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J. DICKSON ET AL

2,740,667

COMPRESSION OPERATED FUEL INJECTOR PUMP

Filed April 4, 1952

2 Sheets-Sheet 1

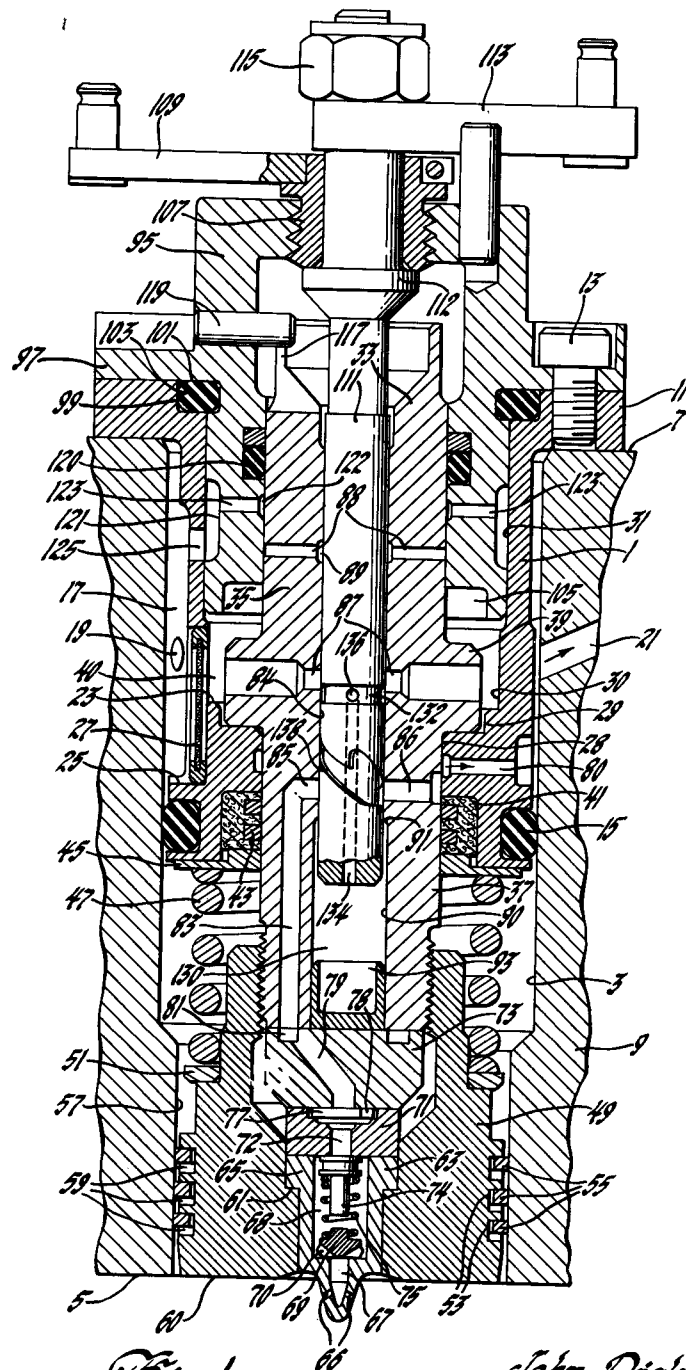


Fig. 1

Inventors
John Dickson &
Kenneth L. Hulsting
By
Willits, Helwig & Baillie
Attorneys

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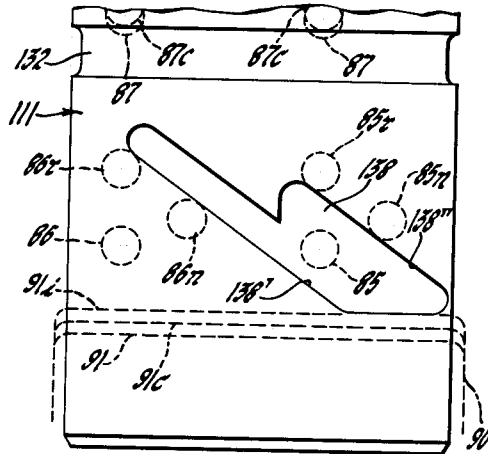


