July 5, 1960 R. BOSCH ET AL 2,943,614

FUEL INJECTION ARRANGEMENT

Filed May 1, 1958

FIG. 1

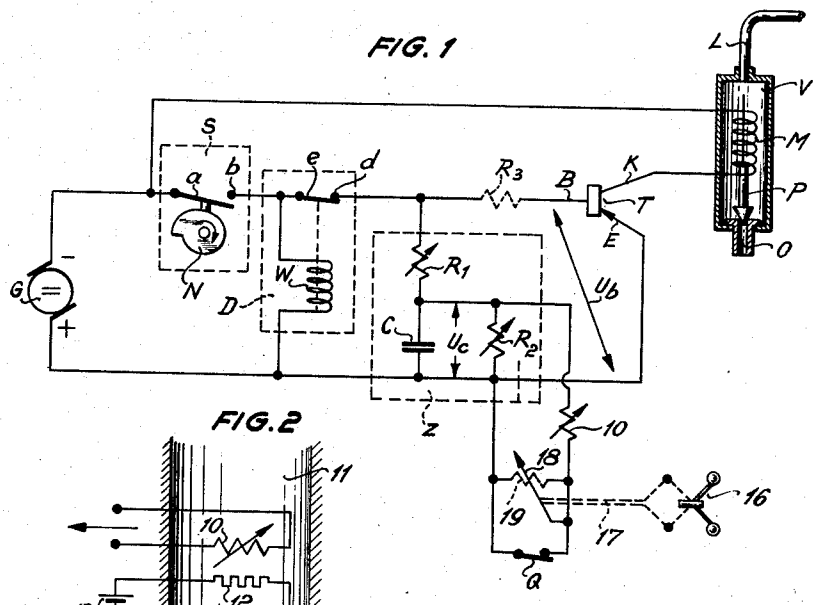


FIG. 2

FIG. 3

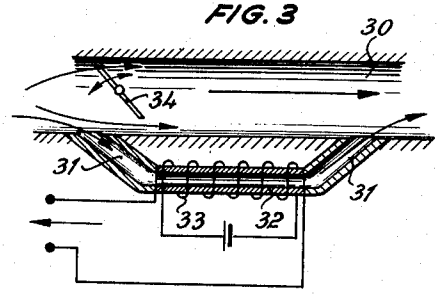


FIG. 4

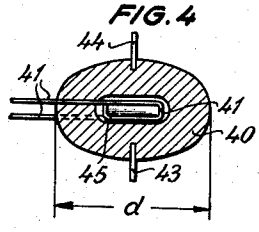


FIG. 5

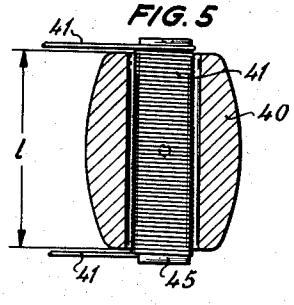
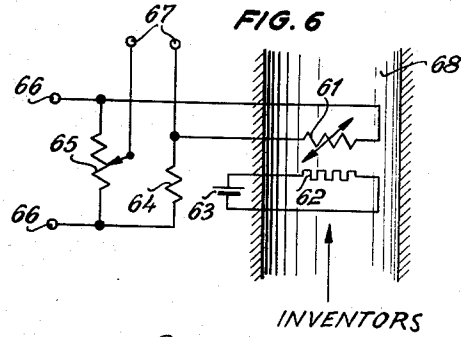


FIG. 6



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United States Patent Office 2,943,614 Patented July 5, 1960

2,943,614

FUEL INJECTION ARRANGEMENT

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Filed May 1, 1958, Ser. No. 732,232

Claims priority, application Germany May 2, 1957

20 Claims. (Cl. 123—139)

The present invention relates to a fuel injection arrangement.

More particularly, the present invention relates to a fuel injection arrangement for an internal combustion engine of the type wherein an electrically operated valve is used to control the flow of fuel to the engine. In known arrangements of this type the valve is a normally closed one and is opened upon energization, and such energization is brought about automatically by a switch device which is synchronized with the operation of the engine. In such arrangements there arises the problem of providing suitable means for controlling the duration of fuel injection, i.e., of providing suitable means for maintaining the valve open the required length of time depending upon the conditions under which the engine is operated, such as high speed, low speed, full load, partial load, etc. Experience has shown that considerable difficulties arose in converting the various required time lengths into electrical quantities which control the operation of the valve that regulates the fuel supply to the engine.

