United States Patent [19]

Suda et al.

[11] **3,786,788**

[45] **Jan. 22, 1974**

[54] **FUEL INJECTION APPARATUS FOR INTERNAL COMBUSTION ENGINE**

[75] Inventors: **Toshi Suda**, Nagoya; **Hideya Fujisawa**, Kariya, both of Japan

[73] Assignee: **Nippondenso Co., Ltd.**, Aichi-ken, Japan

[22] Filed: **May 24, 1972**

[21] Appl. No.: **256,256**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 64,766, Aug. 18, 1970, abandoned.

[52] **U.S. Cl.** ..... **123/32 EA**, 123/119 R, 123/139 E

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

[58] **Field of Search** ..... 123/32 EA, 119 R

[56] **References Cited**

UNITED STATES PATENTS

3,500,801	3/1970	Long	123/119 R
3,500,802	3/1970	Long	123/140 MC
3,610,212	10/1971	Endo	123/32 EA
3,662,720	5/1972	Boeters	123/32 EA
3,683,870	8/1972	Jackson	123/32 EA
3,435,809	4/1969	Bassot et al.	123/119 R
3,504,657	4/1970	Eichler et al.	123/32 EA
3,659,571	5/1972	Lang	123/32 EA
3,673,989	7/1972	Aono	123/32 EA

Primary Examiner—Laurence M. Goodridge
Assistant Examiner—Cort Flint
Attorney, Agent, or Firm—Cushman, Darby & Cushman

[57] **ABSTRACT**

In a fuel injection apparatus for an internal combustion engine, including a fuel pump for feeding fuel from a fuel tank to a fuel distributor, an overflow valve for regulating the pressure of the fuel in said fuel distributor and solenoid valves provided in the same number as the number of cylinders of the engine and connected to said fuel distributor to act as fuel injection valves, said solenoid valves are driven by a variable frequency oscillator and the frequency of said variable frequency oscillator is controlled in accordance with the average quantity of air sucked by the engine per unit time and further said solenoid valves are opened and closed by means of a pulse row independent of the engine speed.

