

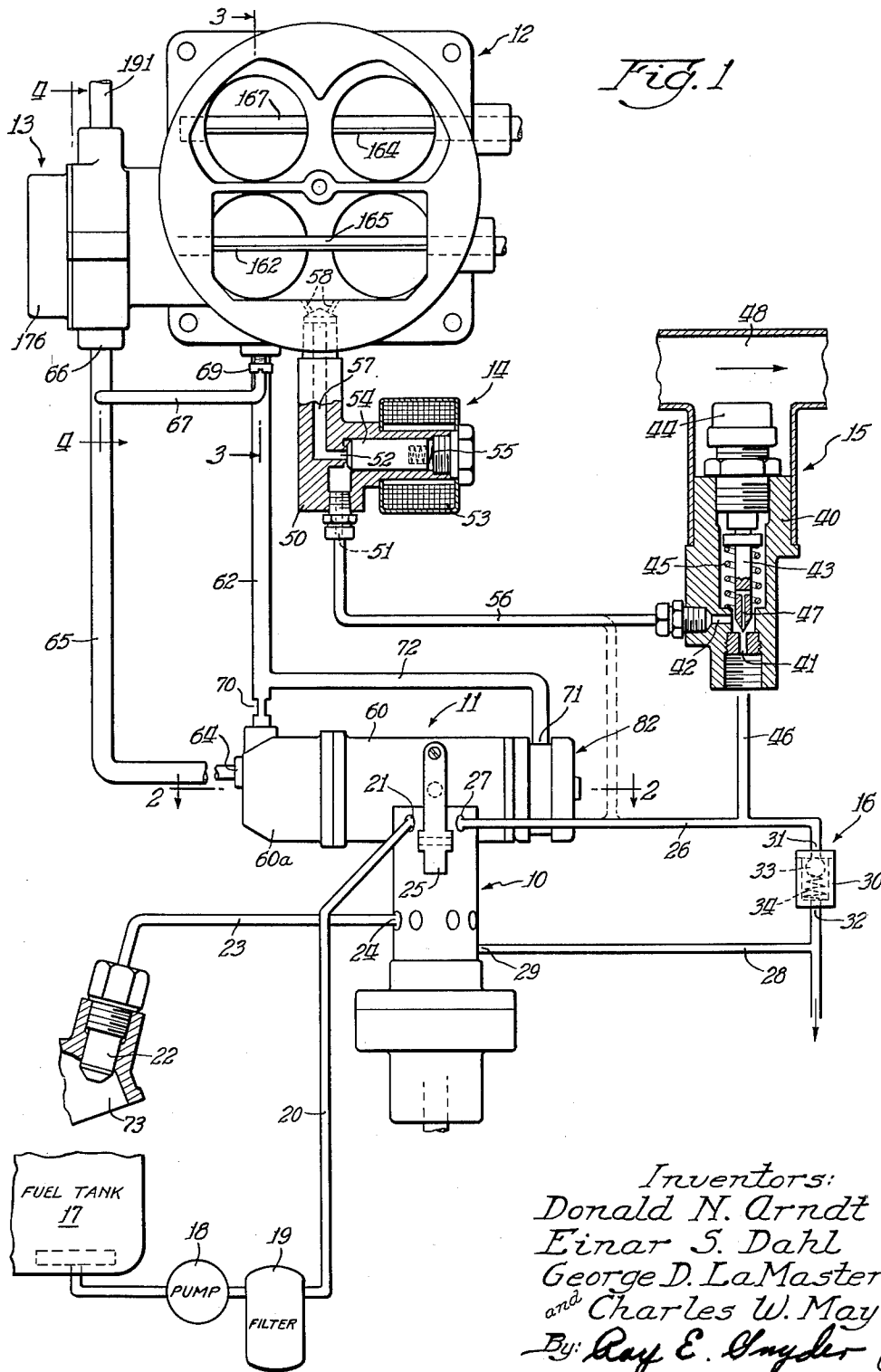
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D. N. ARNDT ET AL
FUEL INJECTION CONTROL

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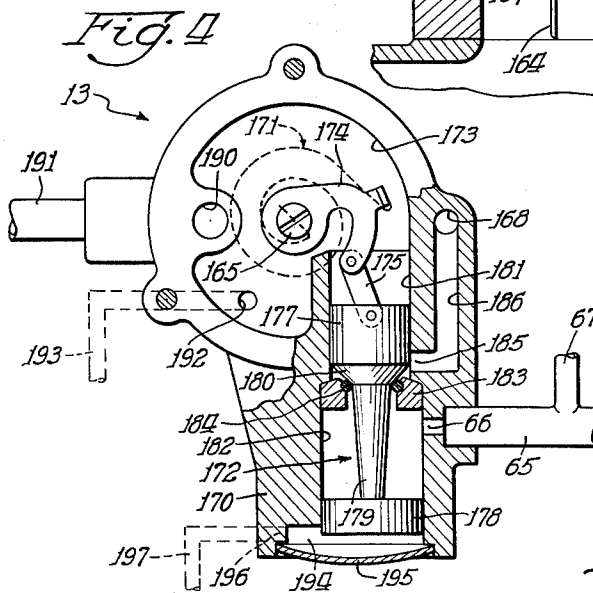
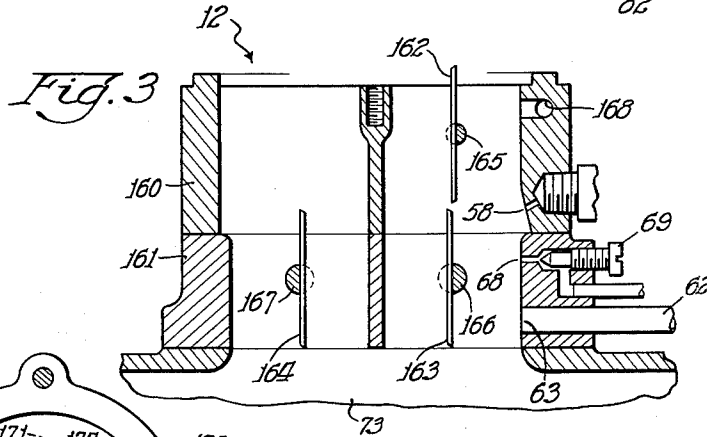
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FUEL INJECTION CONTROL

