

May 24, 1960

S. B. BLODGETT
INJECTION SYSTEM

2,937,858

Filed April 11, 1957

2 Sheets-Sheet 1

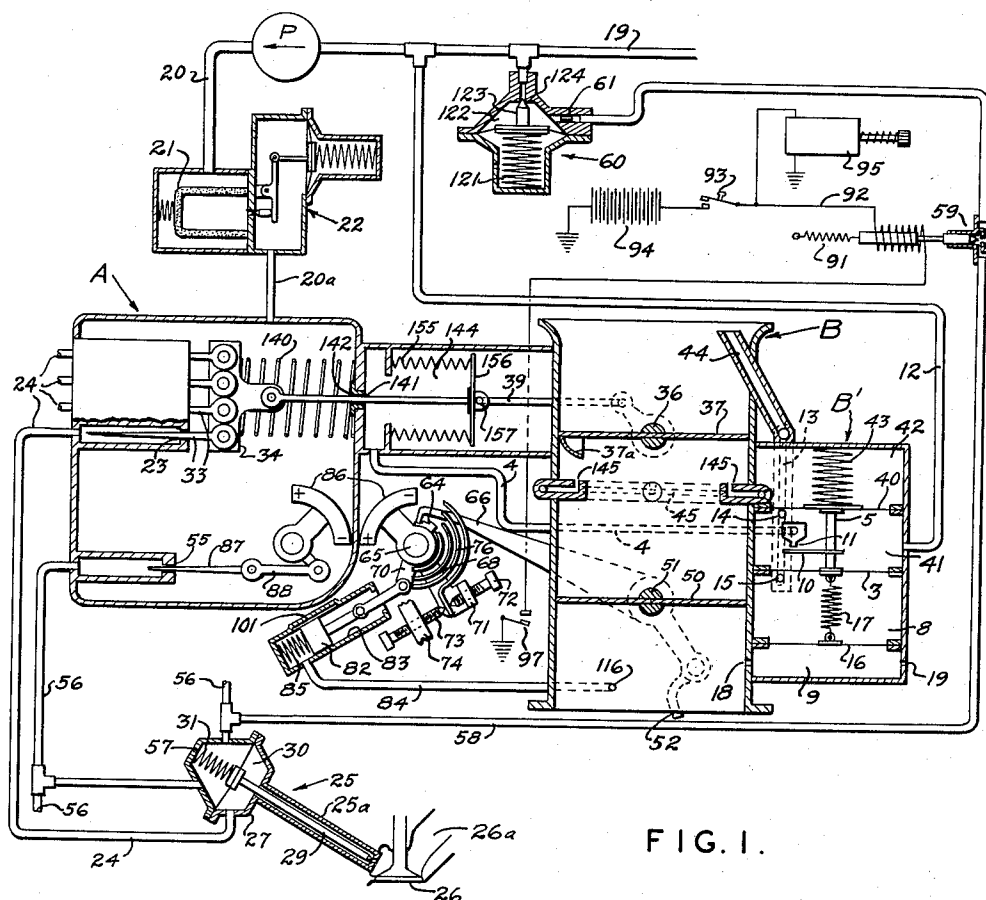


FIG. 1.

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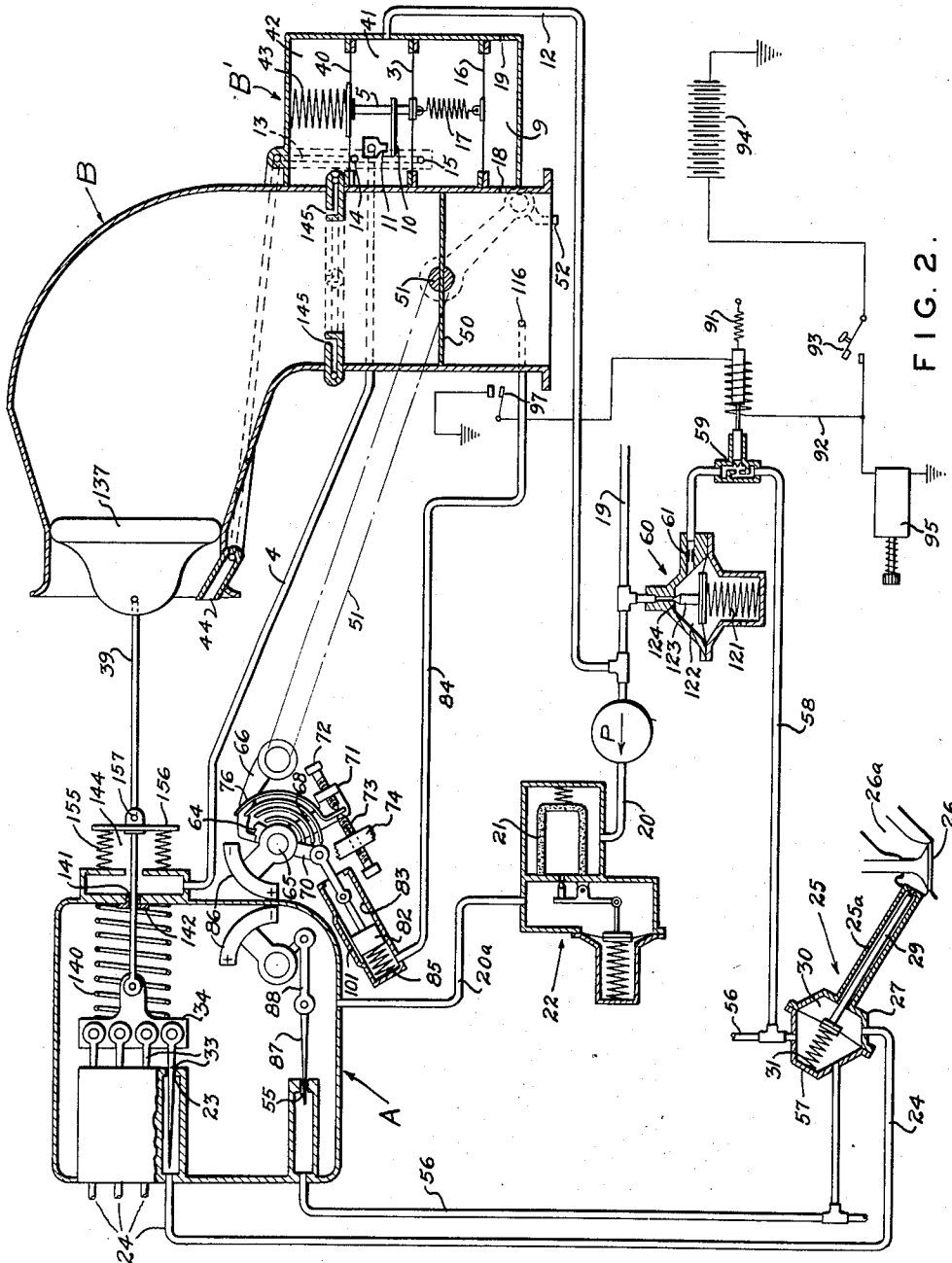


