United States Patent

Baxendale

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[54] FUEL INJECTION SYSTEMS

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[30] **Foreign Application Priority Data**

Sept. 12, 1968 Great Britain 43/503/68

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

[51] **Int. Cl.** **F02b 3/10,** F02b 33/00

[58] **Field of Search** 123/32, 119, 140.3; 133/32

[56] **References Cited**

UNITED STATES PATENTS

2,911,966	11/1959	Pribble	123/32
2,941,519	6/1960	Zechnall	123/32
2,948,272	8/1960	Woodward	123/32
3,089,306	5/1963	Fitchie	60/39.28
3,319,613	5/1967	Begley	123/32
3,335,708	8/1967	Beddoes	123/32
3,429,302	2/1969	Scholl	123/32
3,435,809	4/1969	Bassot	123/119
3,483,851	12/1969	Riechardt	123/140
3,548,791	12/1970	Long	123/32
2,867,200	1/1959	Gryder	123/32
3,240,191	3/1966	Wallis	123/32
3,504,657	4/1970	Eichler	123/32

FOREIGN PATENTS OR APPLICATIONS

858,964	1/1961	Great Britain	123/32

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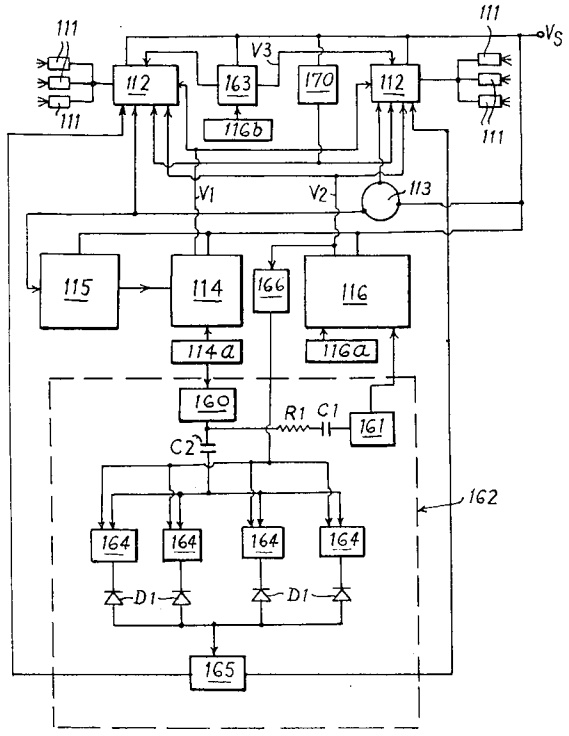
Assistant Examiner—Ronald B. Cox
Attorney—Holcombe, Wetherill & Brisebois

[57] **ABSTRACT**

The invention relates to a fuel injection system wherein enrichment of the fuel is effected, when the engine is conditioned for acceleration, by means applying to the electromagnetic fuel injection valves, further energizing pulses in addition to those which are applied to the injectors during normal operation of the engine.

