

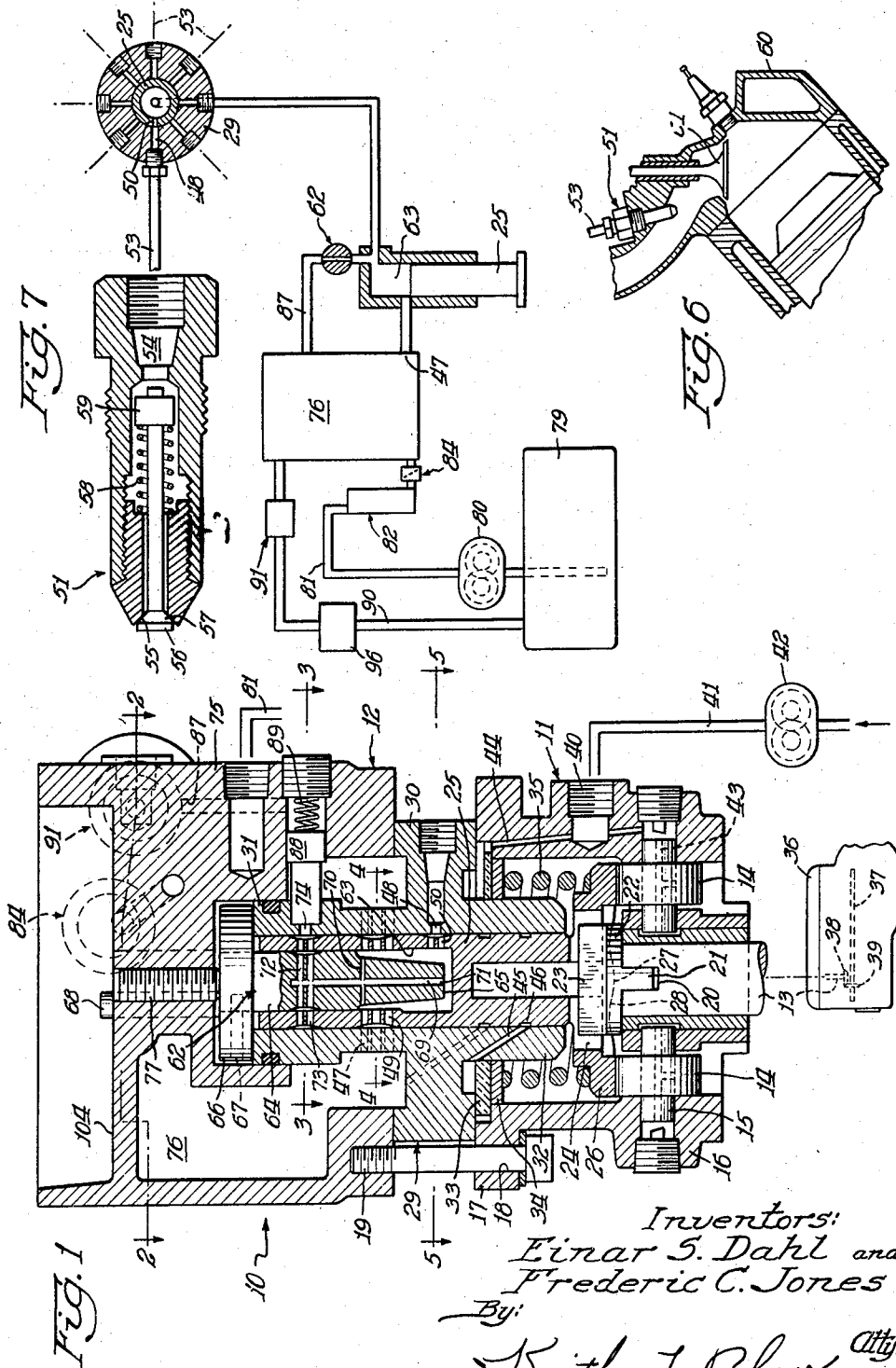
Sept. 9, 1958

E. S. DAHL ET AL
FUEL INJECTION SYSTEM

2,851,026

Filed March 13, 1957

5 Sheets-Sheet 1



Inventors:
Einar S. Dahl and
Frederic C. Jones
By: Keith J. Blew *Att.*

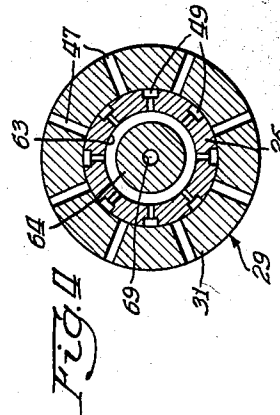
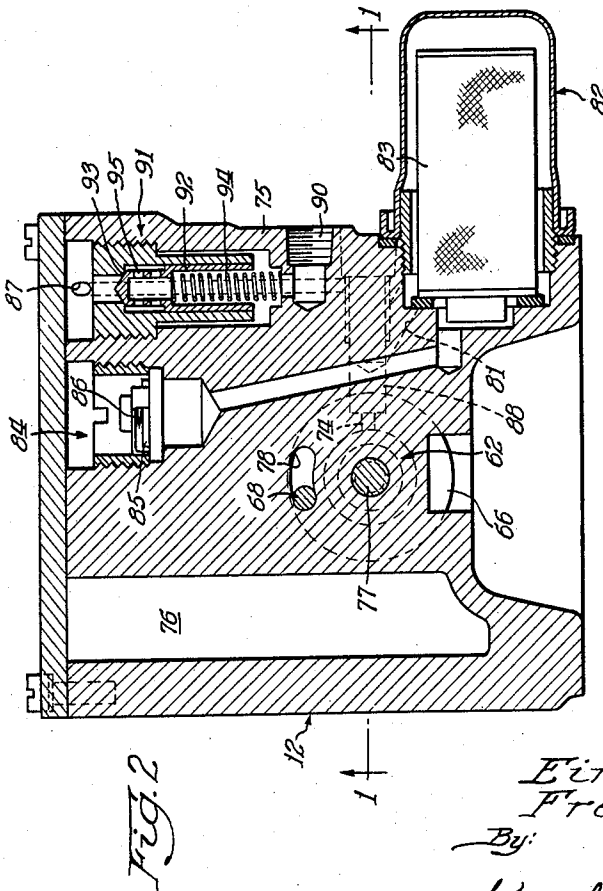
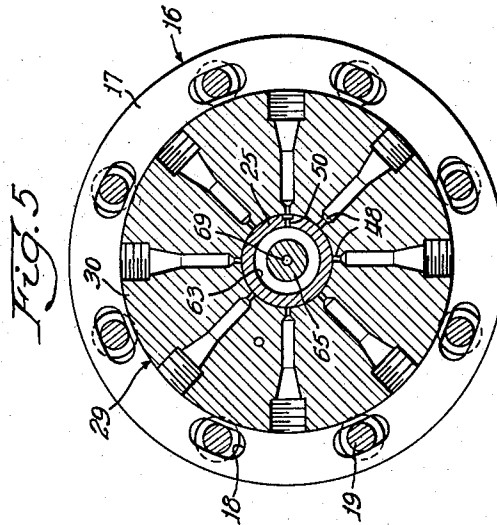
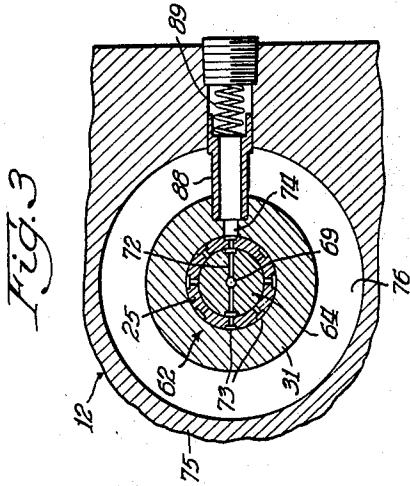
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5 Sheets-Sheet 2



