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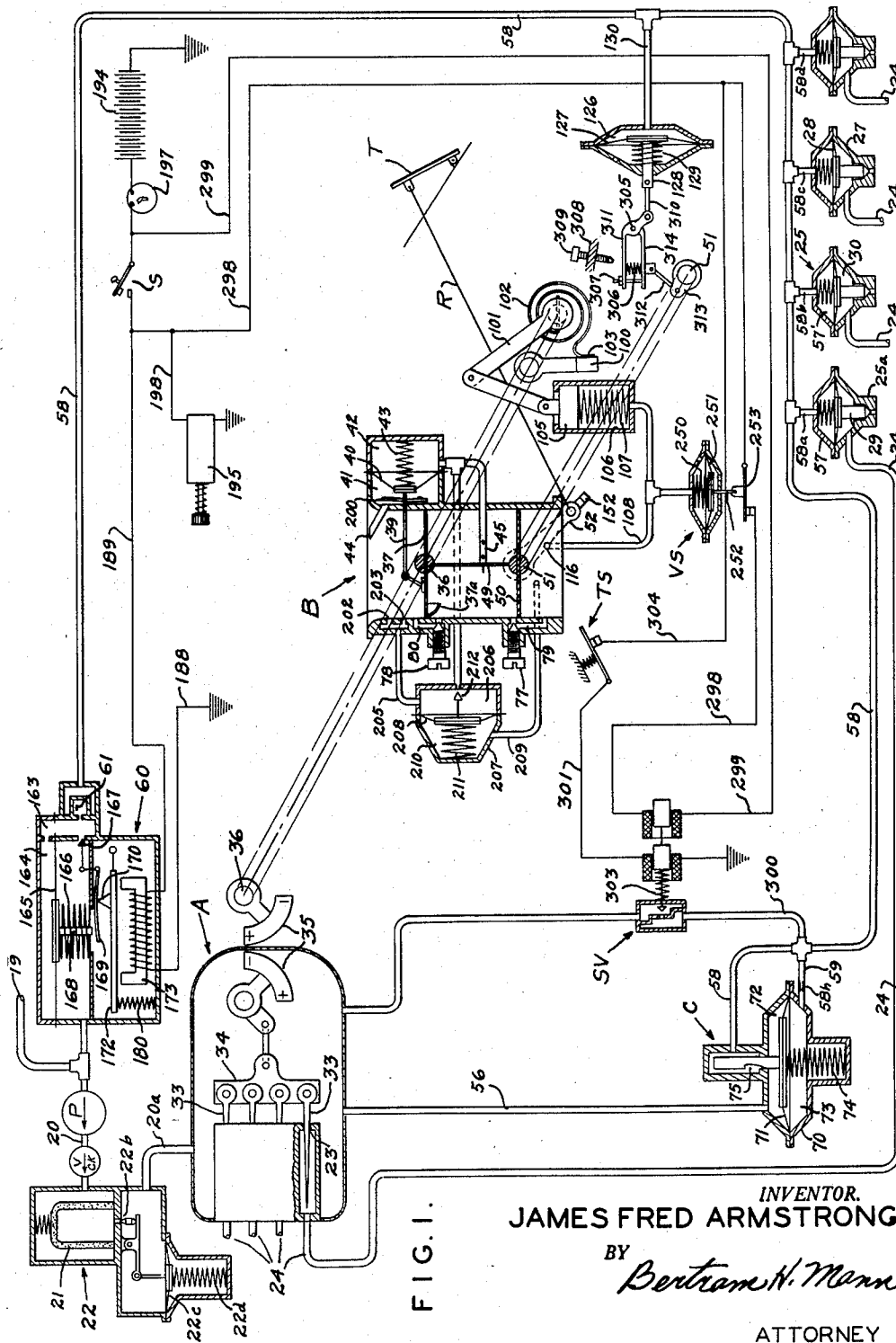
J. F. ARMSTRONG

2,915,053

FUEL INJECTION SYSTEM

Filed May 24, 1957

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

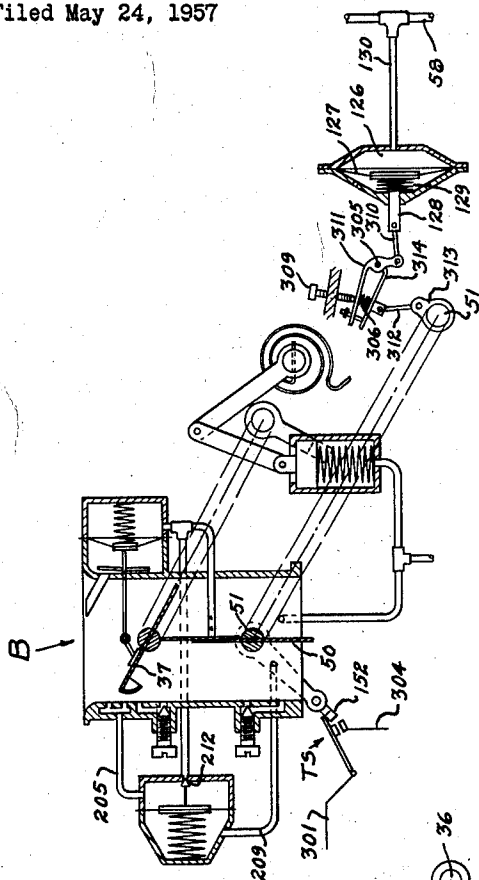
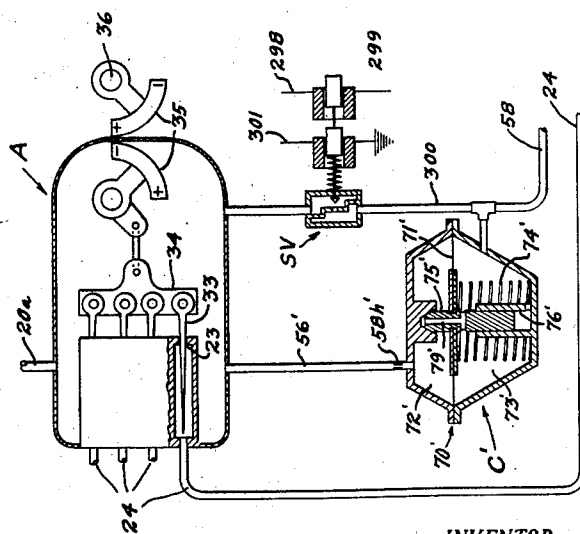


