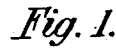


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3 Sheets-Sheet 1



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FUEL INJECTION SYSTEM FOR INTERNAL COMBUSTION ENGINES

Filed Aug. 23, 1944

3 Sheets-Sheet 2

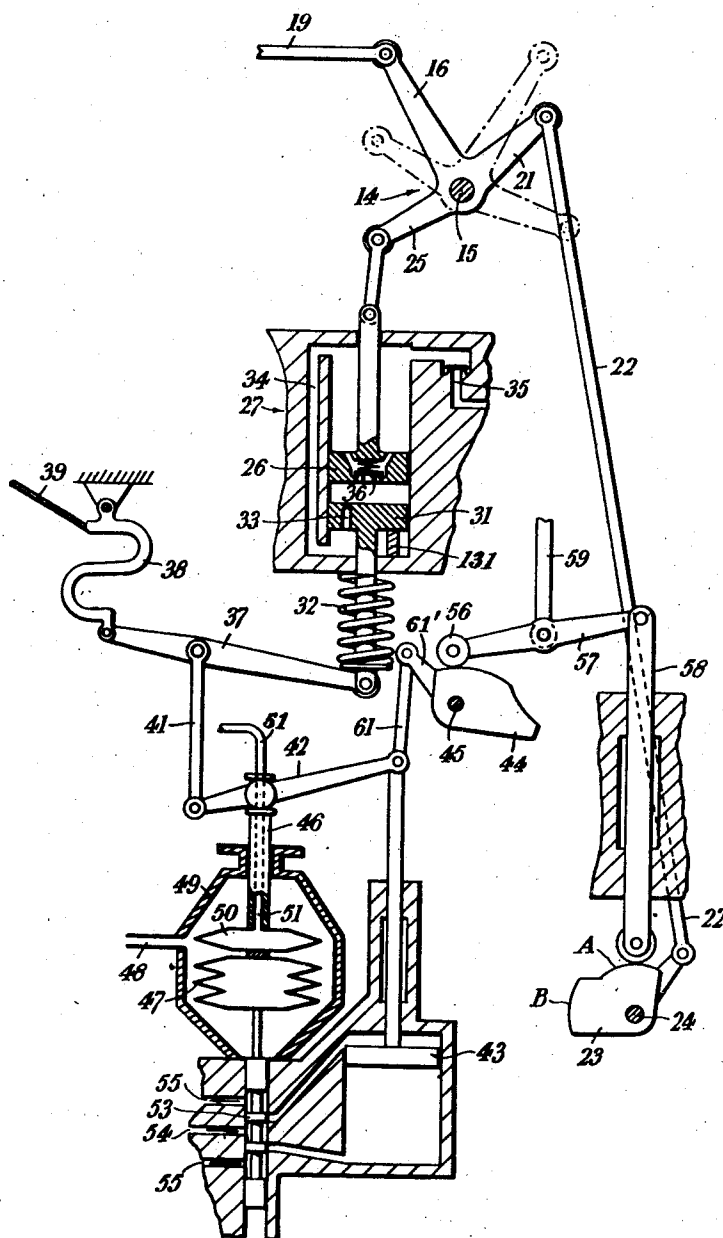


Fig. 2.

