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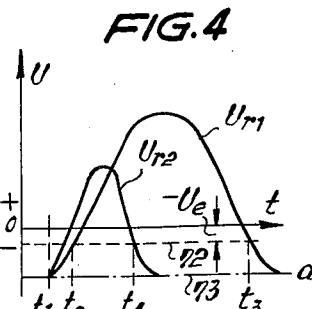
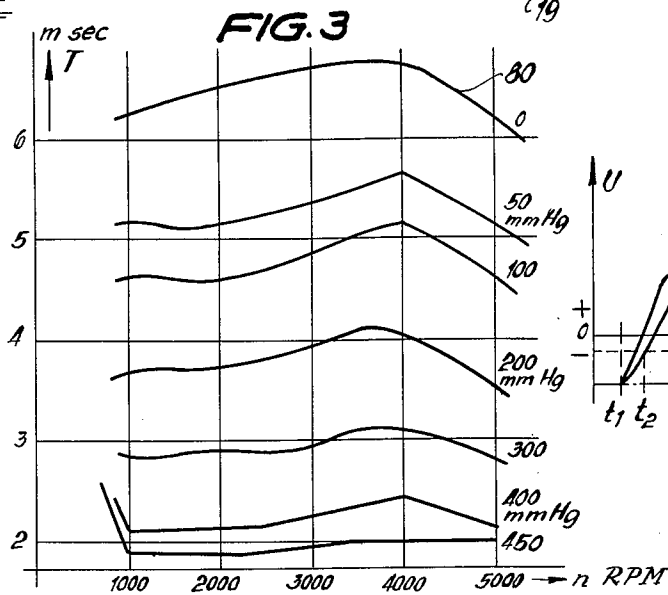
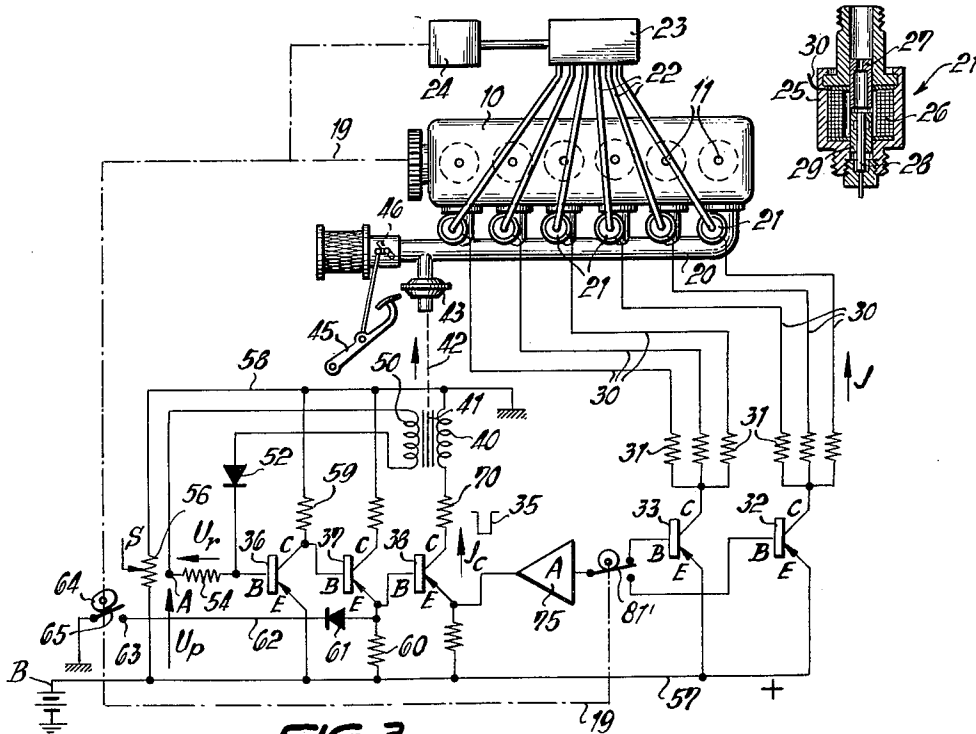
FUEL INJECTION ARRANGEMENT FOR INTERNAL COMBUSTION ENGINES