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2,984,232

FUEL INJECTION CONTROL

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18 Claims. (Cl. 123—179)

This invention relates to a control system for a fuel injection mechanism adapted to be used with the engine of an automotive vehicle.

It is an object of the present invention to provide an improved control system for a fuel injection pump adapted to provide the correct amount of fuel to meet engine demand or the correct fuel to air ratio for all conditions of operation of the engine.

In particular, it is an object to provide an improved fuel injection control system for a fuel injection pump that supplies metering forces to the injection pump in accordance with engine demand for measuring each charge of fuel supplied to the engine cylinders.

It is a more particular object to provide metering forces to a fuel injection control mechanism, one of the forces being developed by manifold vacuum supplied from the air intake manifold, which vacuum is modified by adjustable air bleed or bypass means for adjusting engine idling conditions.

It is another object to provide an additional improved air bleed mechanism for modifying the manifold vacuum supplied to the control mechanism automatically in accordance with changes of temperature of the engine, particularly during engine warm-up.

It is still another object to provide an improved warm-up control valve including a tapered needle element which is acted upon by a thermostatic element and by manifold vacuum, which needle element is effective to bleed or bypass a small amount of air into the manifold vacuum line of the control mechanism for modifying the manifold vacuum in accordance with engine warm-up temperature conditions and varying load conditions.

It is an object to provide optional electrically operated switch means interconnected with said air bleed mechanism for supplying additional starting fuel when the engine is comparatively cold.

It is another object to provide additional fuel enrichment for starting of the engine, the amount of starting fuel being automatically controlled in accordance with engine temperature.

It is an additional object to provide a fuel injection control system that is independent of the force of gravity for its operation and consequently can be mounted in any position with respect to the engine.

It is still another object to provide an improved computer mechanism adapted to transform metering forces supplied from the engine into mechanical motion for metering each charge of fuel supplied by the fuel injection pump.

It is a more particular object to provide a computer mechanism having a two-dimensional cam which is acted upon by a vacuum motor for metering the charges of fuel in accordance with engine load conditions, and also including an atmospheric pressure responsive device for automatically modifying the position of said cam in accordance with changes in atmospheric pressure.

In addition to the preceding object, it is an object to provide vacuum operated power amplifying means that is responsive to atmospheric pressure for moving the cam.

More particularly, it is an object to provide a double diaphragm arrangement acted upon by manifold vacuum, an expansible bellows responsive to atmospheric pressure, a sliding valve mechanism connected to the bellows, and a lever mechanism connected with the diaphragm

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arrangement for automatically repositioning the bellows with changes in atmospheric pressure.

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 appear from the following description of a preferred form of the invention, illustrated with reference to the accompanying drawings, wherein:

Fig. 1 is a schematic diagram of the control and fuel supply system of the present invention, including a fuel injection pump, a computer mechanism, a throttle body, and a warm-up enrichment valve;

Fig. 2 is an enlarged sectional view showing details of constructions of the computer mechanism of Fig. 1;

Fig. 3 is a cross-sectional view of the throttle body taken on line 3—3 of Fig. 1;

Fig. 4 is an enlarged sectional view of the improved warm-up valve taken on line 4—4 of Fig. 1; and

Fig. 5 is a view of the control linkage for the throttle body, and includes a modified version of the starting fuel supply system.

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

Referring to Fig. 1, there is illustrated a schematic diagram of the complete control system for a fuel injection pump 10. The system includes a computer mechanism 11, a throttle body 12, a warm-up enrichment valve 13, a solenoid operated starting valve 14, a starting fuel regulator valve 15, and a fuel pressure regulator valve 16.

The fuel supply system for the pump 10 also includes a fuel tank 17, a primary fuel supply pump 18, and a filter 19, which are connected through a conduit 20 to an input port 21 of the pump 10.

The supply pump 18 is preferably electrically driven and supplies fuel under pressure to the pump 10 whenever the engine ignition switch is on.

The injection pump 10 supplies metered charges of fuel in sequence to a plurality of nozzles 22 mounted in or adjacent to the cylinders of the internal combustion engine. Each of the nozzles 22 is connected by means of a conduit 23 to an outlet port 24 of the pump 10. A metering control arm 25 is mounted on the pump 10 and is operated by the computer mechanism 11, for metering each charge of fuel delivered by the pump 10.

The pump 10 is driven through a rotatable drive shaft 24 which is connected to be driven at a fixed speed ratio with respect to the crankshaft of the internal combustion engine.

The pump 10 may be of the type described in copending application of Einar S. Dahl, entitled "Fuel Injection Pump," Serial No. 791,081, filed February 4, 1959, and will not be further described.

