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[54] **FUEL INJECTION SYSTEM FOR INTERNAL COMBUSTION ENGINES**  
**5 Claims, 2 Drawing Figs.**

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 (E), 32 (E-1), 119, 139.18, 140.2, 140.3

**ABSTRACT:** A fuel injection system for internal combustion engines wherein the fuel injection valves admit fuel into the intake manifold at a frequency which is a function of rotational speed of the engine and for intervals whose length is a function of manifold pressure when the throttle in the intake manifold is at a standstill. An overriding device which is actuated by the throttle causes the fuel injection valves to extend the length of intervals of fuel admission beyond such length which reflects the then prevailing manifold pressure when the throttle is moved toward open position.

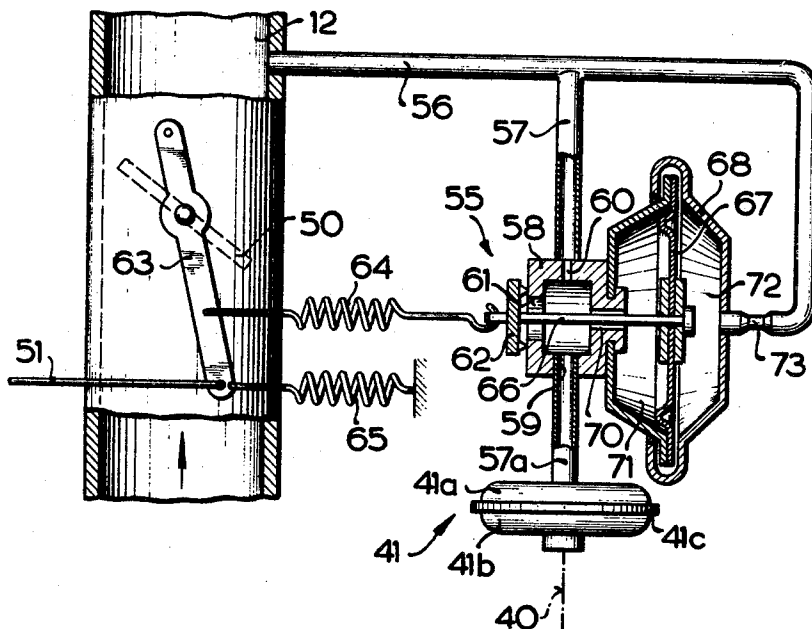


FIG. 1

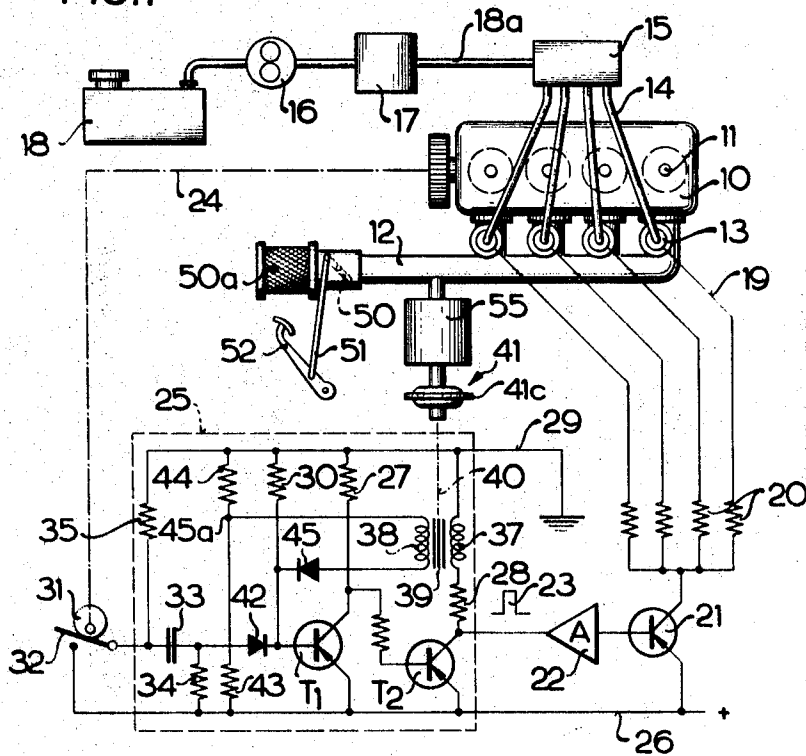
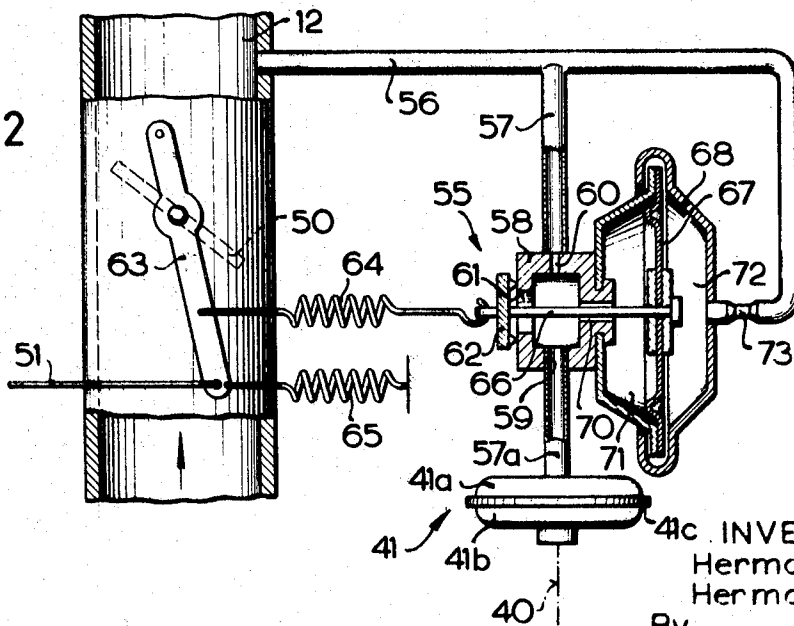


FIG. 2



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## FUEL INJECTION SYSTEM FOR INTERNAL COMBUSTION ENGINES

### BACKGROUND OF THE INVENTION

The present invention relates to fuel injection systems for internal combustion engines, and more particularly to improvements in fuel injection systems of the type wherein the percentage of fuel in the fuel-air mixture which is admitted to the cylinder or cylinders varies as a function of changes in manifold pressure. Still more particularly, the invention relates to improvements in fuel injection systems which employ one or more solenoid-operated fuel injection valves serving to control admission of fuel from a source of constant-pressure fuel into the intake manifold so that the percentage of fuel in the mixture is a function of the length of that interval during which a particular valve is held in open position.

