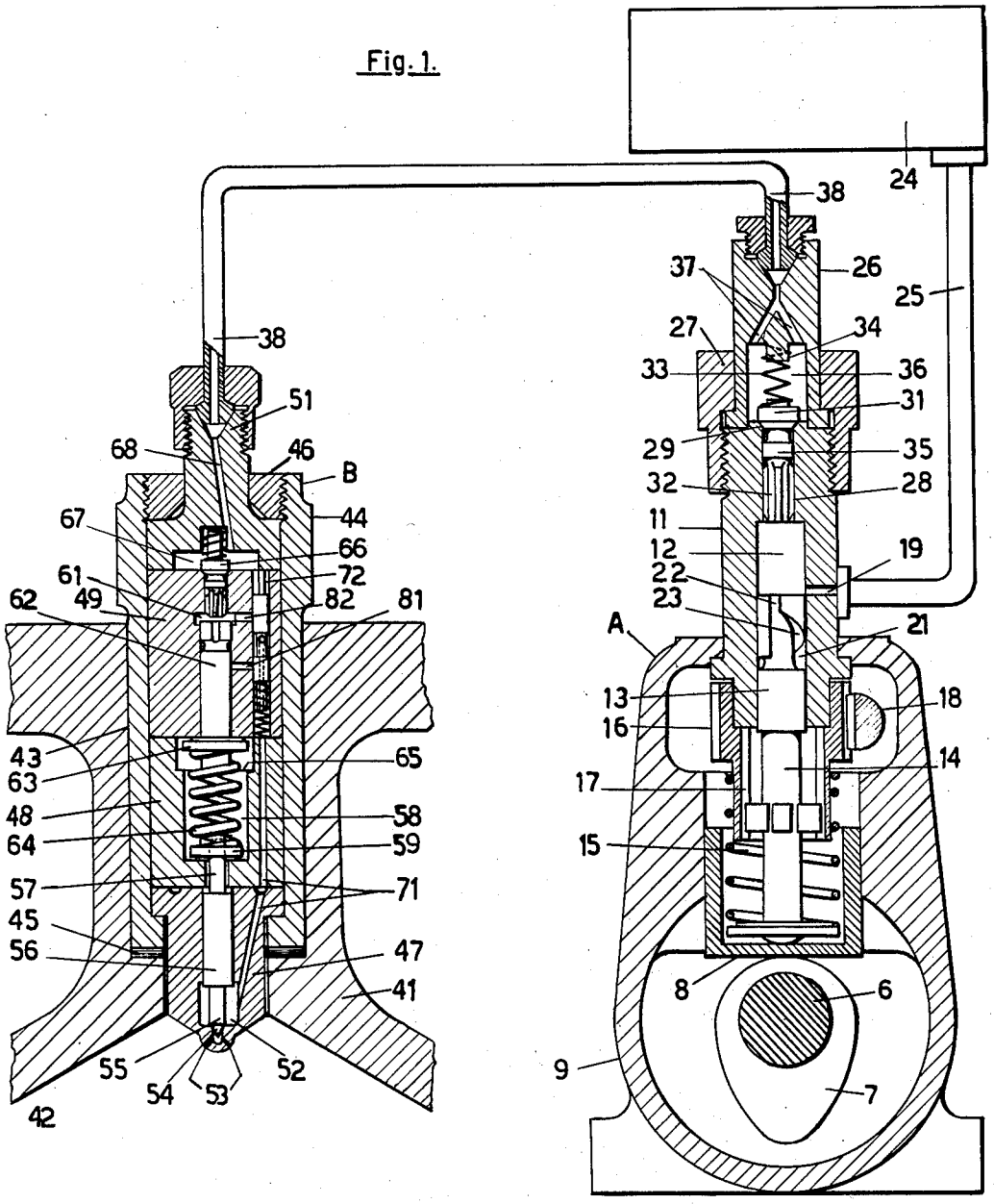
Sept. 19, 1939. B. BISCHOF 2,173,814

FUEL INJECTION APPARATUS FOR INTERNAL COMBUSTION ENGINES

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Fig. 1.



Inventor
Bernhard Bischof
By Dodge and Jones
Attorneys

Sept. 19, 1939. B. BISCHOF 2,173,814

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Fig. 2.

