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ENGINE FUEL CONTROL

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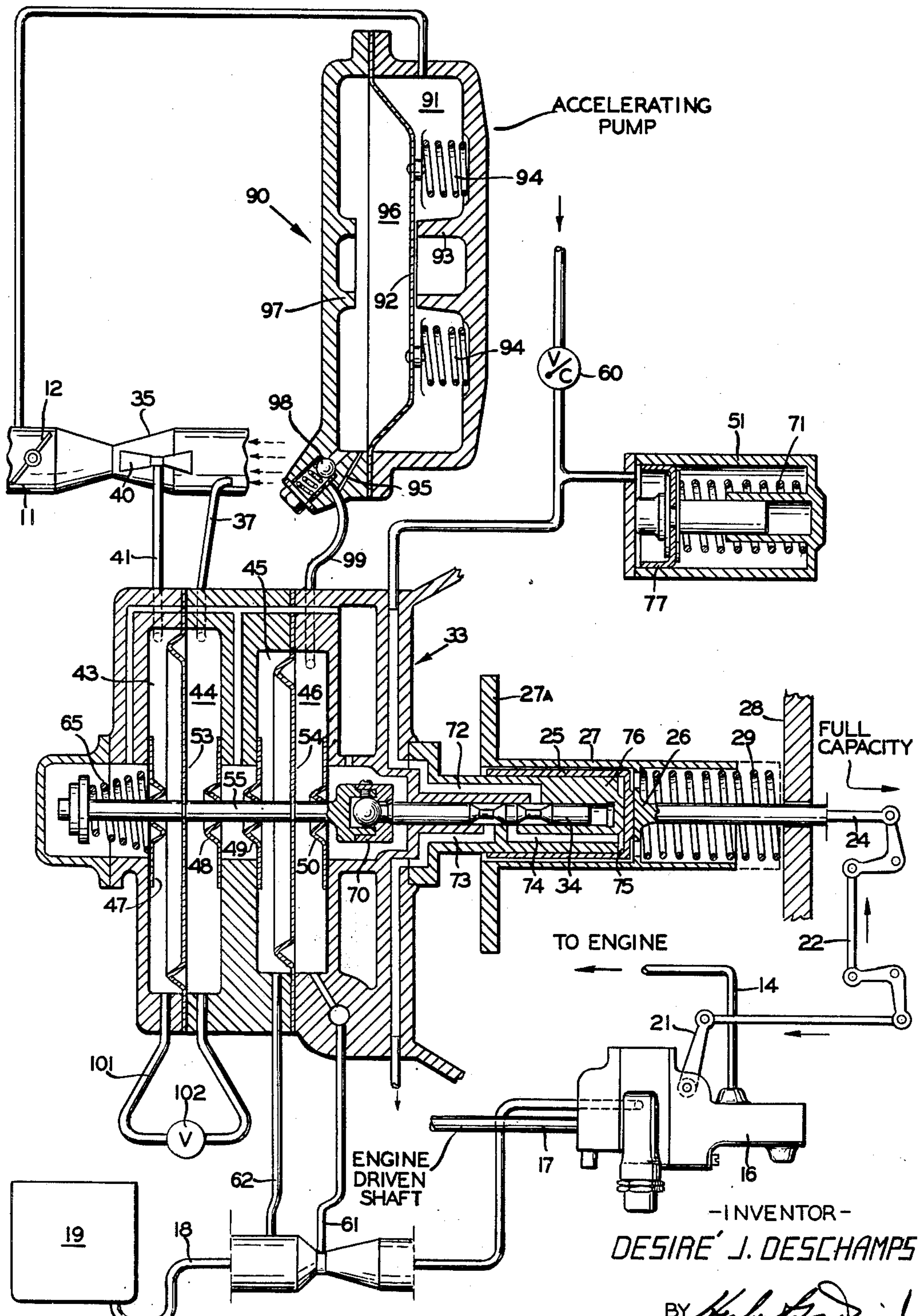

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ENGINE FUEL CONTROL

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Continuation of application Serial No. 348,925, July 31, 1940. This application June 11, 1946, Serial No. 675,981

10 Claims. (Cl. 123—139)

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This invention relates to internal combustion engines, and particularly to the control of the mixture of air and fuel, for combustion of the latter. The present application is a continuation of my copending application Serial No. 348,925 filed July 31, 1940, now abandoned, and assigned to the Bendix Aviation Corporation.

