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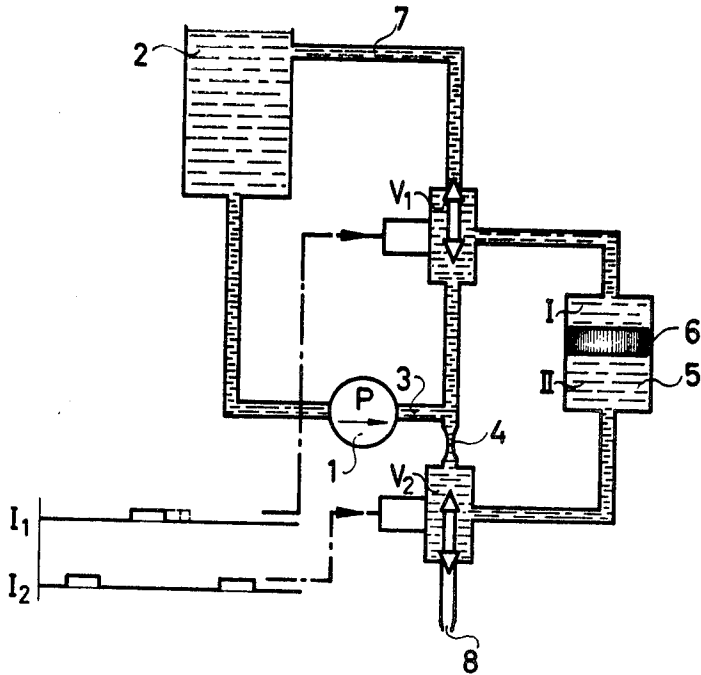
[54] **FUEL INJECTION APPARATUS FOR INTERNAL COMBUSTION ENGINES**
13 Claims, 5 Drawing Figs.

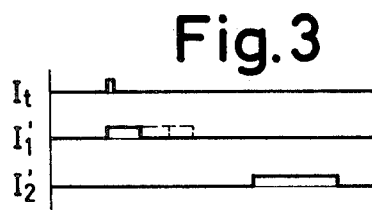
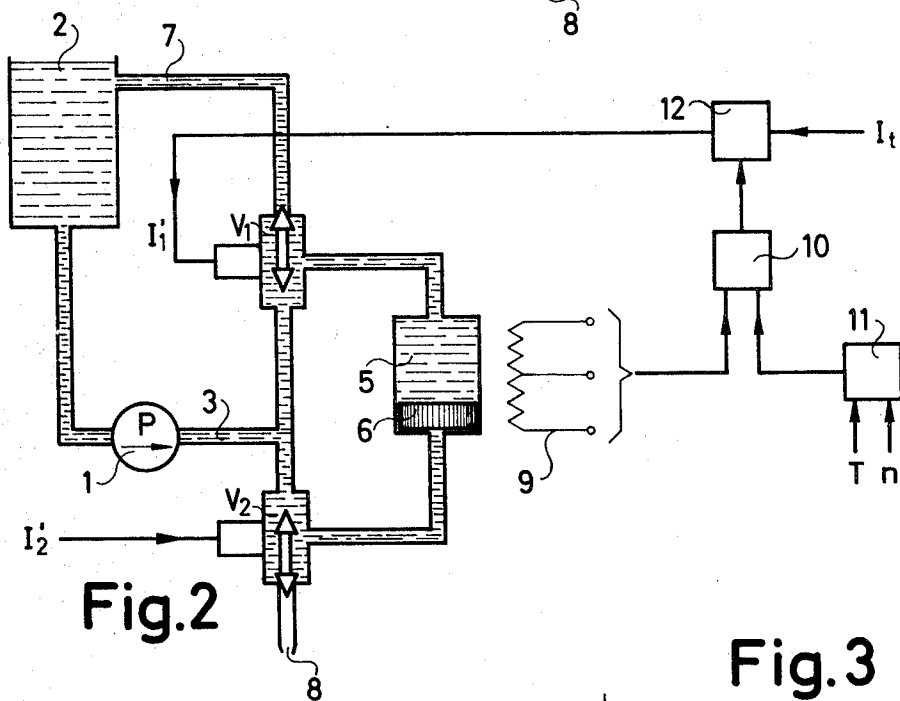
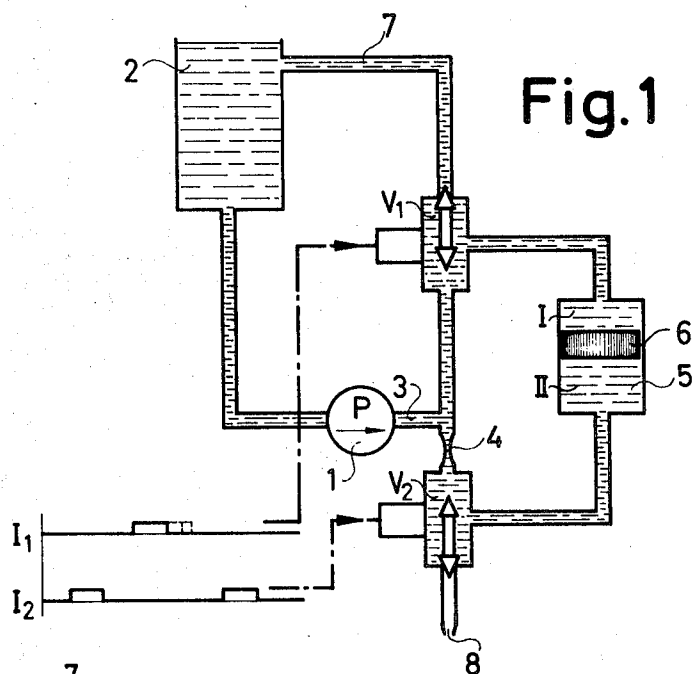
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139.17, 139.18, 140.3

