United States Patent

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[33] **Germany**
[31] **P 17 51 403.3**

[54] **FUEL INJECTION DEVICE**
19 Claims, 9 Drawing Figs.

[52] **U.S. Cl.** ..... **123/32 EA,** 123/119, 123/139 E, 123/139 AW
[51] **Int. Cl.** **F02m 51/00**
[50] **Field of Search** ..... 123/32, 32 E, 119, 148 E, 139

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ABSTRACT: A fuel injection installation, especially for multicylinder internal combustion engines with at least one electromagnetically actuated injection valve and an energy storage device in the load circuit which is triggered in dependence on the rotational speed and in which the discharge of the energy storage device acting on the electromagnet of the injection valve is limited by a control device to a value above the holding current of the injection valve.

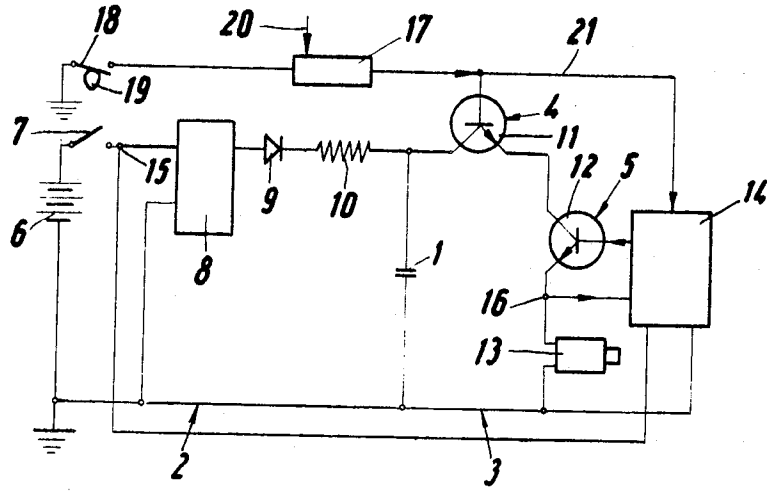


Fig. 1

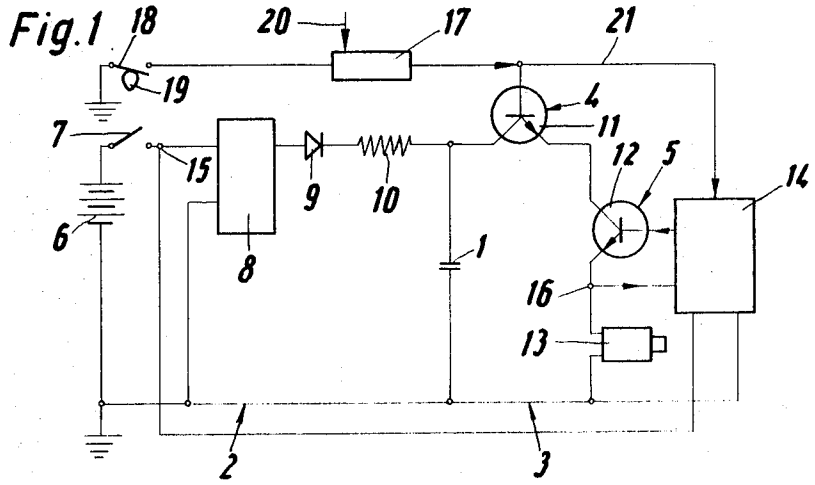


Fig. 2

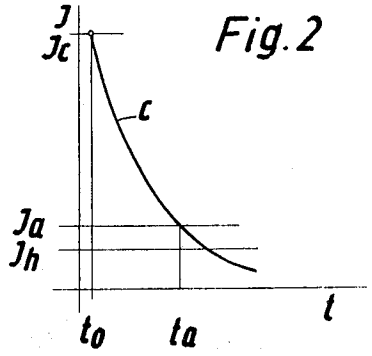


Fig. 4

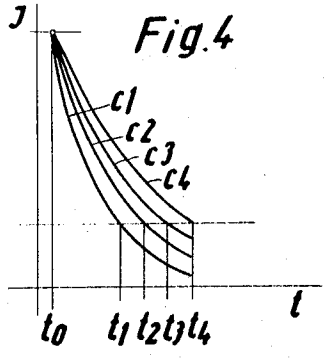
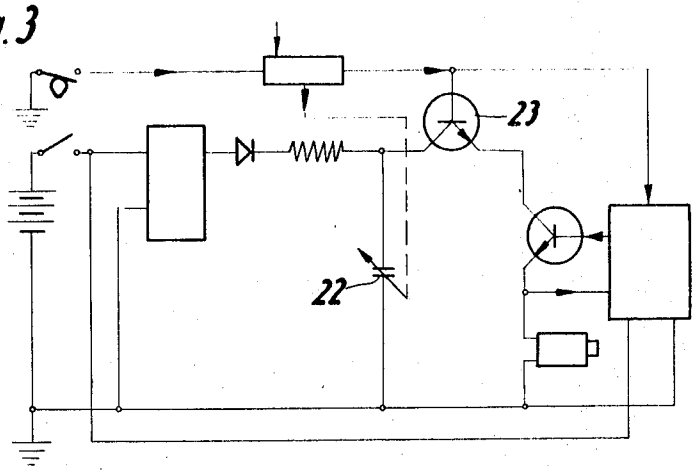


Fig. 3



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Fig.5

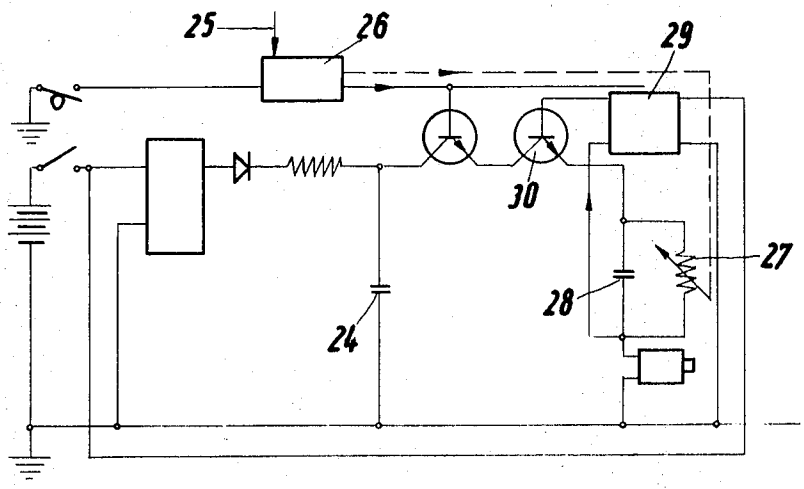


Fig.6

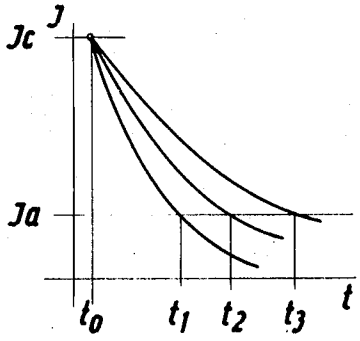
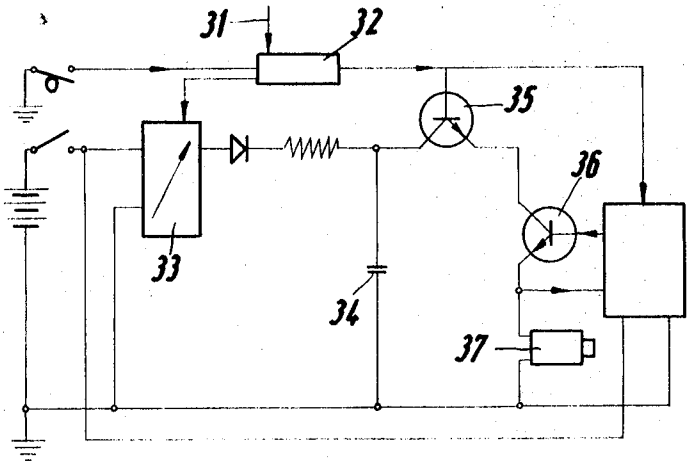