FIG. 2.

FIG. 3.



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2,915,053

FUEL INJECTION SYSTEM

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Application May 24, 1957, Serial No. 661,381

18 Claims. (Cl. 123-119)

This invention is an engine fuel charging device operating as a continuous flow system and adapted for intake port injection, in which system the fuel is pressurized, measured under pressure in accordance with engine requirements, and distributed under pressure to points adjacent the intake valves of the several cylinders or combustion chambers of the engine.

This application shows an improvement applicable to the basic system shown in the prior patent to James Fred Armstrong, No. 2,785,669, dated March 19, 1957, and entitled "Injection Carburetion." A more complete understanding of the invention herein disclosed will be had by reference to other prior applications of James Fred Armstrong, Serial No. 632,798 filed January 7, 1957, for "Fuel Injection System," and Serial No. 646,063 filed March 14, 1957, for "Fuel Injection System."

The improvement herein disclosed may be applied to any of these prior inventions, as well as others which function on similar principles.

This description will be limited to an explanation of modifications in the basic systems above referred to. For example, in the Armstrong application Serial No. 632,798 filed January 7, 1957, for "Fuel Injection Systems," is described a means for stabilizing the datum pressure by a by-pass device for bleeding the datum line rapidly of fuel in response to a pressure increase in the datum system with respect to the pressure in the charging system. It was recognized that, in the basic patented system, an increase in fuel flow through the nozzles resulted in a movement of the nozzle diaphragms to open the nozzle valves, and that this diaphragm movement in response to increases in metered fuel flow caused a slight increase in pressure in the datum system exceeding normal regulated pressure which retarded valve response. In other words, there was a lag in nozzle valve operation which occurred as a result of increases in the metered flow of fuel to the nozzles.

One solution to this problem was to bleed off through a by-pass sufficient fuel to maintain the datum pressure constant. Another solution is to accommodate the fuel displaced into the datum system by movement of the nozzle diaphragms by temporarily enlarging the capacity of the datum system.

According to this invention, the datum system is provided with a variable capacity chamber, the volume of which is increased in anticipation of engine operating events which will result in a need for rapid increase in flow from the fuel nozzles.

According to this invention, variation in capacity of the datum system may increase simultaneously with the increase in rate of fuel flow to the nozzles, or may precede this event so as to result in a mixture enrichment.

According to this invention, variation in datum system capacity may occur simultaneously with or precede decreases in the rate of fuel flow to the engine to increase the datum pressure, and therefore result in a leaning out of the mixture simultaneous with or preceding and anticipating reduction in fuel flow to the engine.

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According to this invention, the capacity of the datum system is changed by throttle movement either through a portion of or throughout the total range of movement thereof.

The accompanying drawings are illustrative of a system with modifications which will carry out all of the objects of the invention.

In the drawings:

Fig. 1 is a schematic representation showing the interconnection of the elements of the system.

Fig. 2 is an operational view of some of the elements shown in Fig. 1.

Fig. 3 is a schematic representation of a modified form of regulator illustrated in Fig. 1.

In the detailed description of the invention which follows, the same reference characters will be used, where possible, to indicate the elements in this system corresponding with those in my prior identified applications and patent.

Engine charging fuel system

In Fig. 1 the fuel supply line 19 from the fuel tank connects with the inlet of the pump P. The outlet of the pump P connects by way of line 20 through a check valve with the pressure regulator 22. Within the pressure regulator is a diaphragm 22c acted upon by the pressure of the fuel passing the valve 22b controlled by the diaphragm. The spring 22d acts upon the rear face of the diaphragm 22c in a direction to open the valve 22b. The casing enclosing the spring 22d is generally vented to atmospheric pressure. A filter 21 is enclosed within the pressure regulator 22 to trap foreign matter passing through to the pressure regulator from the pump and the check valve.

Fuel chamber A is supplied from the pump P through the pressure regulator 22 by way of a line 20a. Within the fuel chamber A are a plurality of metering rods 33 operated within metering orifices 23 by a crosshead device 34. The position of the rods 33 is, in turn, controlled by a magnetic clutch 35 from a shaft 36 operated by an air valve in the air induction system of the engine hereinafter described.

Each metering orifice 23 is connected by a separate line 24 with a fuel nozzle 25. There are usually as many fuel nozzles as there are cylinders of the engine, but only four have been shown here.