ABSTRACT: Fuel injection apparatus for use with internal combustion engines having an intermediate reservoir which stores and makes available the quantity of fuel to be injected before each fuel injection operation. The intermediate reservoir is provided with two chambers separated from each other by a moveable dividing wall. One of the chambers is selectively connected by a first three-way valve either with the outlet or high-pressure line of a fuel pump or with a low-pressure return line leading to a fuel supply reservoir. The second chamber is selectively joined by a second three-way valve either with the outlet line of the fuel pump or with at least one fuel injection nozzle.





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Fig.4

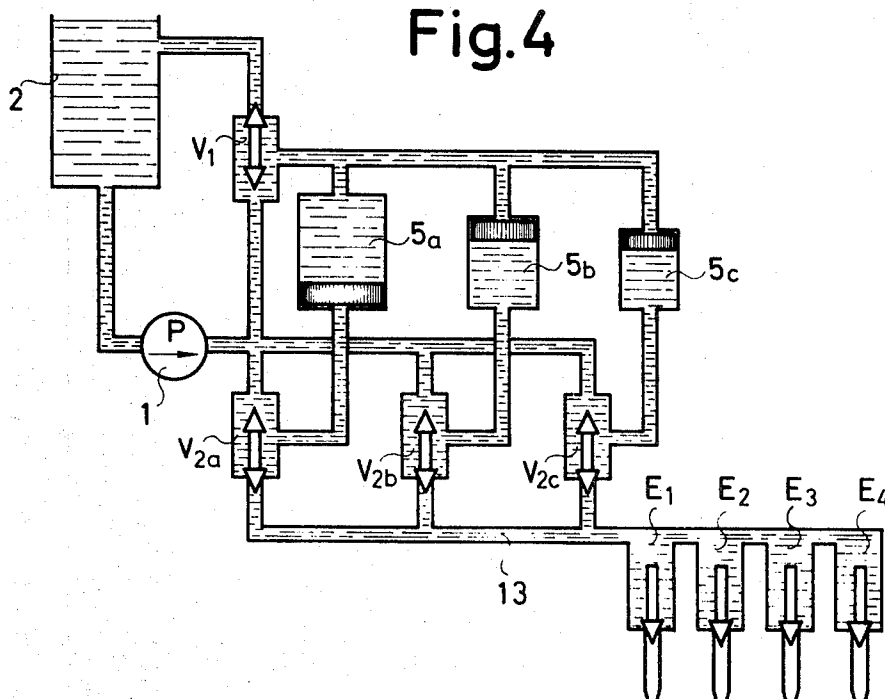
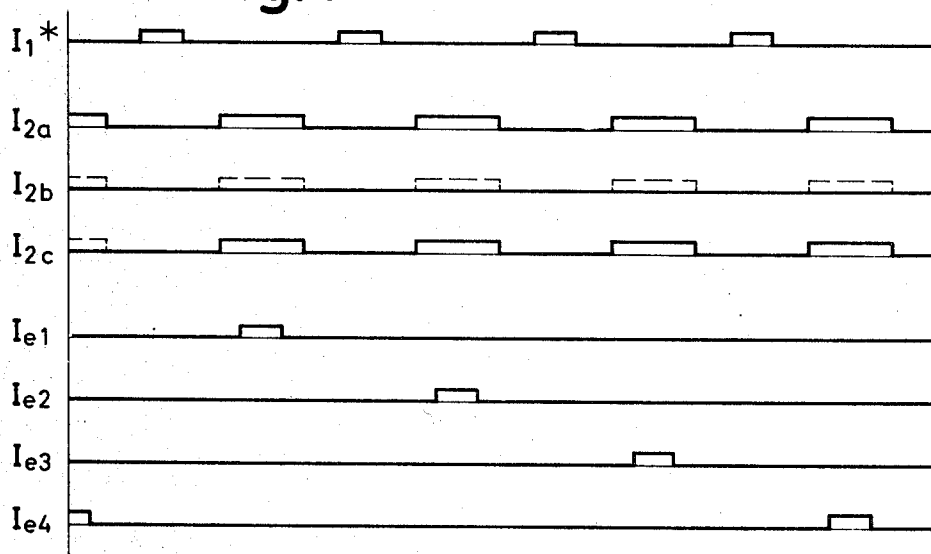


