus 10 which has an injector which includes a plunger 12 reciprocably mounted in a plunger bore 14. Fluid lines 16, 18 are provided for conducting fuel to and from the plunger bore 14, and rotary valves 20, 22, 24 are provided for cooperatively starting and stopping pilot injection and main injection of fuel.

In addition, a rotary valve 26 sequentially directs fuel from the plunger bore 14 for pilot injection through a first nozzle 28 and for main injection through a second nozzle 30.

In Figure 2, the fuel injection apparatus 10 is shown in greater detail operatively connected in a system 11 which includes a fuel supply tank or reservoir 32 from which fuel is transferred, via fluid line or passage 16, to tge plunger bore 14 by a fuel transfer pump 34, preferably through a filter 36. When plunger 12 is in a dotted line position designated "A", fuel enters a cavity 38 formed in the bore 14 between an end 40 of the plunger and an end 42 of bore 14. The fuel is then conducted from cavity 38 by fluid line or passage 18. Ultimately, excess fuel in the apparatus 10 returns to the reservoir 32 via a conduit 44. The valves 20,22, 26 have a common spindle 46 which rotates clockwise in a bore 47. The second valve 24 has a spindle 48 which rotates clockwise in a bore 49 (see Figure 2,3 and 4). The valves 20, 22 and 26, illustrated in sectional views in Figure 2, are shown in the isometric view in Figure 3 in more detail. The valve 26 (at section A-A) includes a groove 56 formed on valve spindle 46. Valve 20 (at section B-B) includes a groove 46a with a blocking shoulder 50, for starting and stopping pilot injection through the nozzle 28. The valve 22, (at section C-C) includes the groove 46a, and a second blocking shoulder 52 in it, for starting main injection through the nozzle 30. The valve 24, is shown in more detail at section D-D of Figure 4, and the spindle 48 can be seen to include a groove 48a having a blocking shoulder 54 for stopping main injection through the nozzle 30.

More specifically, the groove 56 includes a portion 56a (see Figure 2) partitioned from a portion 56b by blocking shoulders 58,60. Should 58 has a leading edge

58a, a trailing edge 58b, and an arcuate face 58c. Arcuate face 58c is at least large enough to momentarily close off the passage 18 so as to avoid unduly high pressure build-up in the apparatus. However, if desired, a relief valve can be provided on the plunger 12 to relieve such unduly high pressure. The shoulder 60 has a leading edge 60a, a trailing edge 60b and an arcuate face 60c. Thus, the groove portion 56a is formed between the leading edge 58a and the trailing edge 60b and the groove portion 56b is formed between the leading edge 60a and the trailing edge 58b. The groove portion 56a, as illustrated in Figure 2, is of a size sufficient to permit fluid communication between passage 18 and a passage 62, which joins a passage 64 which fluidly connects the valve 20 to the first nozzle 28.

The groove portion 56b, as illustrated in Figure 2, is of a size sufficient to permit fluid communication between passage 18 and a passage 70 which joins a passage 72, which, together with a passage 74, fluidly connects valve 22 to the second nozzle 30. As illustrated in Figures 2 and 3, the blocking shoulder 50 of the valve 20 is of a size L1, sufficient to block port 66 of the passage 64. L1 is the arcuate distance between the leading edge 50a and the trailing edge 50b of the shoulder 50. A port 68 fluidly connects the groove 46a of valve 20 with the conduit 44. As illustrated in Figures 2 and 3, blocking shoulder 52 of valve 22 is of a size L2, greater than L1, sufficient to block a port 76 of passage 74. L2 is the arcuate distance between the leading edge 52a and the trailing edge 52b of the shoulder 52. A port 68 also fluidly connects the groove 46a of the valve 46 with the conduit 44.

The passage 72 connects with a passage 80 to fluidly connect the valve 24 with the second nozzle 30. As illustrated in Figures 2 and 3, blocking shoulder 54 of the valve 24 is of a size L3, greater than L1 and L2, and blocks a port 82 of the passage 80. L3 is the arcuate distance between the leading edge 54a and the trailing edge 54b of the shoulder 54. It should be noted, as will be later pointed out in greater detail, that is is preferred that L3 is of a size sufficient to block port 82 during both pilot and main injection. A port 84 fluidly connects the groove 48a of the valve 48 with the conduit 44.

