

June 18, 1946.

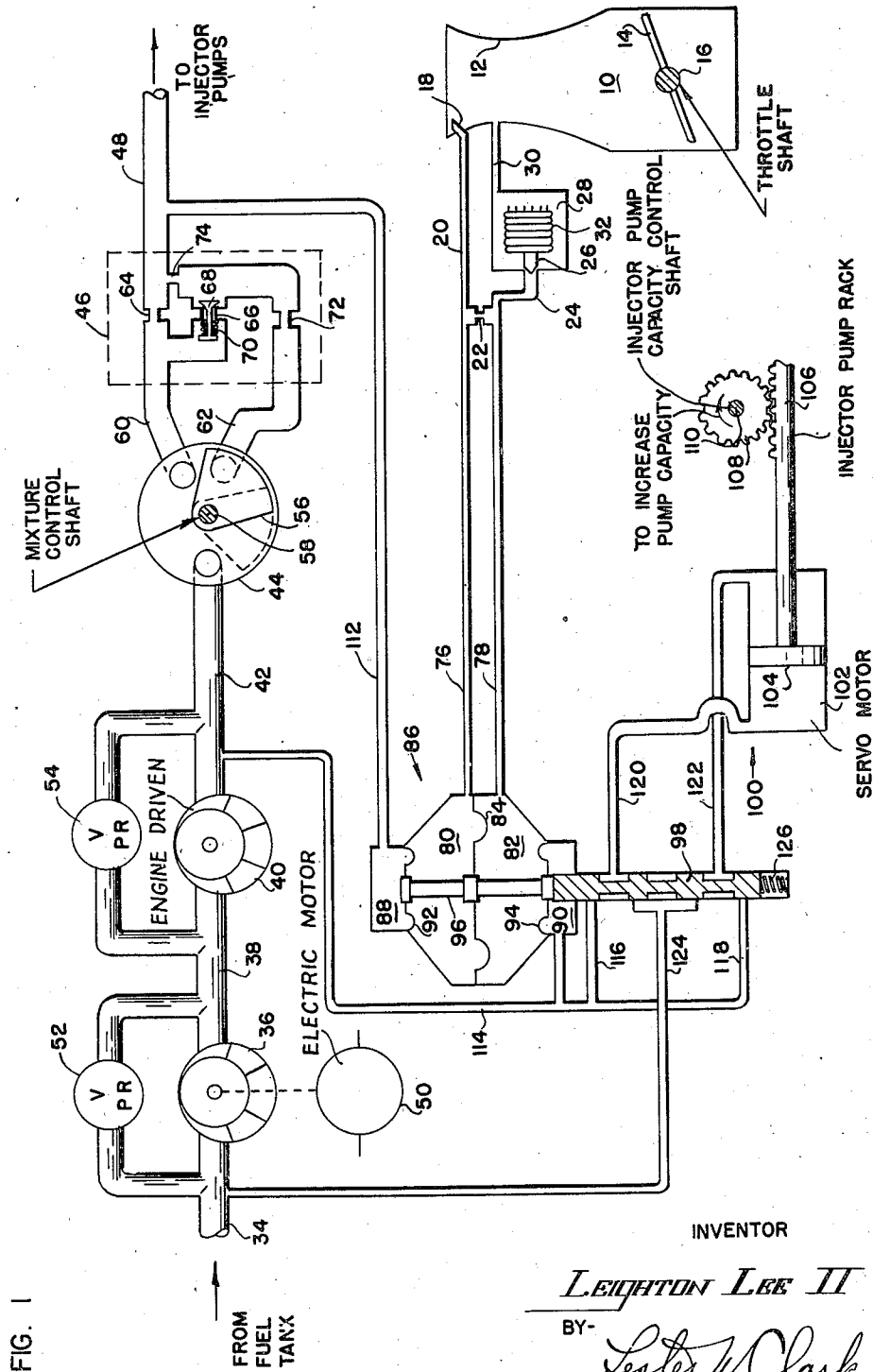
L. LEE, 2D

2,402,332

FUEL SUPPLY SYSTEM

Filed May 4, 1944

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

FIG. 2

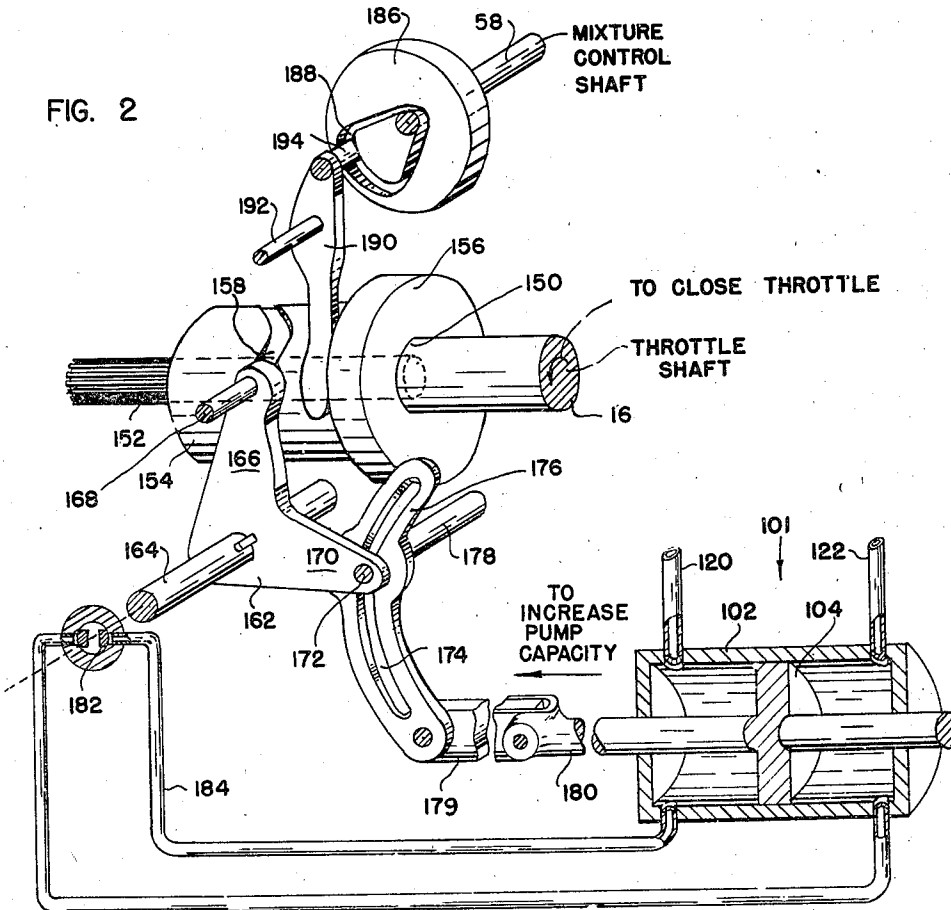
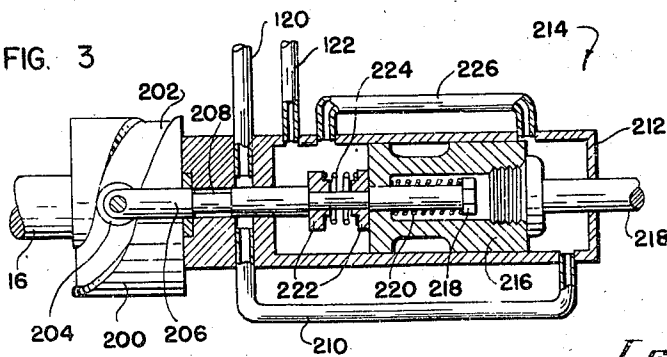


FIG. 3



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2,402,332

FUEL SUPPLY SYSTEM

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20 Claims. (Cl. 123—140)

1

The present invention relates to fuel supply systems for internal combustion engines, and particularly to systems of the type in which fuel is injected directly into the combustion chamber of the engine without first being mixed with air. The invention is especially adapted for use with engines of the spark ignition type, although its utility is not limited to such engines.

Such systems commonly use a set of injector pumps, one for each cylinder of the engine, and means are provided to control simultaneously the capacity per stroke of all the pumps so as to regulate the quantity of fuel delivered to the combustion chamber at each stroke of the engine. An injector pump mechanism of that type is shown in the copending application of Milton E. Chandler, Serial No. 451,874, filed July 22, 1942, and assigned to the assignee of the present application.

It has been proposed to operate the pump capacity control mechanism in accordance with the flow of air thru the air induction system of the engine, in such a manner as to maintain the fuel-to-air ratio within suitable limits. In such fuel supply systems, difficulty has been encountered in controlling the pump capacity when the rate of flow of air thru the induction system is relatively low. Under such conditions, the force produced by the device which meters the air flow is rather small, and the control of the pump capacity by this small force tends to be erratic.

Other difficulties have been encountered in such systems with respect to the control of the pump capacity when it is desired to shut down the engine. Under such conditions, the air flow responsive means tends to maintain the pump at a substantial capacity as long as the engine operates, while the best method of stopping the engine is to cut off the flow of fuel thru the pump before the engine comes to rest, so that no unburned fuel remains in the cylinders of the engine.

It is therefore an object of my invention to provide improved means for controlling the capacity of an injector pump mechanism for supplying fuel to an internal combustion engine.

Another object is to provide, in a fuel supply system including an injector pump mechanism normally controlled by the rate of flow of combustion air to the engine, improved means for controlling the pump capacity under conditions of low air flow.

