

May 29, 1962

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LOW-PRESSURE FUEL INJECTION DEVICE

Filed Nov. 16, 1959

3 Sheets-Sheet 1

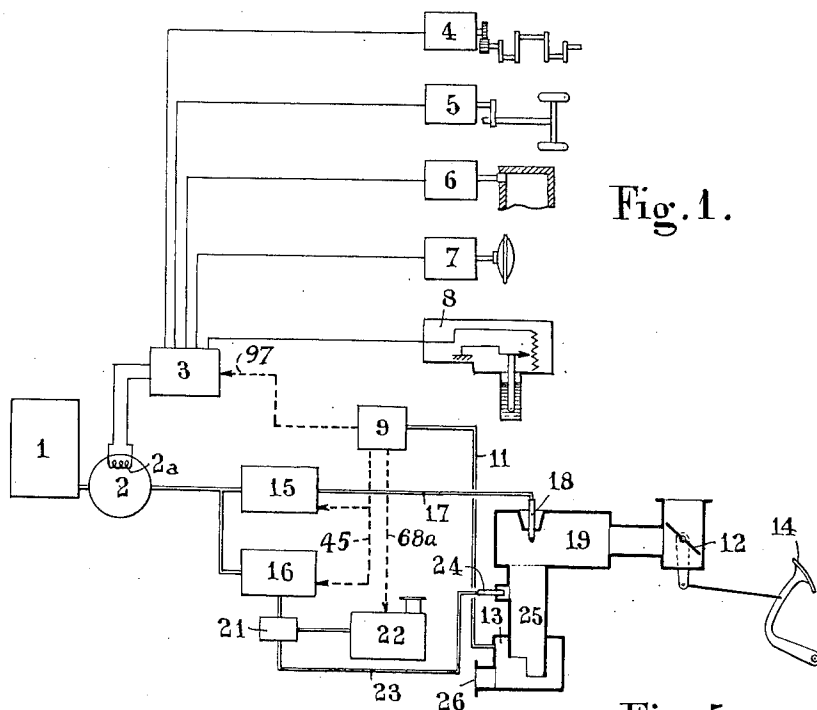


Fig. 1.

Fig. 5.

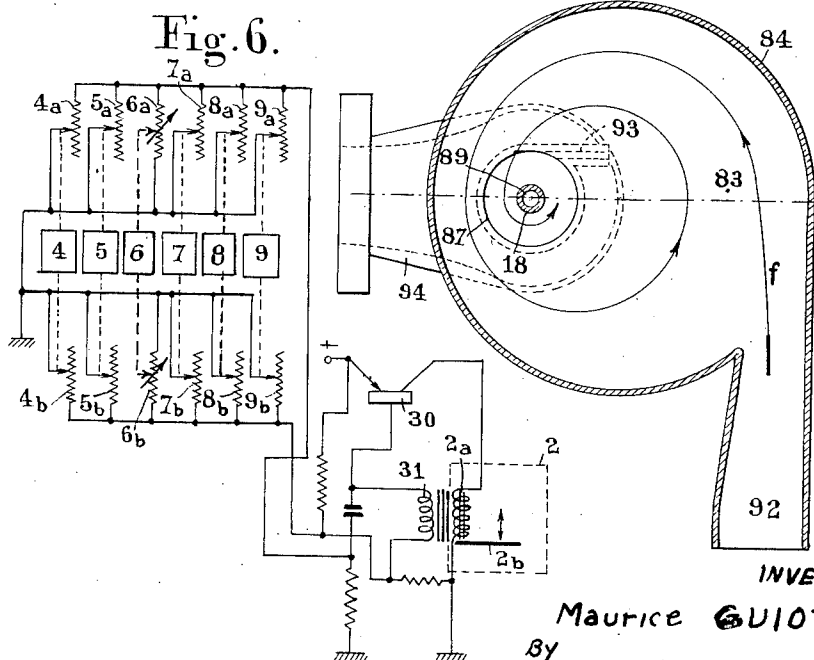


Fig. 6.

