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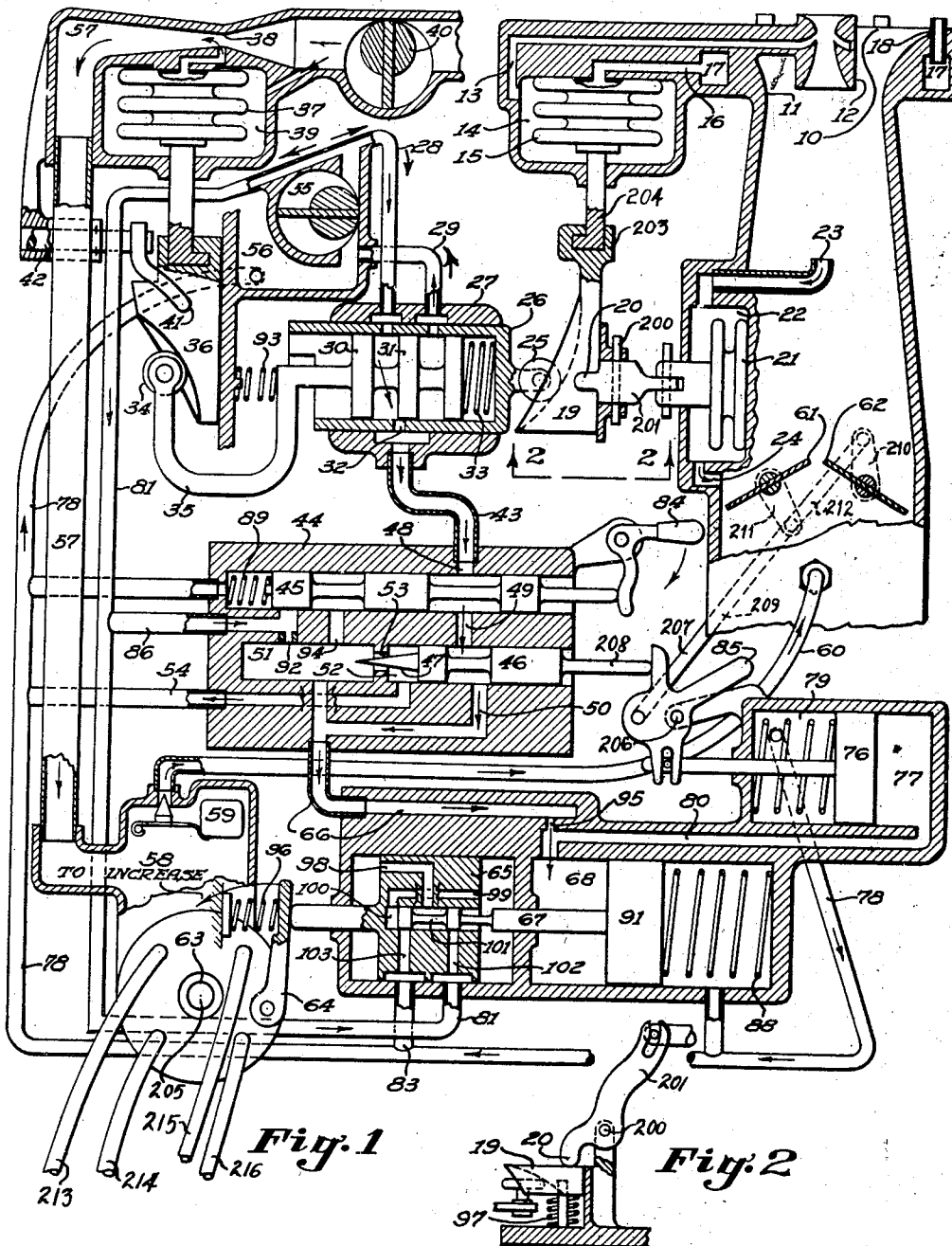
J. F. CAMPBELL

