Aug. 17, 1948. LE ROY J. EVANS 2,447,268

CHARGE FORMING DEVICE

Filed Feb. 13, 1943 5 Sheets-Sheet 1

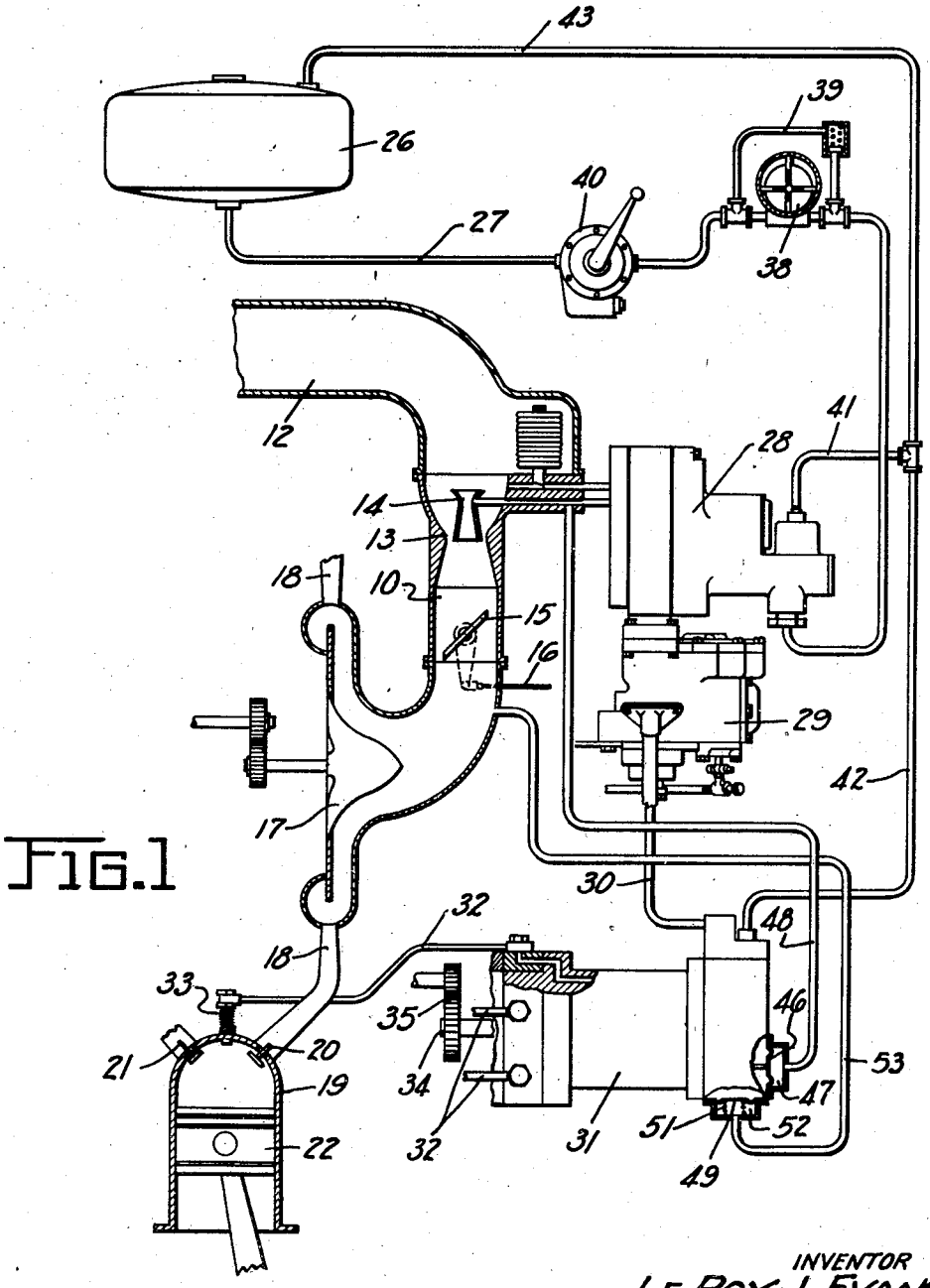


FIG. 1

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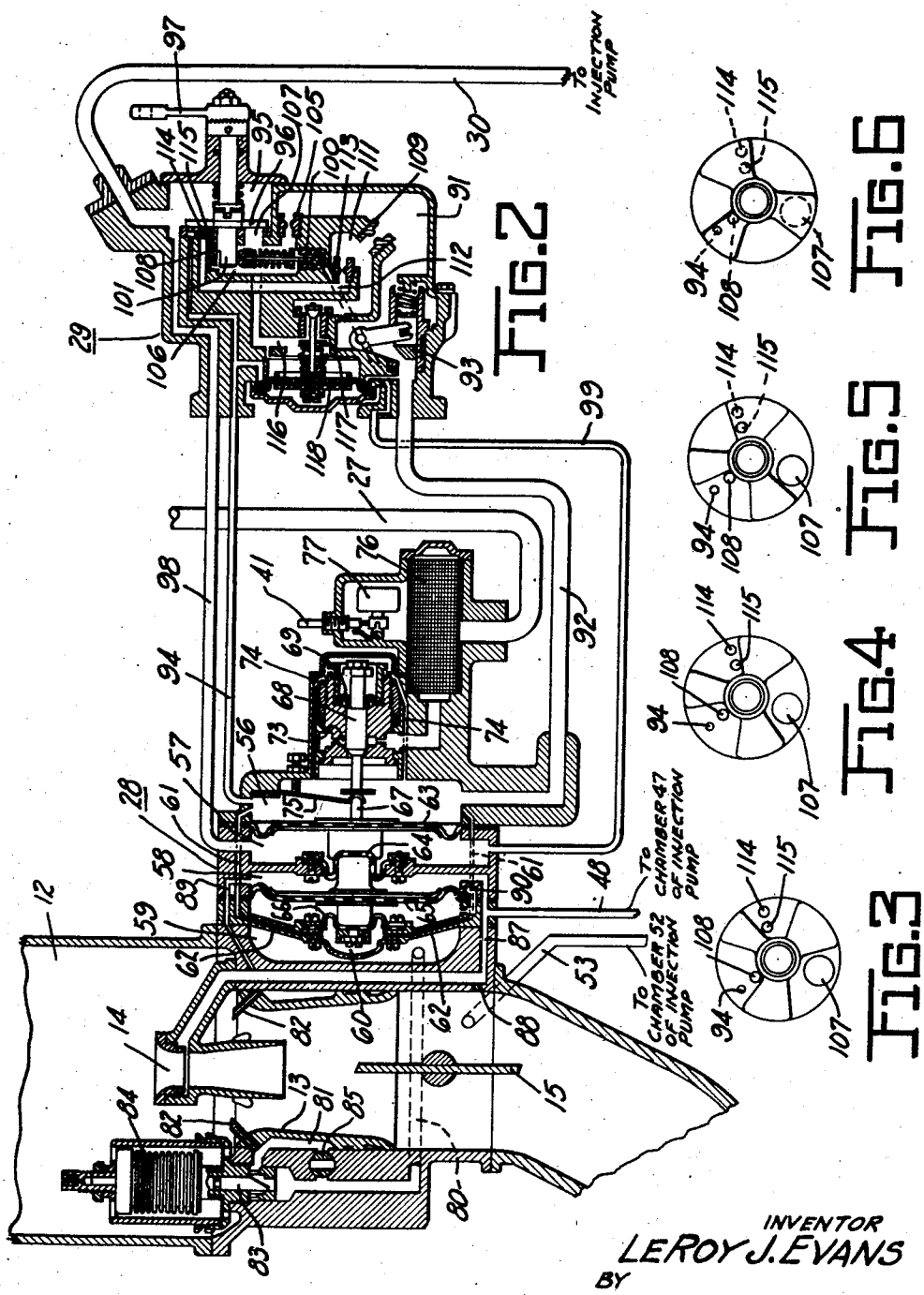


