Oct. 27, 1964 J. F. ARMSTRONG Re. 25,672

FUEL INJECTION SYSTEM

Original Filed Jan. 7, 1957 3 Sheets-Sheet 1

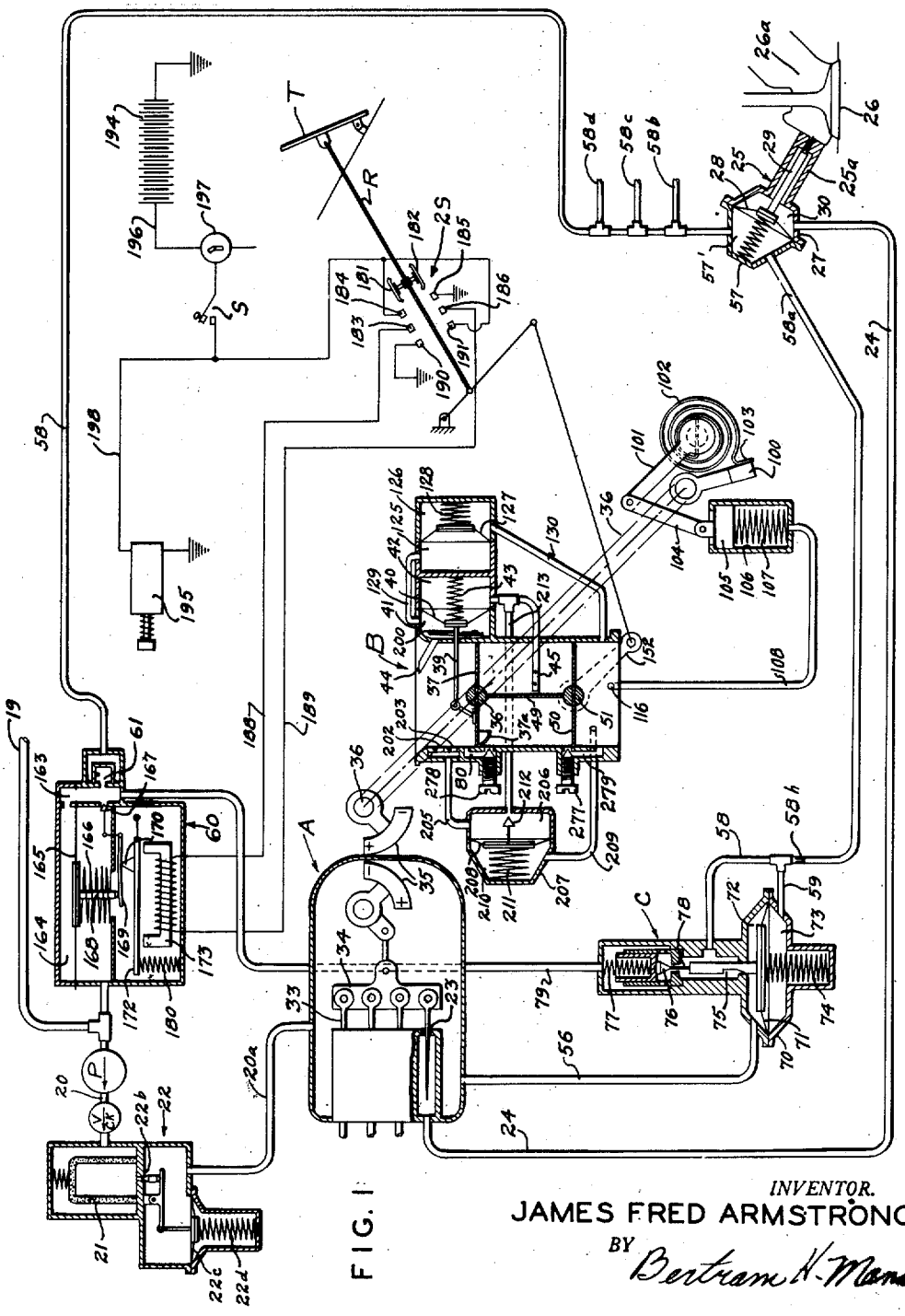


FIG. 1

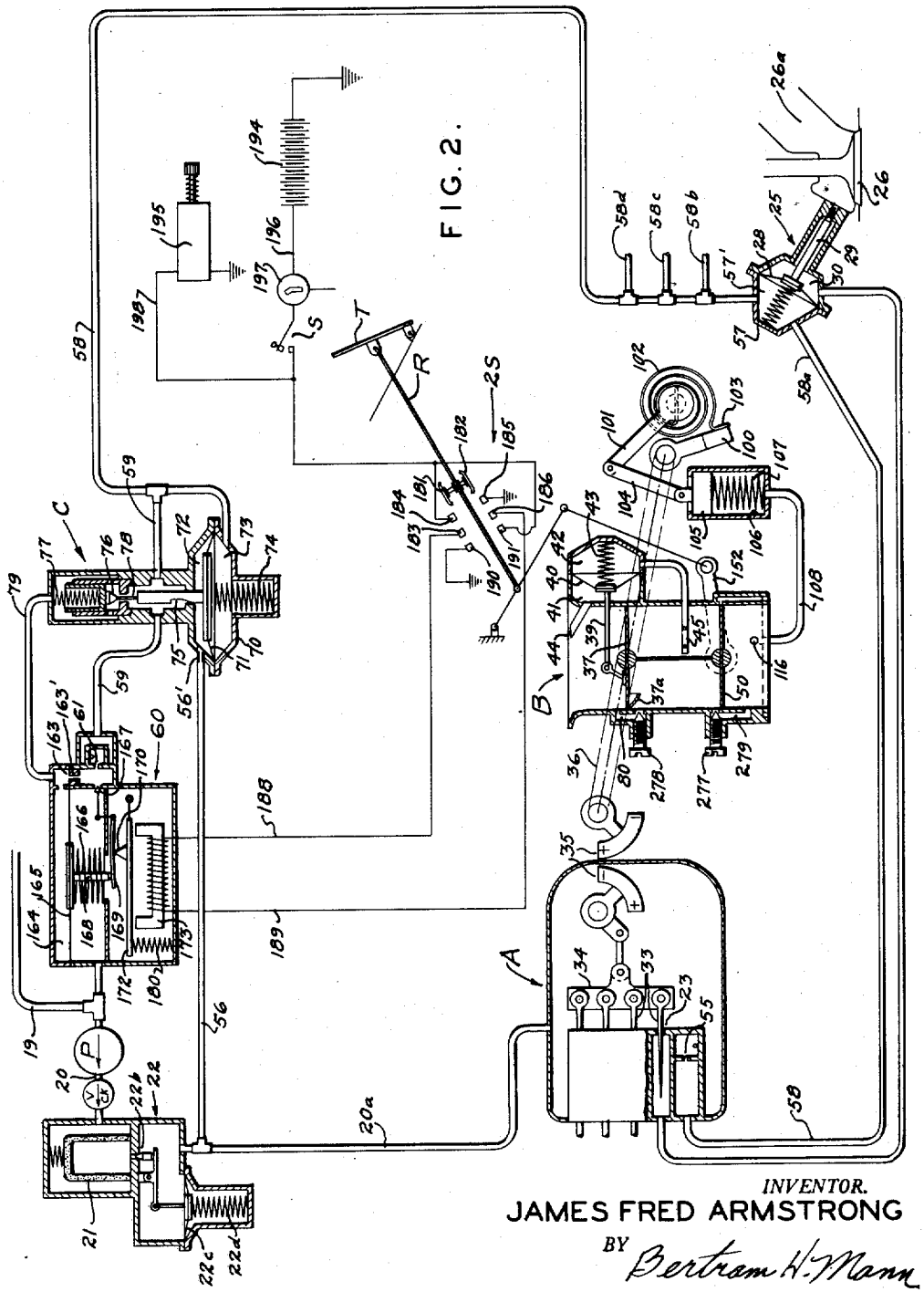
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FUEL INJECTION SYSTEM