FIG. 2.

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2,937,858

INJECTION SYSTEM

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Filed Apr. 11, 1957, Ser. No. 652,246

21 Claims. (Cl. 261—50)

This invention is an engine charge forming device based upon the continuous flow system for fuel metering in which 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 of the engine. More specifically, in this system fuel flow to the engine is held proportional to air flow to the engine by like simultaneous variations in area of a fuel metering orifice and an air metering orifice, both operating at a constant fluid pressure differential. Such a system is shown in a prior application of James Fred Armstrong, Serial No. 516,358, filed June 30, 1955, entitled, "Injection Carburetion," now Patent No. 2,785,669, issued March 19, 1957.

This application discloses an improvement applicable to the Armstrong system or to others in which air flow to the engine is directly measured to control fuel flow.

This description will be limited to the system as applied to one group of cylinders or combustion chambers, but it is contemplated that the combination described, as well as its various parts or subcombinations of parts, has other applications in the general art of fuel feeding, since the same principles apply whether the fuel is supplied to one group or several groups of cylinders, or to one or more groups of burners.

By way of example, this invention is applied to a system such as shown in the above-identified application, wherein the air for engine charging is manually controlled by a throttle valve, and the sensing means for indicating fuel requirements is responsive, either directly or indirectly, to indicate such variables as throttle position, engine speed, engine load, and engine operating temperature. It should be understood that other indications can be taken, such as atmospheric pressure and temperature, to modify the response of the above described sensing means, or the fuel metering means controlled by the sensing means.

In the prior identified device, a manifold with branches leading to each of the combustion chambers has a single inlet controlled by a manually operated throttle. Above the throttle is a balanced air valve operated by a servo-motor powered by the differential in air pressure above and below the valve to adjust its angular position to maintain a substantially constant pressure drop across the valve of approximately six or seven inches of water pressure. This device constitutes the sensing means measuring the air flow to the engine.

According to this invention, the air valve is powered by a servo-motor operated by fluid pressure derived from the fluid metering part of the device, which pressure is in turn controlled by a pilot valve responsive to the pressure drop in the air stream passing the air valve.

In the prior device, the fuel metering system for the charging device has a fuel chamber connected with a pump for charging the chamber with fuel at a substantially constant pressure. This chamber is connected with a plurality of fuel nozzles in the branches of the intake

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manifold by separate fuel lines which correspond in number with the engine cylinders. The inlets of the separate fuel lines are supplied with fuel at equal pressure from the fuel chamber through separate metering orifices, one for each fuel line. Each metering orifice is variable in area by an individual metering rod supported on a common carrier for moving all of the rods in and out of the metering orifices in unison. Angular movements of the air valve will produce a corresponding longitudinal movement of the metering rods within the metering orifices to simultaneously and equally vary the area of all.

As in the prior system, the outlets of the branch fuel lines from the fuel chamber are each controlled by a diaphragm type of pressure regulating nozzle valve so connected with each branch fuel line that the diaphragm in each valve is subject to the pressure of the fuel downstream of each metering orifice which operates on the diaphragm in a direction tending to open the valve.

Likewise, as in the prior identified application, each pressure regulating nozzle valve is also connected with a by-pass fuel passage extending from the fuel chamber to the inlet of the fuel pump. The fuel pressure in this by-pass acts on the opposite side of the diaphragm in each pressure regulator valve in a direction tending to close the valve. The by-pass includes means for establishing therein a datum pressure a pound or so less than the charging pressure in the fuel chamber (pump pressure). The datum pressure acts equally on each diaphragm of each nozzle valve, and it follows that the fuel pressure downstream of each metering orifice is equal, since downstream pressure is maintained the same as datum pressure by action of each pressure regulating nozzle valve.

According to the disclosure in the above-identified application of Armstrong, the datum pressure in the by-pass passage is varied in response to changes in engine load.

According to this invention, the datum pressure is regulated according to engine temperature, and is changed from one range during cranking to another range during warm-up of the engine.