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FIG. 1

FIG. 2



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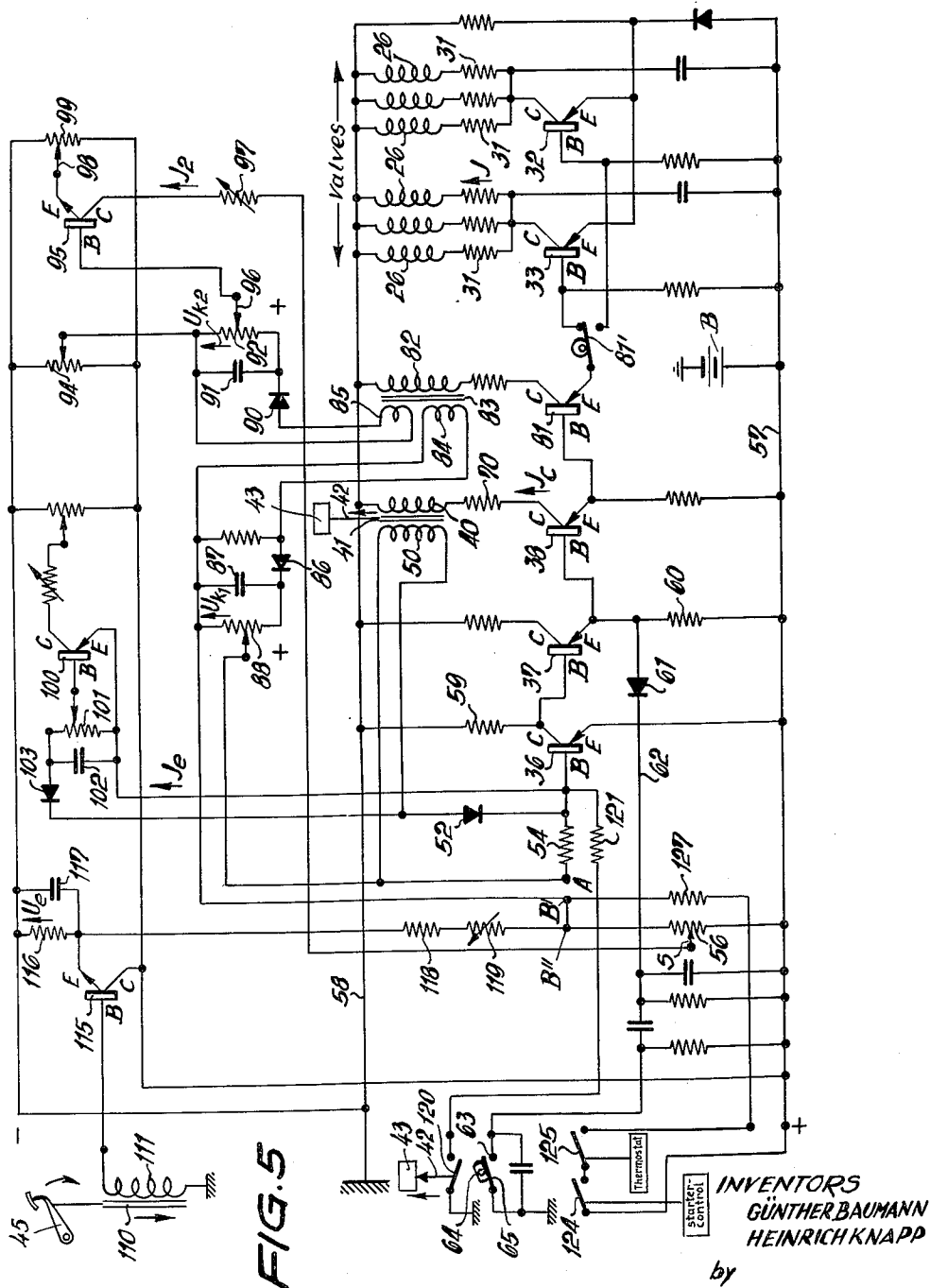
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2 Sheets-Sheet 2



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FUEL INJECTION ARRANGEMENT FOR INTERNAL COMBUSTION ENGINES

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14 Claims. (Cl. 123—119)

The present invention concerns a fuel injection arrangement for internal combustion engines, and more particularly an arrangement which concerns an engine having an air intake manifold and at least one electromagnetically actuable fuel injection valve, and which includes a source of electric energy, switching means responsive to electric pulses applied thereto and connected between the source of energy and the valve for controlling the energization of the latter, and pulse generator means operable by the engine for producing electric output pulses in synchronism with the rotary speed of the engine.

More specifically, the invention concerns a fuel injection arrangement of the type set forth in which means are provided for varying the durations of intermittent openings of the fuel injection valve or valves depending upon the existing degrees of partial vacuums in the air intake manifold of the engine.

Fuel injection arrangements of this kind have been proposed in the past in which the energization of the injection valve is controlled by a power transistor and at least one control transistor controlling the power transistor, the control transistor cooperating with an inductive reactance device, e.g. a choke coil, the inductivity whereof is variable by the action of a pressure sensitive device attached to the air intake manifold, so that a regulation of the duration of opening of the valve or valves can be derived from the variation of the inductivity of the choke coil. Actually, in such a known arrangement the duration of the electric pulses determining the duration of the opening period of the valves has been made dependent upon the time required for the electromagnetic field created in the choke coil to decay to a certain minimum value. However, in practice it has been found that it is very difficult with an arrangement of this type to obtain a regulation of the amounts of fuel injected through the valves in such a manner that they correctly correspond to the actual demand for fuel under prevailing operative conditions. What is needed in addition to a regulation based on varying degrees of partial vacuum in the air intake manifold is an automatic regulation of the amounts of injected fuel also in dependence upon at least the rotary speed of the engine and, preferably, also on the operating temperature of the engine, the latter particularly for the purpose of facilitating the starting of the engine.

It is therefore a main object of this invention to provide for a fuel injection arrangement of the general type set forth in which the automatic regulation of the fuel supply to the engine is made dependent on several operative factors or conditions.

It is a further object of this invention to provide for a fuel injection arrangement as mentioned in which the automatic regulation of the fuel supply follows very accurately the variations of demand for fuel depending upon various operating conditions.

With the above objects in view the invention provides in a fuel injection arrangement for internal combustion engines having an air intake manifold and at least one electromagnetically actuable fuel injection valve, and including a source of electric energy, switching means responsive to electric pulses applied thereto

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and connected between said source and said valve for controlling the energization of the latter, and pulse generator means operable by the engine for producing electric output pulses in synchronism with the rotary speed of the engine, a regulating arrangement for varying the duration of energizing pulses applied through said switching means to the valve, comprising, in combination, first regulating means operatively connected with said air intake manifold and responsive to variations of a partial vacuum in said manifold, and conductively connected with said pulse generator means for subjecting the duration of the output pulses generated thereby to a first regulation in predetermined proportion to variations of said partial vacuum; and second regulating means cooperating with said first regulating means and connected with said pulse generator means and responsive to the frequency of said output pulses for subjecting the duration of said energizing pulses derived therefrom to a second regulation superposed on said first regulation and depending upon varying speeds of the engine, whereby the duration of the pulses energizing the injection valve and therefore the fuel supply therethrough is automatically regulated depending upon the degree of partial vacuum in the air intake manifold and upon the rotary speed of the engine.