Inventors:
Einar S. Dahl and
Frederic C. Jones
By: *Keith J. Blum* *Att.*

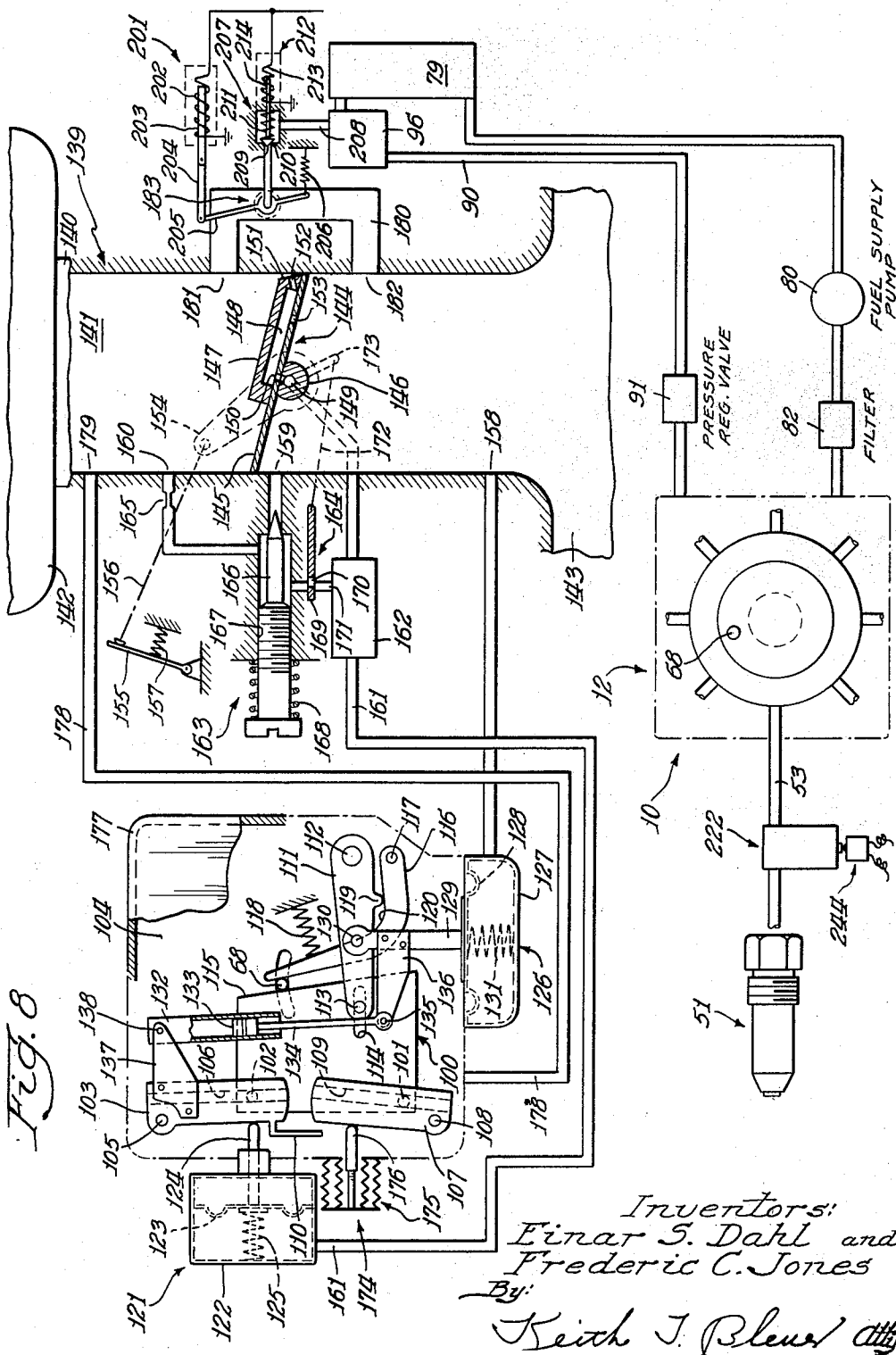
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5 Sheets-Sheet 3



Inventors:
Einar S. Dahl and
Frederic C. Jones
By: Keith J. Bleuer atty.

Sept. 9, 1958

E. S. DAHL ET AL
FUEL INJECTION SYSTEM

2,851,026

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5 Sheets-Sheet 4

Fig. 9

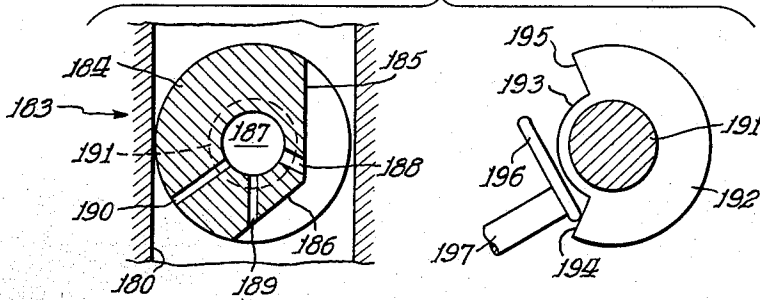


Fig. 10

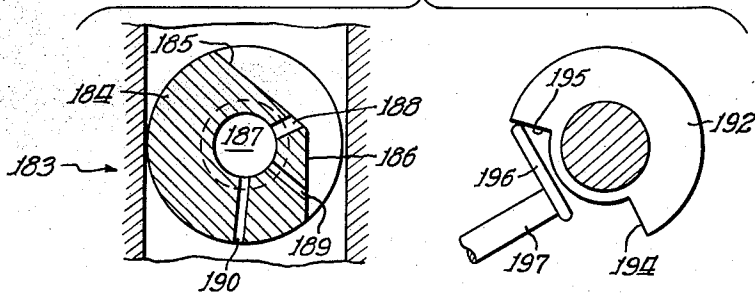


Fig. 11

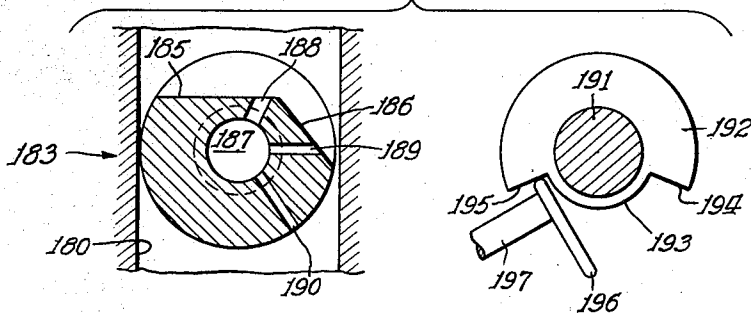
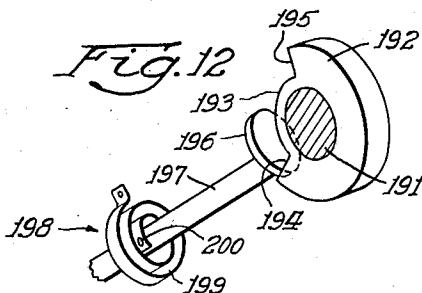


Fig. 12



Inventors:
Einar S. Dahl and
Frederic C. Jones

By:
Keith J. Blum atty.

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2,851,026

FUEL INJECTION SYSTEM

Einar S. Dahl and Frederic C. Jones, Decatur, Ill., assignors to Borg-Warner Corporation, Chicago, Ill., a corporation of Illinois

Application March 13, 1957, Serial No. 645,720

15 Claims. (Cl. 123—179)

Our invention relates to fuel injector mechanisms particularly for use in automotive vehicles.

It has heretofore been proposed to provide a fuel injector pump to supply fuel to nozzles positioned adjacent the cylinders of an automotive vehicle internal combustion engine with the pump being controlled in accordance with the speed and load of the automotive engine. Disclosures of such mechanisms, which are related to the present disclosure, are contained in the application of Einar S. Dahl, Serial No. 608,150, filed September 5, 1956; the application of Einar S. Dahl and Robert M. McCreary, Serial No. 608,269, filed September 6, 1956; the application of Einar S. Dahl, Serial No. 608,578, filed September 7, 1956; the application of Carl F. High, Serial No. 626,905, filed December 7, 1956; and the application of Einar S. Dahl, Serial No. 645,475, filed March 12, 1957.

We have found that in such fuel injection systems comprising a pump connected by fuel lines to fuel injector nozzles, under certain conditions, as when the vehicle sets for a prolonged period of time, particularly at high temperatures, the fuel lines become drained and filled with air or vapor. Such drainage of the fuel lines may be caused by leakages in the pump and discharge through the fuel nozzles when the fuel vaporizes at the high temperatures in the nozzle lines.

In the application of Einar S. Dahl, Serial No. 645,475, filed March 12, 1957, above referred to, mechanism is disclosed for providing a carburetor action for starting the vehicle engine, subsequent operation of the engine being by virtue of discharge through the fuel injection nozzles positioned adjacent the engine cylinders.

It is an object of the present invention to provide improved fuel injection mechanisms which utilize such carburetor action not only during engine starting as long as the starter switch is closed, but also subsequently on opening of the starter switch until the fuel lines connected to the nozzles are filled with fuel.

More particularly, it is an object to provide a pressure sensitive device in one of the fuel lines which is so arranged as to prolong the carburetor action until the fuel line is filled with fuel. It is contemplated that this device preferably shall be a pressure sensitive electric switch which maintains a fuel valve open to the carburetor portion of the system until the line fills with fuel.

The invention consists of the novel constructions, arrangements and devices to be hereinafter described and claimed for carrying out the above stated objects and such other objects as will be apparent from the following description of a preferred embodiment of the invention, illustrated with reference to the accompanying drawings, wherein:

Fig. 1 is a vertical sectional view of the fuel discharge pump for an injector system which is taken on line 1—1 of Fig. 2;

Fig. 2 is a top sectional view of the discharge pump taken on line 2—2 of Fig. 1;

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Figs. 3, 4 and 5 are sectional views taken on lines 3—3, 4—4 and 5—5 of Fig. 1 respectively;

Fig. 6 is a sectional view through the vehicle driving internal combustion engine;

Fig. 7 is a schematic view showing the hydraulic connections in the fuel injection pump and with parts associated with the pump;

Fig. 8 is a schematic view showing controlling mechanism for the fuel injection pump and which is associated with the air throttle valve with an auxiliary carburetor valve for the vehicle internal combustion engine;

Figs. 9, 10 and 11 are views respectively showing the carburetor valve on an enlarged scale in different operating positions;

Fig. 12 is a fragmentary view of certain control parts for the carburetor valve;

Fig. 13 is a longitudinal sectional view of a pressure sensitive switch in one of the fuel nozzle lines; and

Fig. 14 is an electrical diagram of certain electrical parts of the fuel injection system.

Like characters of reference designate like parts in the several views.