According to this invention, changes in engine load affect the response of the air valve in the air stream passing to the engine, which in turn positions the metering rods to increase the flow of fuel to the engine.

According to this invention, the connection between the air valve and the metering rod carrier is direct, which eliminates the magnetic clutches used in the prior Armstrong invention.

The system herein disclosed and subsequently described in detail has several features, as above broadly described, which may take various forms. By way of example, one of these forms is illustrated schematically in the accompanying drawing, in which:

Fig. 1 is a schematic showing of the basic engine charging system illustrating the parts of the system in positions assumed when the engine is at normal temperature and the throttle closed for idle.

Fig. 2 is a similar view showing a modification.

For purposes of convenience, the several parts of this system schematically illustrated in Fig. 1 have been indicated by reference characters similar to those used in the above-identified application of Armstrong.

Air induction system

Fig. 1 of the drawings schematically illustrates one form of an engine charge forming device embodying the above briefly described system. As therein illustrated, the air induction system has a single air inlet or air horn body B through which all of the charging air passes to a plurality of branches 26a, one of which is shown,

which are in turn connected with the cylinder intake ports of the engine. Each branch 26a is separately controlled by an engine intake valve 26, all in a well known manner.

Air flow sensing device

Within the air conduit body B is a balanced butterfly air valve 37 mounted on a shaft 36 journaled for rotation in the side walls of the air conduit body B. The under leading edge of the valve 37 has a deflector or spoiler 37a for the purpose described in an application of James Fred Armstrong, Serial No. 622,917, filed November 19, 1956, entitled "Fuel Injection System" and now Patent No. 2,876,758. Mounted on one side of the air conduit body is a housing B' which is divided into a pair of chambers 41 and 42 by a flexible diaphragm 40. Chamber 41 is connected by a passage 13 with a ram tube 44 facing upstream and located in the air horn B anterior or upstream of the air valve 37. A passage 45 connects the opposite chamber 42 with a plurality of Pitot tubes 145 facing upstream and located in the air horn B posterior or downstream of the air valve 37. A spring 43 of low rate and proper calibration urges the diaphragm 40 in a direction to expand the chamber 42.

Passage 13 also has a port 14 opening into the chamber 41 so that the diaphragm 40 is exposed to pressures anterior and posterior of the air valve 37 acting against the force of spring 43. The diaphragm 40 is, in turn, connected by a rod 5 with a flapper valve 10 located adjacent to the outlet of orifice 11 from a tube 4 connected with a motor, which will be described hereinafter, for operating the valve 37.

From the description so far, during the cranking or running of the engine, the pumping action of the engine will produce a drop in pressure downstream of the air valve 37, which in turn will be sensed by the Pitot tubes 145 and communicated to the chamber 42 to compress spring 43 to close the flapper valve 10 against the orifice 11 when the depression below, or the differential in pressures across, the air valve 37 exceeds about 0.5 inch of Hg pressure. On the other hand, if the differential across the valve 37 is less than this amount, spring 43 expands, moving the flapper valve 10 away from the orifice 11. The flapper 10 and orifice 11 together operate as a pilot valve, which is in turn under control of the pressure drop across the air valve 37, and this pilot valve is the control for the servo-motor, which includes a slave motor for operating the air valve 37 in an opening direction. Power for this servo-motor mechanism is preferably obtained from the fuel metering part of the system, although a separate source of power would likewise be suitable.

Fuel supply system

The source of power for operating this servo-motor is supplied from the fuel pump P, which may be operated by the engine, and obtains its supply of fuel through a line 19 leading from a fuel tank of the vehicle. The pump P delivers the fuel under pressure through a line 20 to the pressure regulator 22. A detailed description of this regulator appears in the prior identified applications or patents. Fuel from the regulator passes through a line 20a to the fuel chamber A containing the fuel metering part of the engine charging device. During operation of the engine, this chamber A will be charged with fuel under pressure as supplied by the pump P as regulated by the output of the regulator 22. No particular pressure is contemplated, but, for purposes of illustration, let it be assumed that the regulator output pressure is approximately 35 pounds, so that chamber A is charged at this pressure.

Within the chamber are a plurality of metering orifices 23 supplying individual fuel lines 24 leading from the chamber A. Each orifice 23 is in turn equally variable in area by metering rods 33 on the common carrier 34.

A spring 140 is biased between the carrier 34 and one wall of the chamber A for urging the carrier 34 to a position in which the rods are fully within the metering orifices 23.

Connected with the carrier 34 is a rod 39 operated by a lever fast on the shaft 36 of the air valve 37. At the point in which the rod 39 passes through the wall of the chamber A is an orifice 141 formed by the clearance between rod 39 and a bush 142 in the wall of the chamber A.

By way of example, the rod 39 may be .187 inch in diameter operating in a bush 142 with a bore of .190" to form an orifice of an area of .0009 square inch. Fuel from the chamber A will continue to flow through this orifice 141 into a chamber 144 formed with flexible side walls 155 and end wall 156 connected with the rod 39 at 157. The fuel in chamber 144 will also flow through the line 4 to the orifice 11 controlled by the flapper valve 10. By way of example, if the orifice 11 is .054 inch, its area in square inches is .0023. The difference in area between the two orifices 11 and 141 provides a pressure drop of 26 pounds across orifice 141, so that the chamber 144 is charged at 9 pounds, which acts on the wall 156. If the area of the end wall 156 is about one square inch, the opening force will be 9 pounds acting on rod 39. Accordingly, it requires a spring force of about 9 pounds to close the air valve.