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 invention in a basic form, showing the circuitry and the essential parts of the pertaining engines;

FIG. 2 illustrates one of the fuel injection valves used in FIG. 1, in axial section;

FIG. 3 is a diagram illustrating the relation between actual fuel requirement in terms of opening times of the injection valves, in relation to the rotary speeds of the engine and to various vacuum conditions in the air intake manifold thereof;

FIG. 4 is a diagram illustrating by way of example two electric pulses occurring in the operation of the arrangement under various conditions, and for explaining the operation of the arrangement; and

FIG. 5 is a circuit diagram illustrating a more elaborate embodiment of the invention.

Referring first to FIG. 1, the circuit arrangement shown therein is applied to a six cylinder internal combustion engine 10 the ignition plugs 11 thereof being connected to a conventional high voltage ignition system not illustrated. Close to the intake valves of the engine, not visible in the drawing, are arranged electromagnetically actuable injection valves 21, one for each cylinder, mounted in the respective branches of the air intake manifold 20. Each of the injection valves 21 is connected by a corresponding fuel supply line 22 with a distributor container 23 which in turn is connected with a fuel supply pump 24 operatively connected with the diagrammatically indicated crank shaft 19 of the engine so that the fuel in the container 23 and in the lines 22 leading to the individual valves 21 is continuously maintained under substantially constant pressure.

Each of the injection valves illustrated by way of example in section in FIG. 2 comprises a housing 25 made of magnetizable material and a magnet coil 26 arranged therein and surrounding partly the stationary iron core 27 and partly the movable armature 29 carrying the valve

pin 28 the tip of which abuts in normal position against the nozzle opening as shown. When the valve is energized the armature 29 is lifted and thus the nozzle opening is cleared by the pin 28 so that the fuel being under pressure is able to pass through the hollow core 27 and around the valve pin 28 so as to be ejected through the nozzle. One end of the coil 26 is connected conductively in a conventional manner, not shown, with the housing 25, while the other ends of each of the coils are connected by connecting lines 30, respectively, with corresponding resistors 31. Groups of three resistors 31 are jointly connected with the collector of the pertaining one of the power transistors 32 and 33, respectively, which constitute components of the regulating and control circuit arrangement described below.

A more complete circuit diagram of an arrangement according to the invention is illustrated in FIG. 5. The following description applies chiefly to the basic arrangement of FIG. 1, but applies also to FIG. 5 as far as the same components having the same reference numerals are referred to.

The circuit arrangement comprises, in addition to the above mentioned power transistors 32 and 33, two control transistors 37 and 38 and a pre-stage transistor 36 which cooperates with an iron core choke coil 40 whose inductive reactance is variable depending upon a partial vacuum existing in the manifold 20. The transistor 38 furnishes output pulses as indicated at 35. The choke coil 40 constitutes the primary winding of a transformer which has a stationary iron core and a movable armature 41 therein. The armature 41 is attached to a control rod 42 diagrammatically indicated by a dotted line, and attached to the diaphragm, not shown, or bellows of a pressure gauge 43. The pressure gauge 43 is connected at its low pressure side with the manifold 20 of the engine directly behind the throttle 46, in air flow direction, which in turn is operated by the foot pedal 45. Whenever the pressure in the manifold 20 decreases i.e. the partial vacuum therein increases, the armature 41 is lifted in the direction indicated by the arrow so that hereby an air gap in the core of the transformer is increased whereby the inductivity of the primary winding 40 is increasingly reduced with the drop of pressure in the manifold 20 i.e. with increasing partial vacuum therein which may be indicated in mm. Hg.

The secondary winding 50 which is wound on the same core as the primary winding 40 is connected in series with a resistor 54. This resistor 54 is located between a terminal point A and the base of the pre-stage transistor 36. One end of the coil 50 is connected with the point A, while the other end is connected via a rectifier 52 having a flow direction as indicated by the symbol, to a junction point between the resistor 54 and the transistor 36. The point A is further connected with the adjustable tap S of a potentiometer 56 one end of which is connected with the common positive line 57 taken from the battery B while the other end of the potentiometer 56 is connected to the common negative line 58. The pre-stage transistor 36 has its emitter connected directly to the positive line 57 while its collector is connected directly with the base of the first control transistor 37 and also, via a load resistor 59, with the negative line 58. The collector of transistor 37 is also connected via a load resistor with the negative line 58 while its emitter is connected directly to the base of the second control transistor 38. However a junction point between the emitter of transistor 37 and the base of the transistor 38 is connected via a load resistor 60 with the positive line 57.

For causing the generation of output pulses in the transistor 38 a junction point between the connected emitter and base electrodes, respectively, of transistors 37 and 38 is connected via a semiconductor diode 61 arranged in a control line 62 with the stationary contact 63 of an actuator switch device having a movable contact arm 65 connected to ground and thus connected with the negative

line 58. The contact arm 65 is operated by a two-cam rotary member 64 which is coupled mechanically, as indicated by a dash-dotted line, with the crank shaft 19 of the engine so that during the operation of the engine the switch device 63—65 is moved to closed condition twice per revolution of the crank shaft 19. Every time the arm 65 engages the contact 63 the transistor 38 is rendered conductive.

Before entering into a description of the more elaborate and more detailed circuit diagram of FIG. 5, it appears to be advisable to describe first in what manner the energizing pulse currents J which determine the opening periods of the injection valves 21 and which are generated everytime when the above-mentioned actuating switch device is moved to closed position, depend upon variations of the partial vacuum in the manifold 20 and corresponding variations of the inductivity of the primary winding 40.