Referring now to the drawings, the illustrated fuel injection pump 10 comprises a drive section 11 and a pumping section 12 mounted thereon. The drive section 11 comprises a drive shaft 13 and a plurality of rollers 14 which serve as cam followers. These rollers are rotatably disposed on pins 15 all mounted in a base casing 16. The base casing 16 is provided with a flange 17 which has elongated holes 18 by means of which the base casing is adjustably attached to the pumping section 12 by means of bolts 19. The drive shaft 13 is provided with a slot 20 on its upper end for receiving the tang 21 of a coupling member 22 rotatably mounted in the base casing 16. The coupling member 22 is provided with an upwardly extending tank 23 fitting in a slot 24 in the base of a plunger 25 to effect the continuous rotation of the latter.

The plunger 25 is formed on its lower end with a face cam 26 having a plurality of lobes 27 and a plurality of depressions 28 therebetween. A pump body 29 having a peripheral flange 30 and upper and lower tubular parts 31 and 32 is disposed with its flange 30 clamped by means of the bolts 19 between the drive section 11 and the pumping section 12. An insulator washer 33 which may be of fibre, for example, rests beneath the flange 30, and a guide collar 34 is disposed beneath the insulator washer 33. A compression spring 35 is disposed between the face cam 26 and the guide collar 34, holding the face cam on the rollers 14.

The drive shaft 13 is driven from the internal combustion engine 36 of the vehicle, particularly from the cam shaft 37 of this engine, which, as is well-known, rotates at one-half the speed of the engine crankshaft. A gear 38 is fixed on the shaft 13, and a gear 39 in mesh with the gear 38 is fixed to the cam shaft 37 so that the gears 39 and 38 drive the shaft 13 at one-half the speed of rotation of the engine crankshaft.

The base casing 16 is provided with a port 40 which is connected by any suitable means, such as a conduit 41, with the oil pump 42 of the engine 36. A passage 43 is connected with the port 40 for supplying oil to the rollers 14 and to the shaft 13 for lubricating the latter parts. A passage 44 is also connected to the port 40 and supplies lubricating oil around the insulator washer 33 to a passage 45 in the tubular portion 32 and thereby to an external groove 46 in the plunger 25. The fuel, such as gasoline, used in the injection apparatus may leak downwardly on the external surface of the plunger 25 above the groove 46, and the presence of lubricating oil in the groove 46 under the pressure from the

pump 42 acts as a block or dam preventing flow of the fuel farther downwardly around the plunger 25 and eventually into the supply of engine lubricating oil.

The pump body 29 is provided with intake ports 47 and discharge ports 48 which register respectively with opposite intake ports 49 and discharge ports 50 in the plunger 25. There are as many discharge ports 48 as there are cylinders of the internal combustion engine 36, and each of the ports 48 is connected to a nozzle 51 directing fluid into the engine 36. Each of the nozzles 51 comprises a nozzle body 52 connected by means of a fluid conduit 53 with one of the ports 48. The nozzle body 52 is provided with an internal passage 54 therein having an outwardly flared seat 55 at its outer end. A valve plunger 56 is disposed in the nozzle body 52 and is provided with an outwardly flared seat 57 adapted to rest and seal on the surface 55. A spring 58 is disposed between a shoulder in the nozzle body 52 and a sleeve 59 fixed on the plunger 56 for yieldably holding the valve plunger 56 on the seat 55.

Each of the nozzles 51 is disposed in the head 60 of the engine 36 and is adapted to spray fuel into the air stream to an intake valve 61. It will, of course, be understood that the nozzles 51 can instead be directed to spray fuel directly into the explosion cavities for the cylinders or else into the engine intake manifold as is well-known. Further details of the nozzles 51 can be secured by referring to a copending application, Serial No. 608,150, filed September 5, 1956, by Einar S. Dahl, inventor.

A metering valve 62 is disposed in a cylindrical cavity 63 in the plunger 25. The metering valve 62 comprises a cylindrical portion 64 and a tapered end portion 65. A round metering valve head 66 is fixed to the metering valve 62 by means of a pin 67. The metering valve head 66 has fixed thereon an upwardly extending metering valve pin 68. The metering valve 62 is provided with a longitudinally extending passage 69 therein connected with ports 70 and 71 at the lower end of the valve 62 and connected with ports 72 in the cylindrical portion 64 of the valve 62. The ports 72 are in alignment with ports 73 in the plunger 25 and with a port 74 in the tubular part 31.

The pumping section 12 comprises a casing 75 which forms, with the pump body 29, a liquid fuel sump 76. An adjustable screw 77 extends downwardly through the casing 75 into contact with the valve 62, and the pin 68 extends upwardly through a slot 78 in the casing 75.

The injector pump is supplied with liquid fuel, such as gasoline, from a gasoline tank 79. The conventional fuel supply pump 80 draws fuel through a fuel line 81 from the tank 79 and supplies it to a fuel filter 82 which is of conventional construction comprising a filtering element 83 through which fuel flows and is filtered. A check valve 84 is connected to receive fuel from the fuel filter and comprises a disc 85 yieldably held on a seat by means of a spring 86. The check valve 84 discharges into the sump 76.

The plunger 25, as will be hereinafter described, receives fuel from the sump 76 through the ports 47 and discharges it through the pump body 29 and conduits 53 to the nozzles 51. The valve 62, depending on the rotative positioning of the valve, allows a certain variable amount of the fluid discharged by the plunger 25 to flow through a parallel passage 87 back to the fuel sump 76. The passage 87, which may be formed in the casing 75, comprises a sleeve 88 held in communication with the port 74 by means of a spring 89.

A fuel return conduit 90 is provided connecting the sump 76 with the fuel tank 79, and a pressure regulator valve 91 is disposed in the conduit 90. The pressure regulator valve 91 comprises a pointed piston 92 held yieldably in place on a seat 93 by means of a spring 94.

The piston 92 has ports 95 therethrough which are in connection with the conduit 90 and the fuel tank 79. An auxiliary fuel reservoir 96 is provided in the conduit 90 between the valve 91 and the fuel tank 79.

In operation, the engine 36 drives the driving shaft 13 of the injector pump through the cam shaft 37 and the gears 39 and 38, rotating the shaft 13 at one-half the speed of the crankshaft of the engine 36. The plunger 25 is rotated through the coupling 22; and the face cam 26, in having its lobes 27 and depressions 28 riding over the rollers 14, causes the plunger 25 to reciprocate. It will be noted that for an eight-cylinder engine and for eight of the nozzles 51, there are accordingly eight lobes 27 and eight depressions 28 in the face cam 26 causing the plunger 25 to reciprocate up and down eight times for each two revolutions of the engine crankshaft. It is assumed at this point that a four-stroke cycle engine 36 is being used—if the fuel injector mechanism is used with a two-stroke cycle engine, then the shaft 13 will be driven at such a speed so that there are eight reciprocations of the plunger 25 for each revolution of the engine crankshaft.

Fuel is maintained in the sump 76 at a relatively low pressure, for example, 20 lbs. per square inch for a particular embodiment of the fuel injection mechanism. The fuel supply pump 80 which may be driven from the engine 36 or may be driven from any auxiliary source of power such as the vehicle electrical system, is of conventional construction and draws fuel out of the fuel tank 79 and discharges it through the fuel filter 82 and the check valve 84 into the sump 76, maintaining the fuel in the sump 76 at this relatively low pressure. The fuel filter 82 is of conventional construction and simply filters the fuel. The valve 84 is a simple check valve and simply prevents back flow out of the sump 76 into the line 81.

The fuel in the sump 76 flows under this relatively low pressure through the ports 47 and 49 into the cylindrical cavity 63 of the plunger 25. As the plunger 25 begins to reciprocate upwardly by reason of the rollers 14 riding on lobes 27, the ports 49 in the plunger 25, due to the rotation of the plunger, move out of alignment with the ports 47. Continued upward reciprocation of the plunger 25 causes a compression of the fuel within the cylinder 63 below the valve 62, and this fuel is forced through the ports 50 and one of the ports 48 and the connected conduit 53 and nozzle 51. It should be noted that the ports 50 are in register with one of the ports 48 during the continued upward reciprocation of the plunger 25 after the ports 47 have been closed, until the upper end of the reciprocation of the plunger 25.

The fuel discharged through one of the conduits 53 and the associated nozzle 51 is at a relatively high pressure, as compared to the pressure of the fluid in the sump 76, perhaps being on the order of 200 to 1000 lbs. p. s. i. in one particular embodiment of the fuel injection system, and this fuel under pressure moves the valve plunger 56 off the seat 55 against the action of the spring 58 causing the fuel to spray outwardly of the nozzle 51.

The valve 62 is adjustably rotated, with its pin 68 moving in the slot 78, to variably relieve the pressure within the cylinder 63 of the plunger 25 as the plunger reciprocates upwardly. As will be noted, there is one port 74, and there are two ports 72, but only one of the latter is active; and there are eight ports 73. When the pin 68 is at one limit of its movement in the slot 78, with the valve head 66 rotated to the limit of its movement counter-clockwise, as seen in Fig. 2, as the plunger 25 reciprocates upwardly, one of the ports 72 is in register with the ports 73 and also with the port 74, so that all of the fuel under pressure in the cavity 63 generated by upward reciprocation of the plunger 25 flows through the ports 71 and 70, the passage 69, the ports 72, 73 and 74 and the passage 87 for discharge back into the sump 76.

On the other hand, when the valve head 66 is moved

to the limit of its movement clockwise, as seen in Fig. 2, with the pin 68 at the other limit of its movement in the slot 78, then the ports 72 are out of register with the ports 73 as the plunger 25 reciprocates upwardly. In this case, there can be no relief of fuel out of the cylinder 63 through the ports 72, 73 and 74, and the fuel is discharged at required pressure through the ports 50 and 48 and one of the nozzles 51.