1 Claims, 6 Drawing Figures



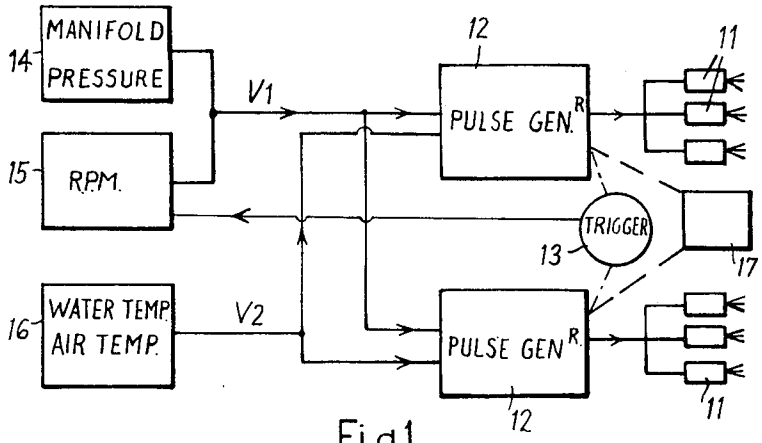


Fig.1

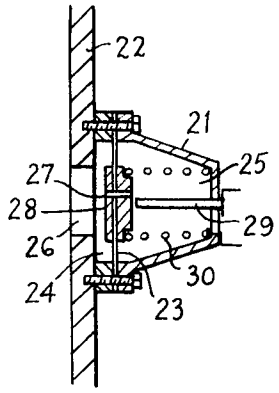


Fig.2

