

July 28, 1959

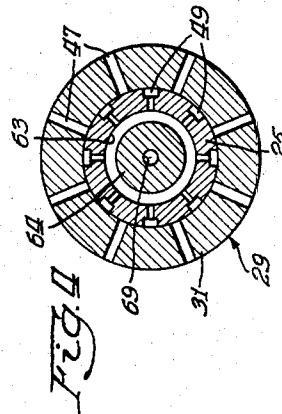
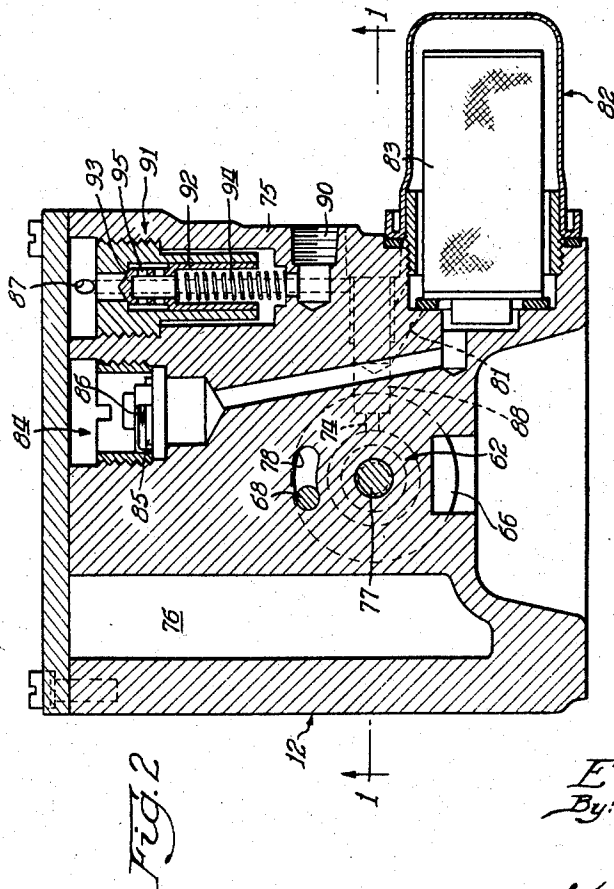
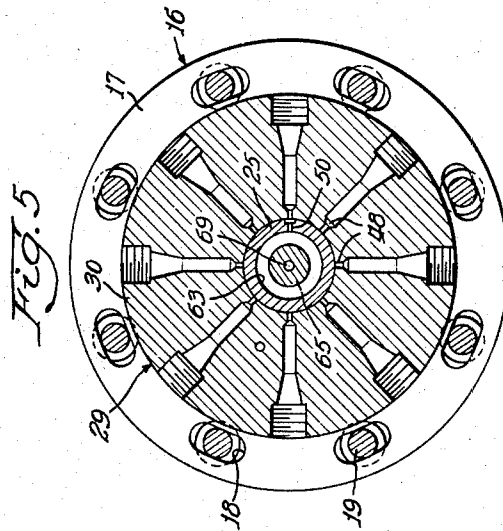
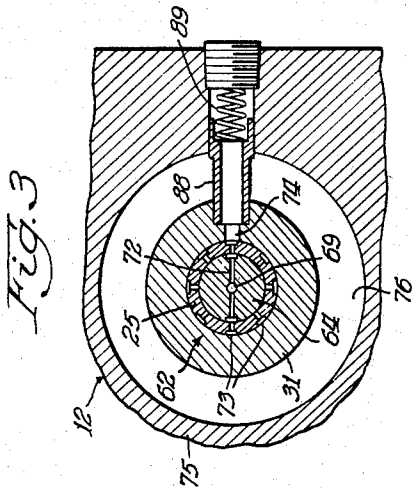
E. S. DAHL