The fuel supply system also includes an auxiliary fuel supply line 26 connected to a port 27 of the pump 10, and a leakage fuel return line 28 which is connected to a port 29 of the pump 10. The auxiliary supply line 26 is connected through the pressure regulator valve 16 to the leakage return line 28 which returns fuel back to the tank 17.

The pressure regulator valve 16 comprises a hollow casing portion 30 formed with an inlet port 31 and an outlet port 32, a ball 33, and a spring 34. The inlet port 31 is connected to the conduit 26 and the outlet port 32 is connected to the conduit 28. The spring 34 tends to force the ball 33 into a fluid sealing position against the inlet port 31, and functions to maintain the pressure within the conduit 26 at predetermined maximum.

The starting fuel regulator valve 15 comprises a casing 40 formed with an inlet port 41 and an outlet port 42, a valve stem 43, a temperature responsive element 44, and a spring 45. The inlet port 41 is connected

through a branch conduit 46 to the auxiliary supply line 26. The valve stem 43 is attached to the temperature responsive element 44 and is positioned within the casing 40 so as to partially restrict the inlet port 41. The valve stem 43 is formed with a small passage 47 which always permits a minimum amount of fuel to flow from the port 41 to the port 42. The spring 45 tends to lift the valve stem 43 away from the inlet port 41. The temperature responsive element 44 is mounted within the casing 40 and extends into a liquid conduit 48 which is connected to the engine liquid cooling system. The temperature responsive element 44 may be of the "Verni-therm" type manufactured by Detroit Controls, Inc. The element 44 responds to the temperature of the cooling liquid so that the valve stem 43 tends to open the port 41 a greater amount when the engine is cold and to restrict the port 41 to a greater extent when the engine is warm, thereby providing the correct amount of additional starting fuel for any given engine temperature.

The solenoid-operated starting valve 14 comprises a casing 50 formed with an inlet port 51 and an outlet port 52, a solenoid 53, a valve armature 54, and a spring 55. The inlet port 51 is connected through a conduit 56 to the outlet port 42 of the regulator valve 15. The outlet port 52 opens into a channel 57 which terminates at jets 58 formed in the throttle body 12. The spring 55 forces the valve armature 54 into a fluid sealing position against the outlet port 52 except when the solenoid 53 is energized. The solenoid 53 is connected in series with the starting circuit of the engine.

In operation, the auxiliary fuel supply system for the fuel injection pump 10 functions as follows:

When the ignition switch for the engine is turned on, the electrically driven supply pump 18 delivers fuel from the tank 17 to the inlet port 21 of the fuel injection pump 10. A portion of this fuel is also supplied through the port 27 and conduit 26 to the inlet port 41 of the regulator valve 15. Fuel under pressure passes through the outlet port 42 to the inlet port 51 of the starting valve 14. When the starting switch is closed, the solenoid 53 is energized and opens the valve armature 54, allowing fuel to pass through the port 52, conduit 57, and jets 58 into the air stream of the throttle body 12. The amount of fuel so passing through the jets 58 for starting is determined by the valve 15 which, as previously stated, is responsive to the temperature of the liquid present within the conduit 48.

The computer mechanism 11 comprises a casing 60 formed with an inlet port or orifice 61 which is connected through a conduit 62 to an orifice 63 formed in the throttle body 12. The casing 60 also has a port or orifice 64 which is connected through a conduit 65 to an orifice 66 formed in the warm-up enrichment valve 13. The conduit 65 is also connected by means of a branch conduit 67 to an orifice 68 formed in the throttle body 12. The orifice 68 constitutes a bleed orifice and is adapted to be restricted by means of a needle valve 69 threaded in the wall of the throttle body 12. The conduit 62 is formed with a restriction 70 at a point near the port 61. The casing 60 is also formed with a port 71 which is connected by means of a conduit 72 to the conduit 62 at a point above the restriction 70. The conduits 62, 65, and 72 are all subjected to pressure existing within the intake manifold 73 of the engine.

Referring to Fig. 2, the computer mechanism 11 in general comprises a two-dimensional cam 80, a vacuum operated servo motor 81 and an atmospheric pressure compensating device 82. The servo motor 81 comprises a diaphragm 83 mounted within a casing portion 60a and a spring 84. The diaphragm 83 is connected to the cam 80 by means of a connecting rod 85. A portion of the diaphragm 83 is sandwiched between a retaining washer 86 and a spring retaining cup 87 which are attached to the connecting rod 85 by means of a nut 88. An extension 89 of the connecting rod 85 is guided with-

in a cylindrical cavity 90 formed in one end of the casing portion 60a. The spring 84 tends to force the diaphragm 83 to the right as shown in the figure. The motion of the diaphragm 83 to the right is limited by means of an annular abutment or casing portion 91 formed within the casing 60. The ports 61 and 64 open into the interior of the casing portion 60a, and the diaphragm 83 is subjected to the pressure existing within the conduits 62 and 65.

The cam 80 is formed with a slanting cam surface 92 and with pivot or contact points 93 and 94. The cam 80 is formed with a slot 95 and is attached to the connecting rod 85 by means of a pin 96 extending through the slot 95. A roller or cam follower 97 is in contact with the cam surface 92 and is carried by a roller arm 98 which is pivotally mounted on a pin 99 within the casing 60. The control arm link 100 in turn acts against the control arm 25 mounted on the exterior of the pump 10 which in turn acts against a metering pin or element within the pump 10 (not shown). A spring 101 is disposed under compression between the casing 60 and the control arm 25 and acts to reduce the force reflected back to the roller arm 98 from the pump 10.