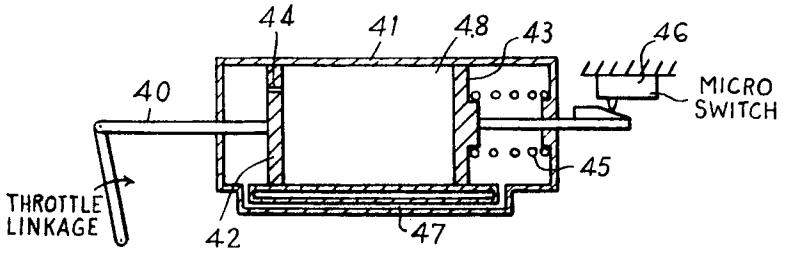


Fig.3

Fig.4

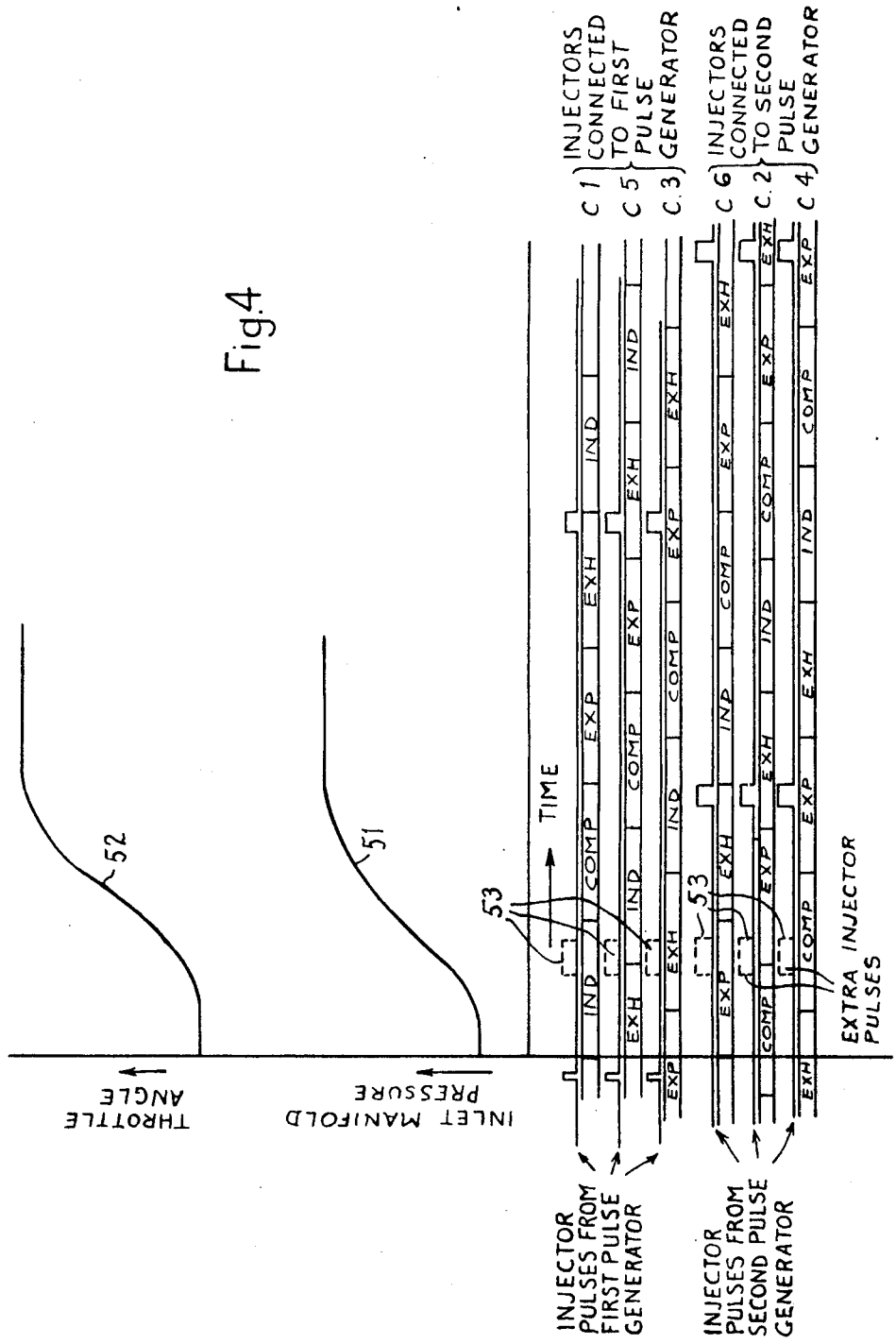
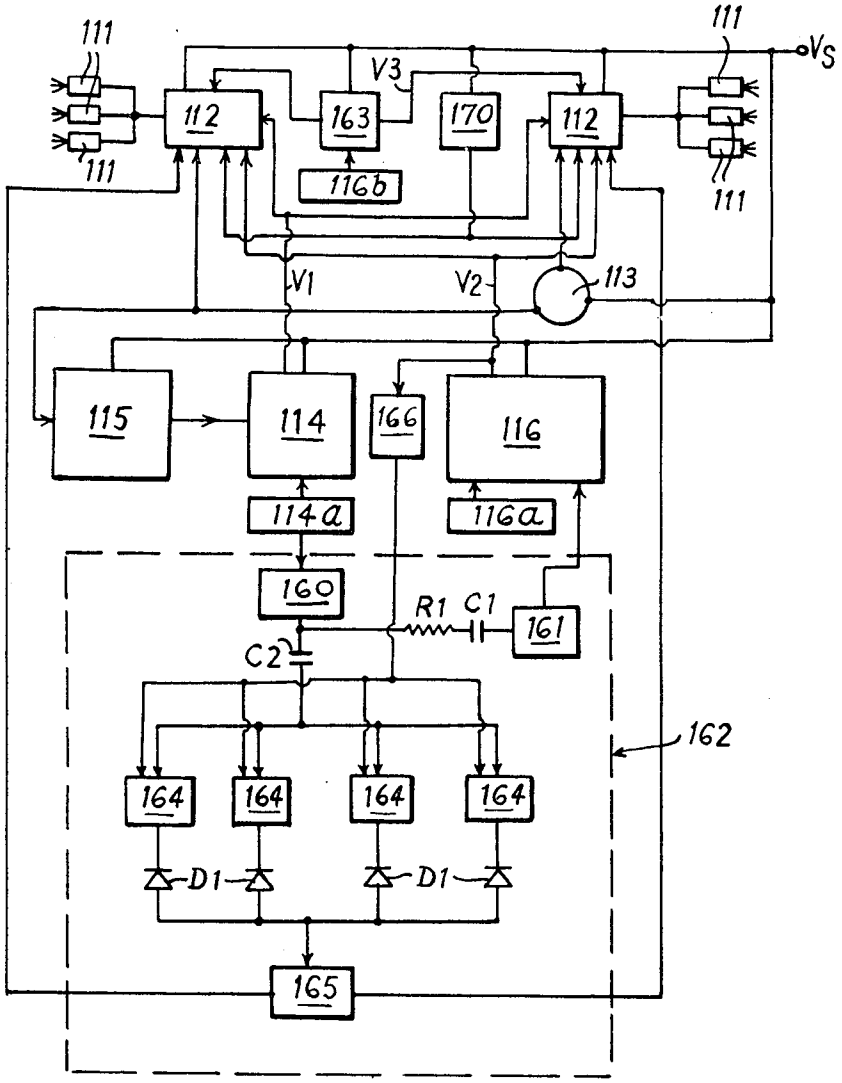