2 Claims, 4 Drawing Figures

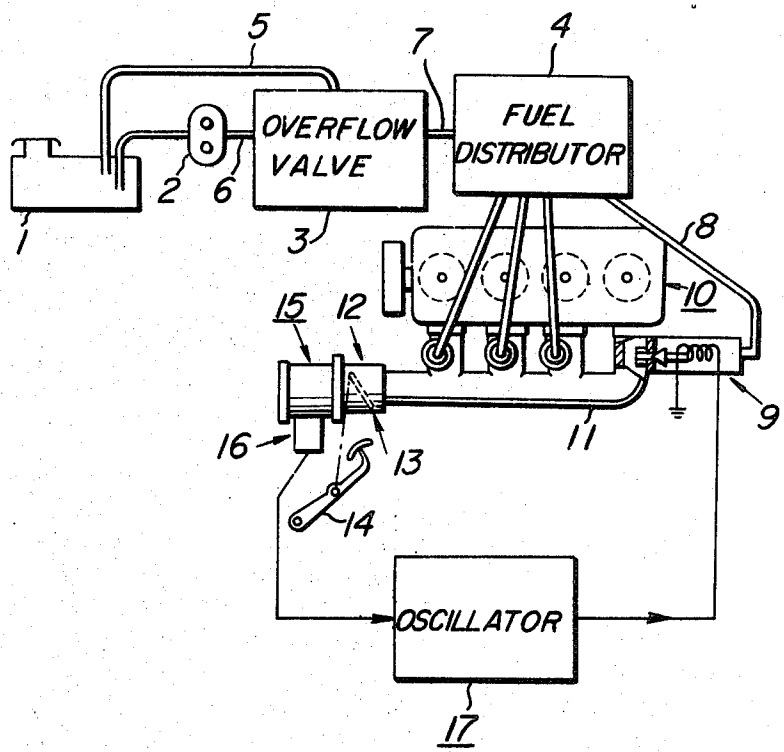


FIG. 1

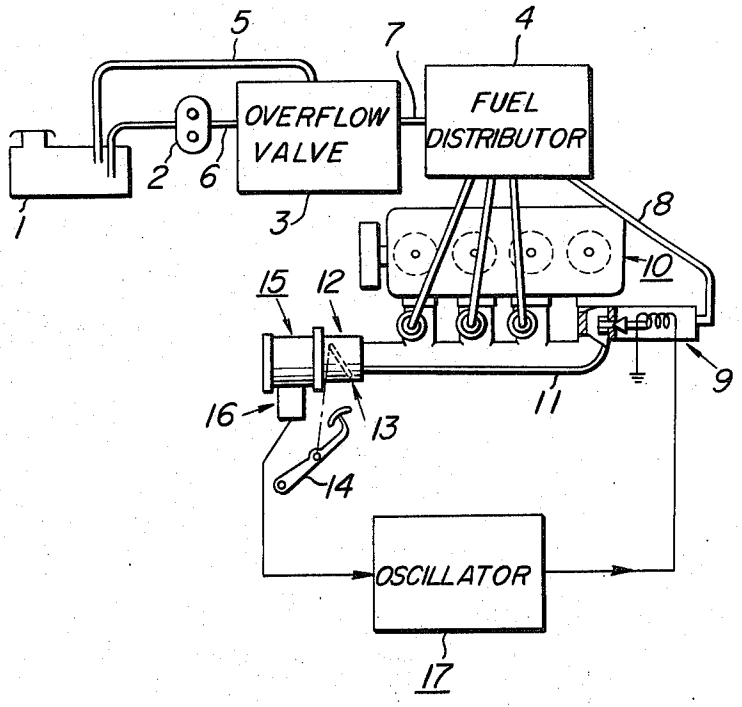

5
7
4
OVERFLOW VALVE
FUEL DISTRIBUTOR
2
6
1
3
8
10
15
12
9
11
16
13
14
OSCILLATOR
17

FIG. 2

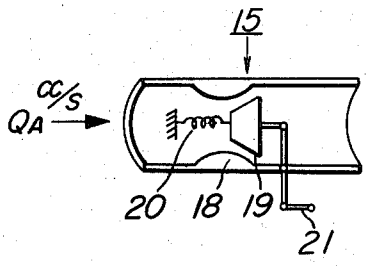

15
cc/s
QA
20
18
19
21

FIG. 3

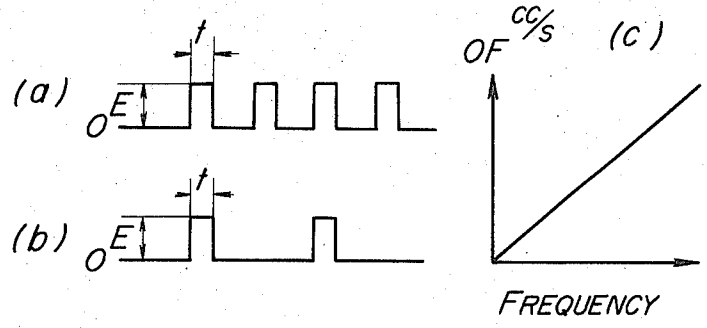
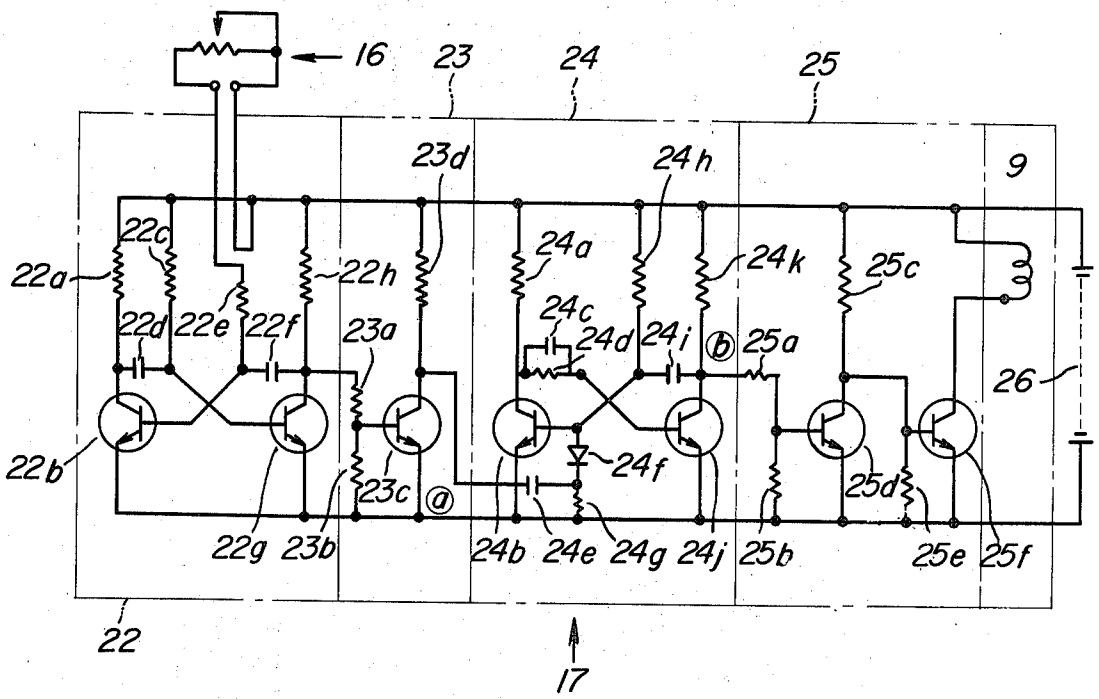