Fig. 2

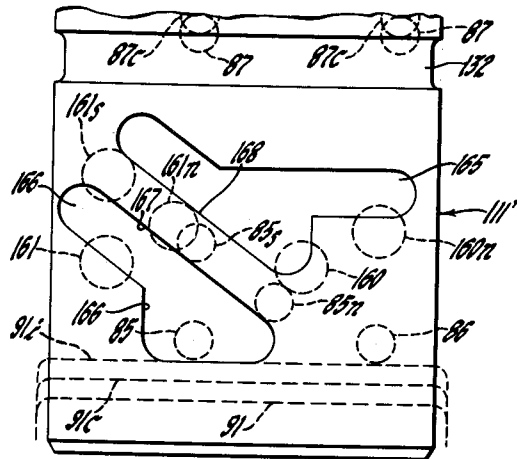


Fig. 3

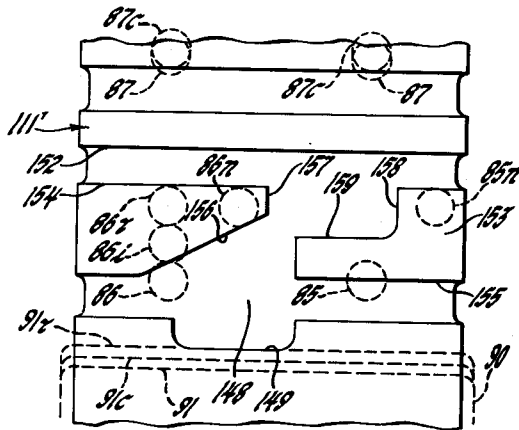


Fig. 4

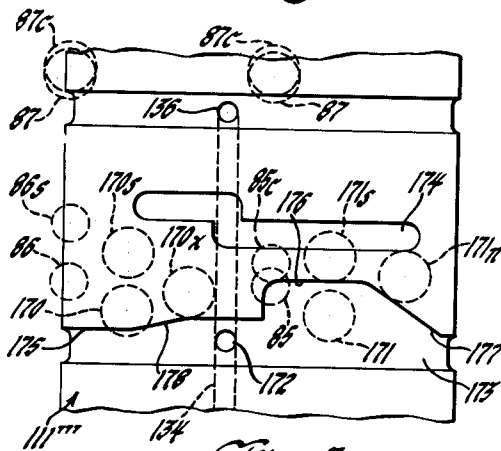


Fig. 5

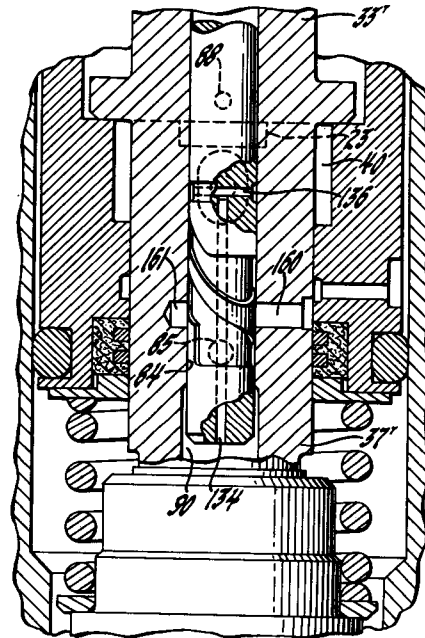


Fig. 6

Inventors
John Dickson &
Kenneth R. Hulsting
Willits, Helwig & Baillie
Attorneys

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COMPRESSION OPERATED FUEL INJECTOR PUMP

John Dickson, Huntington Woods, and Kenneth L. Hulsing, Plymouth, Mich., assignors to General Motors Corporation, Detroit, Mich., a corporation of Delaware

Application April 4, 1952, Serial No. 280,624

20 Claims. (Cl. 299—107.2)

This invention relates to fuel injector pumps for internal combustion engines, and particularly to such pumps as are automatically operable by the compression pressures developed in the engine.

One of the principal objects of the invention is to provide improvements in such compression operated fuel injector pumps wherein the movement of the reciprocating mass in response to said engine pressures may be adjustably retarded to vary the timing of the fuel injection. This is accomplished in accordance with the present invention by providing the compression pressure actuated stroke of the reciprocating mass with a period of "free" travel relative to a stationary plunger member, the amount of which free travel may be adjustably varied during pump operation by means for effecting longitudinal movement of the plunger member independently of the reciprocating mass.

A further object of the invention resides in an improved design of pumping cylinder comprising an open-ended sleeve or bushing into one end of which is pressed an inwardly presenting cup whose side walls tend to expand under pumping pressure and effect a seal with the walls of the bushing.

Another object of the invention relates to an improved seal assembly between relatively reciprocating surfaces of the pump, comprising a soft rubber ring held under axial compression and provided with a plurality of axially spaced apart resilient metal rings which are recessed in the sealing face of the rubber, the rubber between the rings serving to block communication between the ring gaps.

A still further object of the invention is to prevent excessive back pressure developing behind the pump piston as the result of blow-by from the engine combustion chamber. In accordance with this aspect of the invention the piston is provided with conventional piston type rings, the grooves for which have their outer side walls scalloped or notched.

Illustrative embodiments for carrying out these and other objects of the invention will now be described, having reference to the drawings wherein:

Figure 1 is a longitudinal cross section of a fuel injector pump constructed in accordance with the invention and shown inserted in an opening therefor in an engine cylinder head, portions of the latter being broken away.

Figure 2 is an enlarged diagrammatic developed view of the pump plunger of Figure 1, with the cooperating cylinder ports and control edges superimposed thereon in broken outline to show their relative positions during operation of the pump.

Figures 3, 4 and 5 are views similar to Figure 2 showing respective modifications of the invention.

Figure 6 is a fragmentary view similar to Figure 1 but taken in a plane at right angles thereto and showing features of the plunger and bushing corresponding to the modification of Figure 3.