In the following reference is made also to the diagram of FIG. 4. Immediately before the time or moment t_1 indicating the moment when the contact arm 65 engages the contact 63, the pre-stage transistor 36 is in conductive condition and therefore keeps the transistor 37 and the transistor 38 operating in phase therewith in blocked or non-conductive condition. This is due to the fact that the base of the pre-stage transistor 36 is connected with the movable tap S of the potentiometer 56 via the resistor 54 which has a negative potential relative to the positive line 57. As soon as the contact arm 65 is moved by the cam device 64 into engagement with contact 63, the base of the transistor 38 obtains across the rectifier 61 and the arms 65 ground potential and thus renders the up to then non-conductive transistor 38 strongly conductive. The control transistor 38 is then capable of carrying an exponentially rising collector current J_c which flows across the resistor 70. This current passes through the primary winding 40 and creates in the iron core and in the armature 41 of the transformer 40, 50 a likewise increasing magnetic field. The rise of the current J_c is the faster, the greater is the air gap in the core, i.e. as the inductivity of the primary winding 40 decreases on account of an increase of the air gap. In case the inductivity of the primary winding 40 is high, the just mentioned rise of the current induces in the secondary winding 50 a voltage U_{r1} which increases comparatively slowly, reaches a high peak value and then decays comparatively slowly as is illustrated in FIG. 4. However, if the inductivity of the primary winding 40 is comparatively small, then the voltage U_{r2} induced in the secondary winding 50 rises faster or at a steeper angle in the diagram, reaches its peak value which is lower than the first case, at an earlier moment and then decays faster as compared with the voltage U_{r1} . This can be recognized from FIG. 4.

The change of the induced voltages as for instance between U_{r1} and U_{r2} depending upon the variation of the inductivity of the primary winding 40 in proportion with the varying values of the partial vacuum in the manifold 20 can be used according to the invention for providing energizing impulses J of correspondingly different durations in order to control the action of the injection valves.

The manner in which the impulse duration is brought about is illustrated in FIG. 4 in which the moment of the contact arm 65 engaging the contact 63 is marked at t_1 . In this diagram the ordinate represents voltage values above and below 0 and the abscissa through the zero point represents time t . The distance of the dotted line 72 from the zero line t represents that potential difference $-U_c$ which must exist between the potential at the base of the pre-stage transistor 36 and the emitter thereof if the transistor 36 is to remain in conductive condition. The second dotted line 73 represents a negative potential $-a$ below the potential of the positive line 57 which potential $-a$ applying to the junction point A depends upon a selected setting of the movable tap S of the potentiometer 56. It can be seen that the potential $-a$

can be set to be more than sufficient for holding the transistor 36 in conductive condition. The positive voltage U_{r1} produced in the secondary winding 50 is superimposed to the potential $-a$ so that at the moment t_2 the potential difference between emitter and base of the transistor 36 falls short of the minimum value $-U_e$ since the base potential becomes less negative, and consequently the transistor 36 is rendered non-conductive from the moment t_2 on. Only when at the moment t_3 the emitter-base potential difference again increases beyond its minimum value indicated by the lines 72, the transistor 36 becomes again conductive. As long as the pre-stage transistor 36 is non-conductive, the control transistors 37 and 38 are in conductive condition and thus keep also the power transistors 33 or 32 in conductive condition via an amplifier 75 interposed therebetween. It should be noted that a switching device 81' also operated by a mechanical connection with the crankshaft 19 as indicated by dash-dotted line alternatively places the power transistors 33 and 32 and the respectively connected groups of valves 21 in circuit with the amplifier 75.

As soon, however, the pre-stage transistor 36 returns, for instance at the moment t_3 , to its previous non-conductive condition, the transistors 37 and 38 and therefore also the power transistors 32 and 33, respectively, are returned to non-conductive condition. As can be seen from FIG. 4 the duration of the energizing impulse J derived from the output pulses J_e extends from the moment t_1 when the contact arm 65 engages the contact 63, to the moment t_3 in which the voltage U_{r1} intersects in the diagram the reference line 72.

Assuming however, that the inductivity of the primary winding 40 has been greatly reduced so that in the secondary winding 50 a voltage U_{r2} rising and falling more steeply has been induced, then the transistor 36 will be returned to its conductive condition already at the moment t_4 which is much earlier than in the previous example. Consequently, in this case the valves 21 will be closed at a much earlier moment than in the previous case where the inductivity was great and the partial vacuum in the manifold was small and whereby for example the voltage U_{r1} has been created.

As can be seen the above described arrangement operates to regulate, by changing the inductivity of the primary winding 40, the duration of the energizing pulses J determining the opening periods of the injection valves depending upon variations of the degree of partial vacuum in the manifold of the engine. It has been found, however, that the amount of fuel injected should be regulated also in dependence, at least to some extent, on the rotary speed of the engine. Therefore FIG. 3 illustrates in what manner the duration T of the energizing pulses J would have to be varied, e.g. in a 143 cubic inch six cylinder motor, if, while the engine operates at different partial vacuums in the manifold and at different speeds, the combustion is to take place without an excess of air or fuel. Since, as can be gathered from the above description, the energizing pulse durations have a fixed value for each degree of partial vacuum independently of the rotary speed of the engine, further regulating devices are illustrated in the embodiment of FIG. 5 which serve to adjust the pulse durations T in relation to various speeds as illustrated by the diagram of FIG. 3. As will be explained in detail further below the desired further variation of the pulse duration T is obtained by introducing further control voltages between the junction point A and the movable tap S of the potentiometer 56. It is to be understood that the negative bias potential $-a$ represented by the dotted line 73 in FIG. 4 and applying to the base of the transistor 36 is determined according to FIG. 1 by the selected setting of the movable tap S. However, the just-mentioned additional control voltages serve to shift this bias potential in negative direction if the duration

of the pulse currents J is to be shortened, or to shift this potential in positive direction if the pulse duration is to be increased.