Conventionally, the plunger 12 is resiliently biased in a return direction by a spring (not shown) and driven by a lobe 90 of a camshaft 92. As a result, plunger 12 reciprocates in bore 14. Fuel can be expelled through the nozzles 28, 30, due to substantial pressurization of the fuel in the cavity 38 as the plunger 12 reciprocates. Controlling the quantity and timing of fuel injection through the two nozzles 28, 30 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 90 and plunger 12 have a fixed cyclical relationship for pressurizing the fuel in bore 14, variations in controlling quantity and timing of injection usually involve electrical and/or mechanical control of the admittance of fuel to bore 14. For example, this has been conventionally accomplished by a scroll (helix) on the plunger which is rotated with a rack. As illustrated, in Figure 2, the plunger 12 reciprocates between the full line position "B" and dotted line position "A" to permit cavity 38 to fill with fuel. Once plunger moves from "A" to "B" it closes off fluid communication between the passage 16 and cavity 38, and fuel will be compressed in the cavity 38 as the plunger continues toward the end 42 and can be expelled through either the nozzle 28 or 30 depending on the position of the valve 26. However, the expulsion of fuel through the nozzle also requires the path to the return conduit 44 to be blocked by blocking shoulders 50 or 52 and 54.

Figure 2 illustrates a position in which the passage 16 is closed off by the plunger 12 and in which groove portion 56a permits fluid in cavity 38 to be directed towards the first nozzle 28. Shoulders 58, 60 of valve 26 are in a position which prevents fuel access to nozzle 30. However, since the shoulder 50 does not block the port 66, fuel returns to reservoir 32 via the conduit 44. Thus, due to insufficiently high pressure, no injection can occur under the circumstances illustrated in Figure 2.

In Figure 5, valve spindle 46 is illustrated as rotated clockwise from its position illustrated in Figure 2 and the plunger 12 has moved closer to the end 42 of the bore thus reducing the volume and increasing the pressure in the cavity 38. The groove 56a still permits fluid in the cavity 38 to be directed toward the nozzle 28 and fuel access to nozzle 30 is prevented. However, now, the edge 50a of the shoulder 50 has rotated past the port 66 so that the shoulder 50 blocks the port 66 so that fuel is trapped in cavity 38, passage 18, groove portion 56a, passage 62 and passage 64. As a result, high pressure fuel is pilot injected through the nozzle 28 until, upon further clockwise rotation of valve spindle 46, edge 50b of shoulder 50 rotates past port 66 permitting fuel to return to reservoir 32 via conduit 44 thus ending pilot injection. In this manner, groove portion 56a sequences fuel to start and stop pilot injection.

Note that under the conditions described above, the shoulder 54 of valve 24 also blocks port 82 during pilot injection. Although fuel is being directed to nozzle 28, it is preferred that shoulder 54 block port 82 during pilot injection for the following reasons; first, this permits dimensional flexibility and thus reduces cost; and second, the size of shoulder 54 beneficially limits leakage of fuel past the shoulder 54.

In Figure 6, valves 20,22,24,26 are illustrated as rotated clockwise from their positions illustrated in Figure 5 and plunger 12 has moved closer to end 42 thus the reducing volume of cavity 38. Due to rotation of shoulder 58, in valve 26, the groove portion 56a now no longer directs fluid to the nozzle 28 and the groove portion 56b permits fluid in the cavity 38 to be directed toward the nozzle 30. Pilot injection is ended. However, although shoulder 54 of valve 24 blocks port 82, insufficient pressure is available for main injection via nozzle 30 since fuel can still pass through passage 70, 72, 74 and past groove 46a in valve 22 and return to reservoir 32 via conduit 44.

In Figure 7, valves 20,22,24,26, are illustrated as rotated clockwise from their positions in Figure 6 and plunger 12 has moved even closer to end 42 thus further reducing volume and increasing pressure in cavity 38. The groove portion 56b continues to direct fuel towards the nozzle 30 and the shoulder 54 continues to block the port 82. But, in addition, the edge 52a of the shoulder 52 is now rotated to a position where the shoulder 52 blocks port 76, thus enabling main injection to begin through nozzle 30.

In Figure 8, valves 20,22,24,26, are illustrated as rotated clockwise from their positions in Figure 7.

Groove portion 56b continues to direct fuel toward nozzle 30 and the shoulder 52, which began main injection, still blocks port 76. However, the edge 54b of shoulder 54 in valve 24 has rotated past port 82, permitting fuel to pass through groove 48a and ultimately to reservoir 32 via conduit 44, thus ending main injection.

Means 119 are provided for continusouly rotating the valve spindles 46 and 48. However, only one of the identical means 119 is shown in Figures 2 and 9 and is described below. Means 119 is preferably electrical, although it is possible to arrange for mechanical rotation of valves 46, 48. Means 119 includes a control transmitter 120, and a control transformer and servo 122. Control transmitter 120 is driven by camshaft 92 at one-half engine speed (for a 4 cycle engine). Such a control transmitter 120, through suitable buffering networks which are well known, energizes control transfomer and servo 122, which rotates valve spindle 46. By adjusting the position of the stator 124 of the control transmitter 120 relative to the camshaft 92 the starting of main injection is controlled. Since shoulders 50, 52 have a fixed relationship on valve spindle 46, the timing of pilot injection is also adjusted.