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FIG. 2.



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FUEL INJECTION SYSTEM

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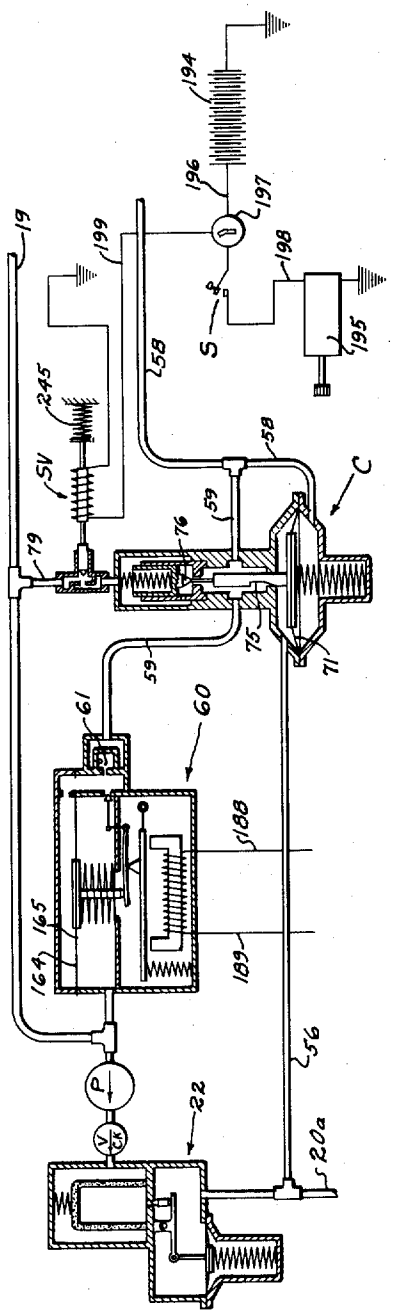


FIG. 3.

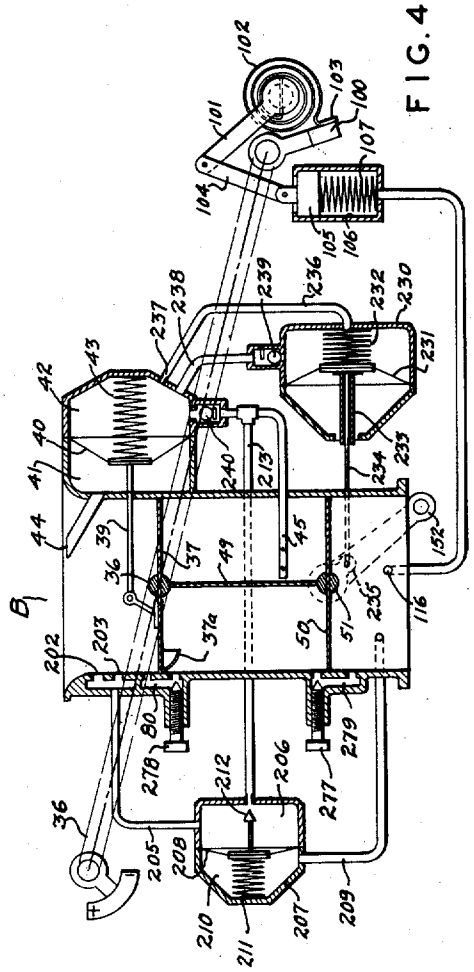


FIG. 4.

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FUEL INJECTION SYSTEM

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Original No. 3,029,800, dated Apr. 17, 1962, Ser. No. 632,798, Jan. 7, 1957. Application for reissue July 31, 1962, Ser. No. 214,796

16 Claims. (Cl. 123—119)

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

This invention is an engine charging device using the continuous flow system adapted for 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. Such a system is shown in my prior application, Serial No. 516,358, filed June 20, 1955, now Patent No. 2,785,669 and entitled "Injection Carburetion," of which this application is a continuation-in-part.

The charge forming device shown in this prior application comprises a plurality of sensing means for engine fuel requirements, preferably responsive to the rate of air flow to the engine through the air induction system, and engine pressures and temperatures for indicating the fuel requirements of the engine. These sensing means, in turn, control fuel metering means in passages supplied with fuel under pump pressure which deliver the metered fuel to the engine.

This application is also a continuation-in-part of my prior application S.N. 622,917 filed November 19, 1956, now patent No. 2,876,758.

According to this invention, the basic system above referred to has been modified in a manner to obtain a more stable datum pressure for more precise control of fuel metering.

According to this invention, the operating device for stabilizing the datum pressure controls a by-pass device for bleeding the datum line rapidly of fuel displaced by movement of the diaphragms opening the several nozzle valves to increase the flow of fuel to the combustion chambers of the engine.

According to this invention, the air flow measuring device in the engine induction system, which in turn controls the fuel metering, has been modified to obtain a variable response depending upon the degree and rate of the throttle valve opening. In this manner, the fuel flow to the engine can be increased and decreased depending upon engine load.

According to this invention, the pressure control device in the datum circuit, together with a means for modifying the rate of response of the air flow measuring device, comprise cooperating devices to improve the throttle response of the fuel system.