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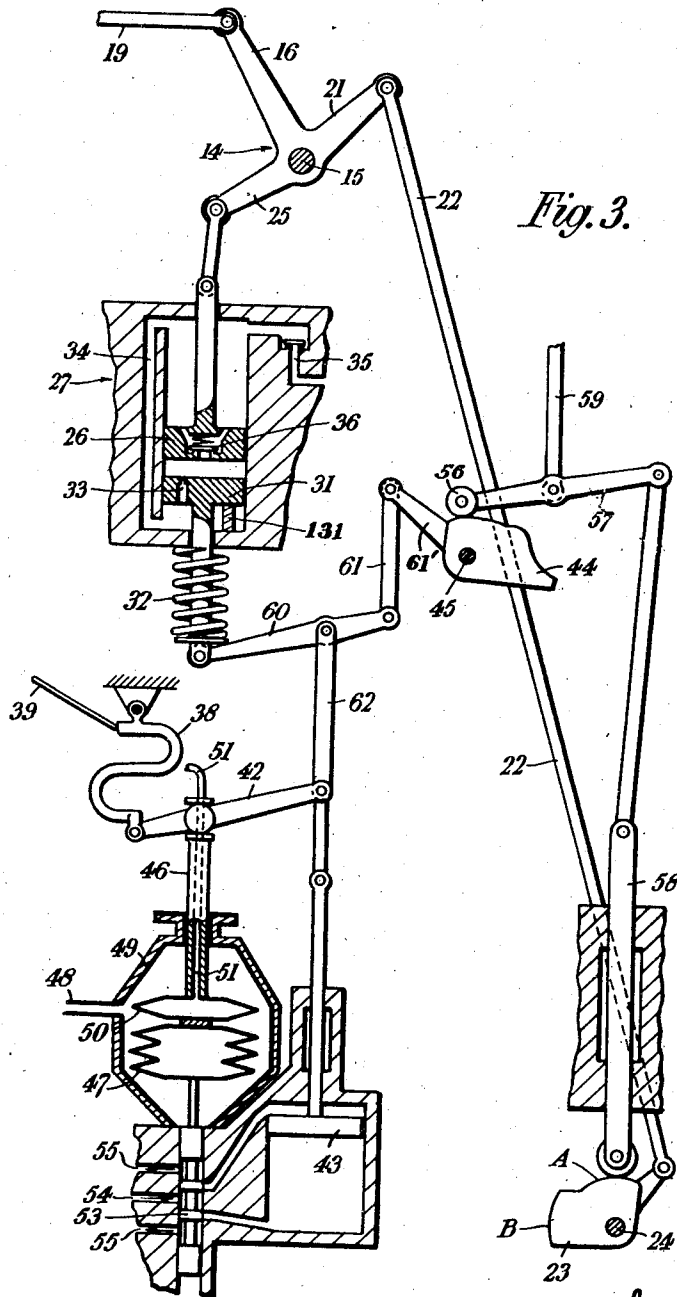
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FUEL INJECTION SYSTEM FOR INTERNAL COMBUSTION ENGINES

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3 Sheets-Sheet 3



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FUEL INJECTION SYSTEM FOR INTERNAL-COMBUSTION ENGINES

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Bridgwater, EnglandApplication August 23, 1944, Serial No. 550,830
In Great Britain September 23, 1943

11 Claims. (Cl. 123-119)

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Internal combustion engines require a richer mixture during acceleration than is needed for steady running, and it is known to provide them with an accelerator pump, which, when the throttle valve is opened suddenly for purposes of acceleration, opens a valve to permit a supplementary flow of fuel to the engine through a normally-closed conduit. One known form of accelerator pump comprises a chamber filled with liquid and communicating through a restricted orifice with a space filled with liquid, two of the walls of said chamber being constituted by movable pistons, diaphragms or the like, one of which is linked to the normally-closed valve and the other of which is linked to a lever or the like for actuating the throttle valve, and is arranged to be moved outwardly when the throttle valve is opened. When the throttle valve is opened suddenly to accelerate the engine, the partial vacuum in the chamber is relieved by inward movement of the other piston or diaphragm against a controlling spring, which movement opens the valve to enrich the mixture, by the extra fuel supplied through the supplementary conduit, the second piston or diaphragm closing the valve again when sufficient liquid to fill the chamber has leaked into it through the orifice. Systems of this character, however, are subject to deleterious effects as the result of sticking or leaking of the valve.

The present invention provides a fuel injection system for an internal combustion engine, comprising an accelerator pump arranged to effect a temporary augmentation of the main fuel supply on sudden opening movement of the throttle valve. By the expression "fuel injection system" is to be understood a system in which the fuel is injected into the induction system at a pressure higher than that prevailing in the system at the point of injection. The expression thus excludes systems involving the use of a suction carburetter.

The invention also provides a fuel injection system for an internal combustion engine comprising mixture control means for varying the fuel/air ratio of the mixture supplied to the engine, a servo mechanism responsive to induction pipe pressure for adjusting said mixture control means to vary the fuel/air ratio as a desired function of induction pipe pressure, and an accelerator pump which is effective, on sudden opening of the throttle valve, to effect an overriding adjustment of the mixture control means to provide a temporary enrichment of the mixture.

In the preferred arrangement according to the invention, the fuel injection system comprises a

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fuel pump for delivering fuel to the engine, means for controlling the delivery of said fuel pump, and an accelerator pump comprising a cylinder containing a pair of pistons or the like, one of which is linked to the throttle lever or equivalent throttle actuating device, and the other of which is normally biased by a spring or the equivalent to a datum position and coupled to said delivery controlling means and effective to enrich the mixture when moved against its spring, the space between the pistons being filled with liquid and communicating by way of a restricted orifice with a supply of said liquid, the arrangement being such that displacement of the first piston consequent upon sudden accelerating movement of the throttle lever causes, by virtue of the restricted flow of liquid through said orifice, a sympathetic movement of the second piston against its spring to effect temporary enrichment of the mixture.