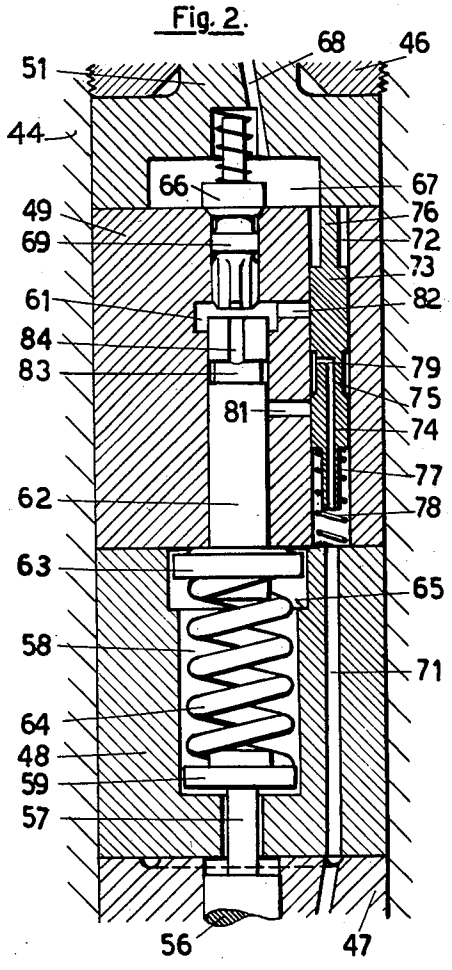
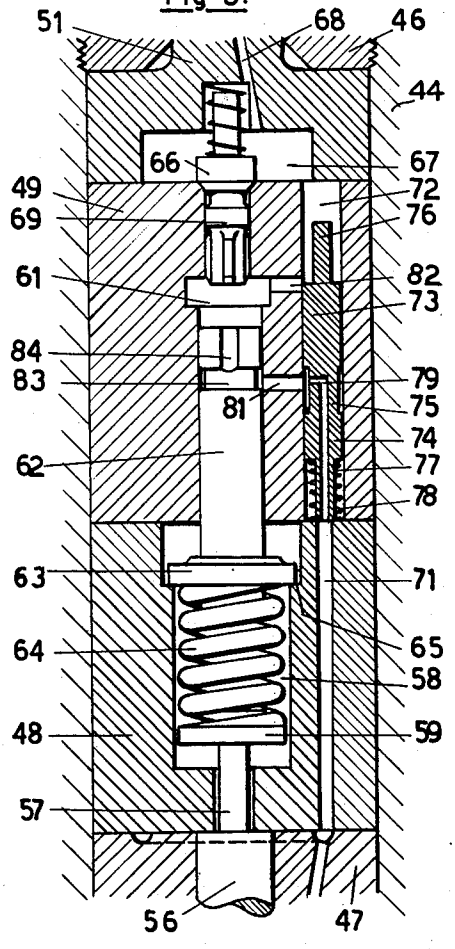


Fig. 3.