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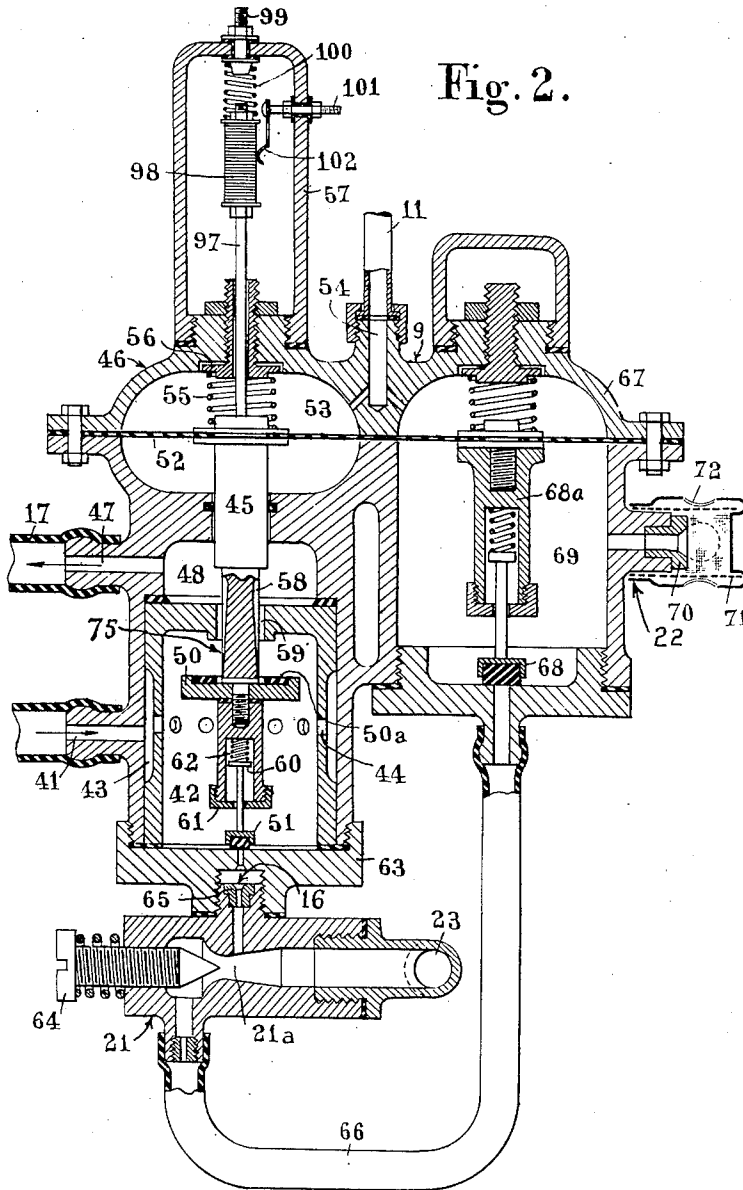


Fig. 2.

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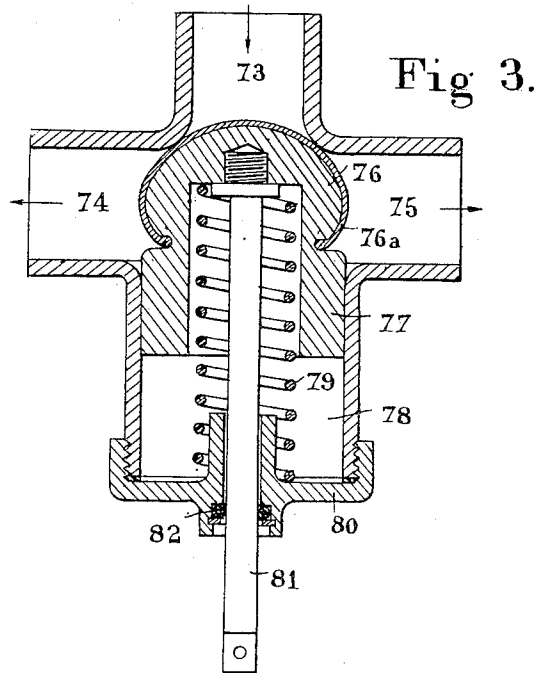


Fig 3.