Fig.5



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FUEL INJECTION APPARATUS FOR INTERNAL COMBUSTION ENGINES

BACKGROUND OF THE INVENTION

The present invention relates to fuel injection apparatus for internal combustion engines of the type having an intermediate reservoir which stores and makes available the quantity of the fuel to be injected immediately before each injection operation.

It is known in the art to provide internal combustion reciprocating engines with fuel injection apparatus having an electromagnetically actuated valve and an injection nozzle associated with each cylinder. Each valve is opened during the intake stroke of the respective cylinder to allow the fuel, which is maintained at an approximately constant pressure, to be injected into the cylinder or intake channel of the engine. The quantity of injected fuel is determined, in this apparatus, by the length of time in which each "injection valve" remains open. It is difficult, however, to exactly control or vary these injection times according to the fuel requirements and operating parameters (speed, temperature, etc.) of the engine, especially when the engine is turning a high r.p.m., since the injection times are very short. The normal variations in the response times of the injection valves are in the order of magnitude of the variations required to control the quantity of injected fuel.

It has therefore been proposed to shift the actual quantizing step to the time interval between two successive intake strokes of the engine so as to gain more time and to reduce the relative influence of the unavoidable inaccuracies in the injection times. According to this proposal there is provided an intermediate reservoir with an elastic or flexible wall which accumulates the quantity of fuel to be injected. This quantity is determined by the time in which a so-called "measuring valve," arranged between the fuel pump and the intermediate reservoir, is open. The reservoir, in turn, is connected to the so-called "injection valve," which is opened during the intake stroke for a period of time independent of the fuel requirements of the engine to allow the measured quantity of fuel to pass through its injection nozzle. The injection time of this injection valve is made sufficiently long to allow the elastic wall of the intermediate reservoir to empty contents of the reservoir through the injection nozzle even when the reservoir is completely full. During this time the measuring valve is kept closed.

Since the conventional injection nozzles require considerable fuel pressure for their operation, the intermediate reservoir must be provided with means—for example, in the form of a strong spring—to store the requisite energy and thus, in conjunction with the elastic wall to provide the pressure. However, as the tension in the spring is released during the injection operation the injection pressure is correspondingly reduced. This reduction in pressure can have the disadvantage of changing the degree of atomization of the fuel. In addition, the pressure at the start of an injection operation will be greater when the quantity of fuel to be injected is large, than when it is small.

SUMMARY OF THE INVENTION

An object of the present invention, therefore, is to provide internal combustion engine fuel injection apparatus of the type having an intermediate reservoir which does not exhibit the disadvantages of the analogous fuel injection apparatus noted above. More particularly, it is an object of the present invention to provide fuel injection apparatus of the above-mentioned type which is capable of delivering an injection pressure of any desired value and of maintaining this pressure at a constant level during the injection process.

This object, as well as other objects which will become apparent in the discussion that follows is achieved, according to the present invention, by providing an intermediate reservoir with a movable wall which divides the reservoir housing into two separated chambers and providing a first connecting

means, such as a three-way valve, for selectively connecting one of the chambers with the outlet line of a fuel pump or with a return line leading to a fuel supply reservoir and a second connecting means, such as a three-way valve, for selectively connecting the other of the two chambers with the outlet line of the fuel pump or with at least one fuel injection nozzle.

According to a preferred embodiment of the present invention the intermediate reservoir is constructed as a simple cylinder containing a freely movable or floating piston. The cylinder is provided with walls at each end to limit the movement of the piston at each end of its travel. The spaces within the cylinder on both sides of the piston thus form the two separated chambers. An opening is provided at each end of the intermediate reservoir to allow fuel to enter and exit from each of the chambers.