A lever arm 102, designated as the low load guide arm, is pivotally mounted on a pin 103 within the casing 60. The contact point 93 of the cam 80 is in sliding contact with a surface 104 on the guide arm 102. An adjusting screw 105 is attached to the guide arm 102 and extends through the wall of the casing 60 and functions to adjust the initial position of the guide arm 102.

An L-shaped lever arm 106 is pivotally mounted upon a pin 107 within the casing 60 and is designated generally as the high load guide arm. The contact point 94 is in sliding contact with a surface 108 on the guide arm 106. The guide arm 106 also carries a knuckle 109 which is in contact with a connecting rod 110 attached to the pressure compensator 82. The connecting rod 110 abuts against a pin 111 mounted within the casing 60, and is formed with a wedge surface 112 in contact with the knuckle 109.

The altitude compensating mechanism 82, in general, comprises a casing portion 120 attached to the casing 60, an expandable bellows 121, two vacuum responsive diaphragms 122 and 123, and a sliding valve mechanism 124. The bellows 121 is carried by a central shaft 125, one end of which is pivotally attached by means of a pin 126 to one end of a lever arm 127, called the repositioning lever. The other end of the lever arm 127 is pivotally attached to the connecting rod 110 by means of a pin 128. The lever arm 127 is pivotally mounted on a fulcrum by means of a pin 129. The other end of the shaft 125 is pivotally attached to a lever arm 130, called the control valve lever, by means of a pin 131. The lever 130 is pivoted on a pin 132 and the other end thereof is pivotally attached to a sliding valve block 133 by means of a pin 134.

The diaphragms 122 and 123 are attached to the connecting rod 110 and are mounted in cavities 140 and 141, respectively, formed in the casing portion 120, and separated by a partition 142. The diaphragm 122 separates the cavity 140 into two parts designated as 140a and 140b. Similarly, the diaphragm 123 separates the cavity 141 into two compartments designated as 141a and 141b. The port 71, which is formed through the wall of the casing portion 120, opens into both of the compartments 140a and 141a. The compartments 140b and 141b are both open to atmospheric pressure through ports 143 and 144, respectively.

The sliding valve 124 comprises the sliding block 133 which is attached to the lever arm 130, a sliding plate 150, and a fixed plate 151. The sliding plate 150 is formed with a central port or opening 152 and is attached to the block 133 by means of a spring washer 153. A piece of felt 154 covers the opening 152 and prevents entry of dirt therein. The fixed plate 151 is formed with

two openings 155 and 156 with which the port 152 is adapted to communicate at times. Two cross-over channels 157 and 158 are formed through the casing portion 120 and terminates at the openings 155 and 156. The channel 157 connects the cavity 140a with the port 156 and the channel 158 connects the cavity 141a with the port 155.

Referring to Fig. 3, the throttle body 12 is mounted on the air intake manifold 73, and comprises contiguous casing portions 160 and 161, a choke valve or valves 162, and a plurality of throttle valves 163 and 164. The choke valves 162 are attached to a shaft 165 which is rotatably mounted through the walls of the casing portion 160. The throttle valves 163 and 164 are attached to shafts 166 and 167, respectively, which are rotatably mounted through the walls of the casing portion 161. The shafts 166 and 167 are interconnected through a suitable mechanical linkage as shown in Fig. 5. The casing portion 160 is formed with the jets 58 which open into the air stream at a point below the choke valves 162, and is also formed with an orifice 168 which opens into the air stream above the choke valve 162. The casing portion 161 is formed with the orifice 63 which opens into the air stream at a point below the throttle valve 163 so as to be subject to manifold vacuum. The bleed orifice 68 opens into the air stream at a point substantially parallel with an edge of the throttle blade 163 in a closed throttle position.

Referring to Fig. 4, the warm-up enrichment valve 13 comprises a casing 170, a thermostatic element 171 and a tapered or needle valve piston assembly 172. The thermostatic element 171 is disposed within a cavity 173 formed in the casing 170, and one end thereof is connected to the valve piston 172 through a bell crank 174 and a link 175. The other end of the thermostatic element 171 is attached to the interior of a cover 176 mounted over the cavity 173. The cover 176 is rotatably mounted on the casing 170 for adjusting the tension of the thermostatic element 171. The bell crank 174 is rigidly attached to one end of the choke valve shaft 165.

The valve piston assembly 172 is formed with a small land 177 and a large land 178, a tapered or needle portion 179, and a flared portion 180. The lands 177 and 178 are interconnected by the tapered portion 179 and are slidably disposed within co-linear cylindrical cavities 181 and 182, respectively, formed in the casing 170. The cylindrical cavities 181 and 182 are separated by means of a washer 183 which carries an O ring 184. The O ring 184 serves as a valve seat for the flared portion 180 of the valve piston 172. The casing portion 170 is formed with the orifice 66 which opens into the cylindrical cavity 182 and with an orifice 185 which opens into the cylindrical cavity 181. The orifice 185 is connected through a channel 186 to the orifice 168 in the throttle body 12.

The casing 170 is also formed with an orifice 190 which opens into the cavity 173 and which is connected through a conduit 191 to a manifold stove (not shown), mounted in the exhaust manifold of the engine. The manifold stove may be of the type conventionally used with the automatic chokes of existing vehicles. The casing 170 is also formed with an orifice 192 which opens into the cavity 173 and which is connected through a conduit 193 to the air intake manifold 73.