In addition, however, it is desirable to control the amount of fuel injected per stroke of the engine in such a manner that for the sake of fuel economy a most favorable ratio between fuel and air drawn into the cylinder is established.

It is therefore an object of this invention to provide a fuel injection arrangement capable of controlling the amount of fuel injection depending upon the amount of air drawn into the cylinder with each effective stroke or cycle.

It is still another object of the present invention to provide a fuel injection arrangement in which the time interval during which fuel is injected is easily controlled.

It is yet another object of the present invention to provide a fuel injection arrangement wherein the time interval during which fuel is injected is predeterminable independently of the instant at which fuel injection commences.

The objects of the present invention also include the provision of a fuel injection arrangement which may be constructed and maintained at very low cost, and which will give long periods of trouble-free service.

The objects of the present invention additionally include the provision of a fuel injection arrangement which may readily be built into existing constructions.

With the above objects in view, the present invention mainly consists in an improved fuel injection arrangement for an internal combustion engine which comprises valve means for controlling the flow of fuel to the engine, and means which are operatively associated with the engine and with the valve means for opening the latter at a predetermined instant during a cycle of operation of the engine and for closing the valve means after the elapse of a time interval the duration of which is predeterminable independently of the instant at which the valve means are opened.

More particularly, the present invention comprises

electrically operated valve means for controlling the flow of fuel to the engine, the construction of the valve means being such that when it is unenergized it occupies its closed position and that when it is energized it occupies its open position; a source of electrical energy; an electron flow control device having a control branch and a power branch through which electrons may flow only when the control branch is electrically biased above a predetermined minimum voltage, the power branch being in a circuit with the source of electrical energy and with the valve means; voltage supplying means for impressing across the control branch at a predetermined instant during a cycle of operation of the engine a voltage greater than the minimum voltage, the voltage supplying means being so constructed and arranged that the duration of the impression of voltage is shorter than the time interval throughout which the valve means is to be maintained in its open position; a resistor-capacitor time delay circuit connected across the control branch and adapted to be charged by the voltage supplying means during the impression of voltage across the control branch to a voltage greater than the minimum voltage for maintaining the voltage across the control branch above the minimum voltage for a predetermined time interval following the cessation of the impression of voltage by the voltage supplying means; and resistance means sensitive to the amount of air drawn-in into the cylinder per cycle of said engine, and connected in parallel with said delay circuit for modifying the delaying action of said delay circuit by shunting the resistor component of said delay circuit depending upon said amount of air.

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:

Fig. 1 is a schematic diagram of a fuel injection arrangement according to the present invention; and

Fig. 2 is a diagrammatic partly sectional illustration of that portion of the arrangement which is sensitive to the amount of drawn-in air;

Fig. 3 is a diagrammatic, partly sectional view of a modification of the embodiment shown in Fig. 2;

Figs. 4 and 5 are cross-sectional and longitudinal-sectional views, respectively of still another modification of the embodiment of Fig. 2; and

Fig. 6 illustrates diagrammatically a bridge-circuit operatively connected with the arangement of Fig. 2.

Referring now to the drawings, and to Fig. 1 thereof in particular, there is shown a fuel injection arrangement which incorporates an electrically operated valve V. The latter controls the flow of fuel from a supply conduit L to a connecting conduit O which communicates with the internal combustion engine (not shown). The valve is of the electro-magnetic type and includes a winding M which attracts a valve plunger P. The latter is continuously urged downwardly, is as viewed in Fig. 1, to its closed position by a suitable bias spring (not shown), but is raised to its open position upon energization of the coil M. Thus, the valve V is one which when unenergized occupies its closed position and when energized occupies its open position.

The winding M is connected in circuit with the collector K and the emitter E of a PNP-type transistor T, as well as with a source of electrical energy G, the latter normally being the battery or other D.C. source which is usually associated with an internal combustion engine. The base of the transistor is indicated at B, the connection

of the transistor being of the common-emitter type so that the collector-emitter circuit constitutes the power branch of the transistor and the base-emitter the control branch. As is well known in the art, the transistor is an electron flow control device which is conductive only when a certain minimum electrical bias is impressed across the control branch. This means that electrons may flow through the power branch of the transistor only when a voltage greater than the required minimum voltage is impressed across the control branch. In practice, the transistor may be a 2N173.

