April 6, 1937. J. R. LEMON 2,075,949

FUEL INJECTION SYSTEM

Filed Nov. 15, 1933

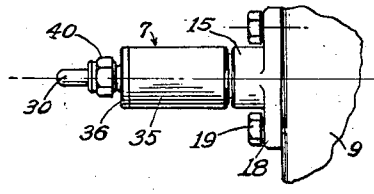


Fig. 2.

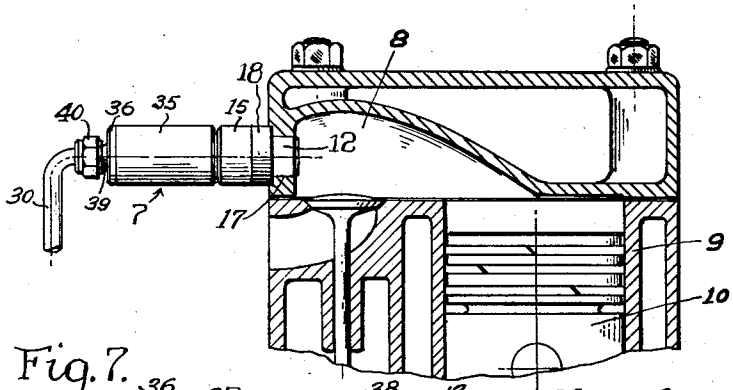


Fig. 1.

Fig. 7.

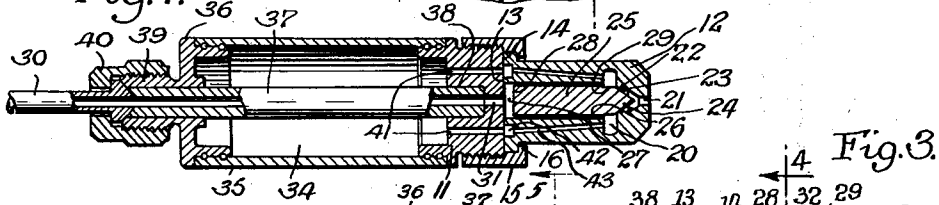


Fig. 3.

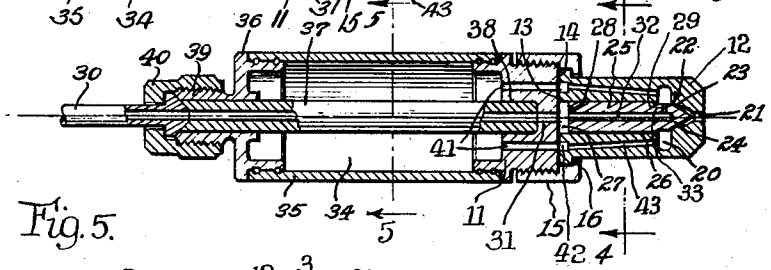


Fig. 5.

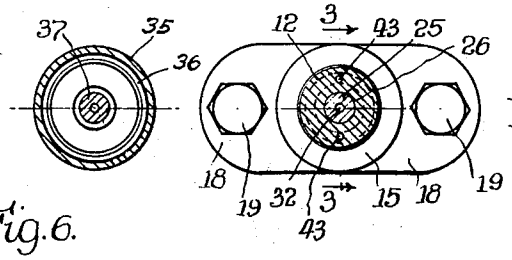
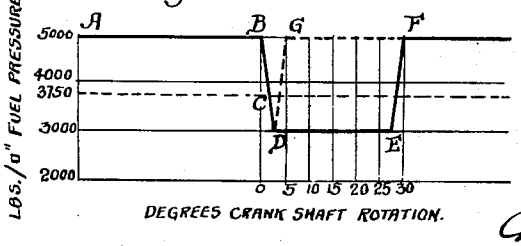


Fig. 4.

Fig. 6.



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FUEL INJECTION SYSTEM

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11 Claims. (Cl. 299—107.5)

The present invention relates to improvements in fuel injection systems, and has particular reference to a new and improved hydraulically operable injection nozzle.

One of the primary features of the invention resides in the provision of a new and improved nozzle having a valve adapted to be opened and closed by the pressure of the fuel, and in which the fuel for operating the valve is supplied through a single line.

A further object is to provide a nozzle of the foregoing character in which the single line also supplies the fuel for injection.

Further objects and advantages will become apparent as the description proceeds.