The conduit 193 connected to the air intake manifold 73 functions to draw air from the cavity 173 and atmospheric pressure forces air heated by the manifold stove through the conduit 191 and port 190 into the cavity 173. The air heated by the manifold stove acts on the thermostatic element 171 as will be described hereinafter.

The casing 170 is formed with a chamber 194 on the lower end of the land 178 which is sealed from atmospheric pressure by means of a cover plate 195. A port 196 opens into the chamber 194 and is connected through a conduit 197 to the air intake manifold 73. The pres-

sure within the chamber 194 which acts upon the lower end of the land 178, therefore is substantially manifold vacuum.

Referring to Fig. 5, there is illustrated a mechanical linkage 200 that may be utilized with the throttle body 12. The linkage 200 comprises a first throttle lever 201, a second throttle lever 202, a third throttle lever 203, a fast idle stop arm 204, a fast idle choke lever 205, and a choke cam lever 206. The first throttle lever 201 is fixedly attached to the throttle valve shaft 166 and is operated by a throttle rod 207 which is connected to a conventional accelerator pedal (not shown). The second throttle lever 202 has a bushing portion 208 formed integrally therewith which is journaled on the throttle valve shaft 166. A spring 209 surrounds and is wound on the bushing portion 208. The first throttle lever 201 is formed with a tab 210 which is adapted to make a lost motion connection with one end of the spring 209. The second throttle lever 202 is connected to the third throttle lever 203 by means of a tie rod 211. The third throttle lever 203 is fixedly attached to the throttle valve shaft 167. The throttle lever 201 is adapted to be rotated clockwise by means of the throttle rod 207 for opening the throttle valve 163 and this clockwise motion is transmitted through the spring 209, the second throttle lever 202 and tie rod 211 to the third throttle lever 203 for opening the throttle valve 164.

The fast idle stop arm 204 is pivotally mounted on a fixed pin 212, and is interconnected with the choke cam lever 206 by means of a connecting rod 213. The first throttle lever 201 is formed with a tab 214 which carries an adjusting screw 215 which is adapted to make contact with a stepped cam surface 216 formed on the arm 204. The first throttle lever 201 is also formed with a tab 217 which carries a throttle stop screw 218.

The choke cam lever 206 is journaled on the choke valve shaft 165 and is formed with a tab 219 and cam surface 220. The tab 219 makes a lost motion connection with the fast idle choke lever 205 which is fixedly attached to the choke valve shaft 165.

The third throttle lever 203 is formed with a tab 221 which is adapted to make contact with the fast idle stop arm 204 through a notch 222 formed thereon. The tab 221 in making contact with the fast idle stop arm 204 functions to lock the throttle valve 164 in a closed position when the choke valve 162 is closed.

A schematic diagram of an optional circuit for supplying additional starting fuel at low engine temperature is also included on Fig. 5. This circuit comprises a normally open switch 230, a normally closed switch 231, the solenoid operated starting valve 14, and a starting circuit 232. The switch 230 has an arm 233 carrying a roller 234 which is in contact with the cam surface 220 of the cam lever 206. The switch 231 has an arm 235 which carries a roller 236 adapted to make contact with a knuckle 237 formed on the throttle rod 207.

In operation, the starting circuit functions as follows: The solenoid valve 14 is connected in series with the normally opened switch 230 and the normally closed switch 231 to the starting circuit of the engine. The switch 230 is closed by the choke cam lever 206 acting against the roller 234 when the choke valve 162 is substantially closed. The circuit through the switches 231 and 230 is then complete and during starting of the engine, the valve 14 is energized for supplying additional starting fuel to the throttle body 12 as previously described. The switch 231 is adapted to be opened by the knuckle 237 of the throttle rod 207 acting against the roller 236 in an open throttle condition, thereby cutting off the starting fuel supplied from the valve 14 for starting the engine under flooded conditions.

In the optional starting circuit shown in Fig. 5, the regulator valve 15 is eliminated, and the auxiliary fuel supply conduit 26 is connected directly to the conduit

In operation: The diaphragm 83 and cam 80, in Fig. 2, are in position for providing the maximum fuel output from the fuel injection pump 10. The roller 97 is in contact with the cam surface 92 of the cam 80 at a point corresponding to the maximum output position. The spring 84 acting against the diaphragm 83 holds the cam 80 in this position until the force of the spring 84 is overcome by a differential in pressure developed across the diaphragm 83.

When the engine is started, the manifold vacuum connected through the conduit 62 and port 61 reduces the pressure within the casing portion 60a and atmospheric pressure tends to force the diaphragm 83 to the left against the action of the spring 84. The diaphragm 83 in turn moves the connecting rod 85 and cam 80 to the left, and the roller 97 takes a position on the cam surface 92 corresponding to a lower output position for the fuel injection pump 10. The distance of travel of the cam 80 and the slope of the cam surface 92 are such that force exerted by the pump 10 does not produce movement of the cam 80. The manifold vacuum is a function of throttle valve opening, and as the pressure within the casing 60a varies with variations in throttle position, the cam 80 moves to the right or to the left in direct relationship to load demand of the engine. The starting and operating conditions just described would correspond to normal warm engine operating conditions.

