

Sept. 24, 1946.

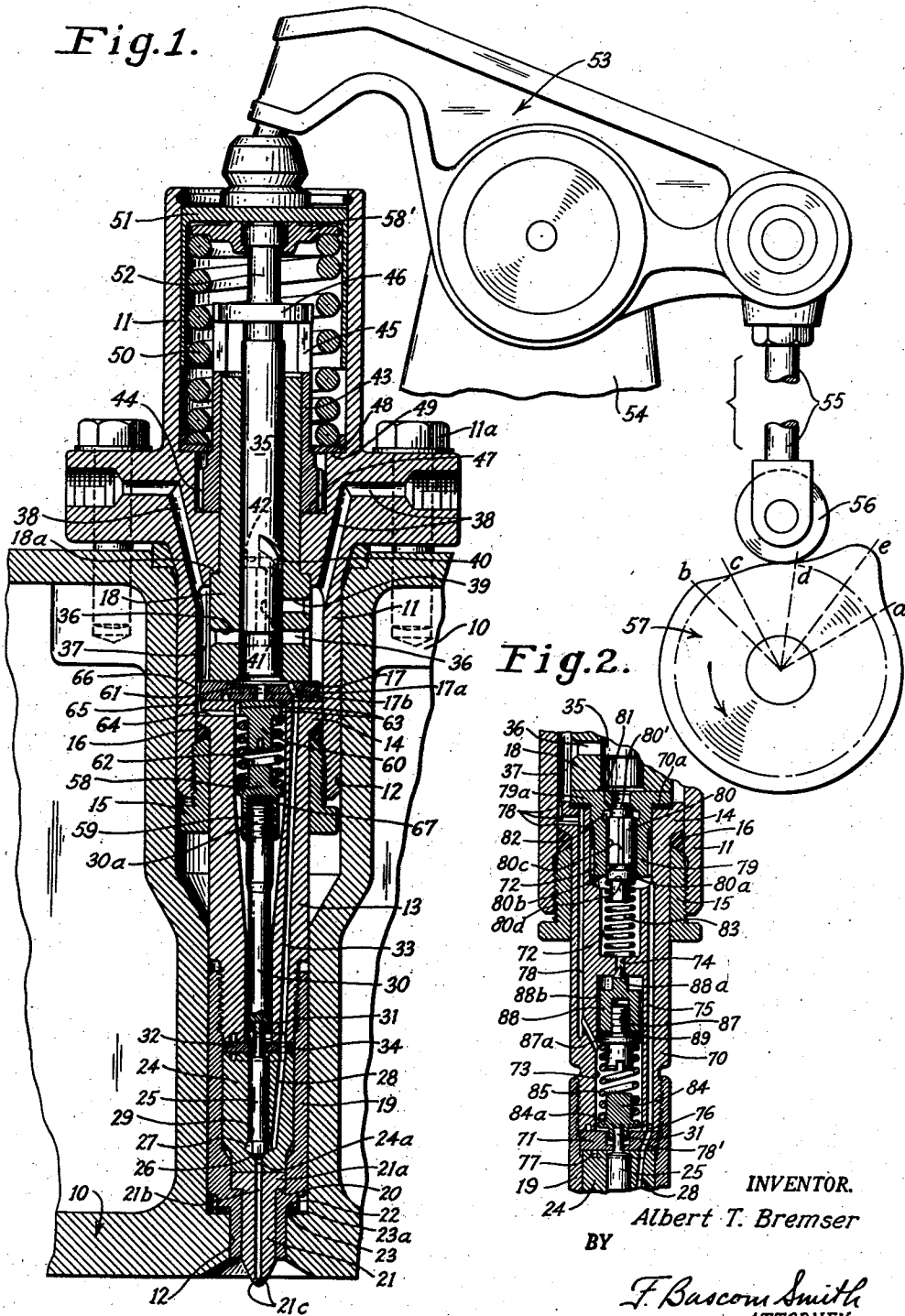
A. T. BREMSER

2,408,288

FUEL INJECTION APPARATUS

Filed Nov. 13, 1942

Fig.1.



INVENTOR.

Albert T. Bremser

BY

F. Bascom Smith
ATTORNEY

UNITED STATES PATENT OFFICE

2,408,288

FUEL INJECTION APPARATUS

Albert T. Bremser, Sidney, N. Y., assignor to
Bendix Aviation Corporation, New York, N. Y.,
a corporation of Delaware

Application November 13, 1942, Serial No. 465,448

17 Claims. (Cl. 103—41)

1

This invention relates to fuel injection apparatus and more particularly to means for controlling and effecting the delivery of fuel under pressure to the cylinder of a solid fuel injection engine.