The force required to close the flapper valve against 35 pounds pressure will be about .08 pound. Thus, if the diaphragm 40 has an area of one square inch, the force developed by a .5 inch Hg drop across the air valve will be about .25 pound. This air pressure on diaphragm 40 will be sufficient, or more than adequate, to close the flapper valve 10 against the 35 pounds pressure at the orifice 11.

The flow through the orifice 141 will be approximately .7 of a cubic inch per second, which means that the bellows will move .7 inch in one second in response to closing of the flapper valve 10. Also, the relative difference in orifice area between 11 and 141 produces the desired differential pressure, in this case 9 pounds, which will be adequate to overcome any friction in the system. Fuel flow into chamber 41 is returned to the pump inlet or fuel tank by a line 12.

Operation of air valve

From the preceding description it should be apparent that the drop in pressure sensed across the air valve 37 by the Pitot tubes 44 and 145, respectively, operates diaphragm 40 and in turn flapper valve 10 to adjust the size of the orifice 11. As the drop in pressure across the air valve 37 increases, orifice 11 will close, thereby increasing the pressure in chamber 144 from 9 pounds up to an amount sufficient to move the air valve 37 in an opening direction against the tension of spring 140. This movement will continue until the pressure drop across air valve 37 decreases to the selected amount (as an example, 0.5 inch of Hg), at which point valve 10 will have moved to a position to maintain sufficient pressure in chamber 144 to balance the closing forces acting on the valve 37. If the pressure drop across the air valve 37 decreases, flapper valve 10 moves away from the orifice 11 under the influence of spring 43 so that valve 37 can close until the pressure drop thereacross increases to balance the force of spring 43. The system reaches a point of equilibrium with the valve 10 positioned to impose just sufficient pressure in the chamber 144 to balance the closing forces acting on the air valve 37.

Thus, the position of the air valve 37 will be an indication of the rate of air flow through the intake conduit B. This device, in effect, acts as a measure of the air flow and in turn positions the needles 33 so as to adjust the size of the orifices 23 to allow fuel flow proportional to the rate of air flow. Suitable adjustment can

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be provided in rod 39 so as to allow a change in needle position with respect to the valve for mixture control.

The structure described for operating the air valve 37 may be considered a servo-motor in which the flapper valve 10 and its operating structure is the pilot valve, and the chamber 144 and its operating structure is the motor.

Since it is necessary to provide a richer mixture when the engine is operating at heavy load rather than at road load, it is necessary to increase the flow of fuel through the metering orifices 23 in response to increases in engine load. In this construction, this function is accomplished by changing the pressure drop or rate of air flow past the air valve 37. Thus, if the pressure drop is increased, the mixture becomes leaner, and conversely.

Mixture control in response to changes in engine load

The extension B' on the air conduit B also contains a diaphragm 3 connected with rod 5 mounting the flapper valve 10. Diaphragm 3 is in turn biased in one direction by a tension spring 17 connected in turn to a diaphragm 16 which forms a chamber 8 between the two diaphragms. Diaphragm 16 forms the end wall of a chamber 9 which is in turn connected to the air intake conduit B downstream or posterior of the throttle valve 50. Chamber 9 may be provided with an atmospheric bleed 19, which is an orifice much smaller in size than the orifice 18, so that substantially manifold pressure will be communicated through the orifice 18 to the chamber 9. The differential between manifold pressure and the pressure at the inlet of conduit B acts on diaphragm 16, and is communicated thereto by port 18 at its lower side and port 14 at its upper side. The diaphragm 3, however, is balanced by like pressures on opposite sides supplied through the ports 14 and 15.

Operation of mixture control

In the lower range of engine speeds and throttle openings, the chamber 9 could be subject to a depression of as much as 8 or 9 pounds, which in turn moves the diaphragm to tension the spring 17 to produce a control force which acts together with the spring 43 tending to move the flapper valve 10 away from the orifice 11. As the throttle 50 is opened, however, the differential in pressure acting on the diaphragm 16 decreases so as to decrease the spring force 17 acting with or augmenting the force of spring 43.

Manifold pressure is an indication of engine load, and, likewise, fuel mixture requirements, and when there is a substantial depression in the engine manifold, as when the throttle 50 is open only partially and the engine operating at road load, the spring force—that is, the total force of spring 17 and spring 43—is increased. When the spring force 17 is added to the force of spring 43, a greater drop in pressure or pressure differential is required to move the flapper valve 10 toward the closed position with respect to the orifice 11. Conversely, when the force of spring 17 is removed, the differential in pressure across the valve 37 required to close the valve 10 against the orifice 11 is decreased. A greater pressure drop occurs across the valve 37 in the part throttle range of operation than in the full throttle range of operation. Likewise, in the part throttle range, when the differential across the valve 37 is the greatest, the displacements of the air valve 37 in the open direction will be less than for the same rate of air flow in the full throttle range. This being the case, the needles 33 will be displaced a lesser distance against the forces of air flow and spring 140 in the part throttle range than in the full throttle range, and consequently the flow of fuel through the orifices 23 will be less at part throttle than at full throttle.

Fuel nozzles

Each of the fuel nozzles 25, one of which is shown, is, in effect, a pressure regulator which controls the pres-

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sure downstream of the orifices 23. The detailed structure of each nozzle has been shown and described in the above-identified Armstrong applications, and will not be repeated here. It is sufficient to point out that each of the fuel lines 24 connects with a separate nozzle 25 located in a separate branch of the intake manifold 26a.