In the accompanying drawing, Figure 1 is a fragmentary vertical sectional view through a cylinder and combustion chamber of an internal combustion engine with a fuel injection nozzle embodying the features of my invention mounted in operative position.

Fig. 2 is a plan view of the nozzle.

Fig. 3 is a longitudinal sectional view of the nozzle taken substantially along line 3—3 of Fig. 4.

Figs. 4 and 5 are transverse sectional views taken respectively along lines 4—4 and 5—5 of Fig. 3.

Fig. 6 is a diagram illustrating the operation of the nozzle.

Fig. 7 is a view similar to Fig. 3 but of a modified form of nozzle.

While the invention is susceptible of various modifications and alternative constructions, I have shown in the drawing and will herein describe in detail the preferred embodiment, but it is to be understood that I do not thereby intend to limit the invention to the specific form disclosed, but intend to cover all modifications and alternative constructions falling within the spirit and scope of the invention as expressed in the appended claims.

Referring more particularly to the drawing, the fuel injection system may comprise any suitable number of discharge nozzles depending in part on the number of engine cylinders to be served, and the nozzles may be operated in a predetermined timed relation, as illustrated in a copending application by Carroll R. Alden, Serial No. 610,612, filed May 11, 1932. In the present instance, a single nozzle 7 is shown mounted to discharge into a combustion chamber 8 in communication with the head end of an engine cylinder 9 in which a piston 10 is reciprocable, and is adapted to be operated periodically in timed relation to the reciprocation of the piston.

The nozzle 7, in its preferred form, has a sectional body comprising a holder 11 and a discharge tip 12, which may be provided in any suitable shape, and which in the present instance are generally cylindrical and in endwise engagement. Preferably, the adjacent ends of the holder 11 and the tip 12 have flat and smoothly lapped contacting faces 13 and 14 affording a pressure tight joint. A flanged nut 15, engaging a peripheral shoulder 16 on the discharge tip 12, is threaded onto the adjacent end of the holder 11 to secure the parts tightly in assembled relation. The nozzle 7 is mounted in position, with the discharge tip 12 extending through an opening 17 in one wall of the combustion chamber 8, by means of two diametrically opposed lugs 18 on the nut 15 which are rigidly secured to the head of the cylinder 9 by bolts 19.

The discharge tip 12 is formed with a fuel chamber 20, and may be provided with any suitable number of injection orifices opening to the combustion chamber 8, and adapted to be connected by fuel pressure operable valves to the fuel chamber. In the present instance, the nozzle 7 is shown with a single orifice 21 controlled by a valve 22.

The valve 22, in its preferred form, comprises a conical seat 23 located between the fuel chamber 20 and the orifice 21, and a coacting valve member 24 operable by a reciprocable plunger 25. The plunger 25 is disposed in a bore 26 which opens axially through the discharge tip 12 from the inner face 14 to the fuel chamber 20, and the inner end of which defines a control chamber 27 adapted to contain fuel under pressure. In the operation of the valve 22, the face 13 limits the extent of movement of the plunger 25, and hence determines the degree of valve opening. A different degree of valve opening can be obtained by substituting a plunger 25 of a different length. The inner end of the plunger 25 defines a face or area 28 exposed to the pressure in the chamber 27 and acting in a direction to seat the valve member 24. The other end of the plunger 25 is reduced in size to define an annular face or area 29 exposed to the pressure in the fuel chamber 20 and acting in a direction to lift the valve member 24. When the valve 21 is open, the end face of the valve member 24 also is exposed to the pressure in the fuel chamber 20, and acts in a direction to hold the valve open. The total effective area of the valve face and the lifting face 29 substantially equals that of the seating face 28. Reciprocation of the plunger 25 is effected by relatively varying the pressures in the chambers

20 and 27, i. e., by reversing the pressure differential acting on the faces 28 and 29—24.

One of the important features of the present invention resides in supplying the fuel for both chambers 20 and 27, and for effecting pressure fluctuations therein to operate the valve 22, through the medium of a single fuel supply line 30 connected to the nozzle 7. In the present instance, the fuel supply line 30 is in constant communication with a passage 31 formed in the holder 11, and opening to the control chamber 27. Fuel under pressure for injection and to exert a lifting force on the plunger 20 is supplied to the chamber 20 from the chamber 27 through a restricted leakage path of high resistance. This path may be provided in various ways. Thus, the plunger 25 may have a loose fit in the bore 26 so that the annular clearance therebetween will define the connecting path, as shown in Fig. 7, wherein this clearance is made to appear on a somewhat larger scale than other parts of the nozzle so as to facilitate illustration thereof. Preferably, however, the path consists of an axial bore 32 opening from the face 14 into the plunger 25, and communicating at its inner or closed end through a restricted orifice or port 33 with the chamber 20. Where a plurality of nozzles 7, or a plurality of plungers 25 for a series of orifices 21 in a single nozzle, are provided, the leakage paths for the respective plungers may be provided in different ways.