In presently known fuel injection systems of the just outlined character, the injection valves can properly control the percentage of fuel in the mixture when the throttle in the intake manifold is at a standstill. As a rule, the length of intervals during which the valves remain open is determined by a pneumatic transducer which changes the length of such intervals as a function of changes in differential between atmospheric pressure and manifold pressure, i.e., as a function of manifold pressure. However, when the throttle is moved toward open position to initiate acceleration of the engine, namely, to cause the transducer to lengthen the intervals during which the fuel injection valves remain open, the rise in manifold pressure normally lags behind the movement of throttle toward open position so that the cylinders of the engine continue to receive a relatively lean mixture of fuel and air. This is due to the fact that a certain period of time is needed before the manifold pressure rises in response to movement of the throttle toward open position and before such pressure rise is communicated to the transducer so that the latter can cause the fuel injection valves to remain open for longer intervals of time and to thus enrich the fuel-air mixture. It is desirable to supply to the cylinders a richer fuel-air mixture in immediate response to movement of the throttle toward open position, and it is equally desirable to insure that the percentage of fuel in the mixture be a function of manifold pressure when the throttle is at a standstill.

### SUMMARY OF THE INVENTION

An object of our invention is to provide a fuel injection system wherein the fuel injection valves can immediately react to changes in the position of throttle in the intake manifold to furnish to the cylinders a richer mixture in response to movement of throttle toward open position and in such a way that the percentage of fuel in the mixture is raised sooner than warranted by existing manifold pressure.

