May 17, 1960 K. PAULE ET AL 2,936,744

FUEL INJECTION SYSTEM

Filed Nov. 26, 1958 2 Sheets-Sheet 1

Fig. 1

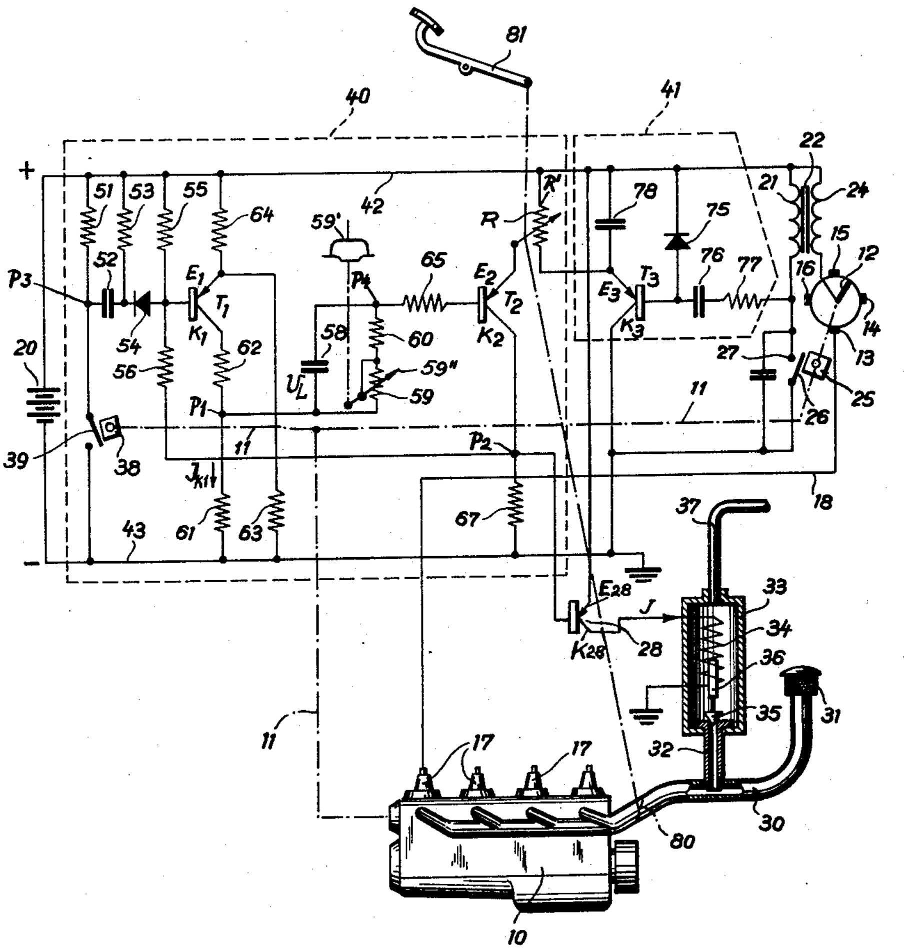

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Fig. 2

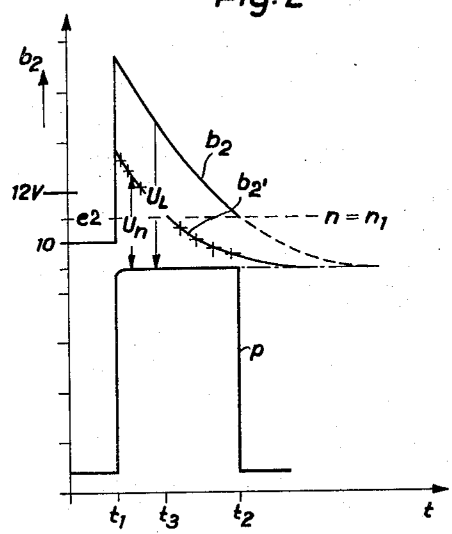
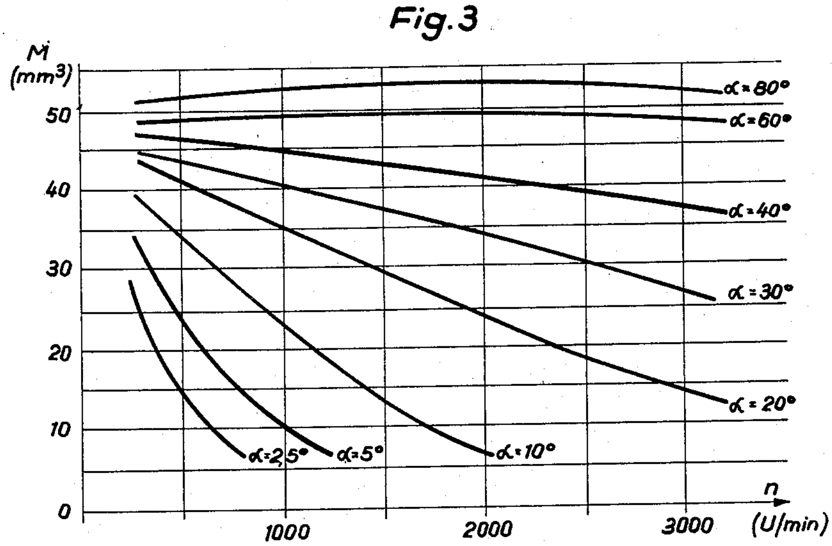