2,896,602

FUEL INJECTION SYSTEM

Filed March 12, 1957

4 Sheets-Sheet 2



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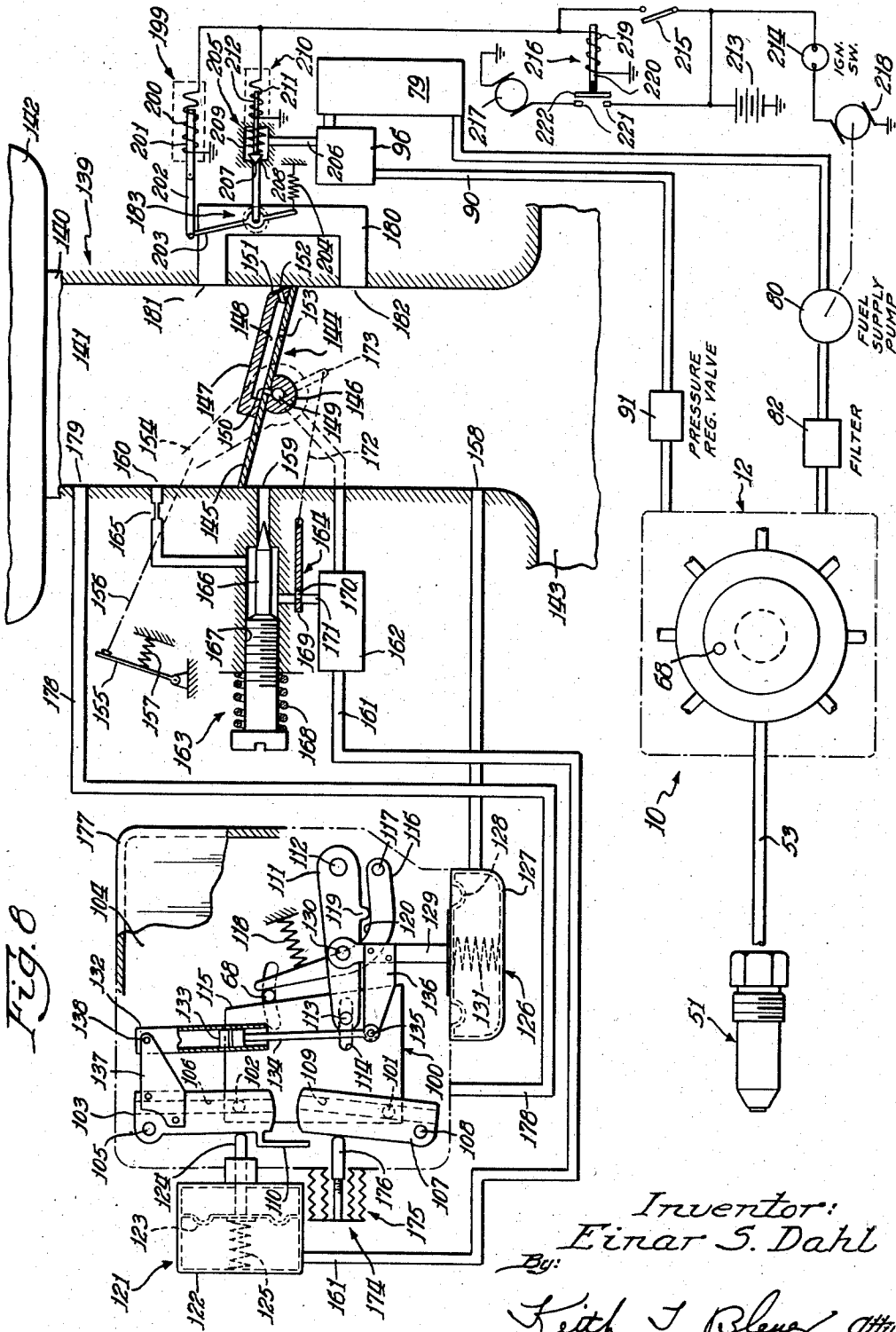
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2,896,602

FUEL INJECTION SYSTEM

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4 Sheets-Sheet 3



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E. S. DAHL
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4 Sheets-Sheet 4