THROTTLE ANGLE
INLET MANIFOLD PRESSURE
TIME
52
51
53
53
C 1 INJECTORS CONNECTED TO FIRST PULSE GENERATOR
C 5
C 3
C 6 INJECTORS CONNECTED TO SECOND PULSE GENERATOR
C 2
C 4
IND
COMP
EXP
EXH
INJECTOR PULSES FROM FIRST PULSE GENERATOR
INJECTOR PULSES FROM SECOND PULSE GENERATOR
EXTRA INJECTOR PULSES

Fig.5


111
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Vs
V3
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163
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116b
V1
V2
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R1
C1
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C2
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D1
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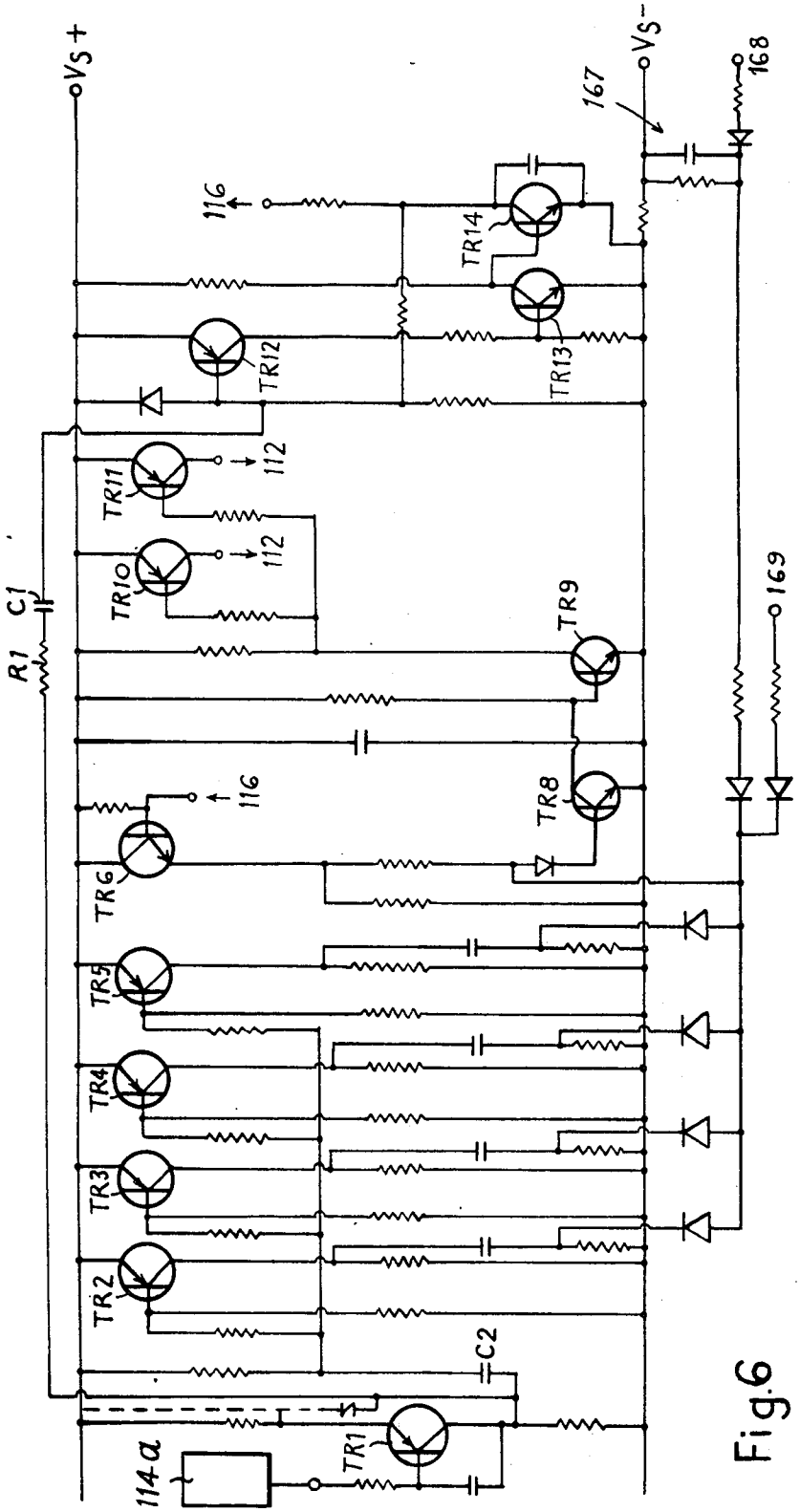
VS+
VS-
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169
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TR14
TR13
TR12
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TR11
TR10
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TR6
TR5
TR4
TR3
TR2
TR1
C1
R1
C2
114a