FIG. 2

FIG. 6

FIG. 5

FIG. 4

FIG. 3

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CHARGE FORMING DEVICE

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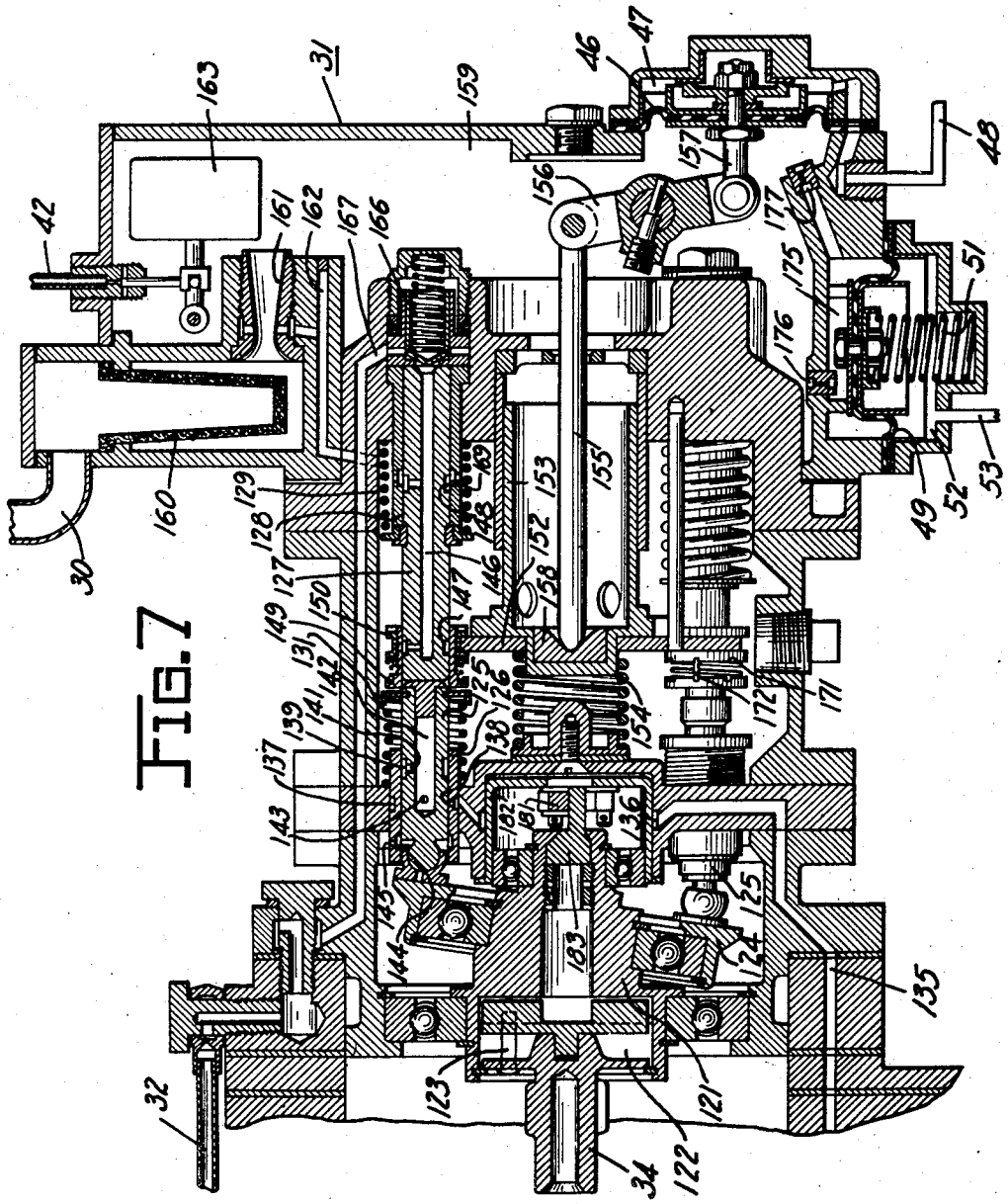


FIG. 7

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CHARGE FORMING DEVICE

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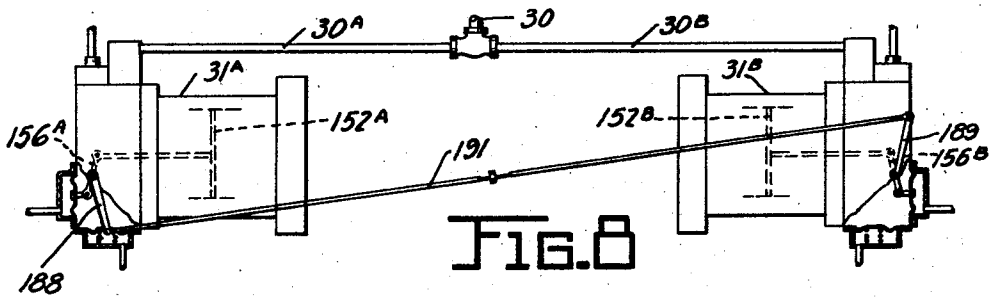
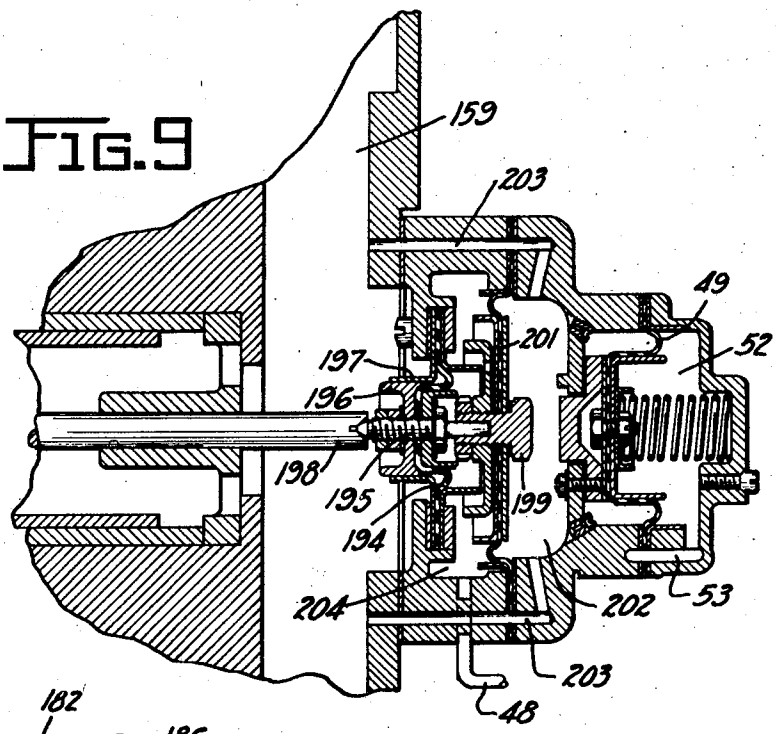


FIG. 8

FIG. 9



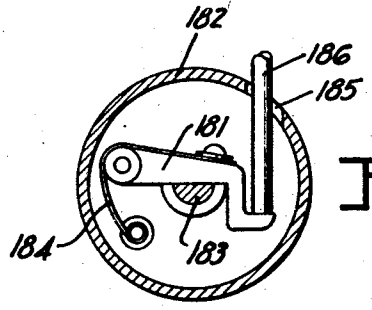


FIG. 10

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CHARGE FORMING DEVICE

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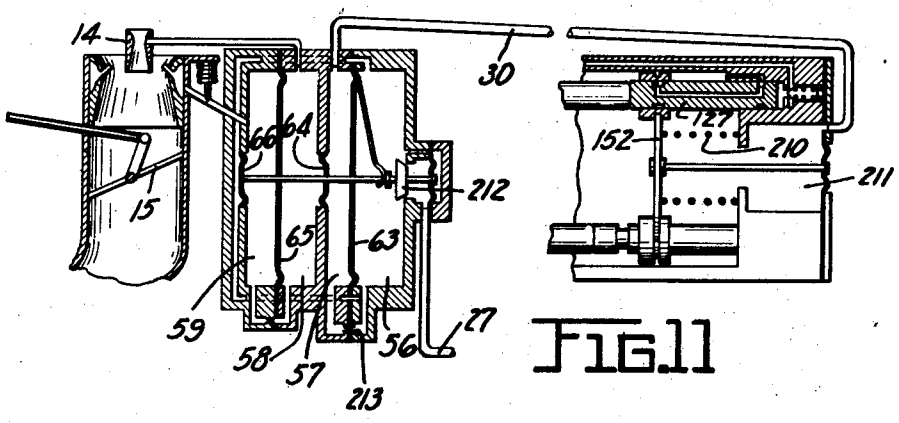