2,427,835

FUEL INJECTION SYSTEM

Filed Sept. 30, 1944

2 Sheets-Sheet 1



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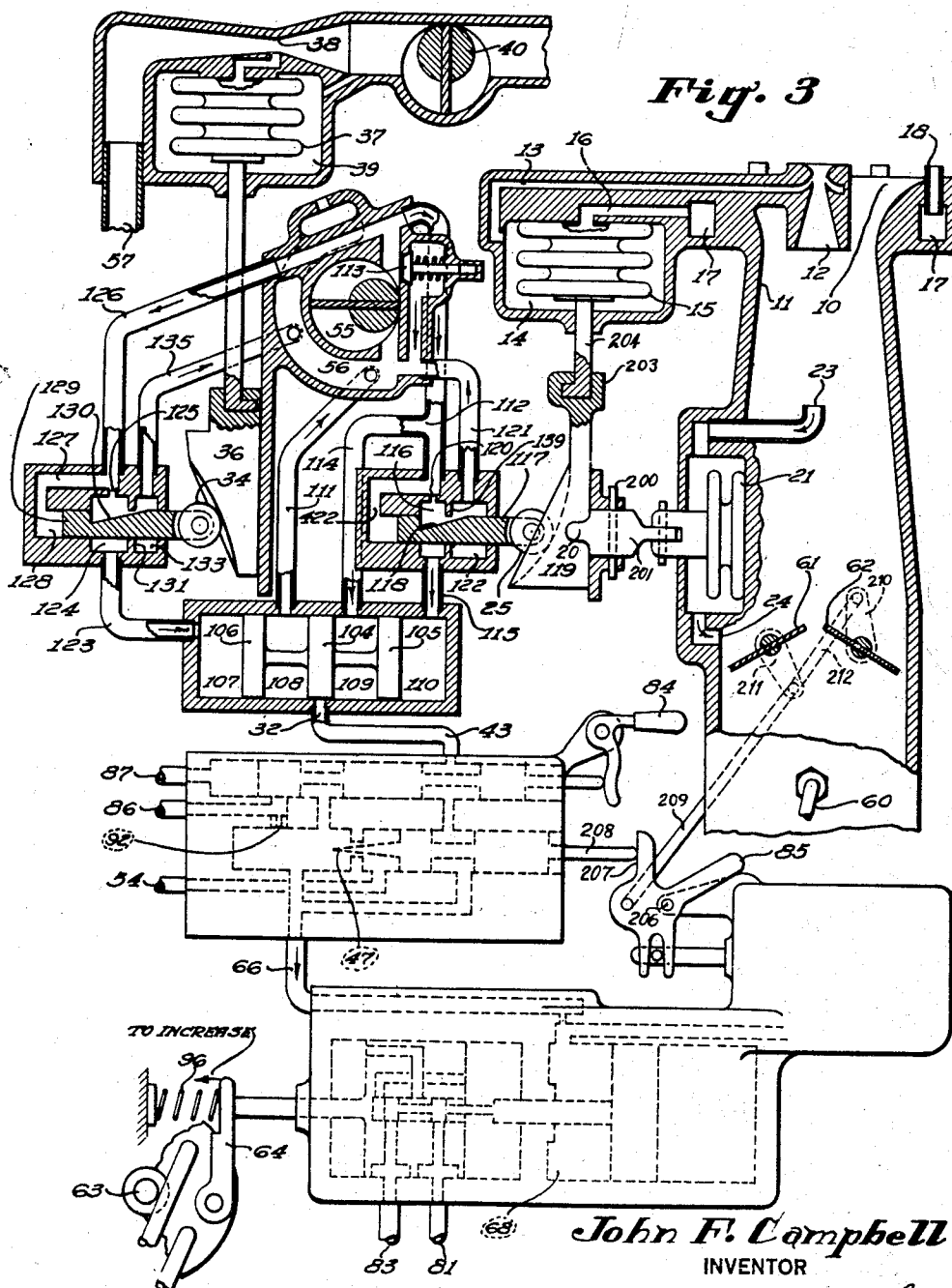
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2 Sheets-Sheet 2



UNITED STATES PATENT OFFICE

2,427,835

FUEL INJECTION SYSTEM

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Application September 30, 1944, Serial No. 556,521

11 Claims. (Cl. 123—119)

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The object of this invention is to improve the fuel control apparatus as shown and described in my patent, 2,281,411, dated April 28, 1942, entitled Fuel control apparatus for internal combustion engines.

Figure 1 shows diagrammatically the general arrangement of the parts constituting one form of construction of my invention.

Figure 2 shows a view taken on plane 2—2 of Figure 1.

Figure 3 shows an alternative construction.

In Figure 1, 10 is the air entrance, 11 is the larger of two venturis, 12 being the smaller, discharging into the throat of the larger venturi. 13 is a passage connecting the throat of the small venturi with the chamber 14, which surrounds an expanding chamber 15, the inside of which communicates through a passage 16 with an annular chamber 17, which annular chamber communicates with the air entrance 10 through tubes 18 which face upstream.

The expanding element 15 slides a cam 19 up and down. This cam 19 engages in the plane of the paper of the drawing with the finger 20, which finger 20 is partially rotated by the expansion and contraction of the partially-evacuated chamber 21 located in the chamber 22, which communicates through the passage 23 with the downstream portion of the venturi 11. The finger 20 is mounted on the lever 201 pivoted at the fulcrum 200.