Fig.6

FUEL INJECTION SYSTEMS

This invention relates to fuel injection systems for internal combustion engines.

More particularly, the invention relates to a fuel injection system for an internal combustion engine which includes a plurality of electromagnetically operated fuel injection valves, a pulse generator circuit producing electrical pulses for energizing said valves, so that each valve is opened for a period depending on the duration of the pulse by which it is energized, to pass fuel to the engine, said pulse generator circuit including a timing circuit for controlling the duration of said pulses, means to feed at least one variable electrical potential, which varies as a function of at least one parameter of engine operation, to the pulse generator circuit to control said pulse duration, and trigger means to initiate said pulses, said trigger means operating at a frequency depending on the rotational speed of the engine. A system of this type is described in U.S. Pat. No. 3272187.

In the said British Patent, it was proposed to provide fuel enrichment during acceleration, so as to enhance acceleration, by extending the duration of the pulses energizing the fuel - injection valves.

It is an object of the present invention to provide a fuel injection system incorporating improved means for providing fuel enrichment to enhance acceleration.

According to the present invention, the system includes means to initiate further pulses when acceleration of the engine is required, in addition to those pulses initiated by said trigger means, whereby additional fuel is delivered through said fuel-injection valves to enhance acceleration.

The said further pulse initiating means may be actuated by changes in a parameter which occur when the engine accelerates or is conditioned to accelerate, for example, changes in the position of the throttle, or resultant changes in pressure in the induction manifold of the engine. Said initiating means may be arranged to energize all the fuel-injection valves simultaneously, either once or several times upon initiation of, or during, acceleration, and in the latter event the pulse spacing, or time delay between successive energizations may vary in dependance upon the rate of acceleration required.

The or each main pulse generator supplying the pulses to the fuel injection valves during normal running of the engine i.e. when not accelerating, may be activated by said initiating means to produce said further pulses. Alternatively, said initiating means may comprise, or be connected to, one or more auxilliary pulse generators for producing said further pulses.

Said further pulse initiating means may be employed in the system either alone or in combination with other acceleration enrichment means, such as the means described in the aforementioned United States Patent.

A number of embodiments of the invention will now be described by way of example, with reference to the accompanying drawings, in which:

FIG. 1 is a block circuit diagram of one embodiment,

FIG. 2 is a detail view of one alternative arrangement of part of FIG. 1,

FIG. 3 is a detail view of another alternative arrangement of FIG. 1,

FIG. 4 is a diagram illustrating the operation of an embodiment of fuel injection system in accordance with this embodiment of the invention,

FIG. 5 is a block circuit diagram of a second embodiment, and

FIG. 6 is a circuit diagram of the auxilliary pulse generators and associated circuitry.

Referring to FIG. 1, the fuel injection system shown is intended for a six-cylinder engine and includes six fuel injection valves 11 arranged in two groups of three. The valves are screwed into housings in the engine induction manifold, just upstream of the inlet valve of the corresponding cylinder. Fuel is supplied at a controlled pressure to each valve 11, for example as described in U.S. Pat. No. 3,240,191, and the fuel injection valves are electromagnetically operated and may be as described in U.S. Pat. No. 3,247,833.