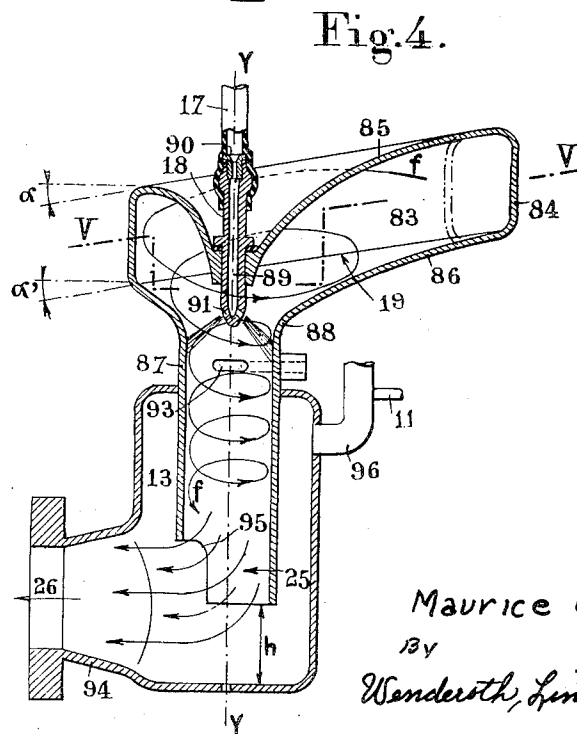


Fig.4.

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LOW-PRESSURE FUEL INJECTION DEVICE

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12 Claims. (Cl. 123-119)

This invention is concerned with low pressure fuel injection devices applicable notably to the fuel systems of automotive vehicles.

Conventional fuel injection systems are designed with a view, as a function of the engine load and speed, to inject directly into the engine cylinders the required quantity of fuel metered by a high pressure pump and atomized through a suitable injector. Devices of this character, although ensuring theoretically the best engine efficiency, are relatively costly due to their construction and therefore the fuel economy resulting from their use will not balance the initial cost of the installation.

It is the essential object of this invention to provide a fuel injection device of relatively simple design, wherein the fuel is injected at a relatively low pressure into the inlet valve chamber of the engine or into an induction pipe but in close proximity of the cylinder head inlet.

To this end, the low-pressure fuel injection device of this invention for internal combustion engine is characterized in that it comprises an electrically operated fuel pump, a transistorized current generator controlling said pump, means for modifying the characteristics of the pump energizing current as a function of the various parameters intervening in the injection process, that is, the strength of the induction vacuum, the velocity of rotation of the engine, the reaction torque, the atmospheric pressure, the engine temperature and the fuel density, a main fuel metering device connected to the pump outlet and adapted to complete the adaptation of the injection output and pressure under normal running conditions, an idling device ensuring the passage from moderate load conditions to idling conditions by metering the supply of idling fuel and air, means responsive to the induction vacuum for actuating the main fuel metering device and the idling device according to the vacuum existing in the induction pipe of the engine, a device for adjusting the induction air, a device for mixing the fuel injected by the main metering device with the induction air, and a device for atomizing the emulsified air-fuel mixture into the inlet valve chambers of the engine.

In the injection device according to this invention the only function of the injector is to effect the rough division of the fuel, as the latter is atomized by virtue of a special arrangement of the induction pipe or manifold of the engine.

In order to afford a clearer understanding of this invention and of the manner in which the same can be carried out in practice, a typical form of embodiment thereof will now be described with reference to the attached drawings forming part of this specification and illustrating diagrammatically by way of example the different component elements of the low-pressure fuel injection system of this invention. In the drawings:

FIGURE 1 is a diagram illustrating the principle of the device of this invention.

FIGURE 2 is an axial section showing a typical form of embodiment of the main device for metering the fuel and of the idling device.

FIGURE 3 is another axial section showing a typical form of embodiment of the induction air regulating device.

FIGURE 4 is a vertical section showing the device for mixing and atomizing the fuel and induction air.

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FIGURE 5 is a section taken along the line V—V of FIG. 4; and

FIGURE 6 is a wiring diagram of the pulse generator controlling the pump.

Referring first to FIG. 1, the low-pressure fuel injection device of this invention comprises a fuel tank 1 connected to an electrically-operated pump 2 located either inside or in close proximity of the tank 1. The winding 2a of the pump driving system is energized with pulses or oscillations generated by a transistorized pulse generator 3. In the case of an electromagnetically operated pump the winding 2a will control the reciprocation of the pump diaphragm. In this case the output and pressure of the fuel delivered by the pump 2 depend on the height and frequency of the pulses delivered by the generator 3.

The transistorized pilot pulse generator 3 may be of any known construction as will be described presently with reference to FIG. 6.

