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Suda et al.

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[54] **FUEL SUPPLY DEVICE FOR INTERNAL COMBUSTION ENGINES**

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[51] **Int. Cl.**.....**F02m 51/00**

[58] **Field of Search**.....123/32, 32 EA, 32 AE, 119, 123/139, 139 E, 140

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[57] **ABSTRACT**

A fuel supply device for use in an internal combustion engine, which is so designed that the period of supplying fuel into a fuel injecting unit and the quantity of fuel to be injected into a cylinder are determined by the period of energization of an electromagnetically operated valve which period is determined on the basis of various factors of the engine electrically detected by a detector, and the fuel injecting unit is imparted with the function of a pump to compress and pressurize the fuel supplied thereinto to be injected into a cylinder thereby.

7 Claims, 4 Drawing Figures

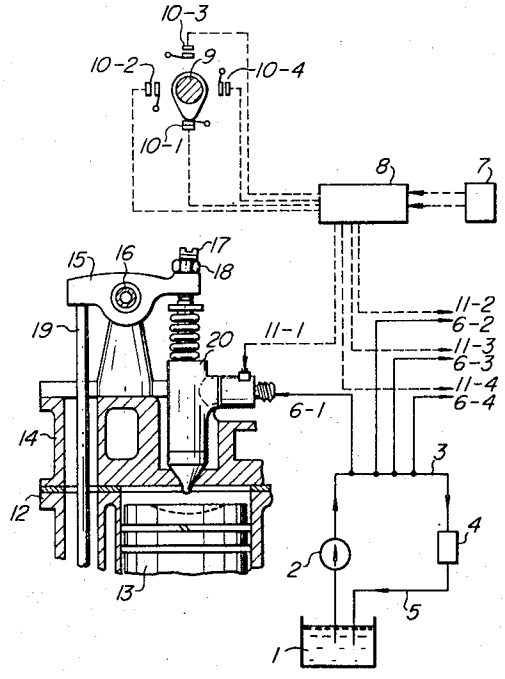
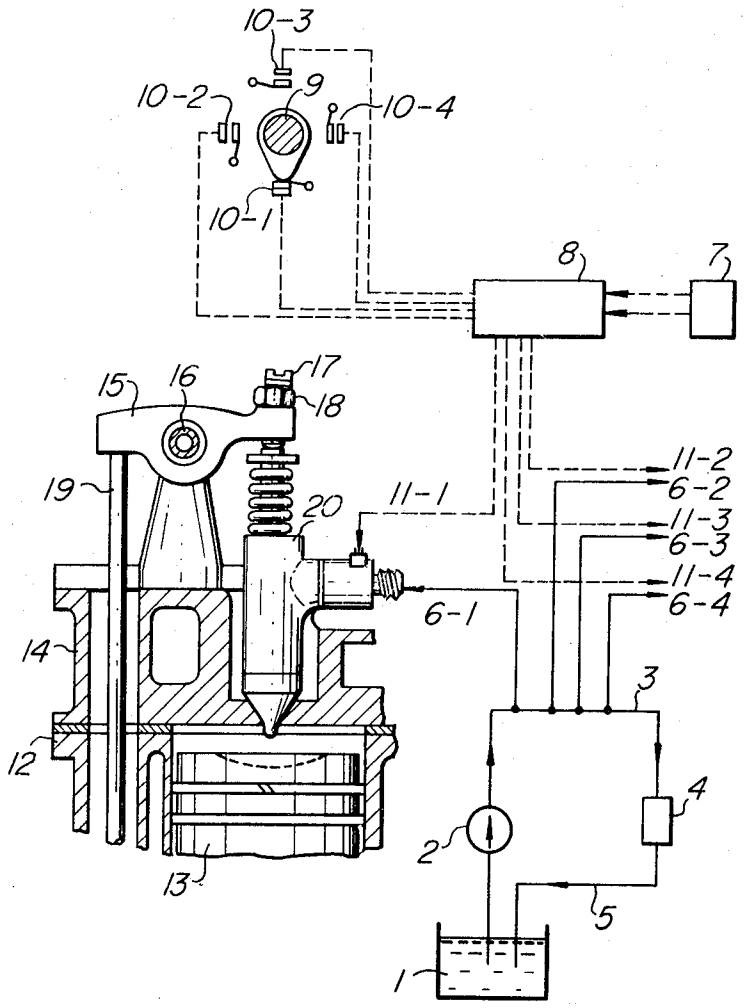