Another object is to provide improved mechanism of the type described wherein the pump capacity is controlled by the throttle position

2

when the throttle is in a range of positions adjacent its closed position.

A further object is to provide, in a fuel supply system of the type described, mechanism operable by a manual lever independent of the throttle for operating the pump capacity control. A still further object is to provide such an arrangement which may be used to cut off the fuel flow thru the pumps completely, regardless of any other factors which might control the pump capacity under usual operating conditions.

Other objects and advantages of the present invention will become apparent from a consideration of the appended specification, claims and drawings, in which

Figure 1 represents, somewhat diagrammatically, a fuel supply system for an internal combustion engine, of the type to which my invention is applicable,

Figure 2 illustrates, partially in perspective and partially in section, an idle and cut off control adapted for use with the system of Figure 1, and

Figure 3 illustrates a modified form of idle control which may be applied to the servo motor of Figure 1.

Figure 1

There is shown in Figure 1 a passage 10 for air flowing to an internal combustion engine. This passage 10 includes a venturi portion 12 which produces a differential pressure varying with the square of the velocity of the air flowing thru the passage. The flow of air thru the passage 10 is controlled by a throttle 14 fixed on a shaft 16 for rotation therewith.

The pressure differential set up by the venturi 12 produces a flow of air thru a secondary air passage extending from an impact tube 18 thru a conduit 20, a restriction 22, a conduit 24, past a valve 26 into a chamber 28 and thence thru a conduit 30 to the throat of venturi 12.

The pressure differential between the ends of the secondary air passage may be divided into two component drops, one appearing across the restriction 22 and the other across the valve 26. The valve 26 is operated by a bellows 32 located in the chamber 28. The bellows 32 is preferably filled with a fluid having a suitable coefficient of thermal expansion, so that the valve 26 is moved in accordance with changes in the pressure and temperature of the air in the chamber 28. The pressure differential appearing across restriction 22 is thereby controlled both as a function of the velocity and the density of the flowing air so that that pressure differential is a measure of

3

the mass of air flowing thru the passage 10 per unit time.