In Figure 2, the end 20 of the lever 201 is shown engaging with the cam 19, which is pushed against the end of lever 201 by a compression spring 97. Cam 19 can slide vertically to the plane of the paper (Fig. 1), the end 203 of cam 19 sliding over the end of the rod 204, which projects from the element 15. Cam 19 also slides parallel to the plane of the paper. In Fig. 1, 24 is a passage communicating with the outlet from the venturi 11 still further downstream in the venturi 11. The left-hand side of the cam 19 engages with the roller 25, which is carried by a sleeve 26, which reciprocates in a block 27; this block 27 has a high pressure oil entrance 28 and a low pressure exit 29.

A piston 30, having a valve portion 31, acts as a valve for a port 32. The piston engages with a compression spring 33 and the piston 30 is mechanically connected to the roller 34 carried by an arm 35. The arm 35 is pushed by spring 93 so as to engage with the cam 36, which is slid up and down by an expanding and contracting chamber 37, which is responsive to the flow of the fuel through a fuel venturi 38. Chamber 37

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is located in a chamber 39, which is in communication with the pressure generated by the fuel pump 40. The cam 36 thus moves up and down in response to the expansion and contraction of the element 37. The cam 36 is moved perpendicular to the plane of the paper in response to the movement of a finger 41, which is rotated by a manually-controlled shaft 42. When the port 32 is in the position shown relative to the piston 31, pressure is admitted to the passage in the pipe 43, which communicates with a housing 44 in which there reciprocates an upper piston 45 and a lower piston 46 carrying a needle 47. The pipe 43 communicates through a passage 48, passage 49, passage 50 with a chamber 51 into which the needle 47 projects through a restriction 53. The chamber 52 to the right of the restriction 53 communicates through the pipes 54 and 78 with the low pressure side of the oil pump 55, pipe 78 discharging into the chamber 56, into which chamber also discharges the low pressure line 29. The purpose of the low pressure line 29 is to provide a return path for the oil discharged right and left by the pump 55.

The fuel from the fuel pump 40 discharges down the pipe 57 into the chamber 58, in which is located the float-controlled valve 59, which allows for a discharge of vapor which may accumulate through the pipe 60 to the air intake pipe on the engine side of the throttles 61 and 62. A pressure injecting pump chamber 63 is controlled by a lever 64, which engages with the servomotor piston 65, which in its turn is controlled by servomotor valve 67. A shaft 205, driven at half-engine speed in case of four-cycle engines and at full engine speed in case of two-cycle engines is provided. The lever 64 varies the effective stroke of the pump.

A passage 99 and a corresponding passage 98 in the servomotor piston 65 respectively connect the chamber 100 with the right-hand side of the servomotor piston 65 and the chamber 101 with the left-hand side of the servomotor piston 65. A passage 102 admits high pressure oil from the pipe 81 which communicates with the oil pump 55 to the right of the piston 65 when servomotor valve 67 moves to the left so that the servomotor piston 65 also moves to the left. At the same time, passage 103 permits oil to escape from the left-hand side of servomotor piston 65 through passage 98. When servomotor valve 67 moves to the right, high pressure oil can flow from passage 81 through passage 102, chamber 101 and passage 98 so that servomotor piston 65 is also moved to the right. The oil pressure escapes from the

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right-hand side of servomotor piston 65 through passage 99, chamber 100 and passages 103 and 83 to the low pressure return line 78. High pressure oil from the passage 55 flows through a pipe 66 and enters the chamber 68 to the left of a servo piston 91 through a restriction 95.

An acceleration device comprises a cylinder and a piston 76, which serves to move liquid in a cylinder 77 at the right of the piston. The line 78 connects with the cylinder at the right of the piston and is the return low pressure line to the chamber 56 for the high pressure oil that leaks past the piston 76 into chamber 79 to the left of the piston 76. A high pressure passage 80 extending from chamber 77 communicates through the restriction 95 with the pipe 66.

A pivot 206 for lever 85 enables the shoulder 207 to engage with the finger 208 of the valve 46—47. A link 209 connects the lever 85 with the throttle levers 210 and 211. The two levers 210—211 are connected together by the link 212. Fuel pressure lines 213, 214, 215 and 216 lead from the variable-stroke pump 63 to the fuel injection nozzles, not shown.

The throttle control lever 85 thus engages with the piston 46 and needle 47 and controls the movement of piston 76 and also is connected with the throttles 61 and 62, which are linked together so that they open simultaneously. When the throttles 61 and 62 are opened rapidly, the piston 76 moves to the left, lowering the pressure in chamber 68 which allows piston 91 to move lever 64 anti-clockwise against the pressure of spring 96, the movement of the piston 91 being transmitted thereto through servomotor valve 67 and servomotor piston 65. A spring 88, to the right of piston 65, serves to move the piston and thus this servomotor valve 67 to the left.