Fig. 9

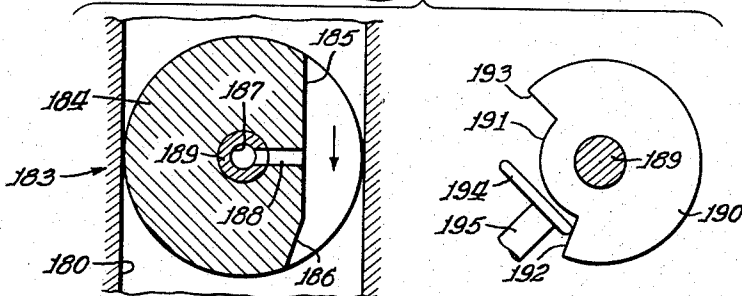


Fig. 10

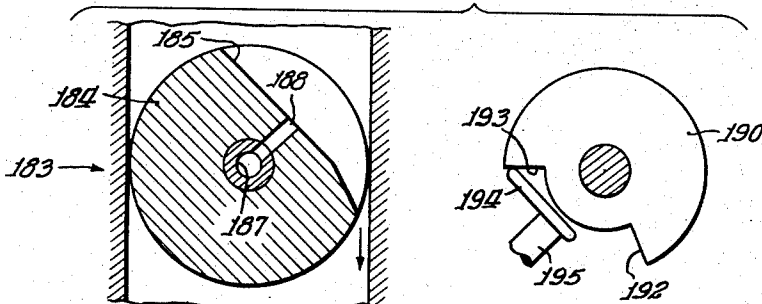
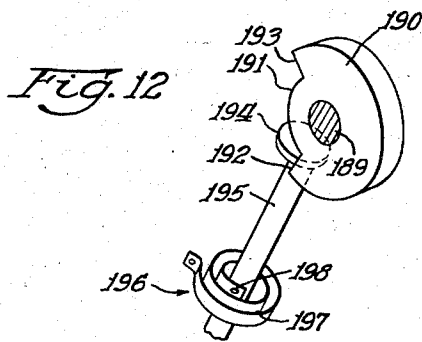
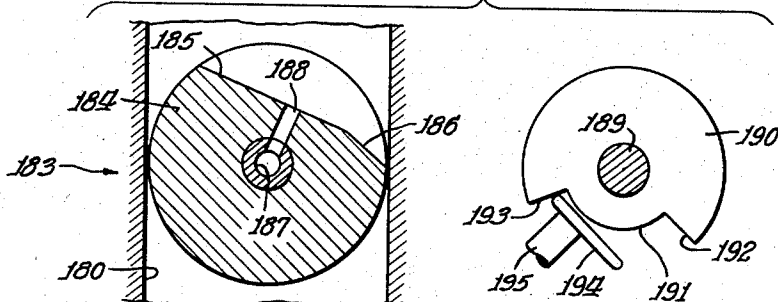


Fig. 11



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2,896,602

FUEL INJECTION SYSTEM

Einar S. Dahl, Decatur, Ill., assignor to Borg-Warner Corporation, Chicago, Ill., a corporation of Illinois

Application March 12, 1957, Serial No. 645,475

14 Claims. (Cl. 123—179)

My invention relates to fuel systems and mechanisms, particularly for use in automotive vehicles.

It has heretofore been proposed to provide a fuel injector pump to supply fuel to fuel nozzles positioned adjacent the cylinders of an automotive vehicle internal combustion engine with the pump being controlled in accordance with the load on the engine and also in accordance with the speed of the engine, such a pump and controls therefor being shown in an application by me and Robert McCreary, Serial No. 608,269, filed September 6, 1956, and in a sole application by me, Serial No. 608,578, filed September 7, 1956, now Patent No. 2,851,026, issued September 9, 1958.

It is an object of the present invention to provide an improved fuel system for automotive vehicle engines which at times, under starting conditions, functions with conventional carburetor action, to mix fuel and air and direct it into the conventional intake manifold of the vehicle engine and to subsequently cause the engine to operate with fuel being supplied to the fuel nozzles of a type of injection system previously mentioned. Previous fuel injector systems which depended on fuel supplied through the injection nozzles for starting the engine required fuel injection pumps of excess capacity in order that a sufficiently rich fuel mixture could be provided for engine starting, and it is, therefore, an object of this invention to provide a fuel system wherein the fuel injection pump may be of minimum capacity.