As best illustrated in Figure 1, one form of this unit fuel injection pump comprises a hollow cylindrical pump

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body 1 insertable into a bore 3 extending from the inner face 5 to the outer face 7 of a cylinder head 9 of an internal combustion engine of a compression ignition type. The pump body 1 is provided at its outer end with an external mounting flange 11 secured by cap screws 13 to the outer face 7 of the cylinder head 9, and the inner face 5 of this cylinder head forms the outer wall of the combustion chamber for the internal combustion engine. An external groove is shown provided adjacent the inner end of the pump body 1 and a compressible packing ring 15 of soft rubber or equivalent material is placed in sealing engagement between the bottom and end walls of this groove and the wall of the cylinder head bore 3. The pump body 1 intermediate the mounting flange 11 and sealing ring 15 is of smaller outside diameter than the cylinder head bore 3 and forms an annular outer fuel receiving space 17. A fuel inlet passage 19 and a fuel return passage 21 provided in the cylinder head connect this space 17 to a transfer pump or other source of fuel under pressure, not shown. The cylindrical wall of the pump body 1 is provided with a combined fuel inlet and outlet port 23 having an enlargement 25 at its outer end in which a fuel filter 27 is press fitted or otherwise secured to exclude foreign particles from entering the pump body with the fuel. The pump body has an axial bore 28 terminating upwardly in successive counterbores 29, 30 and 31.

Guided for longitudinal reciprocation in the pump body is an open ended bushing 33 which forms a movable pump cylinder. This bushing is provided with upper and lower end portions 35 and 37 and an intermediate portion forming an external flange 39. The lower portion 35 of the bushing 33 has a close sliding fit in the body bore 28, and the flange 39 has a loose clearance fit in the body counterbore 29. Between the flange 39 and the body counterbore 30 is an annular inner fuel receiving space 40.

The lower end face of the pump body 1 is provided with a counterbore, and a compressible sealing ring 41 of synthetic rubber is pressed into this counterbore and has two inspringing metallic packing rings 43 imbedded in the internal surface of the ring 41 which snugly engage the cylindrical outer periphery of the portion 37 of the bushing 33 to prevent leakage of fluid at this point between the bushing and pump body 1. The ring 41 is preferably made of neoprene and is held in axial compression by a ring 45 which, in turn, is held in abutment with the lower end face of the pump body by a compression spring 47.

A hollow piston 49 is threaded on the lower end portion of the bushing 33 and the spring 47 is placed between the ring 45 and a washer 51 engaging an external shoulder on the piston. It will be evident that with this arrangement the spring 47 tends to hold the bushing flange 39 in contact with the bottom of the pump body counterbore 29. The piston is provided with external grooves 53 in which outspringing metallic packing rings 55 are placed to effect a seal against loss of engine compression pressure and escape of combustion gases between the piston and a reduced diameter portion 57 of the cylinder head bore 3. The lower walls of each of the piston grooves 53 are provided with circumferentially spaced upwardly open slots 59 extending the full depth of the grooves to prevent a build-up of air and gas pressure above the piston resulting from such leakage as occurs past the packing rings 55.

A small diameter axial bore is provided in the piston 49 adjacent the lower end or working face 60 of the piston and a larger diameter axial bore is located inwardly of the smaller bore to form a shoulder 61 on which an external flange 63 of a fuel spray nozzle 65 is seated. The tip of the spray nozzle 65 is shown projecting through the piston bore and the tip is provided with fuel spray

holes 66 opening into the lower end of a small diameter axial passage 67 in the nozzle. A larger diameter axial counterbore 68 is provided in the nozzle upwardly adjacent the small diameter axial passage 67 to form a shoulder on which a lower spring seat 69 is seated. The lower face of this seat 69 is provided with radial grooves 70 connecting the counterbore 69 with the axial passage 67. A hollow cylindrical valve seat 71 having an axial passage 72 is seated on the upper face of the spray nozzle, and a spacer 73 separates the adjacent end faces of the valve seat 71 and the bushing 33. A downwardly opening check valve 74 is urged upwardly against the seat 71 by a spring 75 compressed between this valve and the lower spring seat 69, and a counterbore is provided in the upper end face of the seat 71 in which a second downwardly opening check valve in the form of a disc 77 is arranged for limited axial travel. The disc 77 has a plurality of notches 78 in its outer periphery, through which fuel may enter the passage 72 in the valve seat 71, but which are closable against flow in the opposite direction by the lower end face of the spacer 73.

The spacer is provided with a fuel discharge passage 79 extending from the center of its lower face to an annular groove 81 in the upper face of the spacer 73, and a longitudinal "tip" passage 83 is provided in the wall of the bushing lower portion 37 for connecting the annular groove 81 to a radial "tip" port 85 provided in the bore 84 of the bushing. A fuel "relief" port 86 is provided in the wall of the bushing diametrically opposite the tip port 85 and registers during the full stroke of the pump with a duct 80 extending through the wall of the body 1 to the fuel space 17.

Above these "tip" and "relief" ports 85 and 86 are one or more "fill" ports 87 (two being shown) which extend through the flange 39 and connect the inner fuel receiving space 40 with the bore 84 of the bushing. Leakage return ports 88 are also shown which extend outwardly through the wall of the upper bushing portion 35 from an internal groove 89 formed in the bore 84. As a predetermined distance below the "tip" and "relief" ports 85 and 86 the bushing bore 84 terminates in a counterbore 90, the juncture between the end wall of the latter and the bore 84 forming a fuel control edge 91. The lower end of this counterbore 90 is closed by an upright cup 93 having a press fit therein and having its bottom end resting on the spacer 73 so that the walls of the cup are expanded into tight sealing relation with the walls of the counterbore when fuel pressure is built up within the bushing above the cup.