Fig. 3



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FUEL INJECTION SYSTEM

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8 Claims. (Cl. 123—32)

The present invention refers to fuel injection systems for internal combustion engines operated by an external ignition control device, particularly to such systems related to motor cars. More specifically the present invention concerns a fuel injection system in which the fuel injection rate is determined by control means which are timed during operation by the actual rotational speed of the engine.

In fuel injection systems of this type the fuel injection rate must be regulated depending upon the varying rotational speeds of the internal combustion engine in such a manner that the fuel-air mixture entering the cylinder always contains sufficient component of fuel. This fuel component must be kept in the stoichiometric proportion with respect to the introduced air.

It is therefore a main object of the present invention to provide for a speed-responsive fuel injection system for engines of the above described type, capable of automatically regulating the fuel injection rate in the above mentioned manner.

It is another object of this invention to provide for a fuel injection system of the type set forth above, directly operated and controlled by the conventional ignition control device of the engine.

It is another object of this invention to provide a speed-responsive fuel injection system of the type set forth, controlled by the air supply control means of the engine or motor vehicle, which usually is a pedal-controlled choke so that the fuel injection rate is always correlated with the varying operating conditions of the engine.

With above objects in view the fuel injection system according to the invention mainly comprises timing means adapted to be actuated by the ignition control device of the internal combustion engine for producing a sequence of electrical pulses in synchronism with the operational frequency of the ignition control device so that the number of said electrical pulses is proportional to the rotational speed of the engine, said timing means including electrical means capable of converting said pulses into a control potential, the average value of which is proportionate to the operational frequency of said ignition control device. The system further includes electrically controllable fuel injection means adapted to be controlled by the above mentioned control potential of said electrical means in such a manner that the injection admission rate of the fuel injection means is determined by said control potential of said electrical means. The system includes moreover actuating means in circuit with said electrically controllable fuel injection means and with said electrical means, whereby the injection admission rate of said fuel injection means is regulated in a predetermined proportion to the rotational speed of the internal combustion engine.

In a preferred embodiment of the invention, the above mentioned electrical means mainly consist in capacitor means capable of being charged by the pulses produced by said timing means to a charge potential, which due to the varying time intervals between the pulses permitting

a more or less substantial discharge of said capacitor assumes an average value which is proportionate to the operational frequency of the ignition control device.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawings, in which:

Figure 1 is a schematic diagram of an embodiment of the fuel injection system according to the invention, showing a circuit diagram of the component electrical parts and in connection therewith a four-cylinder internal combustion engine of the spark-ignition type, including diagrammatically the ignition control means and a fuel injection device;

Figure 2 is a graph with time as abscissa and voltage as ordinate to illustrate the operation of the device; and

Figure 3 is a graph with revolutions per minute as abscissa and volume of fuel injection as ordinate, to illustrate the relation between these two factors and the different possible degrees of choke openings.

Referring now to Fig. 1, the engine **10** includes a distributor shaft **11** which is not illustrated as such but represented by a dash-dot line which branches off into several arms only in order to show the connection between the engine **10** and various elements in the diagram which are to be understood to be rotated by the engine **10**. The distributor shaft **11** of the high voltage ignition device rotates at a rotational speed equal to that of the cam shaft of the engine. The shaft **11** carries a rotating distributor electrode **12** which cooperates with four stationary electrodes **13**, **14**, **15** and **16**. Each one of these last mentioned electrodes is connected by a cable to one of the spark plugs **17** of the engine **10**. In order not to crowd the drawing, only the one cable **18** leading from the electrode **13** to one of the spark plugs **17** is shown in Figure 1.