At intermediate points of adjustment of the pin 68 between these two, at which the pin 68 is between the limits of its movement in the slot 78, there is more or less of the fluid in the cavity 63 tending to be compressed by the upward reciprocation of the plunger 25 relieved through the ports 72, 73 and 74. This is due to the fact that, in these cases, the ports 72 and 73 are aligned for only a portion of the upward reciprocation of the plunger 25, more and more of the fluid pressure tending to be generated toward the upper end of the reciprocation being relieved by the ports 72 and 73 as the pin 68 and the valve head 66 are swung counterclockwise as seen in Fig. 2.

The control system for the fuel injection pump comprises a cam plate 100 having two pins 101 and 102 fixed therein. A cam plate guide 103 is pivotally disposed on a surface 104 by means of a pin 105. The cam plate guide 103 is provided with a groove 106 therein which receives the pin 102 carried by the cam plate 100.

A second cam plate guide 107 is pivotally disposed on the surface 104 by means of a pin 108, and this guide 107 has a groove 109 therein receiving the pin 101. An arm 110 is carried by the cam plate guide 103 for at times contacting and moving the guide 107.

A lever 111 swingingly mounted on the surface 104 by means of a pin 112 carries a pin 113 at its end which is received in a groove 114 in the cam plate 100. The cam plate 100 is provided with a slanted cam surface 115, and the control pin 68 rests on this surface 115.

A lever 116 pivotally mounted on the surface 104 by means of a pin 117 rests on the control pin 68, being urged in this direction by a compression spring 118. The lever 111 carries a boss 119 which rests on a bowed intermediate portion 120 of the lever 116.

A vacuum motor 121 is provided for controlling the cam plate guide 103. The vacuum motor 121 comprises a casing 122 and a flexible diaphragm 123 within the casing. The diaphragm is connected by means of a rod 124 with the cam plate guide 103. A spring 125 is provided for yieldably holding the diaphragm 123 and rod 124 to the right as seen in Fig. 8.

A vacuum motor 126 is provided for actuating the lever 111. The motor 126 comprises a casing 127 and a flexible diaphragm 128 disposed in the casing 127. The diaphragm 128 is connected by means of a rod 129 with the lever 111, being fixed with respect to the lever by means of a pin 130. A spring 131 is provided for urging the lever 111 upwardly as seen in Fig. 8.

A yielding connection is provided between the rod 129 and the cam guide plate 103 which comprises a tube 132 closed on one end and a piston 133 slidably disposed loosely therein. The piston 133 is connected by means of a connecting rod portion 134 extending through the open end of the tube and a pin 135 with a bracket 136 fixed on the rod 129. The tube 132 is swingably mounted and connected to the cam guide plate 103 by means of a bracket 137 fixed to the guide 103 and a pin 138 pinning the tube 132 and bracket 137 together.

The vacuum motors 121 and 126 are controlled by suitable connections to the air throttle valve 139 for the vehicle engine. The air throttle valve comprises a casing portion 140 having an air passage 141 extending downwardly therethrough. A conventional air cleaner 142 is provided on top of the air passage 141, and the passage 141 leads to the conventional intake manifold 143 connected to the cylinders of the internal combustion engine.

An air throttle fly valve 144 is provided in the air passage 141. The valve 144 comprises a thin plate 145 fixed on a throttle shaft 146 rotatably disposed in the casing portion 140. An auxiliary throttle plate member 147 is fixed on the plate 145 and has an internal passage 148 therein. The passage 148 is in communication with a passage 149 extending through the shaft 146, the connection being by means of an opening 150. The auxiliary member 147 has a slanted end 151 with a restricted opening 152 therein communicating with the passage 148. A restricted opening 153 is also provided through the plate 145 into the passage 148. The shaft 146 has the usual throttle lever 154 fixed thereon adapted to be controlled by the vehicle accelerator A by means of any suitable connecting mechanism such as the rod 155. A return spring 156 is provided for yieldably holding the throttle lever 154 in a throttle closed engine idling position. An adjustable closed throttle stop screw 157 is provided to obtain the desired engine idling speed under normal operating conditions.

The vacuum motors 121 and 126 are controlled from orifices 158, 159 and 160. The vacuum motor 121 is connected by means of a conduit 161 with a chamber 162. The chamber 162 is connected with the passage 149 in the throttle shaft 146 and with the orifice 159 through an idle air adjusting screw valve 163 and a throttle controlled valve 164. The chamber 162 is also connected through the valves 163 and 164 and also through a restricted jet 165 with the orifice 160.

The valve 163 comprises a pointed plunger 166 for more or less closing the orifice 159. The plunger 166 is in screw threaded arrangement in a cavity 167; and a spring 168 is provided for maintaining tension on the screw threads so that the plunger will not rotate under vibration.

The valve 164 comprises a slidable plate 169 provided with an opening 170 therein. This plate opens or closes a conduit 171 connecting the valve 163 with the chamber 162. The slidable plate 169 is connected by a link 172 to a lever 173 fixed to the throttle shaft 146.

The cam guide 107 is controlled in its swinging movement by means of an altitude and ambient temperature correction device 174. This device comprises a Sylphon structure 175 having a rod 176 carried thereby and effective on the cam guide plate 107. The Sylphon 175 is partially filled with a liquid and partially with a gas. The liquid is responsive to temperature so that the rod 176 is moved to the left as seen in Fig. 8 when the temperature increases due to the action of the liquid, while the gas in the Sylphon forces the rod 176 in this direction also, when the altitude at which the device is disposed increases with a resultant decrease in atmospheric pressure.

The cam 100, the guides 103 and 107 and the motors 126 and 121 are preferably within a closed casing 177. This casing is vented by means of a conduit 178 with an orifice 179 located in the air passage 141 beneath the air cleaner 142 for assuring that the same value of atmospheric pressure exists within the casing 177 as in the air passage 141.

A conduit or duct 180 is provided for connecting an orifice 181 above the throttle valve assembly 144 and an orifice 182 below the throttle valve assembly 144 to provide a passage in parallel with the passage 141 around the throttle valve assembly 144. A valve 183 is provided in the duct 180 comprising a rotatable core 184. The core 184 is cylindrical except that it is provided with a flat 185 and a second flat 186 disposed at angles to each other as shown. The core 184 is provided with a central fuel passage 187 and radially extending passages 188, 189 and 190 connect with the passage 187. The core 184 is rotatably mounted in the duct 180 on a shaft 191.

A disc member 192 is fixed to one end of the shaft 191 and is rotatable therewith. The disc member 192 is provided with a peripheral cut-out 193 defined by an

end 194 and a second end 195. A cam 196 is fixed on a shaft 197 and is disposed in the cut-out 193. The cam 196 may be circular in shape and is eccentrically disposed on the shaft 197. A thermostatic element 198 is effective to rotate the shaft 197. The thermostatic element 198 comprises a spiral bimetallic spring-like member 199 having one end 200 fixed to the shaft 197 and the other end fixed to a stationary part. The bimetallic element 199 is located where it may sense the engine temperature which may be inside the exhaust manifold or at any other convenient location.

The core 184 of the valve 183 is controlled by a solenoid 201. The solenoid comprises a winding 202 which actuates an armature 203. The armature 203 is connected by means of a link 204 to a lever 205 which is fixed to the shaft 191. A tension spring 206 is effective on an extension of the lever 205 for yieldably maintaining the end 195 of the cut-out 193 of the member 192 against the cam 196.

A valve 207 is provided in a conduit 208 connecting the fuel reservoir 96 to the passage 187 in the valve 183. In this connection, it may here be noted that the reservoir 96 is preferably positioned adjacent and at approximately the same level as the valve 183. The valve 207 comprises a valve plunger 209 adapted to rest against a seat 210. A spring 211 yieldably maintains the valve plunger 209 against the seat 210. A solenoid 212 is effective to open the valve against the pressure of the spring 211. The solenoid 212 comprises a winding 213 and an armature 214 which is connected to the valve plunger 209.

The solenoids 201 and 212 are adapted to be energized when the vehicle engine is being started. The electrical portion of the fuel injector control system and which energizes the solenoids includes the usual battery 215, the ignition switch 216, a starter switch 217, a starter relay 218, a starter motor 219, a motor 220 for driving the fuel supply pump 80, a control relay 221 and a pressure switch 222 in one of the fuel supply conduits 53.

The starter relay 218 comprises a winding 223 and an armature 224 disposed in the winding 223. The armature 224 carries a blade 225 adapted to bridge two contacts 226. One of the contacts 226 is connected to one terminal of the battery 215, and the other terminal of the battery 215 is grounded according to usual practice. The other contact 226 is connected to one terminal of the starter motor 219, and the other terminal of the starter motor is grounded. One end of the relay winding 223 is connected to the starter switch 217, and the starter switch on its other side is connected with the battery 215. The other end of the winding 223 is grounded.

The winding 202 of the solenoid 201 at one end is also connected to the starter switch 217 and it is grounded at its other end.

The control relay 221 comprises a winding 227 connected at one end to the starter switch 217 and grounded at its other end. The relay comprises an armature 228 carrying a blade 229 adapted to bridge two contacts 230. One of the contacts 230 is connected to the battery 215, and the other contact 230 is connected to one end of the winding 213 of the solenoid 212, the other end of the winding 213 being grounded.