The characteristics of the pulses generated by the pilot generator 3 can be modified at will as a function of the various parameters prevailing in the injection process. This is shown in diagrammatic form in FIG. 1 illustrating a number of devices 4, 5, 6, 7 and 8 to which certain elements of the pilot generator 3 are responsive with a view to cause the characteristics of the pulses emitted therefrom to vary as a function of the different parameters involved. As shown in diagrammatic form, the device 4 controls the pilot generator 3 as a function of the velocity of rotation, the device 5 as a function of the reaction torque, the device 6 as a function of the engine temperature, the device 7 as a function of the atmospheric pressure and the device 8 as a function of the fuel density.

The pilot generator 3 is also responsive, as a function of the vacuum prevailing in the induction pipe or manifold, to a vacuum regulator 9. This vacuum regulator 9 communicates through a pipe line 11 with a point of the induction manifold or pipe which lies after the device 12 for adjusting the induction air. This adjustment device 12 is shown in diagrammatic form as consisting of a butterfly shutter responsive to the movements of the accelerator pedal 14.

The electrically actuated pump 2 feeds in parallel a main fuel metering device 15 and an idling fuel metering device 16. The main metering device 15 is connected through a pipe 17 to the injector proper 18 emerging into a mixer device 19 to be described presently.

The idling fuel metering device 16 supplies fuel to an idling mixer 21 to which an idling air metering device 22 is similarly connected, as shown. The idling mixer 21 is connected through a line 23 to an idling injector 24 emerging into the mixer 19 at a point located after the main injector 18.

The vacuum regulator 9 controlling the pilot generator 3 is also adapted to control the main fuel metering device 15, the idling fuel metering device 16 and the idling air metering device 22 as a function of the vacuum prevailing in the cavity 13 after the adjustment device 12.

The injection device proper comprises, after the mixer 19 an atomizing and emulsifying unit 25 opening through the orifice 26 into the inlet valve chambers of the engine.

The main fuel metering device 15 and the idling device 16 are merged into a same unit in FIG. 2, but if desired they can be separated according to the forms of embodiment contemplated.

It is advantageous to pre-emulsify the idling air and fuel before introducing them into the induction pipe or manifold, but this feature should not be construed as a fundamental one in practising the invention.

The fuel from the pump is forced through the orifice 41 into a sealed cavity 42 in which the fuel stream is divided due to its passage through an annular cham-

ber 43 and through orifices 44 opening into the sealed cavity 42.

The fuel may be directed, according to the position of the control rod 45 of the vacuum-responsive regulator 9, either through the main fuel metering device 15 towards the orifice 47 connected to the pipe line 17 leading to the injector 18, after the output has been regularized in a sealed calming chamber 48, or through the idling device 16 towards the idling mixer 21. This distribution is effected through the medium of conjugated valves 50 for the injection fuel and 51 for the idling fuel. These valves 50 and 51 are controlled by the rod 45 of a first vacuum-responsive device 46 of the regulator 9. This device 46 consists essentially of an elastic diaphragm 52 having its center rigidly connected to the rod 45 and its outer periphery clamped between the lateral walls of a sealed chamber 53 communicating through an orifice 54 with the pipe line 11 connected to the induction pipe or manifold of the engine. When the vacuum of the induction pipe or manifold is moderate (as in full-throttle conditions) the diaphragm is urged downwards by a return spring 55 having a flexibility consistent with the desired timing of valve 50.

A screw 56 is provided for finishing the adjustment of the spring 55. A fluid-tight cap 57 prevents any leakage to the outside. Since the movement of the valve member 50 is calculated as a function of the vacuum, it is possible to provide a wide range of adjustments of the main fuel metering device 15 by modifying the cross-sectional area of the passage between the chambers 42 and 48. In the example illustrated this cross-sectional area is variable due to the inclination of the flat portions 58 formed along the rod 45 sliding in a cylindrical bore 59. Alternately, the rod 45 may be given a tapered configuration along this portion. Under full-throttle conditions the cross-sectional area of the passage provided between the flat portions 58 and the bore 59 is maximum, whereas at small throttle openings the fuel stream is throttled.