A manually-operated lever 84 controls the movement of the piston valve 45, compressing a spring 89 as it is moved toward the left. When the lever 84 is moved clockwise to unseat the valve 45, the high pressure oil passage 86, which communicates with the pipe 81, admits high pressure oil by this valve and through the unrestricted passage 94 to the chamber 51 and then through passage 66 and restriction 95 to chamber 68. This decreases the amount of fuel being pumped by pump 63 by increasing the pressure in the chamber 68, which moves a piston 91 and thus lever 64 to the right, the object of this mechanism being merely to cut off the fuel. This is known as the idle cut-off control.

Normally oil under pressure from passage 86 enters chamber 51 through a restriction 92.

In Figure 3, the port 32 is controlled by a piston 104. This piston 104 carries two pistons 105 and 106. These three pistons reciprocate in a cylinder divided into four chambers 107, 108, 109 and 110. Chamber 108 is connected through the pipe 111 with the low pressure chamber 56 connected to the oil pump 55. This oil pump 55 is provided with a spring-loaded pressure relief valve 113. Chamber 109 is connected through a pipe 114 to the high pressure oil pipe 112 leading from pump 55. Chamber 110 is connected through the passage 115 to a chamber 116. In this chamber there slides a valve 117 having a slabbled-off surface 118. This slabbled-off surface 118 makes a variable opening in the partition 139 between chambers 116 and 122. High pressure oil in 112 is admitted to the chamber 116 through the restriction 120 so that the pressure in the chamber 116 is below that of pressure in the pipe 112, and above that in the low pressure pipe 121, which

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connects the chamber 122 with the low pressure chamber 56. The high pressure in the passage 112 is admitted through the passage 422 to the left-hand side of the valve 117. Valve 117 is thus pushed to the right. Valve 117 carries on its extreme right hand a roller 25 which engages with the cam 119 similar to the valve 19 shown and described in Figure 1.

Chamber 107 is connected through the pipe 123 with the chamber 124. Chamber 124 is connected through the restriction 125 with a high pressure pipe 126 leading from pump 55. This high pressure pipe 126 is connected through the passage 127 with the cylinder 128 in which reciprocates the valve 129. Valve 129 has a slabbled-off portion 130 which forms with the partition 131 a variable opening leading from the chamber 124 to a low pressure chamber 133. This low pressure chamber 133 communicates through the low pressure pipe 135 to the low pressure chamber 56. The valve 129 carries a roller 34 which engages with the cam 36 as before, described relative to Figure 1.

Operation (Figs. 1 and 2)

Assuming that the air and fuel are flowing into the engine, the amount of fuel flowing being excessive so that the cam 36 is higher than it should be, spring 93 pushes roller 34 against the face of the cam 36, and as a result, piston valve 31 is moved to the right to uncover port 32, admitting oil under pressure to the pipe 43, which admits oil under pressure through the passages 48, 49 and 50, also 66 and 95 and so to chamber 68. Piston 91 and servo valve 67 are thus pushed to the right, compressing spring 88; the piston 65 moves to the right by action of the servomotor valve 67 contained in it and a reduction in the fuel due to movement of the lever 64 under influence of spring 96 occurs to bring the system into equilibrium. The flow through the fuel venturi 38 becomes lower and the pressure in chamber 37 becomes higher.

Cam 36 then descends and the valve 31 comes to a neutral position, closing port 32. The position of port 32 is determined by the cam 19 which is positioned by the chamber 15 in accordance with the air flow through the venturi 11. By this means, the cams 36 and 19 determine the mixture ratio at every air flow and at every altitude. When the density responsive device 21 causes the cam 19 to be moved normally to the plane of the paper, a different cam surface is substituted for the cam surface illustrated.

When the throttles 61 and 62 approach the closed position, valve 46 and needle 47 move to the left and the pressure in the chamber 68 is thus regulated empirically when the throttles are less than 10° open, 65° to 70° being wide open. An empirical control of the fuel, when the throttles are closed to below 10° open, is the most satisfactory solution of the problem of controlling the mixture ratio, both at idle and immediately above idle. Obviously, at the low air flows associated with small throttle openings, it is not possible to operate the automatic ratio controlling means, as the flow through the venturi 12 creates forces too feeble to be effective.

The quantity of air flowing past the throttles 61—62 increases as the area of throttle opening increases so long as the drop across the throttles is equal to or greater than half the atmospheric pressure. The shape of the needle 47 is thus made to conform so that as the throttles open the valve 47 increases the opening in the partition

53. This decreases the pressure in the chamber 51 and hence in the passage 66 and also in the chamber 68, which allows the piston 91 to move to the left. The servomotor valve 67 and piston 91 are thus moved to the left by the compression spring 88. Or in other words, as the valve 47 moves to the right, the pressure in chamber 68 is reduced. As the servomotor valve moves to the left, servomotor piston 65 also moves to the left so that lever 64 also moves to the left so as to increase the discharge of the fuel pumps 63.