FIG.11

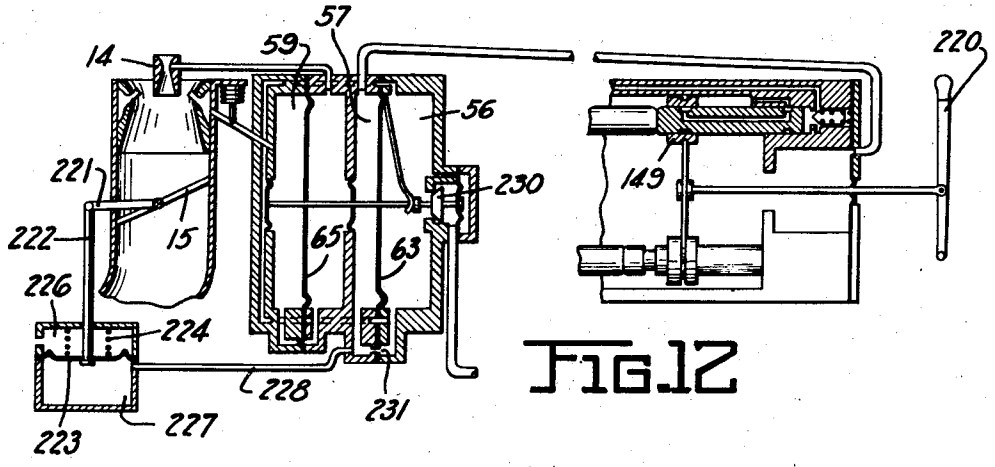


FIG.12

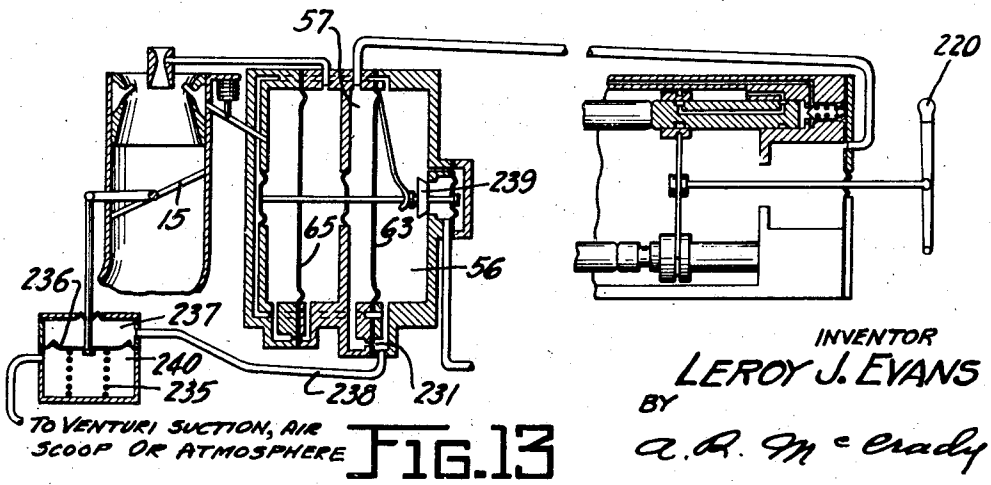


FIG.13

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2,447,268

UNITED STATES PATENT OFFICE

2,447,268

CHARGE FORMING DEVICE

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Application February 13, 1943, Serial No. 475,783

24 Claims. (Cl. 123—119)

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This invention relates to charge forming devices for internal combustion engines having a variably throttled air supply, and more particularly to direct fuel injection systems for such engines wherein a fuel injection pump supplies separate and distinct fuel charges to the engine in timed relation therewith.

It is an object of the invention to provide an improved combination of fuel injection pump and control mechanism therefor.

It is another object of the present invention to provide an improved fuel control system for an engine of the fuel injection type in which the fuel and air are properly proportioned irrespective of speed and load.

It is another object of the invention to manually control the supply of one of the charge components to a direct fuel injection engine, either air or fuel, and to utilize a variably controlled fuel pressure to regulate the position of the element controlling the supply of the other component.

A further object of the invention is to provide a control for an engine of the fuel injection type in which the air or fuel control element is manually controlled and the other is power actuated by a member responsive to a suction derived from the air supply passage and to an automatically controlled and variable fuel pressure.

It is a further object of the invention to provide an improved fuel control system for an engine of the direct fuel injection type in which the effective delivery of the injection pump is controlled by an element mounted within the pump housing and responsive to fuel pressure therein varying with variations in the ratio of the weights of air and fuel supplied to the engine.

Another object of the invention is to provide a control for an engine of the fuel injection type in which the air supply to the engine is manually controlled and the fuel supply is automatically regulated in accordance with the weight of air being supplied to the engine.

Still another object of the invention is to provide a direct fuel injection pump and control mechanism therefor in which air and/or vapor are automatically eliminated.

It is a further object of the invention to provide an accurate and simplified fuel and air control system for a direct injection engine.

Still a further object of the invention is to provide a means for simultaneously controlling two or more injection pumps supplying fuel to an engine having a large number of cylinders.

Another object of the invention is to provide

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an improved lubrication system for a direct injection fuel pump.

Other objects and advantages will be readily apparent from the following detailed description taken in connection with the appended drawings in which:

Figure 1 is a diagrammatic view partially in section showing the general arrangement of the parts of one form of my improved charge forming device as applied to an internal combustion engine, wherein the air supply is manually controlled and the fuel supply is automatically controlled;

Figure 2 is a somewhat diagrammatic view in section of the air passage, the fuel regulator and the fuel control body of the improved charge forming device;

Figures 3, 4, 5 and 6 show the mixture control valve in its full rich, automatic rich, automatic lean, and idle cut-off positions, respectively;

Figure 7 is a sectional view of the injection fuel pump;

Figure 8 is a diagrammatic view showing an arrangement for interconnecting the control mechanisms of two injection pumps supplying the same engine;

Figure 9 is a sectional view of a modified control arrangement and acceleration device for the injection pump;

Figure 10 is a view in section taken on the line 10—10 of Figure 7 disclosing mechanism for checking the timing of the injection pump;

Figure 11 is a simplified diagrammatic view illustrating a modification of the embodiment of Figure 1;

Figure 12 is a simplified diagrammatic view illustrating another embodiment of my invention wherein the fuel supply is manually controlled and the air supply is automatically controlled; and

Figure 13 is a simplified diagrammatic view illustrating a modification of the embodiment of Figure 12.

With reference to Figure 1, air is supplied to the engine through an induction passage 10 which includes an air inlet or scoop 12, one or more venturis 13, 14, a throttle 15 controlled by the link 16 extending from the pilot's compartment, a supercharger 17 of any desired type, and supercharger discharge passages 18 leading to the various engine cylinders such as 19, each of which has an inlet wave 20, an exhaust valve 21 and a piston assembly 22.

Fuel is supplied to the engine from a fuel supply tank 26 through a pipe 27 leading to a fuel regu-

lator 28, thence through the regulator to a fuel control unit 29, and through a pipe 30 to a fuel injection pump 31, from which it is delivered under high pressure through pipes 32 to fuel discharge nozzles such as 33 mounted in the head of and discharging into the individual cylinders 19. The nozzles 33 may be of any known type, and if desired may discharge into the passages 18 adjacent the inlet valves 20 instead of directly into the cylinders. The injection pump 31 has a main pump shaft 34 driven by the engine in timed relation therewith through gears 35. In four cycle engines the injection pump is driven at half engine speed whereas in two cycle engines it is driven at a speed equal to the engine speed. For supplying fuel under pressure to the regulator 28, there is provided in the pipe 27 an engine driven fuel pump 38 which may be of any desired type, the one shown being of the conventional sliding vane type having a pressure responsive by-pass 39 for maintaining at substantially constant pressure the fuel supplied to the regulator 28. To facilitate starting, a hand operated wobble pump 40 is also provided in the pipe 27, preferably located within the pilot's compartment, whereby fuel under pressure may be positively supplied to the regulator 28 prior to and during cranking of the engine. For transmitting vapor and/or air back to the fuel tank 26, pipes 41 and 42 are provided leading respectively from the regulator 28 and the injection pump 31 to a pipe 43 connected to the fuel tank 26.

As will be pointed out more fully hereinafter, the fuel injection pump 31 is provided with a diaphragm 46 for controlling the effective fuel delivery of the injection pump, the inner face of the diaphragm being subjected to the fuel pressure within the housing of the pump and the outer face of the diaphragm 46 forming a wall of a chamber 47 connected to the venturi 14 by a passage 48. If desired the chamber 48 could be connected to the large venturi 13, or could be vented to atmosphere or any other desired pressure, as will be apparent hereinafter. For those installations in which an acceleration pump is required in order to obtain the desired rate of acceleration, a diaphragm 49 may be provided which is urged inwardly by a spring 51. The diaphragm 49 forms a wall of a chamber 52 which is connected to the induction passage 10 posterior to the throttle by a passage 53, all as will be more clearly understood from the detailed description hereinafter.

Referring to Figure 2, it will be noted that the control body 29 has been displaced from its position adjacent the regulator 28, as shown in Figure 1, so that both units could be shown in a single view. Several of the passages likewise have been moved slightly from their true positions to bring them into the plane in which the view is taken. For the most past, however, the various parts have been retained at their respective vertical levels, whereby automatic filling and air and vapor elimination are accomplished.