In the operation of the engine, the injection is timed to occur over a predetermined period, variable in duration for example from 0° to 30° of crank shaft rotation. The pressure fluctuations for effecting operation of the nozzle 7 in timed relation to the reciprocation of the piston 10 are illustrated in Fig. 6, wherein fuel pressures in pounds per square inch are plotted along the ordinate and degrees of crank shaft travel are indicated along the abscissa. Between successive periods of injection, the valve 22 is closed, and fuel under a maximum pressure of 5000 pounds per square inch is directed through the line 30 and passage 31 to the control chamber 27 as represented by the line A—B. Fuel leaking through the bore 32 and the restricted port 33 in Fig. 3 or along the peripheral surface of the plunger 25 in Fig. 7 gradually builds up an equal pressure in the fuel chamber 20. However, the valve 22 remains closed since the area of the face 29 is less than that of the face 28. The ratio of these areas is such that upon a reduction in the seating pressure acting on the face 28 to below a predetermined point, for example 3,750 pounds per square inch, while substantially maintaining the high pressure in the chamber 20, the valve 22 will open. At the point B, representing approximately top dead center of the piston 10, a sudden pressure reduction of approximately 40 per cent. along line B—C—D to a pressure of 3,000 pounds per square inch is instituted in the chamber 27. The restricted port 33 in Fig. 3 or peripheral clearance between the plunger 25 and the bore 26 in Fig. 7 prevents a corresponding drop in pressure in the chamber 20, and hence the valve member 24 is lifted to start injection at the point C, representing approximately one and one-half degrees of crank shaft rotation past top dead center. Fuel stored in the chamber 20 is thereupon injected through the orifice 21 into the combustion chamber 8. The duration of injection is dependent on the duration of pressure reduction in the chamber 27, and may be varied in accordance with the engine operating requirements. For full load operation, the pressure is maintained at 3,000 pounds per square inch along the line D—E, and is then restored suddenly to the initial high pressure along the line E—F. During injection, a slight local pressure drop occurs in the fuel chamber 20 adjacent the lifting areas 29 and 24. Hence, upon restoration of the seating pressure in the chamber 27, the valve 22 is closed. For small or idling loads, the seating pressure may be restored immediately along the line D—G. Upon closing of the valve 22, the fuel in the chamber 20 is replenished in preparation for the next cycle.

It will be evident that the pressures in the chambers 20 and 27 tend slowly to equalize due to the connecting passage 32—33 or the peripheral clearance in Fig. 7. However, because of the relatively short duration of the injection period, and the restricted character of the intercommunication between the chambers, such equalization does not occur during the injection period, and hence the injection pressure does not drop appreciably. On the other hand, the idle period continues during most of the crank shaft travel, and affords adequate time for restoration of the fuel supply in the fuel chamber 20 for the next injection.

The fuel chamber 20 preferably has a relatively large pressure storage capacity so that the injection pressure will remain practically constant. This pressure storage capacity may be obtained in various ways, for example by providing a large confined space, defined by the chamber 26 alone or with a supplemental space open thereto, and/or by providing a confined space with resilient walls, adapted for direct communication through the valve 22 with the orifice 21. Where a plurality of nozzles 7 are employed, the desired pressure storage capacity may be obtained by interconnecting the various fuel chambers. In the present instance, the desired pressure storage capacity is obtained by means of a reservoir or accumulator chamber 34 in direct and unrestricted communication with the chamber 20, and in effect forming a part thereof. The chamber 34 is defined by a cylindrical shell 35 of slightly resilient material, such as seamless steel tubing, closed at one end by the holder 11, and at the other end by a head or closure member 36. A central tube 37 extends axially through the chamber 34, and at one end is seated in a recess 38 in the holder 11 in direct communication with the passage 31, and at the other end extends outwardly through an axial sleeve 39 integral with the member 36. The discharge end of the supply line 30 is removably secured, as by a nut 40, to the outer end of the sleeve 39 in direct communication with the outer end of the tube 37. Preferably, the holder 11, the shell 35, the closure member 36 and the tube 37 are tightly and permanently assembled, as by welding, into an integral structure with pressure tight joints. A plurality of bores 41 open from the chamber 34 through the holder 11 to an annular groove 42 formed in the inner face 14 of the discharge tip 12. The groove 42 in turn is connected through a plurality of bores 43 formed in the discharge tip 12 to the fuel chamber 20. By reason of the large volume of fuel in the combined chambers 20 and 34, and the elasticity of the walls of the shell 35 and the slight compressibility of the fuel, a large pressure storage capacity is obtained which serves to maintain the