Each nozzle 25 has a stem portion 25a which may be fixed within the cylinder head or induction manifold for the engine, so as to discharge fuel adjacent an intake valve of an individual cylinder of the engine (not shown). Within the stem 25a is a valve element 29 controlling the outlet port of the nozzle, and this valve element 29 is, in turn, controlled by a diaphragm 28.

The lines 24, one of which is shown, connect with chambers 30 formed by the diaphragm 28 and the outer housing for the nozzle 27. A cap 57 secures the diaphragm in place and forms a second chamber 57' on the opposite side of the diaphragm 28 to which the datum pressure control line is connected.

The datum pressure system

The datum pressure system connects with each of the chambers 57' of the nozzles 25, and the fuel pressure therein is established by the action of two pressure regulators controlling the inlet and the outlet therefrom, and, incidentally, the pressure drop across a discharge restriction from the datum pressure system to the inlet of the pump P. Fuel pressure is supplied to the datum system from the chamber A by way of a line 56 to pressure regulator C. This regulator comprises a casing 70 containing a diaphragm 71 dividing the casing into a pair of chambers 72 and 73. A spring 74 acts in a

direction on the diaphragm 71 tending to close the valve 75 which is operated from the diaphragm. Referring back to my prior applications, the valve 75 forms a variable restriction for charging the datum system and corresponds in function to metering rod 87. Datum pressure line 58 is supplied with fuel under pressure from line 56 when valve 75 is open, and has a connection 59 with chamber 73 of the pressure regulator C. Line 58 extends to the datum pressure chamber of each of the nozzles 25 by way of the series of branches 58a, 58b, 58c and 58d. At the outlet of the datum pressure line 58 is a metering restriction 61 in the form of a centrifugal jet or orifice.

Downstream of the orifice 61 is the pressure regulator 60 which has a chamber 164 therein formed by a diaphragm 165. A passage 163 connects chamber 164 with the metering restriction 61. Diaphragm 165 has a plunger 168 operating against a lever 169 which, in turn, controls the degree of opening of valve 167. Spring 166 resists the pressure of fuel in the chamber 164 on the diaphragm 165.

The lower portion of the casing of pressure regulator 60 has a pivoted lever 172 forced upwardly by the compression spring 180, which applies a force by way of the pivot 170 to the lever 169.

Air induction system for the engine

The engine (not shown) is provided with an air induction system having an air horn B communicating with a plurality of branches which lead to the separate combustion chambers of the engine. These separate branches are not shown because the parts of the air induction system are conventional.

Air flow metering

The air metering or measuring part of this system, indicated as B in Fig. 1, may be placed anywhere near the engine and connected with the inlet of the engine intake manifold, which has several branches (not shown) leading to the separate intake ports of the engine. This air measuring or metering part, termed the air horn, has a tubular body constructed for connection at its lower or outlet end to the intake manifold of the engine. The outlet of the air horn is controlled by a suitable throttle 50 mounted on a throttle shaft 51, and controlled by a throttle arm 52 actuated by a linkage R from the throttle pedal T.

Above the throttle is a balanced air valve 37 mounted on a suitable shaft 36 journaled in the walls of the air horn B. On the lower leading edge of the air valve 37 is a deflector 37a which produces an aerodynamic unbalance tending to close the valve at openings above 55°. The valve 37 is moved in the opening direction by a servo-motor which has a diaphragm 40 operating against a calibrated spring 43 and a connection 39 with the air valve 37. The servo-motor is powered by the pressure drop across the air valve 37 as sensed by two Pitot tubes 44 and 45 upstream and downstream of the air valve 37, respectively. A slotted baffle 49 extends between the air valve shaft 36 and the throttle shaft 51 in a manner to eliminate aerodynamic interference of the flow around the throttle 50 with displacements of the air valve 37.

A by-pass 79 extends around the edge of the throttle 50 when in the closed position, and has a needle valve 77 for adjusting the by-passed air to control the idle speed of the engine.

A by-pass 80 extends around the edge of the air valve and has a metering screw 78 for adjusting the amount of air by-passing the air valve 37 in the idle range of displacements of this valve so as to adjust the mixture ratio at idle.

The air valve 37 is displaced by the power operated servo-motor so that it takes up an angular position indicating the rate of air flow past the throttle 50 to the

engine. Shaft 36, upon which it is mounted, is in turn connected to the fuel metering part A by means of a magnetic clutch 35 to control the displacement of a plurality of tapered fuel metering rods which are calibrated to flow fuel at a rate to give the full throttle power mixture throughout the range of angular displacement of the air measuring valve 37.

To get a part throttle economy mixture, the response of air valve 37 to air flow is modified to produce a decrease in angular displacement of the air valve 37 for the same rate of air flow as at full throttle. The metering rod displacement likewise is affected, and the rate of fuel delivery is reduced to give an economy mixture for road load operation of the engine.

Part throttle mixture

Air valve response is modified for the above purpose by an air bleed connection 205 in the air horn B which connects the plurality of ports 202 and 203 above the air valve 37 to the suction side 42 of the servo-motor. In this connection is a diaphragm operated valve 212 which is held open against the closing force of the spring 211 by suction connection 209 extending posterior of the throttle valve 50. When the throttle is open far enough so that manifold depression is less than six inches Hg, for example, valve 212 is closed by the spring 211 against the force of suction acting on the diaphragm 208, thus cutting off the air bleed 205 from communication with the suction side 42 of the servo-motor. The response of the air valve 37 is thus changed to increase its opening and the displacement of the fuel metering rods to increase the fuel delivery rate to a full rich mixture.