In the additional identical means 119, the control transmitter, also driven by camshaft 92, directly drives control transformer and servo 122 for rotating the valve spindle 48. By adjusting the position of the stator 124 of control transmitter 120, relative to the camshaft the stopping of injection is controlled. Electrical equipment for supplying the above-described functions of means 119 is available from commercial sources such as AEROFLEX and the SINGER INSTRUMENT COMPANY, both of the United States of America.

Another electrical means is possible for continuously rotating valves 46, 48 and will be briefly discussed. Such means comprises a digital system, several types of which have been used successfully 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 feedback corrections. However, feedback loop equipment is commercially available from DISC INSTRUMENT CORP. of the United States of America.

Rotating the valve spindles 46, 48 at one-half engine speed will result in making one injection of fuel per two engine revolutions in a four cycle engine. A two cycle engine would have valve spindles 46, 48 rotating at crank speed since injection frequency is at crank frequency. The arcuate lengths L1, L2 and L3 of shoulders 50, 52 and 54, respectively, may be expressed in rotational degrees. Thus, by adjusting the position and dimensions L1, L2, of the blocking shoulders 50, 52 relative to the camshaft 92, the starting and stopping of pilot injection and the starting of main injection can be controlled, and, by controlling the position of shoulder 54 relative to shoulders 50, 52, the stopping of main injection can be controlled.

Electrical means are preferably employed to determine the start of injection as well as to determine the quantity 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 even fuel temperature.

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. 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. The UFIS logic requires relatively low milliamperage. Thus, the signal produced by the UFIS logic must be amplified to provide an appropriate UFIS input to control transmitter 120. UFIS type logic can also provide the appropriate adjustment to stator 124 for controlling the position of shoulders 50, 52, relative to camshaft 92 and the position of shoulder 54 relative to shoulders 50, 52 as discussed above.

Figure 10 illustrates an alternative arrangement of the valves 20, 22, 24, 26.

The invention provides using rotating control valves and a single reciprocating plunger per engine cylinder for controlling the injection of pilot fuel at a first nozzle, followed by the main fuel injection at a second nozzle, as well as providing variable timing control.

Preferably, two rotary valve spindles are used. The first rotor sequences the fuel so that blocking shoulders on the first rotor control fuel flow to start and stop pilot injection through the first nozzle and to start main injection through the second nozzle. The first rotor also sequences the fuel to the first and second nozzles and a blocking shoulder on the second rotor controls fuel spill flow to stop the main injection. Both rotors operate at half engine speed on four cycle engines and at engine speed on two cycle engines.

Therotors are rotated and controlled electrically. By adjusting the phase angle between the rotors the quantity of fuel in the main injection is controlled. By simultaneously retarding the rotors, timing is retarded without altering the quantity of fuel injected.

By advancing the rotors, timing is advanced without altering the quantity of fuel injected.

In providing for the use of two separate nozzles, pilot injection can be made into a small precombustion chamber, while main injection is made into the main chamber, thus enhancing the advantages of both prechambered and direct injection type diesel engines.

CLAIMS

1. Fuel injection apparatus for providing both pilot and main injection of a fuel, through a first nozzle (28) and a second nozzle (30); an injector (12, 14); and valve means (20, 22, 24) for starting and stopping pilot injection and main injection of the fuel, the valve means (20, 22, 24) including a plurality of rotary valve spindles (46, 48)fluidly connected to the injector (12, 14); characterized in that means (26) are provided for sequentially directing fuel from the injector (12, 14) to the first nozzle (28) for pilot injection therethrough and to the second nozzle (30) for main injection therethrough.

2. Apparatus according to claim 1, characterized in that the valve means (20, 22, 24) includes a first valve spindle (46) and a second valve spindle (48).

3. Apparatus according to claim 2, characterized in that the first valve spindle (46) forms the means (20) for starting and stopping pilot injection and also the means (22) for starting main injection.

4. Apparatus according to claim 2 or claim 3, characterized in that the second valve spindle (48) forms the means (24) for stopping main injection.

5. Apparatus according to any of claims 2 to 4, characterized in that the first valve spindle (46) includes the means (26) for directing the fuel to the first and second nozzles (28, 30).

6. Apparatus according to claim 2 or claim 3, characterized in that the first valve spindle (46) has a first blocking shoulder (50), cf a size L1, for controlling starting and stopping of pilot injection.

7. Appparatus according to claim 6, characterized in that the first valve spindle (46) has a second blocking shoulder (52) of a size L2 greater than L1, for controlling starting of main injection.

8. Apparatus according to claim 4, and claim 7, characterized in that the second valve spindle (48) includes a blocking shoulder (54), of a size L3 greater than the first L1 and second L2 sizes, for stopping main injection.