(a)
t
E
0
(b)
t
E
0
OF
cc/s
(c)
FREQUENCY

FIG. 4


16
23
24
25
9
23d
24h
22c
24a
22a
22h
24k
25c
22d
22e
22f
23a
24c
24d
24i
b
25a
26
22b
24f
23c
a
25d
22g
23b
24b
24e
24g
24j
25b
25e
25f
22
17

FUEL INJECTION APPARATUS FOR INTERNAL COMBUSTION ENGINE

This application is a continuation-in-part of the U.S. Ser. No. 64,766 filed on Aug. 18, 1970 (now abandoned).

This invention relates to a fuel injection apparatus for an internal combustion engine and more particularly to an electronically controlled fuel injection apparatus for an external ignition-type internal combustion engine, in which solenoid valves are provided as fuel injection valves, and the open period and frequency of said solenoid valves are controlled thereby to meter fuel.

In a conventionally known fuel injection apparatus of this type, the quantity of intake air per one cycle of the engine is determined from the intake pipe pressure, and fuel is metered according to this pressure and supplied to the engine in synchronism with the engine rotation. Such a system is generally called a speed density system. This prior art system is operable on the premise that the intake pipe pressure and the quantity of air supplied per one cycle of the engine completely match with each other. In practice, however, this functional relation between the intake pipe pressure and the quantity of air is variable depending upon the engine speed, and thus it becomes necessary to compensate the engine speed. However, the compensation of the engine speed is extremely difficult and the intended object cannot be fully attained. Therefore, the prior art system has suffered the fatal drawback that the optimum mixture ratio cannot be obtained at a certain engine speed. Moreover, according to this prior art system the metering of fuel must be carried out with respect to two variables, i.e., the engine speed and the intake pressure, and this problem has been solved by a method in which the fuel is injected always in synchronism with the engine speed, thereby controlling the fuel with respect to the intake pressure. However, such a method has imposed on the system the restriction that the fuel injection system injects fuel in synchronism with the enging speed.

In order to obviate the drawbacks described above, the present invention has for its objects the provision of a fuel injection apparatus for an internal combustion engine, in which the flow rate of the intake air in measured and the flow rate of fuel is controlled to be optimum for the measured intake air flow rate by controlling the open period of solenoid valves, used as fuel injection valves, according to the frequency of pulses of a predetermined time width to which said open period is fixed, whereby the air-fuel mixture ratio can be exactly adjusted to the optimum value only by regulating the fuel flow rate per unit time, without being bothered by the problem of synchronizing the fuel injection with the engine speed.