Thus the first piston may, during periods of acceleration, execute a suction stroke, and cause the second piston to be sucked into the cylinder against its spring, and remain there until sufficient liquid has leaked into the space between the pistons.

The second piston may be arranged to enrich the mixture, when displaced against its spring, by varying the effective stroke of the injection pump. Alternatively it may be arranged to control a metering orifice through which the fuel is fed by said pump.

Forms of fuel injection system according to the invention as applied to an aircraft engine will now be described in detail, by way of example, with reference to the accompanying drawings in which:

Fig. 1 is a diagrammatic showing of the complete installation,

Fig. 2 is an enlarged view showing, also diagrammatically but in greater detail, the accelerator pump and associated mechanism for varying the fuel flow of the arrangement of Fig. 1,

Fig. 3 is a diagram, similar to Fig. 2, showing a second embodiment.

Fig. 4 is a diagrammatic view of part of an installation, similar to Fig. 1, but in which the rate of flow of fuel to the engine is varied by controlling the delivery stroke of a fuel pump.

Like reference characters indicate like parts throughout the figures.

Referring first of all to Fig. 1, air is fed to the engine along the induction pipe 10 by an engine-driven supercharger 11, the flow of air being controlled by a throttle valve 12.

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To the pilot's throttle lever 13 is fixed a three-armed lever 14 rotatable about a pivot 15. The arm 16 of the lever 14 is connected, by a link 17, to the controlling cam of a variable datum boost control device 18. This is not illustrated in detail, because its action is fully described in U. S. Patent No. 1,995,800. The piston rod 19 of the servo piston of the boost control device acts on the throttle valve 12 in the well known manner through the agency of a toggle linkage 20 connecting the throttle valve and the arm 21 of the three-armed lever 14. This arm 21 is also connected, by a link 22 to a cam 23, which pivots about the centre 24. This cam forms the subject of my copending application Serial No. 550,831 and its function is described below. The third arm 25 of the lever 14 is connected to the upper piston 26 of an accelerator pump 27.

Fuel is fed to the induction pipe by an engine-driven fuel pump 100, along a pipe 28 terminating in an injection nozzle 29. The rate of flow of fuel through the pipe is varied by a metering valve 30 under the joint control of the accelerator pump 27 and cam 23. The position of the metering valve 30 is also subject to changes in boost pressure, induction temperature and exhaust back pressure, as later described.

The lower piston 31 of the accelerator pump is normally maintained by a spring 32 at the bottom of the pump cylinder and in contact with stop 131, and is formed with a restricted orifice 33 (see Fig. 2). A by-pass conduit 34 connects the upper and lower ends of the pump cylinder, and a pipe 35 communicating with the top of the cylinder serves to maintain the latter full of liquid and to compensate for leakage losses.

When the pilot's throttle lever is in the slow running position S. R., the three-armed lever 14 occupies the position shown in full lines in Fig. 2. When the pilot's lever is moved suddenly towards the full throttle position F. T., the lever 14 moves to the chain-dotted position, and the upper piston 26 of the accelerator pump is lifted. The partial vacuum in the space between the two pistons causes the lower piston 31 to rise against its spring 32, the lower piston remaining in the raised position until the partial vacuum is relieved by leakage of fluid through the orifice 33 in the piston 31. A non-return valve 36 is provided in the upper piston 26 to allow escape of fluid from between the two pistons during movement of the pilot's lever to decelerate.

The piston rod of the lower piston 31 is connected to the right-hand end of a lever 37, the other end of which is connected to a device for imposing a correction on the fuel supply for changes in induction temperature. This is constituted by a Bourdon tube 38 connected by a capillary tube 39 with a thermometer bulb 40 in the induction pipe 10 (see Fig. 1). The bulb 40 and tubes 38, 39 are filled with a liquid having a high coefficient of expansion.

The lever 37 is connected intermediate its ends, by a link 41, with the left-hand end of a lever 42. The other end of lever 42 is connected to the piston rod of a servo piston 43, and via a link 61 and an arm 61' to a cam 44 which is rotatable about the centre 45. Intermediate the ends of the lever 42 is pivoted a rod 46 connected to an aneroid device, consisting of a stack of evacuated capsules 47 located in a chamber 49 exposed to boost pressure through a conduit 48, and a separate capsule 50 exposed internally to exhaust back pressure through a conduit 51 communicating with the exhaust pipe 52 (see Fig. 1).