Structural features of the regulator per se disclosed herein have been claimed in a copending divisional application Serial No. 226,969, filed May 18, 1951, by Desire J. Deschamps and assigned to Bendix Aviation Corporation.

While the invention is disclosed herein in an embodiment which involves an engine of the fuel injection type, it will be apparent, to those who examine the disclosure, that the inventive concept, at least in certain phases thereof (as will appear) is applicable to engines having other means of delivery of fuel in the combustion chambers.

An object of the invention is the control of the ratio between the air and fuel quantities, by the use of novel means operating to maintain said ratio constant (during periods when constancy is desirable) by causing, on the one hand, the maintenance of fuel flow at a constant rate, for a given air flow; and, on the other hand, by causing the rate of fuel delivery to vary automatically in response to every variation in the rate of air delivery; the air delivery being measured in terms of "mass air flow" and therefore lending itself to accurate maintenance of a constant ratio, notwithstanding possible variation in the density of the air. In other words, the "mass air flow" principle is adhered to by causing the ratio maintaining apparatus to respond to every variation in air supply, whether such variation is due to a manually effected change in throttle setting or to an air density variation, or to a combination of both such causes. The system disclosed also operates to vary the fuel/air ratio in response to variations in power output, engine speed and altitude in accordance with the engine requirements set forth by the engine manufacturers, wherefore the fuel/air ratio will follow a given curve.

As already indicated, one object is to provide the ratio maintaining apparatus with the capacity to respond not only to air supply variations but also to every variation in fuel delivery rate, as distinguished from air supply rate. For example, in the event of a pressure drop at the outlet of the fuel transfer pump or at any other point in the path leading to the fuel injection pump, the invention includes the concept of causing the resulting drop in fuel delivery rate to be reflected in the ratio maintaining apparatus in such manner as to cause said ratio maintaining apparatus to move automatically to produce an offsetting increase in the fuel delivery rate; thereby restoring the predetermined constant fuel-air ratio. Conversely, the invention further includes the concept of producing an off-setting decrease in the fuel delivery rate in case the output of the injection pump should increase for any reason, as, for example, an increase in the pressure of the fuel delivered by the fuel transfer pump, or a momentary disturbance in the output control mechanism of the fuel injection pump itself.

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An additional object is to provide a ratio maintaining device embodied in a hydraulic servo-unit, and utilizing, as one of its actuating media, oil derived under pressure from the engine oil supply lines. In this connection a feature of the invention is the provision of means for maintaining the apparatus supplied with oil under a predetermined pressure even during those periods when the engine oil pressure is less than sufficient for such purposes. Thus there is assured an automatic maintenance of the proper fuel-air ratio notwithstanding occasional deenergization of the engine oil supply.

Another feature of the ratio maintaining apparatus is the embodiment therein of the concept of overbalancing the apparatus during idling and rest periods in the engine's operation, wherefore there is assured a relatively rich mixture during idling periods, and a mixture of maximum richness at the moment of resumption of engine operation, following a shut-down. In the embodiment illustrated, said overbalancing means depends, for its operativeness, upon the feature described in the preceding paragraph (namely, the feature of maintaining a predetermined oil pressure in the system, even while the engine is at rest); but it also includes elements additional to—and coacting with—those which embody said pressure maintaining feature.

The invention further provides for adjustment of the system (as, for example, during flight of an aircraft) by substitution of a new ratio (within predetermined limits) for the one previously maintained whenever a leaner or richer mixture is desired; such adjustment to be brought about manually or by operation of altitude controlled means.