More particularly, it is an object to provide a fuel system which functions as a conventional carburetor for starting the engine and subsequently functions as a fuel injection system during running conditions of the vehicle engine.

Such fuel injector systems, as described in the previously filed applications mentioned above, included a throttle plate more or less closing an air intake passage, and an engine speed responsive pressure is taken from the air passage adjacent the throttle plate for varying the output of the fuel injector pump in accordance with engine speed.

It is an object of the present invention to provide an air passage or duct in parallel with the throttle plate having a valve therein more or less opening the passage and to provide a source of fuel to the valve so that as the valve is opened, the mixture of fuel and air may be directed through the passage into the conventional engine intake manifold so that the system operates on conventional carburetor action for starting the engine.

It is also another object to provide mechanism for cutting off the flow of fuel to the valve in the passage when the engine starts so that the valve may supply an additional amount of air around the throttle plate effective on the pump controls for enriching the mixture to the engine from the fuel injection nozzles. It is contemplated that this richer mixture shall preferably be so provided under cold running conditions.

It is another object of the invention to provide means, particularly a thermostat, for controlling the valve in

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the parallel passage for closing the valve as the vehicle engine reaches normal operating temperature, so that the mixture to the engine cylinders is thereafter reduced to normal.

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 and 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;

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; and

Fig. 8 is a schematic view showing controlling mechanism for the fuel injection pump and auxiliary fuel carburetion mechanism for use under starting conditions and which are associated with the air throttle valve of the internal combustion engine;

Figs. 9, 10 and 11 are side views of certain internal portions of a solenoid operated fuel and air valve in a passage in parallel with the conventional engine intake air passage showing different positions of the valve parts; and

Fig. 12 is a perspective view of a stop plate and thermostatic mechanism for the valve parts shown in Figs. 9, 10 and 11.

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 tank 21 of a coupling member 22 rotatably mounted in the base casing 16. The coupling member 22 is provided with an upwardly extending tang 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 a 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

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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 my copending application, Serial No. 608,150, filed September 5, 1956.

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

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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

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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 counterclockwise, 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 link 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

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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 an expandible bellows 175 having a rod 176 carried thereby and effective on the cam guide plate 107. The bellows 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 bellows 175 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 air passage 141 around the throttle valve assembly 144. A valve 183 is provided in the conduit 180. The valve 183 comprises a rotatable core 184 disposed in the conduit 180. 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 a second passage 188 connects the fuel passage 187 with the core flat 185. The core 184 is rotatably mounted in the conduit 180 on a shaft 189.

A disc member 190 is fixed to one end of the shaft 189 and is rotatable therewith. The disc member 190 is provided with a peripheral cut-out 191 defined by an end 192 and a second end 193.

A cam 194 is fixed on a shaft 195 and is disposed in the cut-out 191 of the disc member 190. The cam 194 may be circular in shape and is eccentrically disposed on the shaft 195. A thermostatic element 196 is effective to rotate the shaft 195. The thermostatic element 196 comprises a spiral bimetallic spring-like member 197 having one end 198 fixed to the shaft 195 and the other end fixed to a stationary part. The bimetallic element 197 is located where it may sense the engine temperature. This may be inside the exhaust manifold or at any other convenient location.

The core 184 of the valve 183 is controlled by a solenoid 199. The solenoid comprises a winding 200 which actuates an armature 201. The armature 201 is connected by means of a link 202 to a lever 203 which is fixed to the shaft 189. A tension spring 204 is effective on an extension of the lever 203 for yieldingly maintaining the end 193 of the cut-out 191 of the member 190 against the cam 194.

A valve 205 is provided in a conduit 206 connecting the fuel reservoir 96 to the passage 187 in the shaft 139 of the valve 183. In this connection, it may here be noted that the reservoir 96 is positioned adjacent and approximately at the same level as the valve 183. The valve 205 comprises a valve plunger 207 adapted to rest against a seat 208. A spring 209 yieldably maintains the valve plunger 207 against the seat 208. A solenoid 210 is effective to open the valve against the pressure of the spring 209. The solenoid 210 comprises a winding 211 and an armature 212 which is connected to the valve plunger 207.