According to this invention, a means has been provided to increase the fuel flow for acceleration, which acts directly to effect operation of the fuel metering means by modifying the response of the air valve to the rate of air flow, causing the air valve to over-travel and the fuel delivery to increase when the throttle is opened.

According to this invention, the different fuel requirements of the engine at part throttle and full throttle loads are satisfied by a novel means, changing the fuel flow metering means by acting directly to affect air valve response to variation in the rate of air flow.

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

In the drawings:

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

FIG. 2 is a schematic representation of a modification of the above described system.

FIG. 3 is a schematic representation showing the interconnection of similar elements forming a second modification.

FIG. 4 is a modified form of air horn.

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.

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 as many fuel nozzles as there are cylinders of the engine, but only one has 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 **26** 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. The valve **75** forms a variable restriction for charging the datum system. A small valve **76** is biased to a closed position by a spring **77** and has a stem **78** arranged for contact by the valve **75**, so that when the valve **75** closes, the valve **76** is

opened to allow fuel to escape through a by-pass line **79** to the pressure regulator **60**. 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**.

ENGINE PRIMING AND UNLOADING CONTROL

Lever **172** is a permanent magnet with opposite poles at opposite ends thereof. Below the lever **172** is an electromagnet **173** from which extend two leads **188** and **189** which connect with terminals **183** and **186**, respectively, of a switch 2S.

Throttle pedal T has a throttle operating rod R carrying sliders **181** and **182** of the switch 2S. This switch also has upper contacts **184** and **190**, the latter of which is connected to ground. Contact **184** is connected to a lower contact **191**, while the other lower contact **185** is connected to the ground.

A battery **194** is connected to the ground at one terminal, and has the other terminal connected by way of lead **196** to an ignition switch **197** for the ignition system of the engine. Connected in series with the ignition switch **197** is a starter switch S controlling the flow of current through a lead **198** to starter motor **195** and also the circuit to energize terminals **184** and **191** of the switch 2S.

With the ignition switch **197** and starter switch S closed, the operation of the throttle pedal T to partially open the throttle will energize the electromagnet **173** by closing the circuit between contacts **183** and **184** with slider **181**, and contacts **185** and **186** with slider **182**. The final range of movement of the throttle pedal causes the sliders **181** and **182** to close the circuit from contact **183** to contact **190**, and from contact **186** to contact **191**, thereby reversing the flow of current through the electromagnet **173**.

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 **26a** which lead to the separate combustion chambers of the engine. These separate branches **26a** are, in turn, controlled by separate intake valves **26**. Since the parts of the air induction system (not shown) are conventional, no description or illustration is here included.

AIR MEASURING DEVICE

Within the air horn B is an air valve **37** fixed on a rotatable shaft **36**. The shaft is extended by dotted lines on either side of the air horn, and one end thereof carries one half of magnetic clutch **35**. The movements of the air valve **37** rotate the shaft **36** which, in turn, positions the fuel metering needles **33** through the interconnection of the magnetic clutch **35**. The opposite end of the shaft connects with a temperature responsive means **102** which has a free end **103** positioned to move into abutting relation with one end of a lever **100** fixed to the opposite end of the shaft **36**. The inner end of the thermostat **102** is carried in the slot in the hub of lever **101**

which is pivoted on the fixed structure of the air horn B. Piston **105** is connected with the free end of lever **101** by a link **104**. The piston **105** rides in a cylinder **106** and is operated therein by a spring **107** acting in one direction and by engine suction acting in the opposite direction. Line **108** connects between the bottom of the cylinder **106** and a suction port **116** in the air horn B downstream of the throttle **50**.

AIR FLOW SENSING MEANS

Connected with the air valve **37** is a link **39** which extends through the wall of air horn B and is attached to a diaphragm **40** which separates chambers **41** and **42** within a casing attached to the air horn B. A spring **43** acting against the back of the diaphragm **40** urges the valve **37** in a closing direction. An opening force on the valve is supplied from a servo-motor, which in turn is powered by the difference in pressures across the valve **37** as sensed by a vent tube **44** and a Pitot tube **45** connected with the chambers **41** and **42**, respectively, of the servo-motor. The underside of the leading edge of the air valve **37** has a deflector or spoiler **37*a*** fixed thereto. Below the air valve **37** is a throttle valve **50** mounted on a throttle shaft **51** and operated by lever **152** through a throttle linkage R from the accelerator pedal T. A slotted partition **49** extends between the throttle shaft **51** and the air valve shaft **36**.

The body of the air horn B has a by-pass passage **80** controlled by a metering screw **278**, which extends around the edge of the air valve **37** when in the closed position. By adjustment of this screw **278**, it is possible to vary the position of the air valve **37** in the low range of engine speeds at idle and slightly above. Since the air valve, in turn, controls the size of the fuel metering orifices **23**, it is obvious that this adjustment **278** provides a fuel mixture control in the low range of engine speeds by setting the position of the air valve and needles **33** in the metering restrictions **23**.

The air horn body B also has a by-pass **279** extending around the edge of the throttle **50** controlled by a metering screw **277**. This by-pass is operative when the throttle is closed to adjust the amount of air flowing to the engine, and, in this sense, controls the engine idling speed.

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; in other words, the pressure carburetor or injection system should perform a function of changing 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 contemplates the use of a means responsive to throttle opening for effecting a sudden movement of the air valve in an opening direction, which, in turn, withdraws the metering rods **33** from the orifices **23**, increasing the fuel flow to the nozzles **25**. This means, actually, causes air valve **37** to over-travel in response to throttle opening by applying forces thereto which act independently of, or augment, those forces regulating air valve position in response to the rate of air flow past the valve or the pressure drop across the valve.

One structure for accomplishing this result is shown in FIG. 1, wherein the air horn B is provided with an extension on the servo-motor casing divided into two chambers **125** and **126** by a diaphragm **127**. A spring **128** urges the diaphragm **127** in a direction to compress the air in chamber **125**. Chamber **126** is connected by a line **130** to the air horn B posterior of the throttle **50**, and is thereby subjected to manifold pressure. Chamber **125** is connected by a by-pass passage **129** to the chamber **41** of the servo-motor. The inlet opening to the chamber **41** from the vent tube **44** is controlled by a

leaf spring type of valve **200** ordinarily biased to the open position.