One of the objects of the present invention is to provide a novel fuel injection apparatus of the type wherein an injection nozzle and a fuel pump are embodied in a unitary structure.

Another object of the invention is to provide a fuel injection apparatus having a pressure controlled nozzle valve with novel means for protecting said apparatus and the engine on which the same is mounted in the event of inoperativeness of said valve.

A further object is to provide a fuel injection apparatus having novel means for preventing excessive fuel delivery in the event the nozzle valve controlling fuel injection becomes locked in open position.

Still another object is to provide novel means in the above apparatus for preventing deleterious effects other than non-delivery of fuel when the pressure operated nozzle valve becomes locked or stuck in closed position.

A still further object is to provide a uniflow injector, i. e., an injector having an injection nozzle and fuel pump embodied in a unitary structure, with novel means for effecting adjustment of the nozzle valve so as to control the pressure necessary to effect fuel delivery from the nozzle.

Still another object is to provide a fuel injection apparatus having novel actuating means for controlling the stroke of the movable pumping element of said apparatus.

A further object is to provide a fuel pump embodying a novel arrangement for controlling the flow of fuel therein whereby advantageous cooling thereof is effected.

The above and further objects and novel features of the invention will more fully appear from the following detailed description when the same is read in connection with the accompanying drawing. It is to be expressly understood, however, that the drawing is for the purpose of illustration only and is not intended as a definition of the limits of the invention, reference for this latter purpose being primarily had to the appended claims.

In the drawing, wherein like reference characters refer to like parts throughout the several views,

Fig. 1 is a sectional view, with parts broken away and parts shown in elevation, of one form of

2

fuel injection apparatus embodying the present invention; and,

Fig. 2 is a fragmentary view of a fuel injection apparatus having a modified arrangement for controlling fuel delivery to the injection nozzle.

Referring to Fig. 1, 10 is the head of a cylinder of a solid fuel injection engine whereon is mounted a novel fuel injection apparatus embodying the present invention, said apparatus being preferably of the type combining a fuel pump and a fuel injection nozzle in a unitary structure. The injection apparatus, in the form illustrated, comprises a main barrel or housing 11 secured to cylinder head 10 by suitable means, such as bolts 11a or a clamp (not shown), so that the lower end thereof extends into a recess 12 formed in said cylinder head. A nozzle holder body 13 having an external shoulder 14 formed at the upper end thereof is mounted in the lower end of housing 11 and is secured in operative position by a gland nut 15 which screws into said housing and cooperates with said shoulder, a gasket 16 being preferably interposed between said shoulder and said gland nut. The latter is effective to hold nozzle body 13 in abutting sealing engagement with the lower face of a disc member 17 which, in turn, bears against the lower end of a pump cylinder 18, and presses a shoulder 18a formed on the latter into engagement with an internal shoulder in the bore of housing 11. As a result, nozzle body 13, disc member 17 and pump cylinder 18 are held against axial movement and in fluid-tight engagement with each other, the latter two elements cooperating in a manner more fully described hereinafter.

Threaded on the lower end of nozzle holder body 13 is a sleeve nut 19 which is provided intermediate its ends with an internal shoulder 20 for supporting engagement with the flanged upper end 21a of a nozzle spray or atomizing tip 21, said tip having a central bore or duct 21b therein and a plurality of radially extending orifices 21c adjacent the lower end thereof. The nozzle tip 21 projects through the lower end of sleeve nut 19 into the combustion chamber of the engine cylinder so that fuel can be sprayed from orifices 21c into said chamber. The lower end of said nut fits into the lower end of recess 12, and an external shoulder 22 formed adjacent said lower end seats on a gasket 23a which is, in turn, supported by an internal shoulder 23 in said recess.

Removably mounted in nut 19 above nozzle tip 21 is a valve guide 24 that is centrally bored for slidably receiving the stem or piston portion of a needle valve 25. The bore through said guide

3

member terminates at the lower or inner end of the latter in a small orifice 24a which is coaxial with passage 21b, and a conical seat 26 is provided adjacent said orifice for cooperation with the tapered lower end of needle valve 25. The latter is thus effective to control the flow of fuel from member 24 into duct 21b and hence into the engine cylinder. Preferably, the bore in guide member 24 is enlarged immediately above valve seat 26 to provide a fuel pressure chamber 27 through which a reduced portion of valve 25 extends. Fuel supplied under pressure to chamber 27 through a suitable passage 28 in member 24 in a manner hereinafter described acts against shoulder 29 formed on the valve by the reduction in the diameter thereof, and is thus effective to lift the latter off its seat and permit the flow of fuel from said chamber through passages 24a, 21b and 21c into the engine cylinder.