9. Apparatus according to any of claims 1 to 8, characterized in that the directing means (26) is positioned to direct fuel in parallel to each nozzle (28, 30) and its respective valve means (20; 22 and 24 respectively.

10. Apparatus according to any of claims 1 to 8, characterized in that the directing means (26) is positioned such that fuel is fed from the injector (12, 14) to the directing means (26) and valve means (20, 22, 24) in parallel.

11. Apparatus according to claim 1, characterized in that the directing means (26) comprises a partitioned groove (56) on a valve spindle (46), the groove (56) having a first portion (56a) for directing fuel to the valve means (20) for starting and stopping pilot injection, and a second portion (56b) for directing fuel to the valve means (22) for starting main injection and to the valve means (24) for stopping main injection.

12. Apparatus according to claim 2, further including means (119) for independently rotatably adjusting the first (46) and second (48) valve spindles.

FIG. 1.

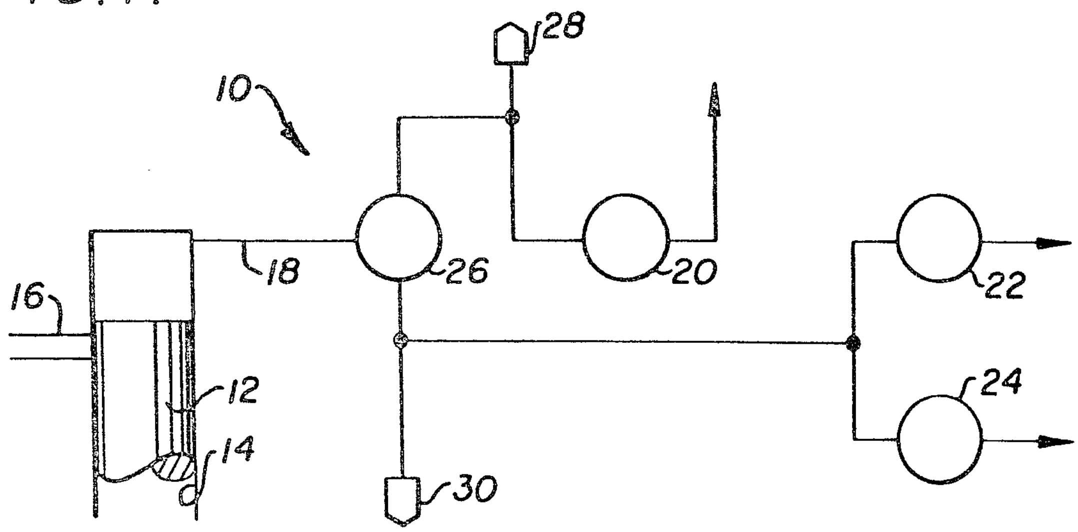

FIG. 3.

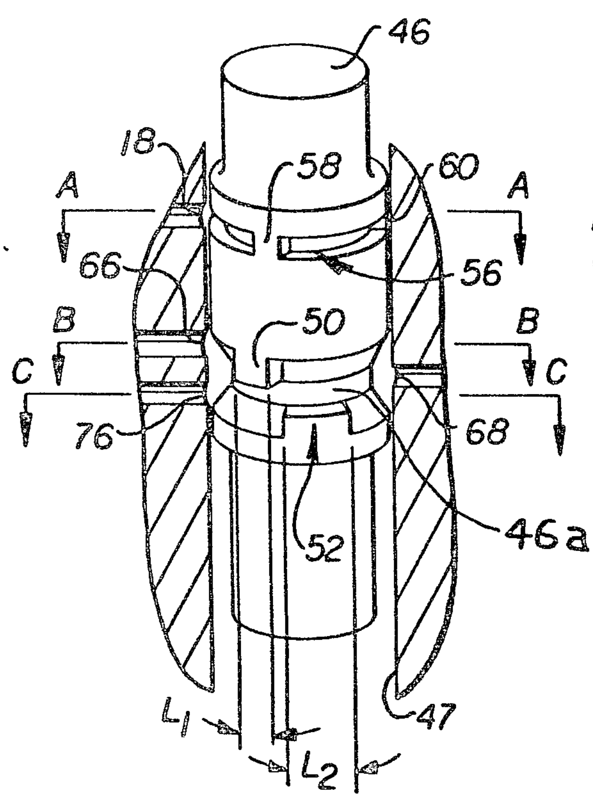

FIG. 4.

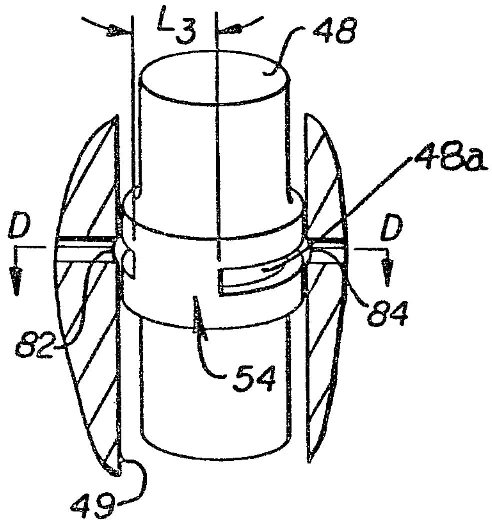

FIG.2.

