United States Patent

Monpetit

[15] **3,669,081**

[45] **June 13, 1972**

[54] ELECTRONICALLY CONTROLLED INJECTING ARRANGEMENTS FEEDING FUEL UNDER CONSTANT PRESSURE INTO INTERNAL COMBUSTION ENGINES

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[52] **U.S. Cl.** ..... **123/32 EA,** 123/136, 123/139 R, 123/139 E, 123/179 G

[51] **Int. Cl.** **F02m 51/00**

[58] **Field of Search** ..... 123/32 AE, 32 EA, 119, 139, 123/139 E, 139 AW, 179 G; 417/14, 18, 42, 44, 45

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[57] **ABSTRACT**

A control of the output of the pump feeding fuel under constant pressure into the manifold of an internal combustion engine, said pump operating under control of an electronic system defining the frequency and duration of the injections. Said control ensures an adjustment of the output of the pump in accordance with the actual requirements of the engine. For instance an electric motor driving the pump is fed by pulses transmitted electronically in synchronism with the injection-producing signals so that the average current feeding the motor which is measured by the integral of said pulses may match such requirements with a delay at the beginning or end of the pulse if required.

5 Claims, 5 Drawing Figures

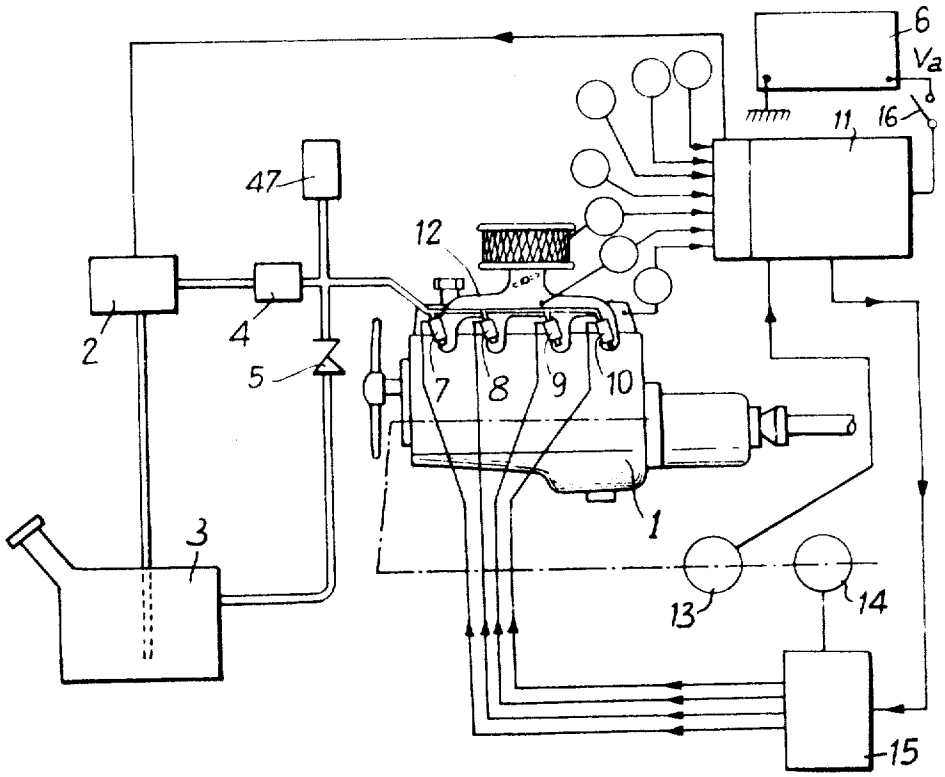

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Fig:1