The idling fuel metering device 16 comprises a valve 51 resiliently mounted on the rod 45 so that it will open only when the valve 50 is seated. Its maximum opening results from the compressibility of the gasket 50a of valve 50 when the engine vacuum is maximum. The valve 51 is controlled by a small flange 60 engaging the inner face of a socket bottom closing member 61 when the spring 62, normally holding the valve 51 in its closed or seated position during the stroke of valve 50, is fully released or expanded.

The idling fuel metering device 16 is secured on the bottom closing member 63 of the main metering device and comprises a jet 65 metering the idling fuel. This device feeds a conventional mixer 21 having a venturi or like convergent-divergent passage 21a, the fuel being atomized by an air stream metered by the jet 65a and adjustable by means of an air screw 64. The idling air is led to the mixer 21 by the pipe line 66. The pre-emulsified idling mixture is fed from the convergent-divergent passage 21a through a line 23 to the emulsifier 25 described hereafter with reference to FIGS. 4 and 5.

The idling air is adjusted by means of a second vacuum responsive device 67 of the vacuum regulator 9 the principle of which is similar to the one governing the first vacuum responsive device 46. The valve 68 is controlled in the same manner as the valve 51 by the way of a control rod 68a. This valve 68 opens slightly before the valve 51 so as to create in the convergent-divergent passage 21a a vacuum likely to promote the flow of fuel immediately as the valve 51 is opened. At the most, the valves 51 and 68 may open simultaneously. The idling air is supplied to the calming chamber 69 of the device through the medium of an air intake comprising inlet orifice 72 associated with a pre-adjustment jet 70 provided with an air filter and silencer unit 71.

The main induction air adjustment device is responsive to a conventional butterfly throttle 12 (FIG. 1) controlled by the accelerator pedal 14. To avoid any asymmetry in the flow it is preferable to use the system illustrated in FIG. 3.

The main air is introduced through the orifice 73 into the adjustment device. This orifice 73 is provided for fitting a conventional or other air filter and induction silencer assembly. The outlets to be connected to the emulsifiers are shown at 74 and 75. These orifices may be connected separately and directly to a cylinder in the case of a single-cylindered engine, or to several pipes, according to the number of engine cylinders and to the arrangement of the induction ports in the cylinder head.

The valve 76 of the device for adjusting the main induction air comprises a guiding skirt 77 sliding in a sleeve 78. It is urged to its closed position by the spring 79 adequately pre-stress in the closed position between the valve 76 and the bottom closing cap 80 mounted in fluid-tight conditions on the sleeve 78. The rod 81 responsive to the accelerator pedal is secured on the valve 76 and slides through an orifice formed to this end in the cap 80 and provided with a rod packing 82.

In order to improve the fluid tightness of the valve 76 the latter may be provided with a lining 76a of a material adapted to preserve a certain flexibility at relatively low and relatively high temperatures with a view to avoid any appreciable change in the adjustment. The valve may also consist wholly or partly of this material, provided that its mechanical strength and dimensional variations as a function of the temperature remain within reasonable limits.

In FIGS. 4 and 5 of the drawings, the fuel and induction air mixer 19 is shown as consisting of a chamber 83 adapted to impart a whirling movement to the air stream as necessary for the improved fuel dividing and emulsifying system of this invention.

According to a characteristic feature of this invention, the chamber 83 comprises a cylindrical outer casing 84 intersected by two oblique planes forming with the perpendicular to the cylinder axis angles that can be equal or not.

These two oblique planes constitute the bottoms and are closed by straight or curvilinear cones 85, 86 the axis Y-Y of which is coincident with the axis of the tube 87 of emulsifier 25. The air inlet pipe 92 merges tangentially into the outer cylinder 84.

The cone 86 is connected to the tube 87 by a portion 88 the cross-sectional area of which decreases gradually. The cone 85 carries at its top the fuel nozzle or injector 18 comprising a passage 89 adapted to receive a calibrating jet 90 and connected to the fuel line 17. The passage 89 comprises a tapered lower end having a plurality of small radial holes formed through its upper portion, these holes being so directed as to cause the fuel jets issuing therefrom to strike the wall in the vicinity of the zone where the portion 88 merges into the tube 87.

This fuel and induction air mixer operates as follows: the air introduced through the duct 92 receives a whirling motion represented by the arrow *f*. At the inlet end of tube 87, whereas in a conventional flow-type the maximum speed is attained at the centre, in the device of this invention the speed is maximum near the outer peripheral wall. The fuel projected by the jet and carried along by the stream is centrifuged, the droplets of fuel are caused to burst against this wall and the fuel is divided by friction, thus ensuring its intimate admixture with the combustion air during the helical travel accomplished within the tube 87.