Inventor
Bernhard Bischof

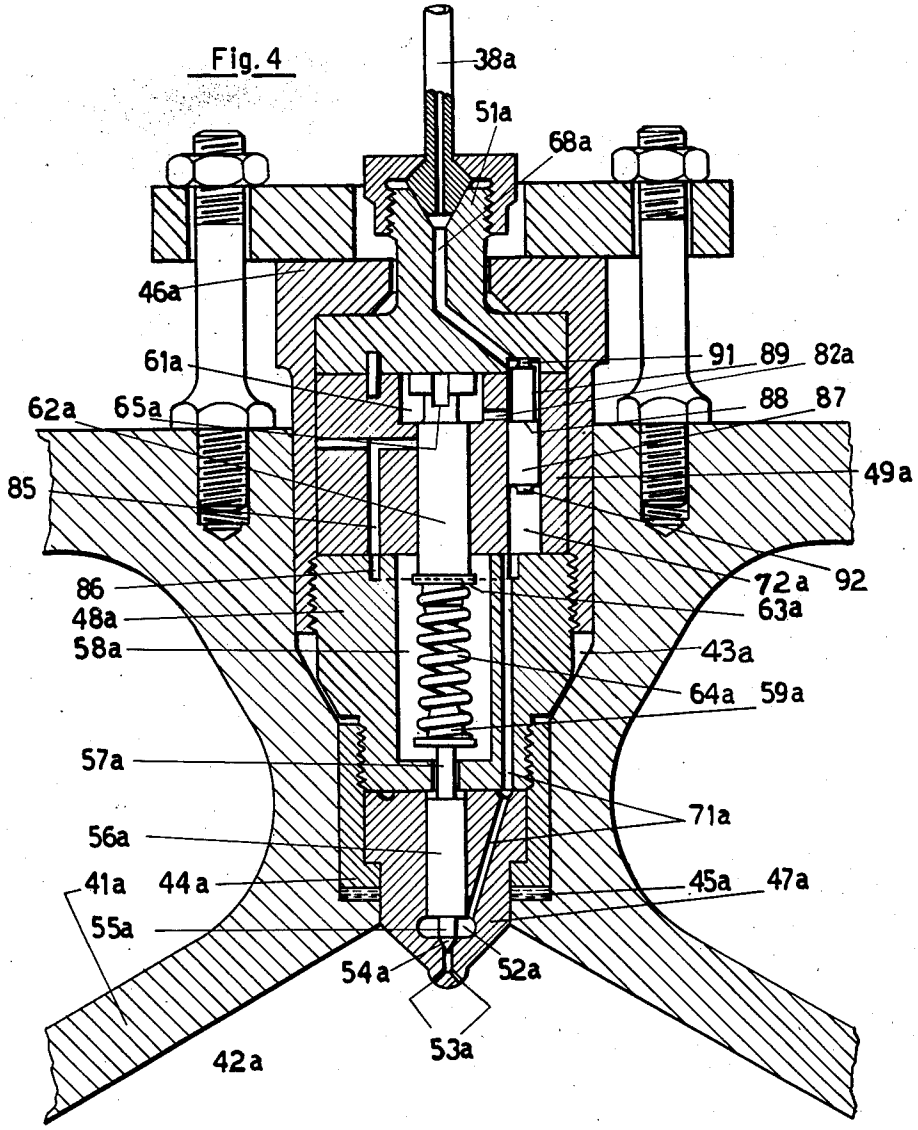
By Dodge and Sons
Attorneys

Sept. 19, 1939. B. BISCHOF 2,173,814

FUEL INJECTION APPARATUS FOR INTERNAL COMBUSTION ENGINES

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Fig. 4



Inventor
Bernhard Bischof

By Dodge Albs Jim.
Attorneys

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FUEL INJECTION APPARATUS FOR INTERNAL COMBUSTION ENGINES

Bernhard Bischof, Winterthur, Switzerland

Application May 10, 1939, Serial No. 272,916
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12 Claims. (Cl. 123—139)

This invention relates to fuel injection devices for internal combustion engines and particularly for Diesel engines.

The invention provides for preliminary injection of a small quantity of fuel, followed after a short interval by the main injection. This two-stage injection is effected by the use of a novel fuel injection valve in conjunction with a fuel feeding pump of the known spill-back charge measuring type, modified only in such a way as to ensure a definitely limited reflux of fuel at the end of its delivery period.

The fuel injection valve is of the type in which a needle valve loaded in a closing direction is forced open by the delivery to its inlet side of fluid under pressure sufficient to overcome the loading. The delivery connection of the pump is normally not connected directly to the injection valve, but leads to a cylinder in which a preliminary injection piston has limited motion. The space beyond this piston is in communication with the injection valve and such space is charged with fuel at the end of each cycle, so that when the pump initially delivers fuel, the delivered fuel shifts the preliminary injection piston a definite amount. This piston forces fuel trapped beyond it into the injection valve, causing the valve to open and effect preliminary injection, fixed in amount, and then close.

The preliminary injection piston has certain valve functions and when displaced as just described, admits fuel under pressure against a loading piston. The resulting shift of the loading piston increases the loading of the injection valve assuring that it is held closed after its opening and closing to effect preliminary injection.

The loading piston is also a valve, and its loading shift completes a connection partially established by the preceding shift of the preliminary injection piston. The connection so completed is from the delivery connection of the pump directly to the fuel injection valve, so that when the pump develops pressure sufficient to overcome the augmented loading of the injection valve, this valve opens and the principal injection occurs.

When the pump ends delivery and a slight reflux of fuel occurs, the injection valve closes sharply, the preliminary injection and loading pistons are restored, and during their restoration deliver fuel to charge the space between the preliminary injection piston and the injection valve, thus conditioning the parts for the next cycle.