According to another preferred embodiment of the present invention the "first connecting means" includes a three-way valve, designated hereinbelow as the "measuring valve," which, in its normal position, connects the first chamber to the fuel pump outlet and blocks the path to the fuel reservoir. The "second connecting means" also includes a three-way valve, designated hereinbelow as the "injection valve," which in its normal position connects the second chamber to the fuel pump outlet and blocks the path to the injection nozzle.

As in the fuel injection apparatus described above in the "Background of the Invention," the quantity of fuel to be injected may be determined by the length of time in which the measuring valve is actuated (i.e., the length of time it provides communication between the first chamber and the fuel supply reservoir). It is advantageous here if a constriction is inserted in the line between the fuel pump and the injection valve—at a point which does not interfere with the free flow of fuel between the pump outlet and the first chamber. This constriction will limit the flow of fuel which passes from the pump to the second chamber, thus extending the time of the filling process and permitting a more exact measurement of the quantum of fuel to be injected. During injection—that is, when the injection valve is actuated to pass the contents of the second chamber to the injection nozzle—this constriction is disconnected from the path of fuel flow and therefore does not interfere in any way, with the injection operation.

In a first modification of the present invention it is proposed that the fuel injection apparatus be provided with a "position sender" which converts the position of the movable dividing wall of the intermediate reservoir into an electrical signal; a signal which thus represents the volume of fuel in the second chamber.

Means are then provided to produce an electrical signal representative of the desired value of the quantity of fuel which is to be injected into the engine. These two signals are passed to a comparator circuit which issues a control signal to switch the appropriate three-way valve to interrupt the filling process when the quantity of fuel in the second chamber reaches the desired value. For example, the comparator circuit can be operated to return the measuring valve to its normal position, closing the path between the first chamber and the fuel reservoir, when the proper quantity of fuel has been measured. In this embodiment also it may be of advantage to employ the constriction described above in the line between the fuel pump and the injection valve.

In the above-described versions of the injection apparatus according to the present invention, the specific switching times of the measuring and injection valves still have an influence on the measured volume of fuel to be injected. As is well known, these switching times—this is, the period for each valve between the moment of receipt of an electrical actuating signal and the time when actuation is complete—does not remain absolutely constant over long periods of use. According to a further modification of the present invention, therefore, this disadvantage is avoided by providing the injection apparatus with additional similarly constructed intermediate reservoirs of differing sizes all having one partial chamber connected to the first chamber of the intermediate reservoir

described above and other partial chambers selectively connected, via an associated three-way injection valve, either with the fuel pump outlet line or with a line leading to the fuel injection nozzle. This arrangement thus provides for a digital measurement of the quantity of injected fuel. In this case the measuring chambers of each intermediate reservoir—that is, the chambers which may be connected to the fuel injection nozzle—are either completely full or empty; their associated movable dividing walls are not allowed to stop in an intermediate position. When the single measuring valve is actuated the fuel measuring chambers are all filled at once. Then, depending on which of the injection valves are actuated, one or more or all the chambers are emptied through the common injection nozzle.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram of a first preferred embodiment of the fuel injection apparatus according to the present invention.

FIG. 2 is a schematic diagram of a second preferred embodiment of the fuel injection apparatus according to the present invention, the hydraulic portion of which is similar to that of the apparatus of FIG. 1.

FIG. 3 is a pulse diagram which illustrates the operation of the apparatus of FIG. 2.

FIG. 4 is a schematic diagram of a third preferred embodiment of the fuel injection apparatus according to the present invention.

FIG. 5 is a pulse diagram which illustrates the operation of the apparatus of FIG. 4.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The preferred embodiments of the present invention will now be described in connection with FIGS. 1 to 5 of the drawings.

FIG. 1 schematically shows a fuel system comprising a fuel pump 1 which draws fuel from a reservoir 2 holding a supply of fuel atmospheric pressure. The outlet line 3 of the fuel pump 1 divides into two branches: a first branch leads to a three-way valve V_1 , the so-called "measuring valve," and the second branch leads to a three-way valve V_2 , the so-called "injection valve." The second branch is provided with a narrowed portion or constriction 4 to limit the rate of flow of fuel.

The central inlet-outlet connections of the two three-way valves are joined to respective openings at the opposite ends of a cylinder 5. A piston 6, which is free to move back and forth within the cylinder 5, divides the space within the cylinder into an upper chamber I and a lower chamber II. The chamber I is connected to the measuring valve, while the chamber II is connected to the injection valve.