The fuel flowing to the engine comes from a tank (not shown) and passes thru a conduit 34, a boost pump 36, a conduit 38, a pump 40, a conduit 42, a mixture control 44, a jet system generally indicated at 46, and a conduit 48 to the injector pumps (not shown).

The pump 36 is driven by an electric motor indicated schematically at 50. The discharge pressure of pump 36 is controlled by a pressure relief valve 52.

Pump 40 is preferably driven by the engine and its discharge pressure is controlled by a pressure relief valve 54.

The mixture control 44 includes a disc valve 56 fixed on a shaft 58. The disc valve 56 controls the flow of fuel thru a pair of conduits 60 and 62 which connect the mixture control 44 to the jet system 46. When the valve 56 is in the position shown in full lines in the drawings, the mixture control is said to be in its "lean" position, since the fuel can then flow to the jet system only thru the conduit 60. When the valve 56 is in the position illustrated in dotted lines in the drawings, the mixture control is said to be in its "rich" position, since the fuel can then flow thru both conduits 60 and 62 to the jet system 46. It may be seen that the valve 56 can be moved to a position wherein it cuts off the flow of fuel thru both the conduits 60 and 62. The mixture control is then said to be in its "cut-off" position.

When the mixture control is in its lean position, fuel can flow to the engine only thru a fixed jet or orifice 64 and a parallel jet 66 controlled by a valve 68 biased closed by a spring 70. When the mixture control is in its rich position, fuel can also flow thru a fixed jet 72. The flow thru the jets 66 and 72 also passes thru another fixed jet 74.

The function of the jet system is to control the fuel flow as a function of the pressure differential across the jet system. When the mixture control is in its lean position, a given pressure differential indicates a certain rate of fuel flow. When the mixture control is in its rich position, the cross-sectional area open to the fuel flow is increased so that the same pressure differential as before produces an increased fuel flow. Since the pressure differential across the jet system is controlled by the air flow, as hereinafter explained, it may be seen that the mixture control may be used to select different fuel to air ratios for different flight conditions. The jet 66 and the valve 68 controlling it are provided to increase the fuel flow whenever the pressure differentials across the jets exceeds a predetermined value, thereby producing an increase in the fuel-to-air ratio at high power outputs.

The pressure differential appearing across the restriction 22 is applied thru a pair of conduits 76 and 78 to chambers 80 and 82, respectively, located on opposite sides of a diaphragm 84 in a pressure meter generally indicated at 86. The pressure meter 86 also includes chambers 88 and 90. Chamber 88 is separated from the chamber 80 by a diaphragm 92 and chamber 90 is separated from the chamber 82 by a diaphragm 94.

The diaphragms 92, 84 and 94 are connected to the stem 96 of a valve 98 which controls the flow of fuel to a servo motor 100 which includes a cylinder 102 enclosing a piston 104 which moves a rack 106 cooperating with a gear 108 mounted on a shaft 110, which is connected to suitable

4

mechanism for controlling the capacity of the injector pumps.

The chamber 88 is connected by means of a conduit 112 to the conduit 48 in the fuel line on the downstream side of the jet system 46. The chamber 90 of the pressure meter 86 is connected by means of a conduit 114 to the conduit 42 in the fuel line on the upstream side of the jet system 46. The conduit 114 also serves to supply fuel under pressure to a pair of conduits 116 and 118 which are selectively connectable by the valve 98 to conduits 120 and 122 leading to the opposite ends of cylinder 102 of the servomotor 100. Conduit 124 connects the valve 98 with the conduit 34 in the fuel line at the low pressure side of the pumps 36 and 40.

The fuel pressure differential across the jet system, which is a measure of the rate of flow of fuel to the engine, is applied to the chambers 88 and 90, with the high pressure in the chamber 90, so that this pressure differential acts upwardly on the valve 98. The air pressure differential, which is a measure of the rate of flow of air to the engine, is applied to the diaphragm 84 so that it acts on the valve 98 in a downward direction as viewed in the drawings.

When the fuel pressure differential is balanced with the air pressure differential, the valve 98 is at the position shown in the drawing. In this position of valve 98, no fuel flows to either end of the cylinder 102 of servomotor 100.

If the amount of air flowing thru the passage 10 increases, the force acting downwardly on the diaphragm 84 increases, thereby moving the valve 98 downwardly, and opening ports so that fuel under pressure may flow from conduit 118 into conduit 122 and the right end of cylinder 102. At the same time, the left end of cylinder 102 is connected thru a conduit 120 and valve 98 to the drain conduit 124. A pressure differential is thereby established across the piston 104, causing it to move to the left, and thereby moving rack 106 to the left. This rotates the gear 108 in a clockwise direction. The pump capacity regulating mechanism is so designed that rotation of gear 108 in a clockwise direction increases the pump capacity, as indicated by the legend in the drawings. The increase in the pump capacity causes a corresponding increase in the fuel flow, thereby increasing the pressure differential across the jet system so as to produce a force acting upwardly on the valve 98 to restore it to its neutral position.

In a similar manner, if the air flow decreases, the valve 98 is moved upwardly to admit pressure to the left hand side of cylinder 102 thru conduits 116 and 120, and to connect the right end of cylinder 102 to the drain conduit 124 thru conduit 122. This produces a rotation of the injector pump capacity control shaft in the opposite, or capacity decreasing direction.

A spring 126 acts upwardly on the lower end of the valve 98, biasing it in a pump capacity decreasing direction. This spring is provided so that when no air or fuel is flowing to the engine, the pump capacity control will be operated to its minimum capacity or cut-off position.