Fig.7



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Fig. 8

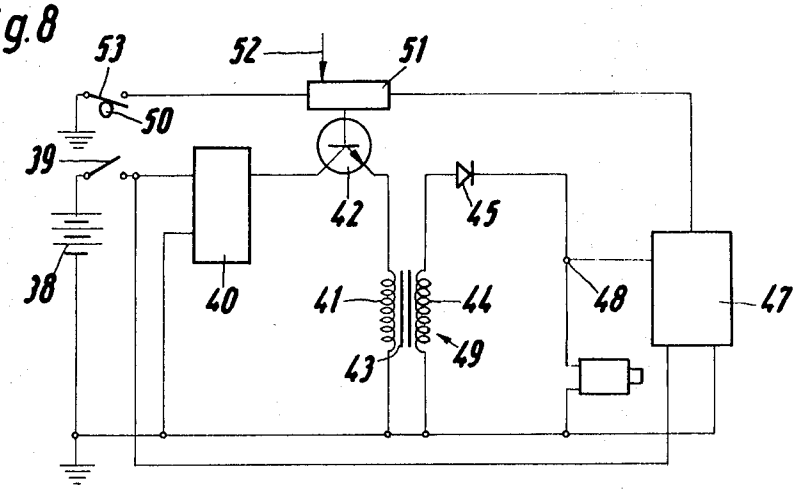
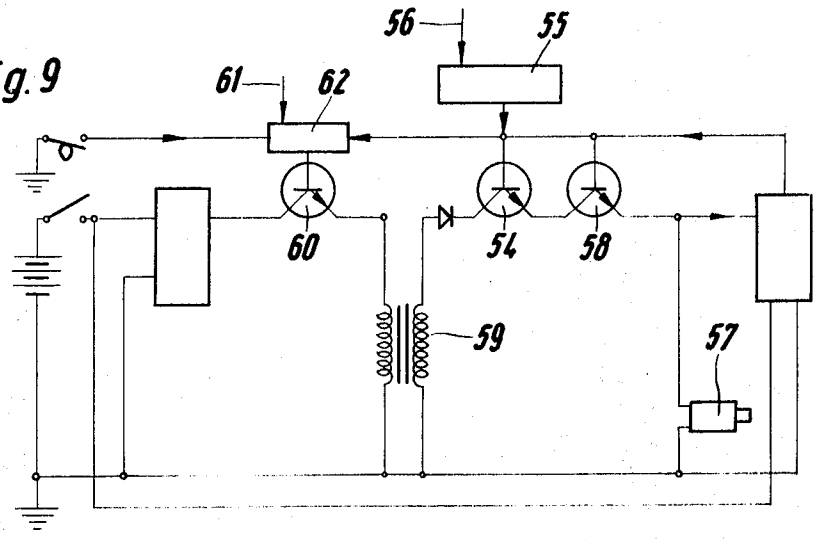


Fig. 9



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FUEL INJECTION DEVICE

The present invention relates to a fuel injection device, particularly for multicylinder internal combustion engines, with at least one electromagnetically actuated injection valve and an energy storage means in the load or output circuit, which storage means is triggered in dependence on the number of revolutions.