Valve 25 is normally held in seated or closed position by novel means described hereinafter which apply a yielding pressure to the valve through a pressure pin or spindle 30 that freely extends through the central bore in nozzle body 13. The lower end of spindle or rod 30 is preferably recessed for freely receiving a pin 31 formed by a reduced portion at the upper end of valve 25. Between the adjacent ends of body 13 and valve member 24 there is preferably interposed a washer member or plate 32 having a central recess therein through which pin 31 of valve 25 extends, said washer being adapted to engage the upper end of the shank of the valve to limit the upward movement of the latter. A passage 33 extending from the upper end of body 13 connects with passage 28 in guide member 24 through an orifice 34 in plate 32. The latter may be readily replaced if it becomes worn by the constant hammering of valve 25 thereagainst.

In order to deliver fuel under pressure to chamber 27 and thence to the combustion chamber, pumping means are provided, the same being preferably contained in housing 11. As shown, said means comprise a plunger 35 slidably mounted for reciprocation in the bore of cylinder 18 so that a pressure chamber is formed at the lower end of said cylinder by said bore walls, said plunger and disc member 17. A passage 17a in disc 17 connects the pressure chamber to an annular groove 17b provided in the lower face of said disc and said groove is adapted to overlap and open into the upper end of passage 33. One or more radial fuel inlet ports 36 are provided in the wall of cylinder 18 to connect said pressure chamber with an annular fuel supply groove 37 formed in the internal wall of housing 11, plunger 35 operating as a slide valve to control the flow of fuel through said ports into cylinder 18 in a manner well understood in the art. In order that fuel from a suitable source may be employed in a novel manner to cool the fuel pump, the latter is novelly constructed with a pair of fuel passages 38 disposed in opposite sides of housing 11 to connect with groove 37. Fuel is admitted from the fuel source through one of said passages and may be discharged from the other so that, by delivering a quantity of fuel to the intake passage at a rate in excess of the amount used by the engine, a continuous circulation of fuel may be maintained through said passages and groove 37 to cool the parts adjoining the latter.

To control the point of fuel by-pass, i. e., the termination of fuel injection, a by-pass port 39 axially spaced above ports 36 is provided in mem-

4

ber 18 for cooperation in a manner well understood in the art, with a helical groove 40 formed in the surface of plunger 35, said groove being continuously connected to the pressure chamber of the pump by suitable passages, such as connected axial and radial passages 41 and 42, respectively. To vary the angular relation between metering groove 40 and cut-off or by-pass port 39 and thereby vary the effective pumping stroke of the piston, suitable means for angularly adjusting plunger 35 are provided and, in the form shown, comprise a sleeve 43 loosely surrounding the upper end of cylinder 18 in the enlarged interior of the upper end of housing 11. Gear teeth 44 are formed on the lower end of sleeve 43 for cooperation with a rack member (not shown) in a manner well-known in the art. The upper end of sleeve 43 is axially slotted at 45 for slidably receiving a cross bar 46 rigidly connected to plunger 35. Sleeve 43 seats on an internal shoulder 47 in housing 11 and is held against axial movement relative to cylinder 18 by a ring member 48 which engages an external shoulder on said sleeve and is positioned against an internal shoulder 49 in housing 11, said ring member being held on the latter shoulder by a spring 50 which constitutes an element of the plunger reciprocating means. The latter comprises a tappet cup 51 which is slidably positioned in the upper end of housing 11 for engagement with the head portion of a member 52 operatively connected to or integrally formed with the upper end of piston 35. Downward movement is imparted to the latter by means comprising a rocker arm or tappet lever 53 which is pivotally mounted intermediate the ends thereof on a suitable rocker support 54 fixed to the cylinder head. One end of said arm bears against the upper end of tappet cup 51 and the other end is connected by a rod 55 to a cam follower 56, the latter being in operative engagement with the cam 57 which is adapted to rock said arm and actuate plunger 35 in a novel manner to be fully described hereinafter. The downward movement of said plunger is resisted and the upward movement thereof is effected by spring 50 which has the lower end thereof seated on ring member 48 and the upper end thereof engaging a washer 58', which, in turn, engages a downwardly facing shoulder formed by the enlarged upper end of member 52 to transmit upward forces to plunger 35.