Another object of the invention is to provide the fuel injection system with a regulating assembly which controls the opening of fuel injection valves at a frequency which is a function of engine speed and for intervals whose length is normally a function of manifold pressure but which can change the length of such intervals independently of manifold pressure during that period when the throttle is in the process of moving toward open position.

A further object of the invention is to provide the fuel injection system with a relatively simple and compact device which can override the means which normally regulates the length of intervals during which the fuel injection valves admit fuel into the intake manifold.

The invention is embodied in an injection system which is incorporated in or combined with an internal combustion engine and comprises an intake manifold, throttle means provided in the manifold and movable between open and closed positions to thereby vary the manifold pressure, i.e., to raise such pressure in response to movement toward open position, at least one normally closed fuel injection valve (preferably a solenoid-operated valve) for admitting fuel into the manifold downstream of the throttle means, a source of constant-pres-

sure fuel connected with the injection valve, and novel regulating means for opening the valve for intervals of variable length and at a frequency which is a function of rotational speed of the engine. The regulating means comprises adjustable pneumatic transducer means for determining the length of intervals as a function of pressure in the manifold when the throttle means is at a standstill, and overriding means for adjusting the transducer means to thereby lengthen the intervals in response to movement of the throttle means toward open position. The overriding means is preferably mounted in conduit means connecting the transducer means with the intake manifold and includes pressure modifying valve means which admits into the conduit means atmospheric air during movement of the throttle means toward open position to thus accelerate the lengthening of intervals during which the injection valve remains open, i.e., to insure that the injection valve admits more fuel not so much in response to increasing manifold pressure but rather in immediate response to movement of throttle means toward open position so that the cylinder or cylinders of the engine receive a richer fuel-air mixture as soon as the person in charge decides to initiate acceleration of the engine, for example, in response to depression of the gas pedal in an automotive vehicle.

The novel features which are considered as characteristic of the invention are set forth in particular in the appended claims. The improved fuel injection system itself, however, both as to its construction and its mode of operation, together with additional features and advantages thereof, will be best understood upon perusal of the following detailed description of certain specific embodiments with reference to the accompanying drawing. BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a schematic view of a fuel injection system which embodies the invention and serves to control the admission of fuel in a four-cylinder internal combustion engine; and

FIG. 2 is an enlarged sectional view of the overriding device in the fuel injection system of FIG. 1.

### DESCRIPTION OF THE PREFERRED EMBODIMENTS

The fuel injection system of the present invention regulates the admission of fuel to the cylinders of a four-cylinder internal combustion engine 10 shown in FIG. 1. The mixture of fuel and air is ignited by spark plugs 11 which are connected with a conventional high-voltage ignition system, not shown. The block of the engine 10 carries four fuel admitting valves (not shown) each of which is immediately or closely adjacent to one of four solenoid operated fuel injection valves 13 installed in the branches of an intake manifold 12. The injection valves 13 receive fuel by way of supply conduits 14 which are connected to a distributor 15. The distributor 15 receives fuel from a main source or tank 18 by way of a fuel line 18a which contains a fuel pump 16 and a pressure regulator 17. The pump 16 is driven by an electric motor, not shown. The regulator 17 maintains the pressure of fuel in the distributor 15 and conduits 14 at a substantially constant value, for example, at two atmospheres superatmospheric pressure.

The windings of solenoids in valves 13 are connected with the ground and with conductors 19 each of which is connected with one of four resistors 20. These resistors are connected to the collector of a transistor 21 having an emitter connected to the positive pole of an energy source. The base of the transistor 21 is connected with the output of an electronic control unit 25 by way of an amplifier 22. The latter produces rectangular impulses 23 in response to each revolution of the engine crankshaft 24 (indicated by phantom lines). The duration of each impulse 23 corresponds to the length of intervals during which the valves 13 inject fuel at constant pressure into the respective branches of the intake manifold 12. The length of such impulses is proportional to the amounts of injected fuel because the pressure of fuel in conduits 14 and distributor 15 is substantially constant. The control unit 25 forms part of a regulating assembly which determines the duration of impul-

ses 23 as a function of prevailing operating conditions of the engine 10.