OPERATION OF MIXTURE CONTROL RESPONSIVE TO THROTTLE MOVEMENT

During operation of the engine with the throttle **50** within the range from closed to part throttle positions, sufficient suction is present posterior thereof acting in the chamber **126** to hold the diaphragm **127** in the position illustrated, with the spring **128** compressed. If the throttle is suddenly opened from any position within this range, suction in chamber **126** becomes insufficient to maintain spring **128** compressed so that spring **128** expands, forcing the air within the chamber **125** into the chamber **41**. The increase in pressure in chamber **41** closes leaf spring valve **200** and, at the same time, causes the diaphragm **40** to be flexed against the compression spring **43**, thereby forcing the air valve **37** to rotate in the opening direction beyond the normal position which it would take in response to the increasing rate of air flow through the intake stack B. This over-travel is a temporary matter, since there is always some leakage past the valve **200**, and the excessive pressure within the chamber **41** will eventually dissipate. It will be appreciated, however, that during the time in which the temporary high pressure prevails in the chamber **41**, valve **37** will over-travel in the opening direction, causing the needles **33** to withdraw from the metering orifices **23** to temporarily increase the fuel flow to the nozzles **25**.

PART THROTTLE AND FULL THROTTLE MIXTURE CONTROL

Most engines of the automotive type will operate satisfactorily on a leaner mixture in the part throttle range corresponding to road load operation than in the substantially full throttle range corresponding to the full load operation. For this reason, it is possible to go to the carburetor art for an analogy. For example, it is customary practice in carburetors to use stepping metering rods in the fuel metering orifices which are operated in response to changes in manifold pressure. The size of the fuel metering orifice is increased by proper rod movement, to enrich the fuel mixture throughout the range of engine speeds within the full open range of throttle positions.

The mechanism just described is usually referred to as a step-up in a carburetor. The corresponding function is performed in my prior application by a control in the datum pressure line. In the instant invention, the same function is performed by a means responsive to a condition indicating increases in load on the engine, which will act to increase the fuel flow to the engine. This means in the present invention accomplishes this function by changing the response indications of the air valve **37** to the rate of air flow through the air horn B. This mechanism is mounted on the air horn, or adjacent the air horn, and connected with the servo-motor in the following manner.

In the wall of the air horn anterior of the air valve **37** are a pair of ports **202** and **203** so placed that they are within a zone influenced by the passage of air between the wall of the air horn B and the edge of the air valve **37** when the latter is in a partially open position. These ports connect with a common passage communicating by way of a tube **205** with a chamber **206** in the casing **207**. A diaphragm **208** separates chamber **206** from chamber **210**. The diaphragm **208** is biased in one direction by a spring **211**, and carries a valve **212** which operates to and from a valve seat in a metered restriction at the entrance of tube **213**, which, in turn, connects with the chamber **42** of the servo-motor by way of the line extending from the Pitot tube **45**. Chamber **210** is connected with the air horn B posterior of the throttle **50** by a tube **209**. Suction posterior of the throttle is thereby communicated to the chamber **210** to compress the spring **211** and separate the valve **212** from its seat.

If there is insufficient suction in chamber **210**, the spring **211** will close the valve **212**.

OPERATION OF PART THROTTLE AND FULL THROTTLE MIXTURE RATIO CONTROL

In the part throttle range of engine operation, it can be assumed that engine intake manifold depression is always greater than six inches of mercury. Accordingly, spring **211** is calibrated in such a manner as to retain the valve **212** unseated, so that restricted amount of air bleeds from the ports **202** and **203** (when one or both are anterior of the air valve **30**) through the chamber **206** and line **213** to modulate the suction in chamber **42** sensed by the Pitot tube **45**. The power exerted by the servo-motor on the air valve **37** and against the spring **43** is thereby reduced an amount which will cause a substantial pressure drop in the air horn B across the valve **37**. In other words, the opening movement of the air valve **37** is somewhat restricted by the operation of the bleed from the ports **202** and **203**, and the position which the air valve **37** assumes, results in a displacement of the needles **33** in the orifices **23** only sufficient to give a mixture proper for part throttle, road load operation of the engine.

After the air valve **37** reaches a substantial open position within the range of 55° or 60°, however, ports **202** and **203** are posterior of the valve and within the high velocity air stream which will be passing between the side wall of the air tube B and the deflector **37a** on the air valve **37**. This drop in pressure, due in part to the high velocity stream, can either cut off or substantially reduce the flow of air through the ports **202** and **203**, and consequently the amount of air bled past the valve **212** and through line **213** to chamber **42**. When the air bleed through ports **202** and **203** is stopped, the servo-motor exerts a greater force on the air valve **37** directly proportional to the drop in pressure measured by the Pitot tubes **44** and **45**, thereby opening the air valve **37** to decrease the drop in pressure across the valve **37**. The response of the air valve causes the needles **33** to move out of orifices **23** sufficiently to provide the power range of fuel mixtures necessary. Generally, this occurs in the higher ranges of engine speed and throttle openings.

At any engine speed, throttle opening which decreases manifold suction to less than the arbitrarily selected example of six inches of mercury causes spring **211** to expand, closing valve **212** and cutting off the bleed from the ports **202** and **203** so that the air valve assumes a position under control of the drop in pressure measured between the Pitot tubes **44** and **45** exclusively. The pressure drop across the valve **37** thereby becomes minimum, and the angular displacement of the valve is increased to withdraw the needles **33** and give increased fuel delivery (corresponding to a full power mixture). Conversely, the reverse operation occurs if the throttle is closed at any engine speed.

From the above described operation, it will be readily understood that the air valve **37** may take up two distinctly different positions for the same rate of air flow. The smaller amount of displacement will occur in the part throttle range of operation of the engine so long as manifold suction indicates low engine loads. Larger displacements of the valve **37** will occur as soon as the valve opening exceeds 55° or 60°, or if the throttle is opened wide enough to decrease the manifold suction below some arbitrary point such as, for example, the intake manifold depression of six inches mercury pressure mentioned.

It is contemplated that the contour of the needles **33** is such that the displacements produced by the air valve **37** when the engine is operated throughout its speed range at full throttle will give the proper fuel flow through the orifices **23** to match the fuel-air ratios demanded by the engine at full load. This means that the part throttle mixture ratios delivered by lesser displacements of the air valve **37** for the same rate or air flow produce lesser displacements of the needles **33** in the orifices **23**. The de-

ree of change in needle displacement can be suitably controlled by calibration of the ports **202** and **203**, by variations in port location and size. Obviously, these ports can e placed in such a relation to the air valve **37** as to be ithin the influence of the air stream passing between ie wall of the air horn and deflector **37a** at any point in ie opening movement of the air valve. Thus the ports an be progressively subject to a zone of low pressure adcent the deflector **37a**, which zone will progressively ass over the ports as the air valve **37** opens. Accordingr, the pressure at the ports **202** and **203** is a variable epending upon air valve displacement.

The shape of the part throttle fuel mixture curve can e determined arbitrarily by a change in location and ze of the ports, and this calibration is flexible over a ibstantial portion of the range of opening movement of ie air valve **37**.