The present invention will be described in detail hereunder with reference to the accompanying drawings, in which:

FIG. 1 is an illustrative diagram showing the overall arrangement of one embodiment of the fuel injection apparatus according to the present invention;

FIG. 2 is a view showing one form of the intake air flow rate detector used in the apparatus;

FIGS. 3(a) and 3(b) are diagram illustrating pulse rows applied to the solenoid valves respectively;

FIG. 3(c) is a diagram illustrating the relationship between the frequency and the average fuel flow rate per unit time; and

FIG. 4 is an electrical circuit diagram of the oscillator.

With reference to FIG. 1, the fuel injection apparatus according to the present invention includes a fuel tank 1, a fuel pump 2, an overflow valve 3 and a fuel distributor 4. The fuel pump 2 is driven from an electric motor not shown to pump fuel from the fuel tank 1. The pumped fuel is partially returned to the fuel tank 1 through the overflow valve 3 and a fuel return pipe 5, so as to maintain the fuel pressure in conduits 6, 7 and the fuel distributor 4 at a constant value. The fuel distributor 4 is connected by fuel injection pipes 8 with solenoid valves 9 provided in the same number as the number of cylinders of the associated engine, so that fuel may be supplied concurrently to said solenoid valves 9. The fuel pressure in each solenoid valve 9 is the same as that in the fuel distributor 4 and is maintained constant.

Each solenoid valve 9 is provided in an intake pipe 11 of the engine 10. The intake air of the engine 10 is introduced into the intake pipe 11 through an intake air flow rate measurer 15 and an intake air flow rate regulator 12, and fed to the respective cylinders, not shown, of the engine 10. The intake air flow rate is regulated by the degree of opening of a throttle valve 13 in the air flow rate regulator 12 and said throttle valve 13 is operatively connected to an accelerator pedal 14 through a link mechanism. Thus, it will be seen that the air flow rate is regulated by the accelerator pedal actuated by the driver.

The flow rate of fuel to be supplied to the engine 10 is controlled in accordance with the flow rate of intake air supplied to the engine, and the metering of fuel is effected by the operation of the solenoid valves 9. Namely, the period of conducting a current through each solenoid valve 9 at a time is always constant but the frequency of the current is varied.

FIGS. 3(a) and 3(b) show drive pulses to be applied to the solenoid valve 9, and FIG. 3(a) exemplifies the case wherein the pulses are applied at a frequency just twice as large as that of the pulses shown in FIG. 3(b). As may be apparent from these Figures, the avarage fuel flow rate Q_F cc/s per unit time is in linear functional relation with the frequency, as shown in FIG. 3(c), and it will, therefore, be understood that the average fuel flow rate Q_F cc/s can be controlled by varying the frequency of the pulses of a completely constant width.

The intake air measurer 15 may, for example, be of the construction shown in FIG. 2, which comprises a ventri 18, a conical body 19 and a spring 20. As is well known the time-wise average air flow rate Q_A cc/s is in proportion to the amount of displacement of the conical body 19. In the present invention, the amount of displacement of the conical body 19 is taken out by a link mechanism 21 and said link mechanism 21 is connected, for example, to a potentiometer (see FIG. 4), whereby the time-wise average air flow rate Q_A cc/s can be detected as the resistance value of a variable resistor 16 (see FIG. 4). It is to be understood that the air flow rate measurer shown in FIG. 2 is only illustrative and a known flow meter of the type which detects the time-wise average air flow rate Q_A cc/s as a voltage, can of course be used for said air flow rate measurer.

A variation of the time-wise average air flow rate Q_A cc/s is detected as a variation of the electric resistance value as stated above, and it will be obviously understood that, in this case, the electric resistance value may be compensated according to the ambient temperature, the ambient atmospheric pressure, the ambient humidity and the throttle acceleration and deceleration as required. By controlling the time-wise average fuel flow rate Q_F cc/s according to the resistance value, it becomes possible to control the fuel supply so as to obtain the optimum air-fuel ratio, only by varying the frequency of pulses at a constant pulse width, independently of the engine speed and without the necessity for synchronizing the fuel supply with the engine speed.