The solenoids 199 and 210 are adapted to be energized when the vehicle engine is being started. The electrical system which energizes the solenoids includes the usual battery 213, the ignition switch 214, a starter switch 215, a starter relay 216, a starter motor 217 and a motor 218 driving the fuel supply pump 80.

The starter relay 216 comprises a winding 219, an armature 220, contacts 221, and a blade 222 carried by the armature 220 and adapted to bridge the contacts 221.

The battery 213 has one terminal grounded, and the other is connected to one contact 221, the starter switch 215 and the ignition switch 214. The other contact 221 is connected to one terminal of an engine starter motor 217, and the other terminal of the starter motor is grounded. The starter motor 217 is a conventional type of motor used for starting internal combustion engines. The starter switch 215 is connected to one end of the winding 219 of the starter relay 216 and the other end of the winding is grounded. This relay 216 is the usual type of starter relay and when the winding is energized, the armature 220 is moved to a position where the blade 222 bridges the contacts 221. The starter switch 215 is also connected to one end of the winding 200 of the air valve solenoid 199, and the other end of the winding 200 is grounded. The starter switch 215 is also connected to one end of the winding 211 of the fuel valve solenoid 210, and the other end of the winding 211 is grounded.

The ignition switch 214 is connected to the conventional ignition system of the vehicle (not shown) and is also connected to one terminal of the fuel supply pump motor 218. The other terminal of the fuel supply pump motor is grounded.

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. I have found that the pressure in the passage 148 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 63 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 for 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 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 hydro-car-

bons in the engine exhaust, which would otherwise prevail are overcome.

The expansible 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 160, 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 conventional carburetor, supplying a fuel-air mixture directly into the intake manifold 143 from which it is drawn into the engine cylinders, this conventional 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, conventional 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 215, the ignition switch 214 previously having been closed. At this time, the fuel supply pump motor 218 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 215 energizes the starter relay 216 thereby closing the circuit to the starter motor 217 through the contacts 221 and the blade 222, causing the crank shaft of the vehicle engine to be rotated. Closing the starter switch 215 also energizes the winding 200 of the solenoid 199, thereby moving the armature 201 to the right as seen in Fig. 8. Such movement of the armature 201 through the linkage 202 and the lever 203 rotates the core 184 of the valve 183 clockwise to the limit of its movement against the action of the spring 204 to the position shown in Fig. 9. The cam 194 limits the amount of rotation by the core 184 under the action of the armature 201, the end 192 of the cut out 191 abutting the cam 194 to limit this clockwise rotation of the core 184. The starter switch 215, when closed, also energizes the winding 211 of the solenoid

210 thereby moving the armature 212 to move the plunger 207 away from the seat 208 so as to open the valve 205.

With the starter motor 217 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 and 188. The air passing the flat 185 of the core 184 draws fuel from the passage 188, and the mixture of air and fuel passes down the conduit 180 into the passage 141 below the throttle valve assembly 144 and into the engine intake manifold 143 and into 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. However, if desirable, the driver may open the throttle plate 145 for starting, and additional air passes the throttle plate assembly 144 and is mixed with the fuel-air mixture entering from the duct 180.

When the starting motor 217 cranks the engine, the fuel injection pump 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 conventional 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 conventional carburetor action.

When the engine commences to fire, the operator releases the starter switch 215. The starter relay 216 is thus de-energized, and the starter motor ceases to operate. At the same time, the fuel valve solenoid 210 is de-energized, and the spring 209 causes the plunger 207 to move into valve closing position against the seat 208, thereby cutting off the flow of fuel from the reservoir 96 through the conduit 206 into the passages 187 and 188. This closing of the valve 205 terminates the conventional carburetor action.

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 196. When the starter switch is opened, the air valve solenoid 201 is de-energized, and the spring 204 rotates the core 184 in a counterclockwise direction to a position determined by the temperature of the engine and particularly the thermostat 196. The counterclockwise rotation of the core 184 is limited by the end 193 of the cut-out 191 abutting against the cam 194. When the engine is cold, the cam 194 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 in which fuel is also admitted through the duct 180.