A hollow cylindrical cap 95 is inserted into the pump body 1 over the upper end of the bushing 33 and is provided with an external mounting flange 97 secured by cap screws to the pump body mounting flange 11. The outer end 101 of the pump body bore is enlarged at 99 and a cooperating external groove is provided in the cap member 95 to receive a compressible synthetic rubber sealing ring 103 which serves to prevent fuel leakage between the pump body 1 and cap member 95. The inner end of the cap member 95 is counterbored as shown at 105 opposite the pump body counterbore 29 to loosely receive the bushing flange 39. As these counterbores 29 and 105 are at all times supplied with fuel from the receiving space 40, they function as hydraulic stops limiting upward and downward travel of the piston 49 and bushing 33 during pump operation.

Extending into the pump and having a close fit in the bore 84 of the bushing 33 is a cylindrical plunger 111. Camming means for thrustably supporting and adjusting the plunger longitudinally of its axis is provided in the end wall of the cap 95 by a central threaded aperture in which is fitted an externally threaded sleeve 107 having an arm 109 fixed to its upper end whereby the sleeve may be rotated to adjustably raise and lower the plunger relative to the cap. The upper portion of this plunger is journaled by the sleeve 107 whose lower end is in abut-

ment with an external flange 112 on the plunger. A plunger rotating lever 113 is suitably fixed to the plunger above the sleeve, and a nut 115 threaded onto the upper end of the plunger serves to retain the lever 113, arm 109 and sleeve 107 in stacked abutting relation against the flange 112.

In order to prevent rotation of the bushing 33 upon rotation of the plunger 111 an axial slot 117 is provided in the upper end of the bushing portion 35 and a pin 119 is secured in the cap 95 and extends into the slot 117. The bore of the cap 95 is provided with an internal groove in which a compressible synthetic rubber packing ring 120 is placed to seal against the upper bushing portion 35 and prevent fuel leakage into the upper end of the cap. An external fuel leakage receiving groove 121 is provided on the inner end of the cap, and radial ports 123 lead to this external groove 121 from an internal groove 122 which is provided in the bore of the cap just below the packing ring 120. The leakage ports 89 in the bushing 33 register with the internal groove 122 in the cap when the piston 49 moves the bushing 33 into the pump body 1 to the end of the fuel discharge or injection stroke against the force of the plunger return spring 47. A radial port 125 provided in the wall of the pump body 1 connects the groove 121 with the outer fuel receiving space 17. With this arrangement any upward leakage of fuel between the plunger 111 and the bushing bore 84 above the "fill" ports 87 is collected by the groove 89 and passes out through the ports 89 in the bushing, leakage ports 123 in the cap and port 125 in the body to the fuel space 17.

The space 130 between the lower end of the plunger 111 and the cup 93 within the counterbore 90 constitutes a fuel pressure chamber. When the piston 49 and bushing 33 are at the lower end of their reciprocatory stroke, as in Figure 1, fuel from the fill ports 87 flows into this pressure chamber 130 by way of an annular groove 132 provided on the periphery of the plunger 111, which groove is connected with a downwardly extending axial plunger passage 134 by a transverse passage 136. As the piston and bushing are driven upwardly in the body 1 relative to the plunger 111, as the result of engine compression and combustion pressures acting on the lower face 60 of the piston, the fill ports 87 are closed off by the upper edge of the groove 132 and the pressure of the fuel trapped below the plunger in the chamber 130 commences to build up. A metering groove or recess 138 is provided on the periphery of the plunger below the groove 132 to control the amount of this fuel pressure build-up and the escape of the fuel from the chamber 130 into either the tip port 85 or the relief port 86. Since the recess 138 is not open to the axial passage 134, the only means by which fuel may enter either of the ports 85, 86 from the space 130 is by the recess 138 providing communication between these ports and the counterbore 90. This does not occur until the control edge 91 moves above the lower extremity of the recess 138 and one of the ports 85, 86 moves into partial registry overlapping relation with the recess 138.

The structural relation of the recess 138 and annular groove 132 of the plunger to the fill ports 87, tip port 85, relief port 86 and counterbore control edge 91 is best seen in Figure 2 which shows a 360° development of the plunger 111 with the various bushing ports and control edge superimposed thereon in broken outline. In Figure 2, the tip, relief and fill ports are in the positions indicated by the reference characters 85, 86 and 87 respectively, corresponding to the "full load" or "full fuel" angular setting of the plunger (as controlled by lever 113 previously described). Also, the relative heights of these ports and the control edge 91 as indicated corresponds to that existing while the piston and bushing are at the lower end of their stroke and the plunger is in its intermediate longitudinal setting relative to the stationary cap and pump body (as controlled by