The regulator 28 is divided into five chambers, an unmetered fuel chamber 56, a metered fuel chamber 57, a venturi suction chamber 58, an air scoop pressure chamber 59, and a chamber 60 connected to the upper and lower portions of the unmetered chamber 56 by means of passages 61 running through arms or spoke-like members 62 by which the chamber 60 is supported within the chamber 59. Diaphragms 63, 64, 65 and 66, which separate the chambers respectively from each other, are all secured to a control rod 67 connected to a main fuel valve 68 which is preferably of a balanced type having substantially no unbalanced force thereon resulting from the differential fuel pressure across the valve. Any type of balanced valve may be used, such as a slide valve, a double-seated poppet valve, or, as shown, a poppet valve balanced by a diaphragm 69 subjected on its left face to the pressure of the fuel anterior to the valve, the pressure being freely transmitted from a groove 73 past the loosely fitting valve body to the diaphragm, and subjected on its right face to the pressures in chamber 56 by means of upper and lower passages 74 which are so arranged to eliminate air during the filling operation. A spring 75, adapted for adjustment, urges the valve 68 to the right to enrich the mixture for idling as will appear hereinafter. A strainer 76 is provided to eliminate dirt, air, and vapor from the fuel supplied from pipe 27 to the groove 73 of the main fuel valve assembly. Vapor and air removed by the strainer are vented to the fuel tank through the pipe 41 controlled by a small float assembly indicated at 77.

The chamber 59 of the regulator 28 is connected to the air inlet 12 by means of a passage 80 leading to an annular chamber 81 which is in communication with the inlet through a plurality of tubes 82. This connection is controlled by an automatic altitude mixture control valve 83 actuated by a sealed capsule 84 responsive to variations in temperature and pressure of the incoming air whereby the valve 83 tends to further restrict the connection upon increase in temperature or decrease in pressure of the incoming air. A by-pass controlled by a valve 85 is provided around the valve 83, and may be opened, as hereinafter described, to render the valve 83 ineffective.

Chamber 58 of the regulator 28 is connected to the venturi 14 by means of a main suction passage 87 leading from the bottom of the chamber to the venturi and having a restricted branch 88 opening into the induction passage posterior to the throttle 15 when closed. A passage 89 connects the top of chamber 58 to the passage 87 leading to the venturi 14. The chambers 59 and 58 are interconnected by means of a calibrated passage 90 for reducing the differential in the pressures in chambers 58 and 59 when the automatic mixture control valve 83 is in position to restrict the passage 80. The passage 90 is preferably located adjacent the bottom of the chambers so that any water or liquid fuel collecting therein may be swept out through passage 87 and the restricted branch 88 upon starting or cranking of the engine.

Unmetered fuel chamber 56 is connected to a chamber 91 of the control body 29 by a main fuel duct 92 which is controlled by a throttle operated idling valve 93 adapted to restrict the passage when the throttle is substantially closed and is moved out of a restricting position as the throttle opens beyond the idling range. To eliminate from chamber 56 all air during the filling operation and any vapor during periods of operation, there is provided a passage 94 leading from the upper portion of chamber 56 to a chamber 95 of the control body 29, the passage 94 being one of several passages controlled by a three-lobe plate type mixture control valve 96, hereinafter described, which is operated by lever 97.

The metered fuel chamber 57 is in free communication with the chamber 95 of the control body by means of a pressure passage 98 leading

from the upper portion of chamber 57. A filling passage 99 is provided leading to the control body 29 from the lower portion of chamber 57 and is controlled by a valve 100 operated by a cam 101 rotatable with the lever 97. The cam is adapted to open valve 100 during normal operation and to close it for idle cut-off when the engine is to be stopped.

The control body 29, now to be described, determines the effective fuel metering area for various settings of the mixture control lever 97, and in addition automatically increases the effective fuel metering area for conditions of high power output. An "automatic lean" metering jet 105 connects the chamber 91 with a chamber 106 having a fuel passage 107 leading to the chamber 95. A vent passage 108 is provided from the top of chamber 106 to the chamber 95. Passages 107 and 108 are controlled by the valve 96. A "power-enrichment" metering jet 109 communicates the chamber 91 with a small chamber 111. A fuel conduit 112 including an "automatic-rich" metering jet 113, leads from the chamber 111 to the chamber 95, the end of conduit 112 adjacent valve 96 being formed as two ports 114 and 115 to provide ample area for flow while reducing the diameter to permit proper lapping thereof by a lobe of valve 96. A fuel conduit 116 leads from the chamber 111 to the chamber 106 and includes a spring closed economizer valve 117 connected to a diaphragm 118 subjected on one side to the metered fuel pressure in chamber 106 and on the other side to the unmetered fuel pressure in the passage 92.

The mixture control valve 96 normally occupies one of the four positions shown in Figures 3–6. Figure 3 represents the "full-rich" position in which all of the passages 94, 107, 108, 114 and 115 are open, valve 100 is open, and the valve 85 is open, the latter valve being operated by a linkage (not shown) connecting the lever 97 and the valve 85. In this position the device is in the full rich position and the automatic altitude control valve 83 is ineffective. Upon movement of the valve 96 to the "automatic-rich" position shown in Figure 4, the only change which occurs is the closing of the valve 85 whereupon the automatic altitude control valve becomes effective to restrict the passage 80 upon increase in altitude. Upon movement of the valve 96 to the "automatic-lean" position shown in Figure 5 the ports 114, 115 are closed rendering inoperative the "automatic-rich" jet 113 and to that extent reducing the effective available fuel metering area. Further movement of the valve 96 to the "idle cut-off" position shown in Figure 6 closes all of the passages and closes the valve 100. All communication is thus cut off between the chambers 91 and 95 of the control body, as well as between the unmetered fuel chamber 56 and the metered fuel chamber 57 of the regulator unit 28, whereby the fuel supply to the pipe 30 leading to the injection pump is completely cut off.

The fuel injection pump 31, shown in Figure 7, includes the main drive shaft 34 which drives a member 121 through an Oldham type universal coupling of known construction, indicated at 122. A locating pin 123 is provided to prevent incorrect assembly of the coupling which would change the timing of the injection pump relative to the engine. A wobble plate 124, bearing-mounted on the member 121, is slidably engaged by a plurality of tappets 125 reciprocably mounted in bushings 126 uniformly spaced around the periphery of the injection pump 31. Pump plungers 127 are coaxially arranged relative to the tappets 125 and are slidably received in bushings 128 which form the individual pump cylinders. In view of the fact that each of the tappet and plunger assemblies and the control mechanism therefor are all alike, the following description will be directed to the upper plunger and tappet as shown in Figure 7. A spring 129 urges the plunger 127 to the left and maintains the plunger and tappet in constant contact with each other and maintains the tappet against the wobble plate 124. The plunger and tappet are preferably made as separate abutting pieces rather than as one piece, so that minor variations in alignment of the bushings 126 and 128 may be accommodated without tending to bind the assembly. A spring 131 is provided to move the tappet out of engagement with the wobble plate in the event the plunger 127 becomes stuck.

In order to lubricate the tappets, an oil passage 135 supplies oil to an annulus 136 which is connected to an annulus 137 in the outer surface of the tappet bushing 126. A single hole 138 in the bushing 126 intermittently communicates with a groove 139 in the tappet 125 having a hole 141 for transmitting oil into a plugged bore 142 in the tappet. The oil in groove 139 effectively lubricates the tappet. A small hole 143 is arranged to communicate at times with an annular groove 144 having an escape port 145 into the interior of the wobble plate housing whereby a limited circulation of oil through groove 139 and bore 142 is obtained. Oil from within the housing is returned to the engine crankcase through the bearings supporting the member 121. Because of the intermittent supply of oil to the tappets, the quantity of oil utilized for lubrication is reduced to within permissible limits without resort to highly restricted passages which would tend to become clogged.

The pumping plunger 127 is provided with a central bore 146 in communication with a pair of spaced annuluses 147, 148. A by-pass sleeve 149 is slidably mounted on the plunger 127 and is provided with a grooved member 150 threaded thereon which is adapted to be carried by a plate 152. The plate 152 is secured to a slidably mounted piston 153 which is urged to the right by a spring 154 and is moved to the left against the spring by a rod 155 pivotally connected to one end of a lever 156 having its other end pivotally connected to a link 157 secured to the diaphragm 46, which as above pointed out forms a movable wall of the chamber 47 connected to the venturi 14 by means of the passage 48. If desired, the chamber 47 may be vented to atmosphere, air scoop, or any desired pressure, as will become apparent hereinafter. The left end of rod 155 is of a rounded conical shape and is abuttingly received in a rounded conical depression in a member 158 secured to the piston 153. This construction facilitates assembly and permits the necessary slight rocking movement of rod 155 upon movement of lever 156.

The interior of the housing of pump 31 forms a fuel reservoir 159 which receives fuel from the control body 29 through the pipe 30, a bead type filter 160 and a venturi 161, the latter being provided to draw out through a passage 162 any vapor which may form and be trapped in the reservoir adjacent the upper pump plunger 127. The vent pipe 42, controlled by a float assembly indicated at 163, transmits any air or vapor back to the fuel tank 26.