Another feature of the invention is the ability of the ratio maintaining apparatus to vary its own action automatically—and without resorting to additional apparatus in the fuel intake line—

to the extent of temporarily producing a richer ratio of fuel-to-air for a brief period following any movement of the air induction control valve ("throttle") in the engine accelerating direction; such action thus producing the same ultimate result as has been produced in the prior art by the use of separate accelerating pumps which deliver an additional quantity of fuel to the fuel intake line, over and above that which is delivered in the normal manner. In reducing, to a concrete exemplification, this novel concept of equipping the ratio maintaining apparatus with the power to increase the predetermined ratio of fuel-to-air, temporarily, and then reestablish said predetermined ratio, I do so in such a manner as to protect the engine against the danger of stalling. In the prior art types of accelerating devices there has been this danger of stalling, due to the possibility that the pilot might "throttle down" the engine immediately after having opened the throttle wide; in which event the sudden decrease of fuel frequently left the previously delivered abnormal supply of air in a condition to interfere with proper combustion of the suddenly decreased quantity of fuel. Such a danger is avoided by my use of compensating means, inherent in the ratio control apparatus itself, which tend to delay the decrease of fuel supply for a brief period following each "throttling down" movement of the air control valve.

Another object of the invention is to enable the pilot merely by a sudden opening of the throttle, momentarily to increase the fuel-air ratio to cause the engine to accelerate quickly, the automatic fuel-air ratio control mechanism immediately thereafter assuming control of the mixture.

Other objects and features of the invention will become apparent upon examination of the following specification and the accompanying drawing wherein is shown schematically the preferred embodiment thereof. It is to be understood, however, that the drawing is merely illustrative of the invention and that it is intended to cover equivalent embodiments falling within the invention scope as defined in the appended claims.

In the drawing there is shown a conduit **11** adapted to supply air flowing in the direction of the arrows to the combustion spaces of an internal combustion engine, the amount of air supplied being controllable by an operator-operative throttle means or by manual operation of the throttle indicated at **12**, said throttle being shiftable about its central pivot shaft which extends to the exterior of the conduit and is adapted to be turned through a suitable linkage, not shown, to which the pilot or other operator of the engine will have access.

Fuel may be injected or otherwise supplied to the combustion spaces of the engine by suitable connections, not shown, leading from the outlet pipe **14** of the fuel injection or fuel delivery pump **16**, the latter having a drive shaft **17** rotatable by and in timed relationship with the crankshaft or other rotatable part of the engine, not shown. Fuel may be supplied to the pump **16** by a fuel conduit **18** leading (either directly, or by way of a transfer pump, not shown) from the tank **19** constituting the fuel source. The pump **16** may be of any suitable type but is shown herein as being of a construction embodying a novel type of variable delivery control, as described in greater detail and claimed in U. S. Patent No. 2,243,374 granted May 27, 1941 to Desire J. Deschamps and assigned to Bendix Aviation Corporation. As indicated at **21**, the novel variable delivery mechanism may include a lever extending from the pump and adapted to be turned about its rockshaft by movement of the linkage **22** connecting with said lever as indicated, and having at the opposite end thereof a rod **24** adapted to be reciprocated by the pressure of a fluid acting upon a cup-shaped piston **25** which abuts the enlarged end **26** in which the rod terminates. As shown, the portion **26** of rod **24** has a cylindrical extension **27** that is movable toward a stationary abutment **28**, and serves to enclose the coiled compression spring **29**. A flange **27***a* is provided on cylinder **27** as an alternative means of actuation of the variable delivery mechanism.