In order to avoid condensations likely to result from the expansion of the pre-emulsified mixture in a large-diameter duct, the idling fuel and air are delivered tangentially at 93 to the emulsifier tube 87. Owing to the preceding remark and to the helical flow the mixing action results from the frictional engagement with the

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walls of tube 87 and the expansion is reduced due to the fact that the middle of the stream is moderately influenced by the movement of the fluid.

The atomizing device provided across the inlet chambers of the engine serves the purpose of separating the fluid stream and the fuel from the wall before entering the valve chamber. As a matter of fact, the emulsified fuel is forced against the walls of the tubular portion 87. Now it would be rather delicate and difficult to construct an elbow capable of avoiding any interference with the helical flow thus produced. To avoid this constructional difficulty the engine suction takes place through the orifice 26 in a cavity 13 connected through a sleeve 94 to the engine, the cross-sectional area of the sleeve 94 increasing gradually from the orifice 26, as shown. The shape of this cavity 13 is immaterial, provided that it surrounds a considerable portion of the tube 87.

As the gaseous flow from the tube 87 engages the edge formed at the lower end of this tube, it is further divided by this edge. If desired, the lower end of the tube 87 may be flat and spaced at a suitable height *h* from the bottom of the aforesaid cavity 13. According to a modified form of embodiment, the lower end of tube 87 is formed with a lateral aperture 95 registering with the orifice 26 with a view to increase the useful length of the aforesaid edge and to avoid any appreciable loss of pressure in this height *h*.

The inoperative or dead zones in the cavities 13 of the various devices installed on the cylinder-head inlet ports of the engine, may be interconnected by vacuum balancing tubes 96, one of these tubes 96 being connected in turn to the pipe line 11.

In FIG. 6 the pulse generator controlling the pump 2 is shown as comprising a transistor 30 having its collector electrode connected to the winding 2a of the pump 2. This winding 2a is coiled around a ferromagnetic core and adapted, when energized, periodically to actuate the armature 2b rigid with the centre of the pump diaphragm.

The winding 2a is coupled to the winding 31 connected to the base of the transistor, thereby causing the latter to operate as an oscillator.

The variable resistors through which the frequency and amplitude of the pulses produced by the generator are regulated, are divided into two groups.

One of these groups comprising the elements 4a, 5a, 6a, 7a, 8a and 9a controls the pulse frequency whereas the other group 4b, 5b, 6b, 7b, 8b and 9b controls the amplitude.

The devices 4, 5, 7 and 9 are mechanically connected to to the slides of pairs of rheostats 4a—4b, 5a—5b, 7a—7b, and 9a—9b respectively, so as to alter the positions of these slides as a function of the velocity of rotation, reaction torque, atmospheric pressure and induction vacuum respectively.

The variable resistors 6a and 6b are a part of the device 6, their resistance varying as a function of the engine temperature, of the external temperature difference or differences, respectively.

Finally, the device 8 comprises two rheostats 8a and 8b the slides of which are displaced as a function of the fuel density.

A typical and practical form of embodiment of the device for varying the fuel output and pressure as a function of the engine load is illustrated in FIG. 2 of the drawings.

In this figure the potentiometer 98, which is a part of the pilot generator 3 of FIG. 1, is rigid with the control rod 45 of the first vacuum responsive device 46. In this case, the supporting rod 97 extends through the adjustment screw 56. The potentiometer 98 is energized by means of an insulated sealed terminal 99 extending through the cap 57. A contact spring 100 is provided for supplying current to the potentiometer 98 and permitting the movement of the diaphragm 52 and valve 50.

The current outlet is provided in the form of an insu-

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lated sealed terminal 101 rigid with a sliding contact 102. The resistance of potentiometer 98 varies as a function of the position of the rod 45 and this change in the potentiometer resistance is used for varying the characteristics of the pulses controlling the pump 2, as in the case of the rheostats 9a, 9b of FIG. 6.

The correction of the velocity of rotation is effected by means of any suitable engine-speed detecting and responsive device. Thus, an alternator may be mounted on the motor shaft, the frequency of this alternator constituting the carrier of the pilot generator 3 feeding the pump 2. The frequency variation will then increase the output and the amplitude variation will increase the pressure.