Datum pressure system

Each of the nozzles 25 is also connected with a datum pressure system which forms a by-pass passage extending from the chamber A to the inlet of pump P. The inlet thereof has a metering orifice 55 controlled by a needle 87. The position of needle 87 is controlled by a mechanism 88 connected with opposed elements of the magnetic clutch 86 for transferring the motion of the control mechanism outside the chamber to the needle 87. This control mechanism is similar to that described in the Armstrong application, and includes a shaft 65 to which is fixed one half of the magnetic clutch 86. A lever 68, also fixed to the shaft 65, carries a lug 71 threaded to receive the adjusting screw 72, against which is biased the thermostat 76. The thermostat 76 is in turn carried in a fixed mounting (not shown) and arranged to wind up as its temperature increases until it comes in contact with adjusting screw 73 mounted in a fixed threaded lug 74. This limits the movement of the lever 68 in a clockwise direction. Carried on the shaft 65 is a lever 70 connected with piston 82 in cylinder 83. A spring 85 urges the piston 82 upwardly in the cylinder, and a line 84 connects below the piston 82 with a port 116 posterior of the throttle 50, so that suction tends to pull the piston 82 downwardly against the force of spring 85.

Shaft 65 carries a fast idle cam 64 which is engaged by a lever 66 carried by the throttle shaft 51.

Operation of datum system

The structure above described operates in response to engine temperature to position the arm 68, and thereby the needle 87 in the orifice 55. During cranking of the engine, the temperature alone affects the position of the arm 68, but after the engine starts, suction will be communicated to the cylinder 83 to produce a force on the piston 82 in a direction to counteract the force of the thermostat 76 at least in part.

The thermostat 76 may be mounted in a closed chamber connected with a stove suitably located and heated by engine operation, all in a well known manner. Air from the stove is drawn through the chamber containing the thermostat, past the piston 82, through the by-pass 101, into the manifold, so as to produce a circulation of hot air over the thermostat to cause it to wind up as engine temperature increases.

The datum system includes a line 56 leading from the orifice 55 with branches connected with the nozzles 25, one of which is shown. A line 58 leads back to the intake of the pump P. The outlet of line 58 is controlled by a metering orifice 61 and a pressure regulator 60, all as described heretofore in the prior Armstrong application.

Engine unloading

Fig. 1 of the drawings also illustrates a lug 52 on the manually operated throttle 50, which is positioned to engage and close a switch 97 when the throttle is moved to the fully open position. The switch 97 in turn closes the circuit 92 through the solenoid operated valve 59 to starter switch 93, connecting battery 94 with starter motor 95 of the engine.

When the starter switch 93 is closed with the throttle 50 wide open, solenoid valve 59 will be closed against the tension of spring 91 so as to build up the datum pressure equal to the pressure in the chamber A, thereby stopping the flow from the nozzles 25.

Air flow sensing device (modified form)

Fig. 2 illustrates a modified form of the invention

which differs only in the type of air valve used. The same reference characters are used to identify like parts.

Most any type of air valve can be used with this system, and, as an example, Fig. 2 substitutes a sliding valve 137 instead of a pivoted valve, which valve 137 is of the type unbalanced in a direction to open in response to air flow through the air horn B. Because of this characteristic, it is necessary to use a stronger spring 140 to counteract the action of air flow on the valve 137 and to modify the air horn B to provide a horizontally arranged inlet with a diffuser shape.

Otherwise the system is identical with that heretofore described, and further explanation would serve no useful purpose.

Operation

During operation of the engine, the pressure drop across valve 137 is sensed by Pitot tubes 44 and 145, which communicate these pressures to chambers 41 and 42, respectively, creating a force to balance the force of spring 43. As above explained, when these forces become unbalanced, flapper valve 10 moves with respect to jet 11, changing the fuel pressure within servo-motor 144 so as to move valve 137 to a new position where the closing force exerted by the spring 140 is balanced by the opening forces generated by servo-motor 144 and air flow on the air valve 137.

In this modification the air valve 137 is connected by a pull rod 39 to carrier 34 for the metering rods 33, so that both the rods and the air valve move in an opening and closing direction together. In all other respects the operation of this embodiment is identical with that above described.

For the purpose of illustration, a structure has been disclosed which will fulfill all the objects of the invention, but it is contemplated that other modifications will occur to those skilled in the art which come within and are protected by the scope of the appended claims.

I claim:

1. An engine charge forming device having an air conduit with an air inlet and air outlets connected with the combustion chambers of the engine, a fuel chamber receiving fuel under pressure and delivering fuel under pressure to the combustion chambers of the engine through a fuel passage connected with the air conduit, and a system for maintaining the flow of fuel proportional to the flow of air, said system comprising: an air valve in said inlet, means mounting said air valve for movement to form a variable air flow restriction in said inlet, a motor connected to operate said air valve to vary the open area of said air flow restriction, a source of power for said motor, a pilot valve for controlling said source of power, means sensitive to changes in the velocity of the air stream passing the air valve for controlling said pilot valve to determine the position of said air valve in the air stream in response to changes in velocity sensed, and fuel metering means in the fuel passage operated by changes in position of said valve.

2. An engine charge forming device having an air conduit with an air inlet and air outlets connected with the combustion chambers of the engine, a fuel chamber receiving fuel under pressure and delivering fuel under pressure to the combustion chambers of the engine through separate branches connected with said air outlets, and a system for maintaining the flow of fuel proportional to the flow of air, said system comprising: a valve in said air inlet, means mounting said valve for opening and closing movement to form a variable air flow restriction in said inlet, a motor connected to operate the said valve on said movable mounting to vary the open area of said air flow restriction, a source of power for said motor, a pilot valve controlling said source of power, means sensitive to pressures in the air stream passing the air valve for controlling said pilot valve to determine the position of said air valve in response to changes in pres-

sure sensed, and fuel metering means in said branches operated by changes in position of said air valve.