When the core 184 is in the Fig. 10 position, the air introduced below the throttle plate 145 through the duct 180 changes the pressure 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 196 rotates the shaft 195 to position the cam 194 against the end 193 of the cut-out 191 of the disc 190, so that the shaft 189 is rotated further in a counterclockwise direction by the spring 204 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 is against the adjacent wall of the duct 180, and the duct is thus closed. Thereafter, normal engine speed variable pressures determined 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. With the valve core 184 in its Fig. 11 position, the speed control of the engine is determined solely by the position of the throttle plate 145. The engine will now idle at a minimum speed when the throttle plate 145 is in its closed position.

I have found that in a certain embodiment, mentioned only for purposes of example, with the valve core 184 in its Fig. 11 position, a pressure of 23.5 inches of mercury existed in the chamber 162 at 500 r.p.m. engine speed, with the throttle plate 145 closed. At 1000 r.p.m. with the throttle plate 145 partly opened, a pressure of 22.5 inches of mercury existed in the chamber 162 with the valve core in its Fig. 11 position. With the throttle closed and the valve core 184 in its Fig. 10 position, a pressure of 23.5 inches of mercury was present in the chamber 162, and the engine speed was again 1000 r.p.m. Thus, it will be observed that the core 184, in partially opening the duct 180 in the Fig. 10 position of the core, had the effect of changing the manifold pressure from 22.5 inches of mercury to 23.5 inches of mercury, and such an increase of pressure or lowering of vacuum has the effect, as has been previously described, of moving the metering pin 68 clockwise as seen in Fig. 8 to increase the fuel delivery by the pump 10 per stroke of the plunger 25. This increase of output by the pump 10 is, of course, in addition to the effect of an increase of engine idling speed due to the air by-passing the throttle plate assembly 144 through the conduit 180.

My improved fuel injection control system advantageously functions as a conventional carburetor during starting conditions, supplying fuel directly from a

source of fuel into an air passage leading to the intake manifold of the vehicle engine, and when the engine cranking action ceases, the conventional carburetor action of the system is terminated, and the engine is operated on the fuel injection system. Since fuel injection is not relied on for starting, a pump 10 is required that is smaller than would otherwise be necessary. It is thus feasible to use a pump having the relatively small capacity necessary only for normal running conditions.

The solenoid operated valve 183 provides this carburetor action, and when vehicle engine cranking ceases, the supply of fuel to the valve 183 is cut off, and thereafter, the valve 183 advantageously functions to both provide an increased idling speed of the vehicle engine and to provide an increased output of the injection pump 10 per stroke of its plunger 25 under cold engine conditions, the thermostat 196 functioning to so control the valve 183.

I wish it to be understood that the 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.

I claim:

1. 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 driven by said engine, a plurality of nozzles respectively positioned adjacent said cylinders and connected with said fuel delivery pump to be supplied with fuel therefrom, mechanism for starting said internal combustion engine, and an auxiliary fuel providing means for supplying an air-fuel mixture into said air inlet conduit and thereby to said engine cylinders and under the control of said engine starting mechanism to be rendered effective thereby.

2. 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 driven by said engine, a plurality of nozzles respectively positioned adjacent said cylinders and connected with said fuel delivery pump to be supplied with fuel therefrom, a throttle valve in said air intake conduit, means providing an air duct connected with said air conduit around said throttle valve, a valve in said duct, means for supplying fuel to said duct and including a fuel valve, means for starting said engine, and means under the control of said engine starting means for both opening said duct valve and for opening said fuel valve so that said duct and fuel valve provide a fuel-air mixture into said conduit and thereby to said cylinders.

3. 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 driven by said engine, a plurality of nozzles respectively positioned adjacent said cylinders and connected with said delivery pump to be supplied with fuel therefrom, a movable throttle valve in said air inlet conduit, means for providing an air duct connected with said conduit in parallel with said throttle valve, a valve in said duct, means for supplying fuel to said duct and including a fuel valve, means for starting said engine and including a starter switch, and means for opening both said duct valve and said fuel valve when said starter switch is actuated for providing an air-fuel mixture in said duct and to said cylinders and including an electric solenoid effective on each of said duct valve and said fuel valve and electrically connected with said starter switch.