A return line 7 leads from the upper terminal of the measuring valve V_1 to the fuel supply reservoir 2. The lower terminal of the injection valve V_2 is connected with an injection nozzle 8.

The solenoids or control windings of the two three-way valves receive voltage pulses from a suitably timed pulse source. This pulse source can be either a mechanically actuated switch, of the type used in internal combustion engine ignition systems to control and distribute electrical ignition power, or can be of electronic design. The two three-way valves are illustrated in their nonexcited state; that is, with the fuel pump 1 connected to both the chamber I and the chamber II via the forked supply line 3. The fuel pump 1 is a "constant pressure pump;" that is, it is operative to maintain constant the pressure in the supply line 3.

The fuel injection apparatus illustrated in FIG. 1 operates in the following manner: When the three-way valves V_1 and V_2 are in their normal or rest positions, as shown, the piston 6 is subjected to the identical pressure on both its sides and will therefore remain stationary in any particular position it happens to be. The quantity of fuel to be injected into the engine is determined by the volume of the chamber II below this piston. If the pulse source, not shown, delivers a pulse I_1 to the

injection valve V_2 in dependence upon the angular position of the crankshaft (that is, shortly before the start of the intake stroke), the valve element of the injection valve will move to its upper position, and connect the chamber II to the injection nozzle 8. The valve element of the injection valve will remain in the upper position for the duration of the pulse I_2 , allowing the pump pressure in the chamber I to force the piston 6 quickly downward, and press the contents of the chamber II through the injection nozzle 8. As a result of the constant pump pressure in the chamber I, the fuel will be injected through the nozzle 8 at a constant pressure. The pulse I_2 is timed to have sufficient duration so that the chamber II can be completely emptied even if the piston 6 is initially positioned at the top of the cylinder 5.

At the termination of the pulse I_2 , the valve element of the three-way valve V_2 moves back to the lower position. This movement restores the balance of pressure on both sides of the piston so that the piston will momentarily remain at its lower end position.

During the subsequent interval of time prior to the next intake stroke, a pulse I_1 is applied to the winding of the measuring valve V_1 . The length of the pulse I_1 is made dependent upon various operating parameters of the engine: for example, rotational speed, temperature, etc. The length of this pulse I_1 determines the quantity of the fuel accumulated in the chamber II. So long as this pulse is applied, the valve element of the measuring valve will remain in its lower position and the pump will force fuel under pressure through the constriction 4 into the chamber II. Since, during this time, the chamber I is connected to the supply reservoir 2 which is at atmospheric pressure, the piston 6 will be forced upward and at least a portion of the contents of the chamber I will be returned to the reservoir.

As soon as the valve element of the measuring valve V_1 is allowed to return to its upper or normal position, the motion of the piston will be instantaneously interrupted because the pump pressure will again appear on both sides of the piston. At this point in time the fuel injection apparatus will have completed one cycle of operation and have returned to the state illustrated in FIG. 1. Upon occurrence of the next injection pulse I_2 , the chamber II will again be emptied, and the process repeated.

When the fuel injection apparatus shown in FIG. 1 is utilized in an internal combustion reciprocating engine having two or more cylinders, a fuel distributor can be connected between the injection valve V_2 and a plurality of injection nozzles 8, one at each cylinder. This fuel distributor can, for example, consist of a number of additional electromagnetically actuated "cylinder valves," each of which is connected to a separated nozzle. In this case, the distribution of fuel is effected by successively actuating individual ones of these cylinder valves together with the three-way valve V_2 .

It may be preferable, however, to provide each engine cylinder with its own measuring cylinder and piston and separate three-way measuring and injection valves, since more time will thus be available to effect the measurement of fuel.

The second preferred embodiment of the present invention, illustrated in FIG. 2, employs the same fluid system that is used in the apparatus of FIG. 1. This embodiment therefore also includes the fuel pump 1, the fuel supply reservoir 2, the feed line 3, the measuring cylinder 5 with its floating piston 6, the three-way valves V_1 and V_2 , the return line 7 and the injection nozzle 8. In this embodiment, however, the quantity of fuel is not determined simply by the prescribed length of the control pulse I_1 applied to the measuring valve V_1 . Rather, the process of filling the chamber II is interrupted at the moment when the actual position of the piston 6 reaches the position required for the desired quantity of fuel.

To this end, the cylinder 5 is provided with a sender 9 which produces a signal in dependence upon the position of the piston 6. This sender 9, which is schematically illustrated in FIG. 2, can, for example, be of the type employed to measure the level of fuel in motor vehicle fuel tanks. In this case the piston 6 can simply replace the usual fuel level float.