The piston **25** is subject to the control not only of the spring **29**, above referred to, but also of the fluid pressure supplying and control means of which the essential parts include a metering unit **33** corresponding in general to the metering unit similarly designated in the copending application Serial No. 314,587 by Frank C. Mock and filed January 19, 1940, and now U. S. Patent No. 2,447,267, granted August 17, 1948, and assigned to Bendix Aviation Corporation. Also as in the said Mock application, the control means includes valve means **34** controlling the supplying of oil under pressure to act upon the piston **25**, but the effect and mode of operation of the valve **34** differs from that disclosed in the said Mock application in various respects, as will be pointed out hereinafter.

The air conduit is shown as including a Venturi section **35** at a point anterior to the throttle, and at a point slightly in advance of the Venturi section **35** there is provided a tube **37** adapted to open into the air stream passing through the conduit, said tube extending into and opening at its other end into a chamber of the metering unit **33** as will be further explained. Due to the location of the entering end of this tube **37** it will be apparent that the tube is subjected to the pressure of the air entering the Venturi section of the conduit. A smaller Venturi tube **40** is positioned in the conduit **11** between the tube **37** and the throat of the main Venturi section, and a tube **41** leads from the throat section of the smaller Venturi **40** to another chamber of the metering unit **33** to be further described.

As in the aforesaid Mock application, the metering unit **33** is divided into four pressure chambers **43**, **44**, **45** and **46**, the separation of the chambers from each other and from the external atmosphere being assured by the provision of the sealing diaphragms **47**, **48**, **49** and **50**. In addition to these small diaphragms there are two large actuating diaphragms **53**, **54**, each of said diaphragms being fastened at its outer periphery to the housing of the unit, and at its central portion having security upon the rod **55**. The diaphragms are shown as formed with an annular groove or depression to permit relatively free axial movement of the rod **55** in response to pressure differences on opposite sides of the diaphragm. The chamber **43** receives one end of the conduit **41** heretofore described, and the chamber **44** receives one end of the conduit **37**; consequently the pressure difference between the chambers **43** and **44** will coincide with the pressure difference prevailing between the two points of entrance of air to the respective tubes, and said difference in pressure will vary with every change in mass air flow through the conduit **11**.

The fuel conduit **18** is also provided with a

Venturi section from the throat of which leads a tube 61 terminating as shown in the chamber 46 of the metering unit 33, while a second tube 62 leads from a point slightly in advance of the Venturi section of the fuel conduit to terminate within the chamber 45 of the metering unit 33. From this it follows that the pressure differences at the Venturi section of the fuel supply conduit will produce a corresponding pressure difference on the opposite sides of the diaphragm 54 which, in conjunction with the diaphragm 53 and the coiled compression spring 65, will control the reciprocating action of the rod 55 to which the said diaphragms are secured. This rod 55 is shown as connecting (through a swivel coupling 70) with the control valve 34 which governs communication between the pressure fluid supplying passage 72 on the one hand, and the two associated passages 73 and 74 on the other, the passage 73 being a discharge passage, returns the oil to the oil sump of the engine. The other outlet passage 74 leads to a chamber 75 of annular shape, bounded at one side by the housing member 76 of the valve, and at the other side by the working face of the piston 25.

The specific structural details of the servo-motor including the cup shaped piston 25 and the arrangement of the valve means 34; the structural details of the metering unit 33 including the structural arrangement of the diaphragms 47, 48, 49 and 50 and 53 and 54; and the specific structural details of the fluid pressure responsive regulator per se including the operator-operative flange 27A for actuation of the variable delivery mechanism independently of the piston 25 have been claimed in the divisional application Serial No. 226,960 filed May 18, 1951 by Desire J. Deschamps and assigned to Bendix Aviation Corporation.