In circuit with a source of energy consisting of a 12 volt battery **20** is connected the primary coil **21** of an ignition coil which carries on a common iron core **22** a secondary high voltage coil **24** which is also connected in circuit with the battery **20**. Current from the battery is applied to the primary winding **21** every time when an interrupter cam **25** also mounted on shaft **11** urges the interrupter switch arm **26** against its stationary contact **27** so as to connect the second end of the primary winding **21** with the grounded minus connection of the battery **20**. Every time when the interrupter arm **26** under the action of a spring, not shown, separates from the stationary contact **27** and thereby interrupts the battery current flowing through the primary winding **21** of the ignition coil, an ignition voltage is induced in the high voltage winding **24** which is connected with the rotating distributor electrode so that this ignition voltage is transmitted to the spark plugs **17** in sequence corresponding to the various positions of the electrode **12** with respect to the stationary electrodes **13**—**16**.

The engine **10** is provided with an air intake pipe **30** equipped with a filter **31**. A tiltable choke plate **80** is mounted inside the pipe **30**, and an injection nozzle **32** is mounted to communicate with the pipe **30**, fuel injection control means being connected with the nozzle **32**. The fuel injection control means comprise a chamber **33** which is supplied with fuel under constant pressure through a feed pipe **37** and a valve cone **35** is mounted therein movable in axial direction. The valve cone **35** is connected with an armature member **36** located movably within a solenoid coil **34**. Whenever and as long as a current J furnished by electronic amplifier means 28 flows through the solenoid coil 34 in a strength sufficient for lifting the armature 36 and consequently the valve cone 35 from its valve seat, fuel is able to flow from the chamber 33 through the nozzle 32 into the air intake pipe 30 for producing the required fuel-air mixture. The longer the valve cone 35 is lifted from its seat, the more fuel will flow from the fuel injection control means into the air intake pipe 30.

The fuel injection valve is opened, as will be explained further below, every time when a control cam 38 mounted on the same shaft 11 as the interrupter cam 25 closes the switch 39. However, the duration of the period through which the fuel injection valve remains open and thus the amount of fuel injected in every cycle of its operation is regulated depending upon the varying operating conditions of the engine by means of the electrical apparatus described further below.

In the particular embodiment illustrated in Figure 1, the electrical apparatus comprised in the fuel injection system according to the invention, includes a monostable flip-flop device 40 and a timing device 41. These two main components are surrounded in Figure 1 by dotted lines. As is generally known, a flip-flop device is capable of changing between a stable condition and an unstable condition. In the present case the flip-flop device serves the purpose of furnishing in its unstable condition a current impulse to the solenoid coil 34 of the injection control means causing the valve 35 to open and to stay open, but permits the closing of the valve 35 by automatically returning to its stable condition when the control impulse which has changed the flip-flop device to its unstable condition, is terminated. In other words, during the time during which the flip-flop device is in its unstable condition the injection valve 35 is open and the duration of the unstable condition of the flip-flop device determines the duration of the open position of the injection valve 35 and thus the amount of fuel injected into the air pipe 30. As will be explained in detail below, the unstable condition of the flip-flop device can be only maintained until a condenser 58 forming part of the flip-flop device and charged during the stable condition thereof is discharged. The time of discharge is determined by a series combination of resistors 59 and 60 connected in parallel with the condenser 58. The purpose of the time control device 41 consists in furnishing a control potential which depends in its magnitude upon the varying rotational speeds of the engine and which determines or at least influences the period of time through which the flip-flop device 40 remains in its unstable condition.

Both the flip-flop device 40 and the time control device 41 are connected on one side with a common supply line 42 which is connected to the positive terminal of the battery 20. A common ground connection 43 is connected to the negative terminal of the battery 20. The actuation of the flip-flop device in synchronism with the rotational speed of the engine is effected by the above mentioned cam member 38 rotating with the distributor shaft 11 and by the switch 39 operated by the cam 38 and connected in series combination with a resistor 51 of e.g. 20,000 ohm between the positive line 42 and the grounded negative line 43. A coupling condenser 52 is connected to a junction point P3 between the switch 39 and the resistor 51 and is connected on the other side with a resistor 53 and a germanium diode 54. The other terminal of the diode 54 is connected with the base of a transistor T1 forming also a part of the flip-flop device 40. The base of this transistor is also connected by a resistor 55 of e.g. 5,000 ohm with the positive line 42, and at the same time by a resistor 56 via junction point P2 with the collector K2 of another transistor T2 of the flip-flop device 40. The just mentioned collector K2 of the transistor T2 is connected via junction point P2 and a resistor 67 of e.g. 5,000 ohm with the grounded line 43. The emitter E2 of the transistor T2 is connected with the sliding tap of a potentiometer R which in turn is connected at one end with the positive line 42 and with its other end with the emitter E3 of a transistor T3 which belongs to the time control device 41.