If, on the other hand, engine speed increases in the part throttle range of engine operation, angular air valve displacement is decreased for the same rate of air flow, giving a lesser displacement to the metering rods 33 so as to lean out the mixture for part throttle operation. As engine speed increases, however, angular air valve displacements will also increase as a result of increasing air flow, so that the edge of the air valve 37 and deflector 37a swings over the ports 202 and 203. This places the ports 202 and 203 in a zone of decreasing air pressure due to high velocity flow to reduce the effectiveness of the air bleed on the action of the servo-motor. Air valve response is accordingly modified to increase air valve opening and, consequently, the rate of fuel flow to the engine, giving a richer mixture at higher engine speeds to eliminate the possibility of part throttle detonation.

Starting mixture enrichment

At low engine temperatures, fuel flow should be increased for starting and engine warm-up. This result is accomplished in the instant device by modification of the response of the air valve 37 instead of by direct connection with the fuel metering rods 33 which is, of course, possible. As illustrated schematically herein, the air horn B mounts a thermostatic spring 102 concentric with respect to one end of the air valve shaft 36. One end of the spring 102 is held fast in a slot in a pivoted lever 101, which in turn is angularly movable by a suction operated piston 105 in a cylinder 106 against the force of a calibrated spring 107. Suction is communicated to the cylinder 106 through a line 103 communicating with the manifold downstream of the throttle 50. The free end of the thermostat 102, indicated as 103, abuts a lever 100 fast on one end of the shaft 36, and, as the engine cools, the thermostat 102 winds up, exerting a force in a clockwise direction on the lever 100 to urge the valve 37 toward an open position. The force of the thermostat depends upon the temperature, but at temperatures below those encountered in normal operation of the engine this force either actually opens the air valve 37 or decreases the force necessary to open the valve, so that the servo-motor produces a greater degree of valve opening and metering

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rod movement for increasing the fuel flow to the engine during cranking. As soon as the engine starts, suction rotates the arm 101 to decrease this opening force exerted by the thermostat spring 102 on the arm 100. Less air valve and metering valve displacements will occur for the same rate of air flow, so that the mixture is leaned out after the engine starts. As engine temperature increases, so does the temperature of the thermostat 102, thus decreasing the force exerted by the spring 102 on the arm 100 until, at normal engine operating temperature, end 103 backs away from the arm 100 entirely.

Fast idle control

The actual structure for producing a fast idle by cracking the throttle 50 at low engine temperatures is shown in a copending application of James Fred Armstrong, Serial No. 622,917, filed November 19, 1956, and entitled "Fuel Injection System." Figs. 25 and 26 of this application illustrate the fast idle control mechanism. The same structure can be used here, although it is not shown, since it forms no part of this invention.

Engine priming circuit

In this system, the mixture ratio furnished may not only be affected by modifying the response of the air valve, as above described, but also by varying the pressure drop across the metering restrictions 23, and since this pressure drop or pressure differential is controlled directly by datum pressure, the mixture ratio can be varied one way or the other, rich to lean, by changes in the datum pressure regulation. Because of this inherent characteristic of the system, it is possible to add to it the many desirable auxiliary features necessary to adapt the system to the needs of the engine.

For example, the particular engine might require a richer mixture during cranking in order to facilitate engine starting. This function can be built into the present system by a control which acts upon datum pressure. The following detailed description is explanatory.

The usual starter and ignition circuit for the engine includes the battery 194 connected at one terminal to ground, and at the other terminal to the ignition key switch 197, which switch, when closed, energizes a circuit to the starter switch S, which is connected, in turn, by a lead 198 with the starter motor 195. Connected with the lead 198 is a second lead 189 extending to the winding on solenoid 173 in the pressure regulator 60 and to ground through the lead 188.

Operation of priming circuit

To crank the engine, both the ignition switch 197 and the starter switch S are closed, so as to complete the circuit to the engine starter motor 195. This circuit, in turn, energizes the circuit through the solenoid 173 by way of the leads 189 and 188, energizing the solenoid 173 and producing a magnetic force attracting the armature 172. The force of the solenoid 173 tends to open the valve 167 against the force of spring 166, and thus change the minimum pressure setting of the pressure regulator 60, so as to lower the pressure downstream of the metering orifice 61 and increase the flow through the datum system 58. This brings into operation the effect of the metering restriction 58H to restrict the fuel flow in the datum system upstream of the metering restriction 61. The increase in flow through the datum system creates a pressure drop between the restriction 58H and the metering restriction 61, thus lowering the datum pressure acting on each of the nozzle diaphragms of the nozzles 25. When the datum pressure is lowered, the pressure downstream of the metering restrictions 23 is likewise lowered, increasing the pressure drop and the fuel flow past the metering rods 33 to the nozzles at any particular position of the rods 33. This priming function is accomplished only when both the ignition switch and the starter switch are closed.

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Ignition switch fuel cut-off circuit

In this system, the datum circuit forms a remote control for the discharge from the nozzles. When the pressures between the charging system and datum system are equalized, the fuel discharge from the nozzles is effectively cut off. One manner contemplated for utilizing this inherent feature is illustrated in Fig. 1.

In this particular embodiment, datum line 58 is directly connected with the fuel chamber A by a pressure equalizing line 300. Communication through the line 300 is in turn controlled by a solenoid operated valve SV, which is spring-biased to an open position and closed by energization from either of two electric circuits connected with separate windings in the solenoid valve SV.