Starting of the engine

As heretofore noted, a novel feature of the invention, tending to produce easy starting, is the control of the piston 25 in such manner as to cause it to move automatically to "full rich" position when the pilot stops the engine. This feature is embodied in a cylinder 51 and a co-operating check valve 69, the latter preventing return flow of operating oil to the engine in case the engine oil pressure should fall, say, below 20 lbs. A spring 71, in cylinder 51, allows the piston 77 to move to the limit of its stroke when the oil pressure reaches, say, 35 lbs. When the engine stops, all air and fuel flow stops, and the force acting on both diaphragms 53 and 54 falls to zero, wheretofore the valve 34 moves to the left under the action of spring 65, opening port 74 and allowing oil from cylinder 51 to be forced into space 75, moving piston 25 to the right, to the full capacity setting, thereby making the setting of the pump correct for the next start. Since the force on piston 25 must be great enough to fully compress spring 29, it is obvious that a reservoir of liquid under pressure must be available to assert such a force upon the piston 25, notwithstanding the falling off in engine oil pressure that accompanies the stopping of the engine. Cylinder 51, in cooperation with check valve 69, provides such a pressure reservoir.

Acceleration

The mixture should momentarily be made richer when the pilot opens the air throttle briskly. With the control as described above, just the opposite would happen due to the lag in the operation of the control. To offset this, I take advantage of the very low pressure which exists in the intake manifold ahead of the air throttle valve 12 in providing for operation of the accelerating pump shown at 90. Diaphragm 92 of this pump functions to produce the desired enrichment upon sudden opening of the throttle. It functions as follows: With the engine running at idling speed, the air throttle valve 12 is nearly completely closed and the pressure ahead of this valve, or engine intake manifold pressure, is then only 15 to 17 inches of mercury absolute, whereas at full power, this pressure reaches around 28 inches with a naturally aspirated engine and may be 42 or more in case of a supercharged engine. This low pressure under these circumstances, holds the diaphragm 92 against stop 93, and compresses springs 94. If the air throttle is quickly opened, the pressure immediately increases, relieving the suction in compartment 91, and the springs 94 push the diaphragm to the left, thereby forcing fuel out of compartment 96 until diaphragm 92 abuts stop 97. This fuel leaves through check valve 98 and enters compartment 46, by way of conduit 99. To get this result, the passage 61 connecting compartment 46 with the Venturi throat in fuel conduit 18 should be relatively small.

When the throttle is again closed, the reduced pressure in 91 will permit return of diaphragm 92 to the right, allowing fuel to enter 96 at slow rate, through conduit 99 and narrow passage 95. Passage 95 is made relatively small to prevent a leaning of the mixture too speedily during the period of deceleration, thus preventing possible stalling.

Manual (or barometric) adjustment of the mixture

Supposing that the air diaphragm 53 is made a little larger than needed to balance the force acting against fuel diaphragm 54, it would then be possible to have a calibrated passage 101 putting compartments 43 and 44 in communication with each other in order to reduce the differential pressure in these two compartments in such a way that the force derived normally from the large air diaphragm just balances the fuel diaphragm.

As shown, this passage 101 has a valve 102 which normally allows restricted flow from 43 to 44. If, now, we close this valve we increase the pressure difference between 43 and 44 and the control valve 34 will immediately increase the output of the fuel injection pump 16, although the air flow entering the engine has not increased. Thus the mixture becomes richer. Conversely, opening the valve 102 beyond its normal setting will correspondingly lean out the mixture.

A similar arrangement on the fuel diaphragm unit could give corresponding results, but may not always be advisable because of the difficulty of sealing a valve which would pass fuel instead of air.

The valve 102 could also be operated by means of an evacuated bellows similar to the one disclosed in the Mock U. S. Patent No. 2,447,267 (above referred to) to correct for changes in temperature and barometric pressure, thus acting as an altitude correcting device to vary the richness of the mixture.

What is claimed is:

1. In a system for controlling the mixture of air and fuel for delivery to an engine having an air supply conduit, a throttle therein adapted to

be adjustably positioned, and fuel supply means having an output proportional to the engine speed and whose output at any given speed is variable, a member movable to control the output of said fuel supply means, an automatic fuel-air flow responsive ratio control mechanism to actuate said member to regulate automatically the fuel-air ratio at all operating positions of said throttle and at different engine speeds, said control mechanism including means responsive to the fuel input to said supply means, and accelerating pump means operated by the throttle to affect said fuel input responsive means so as to increase the fuel output from the supply means to said engine.