The time limit element of the flip-flop device 40 comprises the above mentioned condenser 58 and the series combination of resistors 59 and 60 and is connected in circuit between the junction point P1 and the base of the transistor T2, the junction point P1 being located between two resistors 61 and 62. The resistor 61 has e.g. a value of 5,000 ohm and is connected to the grounded line 43 while the resistor 62 has e.g. only a value of 1,200 ohm and is connected with the collector K1 of the transistor T1. Finally, a resistor 63 of e.g. 5,000 ohm is connected between the ground line 43 and the emitter E1 of the transistor T1, and an emitter resistor 64 of e.g. 500 ohm is connected with the positive line 42.

Of the two resistors forming part of the time limit of the flip-flop device 40, the resistor 59 is preferably variable depending upon the prevailing pressure and temperature of the surrounding air by means of e.g. a diaphragm device 59′ as shown diagrammatically being connected with the control member 59″, while the other resistor 60 is a fixed resistor. Assuming that the condenser 58 has a capacity of 0.1 μf., the total series resistance of the two resistors 59 and 60 should not exceed a value of 150,000 ohm.

The connection between the base of the transistor T2 and the junction point P4 between the resistor 60 and one terminal of the condenser 58, includes a resistor 65 of e.g. 5,000 ohm which is only shown because it favorably influences the operation of the flip-flop device without being absolutely necessary.

An amplifier transistor 28 is connected with its base via junction point P2 with the collector K2 of the transistor T2. The emitter E28 of the transistor 28 is directly connected with the positive line 42 while the collector K28 is connected with one end of the solenoid coil 34 of the injection control device. The other end of the coil 34 is connected to ground and thereby to the negative terminal of the battery 20.

The time control device 41 includes, in addition to the above mentioned transistor T3, a silicon diode 75 which is connected between the positive line 42 and the base of the transistor T3. This base is also connected across a differentiating timing network composed of a coupling condenser 76 of e.g. approximately 100 micromicrofarad and an attenuating resistor 77 of e.g. 20,000 ohm, with the primary winding 21 of the ignition coil. While the emitter electrode E3 of the transistor T3 is connected with a charging condenser 78 of e.g. 200 μf. which is connected, in parallel with the potentiometer R, with the line 42. Thus the above mentioned diode 75 is connected in parallel with the transistor T3 and the charging condenser 78.

It can be seen, that whenever the switch arm 26 of the interrupter device is urged by the interrupter cam 25 against the stationary contact 27, the coupling condenser 76 is charged via the emitter-base circuit of the transistor T3 by the pulses originating in the primary winding 21 of the ignition coil. Each of these pulses causes the transistor T3 to become conductive for a period of time which is determined by the charging time constant of the timing network composed of the resistor 77 and the coupling condenser 76, which however is independent of the number of revolutions or the rotational speed of the engine. As long as the transistor T3 is conductive the condenser 78 is charged. The potentiometer R must have so high a resistivity that the condenser 78 loses thereacross during the intervals between the pulses furnished by the interrupter 25—27 only a portion of the charge built up during the duration of said pulses. Therefore, its average charge potential is the higher the faster the engine rotates because in this case the time available for discharging becomes shorter.

The sliding tap of the potentiometer R is operatively connected with actuating means connecting a foot pedal **81** with the above mentioned choke plate **80** in the air-intake pipe **30**. Therefore, the sliding tap is moved along the potentiometer R in conjunction with the operation of the choke **80**. Therefore, the greater the degree of opening of the choke **80**, the more the sliding tap is moved toward the line **42**, and the smaller is the portion of the charge potential of the charging condenser **78** which is applied to the emitter E2 of the transistor T2. On the other hand, when choke **80** is only slightly opened, e.g. $\alpha=2.5°$, then the sliding tap is positioned near the opposite end of the potentiometer R so that practically the full charge potential of the condenser **78** is applied to the emitter E2 of the transistor T2. This has the effect that the voltage appearing between the emitter E2 and the grounded line **43** is smaller than the full battery voltage. This is due to the fact that the potential of the emitter E3 and therefore also the potential of the emitter E2 becomes smaller than the potential of the positive line **42** as soon as the voltage tapped off of the potentiometer R and acting in opposition to the battery voltage, has a value which is above the value 0. Hence the average charge potential of the condenser **78** increases with increasing rotational speed of the engine, the emitter-base current flowing through the transistor T2 and through the resistors **65**, **60**, **59** and **61** decreases with increasing rotational speed of the engine, as long as the transistor T1 is non-conductive. Thus, the potential U_L of the condenser **58** will always decrease with increasing rotational speed of the engine.