The above general statement of the principle of operation is made to facilitate understanding of the following detailed description of two practical embodiments of the invention, shown in the accompanying drawings.

In the drawings:

Figure 1 is a view partly diagrammatic, showing a measuring fuel pump connected to deliver fuel to a fuel injection valve which is mounted in the cylinder head of an internal combustion engine. The pump and injection valve are shown in axial section and in the positions assumed at the start of the injection cycle.

Figure 2 is an enlarged view of a portion of the injection mechanism in the position of Figure 1.

Figure 3 is a view similar to Figure 2, but showing the parts in the positions assumed during the main injection.

Figure 4 is a view of a modified injection valve with the parts in the positions characteristic of Figures 1 and 2.

Refer first to Figures 1–3 inclusive.

In Figure 1, the fuel pump is indicated generally at A and the fuel injection valve at B.

The shaft 6 is driven by the engine shaft and makes one turn for each combustion cycle of the engine. It carries a cam 7 which reacts against a cup-shaped cross head 8 guided in the housing 9.

Mounted on housing 9 is a cylinder 11 having a working space 12 in which a piston 13 works. The piston has a stem 14 in thrust relation with cross head 8 and is urged downward by the coil compression spring 15. Swiveled on the lower end of cylinder 11 is a pinion 16, which is splined at 17 to stem 14. A rack 18 meshes with pinion 16 and may be actuated manually or by automatic means such as a governor (not shown) to adjust the piston 13 angularly without restraining its reciprocation. Angular adjustment of the piston varies the effective working stroke of the pump piston by controlling a spill-back to the pump intake.

The pump intake port is shown at 19 and is exposed by the upper end of piston 13 when the latter is at its lowermost position (Figure 1). A groove 21 encircles the piston in position to register with port 19 when the piston is in its uppermost position. To this groove 21 a slot 22 leads from the end of the piston, the slot having one side of spiral form as indicated at 23. This side 23 forms a control edge to coact with port 19 and time the spill-back according to the angular position of the piston 13. A fuel supply indicated as a tank 24 delivers fuel under moderate head through tube 25 to port 19.

The mechanism so far described is simply a well known spill-back measuring pump.

The discharge fitting 26 retained by sleeve nut 27 houses a discharge valve of special form. The discharge port 28 leads from working space 12 and has a valve seat 29 at its upper end. A poppet valve 31 with fluted pilot 32 coacts with seat 29 toward which it is urged by coil compression spring 33. The lift of the valve is limited by stop 34 and is such that a piston-like flange 35 carried by pilot 32 and fitting freely in port 28 rises above seat 29 as the valve approaches fully open position.

The space 36 beyond valve 31 is connected through ports 37 with pump discharge tube 38 which leads to the body of the fuel injection valve.

When piston 13 starts its upward displacing stroke it first blanks port 19. Discharge through port 28 then commences, and since piston 35 on valve 31 displaces liquid ahead of it, displacement into tube 38 starts at once When control edge 23 overtravels port 19, displacement stops because port 19 is open and back flow can occur. A definite reflux from tube 38 to working space 12 occurs and is measured partly by the unavoidable "slip" through the valve as it closes and partly by the displacement of piston 35 after it enters port 28.

Thus the total quantity of fuel discharged (and the duration of discharge) are varied by the angular adjustment of the piston, but the amount of reflux in tube 38 is virtually fixed and uniform, and occurs after each delivery stroke. This reflux has functional significance with respect to the operation of the injection valve, now to be described.

In Figure 1 a portion of the cylinder head of an internal combustion engine appears at 41 and 42 is a portion of the working space into which fuel is to be injected. The head 41 has a bore 43 to receive the shell 44 of the injection valve, which shell seats on a shoulder 45 as shown. The means for retaining the shell against cylinder pressure are not shown but would be conventional.

For convenience in manufacture, the body mounted in shell 44 is made in four parts which abut on plane surfaces and are held in sealing engagement by the annular head 46 screwed into the end of shell 44. These four parts are the nozzle member 47 which projects into the working space 42, the loading spring housing 48, the cylinder member 49 and the inlet cap 51, to which last the tube 38 is connected.