Electrically controlled fuel injection devices are known in the prior art, in which a capacitor is arranged in the electrical circuit of the magnet of an injection valve; the stored energy of this capacitor is fed to the magnet in dependence on the number of revolutions of the internal combustion engine. In order to vary the time during which the magnet remains energized, a control resistance is provided, which is influenced by several parameters of the internal combustion engine and by way of which the capacitor is discharged. In this prior art arrangement, the injection valve closes as soon as the current of the discharging capacitor is smaller than the holding current of the magnet for the valve. By the term "holding currentt" is meant thereby that current value which produces in the magnet a force corresponding to the closing force of the springs of the injection valve. It follows therefrom that already with minor deviations of the characteristics of the springs used therewith, the closing times of the individual injection valves differ from one another, and therewith also the amount of the injected fuel. Also mechanical influences, for example, the surface characteristics and the weight of the parts, can effect a shift or displacement in the closing times.

The same disadvantages are encountered in another known arrangement, in which an inductive storage device is provided which discharges by way of a control resistance.

The problem underlying the present invention resides in obtaining, in connection with fuel injection devices with an energy storage means in the load circuit, exact control periods for the injection valves, i.e., those instants at which each of the injection valves of a multicylinder internal combustion engine opens and closes, in order to avoid the above-described disadvantages. Another object of this invention is to provide circuits and control or switching devices having a simple construction and a progressive effect constituting an advance in the art.

This is accomplished in accordance with the present invention in that the discharge of the energy storage device effective on the electromagnet of the injection valve is limited by means of a control device up to a value above the holding current for the injection valve. As a result thereof, an exact point in time is determined during the course of the discharge of the energy storage device at which the injection valves are still completely opened and the range of the holding current has not yet been attained. Mechanical inaccuracies during the manufacture of the injection valves cannot adversely influence the closing times. By limiting the discharge effective on the injection valve, a further control of the duration of injection is likewise facilitated, i.e., that period of time during which the injection valve is kept open. The control installation limits the discharge operation of the energy storage device up to a constant value. It is also possible and, in certain cases, advantageous, if the control installation for limiting the discharge operation of the energy storage device is coupled or operatively connected with a device for varying the period of energization of the electromagnet. This means that the cutoff threshold for the energy storage device serves directly as basis for varying the duration of injection. The control installation for limiting the discharge of the energy storage device is constituted by a conventional voltage or current comparison measuring device. The control installation is furthermore connected with an installation for controlling the charging circuit of the energy storage device and possibly with the device for the speed-triggering action. As a result thereof, inter alia. a charging of the energy storage device is initiated immediately after the interruption of the discharge operation of the storage device.

In accordance with the invention, provision is made in a fuel injection device with a capacitive storage device in the load circuit that a variable capacitor, for example, a stepped capacitor is provided for controlling the duration of the discharge of the storage device. However, it is also possible within the scope of the present invention to connect in the discharge circuit of a capacitor, a resistor which is variable by one or several parameters of the internal combustion engine, with which, a capacitor is connected in parallel and with which circuit element for limiting the discharge of the storage device is connected in series. In both cases, a discharge curve of the capacitor is obtained with an initially nonattenuated current pulse, whereby a rapid opening of the valve is achieved. The closing of the injection valve is likewise effected accurately by means of the device of the present invention limiting the discharge of the capacitor.

In a fuel injection device having an inductive storage device in the load circuit, provision is made in accordance with the present invention that a switch, particularly a semiconductor switch, is connected in the charging circuit of the inductive storage device, which switch receives pulses, by way of a control device for triggering the injection device in dependence on the rotational speed as well as for subsequently closing the charging circuit. This circuit arrangement is further simplified in that the control of the switch in the charging circuit of the inductive storage device for closing the circuit is actuated or triggered by the device for limiting the storage device discharge.

In fuel injection device with an inductive storage device and with a device, independent of speed, for varying the duration of the energization of the magnet of the injection valve, provision is made that the device acts on a switch in the charging circuit of the storage device. However, it can be advantageous in certain cases if the device acts on switches in the charging and discharge circuits, or that the switch in the charging circuit and such a switch in the discharge circuit are influenced in dependence on various parameters or groups of parameters of the internal combustion engine so that a division related to function of the influencing magnitudes is possible.