the regulating arm 109 previously described). With the fill ports 87 thus registering with the plunger groove 132, filling of this groove, internal passages 134 and 136 and the pressure chamber 130 can take place. With no change taking place in the position of the plunger, it will be seen that as the bushing moves upwardly fuel pressure in the pressure chamber will be vented through the fill ports 87 until these ports reach the positions indicated by reference characters 87c and the control edge 91 reaches the level 91c. Upon completion of this initial upward movement of the bushing further venting of the pressure chamber ceases, and continued upward movement of the bushing results in fuel being trapped and compressed in the pressure chamber. As the bushing continues its upward movement to the level corresponding to the control edge position indicated by the reference numeral 91i further compression of fuel in the pressure chamber ceases and injection begins by transfer of fuel from the pressure chamber via the recess 138 to the tip port from which the fuel is conducted to the injector nozzle. Injection continues with further upward movement of the bushing until the tip port reaches the position indicated by reference character 85i which occurs simultaneously with the diametrically opposite relief port reaching the position 86i. Further upward movement of the bushing results in escape of fuel from the pressure chamber through the relief port, and eventual stopping of the piston and plunger is effected by the hydraulic stop action of the bushing flange entering the counterbore 105 as previously described by reference to Figure 1.

In the "no load" or "no fuel" position of the plunger (effected by rotating the plunger to the left as viewed in Figure 2), no compression of fuel takes place during the upward stroke by reason of the relief port coming into registry with the recess 138 simultaneously with closing of the fill ports 87. This is shown in Figure 2, wherein for convenience of illustration, the bushing is assumed to rotate to the right relative to the plunger in effecting the change from no fuel to full fuel positions. Accordingly, it will be seen that when the control edge has reached the level 91i the relief port will have simultaneously reached the position indicated at 86n, the tip port having at the same time reached the position indicated at 85n. In order that the start and end of injection, as determined by the closing off of the tip port and opening of the relief port respectively, may be varied between these limits of "no fuel" and "full fuel," the edges 138' and 138'' are helically inclined to the plunger axis. Further, with these edges 138' and 138'' being parallel, as shown, the ending of fuel injection occurs simultaneously with the relief of pressure in the pressure chamber throughout the angular adjustment range of the plunger between full load and no load.

By adjustment of the plunger longitudinally of its axis, a longer or shorter "fill" period is effected, with the result that the bushing and piston travel a greater distance before the start of pressure build-up in the pressure chamber and before injection commences. This variation in timing of the injection period may of course be accomplished without effecting any change in the total length of the fuel injection period, or any change in the degree of compression of the fuel prior to start of injection. The advantage gained is in enabling a proportioning of the inertia of the reciprocating mass to the length of its initial travel during "fill," thereby effecting both a further means of controlling the injection pressure and the timing of the injection over the speed range of the engine. For this purpose, the control arm 109 (Figure 1) may be arranged for either manual adjustment or automatic adjustment by the engine governor in accordance with changes in speed.

Figure 4 shows a modified form of plunger 111' in which the recess 148 is arranged to provide compression of the fuel in the pressure chamber in similar manner to that of Figure 2 except that the compression is sub-

sequently relieved prior to start of injection, and hence is utilized only to control injection timing through control of speed of travel of the piston and does not utilize this fuel compression at the start of injection. As shown in Figure 4 the recess 148 has a lower extremity or edge 149 which extends circumferentially of the plunger and cooperates with the bushing control edge 91 to control ending of fuel compression in the pressure chamber. The upper edge 152 of the recess is also circumferential and between it and the lower circumferential edge 149 is a land 153 having an upper circumferential edge 154 and a lower circumferential edge 155. The circumferential continuity of the land 153 is interrupted by a helical edge 156 which extends upwardly from the edge 155 to a short vertical edge 157, and circumferentially opposite the vertical edge 157 the upper edge 154 is relieved by a right angle notch formed by a vertical edge 158 and a circumferential edge 159.

The tip port 85, the relief port 86 and the control edge 91 of the bushing, as in the previous modification of Figure 2, are shown in their full fuel positions, as are also the fill ports 87, with the bushing at the lower end of its stroke and the plunger in its intermediate longitudinal position relative to the body and cap. During upward travel of the bushing the control edge first reaches the level indicated by the reference character 91c simultaneously with the fill ports reaching their positions indicated at 87c. As the pressure chamber at this point is still not in communication with the recess 148, further upward travel of the bushing results in compression of the fuel in the pressure chamber, which continues until the control edge reaches the level 91i coincident with the lower edge 149. This occurs simultaneously with the tip port being closed by the circumferential edge 155 of the land 153, preventing any delivery of fuel to the nozzle. At this point the relief port has not yet been covered by the helical edge 156, and during further upward travel of the piston and bushing the fuel pressure in the pressure chamber is relieved by the relief port. This action continues until the relief port reaches the position indicated at 86i at which point the tip port is partially uncovered by the edge 159 and injection thence commences and continues with further upward movement until the relief port reaches the position 86i at which it again becomes open to the recess 148 and injection ceases.

At the "no load" angular setting of the plunger, the tip port and relief port are in the positions indicated at 85n and 86n, respectively, when the bushing has travelled upwardly sufficiently far for the helical edge 156 to effect closing of the relief port. As this also results in the circumferential edge 154 reopening the relief port simultaneously with the opening of the tip port, no injection can take place.