When the throttle is opened, the lever 85 being moved clockwise, piston 76 is moved to the left, lowering the pressure in the chamber 77, therefore, lowering the pressure in the chamber 67. There is thus a temporary condition during which the spring 88 to the right of the piston 65 causes a temporary increase in fuel flow by causing lever 64 to be moved temporarily to the left to increase fuel flow. This takes care of acceleration.

The manual rotation of the shaft 42 moves the cam 36 normal to the plane of the paper by means of the lever 41. By this means a new cam surface is presented to the roller 34; hence, the ratio of fuel to air can be varied manually just as it can be varied automatically by the element 21.

The control of the fuel injection pumps require considerable effort. If the piston 91 engaged directly with the lever 64 without the second servomotor piston 65 being interposed, the control would be irregular due to the pressure required to operate the lever 64. The servomotor 65 and valve 67 multiply many times the force exerted by the piston 91 so that a comparatively insignificant effort on the part of the piston 91 produces a very definite force on the lever 64. The effect on the pressure in pipe 66 of the resistance of lever 64 would be such as to interfere with the empirical control of the fuel during the first 10° movement of the throttles 61 and 62.

In the operating connection between the expanding chamber 37 and the sliding cam 36, between the expanding chamber 15 and the sliding cam 19 and between the expanding chamber 21 and the sliding cam 19, I have found it desirable to use large expanding chambers so as to obtain sufficient power to overcome friction so as to move the cam. Alternatively, if for reasons of space, it is desirable to use relatively small expanding chambers 15, 21 and 37, servomotors and servomotor valves will be interposed between the expanding chamber 37 and the sliding cam 19, between the expanding chamber 15 and the sliding cam 19 and between the expanding chamber 21 and the sliding cam 19, for example, such as the servomotor 65-67, which operates the lever 64.

Operation (Fig. 3)

Assuming that an excessive quantity of fuel, relative to the air flowing through venturi 11, is flowing through the venturi 38, then the cam 36 rises and the roller 34 is pushed to the right as the result of the oil pressure in the chamber 128. The slanted-off portion 130 of valve 129 then increases the opening past the partition 131. An increased flow then occurs past the restriction 125 into the chamber 124. Therefore, there is an increased pressure drop at the restriction 125. The pressure in 123, which equals the pressure in 107, is therefore reduced, and hence is reduced below that in chamber 110. The valve 104 is thus moved to the left. High pressure oil then flows down the pipe 114 and through the chamber 109 and passage 32 to the passage 66, which increases the pressure in the chamber 68 of Figure 1, com-

presses the spring 88 and permits the lever 64 to move to the right, reducing the fuel flow in the fuel injection system 63. With the arrangement shown in Figure 3, the cams 36 and 119 can be located anywhere on the engine and the piston valve 104 can be located anywhere so that the problem of designing is simplified.

Low speed empirical operation (Figs. 1 and 3)

10 In both Figures 1 and 3, the valve 47 controls the fuel-air ratio empirically when the throttles 61-62 approach the closed position for the reason that when the needle 47 restricts the opening through 53, the pressure in the chamber 51 is dominated by the flow of operating fluid under pressure through the restriction 92. When the throttles 61-62 are more than 10° open, the needle 47 moves so far to the right that the restriction through 53 is not sufficient to permit the restriction 92 to be effective. Hence, the mixture ratio becomes great because the pressure in 68 falls and the lever 64 rotates anti-clockwise under the influence of the piston 91 and spring 88, servomotor piston 65 acting against the compression spring 96. This increases the flow through venturi 38 and establishes a rich mixture which causes the cam 36 to rise and the automatic feature of this invention thereupon becomes operative as the throttle is moved from approximately 10° open to 70°, which is wide open. The throttle opening with the throttles as shown 1/4 open are intended to be in the transition position between the position for empirical control of the fuel flow and the position of automatic fuel control by the two venturis 38 and 12.

What I claim is:

1. An empirical control for a fuel injection system comprising an air entrance, a throttle valve therein, a fuel injection system, a control lever therefor, a source of operating fluid under pressure, a passage therefrom, a bypass therein, a needle valve connected to said throttle valve and located in said bypass and adapted to permit said fluid to escape through said bypass, a restriction in said passage upstream from said bypass, a servomotor, a fluid pressure passage therefor connected to said passage and located downstream from said bypass, said servomotor being adapted to control said fuel injection system during the initial opening movement of said throttle.