For cold engine starting, and for engine warm-up conditions, the warm-up enrichment valve 13 functions to modify the manifold vacuum supplied to the interior of the casing 60a. It is desirable that additional fuel or a richer ratio of fuel to air be supplied for starting the cold engine. When the engine is cold, the thermostatic element 171 functions to pull the piston 172 upward, as shown, permitting air from the orifice 168 to bleed through the channel 186, the port 185, the port 66, the conduit 65, and into the casing 60a for modifying or decreasing the manifold vacuum acting on the diaphragm 83. The restriction 70 in the conduit 62 prevents the manifold vacuum in the line 62 from nullifying the air bleed effect from the conduit 65. The lowered differential in pressure across the diaphragm 83 produced by the air bled into the casing 60a causes the cam 80 to take a higher than normal output position. The restriction 70 also prevents the manifold vacuum in the conduit 62 from nullifying the effect of idle adjustment air bled through the orifice 68, conduit 67, and conduit 65 into the interior of 60a.

Manifold vacuum acting through the conduit 193 and the port 192 tends to draw warm air from the manifold stove through the conduit 191 and port 190 into the cavity 173. This warmed air acts on the thermostatic element 171 and tends to warm it so as to reduce the tension or force that lifts the valve piston 172 away from the seat 184. As the thermostatic element 171 is warmed, manifold vacuum supplied through conduit 197 and port 196 acts on the lower end of land 178 of the piston 172, tending to pull it downward so that the flared portion 180 tends to seal against the seat 184, thereby tending to cut off the air bled from the port 185. While the thermostatic element 171 is being warmed and the piston 172 moves downward, the tapered portion 179 gradually decreases the amount of air bled past the seat 184. The configuration of the tapered portion 179 is predetermined so as to decrease the air bled corresponding to engine warm-up, and consequently corresponding to engine fuel requirements during warm-up. In addition, as the piston 172 moves downward during warm-up, the force supplied by manifold vacuum on the land 177 acts through the link 175 and bell crank 174 so as to turn the choke shaft 165 and thereby open the choke valve 162.

The valve piston 172 operates as a function of engine load condition to provide greater enrichment during high

load conditions than at low load conditions. This operation is produced as follows: At low load, the manifold vacuum acting on the lower end of the land 178 is comparatively high. The pressure on the upper side of the land 178 is substantially greater because of the air bled through the orifice 185; therefore, the differential in pressure acting on the land 178 tends to move the piston 172 downward and thereby acts through the link 175, crank 174, and choke shaft 165 so as to open the choke valve 162. During high load conditions, the manifold vacuum acting on the lower end of the land 178 is comparatively low; consequently, the differential in pressure across the land 178 is very low, and the force tending to open the choke valve 162, therefore, is comparatively low. The warm-up enrichment valve 13, therefore, not only modifies the output of the fuel injection pump but also modifies the amount of air being supplied to the engine, thereby further controlling the fuel-air ratio in accordance with engine demand during warm-up.

It should be noted that the switch 230 of the optional starting circuit shown on Fig. 5 is operated by the lever 206 attached to the choke valve shaft 165, which in turn is attached to the thermostatic element 171. The thermostatic element 171, therefore, is also utilized for providing additional starting fuel in addition to the enrichment previously described during warm-up.

It is contemplated that the valve piston 172 may be separated into two separate pistons for performing the same desirable functions as described above. For this purpose, the land 178 should be connected to the choke valve 162 through a suitable linkage so as to tend to open the choke valve with increased differential in pressure across the land 178. The land 177 should carry the tapered portion 179 and be connected to the thermostatic element 171 for performing the air bleed function as previously described.

The output of the fuel injection pump 10 is modified in accordance with atmospheric pressure conditions by the compensating mechanism 82. The connecting rod 110 is adapted to be moved to the right or to the left, as shown on Fig. 2, so that the wedge surface 112 acts against the knuckle 109 and arm 106 for moving the cam 80 into a higher output or lower output position with variations in atmospheric pressure. The distance of travel of the rod 110 and the slope of the surface 112 is such that force exerted by the arm 106 does not produce movement in the mechanism 82. The expandable bellows 121 is directly responsive to absolute atmospheric pressure and expands or contracts in direct relation therewith. The amount of power developed by the bellows 121 is relatively small; consequently, the power amplifying means comprising the diaphragms 122 and 123, and the sliding valve mechanism 124 are provided. Manifold vacuum is supplied through the port 71 to the interior of the chambers 140a and 141a. The diaphragms 122 and 123, being of the same size, are in a balanced position when no air is bled into either of the chambers 140a and 141a.

Assuming the atmospheric pressure to decrease, the bellows 121 expands and, in expanding, this motion is transmitted through the lever arm 130 and sliding valve block 133 so as to move the port 152 into communication with the port 155. This communication permits air to be bled through the ports 152 and 155, and channel 153 into the chamber 141a. The differential in pressure across the diaphragm 123 therefore would be substantially decreased; whereas, the differential in pressure across the diaphragm 122 would remain the same. The differential in pressure across the diaphragm 122, therefore would tend to move the connecting rod 110 to the right, which motion would be transmitted through the knuckle 109 and arm 106 for lowering the output position of the cam 80. The fuel output of the injection pump 10, as dictated by the computer mechanism 11, therefore, is decreased so as to provide the proper fuel-

air ratio for operating at a lower atmospheric pressure.

The motion of the connecting rod 110 is also transmitted through the lever arm 127 to the shaft 125 of the bellows 121 for moving it to the left as shown. This motion in turn is transmitted through the lever arm 130 so as to move the valve block 133 to the right and center the port 152 in a non-communicating position between the ports 155 and 156. The bellows 121 and sliding valve block 133, therefore, are repositioned so as to be operative for a subsequent change in atmospheric pressure.