The ignition switch is also connected to the battery 215 and energizes the usual ignition system (not shown) of the vehicle engine. The ignition switch on its side remote from the battery 215 is connected to one terminal of the fuel supply pump motor 220 which drives the pump 80, and the other terminal of the pump motor 220 is grounded.

The pressure switch 222 comprises switch bodies 231 and 232. The body 232 is threaded into a central cavity 233 in the body 231, and a diaphragm 234 of rubber-like material is clamped at its periphery between the bodies 232 and 231 by means of an annular washer 235. The

body 232 has ports 236 and 237 for receiving adjacent ends of the conduit 53 in which the switch 222 is disposed, and the body 232 is provided with a longitudinally extending passage 238 therein having a restriction 239 connecting the ports 237 and 236 with one surface of the diaphragm 234.

The body 231 has a plunger 240 slidably disposed therein. The plunger 240 is formed with a head 241 adapted to contact the diaphragm 234, and a compression spring 242 is provided between an internal shoulder 243 in the body 231 and the head 241.

An electrical switch 244, which is preferably of the snap action type, is mounted by means of a bracket 245 on the body 231. The switch 244 comprises contacts 246 and also a stem 247 actuated by the plunger 240 for moving the two contacts 246 apart when the plunger 240 is moved against the action of the spring 242.

In operation, the vacuum motor 121 is responsive to the speed of operation of the vehicle engine particularly due to the orifices 152 and 153 in the throttle valve assembly 144. As has been previously noted, the passage 149 in the throttle valve shaft 146 is connected with the chamber 162 and thereby with the motor 121. Due to the orifices 152 and 153 in the throttle fly assembly 144, the pressure in the chamber 162 varies with the speed of the vehicle engine and with the mass of air that passes through the passage 141. The orifices 152 and 153 cooperate in order to provide this variation of pressure in the chamber 162 as follows: The orifice 153, being on the lower face of the plate 145 is always subject to pure manifold pressure. When the plate 145 is closed, the orifice 152 is subject only to atmospheric pressure existing below the air cleaner 142. Since manifold pressure is less than atmospheric pressure, air flows through the orifice 152, the passage 148 and the orifice 153 into the manifold 143. The pressure existing in the passage 148 is thus intermediate between these two pressures and is transmitted without change through the orifice 150 and the passage 149 to the chamber 162 and thereby to the motor 121.

As the throttle assembly 144 is opened, the slanted end 151 becomes more parallel with the sides of the air passage 141 and becomes increasingly subject to manifold pressure instead of the atmospheric pressure existing above the plate 145. Thus, as the plate 145 is swung open, the flow through the orifice 152 and the orifice 153 gradually decreases, and the pressure in the passage 148 which is applied to the motor 121 thus gradually decreases from the intermediate pressure mentioned above to the manifold pressure. The pressure in the passage 148 thus varies inversely with the flow of air through the passage 141 and with the speed of the engine.

Due to the fact that the orifice 152 is increasingly subject to manifold pressure as the plate 145 is rotated, it should be noted that the change in pressure in the passage 148 is quite smooth and gradual, and this pressure changes in accordance with engine speed until the plate 145 has reached approximately 35 degrees throttle opening from its engine idling position.

The vacuum motor 126 being connected directly with the orifice 158 in the manifold 143 is thus subject to the manifold vacuum which varies directly with the load on the vacuum engine. Both the motor 121 subject to engine speed and the motor 126 subject to engine load vary the output per stroke of the plunger 25 as will be described.

It is a well-known fact that internal combustion engines do not have the same volumetric efficiency at all speeds in their working speed range. That is, the mass of air taken into each cylinder during each suction stroke will be less at higher R. P. M. than at low R. P. M., and engines will not necessarily require the same amount of fuel per revolution at high speeds as at lower speeds. It is likewise a known fact that the desired fuel-air ratio does not necessarily remain constant through the speed range

for any given load, for example, one-quarter, one-half or full load.

These controls, therefore, vary the amount of fuel per revolution of the engine in relation to its speed as well as in relation to its load. The two influences, namely, engine speed and the load on the engine are such that when acceleration is desired and a rich mixture is advantageous, then, both influences tend to move the metering pin 68 and its valve 62 toward rich positions; and since these influences are both acting in the same direction, they move these parts toward rich mixture faster than either one alone can. When a leveling out point of load is reached, then the manifold pressure forces remain constant, and the forces responsive to speed adjust the mixture as required by speed variations only.

The position of the cam 100 in the grooves 106 and 109, that is, the vertical position of the cam 100 as seen in Fig. 8 determines to a large degree the positioning of the rotating valve pin 68 which, as previously explained, causes a variation of the output of the plunger 25. The cam plate 100 has its position modified by the positions of the cam guides 103 and 107 which are respectively movable about the pins 105 and 108, as will be described.

The motors 126 and 121 function to move the pin 68 in a clockwise direction for the purpose of increasing the rate of discharge of the plunger 25 per stroke when the load on the engine as evidenced by a change in manifold pressure increases or when the speed of the engine decreases. As has been previously explained, the pressure in the conduit 161 increases as the speed of the engine decreases. This increasing pressure is effective on the diaphragm 123 of the motor 121 causing the plunger 124 to swivel the cam guide 103 counterclockwise about the pin 105, and the guide 103 acting through the pin 102 moves the cam 100 to the right, thus moving the pin 68 clockwise as seen in Figs. 2 and 8 and increasing the output from the plunger 25 per stroke to the nozzles 51. Conversely, as the air flow in the passage 141 and the engine speed increase, the pressure in the conduit 161 decreases, and the spring 118 is effective to move the cam 100 to the left so that the pin 68 moves oppositely and decreases the output of the plunger 25 per stroke.

The manifold pressure is effective through the port 158 on the diaphragm 128 of the motor 126, and as the load increases, the manifold pressure increases moving the cam 100 upwardly through the rod 129 and the lever 111, the pins 101 and 102 moving in the grooves 106 and 109 of the guides 103 and 107. The control pin 68 moves along the slanted cam surface 115 and is moved thereby clockwise so as to increase the output from the plunger 25 to the nozzles 51. Conversely, as the load decreases, the manifold pressure as applied to the diaphragm 128 decreases, and the cam 100 is moved in the opposite direction, so that the pin 68 moves counterclockwise under the influence of the spring 118 effective on the lever 116 to decrease the output of the plunger 25 per stroke.

It is preferable to cause an increase in the pressure in the chamber 162 and in the conduit 161 beyond that due to the throttle assembly 144 when the accelerator A is in a relatively relaxed position. The valve 164 cooperating with the orifices 159 and 160 functions for this purpose. The increase in pressure in the conduit 161 acts through the motor 121 to cause an increase in the output of the plunger 25, to take care of idling conditions of the engine which, as is well known, require a greater amount of fuel per revolution of the crank shaft than at higher speed conditions.

It is contemplated that the valve plunger 166 under all conditions shall open the orifice 159 to some extent. Since the orifice 160 is above the throttle plate 145 and the orifice 159 is below the plate 145, there is a flow of air from the orifice 160 to the orifice 159. This results in a pressure which is transmitted through the valve 164, when the latter is opened, that is, slightly greater than the pressure that exists in the passage 149, so that the

pressure in the chamber 162 is increased slightly from that due only to the throttle assembly 144, thus increasing the output of the plunger 25. The orifices 159 and 160 are effective only under idling conditions, for example, when the throttle plate is not opened more than 4 degrees from its idling position, due to the functioning of valve 164. The lever 173 and link 172 are so arranged that the slide 169 has its passage 170 aligned with the conduit 171 when the throttle plate 145 is opened less than 4 degrees, so that the pressure influence from the orifices 159 and 160 is effective on the pressure in the chamber 162 only below the 4 degrees opening of the throttle plate 145.

Under engine idling conditions, there is a small amount of air that passes around the edges of the plate 145 as well as through the orifices 152 and 153. In addition, air also flows from the orifice 160 to the orifice 159 and the exact amount of this air flow may be adjusted by adjusting the plunger 166. The adjustable valve plunger 166 has an influence on the change in the pressure in the chamber 162 due to the functioning of the orifices 160 and 159, and this is the principal reason for the adjustable valve 163. The fuel requirements for individual engines under idling conditions differ, and the specific amount of fuel supplied to any one individual engine can be exactly adjusted under idling conditions by adjusting the plunger 166. The idling R. P. M. of the engine under normal conditions is determined by the setting of the stop screw 157.

The purpose of the tube 132 and the piston 133 therein is to momentarily increase the output by the plunger 25 when the accelerator A is depressed to accelerate the vehicle. On the opening of the throttle plate 145 caused by such a movement of the accelerator A, the manifold pressure as applied to the motor 126 suddenly increases and moves the lever 111 and the cam 100 upwardly as seen in Fig. 8 so that the slanted side 115 on the cam 100 moves the control pin 68 clockwise toward its rich position. This movement of the cam 100, however, is not sufficient under vehicle accelerating conditions; and, therefore, the piston 133 acting in the closed tube 132 acts through the bracket 137 to swing the guide 103 counterclockwise about its pin 105. This movement of the guide 103 also tends to move the cam 100 toward the right through the pin 102. The arm 110, under these conditions, contacts the guide 107 and functions to cause the guide 107 to move in the clockwise direction about its pin 108, and such movement of the guide 107 through the pin 101 causes additional movement to the right of the cam 100. Such movements of the guides 103 and 107 thus provide the additional movement toward rich position of the control pin 68 which is necessary. The arm 110 is provided so that the cam 100 will be moved substantially to the right for accelerating conditions whether the cam 100 is in a lowermost position as seen in Fig. 8 corresponding to light loads or is in an upper position corresponding to heavy loads for which loading the pins 101 and 102 individually are respectively more effective than the other.