Each group of fuel injection valves 11 is electrically connected to a pulse generator 12, the circuit of which produces a current pulse to energize the group of valves, thereby to inject fuel into the induction manifold. The main pulses are initiated by a trigger device 13, which is in effect a switch which is operated once per engine cycle for each group of cylinders. It will be understood that a fuel injection system in accordance with the invention may be designed for engines having any practical number of cylinders, and moreover each group of valves connected to a pulse generator may include any convenient number of valves, from one upwards.

Each pulse generator 12 includes a timing circuit controlling the duration of the main pulses, and this duration is determined in accordance with the values of two potentials V_1 and V_2, which in turn depend on the values of certain engine operating parameters. In this case, the potential V_1 depends on the engine manifold pressure which is sensed by a pressure transducer forming part of a manifold pressure control circuit 14 and connected to the induction manifold between the throttle and the inlet valves of the engine, and also depends upon the rotational speed of the engine which is sensed from the trigger device 13 by means of an engine speed discriminator 15. The potential V_2 depends on the engine water temperature and the ambient air temperature, which temperatures are sensed, respectively, by a water temperature transducer connected into the water cooling system of the engine and by an air temperature transducer, both of which form part of a start and warm up control circuit 16. These various transducers may incorporate variable resistance elements, the resistances of which will be varied in accordance with the value of the respective operating parameters, and the resistance elements may be incorporated in voltage dividers forming part of associated circuits, namely the inlet manifold pressure control circuit 14, the engine speed discriminator circuit 15, and the start and warm up control circuit 16. Since the present invention is not concerned with the means by which the main pulses or the potentials V_1 V_2 are produced, the pulse generators 12, the circuits 14, 15 16 will not be described or illustrated in detail. It is to be understood, however, that each pulse generator 12, may, for example take the form of, and operate in the manner of, the pulse generator 8 disclosed in the aforementioned U.S. Pat. No. 3272187, and the said circuits and transducers may also take the forms disclosed in this latter Patent, and for further details of the construction and operation of these components, reference should be made to this Patent.

The fuel injection system also includes a device 17, which responds to an increase in induction manifold pressure on opening of the throttle, and which activates the pulse generators 12 to produce further pulses, in addition to the main pulses initiated by the trigger device 13, when the increase in manifold pressure on opening of the throttle valve exceeds certain values. This device 17 activates the pulse generators 12 simultaneously, so that said further pulses are produced simultaneously at all the fuel injectors 11, and therefore, additional fuel is delivered into the induction manifold.

One form of the device 17 for sensing when acceleration is called for is shown in FIG. 2. A housing 21 is secured to the exterior of the induction manifold wall 22, downstream of the engine throttle, and is divided by a diaphragm 23 into two spaces 24, 25. The space 24 communicates with the interior of the manifold through a large hole 26 and is virtually at the same pressure as the interior while the space 25 communicates with space 24 through a small hole 27. The diaphragm carries one switch contact 28, and another contact 29 is carried by, but insulated from, the housing 21. A coil spring 30 loads the diaphragm, and also serves to connect switch contact 28 to one terminal of the switch, which is insulated from the terminal connected to the other contact 29.

When the manifold pressure increases, the pressure in space 24 increases immediately, but that in space 25 lags due to the small hole 27. If the rate of change of manifold pressure exceeds a certain value, the contacts 28, 29 make, and, since they are connected to the pulse generators 12, for example, connected via a diode to the input terminal of each pulse

generator 12, in parallel with the trigger device 13, initiate a pulse, the duration of which depends inter alia on potentials V_1, V_2. This additional pulse opens the fuel injectors 11 simultaneously to deliver fuel into the induction manifold.

Another form of device for sensing when acceleration is called for is shown in FIG. 3, which, in this case responds to rate of change of position of part of the linkage 40 between the accelerator pedal and the engine throttle. This device includes a cylinder 41 containing air or a hydraulic fluid and two pistons 42, 43. One piston 42 is connected to the throttle linkage, and has a bleed orifice 44, the other piston 43 is connected so that, on movement against a spring 45, it causes a switch 46 to make, the switch contacts being connected to the pulse generators 12 as described with reference to FIG. 2. The pressures in the two end spaces of the cylinder are equalized by a connection 47, which is not connected to the central space 48.