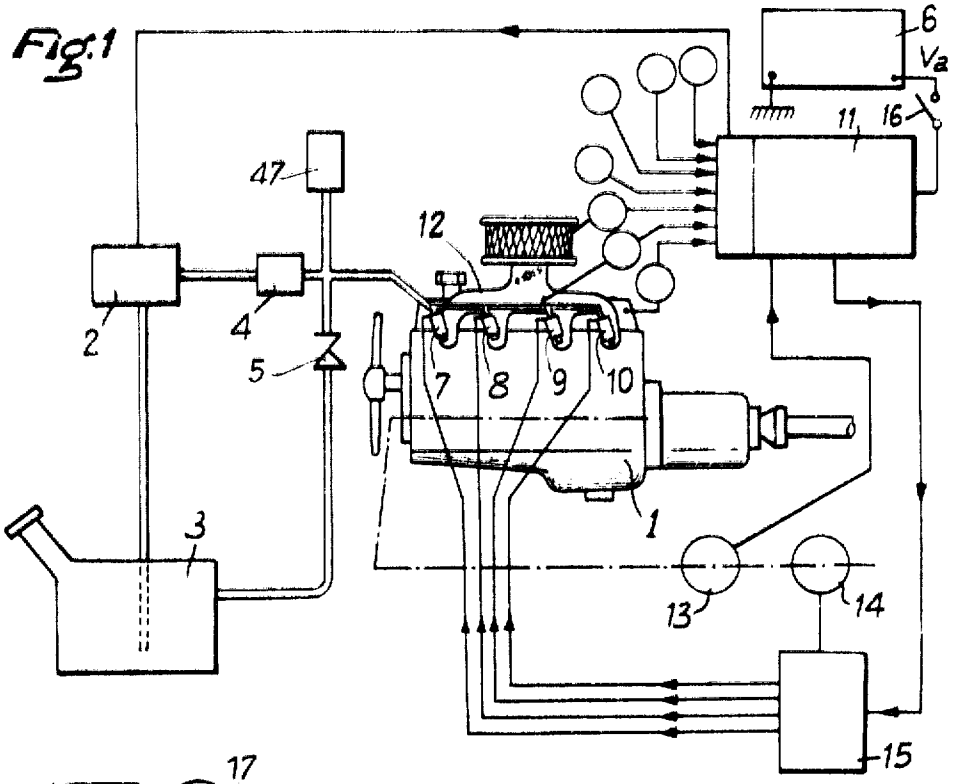

Fig:2

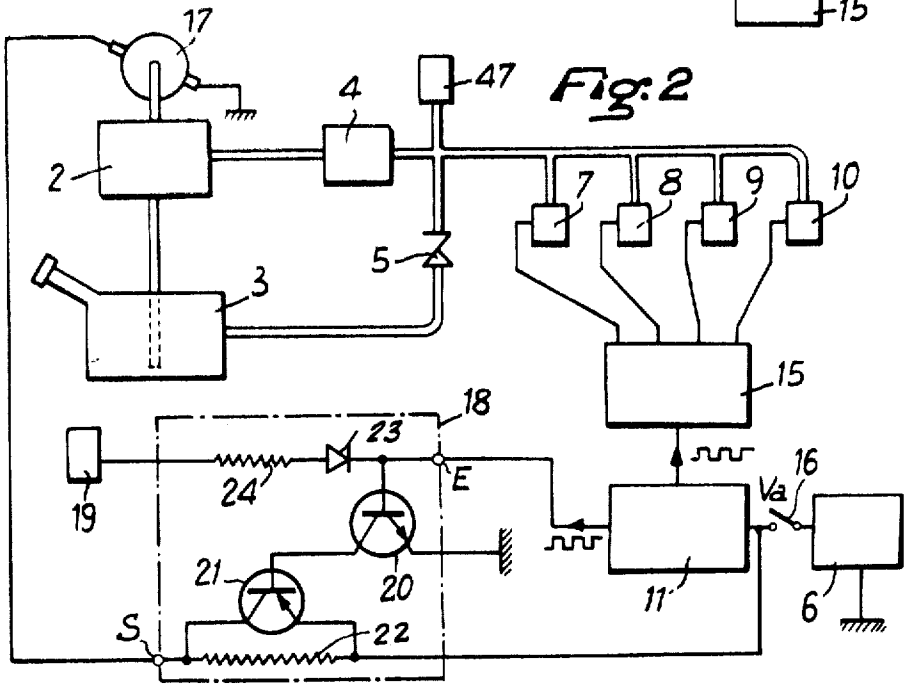

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Fig. 3

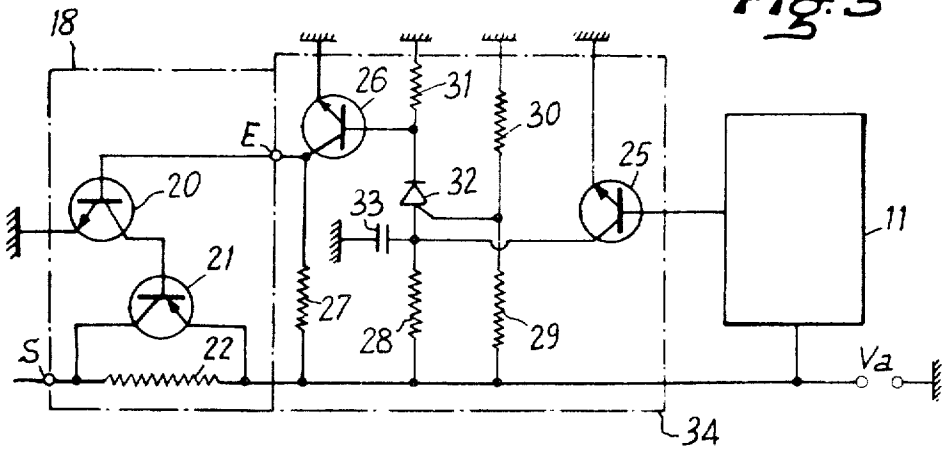


Fig. 4

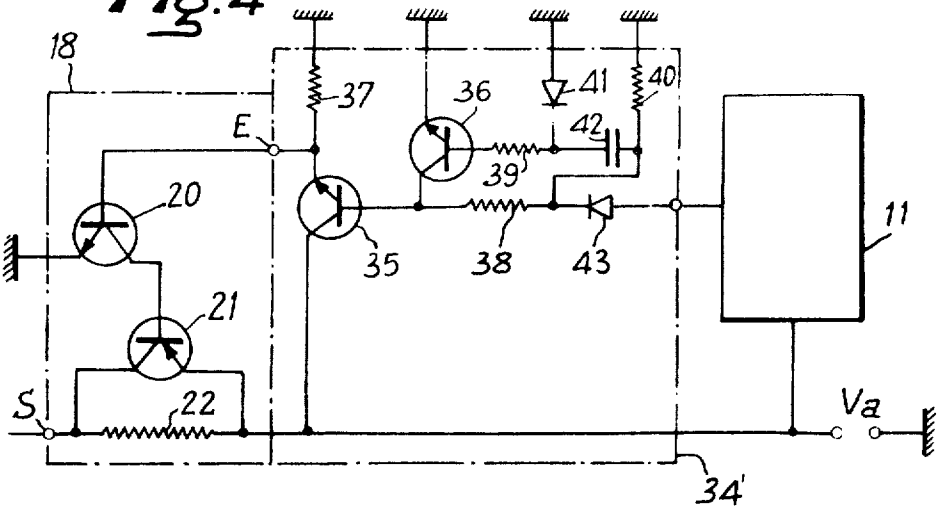
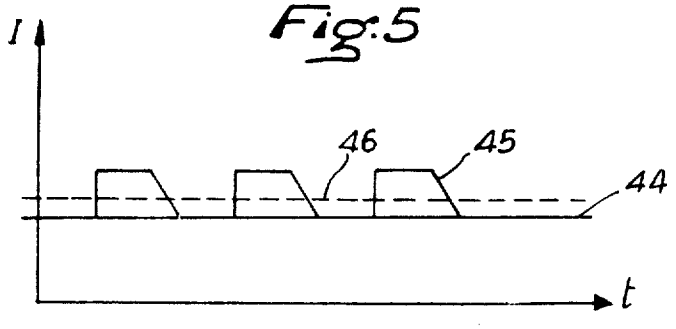


Fig. 5



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ELECTRONICALLY CONTROLLED INJECTING ARRANGEMENTS FEEDING FUEL UNDER CONSTANT PRESSURE INTO INTERNAL COMBUSTION ENGINES

The present invention has for its object improvements in electronically controlled injecting arrangements feeding fuel under a constant pressure into internal combustion engines.