It should be noted that in the circuit illustrated by Figure 1 the transistors T1, T2, and **28** are coupled consecutively with each other in such a manner that each transistor is connected with the collector of the preceding transistor so that each following transistor is always in opposite conductive condition as compared with the condition of the preceding transistor.

In practice, the flip-flop device **40** operates as follows: As long as the switch **39** is in open position the transistor T1 is non-conductive while the transistor T2 is conductive. This will be understood by considering that, under the assumption of the above given values of resistances and voltages, the collector potential $k2$ of the transistor T2 is approximately 10 volt. Under the same assumption the base potential of the transistor T1, determined by the resistors **55** and **56**, has the value $b1=11.3$ volts. The emitter potential of the transistor T1, determined by the resistors **63** and **64**, amounts to $e1=10.9$ volts. Since now the potential $b1$ is higher than the emitter potential $e1$ no control current can flow from the emitter to the base of the transistor T1. Thus the transistor T1 is non-conductive.

Under these circumstances the potential $p1$ at the junction point P1 then depends practically only on that voltage drop which is caused in the resistor **61** by the base current of the transistor T2 flowing from that base through the resistors **65**, **60**, **59** and **61**. If it is now assumed that for a certain rotational speed of the engine and for the position of the sliding tap of the potentiometer R as shown in Figure 1 the emitter potential $e2$ of the transistor T2 is at least temporarily approximately constant in the amount of 11 volts, then the base potential $b2$ of the transistor T2 is approximately 10 volts. Assuming further that the fixed resistor **60** has 40,000 ohms and at the given moment the resistance adjusted at the air pressure controlled resistor **59** is 15,000 ohms then the voltage drop appearing across the resistors **60** and **59** is approximately 8.3 volts while a potential $p1$ of 0.8 volt appears at the junction point P1. Consequently, the condenser **58** is charged to a potential of 8.3 volts as long as the switch **39** is open and the transistor T1 is therefore non-conductive.

As soon as the cam member **38** at the time t_1 (see Fig. 2) closed by the cam member **38** moving the switch **39** into its closed position, the base potential $b1$ of the transistor T1 is lowered temporarily for a short period approximately to 0 because in this instance the coupling condenser **52** is discharged and constitutes at the moment of the closure of the switch **39** practically a short circuit. Only now a control current can flow from the emitter E1 of the transistor T1 to its base so as to make this transistor T1 so strongly conductive that its collector current J_{K1} becomes about 1.8 ma. and causes across the resistor **61** a voltage drop of approximately 9 volts. Consequently, the potential $p1$ at the junction point P1 which is connected with the now charged condenser **58**, rises to a value of 9 volts. Since the condenser **58** has its full charge potential U_L the effect of the started collector current J_{K1} of the transistor T1 is that the potential $b2$ at the base of the transistor T2 is raised by the addition of the above mentioned voltage drop of 9 volts across the resistor **61** to a new potential of 17 volts. This potential is under all circumstances above the emitter potential $e2$ of the transistor T2. However, the transistor T2 can only carry current if and as long as its base potential is lower than its emitter potential. Thus, the closing of the switch **39** causes the transistor T2 to be temporarily non-conductive so that no emitter-base current can flow any longer. The collector potential $k2$ now amounts to 3 volts which potential is practically determined only by the current flowing through the resistor **55**, **56** and **67**. For the reasons stated, after the time t_1 no charge can be applied to the condenser **58** via the resistor **65**. Therefore, the condenser **58** is discharged comparatively quickly via the two resistors **60** and **59**. To the extent as the condenser **58** discharges, and as its potential U_L decreases, also the potential at the base of the transistor T2 drops gradually to a value below the emitter potential $e2$ as can be seen in Figure 2. This condition is established at the time t_2 whereafter the transistor T2 is again capable to cause the flow of a current through the resistor **67** whereby the potential of the junction point P2 is caused to become substantially positive so that the transistor T1 and consequently the transistor **28** are suddenly rendered non-conductive.

Returning once more to the above described performance, the current flowing through the resistors **55**, **56** and **67** which determined the collector potential $k2$ of 3 volts, produces at the resistor **55** connected between the line **42** and the base of the transistor T1 a base potential $b1$ of 9 volts which is sufficiently low in comparison to the emitter potential $e1$ of 10.9 volts for maintaining the transistor T1 in conductive condition even at the time when the switch **39** is again in open condition and the impulse passing through the meanwhile charged coupling condenser **52** has terminated.