In the conventional fuel injection nozzle, the binding or locking of the nozzle valve in either open or closed position, or the clogging of the fuel passages, such as orifices 21c, may produce serious detrimental effects, particularly at high speed operation, which effects substantially diminish the life, efficiency and capacity of the engine. To minimize these deleterious effects to the fullest extent and prevent permanent injury to the engine or fuel injection equipment as a result thereof, novel means are provided in the above-described injection apparatus to insure safe operation. The novel safety means include mechanism adapted to relieve the pressure which tends to build up in the pressure chamber when nozzle valve 25 is locked in its closed position. For the latter purpose, the upper end of the bore of nozzle holder body 13 is preferably enlarged in diameter and receives the threaded upper end portion 30a of spindle 30 on which is mounted a spring supporting member 58, the latter having an internally threaded bore 59 whereby it is adjustably screwed on the end of said spindle.

5

Slidably mounted in the upper end of the bore of body holder 13 for engagement with disc 17 is a valve member 60 which normally seats on the lower surface of said disc to normally close a central port 61 in said disc, said port connecting with the pressure chamber of pump 18, 35. A spring 62 is compressed between member 58 and valve member 60 and normally maintains the latter in operative engagement with disc 17, said spring also applying the downward pressure which yieldably presses valve 25 into engagement with seat 26.

The diameter of port 61 is such that the area of valve member 60, which is subjected through said port to the fuel pressure in the pump pressure chamber, is less than the effective area of valve shoulder 29 which is acted upon by the same fuel pressure. As a result, during normal operation, valve 25 has a greater total upward force acting thereon for a given fuel pressure than the pressure on valve member 60 through port 61 so that the former is raised from its seat while the latter remains in closed position. However, if valve 25 becomes stuck in closed position, a sufficient pressure is built up in the pressure chamber to unseat valve member 60. In order to effect a fuel by-pass from the pump pressure chamber in the latter event, one or more flutes or slots 63 are provided in the periphery of valve member 60 which serve to connect the bore of body 13 below said member with port 61 when said valve member is in open position. A radial passage 64 connects said bore to an axially extending slot 65 in the outer surface of flange 14 and said slot opens at its upper end through a slot 66 to fuel supply groove 37. Accordingly, when valve member 60 is in open position, fuel is by-passed from the pressure chamber to the supply line or sump.

Novel means are provided for effecting adjustment of the compression of spring 62 to thereby control the fuel pressure necessary to raise valve 25 to open position. As shown, said means comprise a plurality of shims 67 located in the upper end of bore 59 of member 58 so as to bear against the end of threaded portion 30a and thereby limit the extent to which the latter can be threaded in said bore. By varying the number of shims utilized in this manner, there is obtained an accurate control of the compression to which spring 62 is subjected. It is to be noted that the pressure of said spring on member 58 prevents the latter from unscrewing from portion 30a and vitiating a satisfactory adjustment once the same has been attained.

In order to guard against detrimental effects of the locking or sticking of valve 25 in open position, plunger 35 is actuated in a novel manner to prevent a relatively continuous flow of fuel into the engine cylinder under the pressure in the fuel supply line. On the up or suction stroke of the plunger, the latter is caused to come to rest with the lower end thereof just below ports 36. When the plunger is in this position, shown in broken lines in Fig. 1, ports 36 as well as port 39 are closed and no fuel is admitted to the pressure chamber and, therefore, none can flow to the combustion chamber of the engine cylinder. Plunger 35 is maintained in this position by cam 57 for a substantial portion of the period between fuel injections. To accomplish this, said cam, which rotates in the direction of the arrow, has a circular contour for a substantial part of its peripheral surface, i. e., between points a and b, which contour when in engagement with follower

6

56 holds plunger 35 in the desired stationary position. From point b to point c of the cam surface, the remainder of the suction or up-stroke of the plunger takes place, ports 36 being opened during this portion of the stroke and remaining open from points c to d when the plunger is in top dead center position. During this latter movement of the pump plunger, the piston in the engine cylinder is in the course of its compression stroke so there will be no danger of fuel being forced into the cylinder by the small pressure in the fuel supply line. At d on the cam the plunger begins its power or down-stroke and reaches bottom dead center position when follower 56 engages point e of the cam. Upon continued rotation of cam 57, the plunger moves upward until surface a—b, is again reached to complete the cycle. As a result of this novel construction of cam 57, fuel injection into the engine cylinder can take place only during a predetermined part of the engine piston stroke even with the nozzle valve locked in open position, so that the combustion chamber of the cylinder cannot be flooded with fuel oil.