For an increase in atmospheric pressure, the bellows 121 contracts and the valve block 133 moves to the right as shown so as to bleed air through the port 152 and port 156 into the chamber 140a for increasing the pressure therein. The bellows 121 and valve block 133 are repositioned by means of the lever 127 as previously described, for a subsequent change in atmospheric pressure. The compensating mechanism 82 thereby provides means for automatically compensating for changes in atmospheric pressure for meeting engine fuel demands. It is contemplated that the sliding valve mechanism 124 may be replaced by a corresponding rotatable device which would perform the same desirable function.

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

We claim:

1. In a control system for a fuel injection pump adapted to supply fuel to an internal combustion engine having an air intake manifold, the combination of choke valve means adapted to restrict the flow of air into said manifold, vacuum responsive means for controlling the output of said pump, conduit means interconnecting the manifold with said vacuum responsive means for supplying manifold vacuum thereto, means defining a restriction in said conduit for limiting the flow of air there-through, temperature responsive valve means for bleeding air into said vacuum responsive means, and means interconnecting said temperature responsive valve means with said choke valve means and operable thereon for restricting the flow of air into the manifold for thereby providing an optimum fuel-air ratio to the engine during warm-up.

2. In a control mechanism for a fuel injection pump adapted to supply fuel to an internal combustion engine having an air intake manifold, the combination of a vacuum responsive motor for controlling the output of the pump; conduit means for interconnecting said manifold with said vacuum responsive motor for supplying manifold vacuum thereto; and air bleed means for supplying a limited amount of air to said motor for modifying the effect of the manifold vacuum acting thereon, said last named means including a valve piston having a tapered portion adapted to restrict the flow of air through said bleed means, and temperature responsive means attached to one end of said valve piston for moving it longitudinally and thereby progressively decreasing the amount of air bled through said valve with increasing temperature.

3. In a control mechanism for a fuel injection pump adapted to supply fuel to an internal combustion engine having an air intake manifold, the combination of a vacuum responsive motor for controlling the output of the pump; conduit means for interconnecting said manifold with said vacuum responsive motor for supplying manifold vacuum thereto; and air bleed means for supplying a limited amount of air to said motor for modifying the effect of the manifold vacuum acting thereon, said last named means including a valve piston having a tapered portion adapted to restrict the flow of air through said air bleed means and vacuum responsive

means including a land formed on one end of said valve piston and means for supplying manifold vacuum to one end of said land for thereby moving said valve piston longitudinally so as to decrease the amount of air flowing through said air bleed means with increased manifold vacuum.

4. In a control mechanism for a fuel injection pump adapted to supply fuel to an internal combustion engine having an air intake manifold, the combination of a vacuum responsive motor for controlling the output of the pump; conduit means for interconnecting said manifold with said vacuum responsive motor for supplying manifold vacuum thereto; and air bleed means for supplying a limited amount of air to said motor for modifying the effect of the manifold vacuum acting thereon, said last named means including a valve piston having a tapered portion adapted to restrict the flow of air through said bleed means, temperature responsive means attached to said valve piston and adapted to move it longitudinally so as to decrease gradually the amount of air flowing through said valve with increasing temperature and vacuum responsive means including a land formed on one end of said valve piston and means for supplying manifold vacuum thereto for moving said valve piston in opposition to said temperature responsive means for thereby reducing the amount of air bled through said valve means with increased manifold vacuum.

5. In a control system for a fuel injection pump adapted to supply fuel to an internal combustion engine having an air intake manifold, the combination of a choke valve adapted to restrict the amount of air flowing into the manifold; a manifold vacuum responsive motor adapted to control the fuel output of the pump; and an air bleed valve mechanism adapted to supply a limited amount of air to said vacuum responsive motor for modifying the output of said pump, said valve mechanism comprising a longitudinally movable valve piston having a land and a tapered portion for restricting the air bled through said valve, means for interconnecting said valve piston with said choke valve, temperature responsive means connected to said piston and adapted to increase the amount of air flow through said valve mechanism, and means for supplying manifold vacuum to said valve piston so as to act on said land for moving said piston in opposition to said temperature responsive means for restricting the amount of air bled through said valve and increasing the air flow through said choke valve.

6. In a control mechanism for fuel injection pump adapted to supply fuel to an internal combustion engine having an air intake manifold in which the pressure varies with load conditions, the combination of a choke valve adapted to restrict the flow of air into the manifold; manifold vacuum responsive means for controlling the fuel output of the pump; and air bleed valve means for supplying a limited amount of air to said vacuum responsive means for modifying the output of said pump, said last named means including a valve piston having a tapered portion and a land portion, means interconnecting said valve piston with said choke valve, and means for supplying manifold vacuum to said valve for acting on said land and thereby move said valve piston into an air flow restrictive position for thereby controlling the amount of air bled to said vacuum responsive means and also controlling the amount of air flowing past said choke valve, for thereby providing an optimum fuel air ratio in accordance with load conditions of the engine.

7. In a control mechanism for a fuel injection pump adapted to supply fuel to an internal combustion engine having an air intake manifold, the combination of manifold vacuum responsive means for controlling the output of said pump; air bleed valve means for modifying the effect of said vacuum responsive means; thermostatic means adapted to control the amount of air bleed through said valve means; and auxiliary fuel supply means for

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supplying additional fuel for starting the engine, said last named means including an electrical starting circuit, a solenoid-operated valve interconnected with said circuit, and switch means also interconnected with said circuit and operated by said thermostatic means for rendering said solenoid valve means inoperative above a predetermined temperature.