In the diagram of FIG. 3 the ordinates represent pulse durations T in msec. while the abscissa represents various speeds n in r.p.m. Each of the various curves starting with the top curve 80 refers to a particular value of the partial vacuum in the manifold 20 measured in mm. Hg. The curve 80 corresponds to zero vacuum, i.e. atmospheric pressure while the other curves correspond to the indicated values of partial vacuum.

In the present example the duration T of the energizing pulses J must, when the engine is operated with fully opened throttle 46, rise from about 6.2 msec. at 1000 r.p.m. to about 6.7 msec. at about 3500 to 4000 r.p.m. and then drop again to 6.1 msec. at 5000 r.p.m. This is indicated by the curve 80.

In order to obtain pulse duration variations of this kind, according to FIG. 5 an amplifier transistor 81 is provided whose emitter can be connected alternately by the above-mentioned switching device 81' with the base of one or the other of the two power transistors 33 and 32. The emitter-collector circuit of the transistor 81 is connected in series with the primary winding 82 of a second transformer having an iron core 83 and two secondary windings 84 and 85. Consequently, every energizing impulse caused by the control transistor 38 and delivered to the power transistors 33, 32, across the amplifier transistor 81, will induce in both secondary windings 84 and 85 a voltage.

The secondary winding 84 is connected with a parallel combination composed of a potentiometer 88 and a filter condenser 87, a dry rectifier 86 being inserted between one end of the winding 84 and one end of the above-mentioned parallel combination. Consequently a rectified voltage of predetermined characteristics will appear at the output of the just-mentioned parallel combination. The second secondary winding 85 is connected with a similar second parallel combination composed of a potentiometer 92 and a filter condenser 91, a rectifier 90 being interposed between one end of the winding 85 and one end of the just-mentioned second parallel combination. Consequently a second rectified voltage of predetermined characteristics will be available at the output side of the second parallel combination.

The rectified output voltage of the first parallel combination, derived from the voltage induced in the winding 84, is applied to the connection points A and B', the latter being connected via junction point B'' with the potentiometer 56. Consequently this rectified output voltage U_{k1} operates between the potentiometer 56, the point A and the base of pre-stage transistor 36 exactly in the same manner as the rectified output voltage of the secondary winding 50 as explained above in detail with reference to FIG. 1. The voltage U_{k1} increases with increasing speed of the engine in view of the correspondingly greater pulse frequency and therefore will act to shift the reference voltage $-a$ represented by line 73 in FIG. 4 together with the curves representing the pulse voltages U_{r1} and U_{r2} in positive direction toward the voltage $-U_e$ represented by line 72. From this results a prolongation of the duration of the impulse current J with increasing values of the correcting or regulating voltage U_{k1} . By this regulation the desired increase of the pulse time T illustrated by the rising branch of the curves in FIG. 3, e.g. curve 80, within the speed range between about 1000 r.p.m. and 3500 to 4000 r.p.m. is obtained.

However, in order to obtain a regulation resulting in a decrease of the pulse time T as required in order to comply with the conditions illustrated by the falling portion of the curves in FIG. 3, e.g. curve 80 in the higher speed range up to about 5000 r.p.m., the voltage induced in the second secondary winding 85 is utilized. The second regulating voltage U_{k2} increases with increasing frequency of the pulses i.e. with increasing speed of the

engine and is intended to shift the potential of the junction point A in negative direction accordingly. However since this effect shall take place only in the speed range above about the 3500 r.p.m. the following arrangement is provided. One output terminal of the second parallel combination is connected to the movable tap of a potentiometer 94, while the output voltage U_{k2} of this parallel combination is taken from the movable tap 96 of the potentiometer 92 to the base of an n-p-n-transistor 95 the collector of which is connected with the movable tap S of the previously mentioned potentiometer 56 via a variable resistor 97. The emitter of transistor 95 is connected with the movable tap 98 of a further potentiometer 99 which is connected between the negative line 58 and the positive line 57. Whenever at the terminals of the filter condenser 91 the correcting voltage U_{k2} increasing with increasing engine speed, appears, the transistor 95 will be rendered more conductive as soon as the correcting voltage U_{k2} exceeds a bias voltage adjusted by setting the potentiometers 94 and 98. The collector current J_2 increasing with increasing engine speed produces under these conditions a voltage drop across that portion of the potentiometer 56 which is located between the tap S and the positive line 57 and hereby the junction point A obtains a more negative potential whereby as described above the duration of the pulses J is reduced.

It is evident that by properly setting the variable components of the circuit described the desired pulse durations can be obtained for practically all possible operational conditions, particularly in view of the substantial similarity of the various curves in FIG. 3. One more refinement of the circuit is desirable. In order to provide for a smooth operation of the engine also during idling, it is of importance to provide for an adjustment of the operation of the arrangement in order to comply with the conditions represented in the left lower corner of the diagram of FIG. 3 concerning idling operation where at speeds below 1000 r.p.m. a greater fuel supply and therefore longer pulse durations T, increasing in direction toward still lower speeds are desired. The necessary correcting voltages are provided from a transistor 100 which is connected at its base with a potentiometer 101 forming part of a third parallel combination including a filter condenser 102 and connected in series with a rectifier 103. In order to save a further winding on the transformer 82—83, the third parallel combination mentioned above is connected in parallel with the previously mentioned rectifier 52 in such a manner that the filter condenser 102 is charged via the rectifier 103 during those voltage half-waves induced in the secondary winding 50 which are induced therein at the end of the current pulses J and therefore have a polarity opposite to those voltage half-waves U_{r1} and U_{r2} generated at the start of the current pulses. Since the emitter electrode of the transistor 100 is connected with the base of the pre-stage transistor 36, the emitter current J_e flowing through the resistor 54 produces a voltage drop between the junction point A and the base of the pre-stage transistor 36 which voltage drop will be the greater, the more the speed of the engine is below 1000 r.p.m. When later this speed is exceeded the positive partial voltage tapped at the potentiometer 101 increases beyond the value of the emitter-base potential difference of the transistor 100 which determines its conductivity, so that under these conditions the transistor 100 becomes non-conductive so that the emitter current J_e is discontinued. The just-mentioned increased voltage drop caused by the emitter current J_e causes a prolongation of the pulse time T of the pulses J as in the same manner described above.