As has been previously mentioned, the piston 133 fits in the tube 132 loosely. This is so that air leaks past the piston, and eventually the piston 133 is of no effect on the cam guides 103 and 107 to increase the fuel output by the plunger 25 to the nozzles 51, after the momentary enriched fuel supply is obtained for accelerating conditions.

The effect of the boss 119 acting on the lever 116 is to move the control pin 68 toward a position of decreased output by the plunger 25 when the vehicle is coasting and the vehicle is in effect driving the engine. Ordinarily, when the engine is driving the vehicle, the pressure in the motor 126 never decreases below a pressure of 8 inches of mercury; however, when the vehicle is coasting and the vehicle is driving the engine, the pressure in the motor 126 decreases below this pressure, for example, from 6 to 7 inches of mercury. This decrease in pressure in the

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motor 126 is effective to swing the lever 111 downwardly about its pin 112 and move the lever 116 counterclockwise by means of the boss 119. The lever 116 in so moving acts against the control pin 68 and moves the control pin 68 to a decreased fuel delivery position. The cam 100 moves to the left allowing this movement of the pin with a yielding by the spring 125. Thus, the excessive use of fuel and the obnoxious smell of unburned hydrocarbons in the engine exhaust, which would otherwise prevail, are overcome.

The bellows 175 functions to move the control pin 68 toward a greater fuel output position when atmospheric pressure increases and the ambient temperature decreases. As has been previously described, the bellows 175 is responsive to the ambient temperature of the vehicle and is responsive to the atmospheric pressure (therefore being responsive to changes in altitude). The fluid within the bellows 175 expands as the temperature increases and moves the plunger 176 to the left, and the bellows 175 expands when the atmospheric pressure decreases (with higher altitude) to move the plunger 176 in the same direction. The plunger 176 is effective on the guide 107, and when the plunger 176 moves to the left, the cam guide 107 will swing counterclockwise, allowing movement to the left of the cam 100, the metering pin 68 and the lever 116 due to the action of the spring 118. Thus, under these conditions of higher altitude or increased temperature, the fuel output to the nozzles 51 of the plunger 25 will be reduced. Conversely, the bellows 175 increases the output of the plunger 25 to the nozzles when the altitude decreases or temperature decreases.

In the hydraulic connections to the sump 76, the purpose of the pressure regulator valve 91 is to maintain the fuel under the desired low pressure in the sump 76. When the pressure in the sump 76 increases beyond this desired low pressure, the piston 92 moves off its seat 93 against the action of the spring 94 allowing flow of fuel from the sump 76 around the seat 93 and through the ports 95 and conduit 90 to the tank 79. The purpose of the check valve 84 is to prevent undesired flow out of the sump 76 back through the filter 82 and pump 80. The disc 85 seals on its seat under the action of the spring 86 to prevent such reverse flow.

One purpose of the duct 180 and the valve 183 therein is to introduce a fuel-air mixture in the lower portion of the air passage 141 below the throttle plate assembly 144 and thereby into the intake manifold 143 during engine starting. The valve 183 within its duct 180 functions in the manner of a carburetor, supplying a fuel-air mixture directly into the intake manifold 143 from which it is drawn into the engine cylinders, this carburetor action being in addition to the fuel injection action by the pump 10 through the nozzles 51 as previously described; this fuel injection action, however, supplies only a small amount of fuel during engine cranking and is thus relatively negligible. Thus, in the illustrated systems, carburetor action is utilized for engine starting, and thereafter for ordinary running conditions, only the fuel injection portion of the system is utilized, exclusive of the carburetor function of the valve 183 and the duct 180.

The vehicle engine is started by closing the starter switch 217, the ignition switch 216 previously having been closed. At this time, the fuel supply pump motor 220 drives the fuel supply pump 80 to supply fuel to the fuel injection pump 10 and to the fuel reservoir 96.

The closing of the starter switch 217 energizes the starter relay 218 thereby closing the circuit to the starter motor 219 through the contacts 226 and the blade 225, causing the crank shaft of the vehicle engine to be rotated. Closing the starter switch 217 also energizes the winding 202 of the solenoid 201, thereby moving the armature 203 to the right as seen in Fig. 8. Such movement of the armature 203 through the link 204 and the lever 205 rotates the core 184 of the valve 183 clockwise to the limit of its movement against the action of

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the spring 206 to the position shown in Fig. 9. The cam 196 limits the amount of rotation by the core 184 under the action of the armature 203, the end 194 of the cut out 191 abutting the cam 196 to limit this clockwise rotation of the core 184. The starter switch 217, when closed, also energizes the relay 221 to move the armature 228 and the blade 229 to connect the contacts 230. The winding 213 of the solenoid 212 is thereby connected to the battery 215 to move the armature 214 and move the plunger 209 away from the seat 210 so as to open the valve 207.

With the starter motor 219 rotating the crank shaft of the vehicle engine, the pistons operating in the cylinders draw air through the air cleaner 142 into the passage 141 and through the duct 180. Fuel is introduced into the duct 180 through passages 187, 188, 189 and 190. The air passing the flat 185 of the core 184 draws fuel from the passage 188, and the flow of air through the passage 180 creates a partial vacuum beneath the core 184 and draws fuel through the passages 189 and 190, the core 184 being at this time in its Fig. 9 position. It may be noted at this point that of the three passages 188, 189 and 190, the passage 189 has the largest diameter; the passage 190 has the smallest diameter; and the diameter of the passage 189 is intermediate the diameters of the passages 188 and 190. The mixture of air and fuel passes down the conduit 180 from the valve 183 into the passage 141 below the throttle valve assembly 144 and into the engine intake manifold 143 and the respective cylinders.

Preferably, the throttle plate 145 is in a closed condition for starting, so that the effective fuel mixture is determined by the fuel and air entering through duct 180. When the starting motor 219 cranks the engine, the fuel injection pump 10 pumps fuel through the nozzles 51, this fuel being introduced adjacent the respective cylinders as has been previously described. Thus, the final fuel mixture for each cylinder is determined both by carburetor action and fuel injection action. However, the fuel requirements of the engine for starting are so high that the amount of fuel introduced to the engine cylinders by the nozzles 51 is negligible for engine starting conditions, and practically all of the fuel for engine starting is derived due to the carburetor action.

When the engine commences to fire, the operator releases the starter switch 217. The starter relay 216 is thus deenergized and the armature 224 and blade 225 move so as to open the contacts 226 with respect to each other, and the starter motor 219 ceases to operate. Opening of the starter switch 217 also deenergizes the solenoid 201 so that the spring 206 is effective to rotate the core 184 counterclockwise to the Fig. 10 position of the core 184 in which the flow of air through the passage 180 is limited, for purposes to be described. Opening of the starter switch 217 also has the effect of deenergizing the winding 227 of the solenoid 221, so that the blade 229 opens the contacts 230 with respect to each other. Assuming that the pressure switch contacts 246 are open, such opening of the relay 221 has the effect of deenergizing the solenoid 212, so that the spring 211 is effective to move the plunger 209 on to the seat 210 to close the fuel valve 207. This closing of the valve 207 terminates the carburetor action. The pressure switch contacts 246 are open whenever there is fuel under pressure in the line 53 in which the pressure switch 222 is disposed which is normally so. Fuel under pressure in this line 53 flows through the passage 230 and restriction 239 onto the diaphragm 234 which is effective on the plunger 240 to move the plunger against the action of the spring 242. When the plunger is so actuated it acts through the switch stud 247 to hold the switch contacts 246 open. When there is an absence of fuel under pressure in the conduit 53, the pressure switch contacts 246 are closed for purposes to be described.

Another purpose of the duct 180 and the valve 183 is to change the engine speed variable pressure existing in the conduit 161 and also to change the engine idling speed under cold operating conditions of the vehicle engine as compared to normal higher temperature operating conditions. This action of the valve 183 and duct 180 is under the control of the thermostat 198. As above mentioned, the spring 206 rotates the core 184 in a counterclockwise direction when the starter switch 217 is released, the core 184 rotating to a position determined by the temperature of the engine and particularly the thermostat 198. The counterclockwise rotation of the core 184 is limited by the end 195 of the cut-out 193 abutting against the cam 196. When the engine is cold, the cam 196 is so positioned that the counterclockwise rotation of the core 184 is limited to the Fig. 10 position of the core in which the flat 186 is approximately parallel with the adjacent side of the conduit 180. With the core 184 in its Fig. 10 position and with the engine running, air passes around the flats 185 and 186 through the conduit 180 and is admitted to the passage 141 below the throttle plate 145. It should be noted that the passage between the flat 186 and the side of the duct 180 is smaller than that between the flat 185 and the adjacent side of the duct 180 as was shown in the Fig. 9 position, and, therefore, less air flows in the Fig. 10 condition as compared with the Fig. 9 condition.

When the core 184 is in the Fig. 10 position, the air introduced below the throttle plate 145 through the duct 180 changes the differential of pressures above the throttle plate and below the throttle plate as compared to the differential if the conduit 180 were not opened and a like total amount of air were admitted to the engine. The pressure below the throttle plate with the conduit 180 opened is higher in relation to the pressure above the plate at the orifice 152 than would be the case if the conduit 180 were closed. This change in pressure differential increases the speed responsive pressure (or reduces the vacuum) in the passage 149 connected to the chamber 162 and the vacuum motor 121, causing the vacuum motor 121 to move the plunger 124 to the right, thereby moving the metering pin 68 through the cam 100 and associated mechanism to a richer position. The vehicle engine thus is supplied the rich fuel mixture necessary for its efficient operation under cold operating conditions.