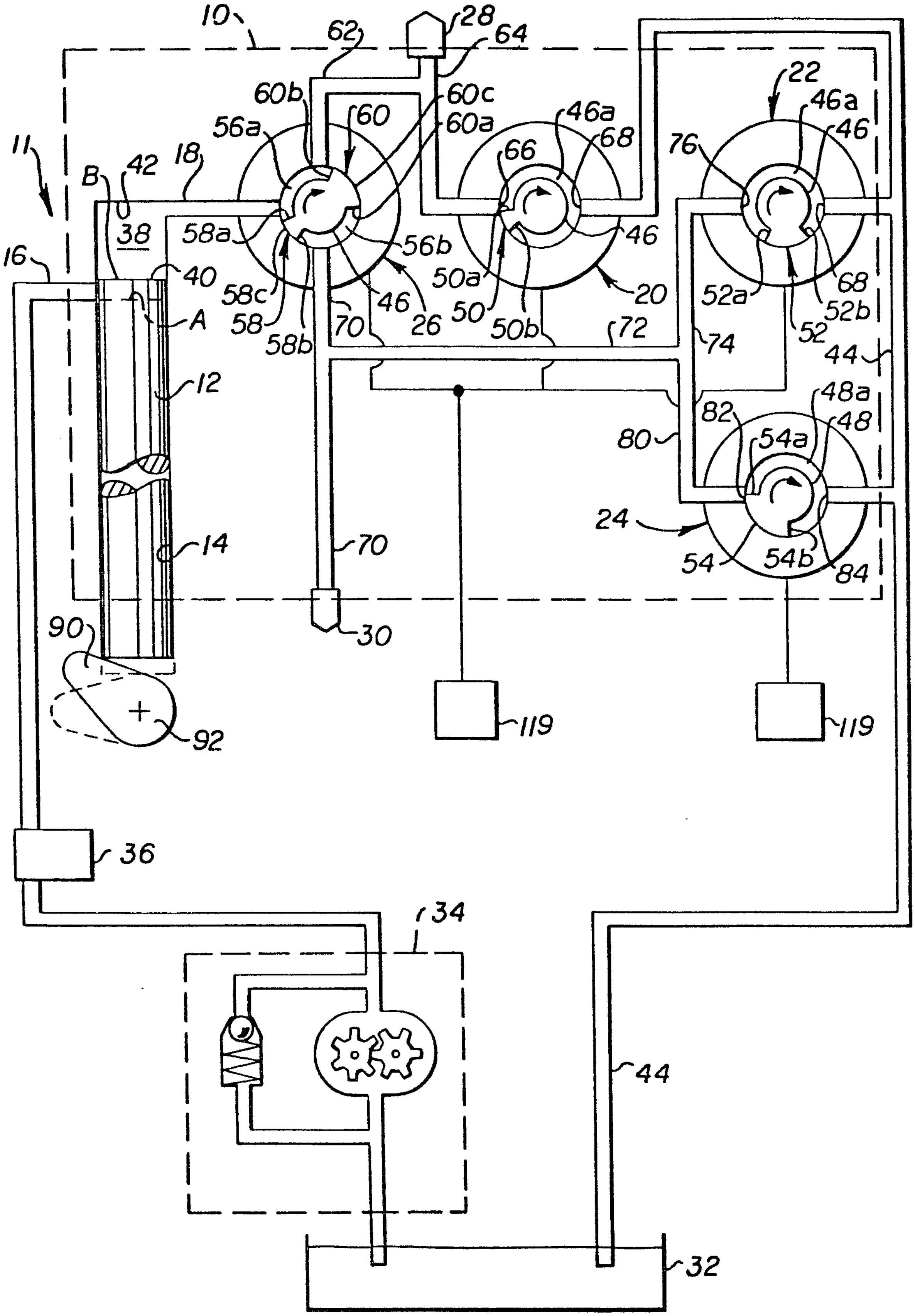
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FIG.5.