Figure 2

The dimensions of the air passage 10 must be designed to provide sufficient capacity to supply air to the engine at its maximum required output. When this is done, the air passage 10 is so large that the air pressure differential set up in the venturi at low air flows is too small to

5

effectively control the valve 98 and hence the injector pump capacity. There is shown in Figure 2 a mechanism by which the injector pump capacity is controlled directly by the throttle when the throttle reaches a predetermined range of positions near its closed position.

The shaft 16 of Figure 2 is there identified as the throttle shaft, but it may be any shaft suitably connected to the throttle shaft so as to rotate concurrently with it. The left end of shaft 16 in Figure 2 is of smaller diameter than the right end. The portion of the small diameter terminates at a shoulder 150, and is splined as indicated at 152. A sleeve 154 is slidably received on the splines 152 and at its right end is provided with a flange 156. The movement of sleeve 154 to the right is terminated by the shoulder 150.

The sleeve 154 has a groove 158 cut in its surface. For the greater portion of its length the groove 158 is parallel to the ends of the sleeve 154 and 156, but near its upper end, as viewed in the drawings, the groove 158 curves toward the left end of the sleeve 156.

The throttle shaft 16 rotates counterclockwise, as viewed from its right hand end in Figure 2, to close the throttle.

A bell crank lever 162 is fixed on a shaft 164 to rotate therewith. One arm 166 of the lever 162 extends upwardly therefrom and carries near its upper end a pin 168, one end of which is adapted to ride in the groove 158.

The other arm 170 of the lever 162 extends to the right from shaft 164 and carries a pin 172 which cooperates with a slot 174 in an elongated arcuate member 176. The member 176 is pivotally supported by a shaft 178, shown near the center of the member 176.

The lower end of member 176 is pivotally attached to a link 179 whose opposite end is pivotally attached to a rod 180 connected to piston 104 of the servomotor 101, which corresponds to motor 100 of Figure 1.

The shaft 164 is connected to a valve mechanism 182 which controls the flow of fluid thru a conduit 184, which connects the opposite ends of the cylinder 102. When the shaft 164 is in its normal position, as shown in the drawings, the valve 182 is closed, but when the shaft 164 is moved from its normal position in either direction, then valve 182 is opened to provide fluid communication between the opposite ends of the cylinder 102.

As long as the throttle is opened by anything more than a predetermined amount, the pin 168 rides in the portion of the groove 158 which is parallel to the ends of sleeve 154, and the position of lever 162 does not change. At such times, the piston 104 may reciprocate in the cylinder 102, causing the element 176 to pivot about its supporting shaft 178, without causing any movement of pin 172 and lever 162.

As the throttle is moved toward closed position, the pin 168 encounters the curved portion of groove 158, which causes the bell crank lever 162 and shaft 164 to be turned counter-clockwise. This opens valve 182, so that the opposite ends of cylinder 102 are connected and the pressure fluid supplied to the cylinder under control of valve 98 no longer has any effect on the position of the piston. At the same time, the pin 172 moves upwardly in the slot 174, thereby rotating the member 176 on its support 178 and moving the piston 104 to the right as it appears in Figure 2. It should be noted that the position of cylinder 102 as viewed in Figure 2 is reversed

6

from the position in which it appears in Figure 1. Therefore movement of the piston 104 in the idle range in the construction illustrated causes an operation of the pump capacity control in a capacity decreasing direction.

It will be readily apparent to those skilled in the art that other contours of the groove 158 may be used if other relationships between the throttle position and the pump capacity setting are desired. The contour illustrated was chosen because it has been found that with a fixed pump capacity setting, the actual flow thru the pump per revolution of the engine tends to increase with decreased speed. Therefore, in order to prevent the mixture from becoming too rich at low speeds, the groove 158 is contoured to decrease the pump capacity setting. If, with a particular type of pump or engine an increased pump capacity setting is required, the groove 158 would be contoured so that its upper end curved to the right, as it appears in Figure 2.

There is also provided in Figure 2 means whereby manipulation of the mixture control shaft 58 to its cut off position causes operation of the piston 104 and pump capacity control mechanism to its minimum capacity position.

For this purpose, there is fixed on the mixture control shaft 58 a disc 186 having a groove 188 cut in one of its lateral surfaces. A lever 190 is pivotally mounted on a shaft 192 and carries at its upper end a pin 194 which rides in the groove 188. The lower end of lever 190 is adapted to cooperate either with flange 156 of the sleeve 154 or with the vertical arm 166 of bell crank lever 162.

Groove 188 has a portion of constant radius extending about the shaft 58 as a center. The pin 194 rides in this portion of the groove whenever the mixture control shaft is in its lean or rich positions. Under these conditions, the lever 190 engages flange 156 and holds the sleeve 154 against the shoulder 150 on the shaft 16.

At the opposite ends of the arcuate portion of groove 188, the groove extends substantially radially of the disc 186. When the shaft 58 is rotated counter-clockwise to move the valve 56 to its cut-off position, the pin 194 rides along this radial portion of the groove 188, and thereby causes the lever 190 to rotate in a clockwise direction about its pivot 192. The lower end of lever 190 thereby moves to the left, engaging the upper end of arm 166 and rotating the bell crank lever 162 in a counter-clockwise direction.

The rotation of shaft 164 opens the valve 182 to take the air flow responsive mechanism out of control of the servomotor 101. At the same time, the pin 172 moves upwardly in the slot 174 rotating the element 176 counter-clockwise and moving the piston 104 to the right, or in a pump capacity decreasing direction. The proportions of the various levers should be such that when the mixture control shaft reaches its cut-off position, the piston 104 is positively set at its minimum capacity position.

When the piston 104 is being positioned by the mixture control shaft, the throttle has no control over the piston, since the sleeve 154 then slides on the splines 152 along the shaft 16, and the position of pin 168 in groove 158 has no effect on the position of the piston 104.