Such arrangements generally include a gear pump driven at a constant speed by an electric motor and feeding fuel into a pipe opening into the different injectors, the pressure being maintained at a constant value by a pressure regulator adapted to open a return channel to a container to a varying extent depending on the fuel consumption of the engine, which depends in turn on the rotary speed of the latter and on its load. The advantage of such an arrangement resides in the simplicity of the drive obtained by an electric motor and the easy starting since the pipes are subjected to pressure as soon as the ignition key is inserted.

It should be remarked however that such a solution shows by reason of its very simplicity, various drawbacks since the rotary speed of the motor and consequently the output of the gear pump are constant so that said output must be at least equal to that required for the maximum possible consumption of the engine under full speed and power. Now the ratio between maximum consumption and minimum consumption under idling conditions of the engine ranges between 20 and 30 so that during the major periods of operation of the engine, a large fraction of the fuel is returned into the fuel container; this leads to an unnecessary expenditure of electric energy and still more to a heating of the fuel resulting in possible trouble in operation.

The present invention has for its object the removal of said drawbacks and to this end means are provided for adjusting the output of the pump to match the actual fuel requirements of the engine.

According to further developments of our invention, further advantageous features to be disclosed hereinafter are as follows:

the pump is of the self-regulating type the output of which varies under constant pressure conditions, said pump being driven by a electric motor running at an constant speed.

the pump, being of the self-regulating type the output of which varies under constant pressure conditions is driven by the internal combustion engine.

the pump is driven by the internal combustion engine through the agency of a variable speed transmission, the speed ratio being defined by means responsive to the load of the engine.

the transmission is provided by a trapezoidal-shaped belt and pulleys of the well-known variable breadth type, the spacing between the flanges of the pulleys being controlled by means sensitive to the reduction in pressure in the admission pipe.

the pump is driven by an electric motor the speed of which is adjusted by electronic means depending on the load and rotary speed of the internal combustion engine.

a transistor is connected in the circuit feeding the electric motor or its energizing winding, the base of said transistor receiving signals through the agency of suitable means operating at the frequency of the injection-triggering signals during periods depending on the duration of the injection whereby the average current flowing through the collector-emitter circuit of the transistor and consequently through the motor or its energizing winding forms the integral of said signals.

a resistance is connected in parallel with the collector-emitter circuit of said transistor and its value is selected so that the motor revolves at a very low speed just sufficient for ensuring a compensation for the leaks and/or a minimum circulation of the fuel when the transistor is cut off.

the transistor is controlled in association with the starter of the internal combustion engine so that the transistor is always conducting during actuation of said starter.

the transistor receives control signals at the frequency of the injection signals, the duration of said control signals being proportional to that of the latter with an addition provided by

control means incorporating a first transistor the base of which receives the injection signals while the collector-emitter circuit of said first transistor is connected in series with a condenser between ground and the anode of a programmable unijunction transistor connected in turn with the supply of voltage through a first resistance ; the electrode controlling the unijunction transistor is subjected to a predetermined voltage by a voltage divider while its cathode is connected with the base of a second transistor the emitter of which is grounded and the collector of which is connected with the supply of voltage through a resistance and also with the base of the first-mentioned transistor controlling the speed of the pump-driving motor.

The transistor receives control signals at the frequency of the injection signals, the duration of said control signals being proportional to that of the latter with an addition provided by control means incorporating a first transistor the base of which receives the injection signals through a diode and a resistance while the collector emitter circuit of said first transistor is connected in series with a further resistance between the supply of voltage and ground, the emitter of said first transistor be further connected with the base of the transistor controlling the speed of the motor-driving pump; a second transistor is provided, the collector of which is connected with the base of the first transistor, and the emitter of which is grounded. The base of said second transistor is connected with the junction between the diode and the associated resistance through a still further resistance and a condenser the positive and negative terminals of said condenser also being grounded respectively through a resistance and a diode.

By way of example and in order to further the understanding of the following description, the accompanying drawings are provided in which:

FIG. **1** is a general block diagram of an arrangement according to the invention;

FIG. **2** is a partly schematic and partly block diagram of the electronic control system of the feed pump;

FIG. **3** is a schematic diagram for an improvement of the control system illustrated in FIG. **2**;

FIG. **4** is a modification of the embodiment of FIG. **3**; and

FIG. **5** is a chart illustrating diagrammatically the current feeding the pump-driving motor.