The output signal of the sender 9 is supplied to a comparator circuit 10. This comparator circuit also receives a signal, produced by a device 11, which represents the desired value of the position of the piston 6. The device or sender 11 produces this desired value signal in dependence upon the rotational speed n , the temperature T and, if necessary, other operating parameters of the engine. These parameters can be employed to form the desired value signal using suitable analogue calculating elements that function to execute any suitable formula known in the art.

The comparator circuit is operative to produce a "difference signal" whenever the actual value and desired value signals are unequal. This difference signal is supplied to a pulse source 12 which produces the control pulse I'_1 for the measuring valve V_1 . The pulse source is triggered by an input pulse I_1 which crankshaft the control pulse I'_1 . This trigger pulse I_1 is produced by a suitable mechanically actuated or electronic switch in dependence upon the angular position of the crankshaft of the engine. The injection valve V_2 is also actuated by corresponding crankshaft pulses I'_2 , which are suitably displaced in time with respect to the trigger pulses I_1 .

The operation of the fuel injection apparatus of FIG. 2 is identical to that of the apparatus of FIG. 1 with the exception of the measuring procedure. This procedure will therefore now be described in connection with the pulse diagram of FIG. 3. It will be assumed, at the outset, that the injection process has just been completed so that the piston 6 is situated at its lower end position as shown in FIG. 2. As the crankshaft of the engine rotates to a certain angular position, the short trigger pulse I_1 is produced and passed to the pulse source 12. The control pulse I'_1 for the measuring valve V_1 is produced by the pulse source 12 immediately upon receipt of the leading edge of the trigger pulse I_1 . At this moment the comparator circuit 10 will be sending the pulse source 12 a strong signal since the output signal of the position sender 9 will have a considerably different value than the desired-value signal produced by the source 11.

The output signal of the comparator circuit 10 will be correspondingly reduced, however, as the piston is moved upward by the fuel in the chamber II. When this piston reaches the position, within the limits of accuracy of the apparatus, forming the desired volume of the chamber II, the output signal of the comparator circuit 10 will fall below a prescribed threshold causing the pulse source 12 to terminate the control pulse I'_1 . The measuring valve V_1 , which opened the path between the cylinder 5 and the reservoir 2 while the control pulse was present, will return to its normal position and equalize the pressure on both sides of the piston. The piston will therefore be stopped and will remain stationary within the cylinder 5 until the pulse I'_2 is sent to the injection valve V_2 and the measured quantity of fuel is injected through the nozzle 8.

In the third embodiment of the fuel injection apparatus according to the present invention, the fuel is measured in digital form. This embodiment, which is illustrated in FIG. 4, includes the hydraulic arrangement described above in connection with FIGS. 1 and 2; however, in this case the previously shown measuring cylinder 5 and injection valve V_2 are designated 5a and V_{2a} , respectively. In addition to this hydraulic system, the embodiment of FIG. 4 includes two additional measuring cylinders 5b and 5c as well as two additional three-way valves V_{2b} and V_{2c} . The upper openings of all three measuring cylinders are connected to the central terminal of the measuring valve V_1 . The two additional three-way valves V_{2b} and V_{2c} each have their upper terminal connected to the outlet line of the pump 1 in the same manner as the injection valve V_{2a} . The central terminals of the injection valves are connected to the lower openings of their corresponding measuring cylinders, and the lower terminals of these three valves V_{2a} , V_{2b} and V_{2c} are all connected to a common fuel injection line 13 which carries the fuel to four cylinder injection valves E_1 , E_2 , E_3 and E_4 . These four cylinder injection valves each selectively open and close the path to a separate fuel injection nozzle. Although the apparatus of FIG. 4 is provided with four

cylinder injection valves and fuel injection nozzles and is thus designed for operation with a four-cylinder internal combustion engine, it will be understood that this same apparatus is adaptable for use in engines having any number of cylinders; e.g., 1, 2, 4, 6 etc.

The individual measuring cylinders are each of differing capacity; it is practical, for example, to make their capacities assume the ratio 1:2:4. The variations in capacity may be accomplished by varying the bore of the cylinders 5a—5c; by varying the piston stroke or by varying both the bore and the stroke, as required.

The measurement of fuel in the embodiment of FIG. 4 is effected, not by filling certain ones of the individual cylinders, but by emptying the contents of selected cylinders, all of which have been filled. This operation will now be described in connection with the pulse diagram of FIG. 5.