These and other features, objects and advantages of the present invention will become more obvious from the following description, when taken in connection with the accompanying drawing, which shows for purposes of illustration only, several embodiments in accordance with the present invention, and wherein:

FIG. 1 is a schematic circuit diagram of an installation for a fuel injection in accordance with the present invention with a capacitive storage device;

FIG. 2 is a current-time discharge diagram of the capacitor according to the circuit of FIG. 1, engine,

FIG. 3 is a schematic circuit diagram of another device for a fuel injection in accordance with the present invention, with a variable capacitor as the energy storage device;

FIG. 4 is a current-time discharge diagram of the capacitor of the circuit according to FIG. 3;

FIG. 5 is a schematic circuit diagram of still another embodiment of an injection device in accordance with this invention, with a variable resistor in the discharge circuit of the capacitor;

FIG. 6 is a simplified current-time diagram with a capacitor discharge curve, corresponding to the circuit of FIG. 5;

FIG. 7 is a schematic circuit diagram of a further embodiment of an injection device according to the present invention, with a capacitive energy storage device and a control of the charging circuit of the capacitor dependent on parameters;

FIG. 8 is a schematic circuit diagram of still another embodiment of a device for the control of the fuel injection according to the present invention, with an inductive energy storage device and a control of the charging circuit dependent on parameters; and

FIG. 9 is a schematic circuit diagram of still a further embodiment of a fuel injection device according to the present

invention with an inductive energy storage device and a control of the charging and discharge circuits of the storage device dependent on parameters.

The device of this invention for controlling and/or limiting the discharge of an energy storage device is provided for fuel injection installations, especially of multicylinder internal combustion engines. In this connection, the energy storage device can be either capacitive or inductive, i.e. it can be formed by a capacitor or by a transformer. Several embodiments of the present invention for electrical injection control installations with capacitive and inductive energy storage devices will be described hereinafter by reference to the various figures.

Referring now to the drawing, wherein like reference numerals are used throughout the various views to designate like parts, the control circuit of a control installation with a capacitive storage device illustrated in FIG. 1 comprises essentially a condenser 1 as the energy storage means, a charging circuit 2 an a discharge circuit 3 of the condenser as well as control devices 4 and 5 for influencing the current flow in the discharge circuit 3.

The control installation is connected by way of the charging circuit 2 with a battery 6 and is adapted to be switched on and off by means of a switch 7. The storage capacitor 1 can be charged by way of a DC voltage converter 8, a charging diode 9 and a current-limiting resistor 10.

Switches 11 and 12 and a fuel injection nozzle 13 are connected in the discharge circuit 3. Conventional transistors are provided as switches 11 and 12. The injection nozzle 13 is fed in a conventional manner, which is not shown in detail in this or in the following figures, with a fuel under a substantially constant pressure and contains a valve actuated by a magnet connected in the discharge circuit 3 of the capacitor 1.

The switching or control transistor 12 is connected to a conventional current or voltage-measuring device 14 and is conventionally controlled thereby. The measuring device 14 is connected to the charging circuit 2 at 15 and to the discharge circuit 3 of the capacitor 1 at 16, at which points the measuring device 14 derives, respectively, the comparison voltage or the comparison current.

The transistor 11 is controlled by a device 17 of conventional construction. This control is effected in dependence on a switch 18 which is closed and opened by a camshaft 19 of the internal combustion engine, i.e., in dependence on the number of revolutions of the engine and on parameters 20 of the internal combustion engine. The measuring device 14 is connected to the device 17 by way of a circuit, over which the measuring device 14 receives pulses for the control of the transistor 12 at the beginning of the discharge of the capacitor 1.