When the position of the throttle linkage changes at more than a predetermined rate, the travel of piston 42 compresses the air or other fluid in the central space 48, by reason of the small size of the bleed orifice 44. This urges the piston 43 to the right against the spring 45, causing the switch 46 to make. This in turn causes additional fuel to be injected, exactly as described with reference to FIG. 2.

The effect is illustrated in FIG. 4 in which, for convenience, both the change in induction manifold pressure (trace 51) and the change in throttle angle (trace 52) are plotted against time, together with traces showing the current pulses supplied to different injectors 11. The latter are drawn for a six-cylinder engine having a firing order 153,624, with injectors for cylinders 1, 5 and 3 connected to the first pulse generator 12, and those for cylinders 6, 2 and 4 connected to the second pulse generator.

It will be seen that the further pulses 53 are fed simultaneously to the different injectors, irrespective of the part of the cycle of each cylinder at which the acceleration demand signal, e.g. increase in manifold pressure or change of throttle angle, begins, and this occurs irrespective of how the acceleration is sensed.

In the embodiment described with reference to FIGS. 1 to 4, it will be apparent that the pulse generators 12 which produced the main pulses are also employed to produce a single group of further fuel enrichment pulses which simultaneously energize all of the fuel injection valves once only. In the embodiment illustrated in FIGS. 5 and 6, however, successive groups of further fuel enrichment pulses are produced by auxilliary pulse generators each time that the engine is conditioned to accelerate.

Referring now to FIG. 5, this system is basically similar to that previously described in that it incorporates two pulse generators 112 each connected to three fuel injectors 111, and operated by a trigger device 113, and in that the duration of the main pulses is dependant upon the two potentials V_1 and V_2. The potential V_1 is derived from an engine speed discriminator 115, and a manifold pressure control circuit 114 having a manifold pressure transducer 114*a*. The potential V_2 is derived from a start and warm up control circuit 116 having a water temperature transducer 116*a*, and, in this embodiment, connected to the manifold pressure transducer 114*a* via a DC amplifier 160, resistor R1, capacitor C1 and controlled-gain DC amplifier 161, all of which form part of an auxilliary pulse generator circuit indicated generally at 162, so that this input signal to circuit 116, and therefore V_2, will be dependant upon the rate of change of pressure in the induction manifold. Thus, the duration of the main pulses produced by the pulse generators 112 will be increased to provide progressive fuel enrichment during, or upon initiation of, acceleration, in addition to the fuel enrichment provided by the further pulses. The air temperature transducer 116*b*, is connected to an air temperature control circuit 163, the output V3 of which is fed separately to the main pulse generators 112, so that the duration of the main pulses will also be dependent upon this potential V_3. A compensator 170 is provided to compensate for variations in supply voltage V_S.

The signal from the manifold pressure transducer 114*a*, after DC amplification by the amplifier 160, is AC coupled via capacitor C_2 to four auxilliary pulse generators 164 connected in parallel. The outputs from the generators 164 are coupled via diodes D1 to a further DC amplifier 165 connected to the amplifier stages of both main pulse generators 112, for example to the input of the transistor TR7 of the pulse generator shown in FIG. 2 of U.S. Pat. No. 3272187.

The auxilliary pulse generators 164 have different sensitivities so that they will be triggered by signals corresponding to different manifold pressure levels relative to a quiescent level corresponding to the manifold pressure before acceleration is initiated. The generators 164 may, for example, be initially adjusted so that they will be triggered by pressures evenly distributed throughout the normal range of manifold pressures between the fully closed and fully open conditions of the throttle. Thus, prior to acceleration, the capacitor C2 will be charged to a value dependent upon the engine speed to determine the quiescent level, and upon opening of the throttle to initiate acceleration, the pressure will increase, the rate and amount of increase depending upon rate and amount of opening of the throttle, thus triggering the auxilliary generators 164 in turn so that groups of further pulses will be applied to the fuel injectors 111. For rapid acceleration, four comparatively closely spaced groups of further pulses will be applied to the injectors, while for lesser degrees of acceleration the group-spacing will increase, and for light accelerations, only one, two or three of the generators 164 may be triggered.