In normal operation, when plunger 35 is at top dead center position prior to the down or power stroke thereof, the pump pressure chamber and the fuel conducting passages 17a, 33, 34 and 28 and chamber 27 are filled with fuel at supply line pressure, inlet ports 36 are open and by-pass port 39 is closed. When plunger 35 moves downward to close inlet ports 36, the pressure of the fuel in the pressure chamber is built up after the port closure and is transmitted to chamber 27, raising valve 25 and thereby permitting fuel to be injected into the combustion chamber of the engine cylinder through passages 24a, 24b and 24c. At a further point in the down-stroke, metering groove 40 overlaps port 39 to connect the fuel supply line 37, 38 with the pump pressure through passages 41 and 42 and fuel delivery is cut off. After bottom dead center position is reached the suction stroke begins and continues until piston 35 reaches a point at which it closes ports 36 and port 39. At this point, plunger 35 comes to a standstill and remains stationary until a short time before fuel injection is desired. The up-stroke is then resumed and the plunger completes its travel to top dead center position, filling the pump and nozzle pressure chamber with fuel at supply line pressure.

The pressure at which valve 25 opens to begin fuel injection to the combustion chamber during the power stroke of plunger 35 is readily predetermined by adjustment of the number of shims 67 in bore 59.

If valve 25 becomes locked in closed position, the building up of fuel pressure in the pressure chamber unseats valve member 60 and the fuel from the pump pressure chamber is by-passed to the supply line through port 61, flutes 63, the bore of body 13, and passages 64, 65 and 66. If valve 25 becomes locked in open position, the delivery of fuel to the combustion chamber in excessive quantities is prevented by plunger 35 which closes ports 36 and 39 for a substantial period between fuel injections.

The flow of fuel in the supply system through groove 37 is continuous, the same entering said groove through one passage 38 and leaving through the oppositely disposed passage 38. The amount of excess fuel circulated in this manner may be regulated in accordance with the need for cooling the apparatus.

A modification of the above-described uniflow

injection apparatus is shown in Fig. 2, wherein a conventional type cam actuates the plunger and novel means in the nozzle holder body guard against the deleterious effects of the locking of nozzle valve 25 in either open or closed position. As shown, the apparatus comprises a nozzle holder body 70 operatively mounted in the lower end of housing 11 by means of a gland nut 15, sleeve nut 19 being secured to the lower end of said body and carrying guide member 24 in which is mounted nozzle valve 25. A washer member 71 is held between the lower end of said body and the upper end of said guide member and has a central recess through which pin 31 of valve 25 extends. Body 70 is provided with upper and lower axial recesses or bores 72 and 73, respectively, which are connected to each other by a port 74. A passage 75 connects bore 72 with an annular groove 76 formed in the lower end of body 70 and said groove communicates with a groove 77 in the upper end of valve guide member 24 by means of one or more passages 78' in washer member 71, groove 77 being in turn connected to the upper end of passage 28. Bore 73 is preferably connected by a passage or series of passages 78 to the upper end of body 70 and, accordingly, opens into fuel supply groove 37.

A delivery valve adapter unit 79 having an external flange 79a formed thereon at the upper end thereof is mounted in the upper portion of bore 72 and flange 79a is pressed tightly between a gasket 70a and the lower end of cylinder 18, said gasket fitting into an annular indentation in the upper end of body 70. The central bore of said adapter opens into the pump compression chamber and a retraction type delivery valve 80 is slidably mounted in said adapter bore to control the fuel flow from said chamber to bore 72. The upper end 80' of said delivery valve is adapted to engage a conical seat 81 in said adapter bore and a cylindrical portion 80a is formed at the lower end of said valve for fluid-tight engagement with the internal walls of adapter 79. An annular groove 80b is provided between the upper end of portion 80a and axial flutes 80c, said flutes connecting at the upper ends thereof with a chamber 82, which is formed immediately below seat 81 by an enlargement of the adapter bore. A spring 83 disposed between the bottom wall of bore 72 and a shoulder 80d formed on valve 80 yieldably urges the latter upward and normally maintains said valve in closed position. When a sufficient pressure is built up in the pressure chamber of the pump 18, 35 to lift said valve from seat 81 and withdraw portion 80a from the adapter bore, the pressure chamber is open to bore 72 and the fuel pressure therein is transmitted to valve 25 through passages 75, 78' and 28. Thus, even if valve 25 is locked in open position fuel delivery to the engine cylinder can occur only when the sufficient pressure is built up in the pressure chamber to move delivery valve 80 to open position.