While I have illustrated the disc 186 as being fixed on the mixture control shaft, it should be apparent that it may with equal facility be placed on a separate shaft which may be manually operated to set the pump capacity.

Figure 3

There is shown in Figure 3 an alternative arrangement by which the throttle position may be used to control the injector pump capacity in the idle range.

In Figure 3, the throttle shaft 16 carries a drum 200 having a cam groove 202 cut in its surface. A follower 204 rides in this groove and is attached to a rod 206. The rod 206 has a portion 208 of relatively small diameter. This portion 208 serves as a valve to control the flow of fuel from the conduit 120, which may be the same as conduit 120 of Figure 1, to a conduit 210 connected to the right end of a cylinder 212. The cylinder 212 is a part of a servo-motor mechanism generally indicated at 214, which includes a hollow piston 216 connected thru a suitable rod 218 to the injector pump capacity control (not shown).

The fuel supply conduit 122 is connected to the left end of cylinder 212. The rod 206 extends into the cylinder 212 and thru one end of the hollow piston 216. At the end of rod 206 inside the piston 216 there is mounted a spring retainer 218, and a spring 220 is held in compression between the retainer 218 and the inside of piston 216.

Just outside the piston 216, the rod 206 carries a pair of spring retainers 222, between which is compressed a spring 224. The retainers 222 are on a portion of the rod 206 of relatively narrow cross-section so that the separation of the retainers 222 is limited by the shoulders at the ends of that portion. The spring 224 has a spring rate twice as great as that of the spring 220, so that when no fluid pressures are acting on the piston 216, the retainers 222 are held against the shoulders on the rod 206 by spring 224. The spring 220 holds the piston 216 against the right-hand retainer 222. The springs 220 and 224 therefore tend to maintain the left end surface of piston 216 aligned with the shoulder at the right end of the narrow portion of rod 206.

When a pressure differential is applied to the ends of cylinder 212 which tends to move the piston 216 from its normal position with respect to rod 206, it may be seen that that spring force which the pressure differential must overcome is the same regardless of the direction in which the piston is to be moved. If the piston is to be moved to the left, for example, the motion is opposed by the spring 224 and aided by spring 220. As previously stated, the force of spring 220 is one half that of spring 224 so that the force required to be overcome is just equal to one half that of spring 224. If the piston is to move to the right, on the other hand, the spring force to be overcome is only that of spring 220, which as previously stated is equal to one half that of spring 224.

A by-pass conduit 226 connects the opposite ends of the cylinder 212, and is opened by the piston 216 when it reaches a predetermined position in its travel. When this by-pass is open, the valve portion 208 of the rod 206 shuts off the supply of fuel thru the conduit 120. The air flow responsive mechanism cannot control the piston 216 when the by-pass 226 is open.

In designing the contour of the cam groove 202, many factors must be considered. In the idle range, when by-pass 226 is open, the cam positively determines the relationship between throttle position and injection pump capacity. In this range, it is usually best to determine empirically the proper cam contour for a given pump and engine. When the throttle is opened

beyond the idle range, the valve portion 208 of rod 206 opens the passage 120 and the piston 216 closes the by-pass 226. The piston 216 is then controlled chiefly by the valve 98 (Figure 1). The only influence of cam 202 at such times is to determine the biasing force due to springs 220 and 224 which must be overcome by the pressure differential acting on the opposite ends of the piston in order to set the rate of fuel flow at any particular value. In order to minimize the effect of this biasing force, the cam 202 should be designed to set the pump capacity control at an optimum position for a given throttle position. I prefer to base the design for the cam on the assumption that the propeller governor controls the relationship between propeller speed and horsepower output to maintain maximum propeller efficiency. If that is assumed, then for a given throttle position, definite values of speed and power are determined, and the cam may be designed to give the best fuel to air ratio for those conditions.

Of course, the engine is seldom controlled in practice so that the speed and power output vary in accordance with the ideal conditions assumed. The variation from those ideal conditions is relatively small under normal operating conditions, however. If the cam is so designed, then the throttle does most of the work of moving the piston 216 and the injector pump capacity control mechanism, and the fluid pressure differential acting on the piston serves merely as a fine adjustment. The operation of the piston by the throttle aids in securing a rapid increase of the fuel supply upon acceleration of the engine, since a force is effective on the piston as soon as the throttle is moved. Also, in case of failure of the hydraulic control system, the injector pump capacity control mechanism is manually positioned in accordance with the throttle position, so that the engine receives a workable mixture, even though it may not be the most desirable mixture.

While I have shown and described certain preferred embodiments of my invention, other modifications thereof will readily occur to those skilled in the art, and I therefore intend my invention be limited only by the appended claims.

I claim as my invention:

1. A fuel supply system for an internal combustion engine, comprising injector pump mechanism for supplying fuel to said engine, means for controlling the delivery of said pump mechanism, fluid motor means for operating said capacity control means including a pair of expandable chambers separated by a movable wall and a connection between said wall and said control means, means for selectively supplying motive fluid to said chambers to cause operation of said control means, a passage for air flowing to said engine for combustion purposes, throttle means for controlling the flow of air thru said passage, a by-pass connection between the opposite ends of said cylinder, and means effective upon movement of said throttle means to a range of positions adjacent its closed position to open said by-pass connection and to cause said wall to move concurrently with said throttle means.

2. A fuel supply system for an internal combustion engine, comprising injector pump mechanism for supplying fuel to said engine, fluid motor means for controlling the delivery of said pump mechanism including a piston moving in a cylinder, means for selectively supplying motive fluid to the opposite ends of said cylinder to cause operation of said control means, a passage

for air flowing to said engine for combustion purposes, throttle means for controlling the flow of air thru said passage, a by-pass connection between the opposite ends of said cylinder, valve means controlling said connection, and means effective upon movement of said throttle means to a range of positions adjacent its closed position to open said valve means and to operatively connect said throttle means to said piston.