3. An engine charge forming device having an air conduit with an air inlet and air outlets connected with the combustion chambers of the engine, a throttle in said inlet, a fuel chamber receiving fuel under pressure and delivering fuel under pressure to the combustion chambers of the engine through separate fuel passages connected with said air outlets, and a system for maintaining the flow of fuel proportional to the flow of air, said system comprising: an air valve in said inlet, means mounting said air valve for movement to form a variable air flow restriction in said inlet, a motor connected to operate said air valve to vary the open area of said air flow restriction, a source of power for said motor, a pilot valve for controlling said source of power, a means sensitive to the pressures in the air stream passing the air valve and to pressures posterior of said throttle for controlling said pilot valve, fuel metering means of the variable area type in each of said branches operated by changes in position of said air valve so that simultaneous changes in area occur in both said air and fuel restrictions, and pressure regulating means in each of said branches downstream of said fuel metering means for maintaining the pressure differential across said fuel metering means relatively constant.

4. An engine charge forming device having an air conduit with an air inlet and air outlets connected with the combustion chambers of the engine, a fuel chamber receiving fuel under pressure and delivering the fuel under pressure to the combustion chambers of the engine through separate branches connected with said air outlets, and a system for maintaining the flow of fuel proportional to the flow of air, said system comprising: an air valve in said air inlet, means mounting said valve for movement to form a variable air flow restriction in said inlet, a motor connected to operate said valve to vary the open area of said air flow restriction, a connection between said motor and said fuel chamber for supplying power to operate said motor, a pilot valve for controlling said connection, a means sensitive to pressures in the air stream passing the air valve for controlling said pilot valve and thereby the power output of said motor for determining the position of said air valve in the air stream in response to changes in pressures sensed, and fuel metering means in said branches operated by changes in position of said valve.

5. An engine charge forming device having an air conduit with an air inlet and air outlets connected with the combustion chambers of the engine, a fuel chamber receiving fuel under pressure and delivering fuel under pressure to the combustion chambers of the engine through separate branches connected with said air outlets, and a system for maintaining the flow of fuel proportional to the flow of air, said system comprising: an air valve in said air inlet, means mounting said air valve for movement to form a variable air flow restriction in said inlet, a motor connected to operate said air valve to vary the open area of said air flow restriction, a connection between said fuel chamber and said motor, a metered restriction in said connection, a fuel outlet from said motor, a pilot valve for controlling said outlet, a means sensitive to pressures in the air stream passing the air valve for controlling said pilot valve for determining the power output of said motor and the position of the valve in the air stream in response to changes in pressures sensed, and fuel metering means in said branches operated by changes in position of said valve.

6. An engine charge forming device having an air conduit with an air inlet and air outlets connected with the combustion chambers of the engine, a fuel chamber receiving fuel under pressure and delivering fuel under pressure to the combustion chambers of the engine through separate branches connected with said air outlets, and a system for maintaining the flow of fuel propor-

tional to the flow of air, said system comprising: an air valve in said air inlet, means mounting said air valve for movement to form a variable air flow restriction in said inlet, a motor connected to operate said air valve to vary the open area of said air flow restriction, a connection between said fuel chamber and said motor, a flow restriction in said connection, a fuel outlet leading from said motor, a pilot valve controlling said fuel outlet, means sensitive to pressures in the air stream passing the air valve for controlling said pilot valve and thereby determining the position of said air valve in response to changes in pressure sensed to maintain a substantially constant pressure drop thereacross, fuel flow metering means in said branches operated by changes in position of said valve so that simultaneous and like changes in area occur in said air metering and said fuel metering means, and means for maintaining a substantially constant pressure drop across said fuel metering means.

7. In an engine charge forming device having a system for maintaining the flow of fuel in one stream proportional to the flow of air in another stream, including a throttle for controlling the flow in the air stream, an air valve in the air stream forming a variable air metering orifice to measure the air flow past the throttle, a motor connected to said air valve for changing the area of said orifice in the air stream, a means sensitive to pressures in the air stream passing said air valve for controlling the power output of said motor to determine the position of said valve in the air stream in response to changes in pressures sensed, so that the valve position changes with each change in the rate of air flow to the engine, and a variable capacity fuel metering orifice in said first stream operated by changes in position of said air valve; the combination of, means for varying the proportion of air flow to fuel flow in response to changes in engine load, said means comprising engine load responsive means acting on one of said variable orifices for varying the proportions of one with respect to the other and thereby the rate of air flow to the rate of fuel flow in response to changes in engine load.

8. An engine charge forming device having a system for maintaining the flow of fuel to the engine in one stream proportional to the flow of air to the engine in a separate stream, said device including a first variable area orifice in said air stream, a motor connected to said orifice in the air stream for changing the area thereof, a means sensitive to the pressures in the air stream passing the valve for controlling the power output of said motor to determine the position of said valve in the air stream in response to changes in pressures sensed, so that the valve position changes with each change of rate of air flow to the engine, and a second variable orifice in said fuel stream operated by changes in position of said first orifice; the combination of a means for sensing changes in engine load and a connection between said load sensing means and said motor for modifying the power output of said motor in response to changes in engine load.