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The lower end of the double capsule stack 47, 50 is connected to a relay piston valve 53 of the double land type, controlling communication between the cylinder for the servo piston 43 and a pressure inlet 54 and exhaust outlets 55. As will readily be seen downward movement of the valve 53 results in upward movement of the servo piston 43 and upward movement of the valve 53 causes the piston 43 to move down, the lever 42 acting as a follow-up lever to restore the valve 53 to the neutral position. The position of the piston 43 in its cylinder, and therefore the setting of the cam 44 are thus determined by the boost pressure, the induction temperature and the exhaust back pressure. Downward movement of the piston 43 causes the cam 44 to rotate anti-clockwise to enrich the mixture as described below.

A sudden movement of the pilot's throttle lever to open the throttle will, by raising the lower piston 31 of the accelerator pump, cause a temporary upward movement of the relay valve 53, and therefore a temporary downward movement of the servo piston 43. The accelerator pump thus overrides the capsule stack and provides a temporary enrichment of the mixture.

Against the cam 44 bears a roller 56 on one end of a floating lever 57 connected at the other end to a follower 58 which bears against the cam 23. Spring 159 (Fig. 1) maintains the roller 56 and follower 58 in contact with cams 44 and 23 respectively. The lever 57 is centrally connected to the metering valve 30 (Fig. 1) by a link 59. The cam 44 is so shaped that, as the servo piston 43 descends in its cylinder, the link 57 will be rocked clockwise about its right-hand end, so lifting the valve 30 to increase the flow of fuel to the engine.

The cam 44 is designed to give an economical mixture over the range of cruising boost, but a richer mixture at the higher boosts, the enrichment amounting to say 35% at take-off boost. The cam 43 has a concentric portion A which gives a weak mixture at cruising boosts, but when the pilot's throttle lever is moved to a position calling for power, the raised portion B of this cam comes beneath the lower end of the follower 58, thus rocking the floating link 57 anti-clockwise about its left-hand end to enrich the mixture, the enrichment amounting to say 15% when the pilot's lever is in the full throttle position.

While, in the embodiments illustrated, in Figs. 1 and 2, the link 59 is caused to vary the fuel/air ratio by adjusting the area of the fuel metering orifice defined by the valve 30, it may as an alternative achieve this result by varying the effective stroke of the fuel pump. Such an arrangement is shown in Fig. 4. Here the area of metering orifice 130 remains fixed and link 59 operates arm 259 to vary, in known and conventional fashion, the effective stroke of a variable delivery fuel pump 200. The installation of Fig. 4 is otherwise identical with that of Fig. 1.

In the alternative arrangement shown in Fig. 3, the accelerator pump, instead of being coupled directly to the servo valve 53, is applied between the servo piston 43 and the cam 44, the lower piston 31 of the accelerator pump acting on the left-hand end of a floating link 60, connected at its right-hand end to the link 61 operating the cam 44 and connected intermediate its ends, via a link 62, to the piston rod of the servo piston 43. In this case the lever 37 and link 41 of Fig. 2 are dispensed with, and the Bourdon tube 38

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acts directly on the left-hand end of the following lever 42.

What I claim as my invention and desire to secure by Letters Patent is:

1. A fuel injection system for an internal combustion engine having a throttle valve, comprising means for supplying fuel and air to the engine, mixture control means for varying the fuel/air ratio of the mixture supplied to the engine, a servo mechanism responsive to induction pipe pressure for adjusting said mixture control means to vary the fuel/air ratio as a desired function of induction pipe pressure, and an accelerator pump which is effective, on sudden opening of the throttle valve, to effect an overriding adjustment of the mixture control means to provide a temporary enrichment of the mixture.

2. A fuel injection system for an internal combustion engine, comprising an injection nozzle, a fuel pump for delivering fuel to said injection nozzle, means for controlling the delivery of said fuel pump, an accelerator pump comprising a cylinder and a pair of pressure-responsive members in said cylinder, a throttle-actuating device linked to one of said pressure-responsive members, a biasing device for biasing the other pressure-responsive member to a datum position and a connection between said other pressure-responsive member and the delivery controlling means arranged to enrich the mixture, by delivery of additional fuel to said nozzle, on movement of said member against the biasing device, the space between the pressure-responsive members being filled with liquid and communicating by way of a restricted orifice with a supply of said liquid and displacement of the first pressure-responsive member by sudden accelerating movement of the throttle-actuating member being effective to displace the other pressure-responsive member against its biasing device.