The base B of the transistor T is connected to the source of electrical energy G by way of a limiting resistor R_3 (shown in dotted lines only, inasmuch as the electrical effect thereof on the entire circuit is inconsequential), a relay-type time delay switch D and an additional switch S. The latter has a stationary contact *b* and a movable contact *a* which can be moved to closed position by a rotating cam N which is suitably coupled to the crankshaft of the engine (not shown) so that the switch S is periodically actuated by, and operates in synchronism with, the engine. In this way, the switch S will, during successive cycles of operation of the engine, always be closed at the same predetermined instant, which, in practice, is the instant at which the work stroke commences.

The time delay switch D has a stationary contact *d* and a normally closed movable contact arm *e* which is mechanically connected to an armature that cooperates with a winding W. The electrical connection of the latter is such that when the switch S is closed, the winding is energized by the source G and the switch D opened. The switch D is so constructed and arranged that there is a brief delay between the instant the winding W starts to be energized and the instant that the arm *e* is actually moved out of engagement with the stationary contact *d*. This time delay, the significance of which will be described below, is of the order of several milliseconds.

Additionally, a resistor-capacitor time delay circuit Z is connected across the control branch of the transistor, i.e., across the base B and the emitter E. The time delay circuit includes a capacitor C, a variable charging resistor R_1, and a variable discharge resistor R_2.

The operation of the above-described fuel injection arrangement is as follows:

The cam N closes the switch at the start of the work stroke of the engine. As a result, the control branch of the transistor T, the time delay circuit Z, and the winding W of the time delay switch D are connected across the source G, and this causes the following:

(1) With the voltage of the source G being greater than the minimum voltage required to render the transistor conductive, a sufficiently high voltage is impressed across the control branch to render the transistor conductive (the transistor having been left non-conductive at the end of the previous cycle of operation). This, in turn, permits a current to flow through the power branch so that the winding M of the valve V is energized, thereby raising the plunger P and opening the valve V. It will be apparent that the valve V will be maintained in its open position only so long as the electrical bias across the control branch of the transistor is sufficient to permit enough current to flow through the power branch as will adequately energize the winding M. For purposes of explanation, it will be assumed that the winding M is sufficiently energized to hold the plunger P in its open position so long as the transistor T is conductive.

(2) A charging voltage is applied to the capacitor C of the time delay circuit Z.

(3) The winding W of the time delay switch D is energized.

The above-described three events occur simultaneously. As set forth above, there is a brief time delay between the instant of the start of energization of the winding W and the actual opening of the switch D, and the capacitance of the capacitor C and the resistances of the resistors R_1 and R_2 are such that the time delay is sufficient for the capacitor C to be charged to a voltage which is higher than the minimum voltage required to maintain the transistor T in conductive state. Consequently, by the time the contact arm *e* of the switch D is actually moved out of engagement with the stationary contact *d*, the voltage U_c across the capacitor C which, upon opening of the switch D, is the voltage U_b impressed across the control branch of the transistor, will be sufficient to maintain the transistor conductive so that current will continue to flow through the power branch thereby maintaining the valve V in its open position.

As soon as the switch D is opened, the capacitor C will commence to discharge by way of a parallel circuit one branch of which is constituted by the resistor R_2 and the other branch of which is constituted by the series circuit formed by the resistor R_1 and the emitter-to-base resistance of the transistor (the resistor R_3 being of no consequence). As soon as the capacitor has discharged to a point at which U_c is less than the voltage required to render the transistor conductive, no further current can flow through the winding M and the valve V assumes its closed position. Thus, the valve will have remained open for a certain predetermined interval following the initial closing of the switch S, it being apparent that the length of this interval can be regulated by varying the resistances of the resistors R_1 and/or R_2.

Thus, the time interval throughout which the valve V remains open subsequent to the closing of the switch S, and consequently the amount of fuel supplied into the engine, may be regulated within very wide limits independently of the instant at which fuel injection commences.

According to the invention the above described circuit is supplemented by an auxiliary circuit containing a heatable resistor **10** and a control switch Q. This auxiliary circuit is connected in parallel with the variable resistor R_2. The resistor **10** has a negative thermal characteristic and is heated up by a heating coil **12** supplied by a constant voltage source **13**. Resistors **10** and **12** are located in the air stream A in the air intake or supply tube **11**. The temperature of the heated resistor **10** is varied by the intensity of air stream A.