Novel means are also embodied in body 70 for yieldably urging valve 25 into engagement with its seat and for preventing any serious detrimental effects when said valve becomes stuck or otherwise inadvertently locked in closed position. In the illustrated embodiment, said means comprise a pressure transmitting element 84 disposed in the lower end of bore 73 and loosely mounted on the upper end of pin 31 so as to transmit downward forces to the latter. An upwardly facing shoulder 84a is formed on said element and the lower end of a spring 85 seats on said shoulder

and is centered by the shank of said element, said spring being held under compression between said shoulder and a valve mechanism in the upper end of bore 73 so that valve 25 is pressed in the direction of its seat. Said mechanism comprises a screw member or stud 87 having a flange 87a formed at the base of the head thereof for engaging the upper end of spring 85, said head serving as a centering guide for said spring. Screw member 87 is threaded into the lower end of a valve member 88 which is slidably mounted in bore 73 and has a needle valve element 88a integrally formed with or otherwise rigidly secured to the upper end thereof. The lower end of port 74 is flared to form a conical seat which co-operates with valve element 88a to normally prevent fuel flow through said port into bore 73. A plurality of axial grooves or flutes 88b are formed in the periphery of valve member 88 to interconnect the upper and lower ends of said bore so that passage 78 communicates with bore 72 when valve 88a is open.

The cross-sectional area of port 74 is such that the total effective fuel pressure acting downwardly on valve 88 is less than the total pressure acting upwardly on valve 25 so that in normal operation valve 88 is always closed and valve 25 is opened periodically in response to the pressure created by the pump to permit fuel delivery from bore 72 to the combustion chamber of the engine cylinder. However, in the event valve 25 becomes locked in closed position, the pressure in bore 72 will, during the effective pumping stroke of the pump plunger, cause valve 88 to open so that fuel is by-passed from said bore through port 74 to bore 73 and from the latter bore back to the fuel supply line via passage 78.

In order to control the compression of spring 85 and, therefore, the fuel pressure at which valve 25 will be lifted from its seat, a plurality of washer-like shims 89 are disposed between the upper face of shoulder 87a and the lower end of member 88. The axial position of screw member 87 can be accurately adjusted by varying the number of shims 89 and thus provides accurate means for regulating the pressure exerted by spring 85.

There is thus provided a novel fuel injection apparatus of the uniflow type wherein a fuel pump and a fuel injector are combined in a unitary structure. The apparatus embodies novel means for insuring against any permanent or serious deleterious results in the event the nozzle valve is bound or otherwise locked against movement either in open or closed position. Novel means are included for preventing excessive fuel delivery to the engine cylinder when the nozzle valve is in open position as well as novel means for relieving the pressure built up in the pump compression chamber when the nozzle becomes clogged or the nozzle valve remains closed during operation. There is also provided a novel arrangement whereby the nozzle valve operation can be controlled, i. e., whereby the fuel pressure at which the valve will be lifted from its seat can be accurately predetermined during assembly of the injector. Additionally, the novel structure provided includes means whereby cooling of the same may be effected in a novel manner. Still another novel feature of the pump and nozzle unit provided is the location of the by-pass port above the inlet port of the pump to insure against any accumulation of air in the pump compression chamber.

Although only two embodiments of the invention have been illustrated and described, it

is to be expressly understood that the same is not limited thereto. For example, it will now be apparent to those skilled in the art that other types of delivery valve units may be employed in the embodiment of Fig. 2, that instead of a single spring, separate springs may be employed for normally maintaining safety valve 60 or 88 and nozzle valve 25 in closed position, and that by-pass port 39 may be connected to any low pressure space other than the supply line 37, 38. It is to be understood also that the nozzle safety valves and adjusting means shown in Figs. 1 and 2 for relieving the fuel pressure in the pump pressure chambers may be interchanged. Various other changes may also be made in the design and arrangement of parts illustrated without departing from the spirit and scope of the invention. For a definition of the limits of the invention, reference is had primarily to the appended claims.