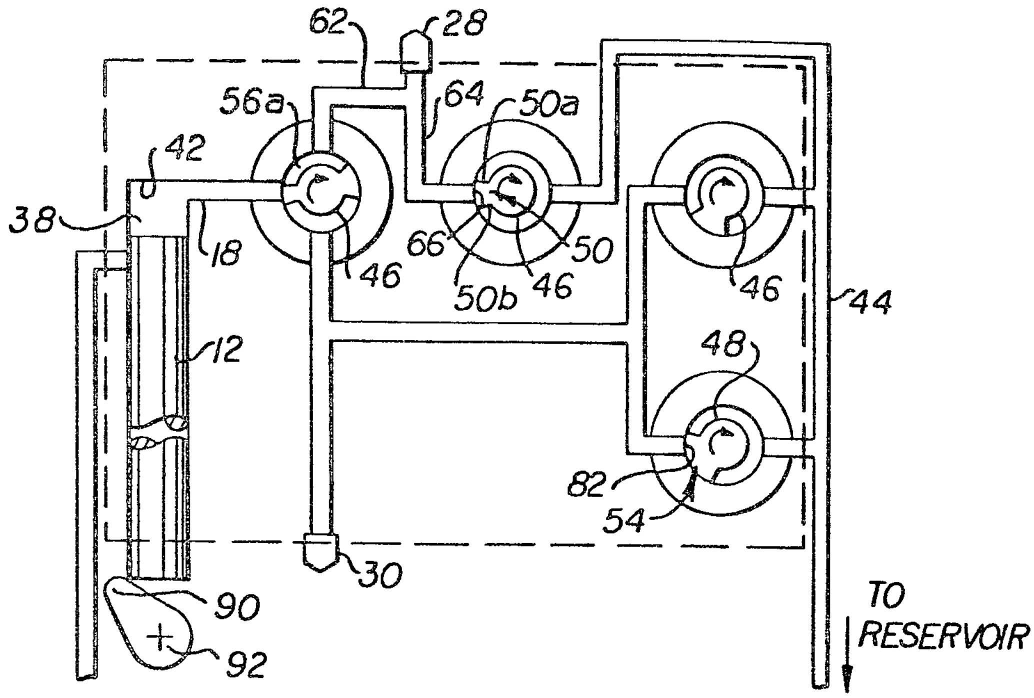
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FIG.6.

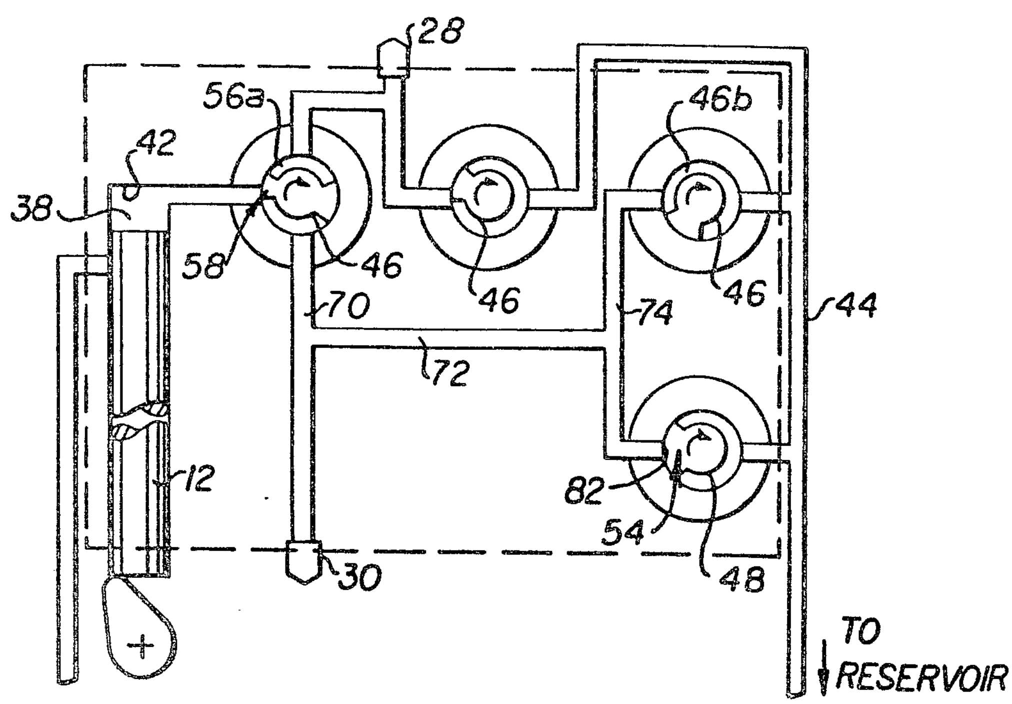
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FIG.7.