Evidently, the period of time during which fuel is injected from the valve O is the longer, the longer is the time required to discharge the condenser C in the time-delay circuit containing the resistor R_2. Since the heatable resistor **10** is connected in parallel with the variable resistor R_2 as long as the contacts of the switch Q are in closed position, the discharge time is small as long as the heatable resistor **10** has a low resistivity on account of low velocity of the air stream in the air supply tube. On the other hand, the discharge time and consequently the duration of the injection period increases substantially when the air velocity in the air supply tube increases because in this case the resistivity of the heatable resistor **10** increases correspondingly.

In view of the fact that the air velocity in the air supply tube also depends upon the rotational speed of the engine so that the latter may be made a factor in the control arrangement, it is also possible according to this invention to account for this factor by adding to the arrangement illustrated in Fig. 1 and described above, a governor **16** which may be coupled with the crank shaft of the engine and operatively connecting this governor through a linkage **17** or the like to the movable contact **18** of a variable resistor **19** which is connected in the delay circuit as shown in dotted lines in Fig. 1. In operation, the governor will adjust the resistor **19** in such a manner that an increase of the resistivity of the heatable resistor **10** is counteracted by a reduction of the resistivity of the resistor **19**, for instance when during a downhill ride of the car driven by the particular engine the air velocity rises due to an increase of the rotational speed of the engine.

The embodiment of the invention illustrated by Fig. 3

includes an auxiliary or bypass tube **31** arranged in parallel with the main air supply tube **30**. The central portion of the bypass tube **31** is constituted by a tubular heatable resistor **32** which is surrounded by a heater coil **33**. In order to adjust or to regulate the ratio between the portion of air passing through the bypass tube and the resistor **32**, on one hand, and the amount of air passing through the main tube **30**, a turnable throttle member **34** is arranged in the main tube **30** so that by suitably positioning the throttle member the above mentioned ratio can be changed and set by fixing the position of the throttle from the outside by conventional means not shown in the drawing.

Still another embodiment of the heatable resistor is illustrated by Figs. 4 and 5, this embodiment offering the advantage that this type of heatable resistor can easily be mounted in a standard air supply tube on account of its comparatively small size.

The heatable resistor preferably consists mainly of finely ground metal oxides, particularly chromium oxides or nickel oxides which are compressed and subsequently sintered at a temperature of approximately 1,000° C. so as to form a resistor body **40** having substantially oval cross section and a central, approximately rectangular channel adapted to accommodate a small heater coil **41**. The length *l* of the body **40**, in a satisfactorily working embodiment of the invention, is approximately 4 mm., its greatest transverse dimension approximately 3 mm. Approximately 20 turns of a constantan wire of .08 mm. diameter are wound about a mica strip **45** of .2 mm. thickness so as to constitute a heater coil. Connecting wires **43** and **44** are attached to the resistor body **40** so that this heatable resistor may be connected into the circuits shown in Figs. 1 and 2. The particular advantage of this embodiment of a heatable resistor consists in the fact that it causes only very small delays on account of its low heat absorption, when used within a circuit or arrangement according to Fig. 1. Therefore, such a control arrangement will respond very promptly to variations of the intensity of the air stream in the supply tube **30**.

In the embodiment illustrated by Fig. 6 a heatable resistor **61** (which may be constructed according to Figs. 4 and 5) is connected in series with a resistor **64** of constant resistivity and constitutes one branch of a non-linear bridge circuit the other branch of which is formed by a potentiometer **65**. If the suitably chosen supply voltage is applied to the input terminals **66** of the bridge circuit, the heatable resistor will create a control voltage across the diagonal terminals **67** of the bridge circuit, this control voltage depending upon the air velocity in the supply tube **68**. If the heatable resistor **61** stays at low temperatures because most of the heat produced by the heater coil **62** connected to the current source **63** is carried away and absorbed by the air passing by the resistor **61** then the resistivity of this resistor is small. As the air velocity increases its resistivity increases. If the bridge circuit is adjusted to some mean value the sensitivity thereof is very great so that very substantial control voltages can be derived from the bridge circuit upon appearance of rather small current variations.

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 arrangement differing from the types described above.