The control unit 25 comprises a monostable multivibrator including two PNP transistors  $T_1$  and  $T_2$ . The emitters of transistors  $T_1$ ,  $T_2$  are connected to a lead 26 which is connected with the positive pole of the energy source, for example, the battery of an internal combustion engine with a nominal potential of 12.6 volts. The collectors of transistors  $T_1$  and  $T_2$  are connected to a second lead 29 by way of working resistors 27, 28. The lead 29 is connected with the ground and with the negative pole of the battery.

When the control unit 25 is in quiescent condition, the transistor  $T_1$  conducts current from its base to the lead 29 by way of a resistor 30. The transistor  $T_2$  blocks the flow of current. The unstable condition, which determines the length of intervals during which the injection valves 13 are open, begins when the crankshaft 24 closes a timer switch 32 by way of a rotary eccentric cam 31. The movable contact of the timer switch 32 is biased toward open position by a spring (not shown) which maintains it in engagement with the face of the cam 31. Closing of the timer switch 32 results in discharge of a control capacitor 33 which is charged while the timer switch is held in open position. The capacitor 33 is charged by way of resistors 34, 35 which are respectively connected to the leads 26 and 29. When the timer switch 32 closes, its contacts connect the negatively charged electrode of the capacitor 33 with the positive lead 26. This causes the transistor  $T_1$  to block the flow of current and the transistors  $T_2$  and 21 to become conductive. Consequently, the injection valves 13 open for the interval of time which elapses before the transistors  $T_2$  and 21 become nonconductive and the transistor  $T_1$  again conducts current. The factor which determines the length of intervals during which the transistors  $T_2$ , 21 conduct current and the transistor  $T_1$  blocks on closing of the timer switch 32 is the inductance of a primary winding 37 which is connected in the collector circuit of the transistor  $T_2$  in series with the working resistor 28 and forms part of a transformer which further includes a secondary winding 38 and a movable iron core 39. The core 39 is coupled to a motion transmitting linkage 40 which is connected with a diaphragm 41c mounted in the container of a pneumatic transducer 41 having two compartments 41a, 41b separated from each other by the diaphragm 41c and respectively connected with the intake manifold 12 and with the atmosphere. The arrangement is such that the inductance of the winding 37 decreases in response to a decrease of absolute pressure in the intake manifold 12. The inductance decreases in response to upward movement of this core 39, as viewed in FIG. 1.

One end of the secondary winding 38 is connected with the base of the transistor  $T_1$  by way of a diode 45. The other end of the winding 38 is connected to a tap 45a between two resistors 43, 44 connected in series with each other between the leads 26, 29. When the timer switch 32 closes and blocks the transistor  $T_1$  by way of a diode 42, the transistor  $T_2$  supplies current which flows through the primary winding 37 at a rate which is inversely proportional to the inductance of winding 37 and induces a voltage in the secondary winding 38. Such voltage then causes the transistor  $T_2$  to conduct current independently of the position of movable contact in the timer switch 32 until the current in the primary winding 37 approximates the saturation value. The induced voltage which blocks the transistor  $T_1$  by way of the diode 45 decreases while the current flow through the winding 37 comes closer to the saturation value and the voltage finally decreases to such an extent that the negative base potential of the transistor  $T_1$  (controlled by the resistors 43, 44) prevails and causes the transistor  $T_1$  to reassume its original condition. This blocks the output transistor 21 and the injection of fuel is terminated.

The pressure in the upper compartment 41a of the transducer 41 corresponds to pressure in the intake manifold 12 downstream of a throttle 50 which is connected with a gas pedal 52 by a linkage 51. The intake end of the manifold 12 draws air by way of a filter 50a. The manifold pressure nor-

mally determines the length of intervals during which the valves 13 inject fuel for admission into the corresponding cylinders. If the operator desires to accelerate the vehicle by depressing the pedal 52 so as to open the throttle 50 and to thereby increase the manifold pressure, the rise in such pressure lags behind movement of throttle 50 toward a different angular position. In order to eliminate such lag, the conduit which connects the intake manifold 12 with the upper compartment 41a of a transducer 41 accommodates a pneumatic overriding device 55 which insures that the cylinders of the engine 10 receive a richer fuel-air mixture with a minimal delay or with no delay whatever following depression of the pedal 52. This overriding device 55 can adjust the transducer 41 independently of existing differential between manifold pressure and the pressure of surrounding atmosphere.