As shown in Figure 7, the upper plunger is in

its extreme right-hand position corresponding to the end of the stroke. Upon rotation of the wobble plate 124, the plunger 127 will move to the left until the annulus 147 passes to the left of the by-pass sleeve 149. At this time, fuel enters through annulus 147 and bore 146 to fill the fuel pumping space to the right of the end of plunger 127. Upon movement of the plunger to the right, fuel will be pumped back out of the annulus 147 until it passes into lapped relation with by-pass sleeve 149 which determines the beginning of injection. Further movement of the plunger forces the trapped fuel past a spring loaded check valve 166 into a passage 167, thence through the nozzle supply pipe 32 to the nozzle 33, which discharges the fuel under high pressure into the engine cylinder. Fuel discharge from nozzle 33 continues until the annulus 148 passes into registry with an annulus 169 vented to the reservoir 159, whereupon the remaining fuel in the cylinder of plunger 127 is pumped into the reservoir 159. This arrangement suddenly relieves the pressure of the fuel being pumped and quickly cuts off injection, thereby eliminating dripping at the nozzle. Preferably the annulus 148 and annulus 169 are brought into registry shortly before the end of the stroke of plunger 127 so that the latter portion of the stroke, which is at a rapidly decreasing plunger velocity which would produce a decreasing fuel injection pressure, will not be utilized for injecting fuel into the engine. This confines the injection period to the relatively high velocity period of the plunger and the resulting high injection pressure period, whereby better atomization at the nozzle is obtained.

Movement of the by-pass sleeve 149 to the right in Figure 7 increases the portion of the stroke during which the annulus 147 is open to the reservoir, or in other words delays the beginning of injection, and consequently reduces the effective stroke of the plunger. If the by-pass sleeve 149 is moved to its extreme right-hand position, the annulus 147 does not lap the sleeve 149 at all, or at least not until the annulus 148 is in registry with the annulus 169, and as a consequence no fuel would be injected into the engine. Thus by varying the position of sleeve 149 the effective pumping capacity of the pump may be varied from zero to the maximum capacity of the pump.

In order to eliminate variations in the quantity of fuel pumped by the individual plungers resulting from variations in the relative assembled locations of the annuluses 147, 148 and 169, each of the by-pass sleeves 149 are adjustable relative to the plate 152. The members 149 and 150 are each provided with a plurality of, but a different number of, equally spaced notches, best shown in the lower plunger assembly of Figure 7. Preferably one of the members has one more notch than the other. A spring 171 is carried by the member 149 and is provided with a bent end 172 adapted to be received in two oppositely disposed notches so as to lock the member 150 relative to the member 149. This arrangement makes it possible to adjust the sleeve 149 laterally relative to the plate 152 in increments equal to the pitch of the thread on member 149 divided by the product of the number of notches on the two members 149 and 150. Thus if there are nine notches on one member and ten on the other and the pitch of the thread is one thirty-second of an inch, then the available increment of adjustment is less than four ten-thousandths of an inch.

Assuming the entire charge forming device hereinabove described has been installed on an engine and does not contain any fuel, the procedure for filling the device with fuel, starting the engine and operating the engine would be as follows. Referring to Figures 1, 2 and 7, the mixture control valve 96 is placed in the "automatic-rich" position (Figure 4) thus uncovering all of the passages controlled by valve 96 and opening the valve 100. Fuel is then supplied to the inlet pipe 27 of the regulator 28 under positive pressure by means of the hand-operated wobble pump 40. The idle spring 75 normally holds the valve 68 off of its seat and therefore allows fuel to enter the unmetered fuel chamber 56 and flow through passage 92 into chamber 91 of the control body 29. The fuel rises uniformly in chambers 56 and 91 until it reaches the jet 105. The fuel in chamber 56 urges the diaphragm 63 to the left tending to close the valve 68 against the force of spring 75; however, the level determined by jet 105 must be insufficient to close the valve 68, otherwise the flow of fuel would be cut off. Additional fuel entering chamber 56 flows through jet 105, past valve 100, through passage 99 and into the metered fuel chamber 57. The fuel in chamber 56 thus remains constant until fuel in chamber 57 reaches the same level, whereupon it rises uniformly in both chambers and in the control body, forcing the air out ahead of it through passage 30 to the injection pump where it escapes through vent pipe 42. Fuel is then supplied to the injection pump until it too is full of fuel, at which time the float assembly 163 closes the vent. Additional operation of the wobble pump 40 increases the fuel pressure throughout the system, and particularly in the pump reservoir 159. The increased pressure on the diaphragm 46 forces it to the right and consequently the by-pass sleeves 149 to the left, whereby the effective stroke of the plungers 127 is increased to a maximum. Upon cranking the engine, a heavy fuel charge is thus supplied to the engine to produce an enriched mixture for starting.

During operation, the pilot controls the air supplied to the engine by manipulating the throttle 15, and the fuel is automatically controlled as hereinafter described. Air flow through the induction passage 10 creates a differential in pressure between the throat of venturi 14 and the air scoop which is proportional to the square of the quantity of air flowing. These pressures are respectively transmitted to the chambers 58 and 59, where in acting on opposite sides of diaphragm 65 they create a net force to the right tending to open valve 68 which is likewise proportional to the square of the quantity of air flowing. The sealing diaphragms 64 and 66 are respectively acted on by these two air pressures and merely have the effect of reducing the effective area of diaphragm 65 without disturbing the proportional relationship between the air flow and the force on the control rod 67.

Fuel supplied by the engine driven pump 38 flows through pipe 27, past the valve 68, into the unmetered fuel chamber 56, and through passage 92 to the chamber 91. If the mixture control valve is in the "automatic-lean" position and the engine is operating at moderate power output, the fuel will flow through the "automatic-lean" jet 105, through passage 107, into chamber 95, and then through pipe 30 to the reservoir 159 of the injection pump 31. The pressure of the fuel

in reservoir 159 acts on the diaphragm 46 and tends to move it to the right in a direction to move the rod 155, plate 152, and by-pass sleeves 149 to the left against spring 154 to thereby determine the effective stroke or pumping capacity of the injection pump. The flow of fuel from the unmetered fuel chamber 56 through the control body 29 to chamber 95 creates a differential fuel pressure which, for a given effective fuel metering area of the body 29, is proportional to the square of the quantity of fuel flowing. It may be noted that the venting passage 94 is open and forms a by-pass around the idling valve 93 and the "automatic-lean" jet 105, thereby adding slightly to the effective area for flow. For convenience, however, it may be disregarded and the orifice 105 considered as having a slightly increased effective area.

The differential pressure across the control body 29 acts on diaphragm 63 and creates a force tending to close valve 68 which is proportional to the square of the quantity of fuel flowing. In the event the fuel force is insufficient to balance the air force on the diaphragm assembly of valve 68, the valve will open an additional amount which will increase the fuel pressures throughout the system on the downstream side of the valve. The increased fuel pressure in the reservoir 159 will urge the diaphragm 46 further to the right to increase the fuel delivery of the injection pump until the quantity of fuel flowing through the fuel metering orifice 105 is sufficient to produce a differential pressure across the control body 29 which in acting on the diaphragm 63 will create a fuel force sufficient to balance the air force on diaphragm 65. Thus the regulator constantly functions to vary the fuel pressure in chamber 159 to establish the necessary fuel flow to produce a fuel differential pressure across diaphragm 63 which will balance the air differential pressure across diaphragm 65, thus maintaining a constant proportion between the air and fuel supplied to the engine for a given effective fuel metering area of the control body 29.

The chamber 47 may be vented to atmosphere, air scoop, the large venturi 13, the small venturi 14, or to any other desired source of pressure. If the chamber is vented to atmosphere then the fuel pressure in chamber 159 must increase substantially with increase in air flow in order to move the plate 152 to the left against spring 154 to thereby correspondingly increase the fuel flow to the engine. This in some respects is undesirable since the engine-driven fuel pump 38 would have to be of a relatively high pressure type in order to provide sufficient pressure in chamber 159 to move the plate 152 to the full pump capacity position, at which time the pressure drop through the regulator 28 and control body 29 is a maximum. By venting the chamber 47 to the venturi 14, suction which increases with air flow is utilized to increasingly assist the fuel pressure in chamber 159 in moving the diaphragm 46 to the right to correspondingly increase the fuel delivery. By proportioning the strength of spring 154 and the size of diaphragm 46, the fuel pressure in chamber 159 can be made to increase or decrease with increase in air and fuel flow to the engine. In any event, the fuel pressure in chamber 159 is regulated by the regulator 28 to establish that pressure in chamber 159 which in combination with the pressure in chamber 47 will set the by-pass sleeves 149 to maintain the fuel force on valve 68 equal to the air force, whereby fuel is supplied to the engine in proportion to the air flow as pointed out hereinabove.

At idle, the idle spring 75 engages the control rod 67 and creates a force in addition to and in the same direction as the air force on diaphragm 65, whereby an increased fuel flow must be provided to create a fuel force on diaphragm 63 sufficient to balance both the air force and the spring force. The mixture richness is thus increased at idle, as is desired. It has been found desirable to adjust the idle spring 75 to provide an excessive enrichment at idle and then to decrease the enrichment with the throttle controlled idling valve 93 which is adjusted to restrict passage 92 at closed throttle and is withdrawn from its restricting position as the throttle opens from its idle position. Any desired idle and near idle enrichment may be obtained by the contour and adjustment of the valve 93.