What is claimed is:

1. In fuel injection apparatus of the class described, pump means comprising a casing, a cylinder in said casing and a reciprocating plunger in said cylinder, said cylinder having port means controlled by said plunger and connecting the interior of the cylinder with an annular space between said casing and cylinder, said space having an inlet and an outlet independent of said ports whereby fuel may be circulated there-through irrespective of the position of said plunger and said space being the sole connection between said inlet and outlet when said port means are closed by the plunger.

2. In fuel injection apparatus, pump means comprising a casing, a cylinder in said casing, said cylinder and casing cooperating to form an annular space therebetween having an inlet and an outlet through said casing, and a reciprocating element in said cylinder for controlling communication between said space and the interior of said cylinder through ports in the walls of said cylinder, said space being annular whereby fuel may be continuously circulated around said cylinder irrespective of the position of said element and said space being the sole connection between said inlet and outlet when said port means are closed.

3. In apparatus of the class described, fuel pumping means for an internal combustion engine, a first valve means responsive to pressure created by said pumping means for controlling the flow of fuel from the pressure chamber of said pumping means into an engine cylinder, a second valve means responsive to said pressure for controlling the flow of fuel from said pressure chamber to a point outside said cylinder, said first valve means being adapted to open in response to a lower pressure than said second valve means, and a single resilient means for normally holding both said valve means in closed position, said first and second valve means being in axial alignment with each other and with said pumping means.

4. In apparatus of the class described, fuel pumping means for an internal combustion engine, a first valve means responsive to pressure created by said pumping means for controlling the flow of fuel from the pressure chamber of said pumping means into an engine cylinder, a second valve means responsive to said pressure for controlling the flow of fuel from said pressure chamber to a point outside said cylinder, said first valve means being adapted to open in response to a lower pressure than said second

valve means, and common yieldable means for normally holding said first and second valve means in closed position.

5. In fuel injection apparatus for internal combustion engines, means for subjecting a liquid fuel to pressure for forcing the same into the cylinder of an internal combustion engine, a first valve means responsive to the pressure of said fuel for controlling the flow of fuel into said cylinder, a second valve means responsive to the pressure of said fuel for controlling the flow of said fuel to a point outside said cylinder, and common means for yieldably biasing said first and second valve means toward closed position, the effective area of said second valve means acted upon by said fuel pressure being less than the corresponding area of said first valve means when both said valve means are in closed position.

6. In apparatus of the class described wherein liquid fuel is supplied under pressure by a fuel pump, the combination of, a valve responsive to fuel pressure created by said pump for controlling the flow of fuel through an orifice, valve means for relieving the pressure in said pump when said valve fails to open in response to a predetermined maximum pressure, and common resilient means interposed between said valve and valve means for normally holding the same in closed position.

7. In apparatus of the class described, a fuel pump comprising a cylinder having inlet and by-pass ports therein, a plunger in said cylinder for controlling the flow through said ports, and means for periodically reciprocating said plunger, said last-named means being operable to cause said plunger to close said ports during at least a major portion of the interval between the beginning of successive cycles of operation of said plunger.

8. In fuel injection apparatus for an internal combustion engine, pump means, means connecting the pressure chamber of said pump means to a source of fuel supply, means connecting said chamber to the cylinder of an internal combustion engine, said pump means comprising means for controlling said first-named connecting means, and means for cyclically operating said controlling means to cut off communication between said chamber and source during at least a major portion of the interval between the beginning of successive cycles of operation of said controlling means.

9. In fuel injection apparatus, a cylinder, a plunger mounted for reciprocation in said cylinder and defining a pressure chamber therewith, means for supplying liquid fuel to said chamber, means for delivering fuel from said chamber to a combustion chamber, said last named means including a pressure responsive control valve, and means for actuating said plunger so as to maintain said plunger stationary for a substantial portion of the duration of each suction stroke thereof, said plunger in the stationary position thereof being effective to cut off communication between said first named means and the pressure chamber.

10. In fuel injection apparatus, fuel pumping means adapted to periodically apply pressure to a quantity of fuel, means comprising a delivery line from said pumping means to an engine compression chamber, a pressure responsive valve normally maintaining said delivery line closed, said valve being moved to open position by the building up of fuel pressure in said line, means

11

comprising a by-pass passage for relieving the pressure in said delivery line, a valve responsive to the pressure of the fuel for controlling the flow of fuel through said passage, and common resilient means for normally holding both of said valves in closed position, said second-named valve being moved to open position only when said first-named valve is closed and a pressure in excess of that necessary to normally open said first-named valve is built up in said delivery line.