The first of these circuits comprises a line 299 connected with the ignition switch 197 and extending to one of the solenoid windings of the switch SV. The lead 298 connects the same winding to the opposite side of the starter switch S. In this circuit is a vacuum operated switch VS, which is held closed by spring pressure from the spring 250 under normal engine operating conditions.

Operation of ignition switch controlled fuel cut-off

In the following discussion of the operation of the above-described circuit, the function of the vacuum operated switch VS will be ignored.

The ignition switch 197 controls the energization of the lead 299, which in turn, when closed, furnishes the necessary current to one of the windings in the solenoid valve SV to close the valve against the resistance of the spring 303, which tends to maintain the valve open. If the starter switch is open, as would be the case when the engine is running, then this circuit is grounded through the starter motor 195 by way of the leads 298 and 198. With the ignition switch 197 closed, therefore, solenoid operated valve SV is energized and closed by the circuit grounding through the starter motor, as described, and the pressure equalizing passage 300 is inoperative. It will be understood that the current flowing through this circuit is necessarily very small, due to the resistance of the solenoid winding, so that it has no effect upon the operation of the starter motor 195. It requires a much greater amperage to operate the starter motor 195 than it does to operate the small solenoid operated valve SV.

When the ignition switch 197 is open, however, the circuit through the leads 299 and 298 is de-energized, allowing spring 303 to open the solenoid operated valve SV. This equalizes the pressure between the fuel chamber A and the datum line 58, so that each of the valves in the fuel nozzles 25 closes and discharge of fuel immediately ceases.

Conversely, when the ignition switch 197 is turned on, valve SV closes.

Operation of deceleration fuel cut-off

In the circuit above described is a switch VS operated in response to a negative load on the engine for opening the circuit 299—298. Preferably, the switch VS has a diaphragm 251 connected through a rod 252 to the switch. The diaphragm 251 is subject to atmospheric pressure on one side, tending to open the switch, and to manifold pressure on its opposite side through the line 108. A spring 250 may be calibrated so that the switch 253 remains closed until manifold suction exceeds the normal range of variations encountered in operating the engine under its own power. In other words, switch 253 remains closed until manifold suction exceeds 21 or 22 inches Hg. When this occurs, the force of spring 250 is overcome, opening the switch 212 and de-energizing the circuit 299 and 298 to the solenoid operated valve SV. Spring 303 opens the valve, equalizing the pressure between the chamber A and the datum line 58, so that fuel discharge from the nozzles 25 is effectively cut off.

Unloading

If, for any reason, the starting mixture is too rich so that the engine will not fire during cranking, it is necessary to provide for some means to unload the engine of fuel. Under these circumstances, continued delivery of fuel from the fuel nozzles 25 is not desirable. Here, again, datum pressure regulation forms a convenient manner for remote control of the discharge from the fuel nozzles 25.

When the ignition switch 197 and starter switch S are closed, the circuit 299 and 298 is short-circuited, so that it becomes inoperative and the current flows directly from the switch S to the starter motor 195 through the line 198.

The unloading circuit connects with the line 198, which is energized under these conditions, through lines 298 and 304 to the switch TS, and from thence through the line 301 through a second winding on the solenoid valve SV to ground. Thus, normally, the valve SV is maintained closed, even though the circuit 298—299 is inoperative.

Operation of unloader

With both ignition switch 197 and starter switch S closed, the engine is cranked due to the energization of the starter motor 195. As above explained, circuit 183 and 189 is also energized at this time to effect priming by lowering the datum pressure in the line 58. The circuit 198, 298, 304 and 301 through the second winding on the solenoid valve SV is likewise energized, maintaining the pressure equalizing passage closed, so that the priming system remains in operation until the throttle is opened wide. This movement of the throttle engages the lug 152 on the throttle arm 52 with the throttle operated switch TS, which opens the circuit between line 304, which is energized, and line 301, which extends to the winding on the valve SV. Spring 303 then opens pressure equalizing passage 300, and the pressure in the charging and datum circuits becomes equalized, closing the nozzle valves 25 to shut off the discharge of fuel to the engine.

As above explained, the starter switch S short-circuits the electric circuit through the lines 298 and 299, so that there is no closing force exerted against the spring 303, and the valve remains open while the throttle is held wide open and the starter switch remains closed.

Fuel mixture control regulation for acceleration

In order to obtain solid throttle response in most engines, it is necessary to increase the fuel-air ratio fed to the engine simultaneously with throttle opening, or at least prevent the occurrence of a lean mixture condition. In other words, the pressure carburetor or injection system should perform the function of maintaining or enriching the fuel-air ratio simultaneously with throttle opening to accomplish the result performed in the carburetor by the accelerating pump. One way of accomplishing this particular result is disclosed in my prior applications, wherein manifold suction changes are used to trigger the response of the air valve 37 and cause it to over-travel in an opening direction. This air valve opening increases the metering area of the jets 23, and therefore the flow through the lines 24 and, of course, from the nozzle valves 25. However, when fuel flow increases through the jets 23 in the lines 24, fuel is displaced into the datum system by movement of the diaphragms 28 as the nozzle valves 25 open. Operation of the diaphragms 28 in response to opening movement of the needles cannot occur until the fuel displaced is discharged through the metering restriction 61. This cannot occur instantly. Consequently, this restriction is responsible for certain lag in performance from the time that the needles are moved open to the time the fuel is delivered to the engine.