Leading through the tip of nozzle member 47 from fuel chamber 52 to working space 42 are the injection ports 53. These are controlled and normally closed by injection valve 54 connected by a slender stem 55 to a larger plunger 56. The plunger is urged in a valve opening direction by fluid pressure in chamber 52, because its lower end is exposed to fluid in said chamber.

The plunger 56 makes a fluid tight sliding fit in an axial bore in member 47 and its upward motion and consequently the lift of valve 54 are limited by collision of the plunger with the lower face of member 48 (see Figure 3).

The member 48 has a smaller aligned bore through which a stem 57 carried by and smaller than plunger 56 passes, entering a large spring chamber 58 within which it carries a disc shaped spring seat 59.

Extending part way through member 49 and terminating in a chamber 61 is a cylinder bore which receives the loading piston 62 which makes a fluid tight sliding fit therein. The piston 62 should be as large as or larger than the plunger 56 against whose action it must load, by means of a hydrostatic pressure which at times is no higher than that acting on plunger 56.

Piston 62 carries at its lower end a disc like spring seat 63 between which and seat 59 a coil compression loading spring 64 is confined. The spring seat 63 also serves to limit downward motion of piston 62 by engaging stop shoulder 65 in chamber 58. In this way the augmented loading is positively limited.

A check valve 66 permits flow from chamber 61 to supply chamber 67 with which tube 38 is in free communication by way of passage 68. Valve 66 is spring loaded in a closing direction as shown, and carries a flange 69 which retards and does not inhibit flow past the valve. It offers a convenient way to limit flow through a valve of substantial size.

A fuel supply passage 71 leads through members 47 and 48 to chamber 52 around the injection valve. An eccentrically located cylinder 72 formed in member 49 is interposed between supply chamber 67 and passage 71, but direct communication by way of such cylinder is interrupted by the preliminary injection piston mounted in the cylinder 72 and comprising two piston heads 73, 74, connected by a reduced stem 75. Stand off lugs 76 and 77 project from the heads 73 and 74, respectively, and limit the upward and downward movements of the piston. A coil compression spring 78 urges the piston to its upper position (Figure 1). A port 79 connects the space around stem 75 with the space below head 74 and hence with passage 71.

When the preliminary injection piston approaches its lowermost position (see Figure 3) the space around stem 75 exposes port 81 which previously was blanked by piston head 74, and thus connects port 81 via port 79 with passage 71. Port 81 leads to the bore on which loading piston 62 works and at such time is blanked by piston 62.

When the preliminary injection piston reaches its lowermost position (Figure 3) its head 73 exposes port 82 which leads to chamber 61. This subjects the upper end of loading piston 62 to supply pressure delivered via tube 38, passage 68, chamber 67 and port 82, so the piston is forced down, augmenting the loading of valve 54 (Figure 3).

Piston 62 has a peripheral groove 83 connected by slot 84 with chamber 61. Before piston 62 reaches its lowermost position, and when it is in that position groove 83 registers with port 81 completing a connection from supply tube 38 (via 68, 67, 72, 82, 61, 84, 83, 81, 79) to passage 71 and hence to chamber 52.

Thus, after the injection valve 54 has opened and closed as the result of the pressure surge which is developed in chamber 52 by the descent of the piston 73, 74 and dissipated by the opening of the valve 54, the valve loading is augmented. Approximately upon the completion of such increase of loading, supply pressure is admitted directly to chamber 52. When pressure rises sufficiently to open the valve, the principal injection commences. It ends when control edge 23 exposes port 19 because the sharp but limited reflux which then occurs causes valve 54 to close sharply, inhibiting dribble.

This same reflux starts the loading piston 62 and the preliminary injection piston 73, 74 up-

ward, the latter closing port 82, so that the rise of piston 62 is delayed by the throttling effect of flange 69, which restricts flow past check valve 66. This action is useful in two respects: (1) it delays relief of the extra load, assuring maintained closure of the valve. (2) It assures supply of fuel from chamber 61 via 84, 83, 81, 79 to the space below head 74, until head 74 rises far enough to lap port 81. The effect is to convey a charge of fuel below head 74 preparatory to the next preliminary injection. Pressure on this charge is relieved by continued upward motion of piston 73, 74.