FIG. 1



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FIG. 2

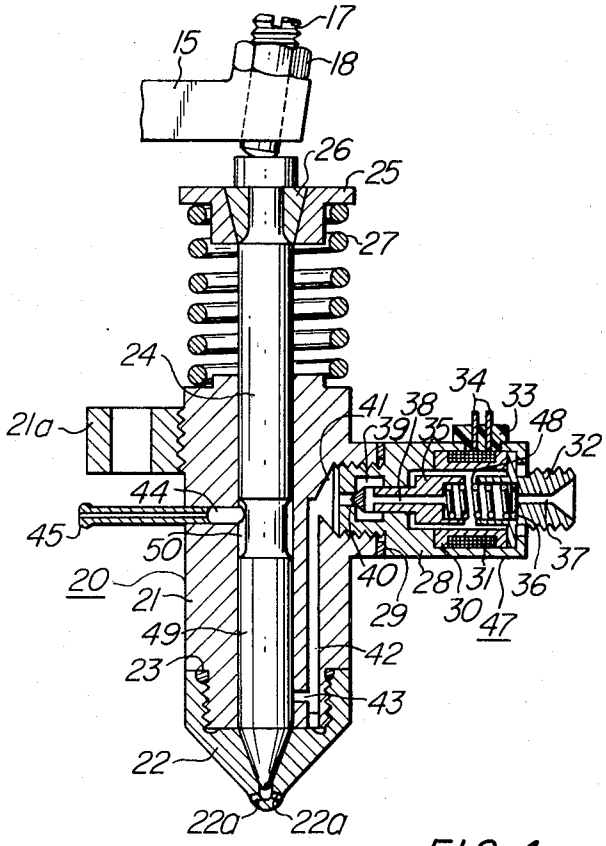


FIG. 3

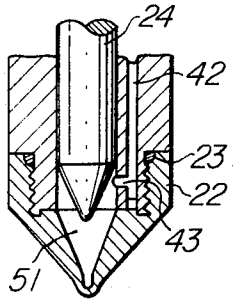
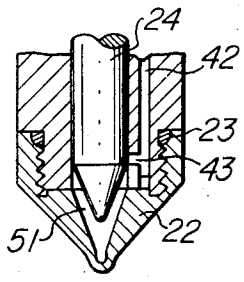


FIG. 4



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FUEL SUPPLY DEVICE FOR INTERNAL COMBUSTION ENGINES

The present invention relates to a fuel supply device adapted for use in internal combustion engines, particularly with the compression ignition engines in which fuel is injected into the cylinders.

In supplying fuel to a compression ignition engine, there has been employed a method wherein all the fuel injection pumps for the respective cylinders are arranged at one place and the fuel discharged from said pumps under pressure is injected into the respective cylinders through fuel injection valves provided in the cylinder heads.

According to this method, it is necessary to provide a pressure conduit for leading the fuel from each injection pump to the associated injection valve. In some cases, such a pressure conduit is as long as 1 meter even in the case of an automobile engine, and it takes about a quarter of a second for the pressure wave, produced in the injection pump, to transmit through the length of the conduit. Such a time lag is a matter of concern in these days, with the speed of engines increasing more and more. Moreover, such a long pressure conduit brings about the disadvantage that the fuel injection rate of the injection valve varies arbitrarily without being properly controlled according to a cam lift, due to a larger quantity of air present in the conduit and the elastic deformation of the conduit.

Further, according to the conventional method the delivery rate of fuel is controlled mechanically by a rack, so that the fuel supply device is subject to a structural limitation and does not fully meet the various requirements of the engine.

The object of the present invention, therefore, is to obviate the drawback of the conventional device resulting from the use of a long pressure conduit, by imparting the function of pressurizing the fuel and injecting the same to fuel injecting means proper which is comprised in a fuel supply device.