For generating a row of pulses at a frequency variable according to the variation of the resistance value of the variable resistor **16**, as described above, an oscillator **17** is used whic will be described hereunder:

With reference first to FIG. **4**, the oscillator to determine the number of pulses is comprised of an astable multivibrator **22**, a shaping circuit **23** for shaping the waveform of the output of astable multivibrator **22**, a monostable multivibrator **24** triggered by said shaping circuit **23** to determine the pulse width and a driving circuit **25** operated by said output to actuate the solenoid valves **9**. Reference numeral **26** designates a battery.

Astable multivibrator **22** is comprised of resistors **22***a*, **22***c*, **22***e* and **22***h*, capacitors **22***d* and **22***f*, transistors **22***b* and **22***g*, and the variable resistor **16**, which are combined in a known manner. If the resistance value of the variable resistor **16** is constant, the multivibrator **22** will oscillate at a constant frequency, but here the resistance value of the variable resistor **16** varies according to the air flow rate and hence the frequency varies. The output of the non-stable multivibrator **22** is applied to the shaping circuit **23** which is composed of resistors **23***a*, **23***b* and **23***d* and a transistor **23***c* and shapes the waveform. The output of the shaping circuit **23** is applied to the monostable multivibrator **24** which is of a known construction and composed of resistors **24***a*, **24***d*, **24***g*, **24***h* and **24***k*, capacitors **24***c*, **24***e* and **24***i*, transistors **24***b* and **24***j*, and a diode **24***f*.

The monostable multivibrator **24** generates pulse signals of a constant width at a frequency as determined by the aforesaid oscillator and non-stable multivibrator **22**. The pulse signals thus generated are applied to a driving circuit composed of resistors **25***a*, **25***b*, **25***c* and **25***e*, and transistors **25***d* and **25***f*, and the solenoid valves **9** are driven for a period corresponding to the pulse width.

Although the manner in which the solenoid valves **9** are controlled has been described above with reference to only one of them, it should be understood that the other solenoid valves are controlled in the similar manner.

As described above, in the fuel injection apparatus for an internal combustion engine, according to the present invention, a variation of the time-wise avarage flow rate of the intake air is detected upon converting it into a variation of resistance value and a row of pulses which are constant in width and variable only in frequency is obtained according to the detected value, and then the pulses are supplied to each solenoid valve **9** to meter the time-wise average fuel flow rate Q_F cc/s as a function of said frequency. Therefore, the fuel injection apparatus has such remarkable advantages that the fuel can be metered and supplied at a time-wise average flow rate optimum to the time-wise average flow rate of the intake air, that the compensation of the engine speed is unnecessary which has been necessary in the conventional speed density system, that the pulse generator is not required to be synchronized with the engine speed, and that, therefore, the apparatus is extremely simple in construction.

What is claimed is:

1. A fuel injection apparatus for an internal combustion engine, comprising

at least one solenoid valve provided in an intake pipe of the engine upstream of an intake valve,

fuel supply means connected to said solenoid valve for supplying fuel at a constant pressure to said solenoid valve,

an air flow rate measuring means provided in the intake pipe for detecting the flow rate of the intake air and generating an output which varies in accordance with the detected intake air flow rate, and

an oscillator connected to said air flow rate measuring means in circuit and generating pulses of a constant width at a frequency in accordance with the output of said measuring means, said oscillator being connected to said solenoid valve in circuit and said solenoid valve being opened every time a pulse is generated by said oscillator, whereby the fuel at the constant pressure is injected and said oscillator including a variable resistor connected to said air flow rate measuring means and being variable in resistance value according to the output of said measuring means, an astable multivibrator connected to said variable resistor in circuit and generating pulses at a frequency in accordance with the resistance value of said variable resistor, and a monostable multivibrator connected to said astable multi-vibrator in circuit and triggered by the pulses from said astable multivibrator to generate pulses of a constant width which are applied to said solenoid valve.

2. A fuel injection apparatus according to claim **1**, wherein said solenoid valve is provided in the same number as the number of cylinders of the engine and said fuel supply means includes a distributor capable of supplying the fuel at the constant pressure concurrently to said respective solenoid valves.

* * * * *