A further modification or supplementation of the above-described arrangement appears to be desirable. In practical experiments with the arrangement as described so far it has been found that in fact the desired amounts of injected fuel under various conditions can be regulated very accurately by properly setting the various po-

tentiometers, but the engine can pick-up or react rapidly to the actuation of the pedal 45 only if provision is made also for a temporarily rapid increase of the injected fuel amount upon actuating the pedal 45 since the requirement of fuel supply at such moments is greater than that which would correspond to the prevailing partial vacuum in the manifold 20. Therefore, for increasing the fuel supply during acceleration a permanent magnet 110 may be connected with the pedal 45 so as to enter a coil 111 upon depression of the pedal 45. During this penetration of the magnet 110 into the coil 111, only during downward movement of the pedal 45, a positive voltage is produced at that end of the coil 111 which is connected with the base of an n-p-n-transistor 113. The collector of this transistor is directly connected with the positive line 57, while its emitter is connected with the negative line 58 via a load resistor 116, which is connected in series with the above-mentioned potentiometer 56. A condenser 117 is connected in parallel with the load resistor 116 which serves to extend the effect of the voltage pulses generated in the coil 111 upon actuation of the pedal 45 to about 1 sec. This is due to the fact that by these voltage pulses the transistor 113 is rendered conductive for a brief period of time. The emitter current of this transistor creates across the load resistor 116 a voltage drop U_e which raises the potential at the junction point B', located between the potentiometer 56, the potentiometer 88 and the resistors 117 and 118, connected in series with the load resistor 116, for a brief period of time in positive direction so that also the potential at the junction point A is raised simultaneously whereby the pre-stage transistor 36 is held longer in non-conductive condition when the voltages U_{r1} or U_{r2} induced in the winding 50 become effective at its base.

As a supplement to the above-described arrangements for automatically regulating the amounts of fuel to be injected under various operative conditions, FIG. 5 shows three auxiliary switches.

The first of these switches, marked 120, is connected between ground and the base of the pre-stage transistor 36 via a protective resistor 121 and is operable by the above described connecting rod 42 of the pressure gauge 43. The purpose of this switch is to prevent the production of energizing pulses J for the injection valves whenever the engine shaft rotates at the speed above 1500 r.p.m. while the engine is not driving but is driven by the car, e.g. during downhill run. Under such conditions a very high partial vacuum is created in the manifold 20 so that the switch 120 is moved to closed position whereby the base of the transistor 36 is connected to ground whereby it is kept in conductive condition and cannot be changed to non-conductive condition.

The further switches 124 and 125 are arranged in series arrangement between the positive line 57 and, with the insertion of a resistor 127, the junction point B'. The purpose of these auxiliary switches is to make sure that during starting the engine the duration of the energizing pulses J is increased in case that the cooling water temperature in the engine is below a predetermined value of say 35° C. The switch 124 is operable jointly with the starter control and connected therewith in suitable manner while the second switch 125 is operable by a thermostat arranged in connection with the cooling system of the engine so as to be able to respond to the temperature therein. If the temperature in the cooling system is below the above-mentioned minimum temperature, then the thermostat holds the switch 125 in closed position. Consequently, when the engine is started at a low cooling water temperature a positive potential is applied at the junction point B' whereby the pulse duration is increased in the same manner as described by the above.

It is a particular advantage of the fuel injection arrangement described above that not only the desired optimum amounts of fuel to be injected are automatically regulated, but it is also possible to preadjust the individual

correcting voltages independently from each other. In this manner it is possible to adjust the arrangement to suit various types of engines irrespective of their power and operating characteristics.

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 arrangements for internal combustion engines differing from the types described above.

While the invention has been illustrated and described as embodied in a fuel injection arrangement for internal combustion engines having an air intake manifold and at least one electromagnetically actuable fuel injection valve, 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 and desired to be secured by Letters Patent is:

1. In a fuel injection arrangement for internal combustion engines having an air intake manifold and at least one electromagnetically actuable fuel injection valve, and including a source of electric energy, switching means responsive to electric pulses applied thereto and connected between said source and said valve for controlling the energization of the latter, and pulse generator means operable by the engine for producing electric output pulses in synchronism with the rotary speed of the engine: a regulating arrangement for varying the duration of energizing pulses applied through said switching means to the valve, comprising, in combination, first regulating means operatively connected with said air intake manifold and responsive to variations of a partial vacuum in said manifold, and conductively connected with said pulse generator means for subjecting the duration of the output pulses generated thereby to a first regulation in predetermined proportion to variations of said partial vacuum; and second regulating means cooperating with said first regulating means and connected with said pulse generator means and responsive to the frequency of said output pulses, for subjecting the duration of said energizing pulses derived therefrom to a second regulation superposed on said first regulation and depending on varying speeds of the engine, whereby the duration of the pulses energizing the injection valve and therefore the fuel supply therethrough is automatically regulated depending upon degree of partial vacuum in the air intake manifold and upon the rotary speed of the engine.