The control potential V_2 is applied to the auxilliary generators 164 via a buffer 166, so that the pulse width of the further pulses will be dependent upon water temperature.

The auxilliary pulse generator circuit 162 is shown in detail in FIG. 6. In this Figure, the transistor TR1 and associated components comprise the DC amplifier 160, the transistors TR2 to TR5 and their associated components comprise the four auxilliary pulse generators 164, TR6 constitutes the buffer 166, and TR8 to TR11 and their associated components constitute the DC amplifier 165. The transistors TR12 to TR14 constitute the controlled gain DC amplifier 161. The auxilliary pulse generators 164 are additionally connected via the network 167 and terminal 168 to the starter motor contact of the engine, which block the generators 164 during starting of the engine, when fluctuating pressures are created in the manifold which might otherwise trigger one or more of the generators 164. The generators 164 are also coupled via terminal 169 to an on-off switch operated by the throttle, which is actuated to block the generators 164 when the throttle is closed and the engine is idling.

It will be understood that various modifications may be made without departing from the scope of the present invention as defined in the appended claims. For example, the system illustrated in FIG. 1 may embody means for increasing the duration of the main pulses triggered by the device 13 upon initiation of, or during, acceleration, either progressively or by a fixed amount, to supplement the fuel enrichment afforded by the further pulses triggered by the device 17.

Moreover, the system illustrated in FIG. 5 may be designed so that the main pulse duration is increased by a fixed amount, instead of progressively, upon acceleration, or is independent of acceleration whereby the fuel enrichment required upon acceleration will be effected solely by the further pulses.

It will be understood that more or less than the four auxilliary pulse generators 164 may be provided in the system of FIG. 5, and these pulse generators may be arranged to be triggered at any desired manifold pressures.

The systems described and illustrated may incorporate means to provide a threshold, which may or may not be adjustable, to prevent the further pulses from being produced, or fed to the fuel injectors when rate of change of manifold pressure is below a minimum value. Moreover, although the further pulses produced by the systems have a variable duration, they may be of fixed duration.

Although, in the embodiments illustrated, the further pulses are produced as a result of signals derived from an absolute

pressure transducer connected into the induction manifold, a transducer which detects the actual rate of change of pressure in the manifold may be employed, or the signals may be derived from a transducer associated with the throttle.

I claim:

1. A fuel injection system for an internal combustion engine which includes a plurality of electromagnetically operated fuel injection valves, at least one pulse generator circuit producing electrical pulses for energizing said valves, so that each valve is opened for a period depending on the duration of the pulse by which it is energized, to pass fuel to the engine, said pulse generator circuit including a timing circuit for controlling the duration of said pulses, means to feed at least one variable electrical potential, which varies as a function of at least one parameter of engine operation, to the pulse generator circuit to control said pulse duration, trigger means to initiate said pulses, said trigger means operating at a frequency depending on the rotational speed of the engine, and further pulse-initiating means operable independently of said trigger means to initiate further pulses when acceleration of the engine is required, said further pulses being applied to the fuel injection valves in addition to those pulses initiated by said trigger means, whereby additional fuel is delivered through said fuel-injection valves to enhance acceleration, said further pulse initiating means including a plurality of auxiliary pulse generator circuits for producing a plurality of successive further pulses each of which simultaneously energizes all the valves, the number of said generator circuits corresponding to the maximum number of said successive further pulses, the system including a manifold absolute pressure transducer which produces an output varying in dependence upon changes in pressure in the induction manifold, the output being fed simultaneously to said auxiliary pulse generator circuits, the auxiliary pulse generator circuits being arranged to be triggered by different levels of said output relative to a quiescent level determined by the value of said output corresponding to the manifold pressure before the engine is conditioned to accelerate, said system further including a pair of main pulse generator circuits, each including an output amplifier connected to a group of fuel injection valves, the auxiliary pulse generator circuits being connected in parallel between said transducer and both of said output amplifiers.

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