The details of the overriding device 55 are shown in FIG. 2. A conduit 56 communicates with the intake manifold 12 downstream of the throttle 50 and with a branch conduit 57 which is connected with a chamber 58 of the device 55. The chamber 58 has a relatively large outlet opening 59 which is connected with the upper compartment 41a of the transducer 41 by a further conduit 57a. The opening 59 is large enough to permit practically unobstructed flow of air between the compartment 41a and chamber 58. The chamber 58 is further provided with a relatively small inlet opening 60 which establishes communication between the interior of this chamber and the branch conduit 57 i.e., with the intake manifold 12. A relatively large inlet opening 61 of the chamber 58 is controlled by a pressure modifying valve member 62 and communicates with the atmosphere when the valve member 62 is caused to move in a direction to the left, as viewed in FIG. 2. The throttle 50 is connected with a lever 63 which forms part of or is coupled to the aforementioned linkage 51 and is connected with the valve member 62 by a helical expansion spring 64. The lever 63 is further connected with a helical return spring 65 which tends to move the throttle 50 toward closed position when the pedal 52 is released.

The valve member 62 is connected with a valve stem 66 which is secured to the central portion of a diaphragm 67 in a pneumatic transducer 68. The diaphragm 67 divides the interior of the transducer 68 into compartments 71, 72 the latter of which communicates with the conduit 56 by way of a flow restrictor 73. The compartment 71 communicates with the interior of the chamber 58 by way of an annular clearance 70 surrounding a portion of the valve stem 66. The lower compartment 41b of the transducer 41 communicates with the atmosphere and is sealed from the compartment 41a.

The parts 67, 68, 66 constitute a closing device which serves to return the pressure modifying valve member 62 into sealing engagement with a seat surrounding the inlet opening 61. The spring 64 and lever 63 constitutes a yieldable motion transmitting device which can open the valve member 62 in response to movement of throttle 50 toward open position.

#### THE OPERATION

When the engine 10 is idling, i.e., when the pedal 52 is released so that the return spring 65 maintains the throttle 50 in closed or substantially closed position, the spring 64 is not stressed and the pressure in compartments 71, 72 is substantially identical with pressure in the manifold 12 downstream of the throttle 50. The diaphragm 67 is installed in prestressed condition so that it maintains the valve member 62 in sealing position in which the member 62 seals the inlet opening 61 and bears with slight pressure against the adjoining portion or seat of the chamber 58. When the pedal 52 is depressed to move the throttle 50 toward open position, the spring 64 is expanded by the lever 63 and moves the valve member 62 away from its seat to admit atmospheric air by way of the inlet opening 61. The thus admitted air flows through the outlet opening 59, conduit 57a and into the upper compartment 41a of the transducer 41. The latter causes its diaphragm 41c to move the linkage 40 downwardly, as viewed in FIG. 1, and to shift

the core 39 so that the inductance of the primary winding 37 increases. Thus, the valves 13 inject substantially increased quantities of fuel in the next following stage so that the mixture of fuel and oil is enriched without delay. This is due to the fact that the valve member 62 admits air into the chamber 58 in immediate response to movement of throttle 50 away from closed position. Greater inductance of windings 37, 38 causes the control unit 25 to produce impulses 23 of greater duration so that the valves 13 remain open for longer intervals of time and admit greater quantities of fuel.