If, with the capacitor 1 in the charged condition, the transistor 11 is actuated by the switch 18 by way of the device 17 to render transistor 11 conductive and the transistor 12 is conductive, then the discharge circuit 3 is closed and the capacitor 1 discharges by way of the injection valve 13. In the injection valve, the aforementioned magnet is energized and the valve opens This operation is illustrated in the graph of FIG. 2, showing a "Current (J)-Time (t)" diagram of the discharge c of the capacitor. J_c is the current at the beginning of the discharge of the capacitor. The progress of the discharging c is constantly monitored by the measuring device 14 and when a predetermined amperage J_a has been reached, the transistor 12 is blocked i.e., rendered nonconductive by the measuring device 14. As a result thereof, the discharge operation of the capacitor is interrupted, and the capacitor can be charged again. The current value J_a at which the discharge operation of the capacitor is interrupted, is larger than the current value J_h of the holding current, i.e., of that current value at which the force of the magnet associated therewith corresponds to the force of the closing spring of the injection valve, i.e, where both forces are in equilibrium.

The control of the injection quantity in dependence on the load of the internal combustion engine, the temperature of the internal combustion engine and of the air, and other characteristics and reference values takes place by means of the device 17 of conventional construction. The parameters 20 are fed to this device 17 in the form of pulses or currents, on the basis of which the control of the transistor 11 and thus the continuous energization of the magnet of the injection valve is determined. The discharge of the capacitor can thus be interrupted at any desired instant between t_o and t_a by the device 17 in dependence on the parameters 20 of the internal combustion engine, but at the latest at the instant t_a by the measuring device is used

The construction of the installation according to the circuit diagram of FIG. 3 corresponds in principle to the arrangement of FIG. 1, however with the difference that a variable condenser 22, such as a stepping capacitor or the like is used as the energy storage device. The semiconductor switch 23 serves exclusively for fixing the beginning of the capacitor discharge, i.e., for closing the discharge circuit.

The "Current (J)-Time (t)" diagram illustrated in FIG. 4 shows several discharge curves c_1, c_2, c_3 and c_4 of a stepped capacitor. These discharge curves intersect the cutoff threshold J_a at instants t_1, t_2, t_3 and t_4 so that, starting from t_o, a different duration of time for the discharge operation results therefrom.

A further embodiment of the present invention can be seen from the circuit diagram of FIG. 5, with a constant limit of the discharge operation of a capacitor 24 as the energy storage device, in which merely the type of the variable control of the injection duration is changed as compared to the preceding embodiments. This control takes place again by means of a conventional device 26 supplied with parameters 25 of the internal combustion engine, which device 26 acts on a variable resistor 27. In order to eliminate a damping or attenuation of the current by the resistor 27 at the beginning of the discharge, a capacitor 28 is connected in parallel to the resistor 27.

The discharging diagram of the capacitor 24 is shown in FIG. 6. A constant discharging current J_c at the beginning of the discharge t_o is attenuated by the variable resistor 27, depending on the setting thereof, to such an extent that the cutoff threshold J_a is attained either at the instant t_1, t_2 or t_3, where the device 29 effecting the limiting of the discharge block or renders nonconductive the switching transistor 30 in the discharge circuit. The change of the variable resistor 27 can, of course, also takes place infinitely variable, or it can be variable with finer steps than illustrated in FIG 6.

As final embodiment for the application of the present invention to installations with a capacitive energy storage device, there is shown in FIG. 7 a control circuit with a control of the charging current for varying the injection duration. This variation is again effected by a conventional device 32 fed with parameters 31 of the internal combustion engine, which acts on a DC voltage converter 33 of the charging circuit of a capacitor 34. The discharge circuit of the capacitor 34 is essentially formed as in the preceding examples, by a transistor 35 which initiates the discharge by a transistor 36 which limits the discharge of the capacitor in accordance with the invention, and by an injection valve 37.