The timing of parts cannot be stated precisely without elaborate discussion of inertia effects, throttling effects, and resulting pressure differentials, all of which enter the problem, but the above discussion gives the general factors. Suffice it to say that the device when constructed as illustrated and described operates satisfactorily, and in the manner generally described.

The embodiment shown in Figure 4 is functionally similar but somewhat simpler to construct. Functionally similar parts are given the reference numerals used for similar parts in Figures 1–3, with the distinguishing letter "a". Parts which are of distinctive form or function are given new reference numbers.

The injection valve unit is mounted in a bore 43a in cylinder head 41a and seals against shoulder 45a. The nozzle member 47a, loading spring housing 48a, cylinder member 49a and inlet cap 51a are held together by two sleeves 44a and 46a, each threaded on housing 48a. The parts 52a to 64a are essentially the same as similarly numbered parts. The stop 65a for the loading piston takes the form of lugs in a reduced extension at the upper end of the piston. These lugs limit motion in both directions. There is no check valve such as parts 66, 69, and no chamber such as 67. Passage 68a, passage 71a, cylinder 72a and port 82a, all correspond with similarly numbered parts in Figures 1 to 3, passage 68a leading directly to the upper end of cylinder 72a.

The loading piston 62a is larger in diameter than plunger 56a and has no ports such as 83 and 84. When piston 62a is moved down to its loading position, it exposes to the interior of chamber 61a a port 85. Port 85 leads to an arcuate port 86 which curves around chamber 58a and communicates directly with passage 71a and hence with chamber 52a. Ports 85, 86 thus replace ports 81 and 79 of Figures 1–3 and perform the same ultimate functions.

The preliminary injection piston 87 in cylinder 72a performs the functions of the preliminary injection piston 73, 74, 75 of Figures 1 to 3 and also the functions of check valve 66, 69. Consequently it is of distinctive form.

The piston proper 87 makes a liquid tight sliding fit in cylinder 72a over that part of piston below shoulder 88. Above that shoulder there is a slight clearance 89 which is exaggerated in the drawings since it is too small to be visible if drawn to true dimension. The piston has standoff bosses 91, 92 on its ends to limit its upward and downward motion. The normal position of the piston is up but no return spring similar to spring 78 of Figures 1–3 is required.

When the piston is up, shoulder 88 is immediately below port 82a so that flow between passage 68a and port 82a is throttled by the small clearance at 89. This throttling diminishes as the piston 87 moves down and ends by the time the piston 87 reaches its lowermost position.

The injection mechanism of Figure 4 is to be used with a pump such as the pump A of Figure 1. Except for the provision for means to ensure a definite reflux, this pump is conventional. Any pump of similar delivery characteristics may be substituted in connection with any embodiment of the invention.

With the embodiment of Figure 4, when the pump starts to deliver fuel through pipe 38a, piston 87 makes it downward displacement stroke before much fuel can reach port 82a. Hence preliminary injection takes place substantially as described for Figures 1–3.

When port 82a is fully open, piston 62a moves down loading the injection valve and ensuring its closure. Motion of the piston connects passages 68a and 71a (via 82a, 85, 86) and the main injection starts when supply pressure is sufficient to overcome the loading.

When supply pressure drops and the limited reflux occurs, the piston 87 moves up, so that the throttling clearance at 89 delays the rise of the loading piston while the lowered pressure in chamber 52a causes sharp closure of valves 54a. As piston 62a rises fuel flows via passages 85, 86 to the space below piston 87 to form a charge for the next preliminary injection.

While it is preferred that piston 87 make a liquid tight fit in cylinder 72a below shoulder 88, it will operate with a leaky fit throughout its length, in which event the shoulder 88 would virtually disappear. The displacing action of the piston and its timing effect on port 82a will occur despite moderate leakage as will be obvious upon consideration of the cycle. Thus the effects of wear or initial loose fitting are not serious, a fact which contributes to sustained operative life and economy of manufacture.

What is claimed is:

1. In a fuel injection device, the combination of a fuel injection valve; yielding means biasing said valve in a closing direction; a movable abutment subject to the pressure of fuel delivered to the fuel injection valve and connected with the valve to open the same in response to rising fuel pressure; a fuel pump having a discharge connection, the pump being adapted to force fuel under pressure periodically through said connection and at the termination of each periodic discharge to cause a limited reflux; a preliminary injection piston interposed in a connection between said pump discharge and said injection valve; means limiting the range of reciprocation of said piston; a movable loading abutment for increasing the loading effect of said yielding means; valve means having an opening characteristic upon motion of said preliminary injection piston toward said injection valve and serving to control admission of fuel from said discharge connection to act on the loading abutment; valve means opened by the loading movement of the loading abutment to open a normally closed path from said discharge connection to said injection valve; and flow restricting means effective upon the occurrence of reflux to permit delay dissipation of pressure acting on said loading abutment.