Another object of the present invention is to provide a fuel supply device which fully satisfies the requirements of an associated engine by controlling the fuel injection by electrical means and not by mechanical means.

According to the present invention, there is provided a fuel supply device for use in an internal combustion engine, which comprises a conduit for supplying fuel therethrough, means for maintaining the fuel pressure in said conduit constant, fuel injecting means for injecting the fuel into each cylinder of the engine and an electromagnetically operated valve disposed between said conduit and said fuel injecting means, the quantity of fuel supplied through said conduit to said fuel injecting means being controlled by the period of energization of said electromagnetically operated valve, and said fuel injecting means having therein a pump element for compressing and pressurizing the fuel so that the fuel metered by said valve may be injected into the cylinder entirely.

FIG. 1 is a system diagram of an embodiment of the fuel supply device according to the present invention;

FIG. 2 is a vertical cross-sectional view showing the construction of the fuel injecting means of the fuel supply device shown in FIG. 1, which is provided with a solenoid operated valve; and

FIGS. 3 and 4 are fragmentary views of the fuel injecting means shown in FIG. 2, showing the position of a plunger when it is at top dead center and the position of the same at the moment when it closes a fuel supply port, respectively.

The present invention will be described in detail hereinafter with reference to a preferred embodiment thereof shown in the drawings. Referring to FIG. 1, reference numeral 1 designates a fuel tank, 2 a fuel pump, 3 a fuel pipe, 4 a pressure regulator and 5 a return pipe. Fuel is supplied from the fuel pipe 3 to the cylinders through respective passages 6-1, 6-2, 6-3 and 6-4. Reference numeral 7 designates a detector to detect the engine r.p.m., the position of the accelerator pedal, etc.; 8 a controlling circuit to determine electrically the period of energization of the electromagnetically operated valve later described, corresponding to the quantity of fuel to be supplied, by performing a comprehensive calculation based on various signals received from the detector 7; and 9 a cam shaft driven in such a manner as to complete one revolution in each cycle of the engine synchronously with the cycle 10-1, 10-2, 10-3 and 10-4 are contacts which are respectively provided for each cylinder. Reference numerals 11-1, 11-2, 11-3 and 11-4 designate electric wirings respectively to send a signal, produced by the controlling circuit 8, to each cylinder. Reference numeral 12 designates a cylinder block of an engine, 13 a piston disposed in one of the cylinders in said cylinder block, 14 a cylinder head, 15 a rocking arm, 16 a shaft on which said rocking arm is pivotally mounted, 17 a contactor extending through one end of the rocking arm 15 in threadable engagement therewith for transmitting a movement of said rocking arm to a plunger 24 to be described later and having an adjustable space between it and the top end of said plunger 24, and 18 a lock nut. The rocking arm 15 is operated by a push rod 19 according to the configuration of a cam which is mounted on the cam shaft (not shown) of the engine. Reference numeral 20 designates a fuel injection unit, the construction of which is shown in detail in FIG. 2.

Referring to FIG. 2, the injection unit includes a main body 21 and a head cover 22 screwed on said main body and having injection nozzles 22*a* formed therein for atomizing and injecting fuel. The main body 21 is mounted by a bracket 21*a*. Between the main body 21 and the head cover 22 is interposed a gasket member 23. The aforesaid plunger, indicated by numeral 24, is fluid-tightly and vertically slidably fitted in an axial bore 49 of the main body 21 and is constantly biased upwardly as viewed in the FIG. 2, under the biasing force of a spring 27 which is mounted between the top end of the main body 21 and a spring seat member 25 supported by a supporting member 26. 47 generally designates a solenoid-operated valve. The housing 28 of the solenoid operated valve 47 is provided with an external thread at one end thereof and is secured to the main body 21 by screwing said external thread into an internal thread provided in the side wall of said main body. Reference numeral 29 designates a gasket interposed between the main body 21 and the housing 28 of the valve. The housing 28 of the valve has a cavity 48 therein which is open at both ends, and in one end of said cavity is disposed a joint 32 for a fuel pipe in such a manner as to retain a coil supporting