3. A fuel supply system for an internal combustion engine, comprising a conduit for supplying fuel to said engine, means for controlling the flow of fuel thru said conduit, fluid motor means for operating said flow controlling means including a pair of expansible chambers separated by a movable wall and a connection between said wall and said control means, means for selectively supplying motive fuel to said chambers, a passage for air flowing to said engine for combustion purposes, throttle means for controlling the flow of air thru said passage, means responsive to the rate of flow of air thru said passage for controlling said motive fuel supply means, and means effective upon movement of said throttle means to a range of positions adjacent its closed position to open a fluid connection between said chambers and to operatively connect said fuel flow controlling means to said throttle for concurrent operation therewith.

4. A fuel supply system for an internal combustion engine, comprising injector pump mechanism for supplying fuel to said engine, means for controlling the delivery of said pump mechanism, fluid motor means for operating said capacity control means including a piston moving in a cylinder and a connection between said piston and said delivery control means, a passage for air flowing to said engine for combustion purposes, throttle means for controlling the flow of air thru said passage, a by-pass connection between the opposite ends of said cylinder, said by-pass connection being closed during normal engine power output conditions, cam means connected to said throttle for movement therewith, follower means associated with said cam means, a connection between said follower means and said piston so as to cause said piston to move concurrently with said follower means, and means in said connection for permitting movement of said piston independently of said follower means, said cam means and follower means cooperating when said throttle means is in a range of positions adjacent its closed position to cause opening of said by-pass and concurrent movement of said throttle means and said piston.

5. A fuel supply system for an internal combustion engine, comprising injector pump mechanism for supplying fuel to said engine, fluid motor means for controlling the delivery of said pump mechanism including a piston moving in a cylinder, a passage for air flowing to said engine for combustion purposes, means responsive to the rate of flow of air thru said passage for controlling the flow of motive fluid to the opposite ends of said cylinder, throttle means for controlling the flow of air thru said passage, a by-pass connection between the opposite ends of said cylinder, valve means controlling said connection, cam means movable with said throttle means, a bell-crank lever having a normal position and movable therefrom, a follower for said cam means carried by one arm of said bell-crank lever, means associated with said lever for operating said valve means, said valve means being

closed when said lever is in its normal position and being opened when said lever is moved from its normal position, a pin carried by the other arm of said lever, an elongated member having a longitudinal slot for receiving said pin, a pivotal mounting for said member at an intermediate point thereof, said mounting being aligned with said pin when said lever is in its normal position, and a link connecting one end of said member to said piston, said member permitting movement of said piston independently of said follower when said pin is aligned with said pivotal mounting, and transmitting motion from said follower to said piston when said pin is out of alignment with said pivotal mounting, said cam means being contoured to maintain said lever in its normal position when said throttle is opened by more than a predetermined amount and to move said lever so as to open said valve means and to cause concurrent movement of said throttle means and said piston as said throttle means approaches its closed position.

6. A fuel supply system for an internal combustion engine, comprising injector pump mechanism for supplying fuel to said engine, fluid motor means for controlling the delivery of said pump mechanism including a piston moving in a cylinder, a passage for air flowing to said engine for combustion purposes, means responsive to the rate of flow of air thru said passage for controlling the flow of motive fluid to the opposite ends of said cylinder, a by-pass connection between the opposite ends of said cylinder, by-pass valve means controlling said connection a conduit for delivering fuel to said pump mechanism, cut-off valve means in said conduit, a manual operator for moving said cut-off valve means to closed position and means effective upon closure of said cut-off valve means by said operator to open said by-pass valve means and to cause concurrent movement of said operator and said piston.

7. A fuel supply system for an internal combustion engine, comprising injector pump mechanism for supplying fuel to said engine, fluid motor means for controlling the delivery of said pump mechanism including a piston moving in a cylinder, a passage for air flowing to said engine for combustion purposes, means responsive to the rate of flow of air thru said passage for controlling the flow of motive fluid to the opposite ends of said cylinder, throttle means for controlling the flow of air thru said passage, a by-pass connection between the opposite ends of said cylinder, by-pass valve means controlling said connection, means effective upon movement of said throttle means to a range of positions adjacent its closed position to open said by-pass valve means and to cause concurrent movement of said throttle means and said piston, a conduit for delivering fuel to said pump mechanism, cut-off valve means in said conduit, a manual operator for moving said cut-off valve means to closed position and means effective upon closure of said cut-off valve means by said operator to open said by-pass valve means and to cause concurrent movement of said operator and said piston regardless of the position of said throttle means.

8. A fuel supply system for an internal combustion engine, comprising injector pump mechanism for supplying fuel to said engine, means for controlling the delivery of said pump mechanism, motor means for operating said delivery control means, a passage for air flowing to said engine for combustion purposes, means respon-

11

sive to the rate of flow of air thru said passage for controlling said motor means, a conduit for delivering fuel to said pump mechanism, cut-off valve means in said conduit, a manual operator for moving said cut-off valve means to closed position and means operable to cause concurrent movement of said operator and said delivery control means regardless of the rate of flow of air thru said passage.

9. A fuel supply system for an internal combustion engine, comprising injector pump mechanism for supplying fuel to said engine, fluid motor means for controlling the delivery of said pump mechanism including a piston moving in a cylinder, a by-pass connection between the opposite ends of said cylinder, valve means controlling said connection, a lever having a normal position and movable therefrom, means associated with said lever for operating said valve means, said valve means being closed when said lever is in said normal position and being moved to open position when said lever is moved from its normal position, a pin carried by an arm of said lever, an elongated member having a longitudinal slot for receiving said pin, a pivotal mounting for said member at an intermediate point thereof, said pin being aligned with said mounting when said lever is in its normal position, a link connecting one end of said member to said piston, said member permitting movement of said piston independently of said lever when said pin is aligned with said pivotal mounting, and transmitting motion from said lever to said piston when said pin is out of alignment with said pivotal mounting, manually operable control means for cutting off the supply of fuel to said pump mechanism, and a connection between said manual control means and said lever, said connection being effective upon operation of said manual control means to cut off the fuel supply to operate said lever in a pump delivery decreasing direction.