9. An engine charge forming device having an air conduit with an air inlet and air outlets connected with the combustion chambers of the engine, a throttle in said inlet, a fuel chamber receiving fuel under pressure and delivering fuel under pressure to the combustion chambers of the engine through separate branches connected with said air outlets, and a system for maintaining the flow of fuel proportional to the flow of air, said system comprising: an air valve in said inlet anterior of said throttle, means mounting said air valve for movement to form a variable air flow restriction in said inlet, a motor connected to operate said air valve to vary the open area of said air flow restriction, a source of power for said motor, a pilot valve for controlling said source of power, a means sensitive to the pressures in the air stream passing the valve and to pressures posterior of said throttle for operating said pilot valve to control the source of

power for operating said motor to determine the position of said air valve in the air stream in response to changes in pressures sensed, and fuel metering means in said branches operated by changes in position of said valve.

10. An engine charge forming device having an air conduit with an air inlet and air outlets connected with the combustion chambers of the engine, a throttle in said air inlet, a fuel chamber receiving fuel under pressure and delivering fuel under pressure to the combustion chambers of the engine through separate branches connected with said air outlets, and a system for maintaining the flow of fuel proportional to the flow of air, said system comprising: an air valve in said inlet anterior of said throttle, means for mounting said air valve for movement to form a variable air flow restriction in said inlet, a motor connected to operate said valve to vary the open area of said air flow restriction, a connection between said motor and said fuel chamber, a fuel flow restriction in said connection, a fuel outlet from said motor, a pilot valve for controlling said outlet, means sensitive to the pressures in the air stream passing the air valve and to pressures in the air stream posterior of said throttle for operating said pilot valve to determine the position of said air valve in the air stream in response to changes in pressures sensed, fuel flow metering means in said branches operated by changes in position of said air valve, and means controlling the pressure drop across said fuel flow metering means.

11. An engine charge forming device having a system for maintaining the flow of fuel to the engine in one stream proportional to the flow of air to the engine in a separate stream, said device comprising a throttle controlling the flow of air to the engine, a variable capacity air metering means for measuring the air flow past said throttle, means for varying the capacity of said air metering means to maintain a substantially constant air pressure differential across the air metering means throughout the range of engine speeds, a second variable capacity metering means in said fuel stream operated directly by changes in capacity of said variable capacity air metering means whereby the capacity of both metering means is increased or decreased together, and means responsive to engine load connected to said second variable capacity metering means to decrease the flow capacity thereof during part throttle operation of the engine.

12. In an engine charge forming device having an air conduit with an air inlet and air outlets connected with the combustion chambers of the engine, a fuel chamber receiving fuel under pressure and delivering fuel under pressure to the combustion chambers of the engine through separate branches connected with said air outlets, and a system for maintaining the flow of fuel proportional to the flow of air, said system comprising: a disk valve in said inlet, a pivot about which said valve is hinged for swinging movement to form a variable air flow restriction in said inlet, a motor connected to operate said valve to vary the open area of said air flow restriction, a means sensitive to pressures in the air stream passing the valve for controlling the power output of said motor for determining the position of said valve in the air stream in response to changes in pressures sensed, means responsive to pressures adjacent said air outlets and connected with said motor for causing said air valve to overtravel when the pressure sensed adjacent said air outlets increases, and fuel metering means in said branches operated by changes in position of said valve.

13. An engine charge forming device having a system for maintaining the flow of fuel to the engine in one stream proportional to the flow of air to the engine in a separate stream, said device comprising a throttle controlling the flow of air to the engine, a variable capacity air metering means for measuring the air flow past said throttle, means for varying the capacity of said air metering means to maintain a substantially constant air

pressure differential across said air metering means throughout the range of engine speeds, a second variable capacity metering means in said fuel stream operated directly by changes in capacity of said variable capacity air metering means whereby the capacity of both metering means is increased or decreased together, and means responsive to engine load connected with said second variable capacity metering means to decrease the flow capacity thereof during part throttle operation of the engine, said last means including a connection operated by air flow to the engine.

14. An engine charge forming device having an air conduit with an air inlet and air outlets connected with the combustion chambers of the engine, a throttle in said air inlet, a fuel chamber receiving fuel under pressure and delivering fuel under pressure to the combustion chambers of the engine through separate branches connected with said air outlets, and a system for maintaining the flow of fuel proportional to the flow of air, said system comprising: an air valve in said air inlet, means mounting said air valve for movement to form a variable air flow restriction in said inlet, a motor connected to operate said air valve to vary the open area of said air flow restriction, a connection between said fuel chamber and said motor, a fuel flow restriction in said connection, a fuel outlet leading from said motor, a fuel flow restriction in said outlet for establishing a minimum pressure between said restrictions, a pilot valve controlling said fuel outlet, a movable wall connected to said pilot valve, spring means for moving said movable wall in a direction to open said pilot valve, a pair of chambers on opposite sides of said wall, means for measuring the differential pressure across said air valve, a connection between said measuring means and said chambers for operating said movable wall against the resistance of said spring, a second movable wall, a spring between said second movable wall and said pilot valve, means for measuring the pressure drop across said throttle, a connection between the last said means and chambers on opposite sides of said second movable wall for applying the force of differential pressure across said throttle to elongate said spring, and fuel flow metering means in said branches operated by changes in position of said valve so that simultaneous and like changes in area occur in said air metering and said fuel metering means.