member 30 between it and the valve housing 28, said coil supporting member 30 having a coil 31 mounted thereon. The joint 32 is fixed to the valve housing 28 in a known manner. The terminals of the coil 31 are respectively connected with leads 34, 34 which extend outwardly of the housing 28 through an electric insulator 33 provided at a suitable location of the housing 28. The aforesaid electric wiring 11-1 is connected to the terminal rods 34, 34. In the other end of the cavity 48 of the housing 28 is disposed a valve body 35 which is in a liquid-tight sliding engagement with said housing and which is constantly urged against a valve seat 40 under the biasing force of a spring 36 interposed between the valve body 35 and the joint 32. The outlet of the valve 35 is communicated with a chamber 51 in the head cover 22 through a fuel passage which is constituted by a chamber 41, a channel 42 and a fuel supply port 43, respectively formed in the main body 21. Reference numerals 44 and 45 are a channel and a pipe respectively through which the fuel leaking through the engaging surfaces of the main body 21 with the plunger 24 is returned to the fuel tank.

The fuel supply device of the invention constructed as described above operates in the following manner: Namely, the fuel supplied from the fuel tank 1 into the fuel pipe 3 by the pump 2 is maintained at a constant pressure by the function of the pressure regulator 4, and the fuel leaving said pressure regulator 4 is returned to the fuel tank 1 through the pipe 5. On the other hand, signals from the detector 7, representing the engine r.p.m., the position of the accelerator pedal, the temperatures at various portions pertinent to the fuel control, etc., are electrically given to the controlling circuit 8. The time to supply fuel to each of the fuel injection units for the respective cylinders is determined by the closure of the associated contacts 10-1, 10-2, 10-3 or 10-4, caused by the cam on the cam shaft 9 which completes one revolution in each cycle of the engine in synchronism with the cycle. Signals from the contacts 10-1, 10-2, 10-3 and 10-4 are also sent to the controlling circuit 8. The controlling circuit 8 supplied a current to the coil 31 in each solenoid-operated valve, based on the signals from the detector 7 and the associated contact, for a predetermined time within the period in which the fuel is to be supplied to said valve. When the current is supplied to the coil 31, said coil is electromagnetically energized and attracts the valve body 35 against the biasing force of the spring 36, so that the valve body 35 is disengaged from the valve seat 40 and thus the solenoid-operated valve is opened.

On the other hand, the fuel passage extending from the pipe 3 to a chamber 39, formed in the valve housing 28 in such a manner as to surround the working end of the valve body 35, through the associated passage 6-1, 6-2, 6-3 or 6-4, a channel 37 formed in the joint 32, the cavity 48 of the valve housing 28 and a channel 38 formed in the valve body 35, is filled with the fuel under a constant pressure. Therefore, the fuel passes through the solenoid-operated valve and flows into the chamber 41 and channel 42 in the main body 21, only for the period in which the coil 31 is held energized. When the push rod 19 is pushed up by the cam mounted on the cam shaft (not shown) of the engine, the upward movement of the push rod is transmitted to the plunger 24 through the rocking arm 15, causing a downward movement of said plunger, while when the action of the cam is ended, the push rod 19 moves downward and the plunger 24 is lifted under the biasing force of the spring 27. Thus, it will be seen that the plunger 24 makes a reciprocal vertical movement repeatedly according to the rotation of the engine. FIG. 2 shows the position of the plunger 24 when it is in the lower end of its stroke, i.e., in its bottom dead center. FIG. 3 shows the position of the plunger 24 when it is at top dead center and FIG. 4 the position of the same at the moment when it closes the fuel supply port 43.

In the above-described operation, if the coil 31 is energized when the plunger 24 is in the position shown in FIG. 3, the fuel supply port 43 communicates with the chamber 51 and the fuel can be supplied from the channel 42 into the chamber 51 through the fuel supply port 43. The quantity of fuel supplied into the chamber 51 in this case can optionally be changed by adjusting the period of energization of the coil 31. The configuration of the chamber 51 is so selected that the volume of the chamber 51 at the instant the supply port 43 is closed by the plunger 24 is larger than the maximum volume of the fuel to be injected.