4. 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 driven by said engine, a plurality of nozzles respectively positioned adjacent said cylinders and connected with said

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delivery pump to be supplied with fuel therefrom, a movable throttle valve in said air inlet conduit, means for providing an air duct connected with said conduit in parallel with said throttle valve, a valve in said duct, said valve comprising a rotatable core having a flattened face and a fuel passage therein connected with said flattened face, a source of fuel connected with said passage and comprising a fuel valve, means for starting said engine, and means under the control of said engine for opening both said duct valve and said fuel valve when said engine is being started so that at this time a fuel-air mixture is produced in said duct and is supplied through said conduit to said cylinders.

5. 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 driven by said engine, a plurality of nozzles respectively positioned adjacent said cylinders and connected with said delivery pump to be supplied with fuel therefrom, a movable throttle valve in said air inlet conduit, means providing an air duct connected with said conduit in parallel with said throttle valve, a valve in said duct, said valve including a rotatable core having a flattened face and a fuel passage connected with said flattened face, means for supplying fuel to said passage including a fuel valve, an electric solenoid for opening said duct valve, an electric solenoid for opening said fuel valve, means for starting the vehicle engine and including a starter switch, and means electrically connecting said starter switch with said solenoids so as to open both said duct valve and said fuel valve and provide a fuel-air mixture in said duct and in said conduit to said cylinders when said engine is being started.

6. A fuel supply apparatus for an internal combustion engine comprising an intake manifold connected with the cylinders of the engine, a fuel delivery pump driven by said engine, a plurality of nozzles respectively positioned to discharge fuel into said cylinders and connected with said fuel delivery pump to be supplied with fuel therefrom, a movable throttle valve in an air inlet passage connected with said intake manifold, means variable with the speed of said engine for decreasing the output of said pump as the engine speed increases and including a pressure change responsive control device connected with orifices at the top and below said throttle valve providing a pressure that varies with engine speed that is applied to said control device, means providing a duct connected with said air passage in parallel with said throttle valve, means for supplying fuel to said duct, a valve in said duct, means for selectively opening said duct valve and rendering said last named fuel supply means effective so as to provide an air-fuel mixture in said duct and said passage and to said cylinders, and a thermostatic means effective on said duct valve for holding it partially open under cold engine operating conditions after said last named fuel supply means has been rendered ineffective to change said engine speed variable pressure for increasing the output of said pump under cold engine operating conditions.

7. A fuel supply apparatus for an internal combustion engine comprising an air intake conduit connected to the cylinders of the engine, a movable throttle valve in said conduit for governing the speed of the engine, means forming a duct connected with said conduit in parallel with said throttle valve, a valve in said duct, means for selectively opening said duct valve and for supplying fuel to said duct for providing an air-fuel mixture in said duct and thereby to said cylinders, and thermostatic means effective on said duct valve for maintaining it partially opened on cold operating conditions when said selective means is inoperative so as to raise the idling speed of the engine when said throttle valve is closed.

8. A fuel supply apparatus for an internal combustion engine comprising an air intake conduit connected to the cylinders of the engine, a movable throttle valve in said

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conduit for governing the speed of the engine, means forming a duct connected with said conduit in parallel with said throttle valve, a valve in said duct, means for supplying fuel to said duct and including a fuel valve, a motor for opening said fuel valve, a motor for opening said duct valve, selectively operable means for simultaneously energizing said motors for opening said fuel and duct valves to provide an air-fuel mixture in said duct and thereby to said cylinders, and thermostatic means effective on said duct valve for maintaining it partially open on cold operating conditions when said selective means is inoperative so as to raise the idling speed of the engine when said throttle valve is closed.