OPERATION OF FUEL INJECTOR

To start the engine, it is first necessary to close the nition switch **197** and then crank the engine by closing ie starter switch S, which, incidentally, energizes the ntacts of switch 2S. When the engine is below normal erating temperature, thermostat **102** will wind up exerg a force on the lever **100**, so that when the throttle is irtly open, as is proper during a cold start, the air valve can open in response to thermostat action and increase e amount of fuel delivered to the engine. After the igine starts, manifold suction acting on the piston **105** ill decrease the opening movement produced on the air ilve **37** by the thermostat **102** so as to reduce the fuel ixture ratio to that proper for warm-up. The force erted by the thermostat **102** decreases as the engine mperature increases until, at normal engine temperares, the end **103** moves out of contact with the lever **0**, leaving the air valve free to be controlled by the rvo-motor. The action of the thermostat **102** on the air ilve **37** affects the displacement of the air valve **37** with spect to air flowing through the air horn B and in a rection to withdraw the needles **33** from the orifices **23** d increase the fuel mixture ratio during cranking and arm-up.

The throttle pedal T also can be opened far enough, if eded, to prime the engine with excess fuel regardless of e action of the engine temperature controlled enrichent produced by the above-described mechanism. The iming operation is accomplished during cranking by ening the throttle part way to close the switch 2S. In is throttle position or range, contacts **183** and **184** are osed by the slider **181**, and the contacts **185** and **186** are osed by the slider **182**. This energizes the electromagnet **3** in the pressure regulator **60**, applying a force to the rmanent magnet **172** to compress the spring **180** and ver the pressure tending to close the valve **167**.

When the force of spring **180** is reduced by the action the electromagnet, the regulated pressure maintained the pressure regulator **60** is reduced, and the pressure ferential across the metering restriction **61** increases by corresponding amount.

During normal operating conditions of the system, the essure in the datum system is controlled by the regula- C, and the presence of the metering orifice **58H** has effect upon the function of the regulator C because of very small amount of flow permitted by the coaction the orifice **61** and the regulator **60**. The orifice **61** is smaller of the two flow restrictions **58H** and **61**.

As will be apparent, the basic datum system has two w metering restrictions, **58H** and **61**, in series, operating a controlled pressure drop between regulator C and gulator **60**. With two or more fixed restrictions in ies, a certain amount of metering will be done by all so ig as there is a measurable pressure drop across each triction. Also, there is less metering done at the larger triction. Consequently, metering requires a pressure op.

In this system, restriction **58H** is larger than restriction **61**, and at normal flow there is no measurable pressure drop across the restriction **58H**. If the flow through the datum system is increased, the pressure drop across **58H** becomes significant. In other words, the more the flow, the greater the pressure drop and the greater the metering effect of restriction **58H**.

When rates of flow through the orifice **61** increase above normal, there will be a substantial increase in the pressure drop across the orifice **58H**, lowering the pressure in the datum system to increase the flow through the nozzles **25** by increasing the pressure drop across the metering orifices **23** which provide the metering in the engine charging system. During the priming operation, however, the function of the pressure regulator C to establish a fixed datum pressure is modified by the action of the orifice **58H**. The metering effect of this orifice prevents the regulator C from maintaining the pressure when the flow in the system is increased by lowering the pressure downstream or orifice **61** to reduce the back pressure maintained by regulator **60** as above described.

When the engine starts, the starter switch is opened, thereby de-energizing the circuit to the electromagnet **173** in the pressure regulator **60**. This builds up the pressure downstream of the metering restriction **61**, decreasing the rate of flow to the normal, which is about 3½ pounds an hour. At this low rate of flow, there is no measurable pressure drop across the metering restriction **58H**, and the pressure in the datum system will increase to the setting of the pressure regulator C. Flow through each of the nozzles **25** will decrease as the datum pressure increases, raising the pressure downstream of the metering orifices **23**. Thus, under normal operation of the system, the pressure drop across the metering orifices **23** becomes the same as the pressure setting of the regulator C, and is maintained constant by this regulator.

If, during the starting of the engine, the combustion chambers are flooded so that unloading is necessary, then the throttle T is fully opened so that the switch 2S closes the circuit between contacts **183** and **190** and **186** and **191** to reverse the flow of current through the electromagnet **173**, changing its polarity. This effects a new relation between the electromagnet **173** and the permanent magnet **172**, placing like poles opposite, and produces an added force augmenting the force of the spring **180**, both forces acting in the direction to close the valve **167**. The pressure downstream of the metering restriction **61** will be increased, and this effect will be felt throughout the datum system, since when flow stops in the datum line **58**, the pressure will increase, tending to close the valve **75** in the regulator C and open the valve **76**. However, the closing of valve **167** will prevent discharge through the line **79**, tending to lower the datum pressure, so that the datum system becomes more or less a sealed system at a higher pressure than normal to effectively close the nozzle valves **25** and shut off the flow of fuel to the engine.

During cranking and running of the engine, pump P will be operating, delivering fuel through the pressure regulator **22** into the fuel chamber A. The metering of the fuel is accomplished by varying the area of the metering orifices **23** in the fuel chamber A, and these variations in area are accomplished simultaneously and equally by a plurality of metering rods **33** controlled from the position of the air valve **37** through the magnetic clutch **35**. As above explained, the air valve **37** will assume positions indicating the rate of air flow to the engine for both the part throttle and full throttle range of engine operation, depending upon engine load.

In this system, the pressure drop across each of the orifices **23** is maintained equal by regulating nozzle valves **25** which are primarily controlled by the pressure regulator C, which is supplied with fuel at chamber pressure A through the line **56**. The action of the pressure regulator C is such that a constant pressure difference is main-

tained between the pressure in line **56** and in the datum system line **58**, regardless of engine operating conditions or pump pressure fluctuations. Only during cranking is the datum pressure variable. The construction of the pressure regulator C is such that the charging pressure in line **56** tends to open the valve **75** of the regulator, while back pressure from the datum system through the line **58a** and connection **59** tends to close the valve **75**. The difference between the charging pressure and the datum pressure is actually controlled by the spring **74** biased against the effective area of diaphragm **71**.

As described above, the effect of sudden throttle opening on the system increases the flow of fuel through each of the lines **24** by withdrawing the needles **33** and increasing the size of the metering orifices. This action is due in part to the over-travel produced on the air valve **37** by the pumping action of the diaphragm **127** and in part to increase air flow. The increase in the rate of fuel flow through the lines **24** causes an increase in fuel pressure in chambers **30**, which moves the diaphragms **28** in each of the nozzles in a direction to displace fuel from chambers **57** on the opposite sides of the diaphragms into the datum pressure system, and primarily into line **58**. Unless provision is made in the system to accommodate the fuel displaced by each of the diaphragms **28**, there will be an instantaneous pressure rise in the datum system which will resist instant opening of nozzle valve **29**, and throttle response of the engine will be adversely affected by the lag in the nozzle valve action.