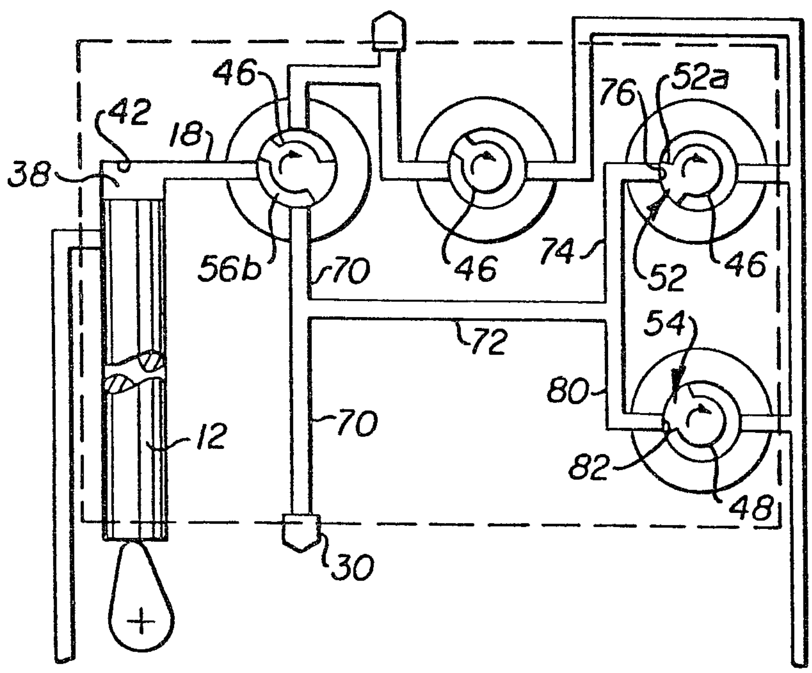
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FIG.8.

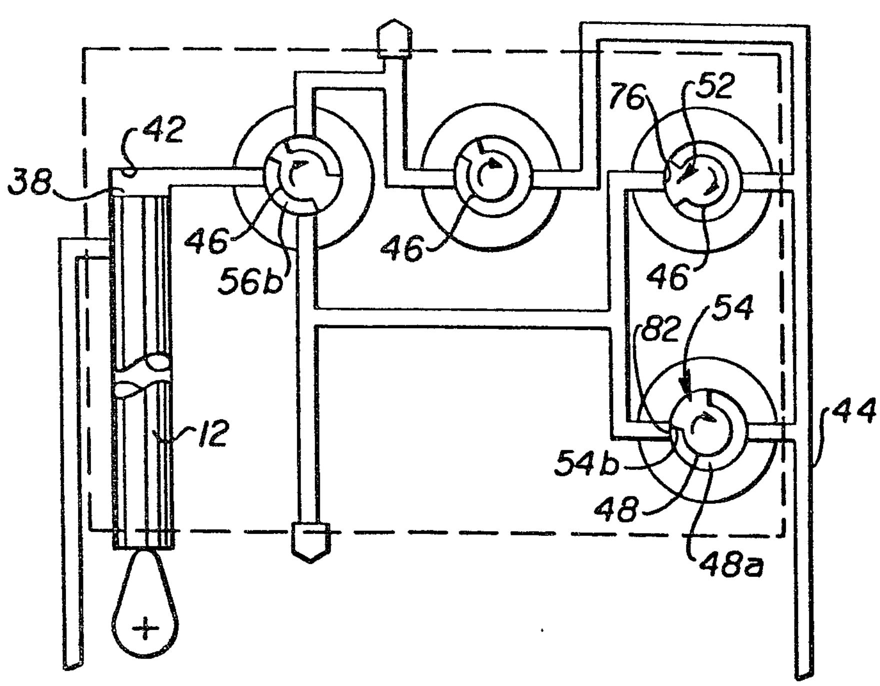
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FIG. 9.