Although in the example set forth and illustrated herein the pump is of the electromagnetically operated diaphragm type, a pump driven from an electromotor is also suitable. The transistor generator may then supply a direct or alternating current according to the type of motor.

In the case of a direct-current motor the energizing current will vary as a function of the injection parameters, whereas if an A.-C. motor is used it will be possible to vary both the amplitude and the frequency of the oscillation.

Of course, many modifications may be brought to the form of embodiment shown and described herein by way of example, without however departing from the spirit and scope of the present invention as set forth in the appended claims.

What I claim is:

1. Low-pressure fuel injection device for internal combustion engine, comprising an electrically operated fuel pump, a main injection fuel metering device connected to the pump outlet for achieving the adjustment of the injection output and pressure under normal running conditions, an idling device connected to the pump outlet and permitting the flow of the reduced load under idling conditions by properly metering the idling fuel and air, means responsive to the induction vacuum for controlling the main fuel metering device and the idling device as a function of the vacuum prevailing in the induction passage, means for adjusting the induction air supply, means for mixing the fuel injected by the main metering device and the induction air, and means for atomizing the emulsified air-fuel mixture.

2. Fuel injection device as set forth in claim 1, wherein said main fuel metering device comprises a rod axially movable under the control of means responsive to the induction vacuum, a first valve rigid with said rod and controlling the passage of the injection fuel, and another valve controlling the passage of the idling fuel, said other valve being resiliently mounted on said rod whereby it will open only when said first valve is closed.

3. Fuel injection device as set forth in claim 2, wherein said main fuel metering device comprises at least one orifice of variable cross-sectional area for adjusting the pressure and output of the injection fuel.

4. Fuel injection device as set forth in claim 3, wherein said variable-section orifice comprises a cylindrical bore through which extends the valve-carrying rod, said rod having in said bore a cross-section variable therealong.

5. Fuel injection device as set forth in claim 1, wherein said idling device comprises a first jet for metering the idling fuel, a mixer having a convergent-divergent passage, said first jet emerging into said passage another jet for metering the idling air, and a screw for adjusting the idling air.

6. Fuel injection device as set forth in claim 1, wherein said means for mixing the fuel injected by said main metering device with the induction air comprises a chamber adapted to impart a whirling movement to said induction air, an emulsifier tube constituting a vertical, downwardly-directed extension of said chamber, and an injector extending coaxially to the tube for injecting the fuel

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into the zone where said tube merges into said chamber, whereby the fuel/air mixture results from the frictional engagement with the walls of the emulsifier tube due to the helical movement of the air stream in said emulsifier tube, said helical movement imparting a high peripheral speed and a relatively low speed centrally of the tube with a view to cause the larger droplets to strike the tube walls and become divided.

7. Fuel injection device as set forth in claim 6, wherein said chamber comprises a cylindrical external lateral casing having a tangential air inlet connected to the outlet of said induction air adjustment means, an upper wall and a lower wall consisting of tapered surfaces facing downwards and having their vertices substantially coincident with the axis of the emulsifier tube, the planes in which said upper and lower walls merge into the cylindrical lateral casing being inclined relative to the axis of said casing.

8. Fuel injection device as set forth in claim 7, wherein said injector is mounted substantially at the top of the tapered surface constituting the upper wall of said chamber, said injector comprising at its lower end a cone in which radial holes are formed whereby the fuel jet issuing therefrom is projected against the inner wall of said emulsifier tube, in the zone of said tube which merges into the lower wall of said chamber.

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9. Fuel injection device as set forth in claim 6, wherein said emulsifier tube is formed in its lower portion with an edge for separating the fluid stream as it enters the inlet valve chambers of the engine, and therefore dividing any residual liquid fuel.

10. Fuel injection device as set forth in claim 9, wherein said edge is formed in the lower end portion of the emulsifier tube.

11. Fuel injection device as set forth in claim 9, wherein said edge consists of the marginal portion of an aperture formed in the lower end portion of said emulsifier tube and registers with the relevant induction port.

12. Fuel injection device as set forth in claim 6, wherein said device comprises a cavity surrounding the lower portion of said emulsifier tube, and a sleeve of gradually decreasing cross-sectional area for connecting said cavity to the induction port of the engine.

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