2. In a system for controlling the mixture of air and fuel for delivery to an engine having an air supply conduit, a throttle therein and fuel supply means having an output proportional to the engine speed and whose output at any given speed is variable, automatic fuel-air ratio control mechanism including means responsive to air flow in the air supply conduit and other means responsive to fuel flow to said supply means to act on the fuel supply means to control automatically the fuel-air ratio at all operating positions of said throttle, a member movable to control the output of said fuel supply means, and mechanism interconnecting said output control member, said automatic control mechanism and said throttle including means to actuate said control member by said automatic control mechanism to either increase or decrease the fuel, and means responsive to change in air pressure in said conduit to act upon said fuel flow responsive means and affected by an increase in the pressure resulting upon adjustment of the throttle to affect the automatic control mechanism to increase the fuel to obtain a fuel-air ratio favorable to fast acceleration.

3. In a system for controlling the mixture of air and fuel for delivery to an engine having an air supply conduit, a throttle therein and fuel supply means having an output proportional to the engine speed and whose output at any given speed is variable, automatic fuel-air ratio control mechanism including means responsive to air flow in the air supply conduit and other means responsive to fuel flow to said supply means to act on the fuel supply means to control automatically the fuel-air ratio at all operating positions of said throttle, a member movable to control the output of said fuel supply means, and mechanism interconnecting said output control member, said automatic control mechanism and said throttle including means to cause said automatic mechanism to actuate said output control member to control the fuel-air ratio, and said last mentioned means including air supply conduit pressure responsive means affected by any sudden opening movement of the throttle to act upon said fuel flow responsive means to actuate said output control member to increase the fuel until said automatic mechanism responds to the more open position of the throttle.

4. In a system for controlling the mixture of air and fuel for delivery to an engine of the type including an air supply conduit, a throttle therein and fuel supply pump means driven by said engine and whose fuel output at any given engine speed is variable, a first fluid pressure operated mechanism responsive to air flow through said supply conduit, a second fluid pressure operated mechanism responsive to flow of fuel to the intake of said fuel supply pump means, said first and second mechanisms coacting on the fuel supply pump means to control the output thereof and thereby control automatically the fuel-air ratio; the improvement comprising a third fluid pressure operated mechanism responsive to the pressure in said conduit between the throttle and the engine and associated with said first and second fluid pressure operated mechanisms and said fuel supply pump means for changing the action of said first and second mechanisms on said pump means to momentarily increase the fuel delivery to the engine upon a sudden opening of said throttle so as to obtain a fuel-air ratio favorable to fast acceleration.

5. In a fuel system for an internal combustion engine, an air conduit, a fuel conduit, operator-operative throttle means for controlling the flow through said air conduit, regulating means including a servo-piston for controlling the flow through said fuel conduit, said regulating means including means responsive to fluid flow through said air and fuel conduits so as to regulate said servo piston in such manner as to maintain said flow in accordance with a predetermined formula establishing a ratio between air and fuel flow, at all times, including the starting period of the engine, and means including an accelerating fuel pump having a diaphragm responsive to change in the fluid pressure in said air conduit and thereby to a quick movement of said operator-operative throttle means toward the full-open position to provide a fuel output, and conduit means operatively connecting the fuel output of said fuel pump directly to said fluid flow responsive means to cause said fuel output to act upon said fluid flow responsive means so as to effect movement of said servo-piston, in the direction corresponding to an increased fuel delivery to the engine.