In FIGS. 8 and 9, two embodiments of the present invention are illustrated in connection with control circuits with inductive storage devices. According to FIG. 8, a DC voltage converter 40 is connected to a battery 38 by way of a main switch 39, which converter supplies a coil 41 with current by way of a switching or control transistor 42. A coil 44 is inductively influenced by the coil 41 by way of a core 43; a diode 45 and an injection valve 46 are connected in series in the circuit of the coil 44. A conventional current or voltage measuring unit 47 is connected, on the one hand, at 48 to the discharge circuit of the transformer 49 consisting of components 41, 43 and 44, and, on the other hand, at 50 with the charging circuit of the transformer. Upon reaching a predetermined voltage or current, a pulse is fed from the measuring device 47 to a device 51. The device 51 of conventional construction receives addi-

tional pulses 52 from parameters of the internal combustion engine and trigger pulses of the rotational speed dependent device 53.

If the switch 39 is closed and the transistor 42 is rendered conductive, then the coil 41 receives current from the DC voltage converter 40. If thereafter the device 51 receives a pulse from the device 53, then the device 51 blocks or renders nonconductive the transistor 42, and the coil 44 of the transformer produces a pulse which effects an opening of the injection valve 46. When the current, in the course of the discharge of the transformer has reached a certain value lying above the holding current value for the injection valve, then the device 51 receives a further pulse from the measuring device 47, and the transistor 42 becomes conductive. At the same moment, the current flows in the charging circuit of the transformer 49, whereby the direction of current flow in the discharge circuit is reversed. The diode 45 blocks the current flow through the injection valve.

The transistor 42 can be rendered conductive in dependence on the parameter pulses 52, independently of the measuring device 47, and more particularly in the sense of shortening the discharge period in the discharge circuit.

The circuit of FIG. 9 corresponds in its basic construction to that of FIG. 8, with the difference that an additional switching or control transistor 54 is connected in the discharge circuit; a separate device 55 of conventional construction and controlled by parameter 56, is associated with this transistor 54 and effects a control of the duration of injection, or of that period of time during which the injection valve 57 is kept open. A transistor 58 is connected in the discharge circuit for limiting the discharge of the energy storage device (transformer 59) and a transistor 60 is connected in the charging circuit for triggering the discharge in dependence on additional parameters 61 of the internal combustion engine by way of a device 62 of conventional construction.

The present invention is not limited to the illustrated embodiments. Thus, it is possible, for example, to omit the DC voltage converters in FIGS. 8 and 9, and to connect the transformers directly by way of the switching transistors to the battery. On the other hand, an already present DC voltage converter, for example a high-voltage capacitor ignition unit, can also be used for the injection device.

AS mentioned above, all circuits and devices illustrated schematically in block form, are of conventional commercially available construction. For example, measuring device 14 intended to compare the input voltage (i.e. battery voltage) with the discharge voltage of condenser 1 may be of the type available form SGS-Fairchild, as described on page 9 and illustrated in Figure 2.4.1 of "Industrial Circuit Handbook," June 1967, or as commercially available from the VALVO Company under the designation DZD 40. The devices 17,26,32,51,55 and 62 which operate in the manner of an electronic computer or data processing device processing electrical or mechanical pulses derived at different places of the engine to detect different parameters thereof, such as rotational speed, temperature of engine and/or of drawn-in air, air quantity, position of gas pedal, etc., are of the type commercially available from the Boscit Company of West Germany as installed at present in series-produced vehicles. The DC converters 8,3 and 40 have the purpose to change the DC battery voltage to an AC voltage, transform (step-up) the AC voltage and then rectify the stepped up voltage for use at the condenser 1. These type of converters are also commercially available, for example, as illustrated on page 29 in the catalogue "Power Application Theory" of Texas Instruments or in Figure 15,5.1 of the aforementioned "Industrial Circuit Handbook."

While we have shown several embodiments in accordance with the present invention, it is understood that the same is not limited thereto but is susceptible of numerous changes and modifications as known to a person skilled in the art, and we therefore do not wish to be limited to the details shown and described herein.