2. Fuel control means for the fuel injection system of a multi-cylinder internal combustion engine comprising an air induction passage, means in said passage responsive to air flow therethrough to provide a differential fluid pressure proportional to air flow, a source of liquid fuel under pressure, a fuel supply passage connected thereto, a fuel injection system connected to said passage and adapted to inject fuel under pressure into said engine, control means for said fuel injection system, including means responsive to the fuel flow in said fuel passage to provide a differential fluid pressure proportional to the rate of fuel flow, an air cam movable by the air differential pressure, a fuel cam movable by the fuel differential pressure, a source of operating fluid under pressure, a servomotor valve therefor having two parts, one controlled by the air cam, the other controlled by the fuel cam, a servomotor, a fluid passage connecting the servomotor with said two-part servomotor valve so as to control the movement of said servomotor, said control means for said fuel injection system being adapted to be controlled by said servomotor whereby the quantity of fuel discharged by said fuel injection

system is increased or decreased depending upon whether the measured rate of fuel flow is respectively greater or less than that required to provide a predetermined variable fuel-air ratio for the measured rate of air flow and in which a throttle is provided in the air induction passage and a needle valve is connected thereto and located so as to control the supply of operating fluid to said servomotor and to bypass the servomotor valve and adapted after the throttle is first opened and until the throttle has been opened approximately $\frac{1}{7}$ to move the control for the fuel injection system empirically.

3. Fuel control means for the fuel injection system of a multi-cylinder internal combustion engine comprising an air induction passage, means in said passage responsive to air flow there-through to provide a differential fluid pressure proportional to air flow, a source of liquid fuel under pressure, a fuel supply passage connected thereto, a fuel injection system connected to said passage and adapted to inject fuel under pressure into said engine, control means for said fuel injection system, including means responsive to the fuel flow in said fuel passage to provide a differential fluid pressure proportional to the rate of fuel flow, an air cam movable by the air differential pressure, a fuel cam movable by the fuel differential pressure, a source of operating fluid under pressure, a servomotor valve therefor having two parts, one controlled by the air cam, the other controlled by the fuel cam, a servomotor, a fluid passage connecting the servomotor with said two-part servomotor valve so as to control the movement of said servomotor, said control means for said fuel injection system being adapted to be controlled by said servomotor whereby the quantity of fuel discharged by said fuel injection system is increased or decreased depending upon whether the measured rate of fuel flow is respectively greater or less than that required to provide a predetermined variable fuel-air ratio for the measured rate of air flow and in which there is an independently and manually operated fuel cut off valve located so as to control the supply of operating fluid to said servomotor and to bypass the servomotor valve and adapted to move the control for the fuel injection system so that it ceases to supply fuel to said internal combustion engine.

4. Fuel control means for the fuel injection system of a multi-cylinder internal combustion engine comprising an air induction passage, means in said passage responsive to air flow there-through to provide a differential fluid pressure proportional to air flow, a source of liquid fuel under pressure, a fuel supply passage connected thereto, a fuel injection system connected to said passage and adapted to inject fuel under pressure into said engine, control means for said fuel injection system, including means responsive to the fuel flow in said fuel passage to provide a differential fluid pressure proportional to the rate of fuel flow, an air cam movable by the air differential pressure, a fuel cam movable by the fuel differential pressure, a source of operating fluid under pressure, a servomotor valve therefor having two parts, one controlled by the air cam, the other controlled by the fuel cam, a servomotor, a fluid passage connecting the servomotor with said two-part servomotor valve so as to control the movement of said servomotor, said control means for said fuel injection system being adapted to be controlled by said servomotor whereby the quantity of fuel discharged by said

fuel injection system is increased or decreased depending upon whether the measured rate of fuel flow is respectively greater or less than that required to provide a predetermined variable fuel-air ratio for the measured rate of air flow and in which the two-part servomotor valve comprises a hollow cylindrical outer valve, a piston slidably mounted within said cylinder, a port in said cylinder, said piston having a valve portion adapted when in the neutral position to close said port, a high pressure port and a low pressure port in said cylindrical valve located on opposite sides of said valve portion whereby the movement of said valve portion relative to said cylindrical valve switches the operative pressure acting on said servomotor from high pressure to low pressure through said first mentioned port and vice versa.