9. A fuel supply apparatus for an internal combustion engine comprising an air intake conduit connected to the cylinders of the engine, a movable throttle valve in said conduit for governing the speed of the engine, means forming a duct connected with said conduit in parallel with said throttle valve, a valve in said duct, means for selectively opening said valve and for supplying fuel to said duct for providing an air fuel mixture in said duct and thereby to said cylinders, additional means exclusive of said last named fuel supplying means for providing fuel to said cylinders and regulated by the opening of said throttle valve for maintaining the engine in operation when said first-named fuel supplying means is inoperative, and thermostatic means effective on said duct valve for maintaining it partially open on cold operating conditions so as to raise the idling speed of the engine when said selective means is inoperative and said throttle valve is closed.

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 to discharge fuel into said cylinders and connected with said delivery pump to be supplied with fuel therefrom, a movable throttle valve in said conduit for varying the passage of air through the conduit and operably connected with said pump to vary its output so as to govern the speed of the engine, means forming a duct connected with said conduit in parallel with said throttle valve, a valve in said duct, means for supplying fuel to said duct, selectively operable means for simultaneously rendering said last named fuel supplying means operative and for opening said duct valve for providing an air-fuel mixture in said duct and thereby to said cylinders, and thermostatic means effective on said duct valve for maintaining it partially open on cold operating conditions when said fuel supply means for said duct is inoperable and said throttle valve is closed for raising the idling speed of the engine while fuel is being supplied from said pump to said nozzles for maintaining the engine in operation.

11. 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 driven by said engine, a plurality of nozzles respectively positioned to discharge fuel into said cylinders and connected with said fuel delivery pump, means for governing the fuel output of said pump and comprising a motor connected with a pair of orifices in said conduit respectively at the top and bottom of said throttle valve so that the output of the pump varies with engine speed, means forming a duct connected with said conduit in parallel with said throttle valve, a valve in said duct, means for supplying fuel to said duct and comprising a fuel valve, means for selectively simultaneously opening said duct and fuel valve so as to provide an air-fuel mixture in said duct and thereby to said cylinders, and thermostatic means effective on said duct valve for maintaining it partially opened on cold operating conditions so as to raise the passage of air to said cylinders and the fuel output of said pump by virtue of control by said orifices when said selective means is inoperative.

12. A fuel supply apparatus for an internal combustion

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tion engine comprising an air intake conduit connected to the cylinders of the engine, a throttle valve in said conduit a fuel delivery pump driven by said engine, a plurality of nozzles respectively positioned to discharge fuel into said cylinders and connected with said fuel delivery pump, means for governing the fuel output of said pump and comprising a motor connected with a pair of orifices respectively at the top and bottom of said throttle valve so that the output of the pump varies with engine speed, means forming a duct connected with said conduit in parallel with said throttle valve; a valve in said duct, means for supplying fuel to said duct and comprising a fuel valve, an electric solenoid for opening said duct valve, an electric solenoid for opening said fuel valve, and means for starting said engine including an electric starter switch, said starter switch being connected with said solenoids so as to open said duct and fuel valves when the starter switch is closed so as to provide an air-fuel mixture in said duct supplied to said cylinders for starting the engine.

13. A fuel supply apparatus for an internal combustion engine comprising an air intake conduit connected to the cylinders of the engines, means defining an air duct connected with said air conduit, a valve disposed in said duct, said valve comprising a rotatable cylindrical core having two intersecting flattened faces formed thereon, and means for rotating said valve to a first position

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for allowing the passage of a relatively small amount of air past one of said flattened faces through said duct, and said last named means also being effective to rotate said core to a second position for allowing the passage of a relatively greater amount of air past said second flattened face through said duct.

14. A fuel supply apparatus for an internal combustion engine comprising an air intake conduit connected to the cylinders of the engine, means defining an air duct connected with said conduit, a valve disposed within said duct, said valve comprising a rotatable core formed with two intersecting flattened faces and a fuel passage opening through one of said faces, means for supplying fuel to said passage, and means for rotating said core to a first position opening said valve for allowing the simultaneous passage of a relatively small amount of fuel and air through said duct and into said conduit, said last named means also being effective to rotate said core to a second position for allowing the passage of a relatively greater amount of fuel and air through said duct and into said conduit.

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