Absolute pressure in compartment 72 rises in response to movement of throttle 50 toward open position whereby the transducer 68 assists the movement of valve member 62 away from its seat because the diaphragm 67 is flexed in a direction to the left, as viewed in FIG. 2. The area of the clearance 70 is selected in such a way that the clearance permits only a gradual rise of pressure in the compartment 71. When the pressure in compartment 71 rises sufficiently to approximate the pressure in compartment 72, the valve member 62 moves toward its seat and stresses the spring 64 to reduce the effective (exposed) area of the inlet opening 61, i.e., this opening is then sealed or substantially sealed from the atmosphere. The pressure in chamber 58 then decreases and approximates the pressure in intake manifold 12 downstream of the throttle 50. This corresponds to normal operating condition subsequent to completed acceleration of the engine. A small difference between the pressures in compartments 71, 72 remains to compensate for initial stressing of the spring 64 and diaphragm 67. When the throttle 50 is held in open position, the valve member 62 preferably remains in slightly open position so that a small amount of air flows through the small inlet opening 60. The pressure drop at the inlet opening 60 corresponds to the differential in pressure between the compartments 71 and 72.

The restrictor 73 serves to insure gradual changes of pressure in the compartment 72. The opening 60 constitutes a similar restrictor and prevents sudden pressure changes in the chamber 58 at unchanging position of the valve member 62. This insures that the diaphragm 41c and linkage 40 cannot respond to minor fluctuations of pressure in the conduit 56.

When the throttle 50 is held in open position, the pressure in upper compartment 41a of the transducer 41 is slightly higher than in the manifold 12 downstream of the throttle. This can be compensated for, either in part or entirely, by proper dimensioning of the spring 64 and by employing a relatively large diaphragm 67. Such difference in pressure between conduit 56 and compartment 41a can be further compensated for by an appropriate selection of fuel as well as by changing the rate at which the length of intervals of fuel injection varies in response to changes of manifold pressure.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can, by applying current knowledge, readily adapt it for various applications without omitting features which fairly constitute essential characteristics of the generic and specific aspects of our contribution to the art.

We claim:

1. In an internal combustion engine, a combination comprising an intake manifold; throttle means provided in said manifold and movable between open and closed positions to

thereby vary the pressure in said manifold; at least one normally closed fuel injection valve for admitting fuel into said manifold downstream of said throttle means; a source of constant-pressure fuel connected with said valve; and regulating means for opening said valve for intervals of variable length and at a frequency which is a function of the rotational speed of the engine, said regulating means comprising adjustable transducer means for determining the length of said intervals as a function of pressure in said manifold when said throttle means is at a standstill, conduit means connecting said transducer means with said manifold downstream of said throttle means to communicate said manifold pressure to said transducer means, and overriding means for adjusting said transducer means, to thereby lengthen said intervals in response to movement of said throttle means toward open position, said overriding means being installed in said conduit and including pressure modifying means for changing the pressure which is communicated to said transducer means during movement of said throttle means toward open position and comprising valve means arranged to admit atmospheric pressure into said conduit means in response to movement of said throttle means toward open position, said overriding means further comprising a chamber installed in said conduit means and having a relatively small first inlet opening in communication with said manifold, a relatively large second inlet opening, a seat surrounding said second inlet opening and normally engaged by said valve means, an outlet opening in communication with said transducer means, motion transmitting means connecting said throttle means with said valve means and arranged to move the latter away from said valve seat to thereby admit to said chamber atmospheric air by way of said second inlet opening in response to movement of said throttle means toward open position and comprising resilient means which stores energy in response to such movement of said throttle means, and closing means for returning said valve means into engagement with said seat in response to termination of movement of said throttle means and comprising second transducer means for returning said valve means into engagement with said seat against the opposite of said resilient means in response to a predetermined differential between manifold pressure and the pressure in said chamber, said second transducer means comprising a container, a deformable diaphragm mounted in and dividing the interior of said container into a first compartment in communication with said manifold and a second compartment in communication with said chamber, and a connector coupling said diaphragm with said valve means.

2. A combination as defined in claim 1, wherein said resilient means comprises a helical expansion spring.

3. A combination as defined in claim 1, wherein said overriding means further comprises flow restrictor means interposed between said first compartment and said manifold.

4. A combination as defined in claim 1, and including an electric circuit arranged to produce output signals whose duration determines the length of said intervals and is a function of the extent of deformation of said diaphragm in response to changes in pressure differential between said compartments, said overriding means comprising means for modifying the pressure in said first compartment.

5. A combination as defined in claim 4, wherein said fuel injection valve is a solenoid-operated valve.