After the current supply to the coil 31 is interrupted, the plunger 24 moves downward under the action of the cam mounted on the cam shaft of the engine and closes the fuel supply port 43 as shown in FIG. 4. As the plunger 24 moves further downward, the fuel supplied in the chamber 51 is compressed by the plunger 24 and injected through the nozzles 22*a* in the head cover 22, incident to the downward movement of said plunger. The fuel present in the chamber 51 is completely injected, as the plunger reaches bottom dead center, and thus fuel injection ends.

As will be clearly understood from the foregoing description, the fuel can be supplied to the injection unit only for the period in which the fuel supply port 43 is held open by the plunger 24. This period can be made relatively long by suitably selecting the configuration of the cam (not shown) mounted on the cam shaft of the engine, and a period of about twenty-five one-thousandths second can be obtained, even in the high speed diesel engines presently being used. A solenoid-operated valve which is operable within such a period can easily be produced by the presently known techniques. In the compression stage of the fuel by the plunger 24, the internal pressure of the chamber 51 reaches several hundred at.. The fuel leaking through the engaging surfaces of the plunger 24 with the main body 21 under such a high pressure is in a negligible quantity with respect to the quantity of the fuel injected. Such a slight quantity of the leaking fluid is collected in an annular space 50 formed between the plunger 24 and the main body 21, withdrawn from said annular space through the channel 44 and the pipe 45, and returned to the fuel tank 1 through a pipe not shown.

As will be apparent from the foregoing description, according to the present invention the quantity of fuel to be injected can accurately be controlled by the period in which the solenoid-operated valve is held open or, in other words, the period in which the current is supplied to the coil 31 to energize the same. Therefore, by determining the period of supply of current to the coil 31 by comprehensive calculation of various

operational conditions of the engine, including the engine r.p.m., the engine load, the ambient temperature and the temperatures of various portions of the engine, it is possible to feed the engine with an optimum quantity of fuel called for by said engine. Namely, according to the present invention it is possible to provide a fuel supply device which is free of the restrictions which the conventional device has been subject to due to the use of mechanical means for the control of fuel supply, and which will fully satisfy the complicated conditions required for the engine.

It is also to be noted that according to the present invention there is no necessity of providing a lengthy pressure fuel pipe between a fuel injection pump and a fuel injection nozzle, as has been in the conventional device, because the function of pressurizing the fuel by the compression and injecting the pressurized fuel is imparted to the fuel injection unit **20** mounted on the engine near the cylinders by which the fuel is injected into each cylinder of the engine. This brings about such excellent advantage that the fuel injection time lag, encountered in the conventional device due to the passage of fuel through a long fuel pipe, can be completely eliminated, which is highly beneficial to the production of higher speed engines. Another excellent advantage of the invention is that, while a solenoid operated valve is not adapted for use as a fuel injection device, because generally the solenoid operated valve is slow in its operation by reason of its construction, whereas the fuel injection device is required to inject fuel within a period shorter than the fuel supplying period; in the present invention the solenoid operated valve is used for supplying fuel and the fuel injection is effected by the fuel injection unit provided independently of said solenoid operated valve, so that the above-described advantages can be obtained by the use of the solenoid operated valve which are not obtainable from the conventional device and the fuel injection can be accomplished in a relatively short period of time.

What is claimed is:

1. A fuel supply device for use in an internal combustion engine, said device comprising:

a conduit for supplying fuel therethrough,

means for maintaining a low constant fuel pressure in said conduit,

a fuel injecting means for each cylinder of the engine mounted on the engine and mechanically connected to the cam shaft of said internal combustion engine for the pressurized injecting of fuel directly into each respectively associated cylinder and

an electromagnetically operated valve means for each cylinder disposed in series fluid communication between said conduit and each of said fuel injecting means and mounted to the side of said fuel injecting means for metering a predetermined quantity of fuel into its respectively associated fuel injecting means at desired times, the quantity of fuel supplied from said conduit through one of said valve means to a respectively associated one of said fuel injecting means being controlled by the time period of electrical energization of said electromagnetically operated valve means, and

said fuel injecting means having therein a pump means element for compressing and pressurizing the fuel so that the fuel quantity metered by said valve means is substantially entirely injected into the cylinder when actuated.