Intermediate these no load and full load angular settings of the plunger the helical edge 156 provides a variable start of injection, while the circumferential edge 154 effects a constant ending of injection. As in the case of the Figure 2 modification, longitudinal adjustment of the plunger provides more or less initial or "fill" travel of the bushing and piston, and thus the timing of the injection is controlled by shifting the fuel compression portion of the stroke toward the lower or upper end of the total stroke, with a resultant effect on the speed and inertia of the reciprocating parts. An advantage of this modification over that of Figure 2 lies in the fact that by relieving the pressure built up in the pressure chamber during fuel compression prior to the start of injection, less opportunity exists for leakage of high pressure fuel into the tip port such as might otherwise cause pre-injection in advance of the desired start of injection.

The plunger 111'' illustrated in Figure 3 is utilized in conjunction with a somewhat different form of bushing from that of bushing 33 previously described. Reference

is therefore first made to Figure 6 which shows the modified bushing 33' (the view being taken at right angles to the section of the assembly shown in Figure 1) having a second "relief" port 160 extending transversely through one wall of the bushing lower portion 37' to the bore 84 at a height slightly above the tip port 85 and its diametrically opposite relief port 86 (not shown). Diametrically opposite the inner end of the "relief" port 160 is a blind extension 161 thereof which serves as a "transfer port" in a manner to be hereinafter described. The bushing incorporates the counterbore 90 the same as in the case of the previously described bushing 33.

Referring now to Figure 3 the plunger 111' will be seen to have upper and lower recesses 165 and 166 respectively which are separate and distinct from each other. As in the case of Figures 2 and 4 previously described, the various ports in the bushing as well as the control edge 91 are indicated in their relative positions on the plunger development corresponding to the positions they occupy with the piston and bushing at the lower end of their stroke, and with the plunger in its "full fuel" angular setting and intermediate longitudinal setting. From these relative positions, upon upward travel of the bushing, the control edge 91 reaches the level indicated at 91c simultaneously with the fill ports reaching their positions indicated at 87c, where they are closed by the upper edge of the filling groove 132. Upon continued upward travel of the piston and bushing, start of injection occurs when the control edge reaches the level 91i. The end of injection occurs when the tip port reaches the position indicated at 85s at which point the helical upper edge 167 of the lower recess 166 closes off the tip port. In the meantime, the transfer port 161 will have moved to the position 161s (tangent with the helical lower edge 168 of the upper recess 165). The upper recess 165 having, up to this point, been out of communication with the lower recess 166, all the fuel displaced from the pressure chamber following the closure of the fill ports has been discharged through the tip port. Since, as will be seen from Figure 3, the transfer port in the position 161s overlaps somewhat the helical upper edge 167 of the lower recess 166 at the end of fuel injection, further upward movement of the bushing initially results in the transfer port partially bridging both the recesses 165 and 166 during which fuel pressure in the lower recess 166 and the pressure chamber is relieved to the upper recess and relief port 160. Also, prior to the tip port being uncovered by the helical lower edge of the upper recess, the helical upper edge 167 of the lower recess will cut off further transfer of fuel to the upper recess, and re-trapping and re-compression of fuel in the pressure chamber will result to oppose further upward movement of the piston and bushing and delay the relief of pressure in the tip passage. This delay of tip pressure relief has been found to have a beneficial effect on engine fuel consumption by permitting the fuel pressure in the tip passage to effect its normal relief through the nozzle spray openings. The extent to which the relief of this tip pressure may be delayed in the manner described is of course variable by varying the diameter of the transfer port and the height and inclination of the upper recess lower edge 168.

At the "no fuel" angular setting of the plunger the tip port, transfer hole and relief port are in the positions indicated at 85n, 161n and 160n respectively when the bushing has travelled upwardly to bring the control edge to the level indicated at 91i, whereupon further upward movement of the bushing results in an initial transfer of fuel from the lower to the upper recess, followed by a re-trapping and recompression of fuel in the pressure chamber.

The bushing employed in the modification shown in Figure 5 is similar to that of Figure 3, differing essentially only in that the axis of the transfer port 161 and relief port 160 is below and at less than a right angle about

the longitudinal axis of the bushing to the axis of the tip port 85 and relief port 86. Also, the counterbore 90 does not have as great a depth as in the case of the bushings previously described and the upper end of this counterbore does not control the ending of fuel compression in the pressure chamber. Instead, the beginning and end of fuel compression in the compression chamber is controlled by the transfer port and the upper extremity of a lower recess in the plunger, which recess is in constant communication with the pressure chamber by way of a transverse passage in the plunger connecting with the longitudinal internal passage.