Turning to FIG. **1**, it is apparent that the arrangement includes an internal combustion engine provided with an intake manifold **12** and with electromagnetically controlled injectors **7, 8, 9, 10**. A feed pump **2** sucks fuel out of the container **3** and delivers said fuel into a common pipe through the filter **4** into the injectors **7, 8, 9** and **10**. The pressure in said pipe is held at a constant value by a regulator **5**, and the fluctuations in pressure are compensated by an hydraulic accumulator **47**. Said injectors **7, 8, 9** and **10** are operated in the desired sequence by an electronic control system **11** of a known type including several inputs and adapted to define the duration of opening of the injectors under the control of the various parameters governing the operation of the engine. The signals are triggered in synchronism with the rotation of the engine **1** by a pulse generator **13** and are sent to the different injectors **7, 8, 9** and **10** by means of a distributor **15** driven by the control means **14**. The electric circuit is supplied with a voltage V_A by the battery **6** through the switch **16**.

In a first embodiment which is not illustrated the pump **2** is of the well-known self-regulating type operating under variable output and constant pressure conditions. Said pump includes axial pistons actuated by an oblique rotary plate assuming various slopes under the action of an internal pressure regulator adapted to maintain constancy of pressure in the pump circuit. Said constancy is ensured by a modification in the slope of the oblique plate producing a modification in the output of the pump such that the pump feeds only that amount of fuel which is to be actually burnt by the internal combustion engine. The pump **2** may be driven either by an electric motor running at a constant speed or by the internal combustion engine **1**.

In the first case the variations in the output of the pump between idling and full power at maximum speed for the engine should be substantially in the ratio of 1 to 10, whereas in the second case the ratio is only 1 to 4.

However in the second case difficulties may be encountered when starting since the engine **1** drives the pump **2** at a very low speed so that no pressure is then applied to the pipes.

According to a further embodiment, which is not illustrated since its components are known per se, the pump **2** which may be a gear pump for example is driven by the engine **1** through the agency of a transmitter providing a variable speed ratio,such as a trapezoidal-shaped belt and pulleys of the variable breadth type, the spacing of the pulley flanges being controlled by an arrangement subjected to the action of the reduced pressure inside the admission pipe so as to increase or reduce the speed of rotation of the pump with reference to that of the engine when the pressure rises or falls within said admission pipe.

FIG. **2** illustrates another embodiment wherein the pump is a gear pump is driven by an electric motor **17**. The latter is fed under the control of electronic regulating means **18** which causes the rotary speed of the motor **17**, and consequently of the pump, to vary in accordance with the frequency of injection , that is, of the rotary speed of the internal combustion engine **1**, and also in accordance with the duration of injection, that is, of the load on the internal combustion engine **1**. To this end, there is inserted in series with the circuit feeding the electric motor **17** or with the winding energizing the latter a transistor **21** the base of which is connected with the collector of another transistor **20** the emitter of which is grounded while its base is connected through the terminal E of the electronic regulating means **18** with the electronic control system **11**.

The operation of the arrangement is as follows:

The positive rectangular signals controlling the injection are transmitted to the injectors **7**, **8**, **9** and **10** through the distributor **15** and are simultaneously applied to the base of the transistor **20** which becomes thereby conductive each time a signal is applied and throughout its duration. Consequently, the transistor **21** becomes conductive at the same rhythm so that the electric motor **17** is fed with corresponding current pulses. It is thus possible to consider that the motor **17** is fed by an average current equivalent to the integral of said pulses so that the motor **17** revolves at a speed corresponding to said average current.

In order to prevent the motor from stopping completely when no signal is applied at the terminal E of the arrangement there is inserted a resistance **22** in parallel with the emitter-collector circuit of the transistor **21**, the value of said resistance being such that the motor revolves at a very low speed such as may just compensate for leaks and/or ensure a minimum output of fuel in a closed circuit.