6. For use in a fuel system for an internal combustion engine having an air conduit, a fuel conduit, and operator-operative throttle means for controlling the flow through said air conduit; regulating means including a servo-piston for controlling the flow through said fuel conduit, means responsive to fluid flow through said air and fuel conduits so as to regulate said servo-piston in such manner as to maintain said flow in accordance with a predetermined formula establishing a ratio between air and fuel flow, at all times, including the starting period of the engine, and means including an accelerating pump having a diaphragm responsive to the fluid pressure in said air conduit and thereby to a quick movement of said operator-operative throttle means toward the full-open position to act upon said fuel flow responsive means so as to effect movement of said servo-piston, in the direction corresponding to an increased fuel delivery to the engine, said accelerating pump further having a fuel chamber and pair of passages directly connecting the chamber to said fuel flow responsive means and thereby to said fuel conduit, one of the passages permitting rapid flow of fuel in one direction only and out of said fuel chamber to affect said fuel flow control means, in response to throttle opening, and the other of the passages permitting the return of fuel to said chamber from said fuel flow responsive means at a relatively low rate to prevent stalling of the engine in response to the subsequent throttle closing.

7. For use in controlling the mixture of air and fuel for delivery to an engine having an air supply conduit, a throttle therein adapted to be adjustably positioned, and a pump having fuel

inlet and outlet conduits, the inlet conduit connected to a source of fuel and the outlet conduit connected to said engine; the combination comprising an air pressure operated diaphragm, an air chamber and a fuel chamber separated by said diaphragm, spring means to bias said diaphragm in a first direction, a pair of conduits for connecting the fuel chamber to a source of fuel, one of the conduits permitting rapid flow of fuel in one direction only and out of said fuel chamber upon movement of said diaphragm in said first direction, and the other of the conduits for the return of fuel to said chamber at a relatively slow rate upon movement of said diaphragm in a second direction, a third conduit for connecting the air chamber to the throttle controlled air supply conduit so that upon a rapid opening of said throttle the movement of said diaphragm in said first direction may be effected for discharging fuel from said fuel chamber, means to vary the fuel output from said pump to said engine, a fourth conduit directly connecting said pair of conduits to said last mentioned means, and said last mentioned means being directly affected by the fuel discharged from the aforesaid fuel chamber to momentarily increase the fuel output to said engine by said pump.

8. The combination defined by claim 7 in which said other conduit is so restricted and arranged as to retard the return flow of fuel to the fuel chamber and thereby momentarily retard said output varying means from decreasing the fuel output from said pump to said engine upon a rapid closing of said throttle.

9. In a system for controlling the mixture of air and fuel, for delivery to an internal combustion engine, an air conduit, a fuel conduit, manually actuated means for controlling the flow through said air conduit, means including a servo-piston for controlling the flow through said fuel conduit, means for delivering the contents of said fuel conduit to the combustion chambers of the engine concurrently with the delivery of the contents of said air conduit to said combustion chambers, whereby the contents of said two conduits become commingled in said combustion chambers, to produce a mixture in which the air and fuel bear a predetermined ratio, one to the other, in accordance with the concurrently prevailing settings of said above-recited air flow controlling means and fuel flow controlling means, and means for subjecting said piston to fluid under pressure, said last named means comprising a cylindrical reservoir, a fluid conduit leading thereto from a pressure source, a non-return valve in said conduit, and a second conduit leading from said first conduit to said servo-piston, and a spring-pressed piston in said cylindrical reservoir, to control the pressure maintained therein.

10. In a system for controlling the mixture of air and fuel for delivery to an engine having an air supply conduit and a throttle therein adapted to be adjustably positionel; the combination comprising fuel supply pump means having an output proportional to the engine speed and driven by said engine at a variable speed and whose output at any given speed is variable, a member movable to control the output of said fuel supply pump means, an automatic fuel-air ratio responsive control mechanism including means responsive to fuel input to said pump means, said control mechanism to actuate said member to regulate automatically the fuel-air ratio at all operating positions of the throttle, and fluid pressure responsive means effective upon rapid opening of the throttle to directly and momentarily act upon the fuel input responsive means to cause said output control member to increase the fuel supplied from said fuel pump.

DESIRE J. DESCHAMPS.

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