11. In fuel injection apparatus, a cylinder, a plunger mounted for reciprocation in said cylinder and defining a pressure chamber therewith, at least one fuel supply port communicating with said pressure chamber, a pressure responsive control valve adapted to regulate the fuel discharge from said chamber, and means including a cam for actuating said plunger, said cam maintaining said plunger stationary for the greater portion of the duration of each complete stroke cycle thereof at a point in the suction stroke when said plunger closes said port.

12. In apparatus embodying a fuel pump, means comprising a delivery passage adapted to deliver fuel from said pump to a discharge orifice, a control valve actuated by the fuel pressure in said passage to open the latter for fuel discharge, a delivery valve operatively associated with said pump to control the fuel delivery to said delivery passage, a by-pass passage connected to said delivery passage at a point between said delivery and control valves, and a by-pass valve normally closing said by-pass passage, said last-named valve being moved to open position by the fuel pressure in said delivery passage when said pressure exceeds the pressure normally necessary to actuate said control valve to open position and all of said valves being co-axial with each other and with said pump.

13. In fuel injection apparatus embodying a fuel pump, means comprising a delivery passage adapted to deliver fuel from said pump to a discharge orifice, a control valve actuated in one direction by the fuel pressure in said passage to open said orifice for fuel discharge, a by-pass passage connected to the pressure chamber of said pump, a by-pass valve normally closing said by-pass passage, said by-pass valve being movable in the opposite direction to open position by the fuel pressure in the pump pressure chamber when said pressure is in excess of that necessary to move said control valve to open position, and common resilient means interposed between said valves for normally holding the same in closed position.

14. In injection apparatus of the uniflow type having a housing and pumping means in said housing including a cylinder and a plunger, a fuel supply chamber in said housing surrounding said cylinder and adapted to be connected periodically with the pressure chamber of said pumping means, and means including a pair of passages disposed on opposite sides of said housing

12

so as to connect with said chamber for continuously circulating fuel through said chamber at a rate exceeding that necessary to feed said pumping means, said chamber being the sole connection between said pair of passages.

15. In apparatus of the class described, a fuel pump comprising a cylinder having inlet and by-pass ports therein, a plunger in said cylinder for controlling the flow through said ports, means for periodically reciprocating said plunger, said last-named means being operable to cause said plunger to close said ports during at least a major portion of the interval between the beginning of successive cycles of operation of said plunger, a first valve means responsive to pressure created by said pump means for controlling the flow of fuel from the pressure chamber of said pump means into an engine cylinder, and a second valve means responsive to said pressure for controlling the flow of fuel from said pressure chamber to a point outside said engine cylinder, said first valve means being adapted to open in response to a lower pressure than said second valve means.

16. In fuel injection apparatus of the class described, a pump casing, a pump cylinder in said casing, a reciprocating plunger in said cylinder, a tubular nozzle holder body extending into said pump casing in axial alignment therewith, means for securing said cylinder and nozzle holder body in said pump casing, an adaptor interposed between said nozzle holder body and said cylinder, a delivery valve operable in said adaptor for controlling the flow of fuel from the pressure chamber in said cylinder to said nozzle holder body, means for supplying liquid fuel to a space in said pump casing around said cylinder, means including a by-pass valve in said nozzle holder body for connecting the interior of said nozzle holder body to said space, a control valve for controlling the flow of fuel through said nozzle holder body to a combustion space, and common resilient means interposed between said by-pass valve and said control valve for normally holding the same in closed position.

17. In fuel injection apparatus of the class described, a fuel pump comprising a casing, a cylinder in said casing and a reciprocating plunger in said cylinder, a nozzle holder body, means for securing said nozzle holder body and said cylinder in said pump casing in axial alignment with each other, a pair of valves in said nozzle holder body adapted to be moved to open position by the fuel pressure created by said pump, one of said valves being a control valve adapted to normally control the flow of fuel to a combustion space and the other being a by-pass valve adapted to control the flow of fuel to a region of low pressure for relieving the fuel pressure in said cylinder and holder body whenever said control valve fails to open in response to a predetermined maximum pressure, and common resilient means interposed between said valves for normally holding the same in closed position.

ALBERT T. BREMSER.