In prior devices, a separate by-pass bleed was provided from the datum system to a point downstream of the

metering restriction 61 to accommodate the fuel displaced by the diaphragms 28.

In this system, throttle movement creates an increase in capacity of the datum system at a rate equal to or greater than the rate of decrease in capacity caused by movement of the diaphragms 28.

Connected with the datum line 58 by the line 130 is an expansible chamber 126 provided with a flexible wall 127. Contacting the flexible wall 127 are a plunger 128 and a spring 129. A link 310 connects plunger 128 with a pivoted lever 311 operated from the throttle shaft 51 by a link 312 interconnecting levers 313 and 314. The pivot 305 forms a common hinge point for both the levers 311 and 314. Between the levers is a compression spring 306, and an adjustable clamping screw and nut 307 is provided adjacent the spring to limit the distance between the two levers 311 and 314. A fixed abutment 308 carries a screw 309 positioned to contact with the lever 311 and limit its travel in response to throttle opening.

Operation of fuel mixture control regulation for acceleration

Fig. 2 is an operational view illustrating the approximate relation between the parts during full throttle acceleration from low speed. Full throttle operation of the engine causes valve 212 to close, cutting off the part throttle bleed through the lines 205 and 209. This will cause the air valve 37 to assume a position displaced a substantial amount from idle position (from about 10 or 12 degrees to 30 degrees or more) so as to withdraw the needles 33 and increase the fuel flow through each of the lines 24 to the nozzles 25.

Operation of the throttle 51 to the wide open position rotates levers 313 and moves link 312 and lever 314 into the position shown in Fig. 2. When lever 314 is moved in this manner, spring 306 lifts lever 311 around pivot 305 until contact is made between the lever 311 and the stop 309. This movement withdraws plunger 128 and allows the movable wall 127 to compress spring 129 an amount which is adjustable by the stop 309. The capacity of the datum system is increased by creating a flow into the chamber 126 at a rate equal to or greater than the rate of decrease in displacement caused by movement of the diaphragms 28. The rate depends upon the calibration of spring 129. The response of the regulator C is limited by restriction 58H in the line 59. This permits the change in capacity produced by the movable wall 127 to maintain the datum pressure constant or decrease the datum pressure, whichever is desirable, with increases in the rate of flow to the nozzles 25 due to increase in air flow to the engine.

The adjustable stop 309 normally limits the action of the diaphragm to an initial range of throttle openings which correspond approximately with operation of the engine in the part throttle range of mixture ratios.

When the throttle is closed, the reverse action will take place. Datum pressure will remain constant or will be temporarily increased due to decrease in the capacity of the chamber 126 as the throttle closes, maintaining constant or decreasing the pressure drop across the metering restrictions 23, and consequently the rate of fuel flow from the nozzles 25.

Fig. 3 illustrates a portion of the same system as illustrated in Fig. 1. In this partial schematic view of the system is illustrated a modified form of the pressure regulator C indicated as C'.

The regulator C' has a casing 70' containing a chamber 72' supplied with fuel from the chamber A by way of a line 56' containing a restriction 58H'. Corresponding parts in this pressure regulator are indicated by the same reference characters with a prime. Within the casing 70' is a flexible diaphragm 71' operating a valve 75' on a tapered seat within the chamber 72'. Within the valve 75' is a passage 79' communicating with cham-

ber 73' containing a cylindrical guide 76' for the valve 75'. Surrounding the guide 76' is a spring 74'. Chamber 73' is connected directly with the datum system 58, etc.

Operation of datum regulator

Fuel under charging pressure enters the chamber 72' through the line 56' lifting the valve 75' from its seat, so that the chamber 73' and datum system 58 is charged with fuel until the fuel pressure on the underside of the diaphragm 71' plus spring pressure 74' equals the force of charging pressure acting on the upper side of the diaphragm 71'. The pressure of the spring 74' is so calibrated as to maintain the pressure in the chamber 73' at about 1 to 1½ pounds gauge pressure less than the charging pressure in the chamber 72'. The restriction 58H' in the line 56' functions in the same manner to restrict the flow into the datum line 58 during operation of the diaphragm 127.

A structure has been described which will fulfill all of the objects of the present invention, but it is contemplated that other modifications will occur to those skilled in the art which come within the scope of the appended claims.

I claim:

1. In an engine charge forming device, in combination, an air passage connected with the engine, throttle means controlling the flow of air through said passage, a fuel passage to the engine, a fuel pump supplying said passage, valve means actuated by the force of fuel pressure for controlling the flow of fuel through said fuel passage, means for urging said valve in a direction to decrease the fuel supply through said passage with a force which is normally constant with respect to the first force and independent of the rate of air flow to the engine, and means controlled by said throttle and acting directly on said means urging said valve in a direction to decrease the fuel supply for modifying the force on said valve.

2. In an engine charging device, in combination, an air passage connected with the engine, throttle means in said air passage, a fuel pump, a fuel passage to the engine supplied from said pump, a valve for varying the fuel supply through said passage, means for urging said valve in a direction to increase the fuel supply with a force which increases with an increase in air flow to the engine, means for urging said valve in a direction to decrease the fuel supply to the engine, and a connection between said throttle and one of said means to unbalance the forces acting on said valve in response to throttle movement whereby valve action occurs substantially simultaneously with throttle movement to anticipate changes in air flow to the engine by changing the rate of fuel flow to the engine.