10. A fuel supply system for an internal combustion engine, comprising injector pump mechanism for supplying fuel to said engine, means for controlling the delivery of said pump mechanism, fluid motor means for operating said delivery control means including a pair of expansible chambers separated by a movable wall, a connection between said wall and said delivery control means, a passage for air flowing to said engine for combustion purposes, means responsive to the rate of flow of air thru said passage for controlling the flow of motive fluid to said chambers, throttle means for controlling the flow of air thru said passage, a by-pass connection between said chambers, by-pass valve means controlling said connection, said valve means being closed under normal engine power output conditions, means effective upon movement of said throttle means to a range of positions adjacent its closed position to open said by-pass valve means and to cause movement of said delivery control means concurrently with movement of said throttle means toward closed position, a conduit for delivering fuel to said pump mechanism, valve means in said conduit, a manual operator for moving said conduit valve means, and means effective upon closure of said conduit valve means by said operator to open said by-pass valve means and to cause concurrent movement of said capacity control means in a delivery decreasing direction regardless of the position of said throttle means.

11. A fuel supply system for an internal com-

12

bustion engine, comprising injector pump mechanism for supplying fuel to said engine, means for controlling the delivery of said pump mechanism, fluid motor means including a pair of expansible chambers separated by a movable wall, a connection between said wall and said capacity control means, a passage for air flowing to said engine for combustion purposes, means responsive to the rate of flow of air thru said passage for controlling the flow of motive fluid to said chambers, throttle means controlling the flow of air thru said passage, a by-pass connection between said chambers, valve means controlling said by-pass connection, a shaft rotatable with said throttle means, cam means splined on said shaft so as to be slidable along said shaft, a bell-crank lever having a normal position and movable therefrom, a follower for said cam means carried by one arm of said bell-crank lever, means associated with said lever for operating said valve means, said valve means being closed when said lever is in its normal position and being moved to open position when said lever is moved from its normal position, a pin carried by the other arm of said lever, an elongated member having a longitudinal slot for receiving said pin, a pivotal mounting for said member at an intermediate point thereof, said pin being aligned with said mounting when said lever is in its normal position, a link connecting one end of said member to said piston, said member permitting movement of said piston independently of said lever when said pin is aligned with said pivotal mounting, and transmitting motion from said lever to said piston when said pin is out of alignment with said pivotal mounting, said cam means being contoured to maintain said lever in its normal position when said throttle is opened by more than a predetermined amount and to move said lever so as to open said valve means and to cause movement of said capacity control means in a capacity increasing direction concurrently with movement of said throttle means toward closed position, a conduit for delivering fuel to said pump mechanism, normally open valve means in said conduit, a manual operator for moving said conduit valve means and means for transmitting motion from said operator to said lever so as to move said lever from its normal position in a direction to cause movement of said capacity control means in a capacity decreasing sense when said conduit valve means is moved toward closed position, said cam means sliding along said shaft when said motion transmitting means is active, so that said cam means does not interfere with the operation of said motion transmitting means.

12. Control apparatus for a device to be selectively positioned either manually or by fluid motor means including a pair of expansible chambers separated by a movable wall which is connected to said device, said control apparatus comprising means for supplying said chambers selectively with motive fluid to cause movement of said device in opposite directions, a by-pass conduit connecting said chambers, by-pass valve means in said conduit, a manually movable control element, a lever having a normal position and movable therefrom, a connection between said element and said lever, means associated with said lever for operating said valve means, said valve means being closed when said lever is in its normal position and being moved to open position when said lever is moved from its normal position, a pin carried by said lever, an elongated member having a longitudinal slot for re-

13

ceiving said pin, a pivotal mounting for said member at an intermediate point thereof, said mounting being aligned with said pin when said lever is in its normal position, and a link connecting one end of said member to said wall, said member permitting movement of said wall independently of said lever when said pin is aligned with said pivotal mounting, and transmitting motion from said lever to said wall when said pin is out of alignment with said pivotal mounting.

13. A fuel supply system for an internal combustion engine, comprising injector pump mechanism for supplying fuel to said engine, means for controlling the delivery of said pump mechanism, fluid motor means for operating said delivery control means including a pair of expandable chambers separated by a movable wall and a connection between said wall and said control means, a passage for air flowing to said engine for combustion purposes, means responsive to the rate of flow of air thru said passage for selectively supplying said chambers with motive fluid, a by-pass conduit connecting said chambers, said by-pass conduit being closed under normal engine power output conditions, a valve for shutting off the supply of fluid to one of said chambers, and means effective upon movement of said throttle means to a range of positions adjacent its closed position to close said shut-off valve and open said by-pass conduit to terminate control of said motor means by said air flow responsive means.

14. A fuel supply system for an internal combustion engine, comprising injector pump mechanism for supplying fuel to said engine, means for controlling the delivery of said pump mechanism, fluid motor means for operating said delivery control means including a pair of expandable chambers separated by a movable wall and a connection between said wall and said control means, a passage for air flowing to said engine for combustion purposes, means responsive to the rate of flow of air thru said passage for selectively supplying said chambers with motive fluid to control the delivery of said pump mechanism, throttle means for controlling the flow of air thru said passage, a rod extending thru said wall, a pair of spring retainers carried by said rod on opposite sides of said wall, a pair of springs each retained between one of said retainers and said wall, said springs biasing said wall to a predetermined position relative to said rod, and a connection between said throttle means and said rod for translating it concurrently with movement of said throttle means.