The Figure 5 modification provides for a primary injection preceding the trapping and compression of fuel in the pressure chamber which, in turn, is followed by a secondary injection. Both the primary and secondary injection periods have constant starting and variable ending times controllable by the angular setting of the plunger between "full fuel" and "no fuel." As shown in Figure 5, the plunger 111'' has its lower recess 173 in constant communication, as mentioned, with the pressure chamber via a transverse passage 172 and the longitudinal passage 134, and has a separate and distinct upper recess 174 by which the start and end of the secondary injection period is controlled. The tip, transfer and two relief ports are in their positions indicated at 85, 171, 86, and 170, respectively, when the bushing is at the bottom of its stroke and the plunger is in its intermediate longitudinal position and its angular position corresponding to "full fuel." Upon upward movement of the bushing the cylindrical edge 175 of the lower recess closes off the relief hole 170 prior to the closure of the tip port 85 by the circumferential upper edge 176 of the lower recess. Primary fuel injection thereupon begins and continues until the tip port reaches the position indicated at 85s. As this occurs prior to the transfer port uncovering the upper recess 174, further upward travel of the bushing results in the trapping and compression of fuel in the pressure chamber. It will be noted that at this point the tip hole in the position 85s is also in partial registry with the upper recess 174, and upon further upward travel of the bushing and uncovering of the upper recess by the transfer hole fuel will be transferred from the lower recess to the upper recess, resulting in simultaneous ending of fuel compression in the pressure chamber and starting of a secondary injection. The secondary injection period will continue until the transfer port moves out of registry with the lower recess to the position indicated at 171s. Since at this time the bleed holes are in the positions indicated at 86s and 170s, respectively, relief of the pressure in the tip passage is delayed, this relief eventually occurring after further upward travel of the bushing until the relief hole 170 uncovers the upper recess 174.

The lower recess circumferential edge 175 has an inclined ramp portion 178 which enables the start of primary injection to be varied by angular adjustment of the plunger about its axis.

When the plunger is rotated to cause the relief port 170 to assume the position 170x at the end of the fuel filling period, no primary injection can take place since the tip port will then have been closed by the circumferential upper edge 176 of the lower recess. Such an angular adjustment of the plunger from the full load fuel setting is less than that necessary to cut off all fuel injection and does not affect the timing or duration of the secondary fuel injection period. The circumferential edge 175 of the lower recess is connected to its circumferential upper edge 176 by a helical edge 177, and the ending of the secondary injection may be varied by angular adjustment of the plunger. Thus, initial angular adjustment of the plunger from its "full fuel" position shortens the duration of the primary fuel injection period, by delaying the start thereof, and a further angular adjustment of the plunger toward the "no fuel" position shortens the duration of the secondary injection period

by advancing the end thereof. This will be evident by noting that when the transfer port is in the position indicated at 171_n it has moved out of registry with the helical edge 177 prior to uncovering the lower edge of the upper recess 174.

We claim:

1. In a fuel injector pump having two members in telescopic interfitted relation forming a fuel compression space opposite one end of the inner of said members, means for reciprocating one of said members, stationary guide means for said reciprocating member, camming means thrustably supporting the other of said members on said stationary means, said camming means being movable relative to said other member and said stationary means to vary the start of fuel compression relative to the limits of the reciprocatory stroke of said reciprocating member, and a control member connected to said camming means for adjustable movement thereof during pump operation.

2. In a compression operated fuel injector pump, a reciprocably driven member forming a fuel compression cylinder, a stationary member slidably guiding said driven member, a plunger supported by said stationary member and extending into said cylinder, said plunger being longitudinally adjustable relative to said stationary member to vary the start of fuel compression relative to the length of stroke of said driven member and also axially rotatable relative to said driven member in any longitudinally adjusted position of said plunger to vary the effective length of stroke of said driven member, and means for effecting longitudinal adjustment of the plunger during pump operation including camming means thrustably interposed between the plunger and said stationary member and a control member connected to said camming means for adjustable movement thereof relative to the plunger and stationary member.

3. In an engine compression pressure operated fuel injector pump, a compression pressure driven piston, a member movable with said piston forming a fuel pumping cylinder and provided with a fuel delivery passage having an entrance port in the bore of said cylinder, a plunger axially rotatable in and slidably fitting the cylinder bore and having surfaces thereon controlling the opening and closing of said port during reciprocation of said member in accordance with both the relative angular and longitudinal positions of said plunger and member, stationary means reciprocably guiding said piston and member, and means for adjusting the longitudinal position of the plunger relative to said stationary means including a sleeve threadedly engaging said stationary means and a control member connected to said sleeve for adjustable movement thereof about its axis of threaded engagement with the stationary means, said plunger being journaled in said sleeve and having a flange and a nut in operative abutment with the opposite ends of the sleeve.

4. In an engine compression pressure operated fuel injector pump, a compression pressure actuated piston, a bushing extending longitudinally of and carried by the piston, said bushing having a bore closed at one end and forming a fuel pumping cylinder, removable closing means for said end including a spacer clamped between said end of the bushing and the piston and a cup having its bottom wall abutting said spacer and its side walls press fitted to the bore of the bushing.

5. In an engine compression pressure operated fuel injector pump, a compression pressure actuated piston having a bushing fixed to and extending longitudinally from one end thereof, said piston having an opening in its end opposite said bushing, a nozzle seated in said opening, a spacer interposed between said nozzle and the adjacent end of said bushing, an upright cup closely fitting the bore of said bushing and resting on said spacer, said bushing and spacer being provided with communicating fuel passages leading to said nozzle from the bore of said bushing above said cup, a stationary body having a bore

reciprocably guiding said bushing, and a plunger thrustably supported by said body and slidably fitting said bushing, said plunger having a recess in the side thereof controlling the opening and closing of said passage during reciprocation of the piston and bushing, said bushing bore, plunger and cup forming a closed chamber for trapping fuel in opposition to the compression pressure actuation of said piston just prior to the opening of said passage by the recess.