3. In an engine charging device, in combination, an air passage connected with the engine, throttle means in said air passage, a fuel pump, a fuel passage to the engine supplied from said pump, a valve for varying the fuel flow through said passage, means for urging said valve in a direction to increase the fuel flow with a force which increases with an increase in air flow to the engine, means for urging said valve in a direction to decrease the fuel flow to the engine, and a connection between said throttle and said means for urging said valve in a direction to decrease the fuel flow acting to unbalance the forces on said valve in response to throttle movement whereby valve action occurs substantially simultaneously with throttle movement to anticipate changes in air flow to the engine by changing the rate of fuel flow to the engine.

4. In an engine charging device, in combination, an air passage connected with the engine, throttle means in said air passage, a fuel pump, a fuel passage to the engine supplied from said pump, a valve for varying the fuel flow through said passage, means for urging said valve in a direction to increase the fuel flow with a force which increases with an increase in air flow to the engine,

means for urging said valve in a direction to decrease the fuel flow through said passage with a force which is normally constant with respect to the first force under static air flow conditions, and means controlled by said throttle and acting directly on said means urging said valve in a direction to decrease the fuel flow to unbalance the forces acting on said valve in response to throttle movement whereby valve action occurs substantially simultaneously with throttle movement to anticipate changes in air flow to the engine by changing the fuel flow thereto.

5. In an engine charge forming device, in combination, an air passage connected with the engine, throttle means in said air passage, a fuel pump, a fuel passage to the engine supplied from said pump, a valve for varying the fuel flow through said passage, means for urging said valve in a direction to increase the fuel flow with a force which increases with an increase in air flow to the engine, means for urging said valve in a direction to decrease the fuel flow to the engine including a fuel passage connected with said valve and a pressure regulator supplying fuel to said passage at a pressure which is normally constant with respect to pump pressure, and a connection between said throttle and said pressure regulator acting to unbalance the forces on said valve in response to throttle movement whereby valve action occurs substantially simultaneously with throttle movement to anticipate changes in air flow to the engine and corresponding changes in fuel requirements therefor.

6. In an engine charging device, in combination, an air passage connected with the engine, throttle means in said air passage, a fuel pump, a fuel passage to the engine supplied from said pump, a valve for varying the fuel flow through said passage, means for urging said valve in a direction to increase the fuel flow with a force which decreases with a decrease in air flow to the engine, means for constantly urging said valve in a direction to decrease the fuel supply to the engine, and a connection between said throttle and one of said means to unbalance the forces acting on said valve in response to throttle closing, whereby valve action to decrease fuel flow occurs substantially simultaneously with throttle closing to anticipate decreases in air flow to the engine and corresponding decreases in engine fuel requirements.

7. In an engine charge forming device having an air conduit with an air inlet and an air outlet connected with a combustion chamber of the engine, a throttle in said conduit, a fuel chamber, a fuel outlet from said chamber for discharging fuel to the engine combustion chamber, a pump supplying fuel under pressure to said chamber, a regulator having a movable wall controlling a valve at said outlet, a datum pressure system including a bypass extending around said pump, opposed expansible chambers separated by said movable wall and connected with said datum system and said fuel chamber, respectively, whereby said regulator maintains the fuel at said fuel outlet at a pressure proportional to the control pressure in said datum system, means for temporarily varying the capacity of said datum system to increase and decrease the opening of said valve, and a connection between said throttle and said last named means for controlling the action of said valve in response to throttle movement.

8. In an engine charge forming device having an air conduit with an air inlet and an air outlet connected with the combustion chamber of an engine, a throttle in said air conduit, an engine fuel charging circuit supplied with fuel from a pump and discharging from an outlet into the combustion chamber of the engine, a regulator having a movable wall controlling a valve at said outlet, a datum pressure circuit, opposed expansible chambers separated by said movable wall and connected with said datum circuit and said charging circuit, respectively, whereby said regulator maintains the fuel in said charging circuit at a pressure proportional to the control pressure in said datum circuit, the combination therewith of

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means for varying the capacity of said datum pressure circuit, and a connection between said throttle and the last said means tending to open and close said valve in response to throttle movement.

9. In an engine charge forming device having an air conduit with an air inlet and an air outlet connected with a combustion chamber of the engine, a throttle in said conduit, an engine fuel charging circuit supplied with fuel under pump pressure and discharging through an outlet to the engine, a datum pressure circuit, and a valve in said engine charging circuit opened by fluid pressure in said engine charging circuit and closed by fuel pressure in said datum circuit, the combination therewith of means for temporarily affecting the pressure in one of said circuits by changing the capacity thereof, and a connection between said throttle and the last said means.

10. The combination defined in the preceding claim wherein the said connection includes a resilient element.

11. The combination defined in the preceding claim wherein a stop is positioned to limit movement of said connection, whereby said resilient element is compressed by further movement of said throttle.

12. In a charge forming system for an internal combustion engine having a plurality of cylinders, each with an air intake pipe, a fuel system comprising a fuel distributing circuit, means for regulating the total fuel flow and for feeding said fuel under pressure to said fuel circuit, fuel discharge valves in said circuit for discharging fuel into each air intake pipe, each of said valves having its inlet side connected to said fuel distributing circuit and being adapted to continuously discharge fuel therefrom into its associated air intake pipe, valve operating means for each of said valves, each of said valve operating means having one side responsive to the pressure of fuel supplied from said circuit to the inlet side of its associated valve for urging the valve in an opening direction, liquid passage means interconnecting the opposite sides of said valve operating means, pressure regulating means for maintaining a predetermined control fluid pressure in said liquid passage means acting with equal force on each of said valves, a throttle controlled air passage leading to said air intake pipes, and throttle operated means for preventing an increase in the controlled fluid pressure by changing the capacity of said liquid passage means.