2. The combination defined in claim 1 in which the loading abutment and preliminary injection piston are assembled with the injection valve in a self-sustaining unit.

3. In a fuel injection device, the combination of a fuel injection valve; yielding means biasing said valve in a closing direction; a movable abutment subject to the pressure of fuel delivered to

the fuel injection valve and connected with the valve to open the same in response to rising fuel pressure; a fuel pump having a discharge connection, the pump being adapted to force fuel under pressure periodically through said connection and at the termination of each periodic discharge to cause a limited reflux; a preliminary injection piston interposed in a connection between said pump discharge and said injection valve; means limiting the range of reciprocation of said piston; a movable loading abutment for increasing the loading effect of said yielding means; means for limiting the movement of said loading abutment; valve means having an opening characteristic upon motion of said preliminary injection piston toward said injection valve and serving to control admission of fuel from said discharge connection to act on the loading abutment; valve means opened by the loading movement of the loading abutment to open a normally closed path from said discharge connection to said injection valve; and flow restricting means effective upon the occurrence of reflux to permit delayed dissipation of pressure acting on said loading abutment.

4. In a fuel injection device, the combination of a fuel injection valve; yielding means biasing said valve in a closing direction; a movable abutment subject to the pressure of fuel delivered to the fuel injection valve and connected with the valve to open the same in response to rising fuel pressure; a fuel pump having a discharge connection, the pump being adapted to force fuel under pressure periodically through said connection and at the termination of each periodic discharge to cause a limited reflux; a preliminary injection piston interposed in a connection between said pump discharge and said injection valve; means limiting the range of reciprocation of said piston; a movable loading abutment of larger effective area than the first named movable abutment, for increasing the loading effect of said yielding means; valve means having an opening characteristic upon motion of said preliminary injection piston toward said injection valve and serving to control admission of fuel from said discharge connection to act on the loading abutment; valve means opened by the loading movement of the loading abutment to open a normally closed path from said discharge connection to said injection valve; and flow restricting means effective upon the occurrence of reflux to permit delayed dissipation of pressure acting on said loading abutment.

5. The combination defined in claim 1 in which the yielding biasing means is a spring interposed between the first named abutment and the loading abutment.

6. The combination defined in claim 3 in which the yielding biasing means is a spring interposed between the first named abutment and the loading abutment.

7. In a fuel injection device, the combination of a fuel injection valve; yielding means biasing said valve in a closing direction; a movable abutment subject to the pressure of fuel delivered to the fuel injection valve and connected with the valve to open the same in response to rising fuel pressure; a fuel pump having a discharge connection, the pump being adapted to force fuel under pressure periodically through said connection and at the termination of each periodic discharge to cause a limited reflux; a preliminary injection piston interposed in a connection between said pump discharge and said injection valve; means limiting the range of reciprocation of said piston; a movable loading abutment for increasing the loading effect of said yielding means; valve means having an opening characteristic upon motion of said preliminary injection piston toward said injection valve and serving to control admission of fuel from said discharge connection to act on the loading abutment; valve means opened by the loading movement of the loading abutment to open a normally closed path from said discharge connection to said injection valve; and a check valve controlling a restricted passage arranged to permit delayed reflux of fuel acting on said loading abutment to said discharge connection while inhibiting flow in the opposite direction.

8. In a fuel injection device, the combination of a fuel injection valve; yielding means biasing said valve in a closing direction; a movable abutment subject to the pressure of fuel delivered to the fuel injection valve and connected with the valve to open the same in response to rising fuel pressure; a fuel pump having a discharge connection, the pump being adapted to force fuel under pressure periodically through said connection and at the termination of each periodic discharge to cause a limited reflux; a preliminary injection piston interposed in a connection between said pump discharge and said injection valve; means limiting the range of reciprocation of said piston; a movable loading abutment for increasing the loading effect of said yielding means; valve means having an opening characteristic upon motion of said preliminary injection piston toward said injection valve and serving to control admission of fuel from said discharge connection to act on the loading abutment; valve means opened by the loading movement of the loading abutment to open a normally closed path from said discharge connection to said injection valve; and flow restricting means associated with said preliminary injection piston for permitting delayed dissipation of fluid pressure acting on said loading abutment, when the pump permits reflux.