It can be seen that the flip-flop device **40** does not return to its original stable condition before the condenser **58** forming part of its time limit component has discharged from its previous charge potential U_L of 8.3 volts to such an extent that the potential $b2$ at the base of the transistor T2 has dropped from 17.3 volts to a value below the emitter potential $e2$ of 11 volts that was tapped off the potentiometer R. As stated above this occurred at the time t_2 and now transistor T2 becomes conductive again and therefore causes current to flow across the resistor **67**. Hereby, as stated above, the potential at the junction point P2 becomes sufficiently positive for causing both the transistor T1 and the transistor **28** to become non-conductive. Hereby, as can be seen from the diagram, the energizing current J for the solenoid coil **34** is cut off so that the injection valve **35** closes. Consequently, the duration of injection of fuel through the nozzle **32** is limited between the times t_1 and t_2, as shown clearly in Figure 2. Referring now to Figure 3 it can be seen that the amount M of fuel injected per cycle of the engine must be regulated in a manner depending upon the number of revolutions n of the engine, and also depending upon the opening angle α of the choke **80** shown in Figure 1. It can be seen from the graph of Fig. 3 that for instance in the case of an angle $\alpha=2.5°$ of choke opening corresponding to idling of the engine, the amount of fuel M must be reduced from an amount of 28 $mm.^3$ at 250 r.p.m. to about 7 $mm.^3$ at 750 r.p.m. while for example in the case of an opening angle of 60° the requirement for fuel supply remains practically unchanged over the entire speed range of the engine and amounts to approximately 48 $mm.^3$.

A performance conforming with curves shown in Figure 3 is obtained by the control device 41 because the sliding tap of the potentiometer is so connected operatively with the foot pedal 81 that, as mentioned above, the sliding tap is moved together with the turning of the foot pedal 81 in counterclockwise direction as seen in Figure 1, in such a manner that the tap moves toward that end of the potentiometer which is connected with the line 42. On the other hand whenever the pedal 81 returns under the action of a return spring not shown, into its position corresponding to idling of the engine, the tap is moved towards the other end of the potentiometer which is connected with the emitter E3 of the transistor T3.

Since the average charge potential of the charging condenser 78 increases with increasing rotational speed of the engine, the emitter potential of the transistor T2 rises simultaneously so that the charging potential built up at the condenser 58 during the intervals between the consecutive changes of condition of the flip-flop device, decreases accordingly. If in this manner the charge potential of the condenser 58 is reduced to a value U_n then the second curve marked $b2'$ in Figure 2 applies to this condition. The reduced charge potential U_n causes the base potential $b2'$ of the transistor T2 to drop earlier to a value at which the transistor T2 cannot be kept any longer in its non-conductive condition, but on the contrary, becomes conductive and therefore causes the injection valve 35 to close substantially earlier. The moment when this condition is obtained is marked in Fig. 2 as t_3.

It can be seen therefore that as long as the sliding tap of the potentiometer R is kept by the corresponding position of the pedal 81 in a position in which a substantial portion of the charge potential of the condenser 78 is tapped off the potentiometer R the amount of fuel M injected per cycle drops off with increasing rotational speed of the engine in conformity with illustration thereof in Fig. 3. However, when the choke plate 80 is in completely open position then the sliding tap will be positioned so close to the potentiometer end R' near the positive line 42 that practically no potential at all is tapped off the potentiometer R. Then the duration of the open position of the injection valve is then practically independent of changes of the speed or number of revolutions of the engine.

It will be understood that each of the elements described above, or two or more together, may also find a useful application in other types of fuel injection systems differing from the types described above.

While the invention has been illustrated and described as embodied in speed responsive fuel injection system for an internal combustion engine, it is not intended to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the spirit of the present invention.

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 that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be secured by Letters Patent is:

1. A speed-responsive fuel injection system for an internal combustion engine having an ignition control device, comprising, in combination, timing means adapted to be actuated by the ignition control device of the internal combustion engine for producing a sequence of electrical pulses in synchronism with the operational frequency of said ignition control device so that the number of said electrical pulses is proportional to the rotational speed of said engine, said timing means including electrical means capable of converting said pulses into a control potential, the average value of which is proportionate to the operational frequency of the ignition control device; electrically controllable fuel injection means adapted to be controlled by said control potential of said electrical means in such a manner that the injection admission rate of said fuel injection means is determined by said control potential of said electrical means; and actuating means in circuit with said electrically controllable fuel injection means and with said electrical means, whereby said injection admission rate of said fuel injection means is regulated in a predetermined proportion to the rotational speed of said internal combustion engine.