13. An engine charge forming device having a system for maintaining the flow of fuel to the engine in one fluid stream proportional to the flow of air to the engine in a separate fluid stream, said device comprising means for measuring the flow of air to the engine, a fuel charging circuit having a fuel inlet, a fuel outlet for discharging fuel to the engine, a pump supplying fuel under pressure to said inlet, a fuel line normally pressurized from said pump connecting said inlet and said outlet, a pressure regulator having a movable wall controlling a valve at said outlet, means for measuring the flow of fuel to said outlet, a connection between said measuring means to maintain the flow through each stream proportional to the other, a datum pressure system including a bypass extending around said pump, opposed expansible chambers separated by said movable wall and connected with said datum system and said fuel line, respectively, whereby said regulator maintains the fuel in said fuel line at a pressure proportional to the pressure in said datum system, an expansible chamber in said datum system for varying the fuel capacity thereof, a manually operated throttle for controlling the rate of flow of air to the engine, and a connection between said throttle and said expansible chamber for increasing the capacity of said datum system during throttle opening.

14. In an engine charge forming device having an air conduit with an air inlet and an air outlet connected with a combustion chamber of the engine, a throttle in said conduit, a fuel chamber, a fuel outlet from said chamber for discharging fuel to the engine combustion

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chamber, a pump supplying fuel under pressure to said chamber, a regulator having a movable wall controlling a valve at said outlet, a datum pressure system, opposed expansible chambers separated by said movable wall and connected with said datum system and said fuel chamber, respectively, whereby said regulator maintains the fuel at said fuel outlet at a pressure proportional to the control pressure in said datum system, means for establishing a controlled pressure in said datum system, and means to maintain the capacity of said datum system constant as said movable wall operates to increase valve opening and fuel flow to the engine.

15. In an engine charge forming device having an air conduit with an air inlet and an air outlet connected with the combustion chamber of the engine, a throttle in said conduit, a fuel chamber, a fuel outlet from said chamber for discharging fuel to the engine combustion chamber, a pump supplying fuel under pressure to said chamber, a regulator having a movable wall controlling a valve at said outlet, a datum pressure system, means for establishing a control pressure in said datum system, opposed expansible chambers separated by said movable wall and connected with said datum system and said fuel chamber, respectively, whereby said regulator maintains the fuel at said fuel outlet at a pressure proportional to the control pressure in said datum system, and means for maintaining the capacity of said datum system substantially constant as said movable wall operates to close said valve to decrease the fuel flow to the combustion chamber of the engine.

16. In an engine charge forming device having an air conduit with an air inlet and an air outlet connected with the combustion chamber of an engine, a throttle in said air conduit, an engine fuel charging circuit supplied with fuel from a pump and discharging from an outlet into the combustion chamber of the engine, a regulator having a movable wall for controlling a valve at said outlet, a datum pressure system, means for charging said datum pressure system with a fluid under controlled pressure, and opposed expansible chambers separated by said movable wall and connected with said datum system and said charging circuit, respectively, whereby said regulator maintains the fuel in said charging circuit at a pressure proportional to the control pressure in said datum system, the combination therewith of means for maintaining the capacity of said datum system substantially constant as said movable wall operates to move said valve to vary the fuel flow from said outlet, and a connection between said last named means and said throttle.

17. In an engine charging device having an air passage connected with the engine, throttle means in said air passage, a fuel inlet, a fuel outlet for discharging fuel to the engine, a pump supplying fuel under pressure to said inlet, a fuel line normally pressurized from said pump connecting said inlet and said outlet, a valve in said outlet, a movable wall controlling said valve, a datum pressure system, opposed expansible chambers separated by said movable wall and connected with said datum system and said fuel line, respectively, whereby said regulator maintains the fuel in said fuel line at a pressure proportional to the control pressure in said datum system, means for establishing a control pressure in said datum system at a fixed differential with respect to pump supply pressure, and means in said fuel line for increasing and decreasing the flow to said outlet valve, the combination therewith of means for varying the capacity of said datum pressure system to produce temporary pressure variations therein, and a connection between said throttle and said last named means.

18. In an engine charging device having an air passage connected with the engine, throttle means in said air passage, a fuel inlet, a fuel outlet discharging fuel to the engine, a pump supplying fuel under pressure to said inlet, a fuel line normally pressurized from said pump connecting said inlet and said outlet, a valve con-

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trolling said outlet, a movable wall for actuating said valve, a datum pressure system, means for controlling the rate of fluid flow into and out of said datum system, opposed expansible chambers separated by said movable wall and connected with said datum system and said fuel line, respectively, whereby said regulator maintains the fuel in said fuel line at a pressure proportional to the control pressure in said datum system, means for establishing a control pressure in said datum system at a fixed differential with respect to said pump supply pressure, and means in said fuel line for regulating the rate of fuel flow therethrough in accordance with air flow

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through said air passage, the combination of means in said datum system for varying the fluid capacity thereof, and means to increase the air flow to the engine adapted to temporarily increase the capacity of said datum pressure system.

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