It is a feature of this invention to compensate for this condition by the valve **76** connecting with the pressure relief by-pass line **79**, for conducting any excess fuel from the datum system to a point downstream of the centrifugal metering jet **61**.

Thus, any instantaneous pressure increase in the datum line **58** is compensated for by the fact that diaphragm **71** will respond, opening relief valve **76** to discharge fluid from line **58** and thus prevent the build-up of back pressure caused by the displacement of the diaphragms **28**.

From this description of the operation it will be readily understood that there is a definite cooperation between the action of the pressure regulator C and the mechanism in the air horn structure controlling the displacement of the air valve **37**, although these devices are controls located in separate systems incorporated in the device.

FIRST MODIFIED FORM

In the form of the invention heretofore described, the pressure regulator C in the datum pressure system is located upstream from each of the nozzles **25**, but this location is not critical to the proper functioning of the system. Actually, the pressure regulator C may just as well be located downstream of the nozzles **25** in the datum pressure system, and yet, in this location, perform in the same manner to produce a similar result.

FIG. 2 illustrates a variation of the combination of elements shown in FIG. 1 in which the pressure regulator C is actually located downstream of the injection nozzles in the datum pressure system.

In FIG. 2 the same reference characters have been used to indicate like parts corresponding with those shown and described in FIG. 1. The detailed description which follows will emphasize the differences between the systems of FIG. 1 and FIG. 2, which differences are confined to the datum pressure system. It is believed that the preceding description will serve to explain the construction and operation of other parts of the system illustrated in FIG. 2.

According to FIG. 2, the datum pressure system is connected to the pressure chamber A by a line **58**, and communicates therewith by way of a suitable metering restriction **55**. As will be pointed out hereinafter, restriction **55** permits a continuous circulation from the chamber A through the datum pressure line to eliminate the accumulation of air or vapors therein, or to remove any air or vapors trapped therein in case the fuel supply fails. If the fuel tank of the vehicle goes dry, some provision must be made to bleed the system of air.

The datum pressure line **58** has branches **58a**, **58b**, **58c** and **58d**, each of which connects with the datum pressure chambers of the nozzles **25**. Adjacent the outlet of the line **58** is the pressure regulator C, which is of the same construction as that heretofore described. The pressure in the line **58** is imposed against a diaphragm **71** of the pressure regulator C. The opposite side of the diaphragm communicates with the pressure downstream of the regulator **22** by way of the line **56**, which has the same pressure as **20a** and chamber A. Branch **59** connects the line **58** with the chamber of the pressure regulator C downstream of valve **75** and extends from this chamber to the metering orifice **61**. A line **79** connects the outlet of the pressure regulator relief valve **76** with a restricted passage **163** leading to the outlet valve **167** of the pressure regulator **60**. The construction of the pressure regulator C is identical with that above described.

OPERATION OF MODIFIED FORM

In this modification, it is preferred to make the metering orifice **55** smaller than the metering orifice **61**, and of less capacity. When this relationship exists, the datum pressure is actually under control of the regulator C, which opens the valve **75** slightly, under normal conditions, to raise the datum pressure in the line **58** to the desired differential between the chamber and line **58**. The diaphragm **71** is balanced by the force of charging pressure from the line **56** on one side, and datum pressure plus the force of the spring **74** on the opposite side, so that the difference between charging pressure and datum pressure is determined by the force of the spring **74**. Under steady conditions, the diaphragm **71** will take up a position opening the valve **75** slightly so that fuel will be flowing into the datum system through both the orifice **55** and the valve **75**.

If the datum pressure in line **58** should increase for any reason, such as the rapid withdrawal of the needles **33**, which would cause the opening of the valves **25** and displacement of the diaphragms **28** therein, the pressure regulator C will react, closing the valve **75** and opening the valve **76** to bleed the pressure rapidly from the datum pressure line **58** through the line **79** into the chamber **164** of the pressure regulator **60**. As before explained, the effect produced on the pressure regulator **60** opens the valve **167** thereof, dropping the pressure downstream of the metering restriction **61**. This effect produces a lowering of the datum pressure throughout the entire datum pressure system by increasing the discharge through the metering restriction **61** so that fuel can escape. At this point it should be noted that the restriction **163'** in the passage **163** will cause a delay in the pressure drop in chamber **164**, and this delay may be regulated by proper calibration of this restriction. By variations in restriction size, the downstream pressure drop can have more or less an instantaneous effect upon the system, or a prolonged effect.

As has been explained heretofore, when the pressure drop across orifice **61** increases, the flow therethrough increases, which makes the restriction **56'** more effective as a pressure control. A greater drop across **61** causes a greater drop across orifice **58'** and lowers the datum pressure, increasing the flow from each of the nozzles **25**. This increase in flow increases the mixture ratio temporarily for acceleration of the engine. If the particular engine requires a prolonged enrichment for satisfactory performance, then the restriction **163'** placed in the passage **163** may be suitably selected to attain this purpose.

For other engines having different characteristics, it may be desirable to have the enrichment of the mixture take place over an extremely short period of time. In such a case, it may not be desirable to prolong the pressure drop in the datum system by increasing the discharge

therefrom through the metering restriction **61**, as heretofore described. For such an engine, a different system is proposed which includes a different interconnection between the same parts of the system as above described. Such a system is shown in FIG. 3.

SECOND MODIFIED FORM

In the system illustrated in FIG. 3, the same reference characters have been used, where possible, to indicate like parts, and the description thereof will be limited to the differences in the interconnections between the parts.

According to FIG. 3, the pressure regulator C is connected by a line **79** directly with the inlet of the pump P, line **19**. In the line **79** is a solenoid valve SV powered by a circuit **199** energized on closing of the ignition switch **197**. The valve is retained open when the engine ignition switch is on, and a spring **245** closes the valve when the ignition is turned off.

OPERATION OF FIG. 3

In this system, the operation of the pressure regulator C produces no delaying effect upon the pressure regulator C produces no delaying effect upon the pressure regulator **60**. Consequently, the action of the two regulators C and **60** is distinct. The regulator C will retain the pressure in the line **58** in the same manner as above described, and further respond to any increase in pressure in the datum pressure line **58** to relieve this pressure through the valve **76** so long as the engine is operating. The opening of the valve **76**, however, will produce very little fluctuation in the datum pressure line **58**. In this system, its function is primarily to prevent the pressure therein from exceeding the fixed or regulated pressure established by the diaphragm **71**. What slight lowering of the pressure does occur below the regulated pressure will be very short in duration. In this respect its action differs from the prior described devices.