While the invention has been illustrated and described as embodied in fuel injection arrangement 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. In an improved fuel injection arrangement for an internal combustion engine, in combination, valve means for controlling the flow of fuel to the internal combustion engine; and control means operatively associated with the engine and with said valve means for opening the latter at a predetermined instant during a cycle of operation of the engine and for closing said valve means after the elapse of a time interval the duration of which in predeterminable independently of said instant at which said valve means are opened, said control means including a control circuit controlling the closing of said valve means and comprising heat-sensitive resistor means installed in the air supply stream of said engine and connected in said circuit for determining said time interval, heating means being mounted adjacent to said resistor means for heating the latter, the temperature and therefore the resistance thereof depending upon the amount of air drawn into the cylinder means of said engine per operational cycle.

2. In an improved fuel injection arrangement for an internal combustion engine, in combination, electrically operated valve means for controlling the flow of fuel to the internal combustion engine, said valve means when unenergized occupying its closed position and when energized occupying its open position; energizing means operatively associated with the engine and in circuit with said valve means for energizing the latter at a predetermined instant during a cycle of operation of the engine; and deactivating means in circuit with said energizing means for deactivating the same after the elapse of a time interval the duration of which is predeterminable independently of said instant at which said valve means are opened, said deactivating means including heat-sensitive resistor means installed in the air supply stream of said engine and connected in said circuit for determining said time interval, heating means being mounted adjacent to said resistor means for heating the latter, the temperature and therefore the resistance thereof depending upon the amount of air drawn into the cylinder means of said engine per operational cycle.

3. In an improved fuel injection arrangement for an internal combustion engine, in combination, electrically operated valve means for controlling the flow of fuel to the internal combustion engine, said valve means when unenergized occupying its closed position and when energized occupying its open position; a source of electrical energy; an electron flow control device having a control branch and a power branch through which electrons may flow only when said control branch is electrically biased above a predetermined minimum bias, said power branch being in circuit with said source of electrical energy and with said valve means; biasing means for impressing across said control branch at a predetermined instant during a cycle of operation of the engine a bias greater than said minimum bias, said biasing means being so constructed and arranged that the duration of the impression of bias is shorter than the time interval throughout which said valve means is to be maintained in its open position; and a time delay circuit including resistor and capacitor means, and being connected across said control branch and adapted to be charged by said biasing means during the impression of bias across said control branch to a bias greater than said minimum bias for maintaining the bias across said control branch above said minimum bias for a predetermined time interval following the cessation of the impression of bias by said biasing means, and a heat-sensitive resistor device mounted in the air supply stream of said engine and connected in parallel with at least a portion of said resistor means for modifying the operation of said time-delay circuit depending upon the

amount of air drawn into said engine per operational cycle.

4. In an improved fuel injection arrangement for an internal combustion engine, in combination, electrically operated valve means for controlling the flow of fuel to the internal combustion engine, said valve means when unenergized occupying its closed position and when energized occupying its open position; a source of electrical energy; an electron flow control device having a control branch and a power branch through which electrons may flow only when said control branch is electrically biased above a predetermined minimum voltage, said power branch being in circuit with said source of electrical energy and with said valve means; a time delay circuit including resistor and capacitor means, and being connected across said control branch, and a heat-sensitive resistor device mounted in the air supply stream of said engine and connected in parallel with at least a portion of said resistor means for modifying the operation of said time-delay circuit depending upon the amount of air drawn into said engine per operational cycle; and means connected in parallel with said control branch and with said time delay circuit for impressing thereacross at a predetermined instant during a cycle of operation of the engine a voltage which is greater than said minimum voltage, said last-mentioned means being so constructed and arranged that the duration of the impression of voltage is shorter than the time interval throughout which said valve means is to be maintained is its open position, whereby said time delay circuit is charged to a voltage higher than said minimum voltage and maintains the voltage across said control branch above said minimum voltage for a predetermined time interval following the cessation of the charging of said time delay circuit.

5. In an improved fuel injection arrangement for an internal combustion engine, in combination, electrically operated valve means for controlling the flow of fuel to the internal combustion engine, said valve means when unenergized occupying its closed position and when energized occupying its open position; a source of electrical energy; a transistor having a control branch and a power branch, the latter being in circuit with said source of electrical energy and with said valve means; voltage supplying means operatively associated with the engine and in circuit with said control branch of said transistor for impressing thereacross at a predetermined instant during a cycle of operation of the engine a voltage greater than that which is required to render said transistor conductive; and a time delay circuit including resistor and capacitor means, and being connected across said control branch of said transistor and adapted to be charged by said voltage supplying means, while the latter impresses a voltage across said control branch, to a voltage greater than said voltage which is required to render said transistor conductive, whereby said transistor remains conductive for a predetermined time interval following the cessation of the impression of voltage by said voltage supplying means, and a heat-sensitive resistor device mounted in the air supply stream of said engine and connected in parallel with at least a portion of said resistor means for modifying the operation of said time delay circuit depending upon the amount of air drawn into said engine per operational cycle.