2. A speed-responsive fuel injection system for an internal combustion engine having an ignition control device, comprising, in combination, timing means adapted to be actuated by the ignition control device of the internal combustion engine for producing a sequence of electrical pulses in synchronism with the operational frequency of said ignition control device so that the number of said electrical pulses is proportional to the rotational speed of said engine, said timing means including capacitor means capable of being charged by said pulses to a charge potential, the average value of which is proportionate to the operational frequency of the ignition control device; electrically controllable fuel injection means adapted to be controlled by said charge potential of said capacitor means in such a manner that the injection admission rate of said fuel injection means is determined by said charge potential of said capacitor means; and actuating means in circuit with said electrically controllable fuel injection means and with said capacitor means, whereby said injection admission rate of said fuel injection means is regulated in a predetermined proportion to the rotational speed of said internal combustion engine.

3. A speed-responsive fuel injection system for an internal combustion engine operated by an external ignition control device, comprising, in combination, a source of electrical energy; timing means connected with said ignition control device for producing a sequence of pulses in synchronism with the operational frequency of said ignition control device, said timing means including capacitor means capable of being charged by said pulses to a charge potential increasing with the operational frequency of said ignition control device; monostable flip-flop means operatively connected with said ignition control device for being sequentially changed into its unstable condition in synchronism with said operational frequency of said ignition control device, and connected with said timing means for being returned to its stable condition after a time interval depending upon said charge potential of said capacitor means; and electrically controllable fuel injection means in circuit with said source of electrical energy and with said flip-flop means in such a manner that said fuel injection means is held in open position as long as said flip-flop means is in its unstable condition, whereby the amount of fuel injected through said fuel injection means into said engine during each operational cycle is automatically regulated in a predetermined proportion to the rotational speed of said internal combustion engine.

4. A speed-responsive fuel injection system for an in-

ternal combustion engine operated by an external ignition control device, comprising, in combination, a source of electrical energy; first timing means connected with said ignition control device for producing a sequence of pulses in synchronism with the operational frequency of said ignition control device and having a predetermined pulse duration independent of variations of said operational frequency of said ignition control device; second timing means connected to said first timing means and comprising transistor means and capacitor means in circuit with each other for converting said sequence of pulses into a charge potential of said capacitor increasing with an increase of said operational frequency of said ignition control device; monostable flip-flop means operatively connected with said ignition control device for being sequentially changed into its unstable condition in synchronism with said operational frequency of said ignition control device, and connected with said second timing means for being returned to its stable condition after a time interval depending upon said charge potential of said capacitor means; and electrically controllable fuel injection means in circuit with said source of electrical energy and with said flip-flop means in such a manner that said fuel injection means is held in open position as long as said flip-flop means is in its unstable condition, whereby the amount of fuel injected through said fuel injection means during each operational cycle is automatically regulated in a predetermined proportion to the rotational speed of said internal combustion engine.

5. A speed-responsive fuel injection system for an internal combustion engine operated by an external ignition control device, comprising, in combination, a source of electrical energy; first timing means connected with said ignition control device for producing a sequence of pulses in synchronism with the operational frequency of said ignition control device and having a predetermined pulse duration independent of variations of said operational frequency of said ignition control device; second timing means connected to said first timing means and comprising first transistor means and capacitor means in circuit with each other for converting said sequence of pulses into a charge potential of said capacitor increasing with an increase of said operational frequency of said ignition control device; monostable flip-flop means operatively connected with said ignition control device for being sequentially changed into its unstable condition in synchronism with said operational frequency of said ignition control device, and connected with said second timing means for being returned to its stable condition after a time interval depending upon said charge potential of said capacitor means, said flip-flop means including at least one second transistor and a sliding tap type potentiometer connected in parallel with said capacitor means, the sliding tap of said potentiometer being connected with the control electrode of said second transistor so that a portion of said charge potential of said capacitor means is applied to said second transistor depending upon the setting of said sliding tap along said potentiometer; and electrically controllable fuel injection means in circuit with said source of electrical energy and with said flip-flop means in such a manner that said fuel injection means is held in open position as long as said flip-flop means is in its unstable condition, whereby the amount of fuel injected through said fuel injection means during each operational cycle is automatically regulated in a predetermined proportion to the rotational speed of said internal combustion engine.