8. In a control mechanism for a fuel injection pump adapted to supply fuel to an internal combustion engine having an air intake manifold, the combination of a choke valve means adapted to restrict the flow of air into the manifold; a manifold vacuum responsive motor for controlling the output of said pump; air bleed valve means for bleeding a limited amount of air into said vacuum responsive motor for modifying the output of said pump; and thermostatic means operable to control the amount of air bled through said valve and also operable to progressively open said choke valve with increasing temperature for thereby providing an optimum fuel-air ratio to the engine.

9. In a control mechanism for a fuel injection pump adapted to supply fuel to an engine having an air intake manifold, the combination of a choke valve adapted to restrict the flow of air into the manifold; thermostatic means connected to said choke valve for progressively opening said valve with increasing temperature; and auxiliary fuel supply means adapted to supply additional starting fuel into said manifold, said last named means including electrically operated valve means and switch means adapted to render said electrically operated valve means inoperative above a predetermined opening of said choke valve.

10. In a control mechanism for a fuel injection pump adapted to supply fuel to an engine having an air intake manifold and having an electrical starting circuit, the combination of manifold vacuum responsive means for controlling the output of the pump; air bleed means for modifying the effect of said vacuum responsive means; and auxiliary fuel supply means for supplying fuel in addition to the output of the pump, said last named means including solenoid-operated valve means interconnected with the engine starting circuit and temperature responsive means for regulating the amount of additional starting fuel in accordance with engine temperature.

11. In a control mechanism for a fuel injection pump adapted to supply fuel to an engine having an air intake manifold, the combination of a manifold vacuum responsive diaphragm, a cam movable in two directions and connected to said diaphragm, means for interconnecting said cam with the pump for controlling the output thereof in accordance with the position of said cam, a first lever mechanism for positioning said cam, a second lever mechanism for also positioning said cam, and pressure responsive means interconnected with said second lever mechanism for modifying the position of said cam in accordance with pressure changes.

12. In a control mechanism for a fuel injection pump, the combination of a vacuum responsive motor; a cam movable in two directions and connected to said vacuum responsive motor, said cam being formed with a cam surface and two pivot points; a cam follower in contact with said cam surface and connected to the pump for controlling the output thereof; a first guide arm in contact with one of said pivot points for positioning said cam; adjustable means for determining the position of said guide arm; a second guide arm in contact with said second pivot point for further positioning said cam; and atmospheric pressure responsive means connected to said second guide arm for adjusting the position thereof in accordance with variations in atmospheric pressure.

13. In a control mechanism for a fuel injection pump, the combination of a movable cam for controlling the output of the pump; a vacuum responsive diaphragm for moving said cam; and atmospheric pressure responsive means for further moving said cam, said last named means

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including an expansible bellows responsive to atmospheric pressure, vacuum responsive means interconnected with said cam, valve means for bleeding air into said vacuum responsive means, means for interconnecting said valve means with said bellows, and repositioning means for interconnecting said vacuum responsive means with said bellows.

14. In a control mechanism for a fuel injection pump for an internal combustion engine having an air intake manifold, the combination of a movable cam for controlling the output of the pump; a manifold vacuum responsive motor for moving said cam; and atmospheric pressure responsive means for further moving said cam, said last named means including an atmospheric pressure responsive device, power amplifying means interconnecting said atmospheric pressure responsive device with said cam, and repositioning means interconnecting said power amplifying means with said atmospheric pressure responsive device so as to position it for a subsequent change in atmospheric pressure.

15. In a control mechanism for compensating for changes in atmospheric pressure, the combination of an output shaft, power amplifying means for moving said shaft, movable control means for controlling said power amplifying means, atmospheric pressure responsive means for operating said control means, and repositioning means interconnecting said output shaft with said pressure responsive means.

16. In a control mechanism for compensating for changes in atmospheric pressure, the combination of an output shaft, power amplifying means including two vacuum responsive diaphragms connected to and adapted to move said shaft, movable valve means for bleeding air to one or the other of said vacuum responsive diaphragms, an expansible bellows for moving said valve, and repositioning means connecting said bellows with said output shaft for repositioning said bellows and rendering it operative for a subsequent change in atmospheric pressure.

17. In a control mechanism for a fuel injection pump adapted to supply fuel to an engine having an air-intake manifold and having an electrical starting circuit, the combination of a throttle valve for restricting the flow of air into the manifold; manifold vacuum responsive means for controlling the output of the pump; and auxiliary fuel supply means for supplying fuel in addition to the output of the pump, said last-named means including an electrically operated valve interconnected with the engine starting circuit for supplying additional starting fuel, and electrical switch means interconnected with said throttle for rendering said valve inoperative when said throttle valve is substantially wide open.

18. In a control mechanism for a fuel injection pump adapted to supply fuel to an engine having an air-intake manifold and having an electrical starting circuit, the combination of a throttle valve adapted to restrict the flow of air into the manifold; means responsive to manifold vacuum for controlling the output of the pump; and auxiliary fuel supply means for supplying fuel in addition to the output of the pump, said last-named means including an electrically operated valve interconnected with the engine starting circuit for delivering starting fuel into the manifold while the engine is being started, first switch means for rendering said valve inoperative above some predetermined temperature, temperature responsive means for actuating said switch, and second switch means interconnected with said throttle and operable to render said valve inoperative for substantially wide open throttle condition.

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