6. In an improved fuel injection arrangement for an internal combustion engine, in combination, electrically operated valve means for controlling the flow of fuel to the internal combustion engine, said valve means when unenergized occupying its closed position and when energized occupying its open position; a source of electrical energy; a transistor having a control branch and a power branch, the latter being in circuit with said source of electrical energy and with said valve means; voltage supplying means operatively associated with the engine and in circuit with said control branch of said transistor for impressing thereacross, at a predetermined instant during

a cycle of operation of the engine, a voltage greater than that which is required to render said transistor conductive, said voltage supplying means being so constructed and arranged that the duration of the impression of voltage is shorter than the time interval throughout which, in said cycle, said valve means is to be maintained in its open position; and a time delay circuit including resistor and capacitor means, and being connected across said control branch of said transistor and adapted to be charged by said voltage supplying means, while the latter impresses a voltage across said control branch, to a voltage greater than said voltage which is required to render said transistor conductive, whereby said transistor remains conductive for a predetermined time interval following the cessation of the impression of voltage by said voltage supplying means and said valve means is maintained in its open position until the charge on said time delay circuit has dropped to a value at which the voltage across said control branch is below said voltage which is required to render said transistor conductive, and a heat-sensitive resistor device mounted in the air supply stream of said engine and connected in parallel with at least a portion of said resistor means for modifying the operation of said time delay circuit depending upon the amount of air drawn into said engine per operational cycle.

7. The combination defined in claim 6 wherein said resistor and capacitor means in said time delay circuit includes a resistor and a capacitor in series-circuit connection.

8. The combination defined in claim 6 wherein said resistor and capacitor means in said time delay circuit includes a resistor and a capacitor in parallel-circuit connection.

9. The combination defined in claim 6 wherein said resistor and capacitor means in said time delay circuit includes a capacitor, a first resistor in series-circuit connection with said capacitor, and a second resistor in parallel-circuit connection with said capacitor.

10. The combination defined in claim 6, wherein said heat-sensitive resistor device comprises a heatable resistor having negative thermal characteristic exposed to said air supply stream, and heating means assembled with said heatable resistor for introducing into the latter a predetermined amount of heat per unit of time so that the resistance across said heatable resistor varies in a predetermined relation to the velocity of said air stream an increase of which lowers the temperature of said heatable resistor, whereby said time interval controlled by said time delay circuit is increased as said velocity increases.

11. The combination defined in claim 3, wherein said heat-sensitive resistor device includes a non-linear bridge-circuit having one branch which is a series-combination of a fixed resistor and a heatable resistor mounted in said air supply stream, and having another branch constituted by a potentiometer so that application of a potential from an outside service to the input terminals of said bridge circuit produces a control potential across said bridge circuit depending upon the varying resistance of said heatable resistor and thereby suitable for controlling electronic amplifier means connected with said electrically operated valve means.

12. The combination defined in claim 10, wherein said heatable resistor is of tubular form and mounted so that at least a predetermined part of said air supply stream passes therethrough.

13. The combination defined in claim 10, wherein said heatable resistor is of substantially tubular form, said heating means being a resistance wire energized by an outside source and mounted within said tubular heatable resistor so that the outer surface of the latter is exposed to said air supply stream.

14. In an improved fuel injection arrangement for an internal combustion engine, in combination, electrically operated valve means for controlling the flow of fuel to

the internal combustion engine, said valve means when unenergized occupying its closed position and when energized occupying its open position; a source of electrical energy; an electron flow control device having a control branch and a power branch through which electrons may flow only when said control branch is electrically biased above a predetermined minimum bias, said power branch being in circuit with said source of electrical energy and with said valve means; biasing means for impressing across said control branch at a predetermined instant during a cycle of operation of the engine a bias greater than said minimum bias, said biasing means being so constructed and arranged that the duration of the impression of bias is shorter than the time interval throughout which said valve means is to be maintained in its open position; and a time delay circuit including a resistor component and a capacitor component, and being connected across said control branch and adapted to be charged by said biasing means during the impression of bias across said control branch to a bias greater than said minimum bias for maintaining the bias across said control branch above said minimum bias for a predetermined time interval following the cessation of the impression of bias by said biasing means, and a heat-sensitive resistor device mounted in the air supply stream of said engine and connected in circuit with at least one of said components for modifying the operation of said time-delay circuit depending upon the amount of air drawn into said engine per operational cycle.