As the air flow and consequently the power output increase, the venturi-to-scoop pressure differential and consequently the unmetered-to-metered fuel pressure differential increase. The economizer diaphragm 118, which is subjected to the unmetered-to-metered fuel pressure differential, is arranged to open the economizer valve 117 when the fuel metering differential exceeds a predetermined value to enrich the mixture for high power operation. When valve 117 opens, fuel is allowed to flow from chamber 91 to chamber 95 through the power enrichment jet 109, past the valve 117, and through conduit 116. The regulator 28 functions to control the fuel flow to maintain the fuel differential pressure between chambers 91 and 95 equal, or proportional, to the air differential pressure on diaphragm 65. Since opening of the economizer valve increases the available fuel metering area by adding thereto the area of jet 109, the fuel flow and consequently the mixture richness will be increased, as is desired at high-power operation.

If the airplane is now taken to a higher altitude, the venturi-to-scoop air differential pressure for a given weight of air flow will increase. If this increased differential were transmitted to the chambers 58 and 59 of the regulator 28, the fuel flow to the engine would increase and the mixture would become richer with increase in altitude. However, as altitude is obtained the bellows 84 expands and the valve 83 restricts the passage 80. As a consequence, air drawn from chamber 59 through the calibrated passage 91 into the Venturi suction chamber 58 tends to reduce the pressure in chamber 59 and thus reduces the differential pressure across diaphragm 65. The valve 83 is designed to variably restrict passage 80 such that the differential pressure across diaphragm 65 will remain substantially constant for a given weight of air flow, regardless of the altitude, thus maintaining a substantially constant mixture richness with change in altitude. It will be obvious that the same result can be obtained by utilizing a bellows-controlled valve to control the venturi connection to chamber 58 rather than the air scoop connection to chamber 59.

If the mixture control valve 96 is placed in its "automatic-rich" position, as shown in Figure 4, with the engine operating at moderate power output, the economizer valve 117 will be closed and the engine will receive fuel through the "automatic-lean" metering jet 105 and also through the "power-enrichment" jet 109, the "automatic-rich" jet 113, and the conduit 112. Thus the available effective fuel metering area has been increased and the mixture is therefore enriched.

Under these conditions the "power-enrichment" jet 109 has little effect since it is larger than the "automatic-rich" jet 113. However, at high power output with the economizer valve 117 open, the jet 109 becomes the primary metering restriction and the power mixture richness is substantially the same as with the mixture control valve 96 in its "automatic-lean" position. This insures that the engine will receive a mixture of proper richness for maximum power and engine safety regardless of whether the valve 96 is in its "automatic-rich" or "automatic-lean" position.

In an emergency at altitude, the pilot may obtain additional richness by moving the valve 96 to its "full-rich" position, shown in Figure 3, whereby through a linkage (not shown) interconnecting lever 96 and valve 85, the valve 85 is opened. This eliminates the effect of valve 83 and allows the full venturi-to-air-scoop differential pressure to be transmitted to the regulator 28 whereby an enriched mixture is obtained.

In order to slightly richen the mixture upon acceleration, the diaphragm 49 (Figure 7) is provided which is urged upwardly by the spring 51. During idling or cruising operation, vacuum from posterior the throttle 15, transmitted through passage 53 to the chamber 52, draws the diaphragm 49 downwardly against the spring 51 and draws fuel into a chamber 175 through calibrated orifices 176 and 177. Upon sudden drop in vacuum in chamber 52 accompanying acceleration, the spring 51 forces the diaphragm 49 upwardly injecting fuel into the reservoir 159. The orifice 177 is positioned so that fuel discharged therefrom is directed against the diaphragm 46 to aid in moving it to the right. In addition, the fuel introduced into chamber 159 makes up for the increase in the effective volume of the chamber 159 resulting from the chamber increasing movement of diaphragm 46, otherwise a portion of the fuel being metered and supplied by the regulator would be used to fill this increased volume instead of being injected into the engine. In many installations, sufficiently rapid acceleration is obtained without an acceleration pump, and in such cases it obviously may be omitted.

In order to check the timing of the injection pump, a finger-like member 181 (Figure 10) is pivotally mounted within a cup 182 fixedly mounted within the pump (Figure 7) and is adapted to cooperate with a flatted end of a member 183 secured to the rotatable member 121 on which the wobble plate 124 is mounted. A spring 184 normally urges the finger 181 in a counterclockwise direction, as shown in Figure 10, to move it out of engagement with the flatted end of the member 183. An aperture 185 is provided in the cup 182, which is in alignment with similar apertures (not shown) in the various other members of the pump, whereby a rod 186 may be inserted to force the finger 181 against the flatted member 183, as shown in Figure 10. The flat on member 183 and the wobble plate 124 are so arranged relative to each other that with the rod in its most inwardly position the number one plunger, or any known plunger, is at the end of its stroke. The pump may thus be checked to determine if it is properly timed with the engine.

In engines having a large number of cylinders, I have sometimes found it desirable to utilize two separate injection pumps rather than to use a single pump of sufficient diameter to accommodate all of the plungers peripherally spaced therein. Figure 8 diagrammatically illustrates an arrangement whereby two injection pumps 31A and 31B may be used with a single regulator and control body. The pipe 30, receiving fuel from the control body 29, is provided with a pair of branches 30A and 30B leading to the individual injection pumps. Equal length levers 188 and 189 are secured to and rotatable with the pivoted levers 156A and 156B, respectively, and are interconnected by an adjustable link 191. The link 191 is initially adjusted to make the delivery from the two pumps equal, and thereafter the plates 152A and 152B actuating the by-pass sleeves will be moved together, regardless of any variations in plunger friction in the pumps 31A and 31B or regardless of variations in the springs resisting movement of the plates 152A and 152B.

Figure 9 discloses a modified arrangement for actuating the plate carrying the plunger by-pass sleeves. In this arrangement a guided diaphragm assembly is provided comprising a small diaphragm 194 having a central bolt-like member 195 which clamps the diaphragm between a guide member 196 and a diaphragm supporting cup-shaped member 197. The left end of bolt 195 is in abutting relation with a guided rod 198 secured to or in abutting relation with the plate carrying the by-pass sleeves, as in Figure 7. The other end of bolt 195 is formed with a reduced diameter portion slidably received within and in abutting relation with a central clamping bolt 199 of a larger diameter diaphragm 201. A chamber 202 to the right of diaphragm 201 is in free communication through passages 203 with the reservoir 159 of the injection pump. A chamber 204 between the diaphragms is vented to venturi 14 through the passage 48. As in the modification of Figure 7, the chamber 204 may be vented to atmosphere, air scoop, or any desired pressure instead of to the venturi. The modification of Figure 9 functions in a manner similar to that of Figure 7. An increase in fuel pressure in chamber 159 is transmitted to the chamber 202 and urges both of the diaphragms and the rod 198 to the left to increase the effective stroke of the pump plungers, the same as with the arrangement of Figure 7. Likewise an increase in venturi suction is transmitted to chamber 204 and, due to the difference in the areas of diaphragms 201 and 194, urges the diaphragms and rod 198 to the left to assist the fuel pressure, the same as in Figure 7. With this modification, the acceleration pump is preferably placed adjacent the diaphragm 193 so that the pump discharge will tend to move the diaphragm 193 to the left, in a manner similar to the acceleration pump of Figure 7.

Figures 11, 12 and 13 diagrammatically illustrate further embodiments of the invention. It will be noted that in the embodiment of Figures 1–7, the spring 154 and diaphragm 46 are so arranged that an increase in fuel pressure in chamber 159 is effective to move the by-pass sleeves 149 to the left to increase the fuel flow. The valve 68 of the regulator is therefore arranged to open valve 68 if additional fuel flow is required in order to balance the air force on diaphragm 65. Opening valve 68 increases the pressure in chamber 159 which urges the diaphragm 46 to the right to increase the effective stroke of the plungers, thereby increasing the fuel flow as desired.

In Figure 11, a spring 210 urges to the left the plate 152 carrying the by-pass sleeves, thereby tending to increase the effective stroke of the plungers 127. The fuel pressure in chamber 211 must therefore be increased in order to decrease

the pumping capacity, or decreased in order to increase the pumping capacity. To accomplish this end, the fuel valve 212 of the regulator is arranged to close upon movement to the right in contrast to valve 68 of Figure 2 which opens with such movement. Thus if the fuel metering differential pressure across diaphragm 63 and consequently the fuel flow to the engine are insufficient to balance the air differential pressure across diaphragm 65, the valve 212 will tend to close thereby reducing the pressure in chamber 211 and allowing the spring 210 to move the by-passes to the left to increase the pumping capacity of the injection pump whereby the drop across the metering orifice 213 and consequently the fuel differential pressure across the diaphragm 63 will increase until the latter balances the air differential pressure.