2. In a fuel injection arrangement for internal combustion engines having an air intake manifold and at least one electromagnetically actuable injection valve in combination, a source of electric energy; switching means changeable between open and closed conditions by application of electric pulses and connected between said source and said electromagnetically actuable valve for energizing the latter upon being changed to conductive condition; pulse generator means operable by a cyclically moving member of the engine for producing electric output pulses in synchronism with the rotary speeds of the engine and for applying energizing pulses derived from said output pulses to said switching means; first regulating means operatively connected with said air intake manifold and responsive to variations of a partial vacuum in said manifold, and conductively connected with said pulse generator means for subjecting the duration of the output pulses generated thereby to a first regulation in predetermined proportion to variations of said partial

vacuum; and second regulating means cooperating with said first regulating means and connected with said pulse generator means and responsive to the frequency of said output pulses, for subjecting the duration of said energizing pulses derived therefrom to a second regulation superposed on said first regulation and depending on varying speeds of the engine, whereby the duration of the pulses energizing the injection valve and therefore the fuel supply therethrough is automatically regulated depending upon the degree of partial vacuum in the air intake manifold and upon the rotary speed of the engine.

3. In a fuel injection arrangement for internal combustion engines having an air intake manifold and at least one electromagnetically actuable injection valve, in combination, a source of electric energy; power transistor means changeable between conductive and non-conductive conditions by application of electric pulses to its base and having its emitter-collector circuit connected between said source and said electromagnetically actuable valve for energizing the latter upon being changed to conductive condition; pulse generator means including switch means connected with one terminal of said source and operable by a cyclically moving member of the engine and including at least one control transistor means connected between said switch means and said power transistor means for producing electric output pulses at the collector of said control transistor in synchronism with the rotary speeds of the engine and for simultaneously applying energizing pulses derived from said output pulses to said power transistor means; first regulating means operatively connected with said air intake manifold and responsive to variations of a partial vacuum in said manifold, and including variable inductive reactance means adjustable in proportion therewith and conductively connected with the collector of said control transistor means for subjecting the duration of the output pulses generated thereby and passed through said reactance means to a first regulation in predetermined proportion to variations of said partial vacuum, said regulating means including inductance means inductively coupled with said variable reactance means and being in circuit connection with the base connection of said control transistor for controlling the duration of said output pulses by applying to said base a control potential depending upon the voltage induced in said inductance means by said output pulses passed through said reactance means; and second regulating means cooperating with said first regulating means and connected with said pulse generator means and responsive to the frequency of said output pulses, for subjecting the duration of said energizing pulses derived therefrom to a second regulation superposed on said first regulation and depending on varying speeds of the engine, whereby the duration of the pulses energizing the injection valve and therefore the fuel supply therethrough is automatically regulated depending upon the degree of partial vacuum in the air intake manifold and upon the rotary speed of the engine.

4. An arrangement as claimed in claim 3, including pre-stage transistor means connected between said one terminal of said source and said control transistor means for rendering the latter non-conductive as long as said pre-stage transistor means is conductive, and vice versa; adjustable resistance connected between said source and the emitter-base circuit of said pre-stage transistor means for applying to the base thereof a base potential more than sufficient to render the same conductive, said inductance means being connected in parallel with a circuit portion of the connection between said adjustable resistance means and said base of said pre-stage transistor for applying the output voltage of said inductance means with a polarity opposite to said base potential in superposition thereon so as to determine the start and end of periods of conductivity of said pre-stage transistor means depending on when the difference between said base potential and said output voltage equals the minimum base poten-

tial causing conductivity of said pre-stage transistor means.

5. An arrangement as claimed in claim 4, including rectifier means connected between said inductance means and said circuit portion, and including a resistor connected in said circuit portion so that said output voltage is applied to the ends of said resistor.

6. In a fuel injection arrangement for internal combustion engines having an air intake manifold and at least one electromagnetically actuable injection valve, in combination, a source of electric energy; normally non-conductive power transistor means connected between said source and the injection valve for intermittently opening the same by current passing therethrough when said power transistor means is rendered conductive; at least one normally non-conductive control transistor means connected with said power transistor means for rendering the latter conductive during periods when said control transistor is rendered conductive; actuating means operable by a cyclically moving member of the engine for applying, in synchronism with the rotary speed thereof, electric pulses to said control transistor means capable of rendering the latter intermittently conductive and to initiate thereby output pulses therefrom; variable inductive reactance means inserted in the emitter-collector circuit of said control transistor means for subjecting the duration of said output pulses to a regulation thereof depending upon varied inductivity of said inductive reactance means; control means operatively connected with the air intake manifold of the engine and with said variable inductive reactance means, and responsive to variations of a partial vacuum in said manifold, for varying the inductivity of said inductive reactance means in proportion to said variations of said partial vacuum; normally conductive pre-stage transistor means having its collector connected to said control transistor means for controlling the duration of conductivity of the latter depending upon conductivity and non-conductivity, respectively, of said pre-stage transistor means, the emitter-base circuit thereof containing means for applying to the base thereof a portion of the potential of said source as a base potential more than sufficient for rendering said pre-stage transistor means conductive; and means for varying the duration of conductivity of said power transistor means, comprising circuit means connected in parallel with a circuit portion of said emitter-base circuit of said pre-stage transistor means and including inductance means coupled with said variable inductive reactance means for applying to said emitter-base circuit control pulses proportional to said output pulses regulated in duration by said variable reactance means and for superimposing said control pulses on said base potential with opposite polarity so as to determine the start and end of periods of conductivity of said pre-stage transistor means depending on when the difference between said base potential and the rising and falling potential of said control pulses equals the minimum base potential causing conductivity of said pre-stage transistor means; whereby the duration of conductivity of said power transistor means and thus the opening time of said valve is made dependent upon the degree of partial vacuum existing in the air intake manifold.