15. A fuel supply system for an internal combustion engine, comprising injector pump mechanism for supplying fuel to said engine, means for controlling the delivery of said pump mechanism, fluid motor means for operating said delivery control means including a pair of expandable chambers separated by a movable wall and a connection between said wall and said control means, a passage for air flowing to said engine for combustion purposes, means responsive to the rate of flow of air thru said passage for selectively supplying said chambers with motive fluid to control the delivery of said pump mechanism, throttle means for controlling the flow of air thru said passage, a rod extending thru said wall, a pair of spring retainers carried by said rod on opposite sides of said wall, a pair of springs each retained between one of said retainers and said wall, said springs biasing said wall to a predetermined position relative to said rod, cam means

14

movable with said throttle, and cam follower means attached to said rod for translating it concurrently with movement of said throttle means, said cam means being contoured to position said capacity control means at the position required to produce the desired fuel to air ratio when the relationships of the throttle opening, air flow, and engine speed are those obtained when the propeller load is controlled with respect to power output to secure maximum propeller efficiency.

16. A fuel supply system for an internal combustion engine, comprising injector pump mechanism for supplying fuel to said engine, means for controlling the delivery of said pump mechanism, fluid motor means for operating said delivery control means including a piston movable within a cylinder and a connection between said piston and said control means, a passage for air flowing to said engine for combustion purposes, means responsive to the rate of flow of air thru said passage for selectively supplying the ends of said cylinder with motive fluid to control the delivery of said pump mechanism, throttle means for controlling the flow of air thru said passage, a rod extending thru said wall, a pair of spring retainers carried by said rod on opposite sides of said wall, a pair of springs each retained between one of said retainers and said wall, said springs biasing said wall to a predetermined position relative to said rod, a connection between said throttle means and said rod for translating it concurrently with movement of said throttle means, and a by-pass conduit connecting one end of said cylinder with a port on the side of said cylinder which is uncovered by said piston at a point in its travel corresponding to a nearly closed position of said throttle means, said by-pass conduit being effective when open to prevent control of said piston by said air flow responsive means.

17. A fuel supply system for an internal combustion engine, comprising injector pump mechanism for supplying fuel to said engine, means for controlling the delivery of said pump mechanism, fluid motor means for operating said delivery control means including a pair of expandable chambers separated by a movable wall and a connection between said wall and said control means, a passage for air flowing to said engine for combustion purposes, means responsive to the rate of flow of air thru said passage for selectively supplying said chambers with motive fluid to control the delivery of said pump mechanism, throttle means for controlling the flow of air thru said passage, a rod extending thru said wall, a pair of spring retainers carried by said rod on opposite sides of said wall, a pair of springs each retained between one of said retainers and said wall and biasing said wall to a predetermined position relative to said rod, a connection between said throttle means and said rod for translating it concurrently with movement of said throttle means, a by-pass conduit connecting said chambers, and means movable to open said by-pass conduit to place said capacity control means under direct control of said throttle means.

18. A fuel supply system for an internal combustion engine, comprising injector pump mechanism for supplying fuel to said engine, means for controlling the delivery of said pump mechanism, fluid motor means for operating said delivery control means including a pair of expandable chambers separated by a movable wall and a connection between said wall and said control means, a manually movable control device, a passage for combustion air flowing to said en-

15

gine, a second control device responsive to the rate of air flow thru said passage, valve means operated by said second control device for regulating the supply of motive fluid to said chambers to cause operation of said control means, mechanical connecting means associated with said manual control device and said movable wall and operable selectively to cause concurrent movement of said manual device and said wall or to permit independent movement of said device and said wall, a by-pass connection between said chambers, a valve in said by-pass, and a common operator for said by-pass valve and said mechanical connecting means, said operator being movable between a first position wherein said valve is closed and said connecting means permits independent movement of said wall and a second position wherein said valve is open and said wall is movable concurrently with said manual control device.

19. A fuel supply system for an internal combustion engine, comprising injector pump mechanism for supplying fuel to said engine, means for controlling the delivery of said pump mechanism, motor means for operating said delivery control means, a passage for air flowing to said engine for combustion purposes, means responsive to the rate of flow of air thru said passage for controlling said motor means, means for interrupting control of said motor means by said air flow responsive means, a manually movable control device, mechanical connecting means associated with said manual control device and said motor means and operable selectively to cause concurrent movement of said manual control device and said motor means or to permit independent movement of said motor means, and a common operator for said interrupting means and said connecting means, said operator being movable between a first position wherein said air

16

flow responsive means controls said motor means and said connecting means permits independent movement of said motor means and a second position wherein control of said motor means by said air flow responsive means is interrupted and said motor means moves concurrently with said manual control device.

20. A fuel supply system for an internal combustion engine, comprising injector pump mechanism for supplying fuel to said engine, means for controlling the capacity of said pump mechanism, motor means for operating said capacity control means, a passage for air flowing to said engine for combustion purposes, means responsive to the rate of flow of air thru said passage for controlling said motor means, throttle means for controlling the flow of air thru said passage, means for interrupting control of said motor means by said air flow responsive means, mechanical connecting means associated with said throttle and said motor means and operable selectively to cause concurrent movement of said throttle means and said motor means or to permit independent movement of said throttle means and said motor means, a common operator for said interrupting means and said connecting means, said operator being movable between a first position wherein said air flow responsive means controls said motor means and said connecting means permits independent movement of said motor means, and a second position wherein control of said motor means by said air flow responsive means is interrupted and said motor means moves concurrently with said throttle means, and means effective upon movement of said throttle means into a range of positions adjacent its closed position to cause movement of said operator to said second position.

LEIGHTON LEE, II.