fuel available for injection at a substantially constant pressure, except for a slight flow drop at the inlet to the valve seat **23**.

It will be evident that operation of the nozzle **7** is effected solely by pressure fluctuation in the single control and fuel supply line **30**. When a plurality of nozzles **7** are provided for the cylinders of a multi-cylinder engine, the pressure fluctuations in the respective lines are effected in timed sequence. Any suitable means (not shown), such for example as an adaptation of the fuel distributor disclosed in said copending application, may be provided to supply the fuel under pressure and to effect the desired pressure control.

I claim as my invention:

1. A unitary fuel injection nozzle comprising, in combination, a body having a valve chamber with an outlet valve seat, a discharge passage opening from said seat, a pressure storage space within said body and having a resilient wall and being in open communication with said valve chamber, a control chamber, and a bore connecting said chambers, a plunger reciprocable in said bore and having oppositely acting pressure faces exposed respectively in said chambers, one of said faces being formed with a valve member adapted to coact with said seat, means for supplying fuel under pressure to said control chamber, and a restricted leakage path located within the confines of said bore longitudinally of said plunger and independent of said space and establishing a direct constant intercommunication between said valve chamber and said means for permitting a gradual flow of fuel on occasion to said valve chamber.

2. A fuel injection nozzle comprising, in combination, a body having a valve chamber with an outlet valve seat, a discharge passage opening from said seat, a control chamber, and a bore connecting said chambers, a plunger reciprocable in said bore and having oppositely acting pressure faces exposed respectively in said chambers, one of said faces being formed with a valve member adapted to coact with said seat, said plunger being substantially smaller in diameter than said bore to define a restricted leakage path between said chambers adapted to permit a gradual equalization of the pressures therein, and means for supplying fuel under pressure to said control chamber, whereby predetermined pressure fluctuations in opposite directions in said means will cause said valve member to move respectively into and out of engagement with said seat.

3. A fuel injection nozzle comprising, in combination, a body having a valve chamber with an outlet valve seat, a discharge passage opening from said seat, a control chamber, and a bore connecting said chambers, a plunger reciprocable in said bore and having oppositely acting pressure faces exposed respectively in said chambers, the area of the pressure face exposed in said control chamber being as large as that of the pressure face exposed in said valve chamber, a valve member movable with said plunger and adapted to coact with said seat, said plunger being formed with a passage open at one end to said control chamber and with a restricted leakage orifice connecting the other end of said passage to said valve chamber, and passage means for supplying fuel under pressure to said control chamber, whereby predetermined pressure fluctuations in opposite directions in said means will cause said valve member to move respectively into and out of engagement with said seat.

4. A fuel injection nozzle comprising, in combination, a body having a valve chamber of relatively large storage capacity with an outlet valve seat, a discharge passage opening from said seat, a control chamber of relatively small capacity, and a bore connecting said chambers, a plunger reciprocable in said bore and having oppositely acting pressure faces exposed respectively in said chambers, one of said faces being formed with a valve member adapted to coact with said seat and being equal in effective area to the other of said faces when said member is lifted and less in effective area than said other face when said member is seated, said plunger being formed with a restricted passage open at one end to said control chamber and at the other end to said valve chamber, and means for supplying fuel under pressure to said pressure chamber, whereby equal pressures in said chambers will cause said valve member to be seated and a sudden pressure drop in said control chamber will effect lifting of said valve member.

5. A fuel injection nozzle comprising, in combination, a body having a confined chamber and a control chamber, a reversibly movable pressure responsive element interposed between and having pressure faces at opposite sides exposed respectively to said chambers, the area of the pressure face exposed in said control chamber being as large as that of the pressure face exposed in said confined chamber, an injection valve operable by said element, a restricted leakage passage formed in said element and establishing intercommunication between said chambers, and means for supplying fuel under pressure to said control chamber, said confined chamber being adapted to receive fuel from said control chamber only through said restricted passage.