7. An arrangement as claimed in claim 6, including rectifier means connected between said inductance means and said emitter-base circuit for determining the polarity of said control pulses, and resistor means arranged in said circuit portion so that said control pulses are applied to the ends of said resistor means.

8. In a fuel injection arrangement for internal combustion engines having an air intake manifold and at least one electromagnetically actuable injection valve, in combination, a source of electric energy; normally non-conductive power transistor means connected between said source and the injection valve for intermittently opening the same by current passing therethrough when said power transistor means is rendered conductive; at least

one normally non-conductive control transistor means connected with said power transistor means for rendering the latter conductive during periods when said control transistor is rendered conductive; actuating means operable by a cyclically moving member of the engine for applying, in synchronism with the rotary speed thereof, electric pulses to said control transistor means capable of rendering the latter intermittently conductive and to initiate thereby output pulses therefrom; first regulating means comprising variable inductive reactance means inserted in the emitter-collector circuit of said control transistor means for subjecting the duration of said output pulses to a first regulation thereof depending upon varied inductivity of said inductive reactance means; control means operatively connected with the air intake manifold of the engine and with said variable inductive reactance means, and responsive to variations of a partial vacuum in said manifold, for varying the inductivity of said inductive reactance means in proportion to said variations of said partial vacuum; normally conductive pre-stage transistor means having its collector connected to control transistor means for controlling the duration of conductivity of the latter depending upon conductivity and non-conductivity, respectively, of said pre-stage transistor means, the emitter-base circuit thereof containing means for applying to the base thereof a portion of the potential of said source as a base potential more than sufficient for rendering said pre-stage transistor means conductive; means for varying the duration of conductivity of said power transistor means, comprising circuit means connected in parallel with a circuit portion of said emitter-base circuit of said pre-stage transistor means and including inductance means coupled with said variable inductive reactance means for applying to said emitter-base circuit control pulses proportional to said output pulses regulated in duration by said variable reactance means and for superimposing said control pulses on said base potential with opposite polarity so as to determine the start and end of periods of conductivity of said pre-stage transistor means depending on when the difference between said base potential and the rising and falling potential of said control pulses equals the minimum base potential causing conductivity of said pre-stage transistor means; and second regulating means cooperating with said first regulating means and connected with said pre-stage transistor means and with the output of said control transistor, said second regulating means being responsive to the frequency of said output pulses and serving to subject the duration of said output pulses to a second regulation depending on varying speeds of the engine by applying a control voltage depending upon said speeds to the base of said pre-stage transistor in superposition on said base potential thereof, whereby the duration of conductivity of said power transistor means and thus the opening time of said valve is made dependent upon the degree of partial vacuum existing in the air intake manifold and upon the rotary speed of the engine.

9. An arrangement as claimed in claim 8, including rectifier means connected between said inductance means and said emitter-base circuit for determining the polarity of said control pulses, and resistor means arranged in said circuit portion so that said control pulses are applied to the ends of said resistor means.

10. An arrangement as claimed in claim 9, wherein said second regulating means include amplifier transistor means connected between said control transistor means and said power transistor means for transmitting said output pulses to the latter and for delivering from its emitter-collector circuit second output pulses in synchronism with said first mentioned output pulses; transformer means having a primary winding in circuit with said emitter-collector circuit for being energized by said second output pulses, and at least one secondary winding, time-constant determining means including rectifier means and filter-condenser means connected to the output of said secondary winding and furnishing a second control volt-

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age increasing with increasing frequency of said output pulses, and circuit means for connecting the output of said time-constant determining means with the emitter-base circuit of said pre-stage transmitter means for superimposing said second control voltage on said base potential thereof.

11. An arrangement as claimed in claim 10, wherein said second regulating means include a second secondary winding in said transformer means, second time-constant determining means including rectifier means and filter-condenser means connected to the output of said second secondary winding and furnishing a third control voltage increasing with increasing frequency of said output pulses, auxiliary transistor means connected at its base with the output of said second time-constant determining means for being controlled by said third control voltage, and circuit means connecting the collector of said auxiliary transistor with the emitter-base circuit of said pre-stage transistor and containing voltage divider means for varying the bias potential of said pre-stage transistor means depending upon said third control voltage and upon the resistance values of said voltage divider means.

12. An arrangement as claimed in claim 11, comprising auxiliary pulse generator means including inductance coil means and a permanent magnet movable relative to said inductance coil means and operable in conjunction with the accelerator means of the engine, for furnishing a control pulse whenever said accelerator means are actuated, and circuit means for applying such

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pulses to said second regulating means for increasing the duration of said output pulses.

13. An arrangement as claimed in claim 12, including third auxiliary transistor means connected at its base with said inductance coil means, the emitter-collector circuit of said third auxiliary transistor means being connected in parallel with at least one portion of said voltage divider means.

14. An arrangement as claimed in claim 9, including a rectifier circuit connected in parallel with said resistor in the emitter-base circuit of said pre-stage transistor and comprising a rectifier connected with a polarity opposite to that of said rectifier between said inductance means and said emitter-base circuit and filter-condenser means for furnishing at the output thereof a fourth control voltage increasing with increasing frequency of said output pulses, and second auxiliary transistor means connected at its base with said output of said rectifier circuit for being controlled by said fourth control voltage and for being rendered non-conductive at a predetermined value of said fourth control voltage corresponding to an engine speed exceeding a predetermined speed, the emitter-collector circuit of said second auxiliary transistor means being connected with said emitter-base circuit of said pre-stage transistor means for varying its base potential so as to increase the duration of said output pulses during operation of the engine at speeds before said predetermined speeds.

No references cited.