The starting characteristics can be enhanced by connecting relay **19** controlling the starter through a resistance **24** and a diode **23** with the base of the transistor **20** so that the transistors **20** and **21** are conductive as long as the starter relay **19** is energized and provide a maximum output of the pump **2**.

In certain cases, it may be of interest to apply at the input terminal E of the electronic regulating means **18** pulses which last longer than the injection pulses transmitted by the electronic control system **11**. To this end,there may be provided as illustrated in FIG. **3**, a circuit system **34** comprising a transistor **25** connected through its base with the control system **11**, while its collector-emitter circuit is connected between the anode of the programmable unijunction transistor **32** and ground in parallel with a grounded condenser **33**. Said unijunction transistor **32** is connected in series with the resistances **28** and **31** between the source of voltage *Va* to ground while its control electrode is held at a predetermined voltage by a voltage divider constituted by the resistances **29** and **30** also connected between the source of voltage *Va* and ground. The cathode of the programmable unijunction transistor **32** is further connected with the base of a transistor **26**, the collector-emitter circuit of which is connected between the supply of voltage and ground through the resistance **27**, the collector of said transistor **26** being further connected with the input E of the regulating means **18**.

It is apparent that each time a positive pulse is applied to the base of the transistor **25**, the latter becomes conductive, thus discharging condenser **33** and reducing substantially to zero the voltage applied to the anode of unijunction transistor **32** so that said unijunction transistor is deenergized. Consequently the transistor **26** is also cut off, and a voltage appears at the input E of the regulating means **18** whereby the transistors **20** and **21** become conductive, as stated above. When the signal applied on the base of the transistor **25** disappears,the voltage applied through the resistance **28** on the anode of the unijunction transistor **32** increases as the charge on the condenser **33** increases until the unijunction transistor again becomes conductive at a condenser voltage determined by the voltage applied to the control electrode of said unijunction transistor **32**. It is thus apparent that the regulating means **18** remain conductive throughout the duration of the injection pulse increased by the additional time defined by the time constant of the RC circuit constituted by the resistance **28** and condenser **33**.

If, in contradistinction, it is desired to shorten the pulses applied to the regulating means **18**, it is possible to connect between the latter and control system **11** a circuit **34'**(FIG. **4**) including a transistor **35** the base of which receives the injection pulses through a diode **43** and a resistance **38**. The collector emitter circuit of said transistor **35** is connected in series with a resistance **37** between the source of voltage *Va* and ground while the emitter of the transistor **35** is further connected with the input E of the regulating means **18**. In order to shorten the pulses transmitted to the regulating means **18** the collector-emitter circuit of a further transistor **36** is connected between the base of the transistor **35** and ground while the base of said transistor **36** is connected through the resistance **39** and condenser **42** with the junction between the resistance **38** and diode **43**, the positive and negative terminals of said condenser **42** being grounded through a resistance **40** and a diode **41** respectively.

This circuit is such that the injection signal is applied to the base of the transistor **35** with some lag since the transistor **36** is conductive during the time required for charging the condenser **42** through the resistance **39** whereby the voltage applied on the base of the transistor **35** is returned to zero during said time.

FIG. **5** illustrates diagrammatically the curve defining the current I with reference to time *t*, the horizontal line **44** corresponding to the constant current flowing through the resistance **22** of the regulating means **18**, the pulses **45** corresponding to the injection pulses modified if required by a circuit such as **34** or **34'**, while the dashed line **46** corresponds to the average current forming the integral of the pulses **45** with the addition of the constant current **44**.

What I claim is:

1. In an electronically controlled fuel supply system for internal combustion engines comprising a common pipe feeding the fuel injectors with fuel under constant pressure, a fuel pump feeding said pipe, a variable speed electric motor for driving said pump, electronic control means for producing fuel injection signals in synchronism with the rotation of the engine and of variable duration according to the load on the engine, an improved electronic regulating means connected to the electronic control means for acting on the electric motor in response to the varied fuel injection signals to adjust its speed in conformity with the load and the rotary speed of the engine, said electronic regulating means comprising:

a source of voltage for energizing the electric motor,

a transistor having its collector-emitter circuit inserted between said voltage source and said electric motor, and

means feeding the base of said transistor with pulses at a frequency which is that of the injection producing signals and of a duration which is a function of that of the injec-

tion-producing signals, said pulses producing an average current passing through said collector-emitter circuit and causing the motor to turn at a speed corresponding to the integral of said pulses.