When the engine is shut off by turning off the ignition switch **197**, solenoid valve SV will close so as to prevent any bleed-down in the datum pressure line **58**.

MODIFIED FORM OF FUEL MIXTURE CONTROL REGULATION FOR ACCELERATION

In the description of FIG. 1 a means was described to obtain solid throttle response of the engine. This means was likened in result to the effect of an accelerating pump in a carburetor. In FIG. 4 is shown a modified form of such a device which is mechanically actuated from the throttle, instead of pneumatically actuated from manifold pressure.

In FIG. 4 the same reference characters have been used to indicate like parts, and this description will be limited to the modified form of the device operating to attain this result. The throtle operating shaft **51** carries a fixed lever **235** connected with a rod **234** which extends within a tube **233**, which guides the rod **234** during movement of the throttle from open to closed positions. The tube **233** is attached to a diaphragm **231** in a suction pump casing **230**. The rod **234** is not solidly attached to the diaphragm, and actually forms a one-way operating connection for forcing the diaphragm **231** against the pressure of a spring **232** when the throttle is moved in the closing direction. Opening movement of the throttle withdraws the rod **234** within the tube **233**, permitting the spring **232** to expand, moving the diaphragm **231** to the left.

The movement of the diaphragm **231** to the left produces a depression within the diaphragm chamber of the pump **230**, which is communicated by way of the line **236** controlled by restriction **237** to the suction chamber **42** of the servo-motor for operating the air valve **37**. A second line **238** connects the pump chamber to the servo-motor chamber **42**, and is controlled by a check valve **239**, which closes in response to the action of the pump **230** when the throttle is opened, and opens when the throttle is returned.

The connection between the Pitot tube **45** and lead line **213** with the servo-motor chamber **42** is controlled by a one-way check valve **240** which opens when the pressure in the lines **213** and **45** is less than in the diaphragm chamber **42** of the servo-motor. The check valve **240** is here illustrated as a ball valve and is designed to have a slight leakage when closed, due to the fact that the depression in the chamber **42** is less than in the connecting lines **213** and Pitot tube **45**, but it is contemplated that a flat check valve may be used at this point actuated in the same manner by the same differential pressures and provided with a metered hole, if desired. The size of that hole will control the duration of over-travel of the air valve **37**, as will be explained hereinafter.

OPERATION

In this modification, opening movement of the throttle **50** by operation of the throttle control arm **152** connected with the throttle pedal T permits expansion of the spring **232** and movement of the diaphragm **231** to the left, as viewed in FIG. 4. Since the check valve **239** is closed, diaphragm movement creates a depression within the suction pump **230** which is communicated by way of the line **236** to the chamber **42** of the servo-motor controlling the air valve **37**. The strength of the spring **232** is sufficient to produce an action of the diaphragm **231** which is rapid, and which will close the check valve **240** so that the pumping action will be communicated directly to the chamber **42** to affect air valve position by increasing the differential pressure across the diaphragm **40** of the servo-motor. As the valve **37** opens in response to the action of the pump **230**, metering needles **33** will be withdrawn to increase the flow of fuel to the nozzles **25** and thereby increase the mixture ratio by supplying a greater amount of fuel to the engine. The duration of this effect, as well as the rate of response of the air valve **37**, can be easily controlled by adjusting the leakage past the check valve **240** and the size of the restriction **237**. As above mentioned, if a disk valve is used, it can be formed with a hole for metering the leakage past the valve **240**.

When the throttle **50** is closed by removing pressure from the throttle pedal T, a return spring in the linkage moves the throttle toward closed position until the rod **234** begins to force the diaphragm **231** to the right, forcing the air trapped in the diaphragm chamber of the pump **230** out of the chamber through the lines **236** and **238**. Since both lines **238** and **237** can open, the rate of closing movement of the throttle is not substantially retarded, and the effect on the servo-motor is rapid. In all other respects, the modification in FIG. 4 is constructed and operates in the manner already described above with reference to FIG. 1.

The foregoing describes a structure which will perform all of the functions and attain all of the results set forth above, but it is contemplated that other modifications will occur to those skilled in the art which come within the terms of the appended claims.

I claim:

1. 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 valve in said air stream, a servo-motor for moving said valve in an opening direction, and a source of power for operating said servo-motor in response to changes in the rate of flow in the air stream past said valve so that changes in air valve position produced by said servo-motor indicate a measure of the rate of air flow to the engine, a throttle valve in the air stream for limiting the flow of air to the engine, and means responsive to throttle movement connected to said servo-motor for temporarily changing the power output of said servo-motor and thereby the rate of

response of said air valve to changes in the rate of air flow past said valve.

2. 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 means for measuring the flow of air to the engine, said means including a member movable in the air stream in response to variation in the rate of air flow to the engine, means for measuring the flow of fuel to the engine, a connection between said measuring means to maintain the flow through each stream proportional to the other, a throttle valve in the air stream for limiting the rate of air flow, and means connecting said movable member with said throttle and operated by said throttle for temporarily and suddenly changing the proportions of fuel flow to air flow during throttle movement.

3. 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 valve in said air stream, a servo-motor for moving said valve in an opening direction, a source of power for operating said servo-motor in response to changes in the rate of flow in the air stream so that changes in air valve position indicate a measure of the rate of air flow, means for measuring the flow of fuel to the engine, a connection between said measuring means to maintain the flow through each stream proportional to the other, a throttle valve in the air stream for limiting the flow of air to the engine, and means connecting said fuel metering means and said throttle for temporarily and suddenly changing the proportions of fuel flow to air flow during throttle movement.

4. 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 valve in said air stream, a servo-motor for moving said valve in an opening direction, and a source of power for operating said servo-motor in response to changes in the rate of flow in the air stream so that changes in air valve position indicate a measure of the rate of air flow, means for measuring the flow of fuel to the engine, a connection between said measuring means to maintain the flow through each stream proportional to the other, a throttle valve in the air stream for limiting the flow of air to the engine, and means responsive to throttle movement for temporarily changing the proportions of fuel flow to air flow by modifying the source of power supplied to said servo-motor.