2. A fuel supply device for use in an internal combustion engine, as in claim **1**, wherein each of said electromagnetically operated valve means comprises:

a housing including means for connecting it to a main body of the fuel injecting means,

a valve body and a valve seat being provided in said housing, and

an electrical coil being provided in said housing, said valve body being forced to disengage from said valve seat when said coil is energized and being forced to engage with said valve seat when said coil is de-energized whereby the quantity of fuel metered through said valve means is substantially proportional to the time period during which said electrical coils is energized.

3. A fuel supply device for use in an internal combustion engine, as in claim **1**, which further comprises:

a detector means for electrically detecting engine operating factors including the engine r.p.m., the engine load, the ambient temperature of the engine and the temperatures at predetermined portions of the engine;

electric control means for determining the time period of supplying a current to said electromagnetically operated valve means by receiving said engine operating factors detected by said detector means and performing a comprehensive calculation based on said factors;

a cam shaft driven by the engine to complete one revolution during one cycle of the engine in synchronism with the cycle;

a cam mounted on said cam shaft; and

electrical contacts which are held closed by the action of said cam during the period in which the fuel is to be supplied;

the factors detected by said detector means and a signal emitted by said electrical contacts upon closure of the same being routed to said electric control means, which in turn includes means for sending a signal to said valve means determining the time period in which the fuel is to be supplied and thus the metered quantity of fuel to be injected, based on said factors.

4. A fuel supply device for use in an internal combustion engine, as in claim **1**, wherein said fuel injecting means comprises:

a main body having a vertically extending bore therein;

a plunger liquid-tightly and slidably received in said bore;

means for causing said plunger to reciprocate within said bore along a predetermined stroke;

a fuel passage provided in said main body for passing the fuel from the outside of said main body to the lower end portion of said bore and

a plurality of injection nozzles provided at the lower end of said main body for injecting into the cylinder the fuel which has been supplied into a space below said plunger and then compressed by said plunger, the communication between said fuel passage and said bore being established when said plunger is near the terminal end of its ascending

stroke and being intercepted when said plunger goes into a descending stroke.

5. A fuel supply and injection system for individually metering predetermined quantities of fuel to each of a plurality of cylinders of an internal combustion engine in dependence upon the time duration of electrical metering pulse signals supplied thereto from a fuel injection control circuit, said system comprising:

fuel supply means for providing a source of substantially constant but relatively low pressure fuel,

a fuel injector means associated with each of said cylinders and mounted on said engine and mechanically connected to the cam shaft of said internal combustion engine for periodically accepting a quantity of relatively low pressure fuel and for thereafter forcing substantially all of said quantity of fuel directly into its respectively associated cylinder under a relatively higher pressure, and

an individual metering valve means associated with each of said fuel supply means and its respectively associated fuel injector means each individual metering valve means being mounted to the side of a separate fuel injector means and also electrically connected to said fuel injection control circuit; said individual metering valve means including an electromagnetically operated fluid valve for metering a predetermined quantity of fuel into its respectively associated fuel injector means in direct dependence upon the time duration of said electrical metering pulse signals.

6. A fuel supply and injection system as in claim 5 wherein said individual metering valve means comprises:

a main body directly attached to a respectively associated fuel injector means and having a fluid output port of the valve means in fluid communication with a fuel receiving port of the injector means,

a fuel receiving port for the valve means connected to said fuel supply means, and

a slidably operated valve stem and valve seat assembly in series fluid communication between said fuel receiving port and said fluid output port of the valve means.

7. A fuel supply and injection system as in claim 6 wherein said individual metering valve means further comprises:

an electrical solenoid disposed about a slidable portion of said valve stem and valve seat assembly for effecting sliding operation thereof in dependence upon the electrical energization and de-energization of said solenoid.

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