Assuming that the throttle plate 145 is closed and the vehicle engine is thus at idling condition, the valve 183 in its Fig. 10 condition as is apparent, provides a flow of air from above the throttle plate assembly 144 into the passage 141 below the throttle plate assembly 144, thus providing a flow of air into the manifold 143 as if the throttle plate 145 had been opened partially. Thus, the valve 183 and duct 180, in addition to providing an increased fuel output by the pump 10 per stroke of the plunger 25 also cause the vehicle engine to run at a faster idling speed under cold engine conditions as compared to a condition when the duct 180 is completely closed.

When the engine reaches normal operating temperature, a leaner fuel mixture is required, and the core 184 is rotated from its Fig. 10 position to its Fig. 11 position. On such increased temperature, the helical thermostatic element 199 rotates the shaft 197 to position the cam 196 against the end 195 of the cut-out 193 of the disc 192, so that the shaft 191 is rotated further in a counterclockwise direction by the spring 206, moving the core 184 from its Fig. 10 position to the position shown in Fig. 11. In the latter position, the edge of the flat 186 just clears the adjacent wall of the duct 180 providing a small opening therebetween. Thereafter, normal engine speed variable pressures determined primarily by the throttle plate assembly 144 exist in the conduit 161, and all fuel is supplied to the vehicle engine through the normal fuel injection system including the pump 10, the lines 53 and

the nozzles 51, in the manner which has been previously described.

The above described operation of the injection system in the Fig. 10 and Fig. 11 positions of the core 184 assumes that the lines 53 to the nozzles 51 are filled with fuel. At times, when the vehicle has been standing idle for some time, particularly when the temperatures are high, the lines 53 are exhausted due to leakages in the system and vaporization of fuel in the lines 53 forcing the fuel out of the lines 53 through the pump 10 and the nozzles 51. Under these conditions, the fuel injection system operation as such utilizing discharge through the nozzles 51 will not maintain the engine in operation when the starter switch 217 is opened, since the lines 53 are empty, and fuel will not be supplied to the nozzles 51 immediately through the lines 53. The pressure switch 222 has therefore been provided, functioning to maintain the system operating as a carburetor until the lines 53, and particularly the line 53 in which the pressure switch 222 is disposed, are filled with fuel.

When fuel under pressure is present in the line 53 in which the switch 222 is disposed, the fuel under pressure is present in the passage 238 and the restriction 239 and acts against the diaphragm 234 to maintain the plunger 240 moved downwardly against the action of the compression spring 242. The plunger 240 acts on the switch 244 holding the switch contacts 246 open. The switch 222 is in parallel with the relay 221 and has no effect when the contacts 246 are open.

On the other hand, when the line 53 in which the pressure switch 222 is disposed does not have fuel in it, in this case the spring 242 holds the plunger 240 upwardly, and the contacts 246 of the micro switch 244 are closed. The switch 222 at this time completes, in conjunction with the ignition switch 216 which is closed, a circuit in parallel with the relay contacts 230. The relay 221 is under the control of the starter switch 217, as has been described, and whenever the starter switch 217 is opened, the relay 221 is deenergized opening the relay contacts 230 with respect to each other. With the pressure switch contacts 246 being closed, however, such opening of the contacts 230 has no effect, and the fuel valve solenoid 212 remains energized when the starter switch 217 is opened.

The valve 207 under control of the solenoid 212 thus remains open, and fuel continues to be supplied to the passage 187 in the core 184. Opening of the starter switch 217 however, as previously described, does have the effect of deenergizing the relay 218 and the starter motor 219 connected thereto and of deenergizing the solenoid 201 and the pressure switch 222 has no effect on these parts. When the solenoid 201 is deenergized, the spring 206 causes the core 184 to be moved to its Fig. 10 or Fig. 11 position or a position therebetween, depending on the engine temperature and the position of the cam 196 controlled by the bimetallic element 198.

The carburetor action of the valve 183 thus continues with the pressure switch contacts 246 closed and with the starter switch 217 open, and the vehicle engine is in self sustaining operation due to the fuel supplied through the valve 183 functioning as a carburetor. The fuel flows from the central passage 187 through the radial passages 189 and 190, the passage 189 being particularly effective in the Fig. 10 position of the core 184 and the passage 190 being particularly effective when the core 184 is rotated to its Fig. 11 position at higher engine temperatures. As previously noted, fuel passes through the passages 189 and 190 in the Fig. 10 position of the core 184, and fuel passes through the passage 190 in the Fig. 11 position of the core 184. This fuel mixes and vaporizes in the air passing through the duct 180, and since the clearance between the periphery of the core 184 and the sides of the duct 180 is less in the Fig. 11 position of the core 184 than in the Fig. 10 position, the amount of air for a certain amount of fuel is less in the Fig. 11 position of the core 184 than in the Fig. 10

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position which is in accordance with engine requirements at high temperatures as contrasted to engine requirements at lower temperatures.

When the line 53, in which the switch 222 is disposed, fills with fuel due to operation of the pump 10, this fuel acts through the passage 238 and the restriction 239 on the diaphragm 234 moving the plunger 240 against the spring 242 to open the micro switch contacts 246 and break the parallel circuit to the fuel valve solenoid 212. The solenoid 212 is thus deenergized, so that the spring 211 is effective to close the fuel valve 207, and flow of fuel through the passages 187, 189 and 190 thus ceases, and the fuel injection nozzles 51 are thereafter effective to provide the fuel to the engine which is necessary for keeping the engine in operation. The core 184 at this time functions as previously described to vary the flow of air through the duct 180 for changing the idling speed of the engine and to vary the pressure in the conduit 161 for changing the amount of fuel supplied by the pump 10 per stroke. The air which has been present in the lines 53, as the pump 10 operates, is compressed by the pump 10 to the relatively high pressure with which the fuel is discharged through the nozzles 51, so that, even before the air is completely forced out of the lines 53, the air takes up a very small volume. Therefore, the air or vapor does not cause any appreciable missing in the engine even though the switch contacts 246 are opened when this residual air still remains in the lines 53.

The pressure switch 222 is incidentally, preferably placed in the particular conduit 53 which is most likely to be emptied of fuel due to allowing the vehicle to set for prolonged periods and due to high temperatures. This line 53 can be determined in any particular vehicle by experimentation. The purpose of the restriction 239 connected to the passage 238 is to prevent pulsations of the diaphragm 234 and the plunger 240 and alternate openings and closings of the switch 244. When the vehicle engine is idling or running at a slow speed, the nozzles 51 discharge at correspondingly widely spaced intervals so that the pressure in the individual lines 53 rises and falls in the same manner. This could give rise to pulsations of the plunger 240 and diaphragm 243 with alternate openings and closings of the switch 244 if the pressure on the diaphragm were allowed to increase and decrease in the same manner as the pressure in the line 53 to which the pressure switch 222 is connected. The restriction 239, however, prevents a substantial flow through the passage 238 with such periodical increasing and decreasing pressures in the conduit 53 to which the switch 222 is connected, and the pressure on the diaphragm 234 is rather maintained at a rather steady value sufficient for holding the plunger down against the action of the spring 242 when the pump 10 is discharging fluid through the line 53 either at a slow rate with the slow engine speeds or at a faster rate.

Our improved controls advantageously assure that a carburetor action is maintained until the lines 53 connected to the fuel nozzles 51 are actually filled with fuel, so that the nozzles can be effective to provide the fuel for the engine necessary for sustained operation. Due to the provisions of the three passages 188, 189 and 190 in the rotary valve element 184 controlled by the thermostatic element 198, this carburetor action is controlled properly in accordance with changes in engine temperature.

We wish it to be understood that our invention is not to be limited to the specific constructions and arrangements shown and described except only insofar as the claims may be so limited, as it will be understood to those skilled in the art that changes may be made without departing from the principles of the invention.

We claim:

1. A fuel supply apparatus for an internal combustion engine comprising a plurality of nozzles respectively

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positioned adjacent the cylinders of the engine to discharge fuel into the cylinders, a fuel delivery pump connected to supply fuel to said nozzles, and pressure responsive means responsive to the pressure of fuel supplied from said pump to said nozzles for instead supplying a fuel-air mixture to said cylinders exclusive of any fuel discharged through said nozzles when said pressure is low.

2. A fuel supply apparatus for an internal combustion engine comprising a plurality of nozzles respectively positioned adjacent the cylinders of the engine to discharge fuel into the cylinders, a fuel delivery pump connected to supply fuel to said nozzles, an air intake conduit connected to the cylinders of the engine, auxiliary fuel supply means for said cylinders including means for supplying fuel to said conduit so that a fuel-air mixture passes through said conduit to said cylinders, and pressure responsive means responsive to the pressure of fuel supplied from said pump to said nozzles for rendering said auxiliary fuel supply means operative when said pressure is low and inoperative when said pressure increases above a predetermined value.

3. A fuel supply apparatus for an internal combustion engine having a fuel explosion cylinder, said apparatus comprising a nozzle positioned adjacent the cylinder to discharge fuel into the cylinder, a fuel delivery pump connected by means of a fuel line with said nozzle to supply fuel thereto, and a pressure responsive means responsive to the pressure of the fuel in said fuel line for instead supplying a fuel-air mixture to said cylinder exclusive of any fuel discharged through said fuel line and nozzle when said pressure is low.