2. In an electronically controlled fuel supply system for internal combustion engines comprising a common fuel pipe feeding the fuel injectors with fuel under constant pressure, a fuel pump feeding said pipe, a variable speed electric motor for driving said pump, electronic control means for producing fuel injection signals in synchronism with the rotation of the engine and of variable duration according to the load on the engine, an improved electronic regulating means connected to the electronic control means for acting on the electric motor in response to the varied fuel injection signals to adjust its speed in conformity with the load and the rotary speed of the engine, said electronic regulating means comprising:

a source of voltage for energizing the electric motor

a transistor having its collector-emitter circuit inserted between said voltage source and said electric motor,

means feeding the base of said transistor with pulses at a frequency which is that of the injection-producing signals and of a duration which is a function of that of the injection-producing signals, said pulses producing an average current passing through

said collector-emitter circuit and causing the motor to turn at a speed corresponding to the integral of said pulses, and

a resistance shunting said collector-emitter circuit, the value of said resistance defining the passage of a constant current which produces a slow basic rotation of the motor at a slow speed added to that speed produced by said average current.

3. In an electronically controlled fuel supply system for internal combustion engines comprising a common pipe feeding the fuel injectors with fuel under constant pressure, a fuel pump feeding said pipe, a variable speed electric motor for driving said pump, electronic control means for producing fuel injection signals in synchronism with the rotation of the engine and of variable duration according to the load on the engine, an improved electronic regulating means connected to the electronic control means for acting on the electric motor in response to the varied fuel injection signals to adjust its speed in conformity with the load and the rotary speed of the engine, said electronic regulating means comprising:

a source of voltage for energizing the electric motor,

a transistor having its collector-emitter circuit inserted between said voltage source and said electric motor,

means feeding the base of said transistor with pulses at a frequency which is that of the injection-producing signals and of a duration which is a function of that of the injection-producing signals, said pulses producing an average current passing through said collector-emitter circuit and causing the motor to turn at a speed corresponding to the integral of said pulses, and

means operatively connecting the starter with said transistor for causing the transistor to conduct continuously during actuation of the starter to produce full speed rotation of the pump motor while the starter is actuated.

4. A system as claimed in claim 1 wherein the electronic regulating means include an additional transistor, means feeding the base of said additional transistor with pulses at a frequency which is that of the injection producing signals, a program-controlled unijunction transistor, a resistance in series therewith inserted between the source of voltage and ground, a potentiometer inserted between the source of voltage and ground and a point of which is connected with the control electrode of the unijunction transistor, a condenser grounding the anode of the unijunction transistor, a connection between last-mentioned anode and ground and in which the collector-emitter circuit of the further transistor is inserted, a still further transistor base having its base connected with the cathode of the unijunction transistor, the emitter of which is grounded, an additional resistance connecting the collector of said still further transistor with the source of voltage and a connection between the last-mentioned collector and the base of the first-mentioned transistor, to feed the latter with pulses at a frequency which is that of the injection-producing signals and of a duration which is equal to that of said signals with the addition of the duration of discharging of the condenser and of the time constant defined by the condenser circuit.

5. A system as claimed in claim 1 wherein the electronic regulating means include an additional transistor having its collector-emitter circuit inserted between the source of voltage and ground, a resistance and a diode in series inserted between the signal generator and the base of said further transistor, an additional resistance between the emitter of said additional transistor and ground, means connecting the last-mentioned emitter with the base of the first-mentioned transistor to feed said base with pulses at a frequency which is that of the injection-producing signals and of a duration which is a function of that of said signals, and including a still further transistor the collector of which is connected with the base of the further transistor and the emitter of which is grounded, a still further resistance and a condenser inserted in series between the base of the further transistor and the point connecting said diode with the cooperating first-mentioned resistance, and a further diode and fourth resistance grounding the corresponding terminals of the condenser respectively, the duration of loading of said condenser delaying the application of the pulses to the base of the first-mentioned transistor.

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