The pulses I_1^* control the three-way valve V_1 ; the pulses I_{2a} — I_{2c} control the three-way injection valves V_{2a} — V_{2c} , and the pulses I_{e1} — I_{e4} successively open individual ones of the cylinder injection valves E_1 — E_4 . The apparatus of FIG. 4 is illustrated shortly after the moment when the injection pulse I_{e4} has ended. During this injection, and for a short time thereafter, only the Valve V_{2a} was actuated by a pulse I_{2a} so that only the cylinder 5a was permitted to empty its contents.

When the next filling pulse I_1^* appears, the valve V_1 is actuated for a sufficient time to allow the pump pressure to drive the piston in the cylinder 5a all the way up to its upper end position. Soon thereafter, the motor will require more fuel again; an electronic digital selection device therefore makes a fast determination of the desired quantity of fuel from the engine operating parameters and produces appropriate ones of the pulses I_{2a} — I_{2c} to actuate the combination of valves V_{2a} — V_{2c} which will cause the required quantity of fuel to be injected. In the operating example illustrated in FIG. 5, actuating pulses I_{2a} and I_{2c} are provided to actuate the respective valves V_{2a} and V_{2c} . Shortly after the start of these two valve-actuating pulses, a pulse I_{e1} is sent to the next successive injection valve E_1 to open the path to its associated nozzle. The pistons in the two cylinders 5a and 5c will therefore be forced downward completing the cycle of operation. So long as the quantity of measured fuel does not change, these two pistons will move back and forth during each cycle of operation, injecting fuel into successive ones of the engine cylinders. The piston of the measuring cylinder 5b will remain at the top of its stroke until the valve V_{2b} is actuated to empty the contents of the cylinder 5b.

The more measuring cylinders are provided, the finer will be the measurement of fuel. One important characteristic of this embodiment is the extremely short filling time of the measuring cylinders. Each measuring cylinder contains only a fraction of the total quantity of fuel to be injected so each cylinder can be made very small. In addition, the fuel flow resistances with this embodiment are very low since the individual measuring cylinders are filled through parallel fuel lines which need not contain a constriction (such as the constriction 4 illustrated in FIG. 1). For this reason this embodiment of the fuel injection apparatus according to the present invention can also be employed with internal combustion engines having relatively many—e.g., eight—cylinders.

It will be understood that the above description of the present invention is susceptible to various modifications, changes and adaptations.

We claim:

1. Fuel injection apparatus for internal combustion engines comprising, in combination:

- a. a fuel reservoir;
- b. fuel pump means, connected to said reservoir, for delivering fuel under pressure at an outlet of said fuel pump means;
- c. at least one fuel injection nozzle means for injecting fuel into an engine;
- d. intermediate reservoir means for feeding fuel to said fuel injection means, and comprising:
 1. a housing; and

2. means arranged within said housing for dividing the same into first and second chambers, said dividing means being a single member movable to and fro to increase the volume of one of said chambers while decreasing the volume of the other of said chambers, said housing defining only first and second openings, the first opening communicating with said first chamber and the second opening communicating with said second chamber;
- e. first connecting means, connected to said first opening, to said fuel reservoir and to said outlet of said fuel pump means, for selectively establishing communication between said first chamber and said fuel reservoir and between said first chamber and said outlet of said fuel pump means; and
- f. second connecting means, connected to said second opening, to said at least one nozzle means and to said outlet of said fuel pump means, for selectively establishing communication between said second chamber and said at least one nozzle means and between said second chamber and said outlet of said fuel pump means.
2. The apparatus defined in claim 1, wherein said first connecting means includes a first three-way valve and said second connecting means includes a second three-way valve.
3. The apparatus defined in claim 2, wherein said intermediate reservoir means includes a housing having a cylindrical bore and said dividing means is a floating piston arranged within said bore.
4. The apparatus defined in claim 3, wherein said second connecting means includes a constriction in the communicating path between said second chamber and said outlet of said fuel pump means.
5. Fuel injection apparatus for internal combustion engines comprising, in combination:
 - a. a fuel reservoir;
 - b. fuel pump means, connected to said reservoir, for delivering fuel under pressure at an outlet of said fuel pump means;
 - c. intermediate reservoir means comprising:
 1. a housing; and
 2. dividing means arranged within said housing and dividing the same into first and second chambers, said dividing means being movable to and fro to increase the volume of one of said chambers while decreasing the volume of the other of said chambers, said housing having a first opening communicating with said first chamber and a second opening communicating with said second chamber;
 - d. at least one fuel injection nozzle means for injecting fuel into the engine;
 - e. first connecting means, connected to said first opening, to said fuel reservoir and to said outlet of said fuel pump means, for selectively establishing communication between said first chamber and said fuel reservoir and between said first chamber and said outlet of said fuel pump means;
 - f. second connecting means, connected to said second opening, to said at least one nozzle means and to said outlet of said fuel pump means, for selectively establishing communication between said second chamber and said at least one nozzle means and between said second chamber and said outlet of said fuel pump means;
 - g. means, connected to said intermediate reservoir means, for producing a first electrical signal having a value which is dependent upon the volume of said second chamber;
 - h. means for producing a second electrical signal having a value which is dependent upon the desired quantity of fuel to be injected into the engine;
 - i. comparator means, connected to receive said first and second electrical signal, for producing a third electrical signal having a value which is dependent upon the relative values of said first and second electrical signals; and
 - j. control means, connected to said comparator means, and to at least one of said first and second connecting means,