9. The combination of a fuel injection valve having a fuel chamber, discharge from which is controlled by said valve; yielding means urging the injection valve in a closing direction; a plunger connected with the injection valve, subject to the pressure of fuel in said chamber and arranged to urge said injection valve in an opening direction; pressure operated loading means for increasing the stress on said yielding means; a fuel pump having a discharge connection, the pump being arranged to discharge fuel under pressure periodically through said connection and after each periodic discharge cause a limited reflux; a communication leading from said discharge connection to said fuel chamber; a floating piston substantially obstructing said communication but capable of limited shifting motion in response to pressure impulses, said floating piston being arranged to establish free communication between said discharge connection and said loading means when the floating piston is shifted toward said chamber and at least partially obstruct such communication at other times; and means rendered effective by the loading shift of said loading means to afford a by-pass from said discharge connection around said floating piston to said chamber.

10. The combination of a fuel injection valve having a fuel chamber, discharge from which is controlled by said valve; yielding means urging

the injection valve in a closing direction; a plunger connected with the injection valve, subject to the pressure of fuel in said chamber and arranged to urge said injection valve in an opening direction; pressure operated loading means for increasing the stress on said yielding means; a fuel pump having a discharge connection, the pump being arranged to discharge fuel under pressure periodically through said connection and after each periodic discharge cause a limited reflux; a communication leading from said discharge connection to said fuel chamber; a floating piston substantially obstructing said communication but capable of limited shifting motion in response to pressure impulses, said floating piston being arranged to establish free communication between said discharge connection and said loading means when the floating piston is shifted toward said chamber and at least partially obstruct such communication at other times; means rendered effective by the loading shift of said loading means to afford a by-pass from said discharge connection around said floating piston to said chamber; and restricted, one-way flow means for permitting delayed reflux of fuel from said loading means to said discharge connection.

11. The combination of a fuel injection valve having a fuel chamber, discharge from which is controlled by said valve; yielding means urging the injection valve in a closing direction; a plunger connected with the injection valve, subject to the pressure of fuel in said chamber and arranged to urge said injection valve in an opening direction; pressure operated loading means for increasing the stress on said yielding means; means for limiting the loading movement of said loading means; a fuel pump having a discharge connection, the pump being arranged to discharge fuel under pressure periodically through said connection and after each periodic discharge cause a limited reflux; a communication leading from said discharge connection to said fuel chamber; a floating piston substantially obstructing said communication but capable of limited shifting motion in response to pressure impulses, said floating piston being arranged to establish free communication between said discharge connection and said loading means when the floating piston is shifted toward said chamber and at least partially obstruct such communication at other times; and means rendered effective by the loading shift of said loading means to afford a by-pass from said discharge connection around said floating piston to said chamber.

12. In a fuel injection device, the combination of a fuel injection valve; yielding means biasing said valve in a closing direction; a movable abutment subject to the pressure of fuel delivered to the fuel injection valve and connected with the valve to open the same in response to rising fuel pressure; a fuel pump having a discharge connection, the pump being adapted to force fuel under pressure periodically through said connection and at the termination of each periodic discharge to cause a limited reflux; a movable abutment for increasing the stress on said yielding means; means operated by the motion of said abutment and serving to open in the load-increasing position of the abutment and close in other positions of the abutment a passage from said discharge connection to said injection valve; a preliminary injection piston interposed in and substantially obstructing a connection between said pump discharge connection and said injection valve, said piston being subject on one end to pressure of fuel at the pump discharge and on the other end to pressure of fuel at said injection valve and being arranged for limited reciprocatory motion in response to changes of pressure differential; and means rendered effective by the reciprocation of said preliminary injection piston to afford free communication from said pump discharge connection to said loading abutment when the piston is near the end of its travel toward said injection valve and to afford controlled reflux from said abutment toward said discharge connection when the piston reverses its motion in response to reflux through said discharge connection.

BERNHARD BISCHOF.