5. Fuel control means for the fuel injection system of a multi-cylinder internal combustion engine comprising an air induction passage, means in said passage responsive to air flow there-through to provide a differential fluid pressure proportional to air flow, a source of liquid fuel under pressure, a fuel supply passage connected thereto, a fuel injection system connected to said passage and adapted to inject fuel under pressure into said engine, control means for said fuel injection system, including means responsive to the fuel flow in said fuel passage to provide a differential fluid pressure proportional to the rate of fuel flow, an air cam movable by the air differential pressure, a fuel cam movable by the fuel differential pressure, a source of operating fluid under pressure, a servomotor valve therefor having two parts, one controlled by the air cam, the other controlled by the fuel cam, a servomotor, a fluid passage connecting the servomotor with said two-part servomotor valve so as to control the movement of said servomotor, said control means for said fuel injection system being adapted to be controlled by said servomotor whereby the quantity of fuel discharged by said fuel injection system is increased or decreased depending upon whether the measured rate of fuel flow is respectively greater or less than that required to provide a predetermined variable fuel-air ratio for the measured rate of air flow and in which a throttle is provided in the air induction passage, a moving wall is connected thereto, a chamber closed at one end by said moving wall, a connection from said chamber to the fluid passage connecting the servomotor valve to the servomotor, said moving wall being adapted when the throttle is suddenly opened to temporarily reduce the pressure in said passage by expanding the chamber so as to move said fuel injection control to the position for an increase in fuel flow.

6. Fuel control means for the fuel injection system of a multi-cylinder internal combustion engine comprising an air induction passage, means in said passage responsive to air flow there-through to provide a differential fluid pressure proportional to air flow, a source of liquid fuel under pressure, a fuel supply passage connected thereto, a fuel injection system connected to said passage and adapted to inject fuel under pressure into said engine, control means for said fuel injection system, including means responsive to the fuel flow in said fuel passage to provide a differential fluid pressure proportional to the rate of fuel flow, an air cam movable by the air differential pressure, a fuel cam movable by the fuel differential pressure, a source of operating fluid under pressure, a servomotor valve engag-

ing with the air cam, a second servomotor valve engaging with the fuel cam, a servomotor, a passage for fluid under pressure adapted to be jointly controlled by both of said servomotor valves and to be connected with said servomotor so that the servomotor is operated by the fluid under pressure and controlled by the relative position of said cams, said control means for said fuel injection system being adapted to be controlled by said servomotor whereby the quantity of fuel discharged by said fuel injection system is increased or decreased depending upon whether the measured rate of fuel flow is respectively greater or less than that required to provide a predetermined variable fuel-air ratio for the measured rate of air flow and in which a throttle is provided in the air induction passage and a needle valve is connected thereto and located so as to control the supply of operating fluid to said servomotor and to bypass the servomotor valve and adapted after the throttle is first opened and until the throttle has been opened approximately $\frac{1}{7}$ to move the control for the fuel injection system empirically.

7. Fuel control means for the fuel injection system of a multi-cylinder internal combustion engine comprising an air induction passage, means in said passage responsive to air flow therethrough to provide a differential fluid pressure proportional to air flow, a source of liquid fuel under pressure, a fuel supply passage connected thereto, a fuel injection system connected to said passage and adapted to inject fuel under pressure into said engine, control means for said fuel injection system, including means responsive to the fuel flow in said fuel passage to provide a differential fluid pressure proportional to the rate of fuel flow, an air cam movable by the air differential pressure, a fuel cam movable by the fuel differential pressure, a source of operating fluid under pressure, a servomotor valve engaging with the air cam, a second servomotor valve engaging with the fuel cam, a servomotor, a passage for fluid under pressure adapted to be jointly controlled by both of said servomotor valves and to be connected with said servomotor so that the servomotor is operated by the fluid under pressure and controlled by the relative position of said cams, said control means for said fuel injection system being adapted to be controlled by said servomotor whereby the quantity of fuel discharged by said fuel injection system is increased or decreased depending upon whether the measured rate of fuel flow is respectively greater or less than that required to provide a predetermined variable fuel-air ratio for the measured rate of air flow and in which there is an independently and manually operated fuel cut off valve located so as to control the supply of operating fluid to said servomotor and to bypass the servomotor valve and adapted to move the control for the fuel injection system so that it ceases to supply fuel to said internal combustion engine.

8. Fuel control means for the fuel injection system of a multi-cylinder internal combustion engine comprising an air induction passage, means in said passage responsive to air flow therethrough to provide a differential fluid pressure proportional to air flow, a source of liquid fuel under pressure, a fuel supply passage connected thereto, a fuel injection system connected to said passage and adapted to inject fuel under pressure into said engine, control means for said

fuel injection system, including means responsive to the fuel flow in said fuel passage to provide a differential fluid pressure proportional to the rate of fuel flow, an air cam movable by the air differential pressure, a fuel cam movable by the fuel differential pressure, a source of operating fluid under pressure, a servomotor valve engaging with the air cam, a second servomotor valve engaging with the fuel cam, a servomotor, a passage for fluid under pressure adapted to be jointly controlled by both of said servomotor valves and to be connected with said servomotor so that the servomotor is operated by the fluid under pressure and controlled by the relative position of said cams, said control means for said fuel injection system being adapted to be controlled by said servomotor whereby the quantity of fuel discharged by said fuel injection system is increased or decreased depending upon whether the measured rate of fuel flow is respectively greater or less than that required to provide a predetermined variable fuel-air ratio for the measured rate of air flow and in which a cylinder divided into four chambers by three pistons connected together, one end chamber being connected through a passage with the servomotor valve engaging with the air cam, the other end being connected through a passage with the servomotor valve engaging with the fuel cam, one of the two intermediate chambers being connected to the fluid under pressure, a central port in said cylinder, the middle of the three pistons being adapted to control said central port, said port being connected with said servomotor for the purpose described.