In the modification of Figures 12 and 13 the fuel injection pump is manually controlled and the air throttle is automatically controlled. Thus in Figure 12 a manually operated lever 220 sets the position of the by-pass sleeves 149 and determines the quantity of fuel being pumped to the engine. The throttle 15 is connected through a lever 221 and a link 222 to a diaphragm 223 urged by a spring 224 in a direction to open the throttle. A chamber 226 above the diaphragm is preferably vented to atmosphere or airscoop. A chamber 227 below the diaphragm is connected by a pipe 228 to the metered fuel chamber 57, although it could as well be connected to the unmetered fuel chamber 56 or to any point in the fuel system downstream of the fuel valve 230. During operation, if the lever 220 is moved to increase the capacity of the injection pump, the fuel metering differential pressure across the metering orifice 231 acting on diaphragm 63 will increase and will move the fuel valve 230 toward closed position. This will decrease the absolute fuel pressures in chambers 56 and 57 and also in chamber 227, whereupon the spring 224 will move diaphragm 223 downwardly to open the throttle 15 to provide additional air for the increased fuel. The diaphragm 223 will move down until the throttle is opened sufficiently to provide the necessary air flow for creating an air differential pressure across diaphragm 65 which will balance the fuel differential pressure across diaphragm 63. Constant fuel-air proportioning is thus obtained.

In the modification of Figure 13 a spring 235 urges a diaphragm 236 in a direction to close the throttle 15. The chamber 237 above the diaphragm 236 is subjected to fuel pressure transmitted thereto through a passage 238 from the unmetered fuel chamber 56, although the fuel pressure at any point in the system downstream of the fuel valve 239 could be utilized. The valve 239 is arranged to open upon movement to the left in contrast to the valve 230 of Figure 12. During operation, if the injection pump control lever 220 is moved to the left to increase the pumping capacity of the injection pump, the fuel metering differential pressure across the metering orifice 231 acting on diaphragm 63 will increase and will move the valve 239 toward open position. This will increase the fuel pressures in chambers 56 and 57 and also in chamber 237, which will force the diaphragm 236 upwardly and further open the throttle to compensate for the increased fuel flow. The diaphragm 236 will move upwardly until the throttle is opened sufficiently to provide the necessary air flow for creating an air differential pressure across diaphragm 65 which will balance the fuel differential pressure across diaphragm 63. Constant fuel-air proportioning is thus obtained. The chamber 240 below the diaphragm 236 may be vented to atmosphere, air scoop, venturi, or any other desired pressure. The use of venturi suction in chamber 240 aids in opening the throttle upon increase in air and fuel flow, and as a result lower fuel pressures will obtain in chamber 237 than if the chamber 240 were vented to atmosphere.

The arrangements shown in Figures 12 and 13 are particularly adapted for use in highly supercharged engines since there is substantially no need for the boost or charging pressure control which is generally required in order to prevent overcharging of the engine when a manually actuated throttle is used. Thus by limiting the maximum effective stroke of the injection pump, by means of a substantially fixed stop, the air charge will be automatically limited regardless of the altitude or entering air density. At ground level with the injection pump in its maximum stroke position, the air throttle will only be partially opened, and as altitude is attained the throttle will be further opened to maintain the desired charging. Overcharging of the engine is thus prevented.

Although Figures 11, 12 and 13 illustrate various embodiments in a simplified, diagrammatic manner, it will be readily understood that the individual parts of the devices may be made in accordance with the corresponding parts shown in detail in Figures 2–7. Thus a single fuel metering orifice has been used in Figures 11–13 to represent the control body 29 of Figure 2. The other parts have likewise been shown in simplified form.

Although several embodiments of the invention have been shown, it will be readily apparent that many changes or arrangements of the parts may be made without departing from the spirit of the invention. For example, the diaphragms 63 and 65 of the regulator could be of different size, the number and position of the diaphragms could be changed, and other changes apparent to those skilled in the art may be made without departing from the teachings of the invention. Likewise the altitude control capsule 84 and attached valve 83 could control the Venturi connection to chamber 58 rather than the air entrance connection to chamber 59. Likewise the arrangement of the metering jets in control body 29 may be other than that shown; and the control valve 68 may be either anterior or posterior to the fuel metering orifices. Also, in the injection pump the by-pass could variably control the end of injection rather than the beginning of injection. Many other modifications will likewise be apparent to one skilled in the art from the foregoing description taken in connection with the appended drawings, and it should therefore be understood that the invention is not to be limited to the particular modifications disclosed nor otherwise except in accordance with the terms of the appended claims.

I claim:

1. In a fuel supplying system, an air passage, an element controlling the passage, a fuel injection pump having a housing, a plurality of pumping units receiving fuel from said housing and having by-pass sleeves for varying the effective stroke of the units, an element for varying the position of the sleeves to thereby vary the delivery of said injection pump, a fuel conduit receiving fuel from a source of fuel under pressure and supplying it to the housing, man-

ual means for actuating one of the elements, a movable wall responsive to variations in pressure for actuating the other of the elements and subjected to fuel under pressure, and valve means in the conduit responsive to pressures at spaced points in the air passage and at spaced points in the fuel conduit for varying the fuel pressure on the movable wall to control the said other element.

2. In a fuel feeding system for a direct injection engine, an air passage for supplying air to the engine, a venturi and a throttle in the passage, an element connected to the throttle, a fuel injection pump for intermittently supplying individual fuel charges to the engine cylinders in timed relation therewith, a movable element for varying the quantity of fuel in the fuel charges, a fuel conduit for supplying fuel to the pump, area restricting means in the conduit, a valve in said conduit, means responsive to the pressure in the venturi and to the pressures in the fuel conduit anterior and posterior to the area restricting means for controlling said valve and so arranged that a decrease in pressure in the venturi tends to close said valve, manual means for actuating one of said elements and means responsive to the fuel pressure in said conduit posterior to the valve for actuating the other of said elements.

3. In a fuel feeding system for an internal combustion engine, a fuel injection pump having a housing forming a fuel chamber, said pump including a plurality of fuel pumping units receiving fuel from said chamber and intermittently delivering charges of fuel directly to the engine cylinders in timed relation with the engine, a movable wall subjected on one side to the fuel pressure in the chamber and on the other to a pressure decreasing with increase in air flow to the engine, means actuated by the wall for varying the volume of the fuel charges, and means responsive to fuel pressures varying with variations in fuel flow to the engine for automatically varying the fuel pressure in the chamber for actuating the movable wall.

4. In a fuel feeding system for an internal combustion engine, an air passage having a throttle, a fuel injection pump comprising a housing having a fuel chamber therein, a plurality of engine driven fuel pumping units disposed within the chamber and receiving fuel therefrom, a movable wall mounted on the housing and forming a wall of the fuel chamber, means actuated by said wall in response to variations in fuel pressure in the chamber for varying the effective pumping capacity of said pumping units, said means and wall being so constructed and arranged that an increase in pressure in the fuel chamber increases the effective pumping capacity of the pumping units, a fuel conduit supplying fuel at variable pressure to the chamber, means responsive to pressures varying with variations in flow through the conduit and through the air passage for varying the fuel pressure in the chamber, a second fuel chamber in restricted communication with the first fuel chamber, a pressure chamber connected to the air passage posterior to the throttle, and a movable wall separating the second fuel chamber and the pressure chamber and spring-urged in a direction to decrease the volume of the second fuel chamber.

5. The invention defined in claim 4 wherein the restricted communication between the fuel chambers includes a passage directed for discharge toward the first named movable wall.

6. A fuel pump for an engine comprising a housing forming a fuel chamber, a plurality of pump cylinders in the housing, a plurality of split plungers having separable pumping portions and tappet portions, the pumping portion of each being slidably received in the cylinders and the tappet portion being slidably mounted and projecting through an oppositely disposed wall of the chamber, means for reciprocating the tappet portions, spring means urging the pumping portions into abutting relation with the tappet portions, means including annular grooves in the pumping portions and movable sleeves cooperating therewith for varying the effective stroke of the plungers, a movable member subjected to and movable in response to variations in the fuel pressure in the chamber connected to the sleeves for actuating the same, annular grooves in the tappets intermittently in communication with ports in the wall of the fuel chamber, and means for supplying oil under pressure to said ports for lubricating the tappets.

7. A fuel pump for an engine comprising a housing forming a fuel chamber, a plurality of pump cylinders within the chamber, engine reciprocated plungers slidably received in the cylinders, means including a port in the plunger and movable sleeves cooperating therewith for varying the effective stroke of the plungers, a diaphragm forming a movable pressure responsive wall of the chamber, and means operatively connecting the diaphragm to the sleeves for varying their position in response to variations in the fuel pressure in the chamber.

8. A fuel pump comprising a housing, a fuel chamber therein adapted to receive fuel from a source, a plurality of pumping plungers reciprocably mounted in the housing for pumping fuel from the chamber, a control member movable simultaneously to vary the effective stroke of all of the plungers, and a flexible member connected to said control member subjected to and movable in response to variations in the pressure of the fuel in the chamber, and to a variable air pressure for actuating the control member.