3. A fuel injection system for an internal combustion engine, comprising an injection nozzle, a fuel pump for delivering fuel to said injection nozzle, means for controlling the delivery of said fuel pump, an accelerator pump comprising a cylinder and a pair of pistons in said cylinder, a throttle actuating member linked to one of the pistons and arranged to give it a suction stroke during periods of acceleration, a spring for biasing the other piston towards the associated end of the cylinder, a restricted outlet from the space between said pistons communicating with a supply of liquid which normally fills said space, and a connection between said other piston and the delivery controlling means arranged to enrich the mixture, by delivery of additional fuel to said nozzle on movement of said other piston against its biasing spring.

4. A fuel injection system for aircraft engines as claimed in claim 1, comprising capsules responsive to boost pressure and to exhaust back pressure for controlling the servo mechanism, a device responsive to induction temperature for further controlling the servo mechanism and a cam for transmitting movement from the servo mechanism to the mixture control means, said cam determining the relationship between fuel/air ratio and boost pressure.

5. A fuel injection system for aircraft engines as claimed in claim 1, comprising capsules responsive to boost pressure and to exhaust back pressure for controlling the servo mechanism, by operation of a control valve associated therewith, a device responsive to induction temperature for further controlling the servo mechanism

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and a cam for transmitting movement from the servo mechanism to the mixture control means, said cam determining the relationship between fuel/air ratio and boost pressure and said accelerator pump serving to effect bodily displacement of said capsules and control valve.

6. A fuel injection system as claimed in claim 1, in which the accelerator pump is linked to a control valve associated with the servo mechanism.

7. A fuel injection system as claimed in claim 1, comprising a linkage connecting the servo mechanism and the mixture control means, and an operative connection between said linkage and the accelerator pump.

8. A fuel injection system for an internal combustion engine having a throttle valve and a pilot's lever for adjusting said throttle valve, comprising means for supplying fuel and air to the engine, mixture control means for varying the fuel/air ratio of the mixture supplied to the engine, a variable datum boost control device for positioning the throttle valve to maintain the boost pressure at a value selected by said pilot's lever, mechanism operated by said control device for adjusting said mixture control means to vary the fuel/air ratio as a desired function of selected boost pressure, and means operated by said pilot's lever for effecting, on sudden movement of said lever to select a higher boost, a temporary overriding adjustment of said mixture control means to enrich the mixture.

9. A fuel injection system for an internal combustion engine, having a throttle valve and a pilot's lever for adjusting said valve, comprising an injection nozzle, a fuel pump for delivering fuel to said nozzle, a metering orifice for controlling the rate of supply of fuel to said nozzle, a fuel control valve for controlling the effective area of said metering orifice, means responsive to induction pipe pressure for operating said fuel control valve to vary the rate of flow of fuel to said nozzle as a desired function of induction pipe pressure, and means operated by said pilot's lever for effecting, on sudden accelerating movement of said lever, a temporary movement of said fuel control valve to increase the rate of flow of fuel to said nozzle.

10. A fuel injection system for an internal combustion engine, having a throttle valve and a pilot's lever for adjusting said valve, comprising an injection nozzle, a fuel pump for delivering fuel to said nozzle, a metering orifice for controlling the rate of supply of fuel to said nozzle, a fuel control valve for controlling the effective area of said metering orifice, a variable datum boost control device for positioning the throttle valve to maintain the boost pressure at a value selected by said pilot's lever, mechanism operated by said boost control device for adjusting said fuel control valve to vary the rate of supply of fuel to said nozzle as a desired function of boost pressure, and means operated by said pilot's lever for effecting, on sudden movement of said lever to select a higher boost, a temporary overriding adjustment of said fuel control valve to increase the rate of flow of fuel to said nozzle.

11. A fuel injection system for an internal combustion engine, having a throttle valve and a pilot's lever for adjusting said valve, comprising an injection nozzle, a fuel pump for delivering fuel to said nozzle, means for controlling the delivery of said fuel pump to vary the rate of flow of fuel to said nozzle, a device responsive to induction pipe pressure for adjusting said delivery control means to vary the rate of flow of

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fuel as a desired function of induction pressure, and means operated by said pilot's lever for effecting, on sudden movement of said lever to select a higher boost, a temporary overriding adjustment of said delivery controlling means to increase the rate of flow of fuel to said nozzle.

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