6. A fuel injection nozzle comprising, in combination, a body section, a cylindrical shell mounted on one end of said section and defining a confined reservoir chamber, a discharge tip mounted on the other end of said section and formed with a valve chamber and a control chamber and with a discharge passage opening from said valve chamber, a valve for controlling said passage, means connecting said reservoir chamber and said valve chamber, a pressure responsive member exposed at opposite sides to said valve and control chambers, a restricted leakage path connecting said valve and control chambers, a tube extending through said reservoir chamber and opening to said control chamber, and a fuel supply conduit connected to said tube.

7. A fuel injection nozzle comprising, in combination, a body having a valve chamber and a control chamber, an element reciprocable in said body and having oppositely acting pressure faces exposed respectively in said chambers, means for directing fuel under pressure to said control chamber, a restricted flow passage located entirely within said body and independent of said last mentioned means and extending from said control chamber to said valve chamber along said element to establish a direct constantly open intercommunication between said chambers for permitting a gradual equalization of the pressures therein, said valve chamber being adapted to receive fuel under pressure from said control chamber only through said restricted passage, said element being hydraulically operable solely in response to the varying differential determined by the fuel pressures acting on said faces, and injection valve means operable by said element.

8. A fuel injection nozzle comprising, in combination, a body section, a cylindrical shell secured to one end of said section and defining a confined reservoir chamber, a discharge nozzle removably secured to the other end of said section and formed with a valve chamber and a control chamber and with a discharge passage opening from said valve chamber, the face of said discharge tip adjacent said body section being formed with an annular groove, passages formed in said body section and establishing communication between said reservoir and said groove, passages in said discharge nozzle and establishing communication between said valve chamber and said groove, a pressure responsive member reciprocable in said discharge nozzle and having oppositely acting faces exposed respectively in said chambers, the area of the face exposed in said control chamber being at least as great as the area of the face exposed in said valve chamber, a restricted bore extending longitudinally in said member and opening at opposite ends respectively to said valve and control chambers, and means for supplying fuel under varying pressure to said control chamber.

9. A unitary fuel injection nozzle comprising, in combination, a body having an enlarged valve chamber, a discharge orifice opening from said chamber, a valve seat at the inlet of said orifice, a control chamber and a bore connecting said chambers, an element reversibly slidable in said bore solely by hydraulic pressure and having a valve member on one end adapted to engage said valve seat and having a lifting pressure face about said valve member constantly and freely exposed in said valve chamber and a seating pressure face on the other end exposed in said control chamber and at least equal in effective transverse area to the aggregate area of said valve member and said lifting face, means for supplying fuel under pressure to said control chamber, and means defining a restricted constantly open leakage passage in said body effecting a direct uninterrupted intercommunication along said element between said chambers, and affording means for the supply of fuel solely from said control chamber directly to said valve chamber.

10. A fuel injection nozzle comprising, in combination, a body having an enlarged valve chamber, a discharge orifice opening from said chamber, a valve seat at the inlet of said orifice, a control chamber and a bore connecting said chambers, an element reversibly slidable in said bore solely by hydraulic pressure and having a valve member on one end adapted to engage said valve seat and having a lifting pressure face about said valve member constantly and freely exposed in said valve chamber and a seating pressure face on the other end exposed in said control chamber and at least equal in effective transverse area to the aggregate area of said valve member and said lifting face, means for supplying fuel under pressure to said control chamber, means defining a restricted constantly open leakage passage in said body effecting a direct uninterrupted intercommunication along said element between said chambers, and an enlarged storage reservoir out of direct communication with said control chamber and in open intercommunication with said valve chamber independently of said leakage passage.

11. A fuel injection nozzle comprising, in combination, a body having a valve chamber with an outlet valve seat, a discharge passage opening from said seat, a control chamber, and a bore connecting said chambers, a plunger reciprocable in said bore and having oppositely acting pressure faces exposed respectively in said chambers, the area of the pressure face exposed in said control chamber being as large as that of the pressure face exposed in said valve chamber, a valve member movable with said plunger and adapted to coact with said seat, said plunger being formed to define a restricted passage opening from said control chamber through said bore to said valve chamber, and passage means for supplying fuel under pressure to said control chamber, whereby predetermined pressure fluctuations in opposite directions in said means will cause said valve member to move respectively into and out of engagement with said seat.

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