15. In an improved fuel injection arrangement for an internal combustion engine, in combination, electrically operated valve means for controlling the flow of fuel to the internal combustion engine, said valve means when unenergized occupying its closed position and when energized occupying its open position; a source of electrical energy; an electron flow control device having a control branch and a power branch through which electrons may flow only when said control branch is electrically biased above a predetermined minimum voltage, said power branch being in circuit with said source of electrical energy and with said valve means; a time delay circuit including a resistor component and a capacitor component, and being connected across said control branch, and a heat-sensitive resistor device mounted in the air supply stream of said engine and connected in circuit with at least one of said components for modifying the operation of said time-delay circuit depending upon the amount of air drawn into said engine per operational cycle; and means connected in parallel with said control branch and with said time delay circuit for impressing thereacross at a predetermined instant during a cycle of operation of the engine a voltage which is greater than said minimum voltage, said last-mentioned means being so constructed and arranged that the duration of the impression of voltage is shorter than the time interval throughout which said valve means is to be maintained in its open position, whereby said time delay circuit is charged to a voltage higher than said minimum voltage and maintains the voltage across said control branch above said minimum voltage for a predetermined time interval following the cessation of the charging of said time delay circuit.

16. In an improved fuel injection arrangement for an internal combustion engine, in combination, electrically operated valve means for controlling the flow of fuel to the internal combustion engine, said valve means when unenergized occupying its closed position and when energized occupying its open position; a source of electrical energy; a transistor having a control branch and a power branch, the latter being in circuit with said source of electrical energy and with said valve means; voltage supplying means operatively associated with the engine and in circuit with said control branch of said transistor for impressing thereacross at a predetermined instant during a cycle of operation of the engine a voltage greater than that which is required to render said transistor conductive; and a time delay circuit including a resistor component and a capacitor component, and being connected across said control branch of said transistor and adapted to be charged by said voltage supplying means, while the latter impresses a voltage across said control branch, to a voltage greater than said voltage which is required to render said transistor conductive, whereby said transistor remains conductive for a predetermined time interval following the cessation of the impression of voltage by said voltage supplying means, and a heat-sensitive resistor device mounted in the air supply stream of said engine and connected in circuit with at least one of said components for modifying the operation of said time delay circuit depending upon the amount of air drawn into said engine per operational cycle.

17. In an improved fuel injection arrangement for an internal combustion engine, in combination, electrically operated valve means for controlling the flow of fuel to the internal combustion engine, said valve means when unenergized occupying its closed position and when energized occupying its open position; a source of electrical energy; a transistor having a control branch and a power branch, the latter being in circuit with said source of electrical energy and with said valve means; voltage supplying means operatively associated with the engine and in circuit with said control branch of said transistor for impressing thereacross, at a predetermined instant during a cycle of operation of the engine, a voltage greater than that which is required to render said transistor conductive, said voltage supplying means being so constructed and arranged that the duration of the impression of voltage is shorter than the time interval throughout which, in said cycle, said valve means is to be maintained in its open position; and a time delay circuit including a resistor component and a capacitor component, and being connected across said control branch of said transistor and adapted to be charged by said voltage supplying means, while the latter impresses a voltage across said control branch, to a voltage greater than said voltage which is required to render said transistor conductive, whereby said transistor remains conductive for a predetermined time interval following the cessation of the impression of voltage by said voltage supplying means and said valve means is maintained in its open position until the charge on said time delay circuit has dropped to a value at which the voltage across said control branch is below said voltage which is required to render said transistor conductive, and a heat-sensitive resistor device mounted in the air supply stream of said engine and connected in circuit with at least one of said components for modifying the operation of said time delay circuit depending upon the amount of air drawn into said engine per operational cycle.

18. The combination defined in claim 17, wherein said resistor and capacitor components in said time delay circuit are connected in series.

19. The combination defined in claim 17, wherein said resistor and capacitor components in said time delay circuit are connected in parallel.

20. The combination defined in claim 17, wherein said time delay circuit includes a capacitor component, a first resistor component in series-circuit connection with said capacitor component, and a second resistor component in parallel-circuit connection with said capacitor component.

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