5. 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 valve in the air stream, a servo-motor for operating said valve in an opening direction, means for operating said servo-motor in response to changes in pressure differential in the air stream across said valve, whereby the position of the valve in the air stream becomes a measure of air flow to the engine, means for measuring the flow of fuel to the engine, a connection between said measuring means to maintain the flow through each stream proportional to the other, a throttle in the air stream for limiting the air flow to the engine, means connected to said servo-motor comprising an air bleed passage, and inlet ports for said passage located in the air stream adjacent the opening edge of one of said valves.

6. 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 valve in the air stream, a servo-motor for operating said valve in an opening direction, means for operating said servo-motor in response to changes in pressure differential in the air stream across said valve, whereby the position of the valve in the air stream becomes a measure of air flow to the engine, means for measuring the flow of fuel to the engine, a connection between said measuring means to maintain the flow through each stream proportional to the other, a throttle valve in the air stream for limiting the air flow to the engine, and means connected to said servo-motor and operated by changes in pressure downstream of the throttle including a suction operated valve to modify the action of said servo-motor, an air bleed passage controlled by said valve and connected to said servo-motor, and inlet ports for said passage located in the air stream adjacent the opening edge of said air valve.

7. 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 the rate of air flow therethrough within a given range in the higher range of engine speeds and throttle openings, means to modify the response of said air valve to the rate of air flow at different engine speeds and lower range of throttle openings, 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 throttle operated means for temporarily varying the response of said air metering means.

8. 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 throttle valve 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, 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 deflector surface on the leading edge of said valve relative to the direction of air flow to said engine, said deflector surface being positioned on said valve to coact with the air stream and the wall of said inlet so as to modify the slope of the curve representing opening torque for the valve, a motor connected to operate said valve to vary the opening area of said air flow restriction, a means sensitive to velocity of 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 velocity sensed, means responsive to throttle opening for effecting a sudden movement of the air valve in an opening direction, and fuel metering means in said branches operated by change in position of said valve.

9. 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 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, and a system for maintaining the flow of fuel proportional to the flow of air, said system comprising: a disk valve in said inlet anterior of said throttle, a pivot about which said valve is hinged for swinging movement to form a variable air flow restriction in said inlet, a deflector surface on the leading edge of said valve relative to the direction of air flow to said engine, said deflector surface being positioned on said valve to coact with said air stream and the wall of said inlet so as to modify the slope of the curve representing opening torque for the valve, a motor connected to operate said valve to vary the open area of said air flow restriction, a means sensitive to the pressures in the air stream passing the valve and operative in response to

throttle movement for controlling the source of power for operating the servo-motor to determine the position of said valve in the air stream in response to changes in pressures sensed, means connected with said motor and operated by changes in load on said engine for modifying the action of said motor, and fuel metering means in said branches operated by changes in position of said valve.

10. In an engine fuel charging system of the pressure type 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, a datum pressure system including a by-pass extending around said pump, and 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 controlled pressure in said datum system, the combination therewith of means for establishing a controlled pressure in said dataum system at a fixed differential with respect to said pump supply pressure, a datum pressure relief passage from said control means, and means responsive to a pressure increase in said established datum pressure from said fixed differential for opening said pressure relief passage.

11. In an engine fuel charging system of the pressure type 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, a datum pressure system including a by-pass extending around said pump, and 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, the combination therewith of means for establishing a controlled pressure in said datum system proportional to the fuel supply pressure comprising a metering restriction in said by-pass downstream of said pressure regulator, means controlling the pressure drop across said metering restriction, a datum pressure relief passage by-passing said restriction, and means responsive to a pressure increase in said datum pressure system from said established proportional pressure for opening said pressure relief passage.

12. In a fuel charging system of the pressure type 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, a datum pressure system including a by-pass extending around said pump, and 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, the combination therewith of means for establishing a controlled pressure in said datum system at a relative differential with respect to said fuel supply pressure, said means comprising a metering restriction in said by-pass passage, means for regulating the pressure upstream and downstream of said metering restriction, a pressure relief by-pass extending around said metering restriction to the inlet of said pump, means responsive to a pressure rise in said datum system from said established differential pressure for closing the supply of fuel to said datum system and for opening said relief by-pass passage, and means in said datum system for limiting the rate of pressure rise therein.

13. In an engine fuel charging system of the pressure type 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, a datum pressure system including a by-pass extending around said pump, and 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, the combination therewith of means in said datum system to accommodate fuel displaced by movement of said movable wall during valve opening to increase the fuel supply to the engine, said means comprising a second pressure regulator in said datum system supplied with fuel from said pump and controlling the pressure in said datum system, a datum pressure relief line connecting said second pressure regulator with the intake of said pump, and valve means in said second pressure regulator for closing the supply thereto and opening the relief passage thereof in response to increases in pressure in the datum system beyond the pressure setting of said second pressure regulator.

14. In an engine fuel charging system of the pressure type 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, a datum pressure system including a by-pass extending around said pump, and 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, the combination therewith of means for establishing a controled pressure in said datum system proportional to the fuel supply pressure comprising a metering restriction in said by-pass passage, means for regulating the pressure upstream and downstream of said metering restriction, a pressure relief by-pass by-passing said metering restriction and extending between said means for regulating the pressure upstream and downstream thereof, means responsive to a pressure rise in said datum system for closing the supply of fuel to said datum system and opening said relief by-pass passage, and a connection between said relief by-pass passage and said downstream regulator operating to communicate upstream pressure thereto to cause a pressure drop downstream of said metering restriction and a decrease in the datum pressure.

15. In an engine fuel charging system of the pressure type 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, a datum pressure system including a by-pass extending around said pump, and 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, the combination therewith of means for establishing a controlled pressure in said datum system at a substantially fixed differential pressure with respect to the fuel supply pressure, said means comprising a metering restriction adjacent the outlet of said by-pass passage, a second metering restriction of greater capacity adjacent the inlet of said by-pass passage, means for regulating the pressure upstream and downstream of said metering restrictions, a pressure relief by-pass connected between said datum pressure system upstream of said metering restrictions to the inlet of said pump, means responsive to a pressure rise in said datum system for closing the supply of fuel to said datum system and opening said relief by-pass passage, and a connection between said relief by-pass passage and said downstream regulator op-

erating to communicate upstream pressure thereto to cause an increase in pressure drop at said downstream metering restriction and a decrease in datum pressure.

16. A charge forming device for an internal combustion engine comprising an induction passage, a throttle valve rotatably mounted in said induction passage, an air valve rotatably mounted in said induction passage anteriorly of said throttle valve, a servo device operatively connected to and adapted to control the position of said air valve in accordance with the pressure drop across the air valve, conduit means for supplying fuel to said induction passage, means operatively connected to said air valve for controlling fuel flow through said conduit means, and engine temperature responsive means for varying the degree of opening of said air valve during engine idling conditions.

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