15. An engine charge forming device having an air conduit with an air inlet and air outlets connected with the combustion chambers of the engine, a throttle in said air inlet, a fuel chamber receiving fuel under pressure from a pump and delivering fuel under pressure to the combustion chambers of the engine through separate branches connected with said air outlets, and a system for maintaining the flow of fuel proportional to the flow of air, said system comprising: an air valve in said inlet anterior of said throttle, means for mounting said valve for movement to form a variable air flow restriction in said inlet, a motor connected to operate said valve to vary the open area of said air flow restriction, a connection between said motor and said fuel chamber, a fuel flow restriction in said connection, a fuel outlet from said motor, a fuel flow restriction in said outlet for establishing a minimum operating pressure between said restrictions acting in said motor, a pilot valve for controlling said outlet, a movable wall connected to said pilot valve, a pair of chambers on opposite sides of said movable wall, a spring acting on said wall in a valve opening direction, means for sensing the pressure differential across the said air valve connected to said chambers to oppose the action of said spring, a second movable wall, a pair of chambers on opposite sides of said second movable wall, a spring between said second movable wall and said pilot valve, means for sensing the pressure differential across said throttle connected to said chambers on opposite sides of said second movable wall and acting thereon in a direction to tension said spring, means for conveying fuel dis-

charged past said pilot valve to the inlet of said pump, fuel flow metering means in said branches operated by changes in position of said air valve, and means controlling the pressure drop across said fuel flow metering means.

16. An engine charge forming device having an air conduit with an air inlet and air outlets connected with the combustion chambers of the engine, a fuel chamber receiving fuel under pressure and delivering fuel under pressure to the combustion chambers of the engine through a fuel passage connected with the air conduit, and a system for maintaining the flow of fuel proportional to the flow of air, said system comprising: an air flow measuring means including a variable air flow restriction in said air conduit and means for sensing variations in air pressure adjacent said restriction, a variable fuel metering means for said passage, a motor, a connection from said motor to operate said fuel metering means and said variable air flow restriction together, a source of power for said motor, and means responsive to pressures sensed by said air metering means and to an operating condition of the engine for controlling the power input from said source to said motor.

17. An engine charge forming device having an air conduit with an air inlet and air outlets connected with the combustion chambers of the engine, a fuel chamber receiving fuel under pressure and delivering fuel under pressure to the combustion chambers of the engine through a fuel passage connected with the air conduit, and a system for maintaining the flow of fuel proportional to the flow of air, said system comprising: an air flow measuring means including a variable air flow restriction in said air conduit and means for sensing variations in air pressure adjacent said restriction, a variable fuel metering means for said passage, a motor, a connection from said motor to operate said fuel metering means and said variable air flow restriction together, a source of power for said motor, and means responsive to pressures sensed by said air metering means for controlling the power input from said source to said motor.

18. An engine charge forming device having an air conduit with an air inlet and air outlets connected with the combustion chambers of the engine, a fuel chamber receiving fuel under pressure and delivering fuel under pressure to the combustion chambers of the engine through a fuel passage connected with the air conduit, and a system for maintaining the flow of fuel proportional to the flow of air, said system comprising: an air flow measuring means including a member movable in the air flow in said air conduit and means for sensing pressure variations in said air conduit, a variable fuel metering means for said passage, a fluid pressure operated motor connected with said chamber, with said fuel metering means, and with said movable member, and means responsive to operation of said air flow measuring means connected with said motor for varying the fuel pressure in said motor with changes in pressure variations sensed by said sensing means.

19. An engine charge forming device having an air conduit with an air inlet and air outlets connected with the combustion chambers of the engine, a fuel chamber receiving fuel under pressure and delivering fuel under pressure to the combustion chambers of the engine through a fuel passage connected with the air conduit, and a system for maintaining the flow of fuel proportional to the flow of air, said system comprising: an air flow measuring means including a variable air flow restriction in said air conduit and means for sensing variations in pressure adjacent said restriction, a variable fuel metering means for said passage, a motor, an operating connection from said motor to operate said fuel metering means and said variable air flow restriction together, a connection between said chamber and said motor for operating said motor, and means responsive to pressures sensed by said air metering means for vary-

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ing the fuel pressure in said connection with changes in air pressures sensed.

20. An engine charge forming device having an air conduit with an air inlet and air outlets connected with the combustion chambers of the engine, a fuel chamber 5 receiving fuel under pressure and delivering fuel under pressure to the combustion chambers of the engine through a fuel passage connected with the air conduit, and a system for maintaining the flow of fuel proportional to the flow of air, said system comprising: an air 10 flow measuring means including a member movable in the air stream in said conduit, a fuel metering means for said fuel passage including a member movable in the fuel stream supplying said fuel passage, a connection between 15 said member movable in the air stream and said member movable in the fuel stream, a fluid motor in said connection between said movable means, a source of positive fluid pressure connected to operate said fluid motor, and means responsive to operation of said air measuring 20 means for controlling the power input from said source to said motor.

21. An engine charge forming device having an air conduit with an air inlet and air outlets connected with

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the combustion chambers of the engine, a fuel chamber receiving fuel under pressure and delivering fuel under pressure to the combustion chambers of the engine through a fuel passage connected with the air conduit, and a system for maintaining the flow of fuel proportional to the flow of air, said system comprising: an air flow measuring means including a member movable in the air stream in said conduit, a fuel metering means for said fuel passage including a member movable in the fuel stream supplying said fuel passage, a connection between said member movable in the air stream and said member movable in the fuel stream, a fluid motor in said connection between said movable means, a source of positive fluid pressure connected to operate said fluid motor, separate means for sensing an operating condition of the engine, and means responsive to operation of said air measuring means and said separate sensing means for controlling the power input from said source to said motor.

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