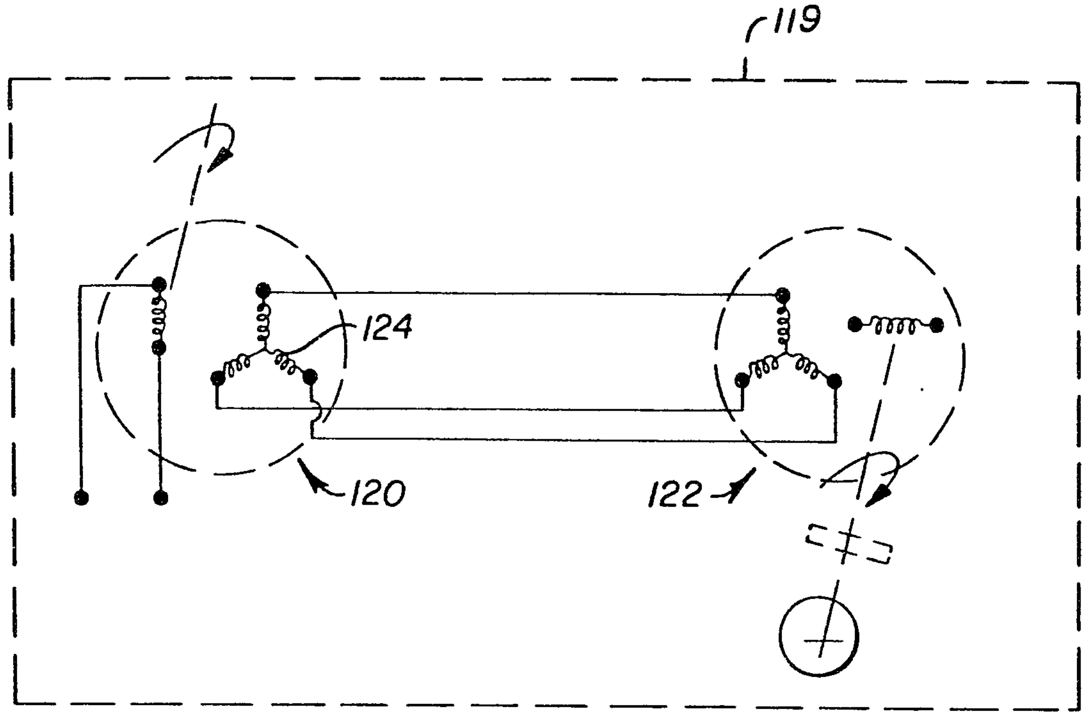
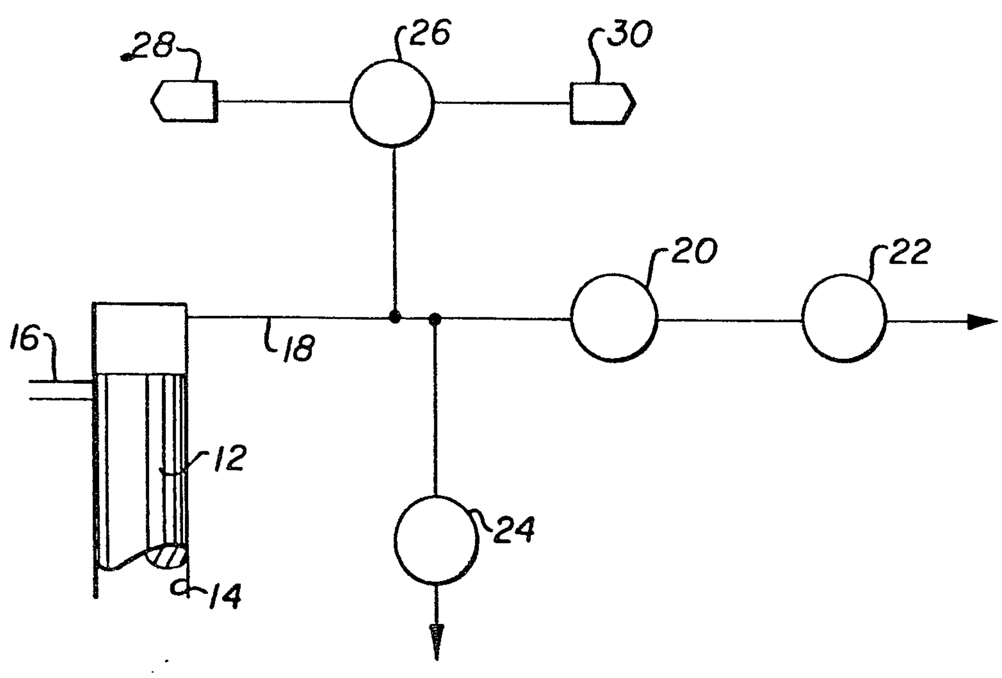


FIG. 10.



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EUROPEAN SEARCH REPORT

Application number
EP 80 30 3080.8

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.3)
X	DE - C - 914 080 (DEUTSCHE VERSUCHSANSTALT FÜR LUFTFAHR E.V.) * claims 1, 2; fig. 1, 2 *	1,5,6	F 02 M 41/06
X	US - A - 3 891 151 (SHOWALTER) * column 4, line 58 to column 5, line 12 *	1,2, 12	
A	US - A - 3 348 488 (WOLFF) * column 2, line 48 to column 3, line 16 *	1,5,6	
A	DE - A - 2 325 940 (TOYO KOGYO CO. LTD.) * claims 1 to 6; fig. 1, 2 *		
A	US - A - 3 143 104 (CUMMINS et al.) * column 13, line 30 to column 16, line 45 *		
A	US - A - 2 871 796 (DREISIN et al.) * column 1, lines 35 to 64; fig. 1, position 53 *		
A	US - A - 2 747 555 (BRUNNER) * column 3, line 38 to column 5, line 6; fig. 2 *		

TECHNICAL FIELDS SEARCHED (Int.Cl.3)

F 02 D 1/00
F 02 D 3/00
F 02 M 41/00
F 02 M 45/00
F 02 M 59/00
F 02 M 63/00

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

X The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Berlin	19-12-1980	STÖCKLE