9. Fuel control means for the fuel injection system of a multi-cylinder internal combustion engine comprising an air induction passage, means in said passage responsive to air flow therethrough to provide a differential fluid pressure proportional to air flow, a source of liquid fuel under pressure, a fuel supply passage connected thereto, a fuel injection system connected to said passage and adapted to inject fuel under pressure into said engine, control means for said fuel injection system, including means responsive to the fuel flow in said fuel passage to provide a differential fluid pressure proportional to the rate of fuel flow, an air cam movable by the air differential pressure, a fuel cam movable by the fuel differential pressure, a source of operating fluid under pressure, a servomotor valve engaging with the air cam, a second servomotor valve engaging with the fuel cam, a servomotor, a passage for fluid under pressure adapted to be jointly controlled by both of said servomotor valves and to be connected with said servomotor so that the servomotor is operated by the fluid under pressure and controlled by the relative position of said cams, said control means for said fuel injection system being adapted to be controlled by said servomotor whereby the quantity of fuel discharged by said fuel injection system is increased or decreased depending upon whether the measured rate of fuel flow is respectively greater or less than that required to provide a predetermined variable fuel-air ratio for the measured rate of air flow and in which a throttle is provided in the air induction passage, a moving wall is connected thereto, a chamber closed at one end by said moving wall, a connection from said chamber to the fluid passage connecting the servomotor valve to the servomotor, said moving wall being adapted when the throttle is suddenly opened to temporarily re-

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duce the pressure in said passage by expanding the chamber so as to move said fuel injection control to the position for an increase in fuel flow.

10. Fuel control means for the fuel injection system of a multi-cylinder internal combustion engine comprising an air induction passage, means in said passage responsive to air flow therethrough to provide a differential fluid pressure proportional to air flow, a source of liquid fuel under pressure, a fuel supply passage connected thereto, a fuel injection system connected to said passage and adapted to inject fuel under pressure into said engine, control means for said fuel injection system, including means responsive to the fuel flow in said fuel passage to provide a differential fluid pressure proportional to the rate of fuel flow, an air cam movable by the air differential pressure, a fuel cam movable by the fuel differential pressure, a source of operating fluid under pressure, a servomotor valve engaging with the air cam, a second servomotor valve engaging with the fuel cam, a servomotor, a passage for fluid under pressure adapted to be jointly controlled by both of said servomotor valves and to be connected with said servomotor so that the servomotor is operated by the fluid under pressure and controlled by the relative position of said cams, said control means for said fuel injection system being adapted to be controlled by said servomotor whereby the quantity of fuel discharged by said fuel injection system is increased or decreased depending upon whether the measured rate of fuel flow is respectively greater or less than that required to provide a predetermined variable fuel-air ratio for the measured rate of air flow and in which the servomotor valve engaging with said air cam is pressed into engagement therewith, said operating fluid acting on the end of said servomotor valve so as to provide said pressure.

11. Fuel control means for the fuel injection system of a multi-cylinder internal combustion engine comprising an air induction passage, means in said passage responsive to air flow therethrough to provide a differential fluid pressure proportional to air flow, a source of liquid

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fuel under pressure, a fuel supply passage connected thereto, a fuel injection system connected to said passage and adapted to inject fuel under pressure into said engine, control means for said fuel injection system, including means responsive to the fuel flow in said fuel passage to provide a differential fluid pressure proportional to the rate of fuel flow, an air cam movable by the air differential pressure, a fuel cam movable by the fuel differential pressure, a source of operating fluid under pressure, a servomotor valve engaging with the air cam, a second servomotor valve engaging with the fuel cam, a servomotor, a passage for fluid under pressure adapted to be jointly controlled by both of said servomotor valves and to be connected with said servomotor so that the servomotor is operated by the fluid under pressure and controlled by the relative position of said cams, said control means for said fuel injection system being adapted to be controlled by said servomotor whereby the quantity of fuel discharged by said fuel injection system is increased or decreased depending upon whether the measured rate of fuel flow is respectively greater or less than that required to provide a predetermined variable fuel-air ratio for the measured rate of air flow and in which the servomotor valve engaging with said fuel cam is pressed into engagement therewith, said operating fluid acting on the end of said servomotor valve so as to provide said pressure.

JOHN F. CAMPBELL.

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