- for interrupting the filling of said second chamber when the volume thereof is substantially equal to the volume of said desired quantity of fuel.
6. The apparatus defined in claim 5, wherein said first connecting means includes a first electrically actuated three-way valve and said second connecting means includes a second electrically actuated three-way valve, and wherein said control means is a controllable pulse source, means, connected to said comparator means and to said first three-way valve, for producing a pulse in dependence upon said third electrical signal.
7. The apparatus defined in claim 5, wherein said means for producing said first electrical signal includes position sender means, responsive to the position of said dividing means within said housing.
8. Fuel injection apparatus for internal combustion engines comprising, in combination:
 - a. a fuel reservoir;
 - b. fuel pump means, connected to said reservoir, for delivering fuel under pressure at an outlet of said fuel pump means;
 - c. intermediate reservoir means comprising:
 1. a housing; and
 2. dividing means arranged within said housing and dividing the same into first and second chambers, said dividing means being movable to and fro to increase the volume of one of said chambers while decreasing the volume of the other of said chambers, said housing having a first opening communicating with said first chamber and a second opening communicating with said second chamber;
 - d. at least one fuel injection nozzle means for injecting fuel into the engine;
 - e. first connecting means, connected to said first opening, to said fuel reservoir and to said outlet of said fuel pump means, for selectively establishing communication between said first chamber and said fuel reservoir and between said first chamber and said outlet of said fuel pump means;
 - f. second connecting means, connected to said second opening, to said at least one nozzle means and to said outlet of said fuel pump means, for selectively establishing communication between said second chamber and said at least one nozzle means and between said second chamber and said outlet of said fuel pump means;
 - g. at least one additional intermediate reservoir means comprising:
 1. a housing; and
 2. dividing means arranged within said housing and dividing the same into first and second chambers, said dividing means being movable to and fro to increase the volume of one of said chambers while decreasing the volume of the other of said chambers, said housing having a first opening communicating with said first chamber and a second opening communicating with said second chamber;
 - h. third connecting means, connected to said first opening of said intermediate reservoir means (c) and to said first opening of said at least one additional intermediate reservoir means (g), for establishing communication between said first chamber of said intermediate reservoir means (c) and said first chamber of said at least one additional intermediate reservoir means (g);
 - i. at least one fourth connecting means, each connected to said second opening of one of said at least one additional intermediate reservoir means (g), to said at least one nozzle means and to said outlet of said fuel pump means, for selectively establishing communication between said second chamber of said one of said additional intermediate reservoir means (g) and said at least one nozzle means and between said second chamber of said one of said additional intermediate reservoir means (g) and said outlet of said fuel pump means.

9. The apparatus defined in claim 8, wherein the total volume of said first and second chambers of each of said intermediate reservoir means (c) and said at least one additional intermediate reservoir means (g) is different.

10. The apparatus defined in claim 8, wherein there are a plurality of said fuel injection nozzle means, and each of said fuel injection nozzle means includes an electrically actuated injection valve means, for controlling the passage of fuel through said nozzle means.

11. The apparatus defined in claim 8, wherein there are a plurality of additional intermediate reservoir means each defining first and second openings, and a like number of valve means connected to a respective one of said additional intermediate reservoir means and to said at least one nozzle means

for selectively filling a predetermined number of said intermediate reservoir means to determine the amount of fuel ejected by said nozzle means, the predetermined number of intermediate reservoir means always being filled to their maximum.

12. The apparatus defined in claim 8, wherein said first, second, and fourth connecting means each have a three-way valve.

13. The apparatus defined in claim 8, wherein said intermediate reservoir means and said at least one additional intermediate reservoir means each having a housing having a cylindrical bore, and wherein in each instance said dividing means is a floating piston arranged within said bore.

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