We claim:

1. A fuel injection apparatus, especially for a multicylinder internal combustion engine comprising:

at least one electromagnetically actuated injection valve means;

energy storage means for storing the energy to be used in actuating said injection valve means, said injection valve means forming a portion of the discharge circuit for said energy storage means;

means, responsive to the rotational speed of the engine for triggering the discharge of said energy storage means; and

first control means for limiting the discharge of energy from said energy storage means through said electromagnetically actuated injection valve means to a value above the amount of energy required for holding said injection valve means open, said control means including electric-comparison-measuring means for comparing the value of the energy being discharged from said storage means through said electromagnetically actuated injection valve means with a reference value of energy, whereby the discharge of energy from said storage means will be limited when the value of said energy reaches said value above said amount of holding energy, to thereby provide precise control of the duration of time during which said electromagnetically actuated injection valve means supplies fuel to said internal combustion engine.

2. A fuel injection apparatus according to claim 1, characterized in that the first control means limits the discharge of the energy storage means up to a constant value.

3. A fuel injection apparatus according to claim 1 further including a second control means, connected with said first control means for changing the duration of time of the energization of the electromagnet which actuates said injection valve.

4. A fuel injection apparatus according to claim 1, further including a charging circuit for supplying energy to said energy storage means, and further including third control means connected with said first control means for controlling the charging of said energy storage means.

5. A fuel injection apparatus according to claim 4, wherein said first control means is responsive to the output of said rotational speed dependent trigger means, whereby first control means limits the discharge of said energy storage means in dependence on said trigger means.

6. A fuel injection apparatus according to claim 5, characterized in that the first control means limits the discharge of the energy storage means up to a constant value.

7. A fuel injection apparatus according to claim 5, further including a second control means connected with said first control means for changing the duration of time of the energization of the electromagnet which actuates said injection valve means.

8. A fuel injection apparatus according to claim 1, wherein said energy storage means comprises a variable capacitor for controlling the duration of the discharge of the energy storage means.

10. A fuel injection apparatus according to claim 1, wherein said energy storage means comprises capacitive storage means and further including a parallel connected resistor-capacitor network connected to said first control means and said electromagnetically actuated injection valve means in said discharge circuit, said resistor disposed in said network being variable by at least one parameter of the internal combustion engine in response to an output from said triggering means.

11. A fuel injection apparatus according to claim 1, wherein said energy storage means comprises an inductive storage means and further including switch means in the charging circuit of the inductive storage means and wherein said triggering means includes a further control means for delivering pulses to said switch means to control the opening and closing thereof in response to additional parameters of said engine.

12. A fuel injection apparatus according to claim 11, wherein said switch means in the charging circuit of the inductive storage means is triggered by the first control means for limiting the storage discharge.

13. A fuel injection apparatus according to claim 12, further including means dependent on the rotational speed for changing the duration of the energization of the electromagnet of the injection valve, characterized in that said changing means controls said switch means in the charging circuit of the storage means.

14. A fuel injection apparatus according to claim 13, wherein said switch means is connected both in the charging and discharge circuits of said storage means.

15. A fuel injection apparatus according to claim 13, wherein the switch means in the charging circuit and switch means in the discharge circuit are influenced in dependence of difference parameters of the internal combustion engine.

16. A fuel injection apparatus according to claim 11, further including means dependent on the rotational speed for changing the duration of the energization of the electromagnet of the injection valve, characterized in that said changing means controls said switch means in the charging circuit of the storage means.

17. A fuel injection apparatus according to claim 16, wherein said switch means is connected both in the charging and discharge circuits.

18. A fuel injection apparatus according to claim 16, wherein the switch means in the charging circuit and switch means in the discharge circuit are influenced in dependence of different parameters of the internal combustion engine.

19. A fuel injection apparatus according to claim 18, wherein each of said switch means is a transistor switch.