6. A speed-responsive fuel injection system for an internal combustion engine operated by an external ignition control device, comprising, in combination, a source of electrical energy; first timing means connected with said ignition control device for producing a sequence of pulses in synchronism with the operational frequency of said ignition control device and having a predetermined pulse duration independent of variations of said operational frequency of said ignition control device; second timing means connected to said first timing means and comprising first transistor means and capacitor means in circuit with each other for converting said sequence of pulses into a charge potential of said capacitor increasing with an increase of said operational frequency of said ignition control device; monostable flip-flop means operatively connected with said ignition control device for being sequentially changed into its unstable condition in synchronism with said operational frequency of said ignition control device, and connected with said second timing means for being returned to its stable condition after a time interval depending upon said charge potential of said capacitor means, said flip-flop means including at least one second transistor and a sliding tap type potentiometer connected in parallel with said capacitor means, the sliding tap of said potentiometer being connected with the control electrode of said second transistor so that a portion of said charge potential of said capacitor means is applied to said second transistor depending upon the setting of said sliding tap along said potentiometer; control means operatively connected with said sliding tap of said potentiometer and with the air supply control means in the engine, for causing said portion of said charge potential to increase in proportion with an increase of air supply effected by operation of said air supply control means, so as to correlate said portion of said charge potential with the varying operating conditions of said engine; and electrically controllable fuel injection means in circuit with said source of electrical energy and with said flip-flop means in such a manner that said fuel injection means is held in open position as long as said flip-flop means is in its unstable condition, whereby the amount of fuel injected through said fuel injection means during each operational cycle is automatically regulated in a predetermined proportion to the rotational speed of said internal combustion engine.

7. A speed-responsive fuel injection system for an internal combustion engine operated by an external ignition control device, comprising, in combination, a source of electrical energy; first timing means connected with said ignition control device for producing a sequence of pulses in synchronism with the operational frequency of said ignition control device and having a predetermined pulse duration independent of variations of said operational frequency of said ignition control device; second timing means connected to said first timing means and comprising first transistor means and capacitor means in circuit with each other for converting said sequence of pulses into a charge potential of said capacitor increasing with an increase of said operational frequency of said ignition control device; monostable flip-flop means operatively connected with said ignition control device for being sequentially changed into its unstable condition in synchronism with said operational frequency of said ignition control device, and connected with said second timing means for being returned to its stable condition after a time interval depending upon said charge potential of said capacitor means, said flip-flop means including at least one second transistor and a sliding tap type potentiometer connected in parallel with said capacitor means, the sliding tap of said potentiometer being connected with the control electrode of said second transistor so that a portion of said charge potential of said capacitor means is applied to said second transistor depending upon the setting of said sliding tap along said potentiometer; control means operatively connected with said sliding tap of said potentiometer and with the air supply control means of the engine, for causing said portion of said charge potential to increase in proportion with an increase of air supply effected by operation of said air supply control means, so as to correlate said portion of said charge potential with the varying operating conditions of said engine; and electrically controllable fuel injection means in circuit with said source of electrical

energy and with said flip-flop means in such a manner that said fuel injection means is held in open position as long as said flip-flop means is in its unstable condition; transistor amplifier means being connected in said circuit between the output of said flip-flop means and said electrically controllable fuel injection means, for amplifying the current supplied by said source of energy through said flip-flop means, whereby the amount of fuel injected through said fuel injection means during each operational cycle is automatically regulated in a predetermined proportion to the rotational speed of said internal combustion engine.

8. A speed-responsive fuel injection system for an internal combustion engine operated by an external ignition control device, comprising, in combination, a source of electrical energy; first timing means connected with said ignition control device for producing a sequence of alternating positive and negative pulses in synchronism with the operational frequency of said ignition control device and having a predetermined pulse duration independent of variations of said operational frequency of said ignition control device; second timing means connected to said first timing means and comprising transistor means and capacitor means in circuit with each other

for converting said sequence of pulses into a charge potential of said capacitor increasing with an increase of said operational frequency of said ignition control device, rectifier means being connected in parallel with said transistor and capacitor means, for short-circuiting every other one of said alternating pulses; monostable flip-flop means operatively connected with said ignition control device for being sequentially changed into its unstable condition in synchronism with said operational frequency of said ignition control device, and connected with said second timing means for being returned to its stable condition after a time interval depending upon said charge potential of said capacitor means; and electrically controllable fuel injection means in circuit with said source of electrical energy and with said flip-flop means in such a manner that said fuel injection means is held in open position as long as said flip-flop means is in its unstable condition, whereby the amount of fuel injected through said fuel injection means during each operational cycle is automatically regulated in a predetermined proportion to the rotational speed of said internal combustion engine.

No references cited.