4. A fuel supply apparatus for an internal combustion engine having a fuel explosion cylinder, said apparatus comprising a nozzle positioned adjacent the cylinder to discharge fuel into the cylinder, a fuel delivery pump connected by means of a fuel line with said nozzle to supply fuel to the nozzle, an air intake conduit connected to said engine cylinder, a throttle valve in said conduit, an auxiliary fuel supply means for supplying an air-fuel mixture to said conduit and thereby to said engine cylinder, and means responsive to the pressure in said fuel line for rendering said auxiliary fuel supply means operative when the pressure in said fuel line is below a predetermined value.

5. A fuel supply apparatus for an internal combustion engine comprising a plurality of nozzles respectively positioned adjacent the cylinders of the engine to discharge fuel into the cylinders, a fuel delivery pump, a fuel supply line connecting said delivery pump and each of said nozzles, an air intake conduit connected to said engine cylinders, auxiliary fuel supply means for providing fuel to said cylinders and including means for introducing fuel into said conduit to provide a fuel-air mixture to said cylinders, and pressure responsive means responsive to the pressure in one of said fuel lines for rendering said auxiliary fuel supply means operative when the pressure in said one line is below a predetermined value.

6. A fuel supply apparatus for an internal combustion engine comprising a plurality of nozzles respectively positioned adjacent the cylinders of the engine to discharge fuel into the cylinders, a fuel delivery pump connected to supply fuel to said nozzles, an air intake conduit connected to the cylinders of the engine, a throttle valve in said conduit for varying the air flow therethrough to said cylinders, an auxiliary fuel supply means for said cylinders and including means providing a duct connected with said conduit in parallel with said throttle valve and means for supplying fuel to said duct in order to provide a fuel-air mixture in said conduit to said cylinders, and pressure responsive means responsive to the pressure of fuel supplied from said pump to said nozzles for rendering said auxiliary fuel supply means operative when said pressure is below a predetermined value.

7. A fuel supply apparatus for an internal combustion engine comprising a plurality of nozzles respectively posi-

tioned adjacent the cylinders of the engine to discharge fuel into the cylinders, a fuel delivery pump connected to supply fuel to said nozzles, an air intake conduit connected to the cylinders of the engine, a throttle valve in said conduit for varying the air flow therethrough, an auxiliary fuel supply means for said cylinders and including means forming a duct connected with said conduit in parallel with said throttle valve and means for introducing fuel into said duct so as to provide an air-fuel mixture into said conduit and to said cylinders, a valve in said duct, thermostatic means for closing said last named valve as the temperature increases, and pressure responsive means responsive to the pressure of fuel supplied from said pump to said nozzles for rendering said auxiliary fuel supply means operative when said pressure is below a predetermined value.

8. A fuel supply apparatus for an internal combustion engine having a fuel explosion cylinder, said apparatus comprising a nozzle positioned adjacent the engine cylinder to discharge fuel into the cylinder, a fuel delivery pump connected by means of a fuel supply line to said nozzle to supply fuel thereto, an air intake conduit connected to said engine cylinder and having a throttle valve therein, auxiliary fuel supply means including means forming a duct connected with said conduit in parallel with said throttle valve and means for introducing fuel into said duct, a fuel valve for controlling the introduction of fuel into said duct, and a pressure responsive device responsive to the pressure within said fuel supply line for rendering said auxiliary fuel supply means operative by opening said fuel valve when said pressure is below a predetermined value.

9. A fuel supply apparatus for an internal combustion engine comprising a plurality of nozzles respectively positioned adjacent the cylinders of the engine to discharge fuel into the cylinders, a fuel delivery pump connected with each of said nozzles by means of a fuel line for supplying fuel to the nozzles, an air intake conduit connected to said cylinders, a throttle valve in said conduit for varying the flow of air therethrough and to said cylinders, means for varying the output of said pump in accordance with the speed and load on said engine, auxiliary fuel supply means for said cylinders and including means providing a duct connected with said conduit in parallel with said throttle valve and means for introducing fuel into said duct so as to provide an air-fuel mixture into said conduit and to said cylinders, a valve for controlling the fuel introduced into said duct, a solenoid for controlling said fuel valve, and a pressure responsive switch responsive to the pressure within one of said fuel lines and connected to said solenoid for opening said fuel valve and rendering said auxiliary fuel supply means operative when the pressure in said last named line is below a predetermined value.

10. A fuel supply apparatus for an internal combustion engine comprising an air intake conduit connected to the cylinders of the engine, a fuel delivery pump, a plurality of nozzles respectively positioned adjacent said cylinders and connected with said fuel delivery pump to be supplied with fuel therefrom, an auxiliary fuel supply means for supplying an air-fuel mixture into said air intake conduit and thereby to said engine cylinders, means for starting said engine, and pressure responsive means responsive to the pressure of fuel supplied from said pump to said nozzles, said auxiliary fuel supply means being under the control of said starting means and said pressure responsive means so that said auxiliary fuel supply means is operative both when said engine is being started and also when said pressure is below a predetermined value.

11. A fuel supply apparatus for an internal combustion engine having a combustion cylinder and comprising an air intake conduit connected to said cylinder, a fuel delivery pump, a nozzle positioned so as to discharge fuel into said cylinder and connected by means of a fuel supply line with said pump, an auxiliary fuel supply means

supplying an air-fuel mixture into said air intake conduit and thereby to said engine cylinder, means for starting said engine, and a pressure responsive means responsive to the pressure in said fuel line, said pressure responsive means and said engine starting means both being effective on said auxiliary fuel supply means to render the latter operative when said engine is being started and when the pressure in said fuel line is below a predetermined value.

12. A fuel supply apparatus for an internal combustion engine comprising an air intake conduit connected to the cylinders of the engine, a throttle valve in said conduit, a fuel delivery pump, a plurality of nozzles respectively positioned adjacent said cylinders to supply fuel thereto and connected with said fuel delivery pump, an auxiliary fuel supply means for supplying an air-fuel mixture into said conduit and thereby to said engine cylinders, said auxiliary means including a duct connected with said conduit in parallel with said throttle valve and means for introducing fuel into said duct and including a fuel valve, means for starting said internal combustion engine, and pressure responsive means responsive to the pressure of fuel supplied from said pump to said nozzles, said fuel valve being under the control of said engine starting means and said pressure responsive means to maintain said valve open and said auxiliary fuel means operative when said engine is being started and when said pressure of fuel is below a predetermined value.

13. A fuel supply apparatus for an internal combustion engine comprising an air intake conduit connected to the cylinders of the engine, a throttle valve in said conduit, a fuel delivery pump, a plurality of nozzles respectively positioned adjacent said cylinders to supply fuel thereto, an auxiliary fuel supply means for supplying an air-fuel mixture into said air intake conduit and thereby to said engine cylinders, said auxiliary means comprising a duct connected to said conduit in parallel with said throttle valve and a valve in said duct and means for introducing fuel into said duct including a fuel valve, means for starting said engine, a pressure responsive device responsive to the pressure of the fuel supplied from said pump to said nozzles, and means operatively connecting said starting means and said pressure responsive device with said fuel valve and said duct valve so as to open said duct valve with a relatively large opening and to open said fuel valve when said engine is being started and to open said duct valve with a relatively small opening and open said fuel valve when said pressure is below a predetermined value.

14. A fuel supply apparatus for an internal combustion engine comprising an air intake conduit connected to the cylinders of the engine, a throttle valve in said conduit, a fuel delivery pump, a plurality of nozzles respectively positioned adjacent said cylinders and connected with said fuel delivery pump by means of a fuel delivery line for each nozzle, an auxiliary fuel supply means for supplying an air-fuel mixture through said conduit to said engine cylinders, said auxiliary means comprising a duct connected with said conduit in parallel with said throttle valve, a valve in said duct comprising a rotatable valve core more or less closing the duct with rotation of the core and provided with fuel passages terminating at the periphery of the core, a source of fuel connected to said passages by means of a fuel valve, means for starting the vehicle engine, a pressure responsive device responsive to the pressure in one of said fuel lines, and means interconnecting said starting means and said pressure responsive device so that said duct valve is opened to a large extent and said fuel valve is opened when said engine is being started and said duct valve is opened to a relatively small extent and said fuel valve is opened when said pressure is below a predetermined value.

15. A fuel supply apparatus for an internal combustion engine comprising an air intake conduit connected to the cylinders of the engine, a throttle valve in said conduit, a fuel delivery pump, a plurality of nozzles respec-

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tively positioned adjacent said cylinders and connected with said fuel delivery pump by means of a fuel delivery line for each nozzle, an auxiliary fuel supply means for supplying an air-fuel mixture through said conduit to said engine cylinders, said auxiliary means comprising a duct connected with said conduit in parallel with said throttle valve, a valve in said duct comprising a rotatable valve core more or less closing the duct with rotation of the core and provided with fuel passages terminating at the periphery of the core, a source of fuel connected to said passages by means of a fuel valve, means for starting the vehicle engine, a pressure responsive device responsive to the pressure in one of said fuel lines, said starting means including a starter switch and said pressure

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responsive device including an electric switch, solenoids for operating said duct valve and said fuel valve, and means interconnecting said solenoids and said switches so that said duct valve is maintained opened with a relatively large opening and said fuel valve is open when said engine is being started, and said duct valve is opened when the pressure in said fuel line is below a predetermined value, and thermostatic means responsive to the temperature of the engine for varying said relatively small opening of said duct valve and decreasing the opening as the engine temperature increases.

No references cited.