9. A pump for supplying fuel to an engine comprising, a housing, a plurality of pumping plungers peripherally spaced within the housing, by-pass sleeves for varying the effective stroke of the plungers, a member carrying the sleeves, means forming an adjustment of the individual sleeves relative to the plate, a fuel chamber within the housing, and a movable pressure responsive wall operatively connected to the member and subjected on one side to the fuel pressure within said chamber.

10. The invention defined in claim 9 comprising in addition means for subjecting the other side of the movable wall to a variable air pressure.

11. A fuel injection pump for supplying fuel directly to the cylinders of an engine comprising, a housing, a plurality of pumping plungers within the housing, a fuel chamber in the housing for supplying fuel to the pumping plungers, means movable within the housing for varying the effective pumping capacity of the plungers, a diaphragm in the housing responsive to the pressure of the fuel in the chamber for actuating said movable means, and means for subjecting the diaphragm to an air pressure decreasing with increase in air flow to the engine.

12. A fuel pump comprising a housing, a par-

tition in said housing dividing it into two chambers, one of which is a fuel chamber, a plurality of tappets peripherally spaced in said housing and slidably mounted in the partition, a wobble plate in the other of the chambers for actuating the tappets, a plurality of pumping plungers peripherally spaced within the fuel chamber in alignment with said tappets and having one end slidably received within cylinders provided in the fuel chamber, springs urging the plungers into abutment with the tappets, a bore in each of the plungers, an annular groove in the other end of each of the plungers having a connection with said bore, sleeves slidably mounted on the plungers and adapted to lap the grooves during a portion of the plunger stroke, and means including a member responsive to the fuel pressure in said fuel chamber connected to said sleeves.

13. In a fuel system for an internal combustion engine, a fuel injection pump for delivering separate and distinct charges of liquid fuel to the engine in timed relation therewith, a conduit supplying fuel to the pump, a fuel pump control element for varying the quantity of liquid fuel in the said charges, an air passage including a venturi for supplying air to the engine, means responsive to air and fuel pressures varying in accordance with variations in the weight of fuel and air supplied to the engine for varying the pressure of the fuel in the conduit, and a pressure responsive device subjected to variations in pressures in the conduit and in the venturi for actuating said fuel pump control element.

14. In a fuel supplying system for an internal combustion engine, a fuel injection pump for delivering liquid fuel directly to the engine cylinders, said pump including a fuel chamber, a fuel conduit supplying fuel from a source of fuel under pressure to the chamber, a fuel pump control element for varying the effective capacity of the pump, an air passage supplying air to the engine, a throttle controlling the passage, means responsive to fuel pressures at spaced points in the conduit and to air pressures at spaced points in the air passage for varying the fuel pressure in the fuel chamber, and a pressure responsive device subjected to the pressure in the fuel chamber and to a pressure in the air passage decreasing with increase in air flow for actuating the fuel pump control element.

15. In a charge forming device for an engine, an air passage supplying air to the engine, differential pressure creating means in the air passage, a throttle in the passage, a fuel injection pump for delivering discrete charges of liquid fuel to the engine, a fuel conduit supplying fuel to said pump, differential pressure creating means in the conduit, a valve controlling the conduit, means responsive to the differential pressures in the air passage and in the fuel conduit controlling said valve, means for controlling the injection pump to vary the rate of fuel supply to the engine, a pressure responsive member controlling the throttle, and a connection from the conduit posterior to the valve to said pressure responsive member.

16. A fuel pump for an engine comprising a housing forming a fuel chamber, a plurality of pump cylinders in the housing, a plurality of split plungers having separable pumping portions and tappet portions, the pumping portion of each being slidably received in the cylinders and the tappet portion being slidably mounted and projecting through an oppositely disposed wall of the chamber, means for reciprocating the tappet portions, spring means urging the pumping portions into abutting relation with the tappet portions, means including annular grooves in the pumping portions and movable sleeves cooperating therewith for varying the effective stroke of the plungers, and a movable member subjected to and movable in response to variations in the fuel pressure in the chamber connected to the sleeves for actuating the same.

17. In combination with an engine having an air-intake conduit provided with a throttle and fuel supply means having an output proportional to engine speed and whose output at any given speed is variable, a member movable to control the output of the fuel supply means, automatic fuel-air ratio mechanism functioning to meter fuel to said fuel supply means at a predetermined fuel-air ratio for all operating positions of said throttle, and a diaphragm operatively connected to said member and exposed on one side to the pressure of the metered fuel and on its opposite side to a pressure varying with variations in engine operation for regulating the effective delivery of said fuel supply means.

18. In a fuel supply system for an internal combustion engine, a fuel injection pump having a first fuel chamber, means for conducting fuel to said chamber including a flow passage having a venturi therein, a second fuel chamber receiving fuel from said first chamber for injection, a vapor passage communicating said second chamber with said venturi whereby flow of fuel through said flow passage acts to remove any vapor that may accumulate in said latter chamber, and means for venting vapor from said first fuel chamber.

19. In a fuel feeding system for an internal combustion engine, an air passage having a throttle, a fuel injection pump comprising a housing having a fuel chamber therein, a plurality of engine-driven pumping units disposed adjacent the chamber and receiving fuel therefrom, a movable wall mounted on the housing and forming a wall of the fuel chamber, means actuated by said wall in response to variations in fuel pressure in the chamber for varying the effective pumping capacity of said pumping units, said means and wall being so constructed and arranged that an increase in pressure in the fuel chamber increases the effective pumping capacity of the pumping units, a fuel conduit supplying fuel at variable pressure to the chamber, a second fuel chamber in restricted communication with the first fuel chamber, a pressure chamber connected to the air passage posterior to the throttle, a movable wall separating the second fuel chamber and the pressure chamber, and means normally urging said latter wall in a direction to decrease the volume of the second fuel chamber.

20. In a fuel feeding system for an internal combustion engine, an air supply passage provided with a venturi, a fuel injection pump including a housing providing a fuel chamber, means supplying fuel at variable pressure to the chamber, a plurality of pumping plungers reciprocably mounted in the housing for pumping fuel from the chamber to the engine cylinders, a member movable to vary the effective stroke of the plungers, and a movable pressure-responsive element for actuating said member subjected on one side to fuel pressure in said chamber and on its opposite side to venturi suction.

21. A fuel pump comprising a housing defining a fuel chamber, a plurality of tappets, means slidably supporting said tappets in spaced relation in the housing, means for actuating said tappets, a plurality of pumping plungers in substantial alignment with said tappets each having one extremity slidably received within a cylinder provided in the fuel chamber, means normally urging the plungers into abutment with the tappets, a bore in each of the plungers, spaced annular grooves in each of the plungers having a connection with said bore, sleeves slidably mounted on the plungers and adapted to lap the grooves during a portion of the plunger stroke, the period of lap determining the pumping period of the plungers, and means responsive to fuel pressure in said fuel chamber connected to said sleeves.

22. A fuel injection pump comprising a housing defining a fuel chamber, a plurality of tappets, means slidably supporting said tappets in spaced relation in the housing, means for actuating said tappets, a plurality of pumping plungers in substantial alignment with said tappets each having one extremity slidably received within a cylinder provided in the fuel chamber, means normally urging the plungers into abutment with the tappets, a bore in each of the plungers, spaced annular grooves in each of the plungers having a connection with said bore, sleeves slidably mounted on the plungers and adapted to lap the grooves during a portion of the plunger stroke, the period of lap determining the injection period of the plungers, a member supporting said sleeves, means responsive to fuel pressure in the fuel chamber connected to said member for regulating the position of said sleeves, and means for guiding said member to maintain the sleeves in freely-sliding aligned relation on the plungers.

23. In a fuel feeding system for an internal combustion engine having cylinders provided with fuel-discharge nozzles, a fuel injection pump having a housing defining a fuel chamber, means for supplying fuel to said chamber at pressures varying in relation to a function of engine operation, fuel conduits leading from the

pump to said nozzles, a plurality of pumping plungers for pumping fuel from said chamber to said nozzle in timed relation with the engine, a bore in each of the plungers, spaced annular grooves in each of the plungers having a connection with said bore, sleeves slidably mounted on the plungers and adapted to lap the grooves during a portion of the plunger stroke, the period of lap determining the period during which fuel is discharged by each of said nozzles, and means for variably positioning said sleeves with respect to said plungers and whereby the injection period may be confined to that portion of the travel of the plungers which is of greatest velocity.

24. In a charge forming device for an engine, an air passage supplying air to the engine, a throttle controlling the passage, a fuel conduit supplying fuel to the engine, a movable wall connected to the throttle for operating it, means for subjecting said wall to a fuel pressure varying in accordance with variations in the rates of air and fuel flow to the engine, and means for subjecting the wall to an air pressure decreasing with increase in air flow to the engine.

LE ROY EVANS.

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