6. In an engine compression pressure operated fuel injector pump, stationary means forming a fuel receiving chamber, reciprocating means slidably guided by said stationary means and forming a fuel pressure chamber, spring means normally holding said reciprocating means at one end of its stroke, a plunger thrustably supported by said stationary means and extending into said pressure chamber, said reciprocating means having a bore slidably fitting said plunger and terminating in a control edge defining the upper end of said pressure chamber, a fuel nozzle, said bore having a tip port connected to said nozzle and relief and fill ports connected to said receiving chamber, said plunger having connecting transverse and longitudinal passages, said longitudinal passage being continuously open to said pressure chamber and said transverse passage being in registry with said fill port only during the initial portion of the movement of the reciprocating means towards the opposite end of its stroke, said plunger also having an external recess providing and controlling communication between said pressure chamber and said tip and relief ports respectively during successive portions of further movement of the reciprocating means toward the opposite end of its stroke, said recess having its lower extremity spaced below said tip and relief ports and above said control edge when said reciprocating means reaches the end of its said initial movement, whereby during the first portion of its said further movement the reciprocating means is opposed both by said spring means and compression of fuel in said pressure chamber by said plunger.

7. The invention defined in claim 6, wherein said recess has other spaced apart extremities located to effect registry between said tip port and said recess and to prevent registry between said relief port and said recess when said control edge reaches said recess lower extremity, whereby during the second portion of said further movement fuel is delivered from said pressure chamber to said nozzle via said recess and tip port.

8. The invention defined in claim 7, including plunger thrust supporting means adjustably movable longitudinally of the plunger axis relative to said stationary means for varying the extent of said initial movement of the reciprocating means.

9. The invention defined in claim 8, wherein said plunger is also angularly adjustable about its longitudinal axis relative to said thrust supporting means and said bore and at least one of said other recess extremities is inclined to the plunger axis, whereby the extent of said second portion of movement of the reciprocating means may be varied.

10. In an engine compression pressure operated fuel injector pump, stationary means forming a fuel receiving chamber, reciprocating means slidably guided by said stationary means and forming a fuel pressure chamber, spring means normally holding said reciprocating means at one end of its stroke, a plunger thrustably supported by said stationary means and extending into said pressure chamber, said reciprocating means having a bore slidably fitting said plunger and terminating in a control edge defining the upper end of said pressure chamber, a fuel nozzle, said bore having a tip port connected to said nozzle and relief and fill ports connected to said receiving chamber, said plunger having connecting transverse and longitudinal passages, said longitudinal passage being continuously open to said pressure chamber and said transverse passage being in registry with said fill port only during

the initial portion of the movement of the reciprocating means towards the opposite end of its stroke, said plunger also having an external recess providing and controlling communication between said pressure chamber and said tip and relief ports respectively during successive portions of further movement of the reciprocating means toward the opposite end of its stroke, said recess having its lower extremity spaced below said tip and relief ports and above said control edge when said reciprocating means reaches the end of its said initial movement, whereby during the first portion of its said further movement the reciprocating means is opposed both by said spring means and compression of fuel in said pressure chamber by said plunger, said recess having a land located intermediate its upper and lower extremities, said tip port being closed by said land and said relief port being in registry with the recess below said land when said control edge reaches said recess lower extremity, whereby during the second portion of said further movement fuel is returned from said pressure chamber to said receiving chamber via said recess and relief port, said land having upper and lower extremities successively effecting opening of said tip port, closing of the relief port and reopening of the relief port, whereby during the third and fourth portions of said movement fuel is delivered from said pressure chamber via the recess to first said tip port and then said relief port, respectively.

11. The invention defined in claim 10, including plunger thrust supporting means adjustably movable longitudinally of the plunger axis relative to said stationary means for varying the extent of said initial movement of the reciprocating means.

12. The invention defined in claim 11, wherein said plunger is also angularly adjustable about its longitudinal axis relative to said thrust supporting means and said bore and at least one of said land extremities is inclined to the plunger axis, whereby the duration of fuel delivery to said tip port may be varied.

13. In an engine compression pressure operated fuel injector pump, stationary means forming a fuel receiving chamber, reciprocating means slidably guided by said stationary means and forming a fuel pressure chamber, spring means normally holding said reciprocating means at one end of its stroke, a plunger thrustably supported by said stationary means and extending into said pressure chamber, said reciprocating means having a bore slidably fitting said plunger and terminating in a control edge defining the upper end of said pressure chamber, a fuel nozzle, said bore having a tip port connected to said nozzle, relief and fill ports connected to said receiving chamber and a blind transfer port, said plunger having connecting transverse and longitudinal passages, said longitudinal passage being continuously open to said pressure chamber and said transverse passage being in registry with said fill port only during the initial portion of the movement of said reciprocating means toward the opposite end of its stroke, said plunger also having upper and lower external recesses providing and controlling communication between said pressure chamber and said tip and relief ports respectively, further movement of the reciprocating means toward the opposite end of its stroke, said lower recess having its lower extremity spaced below said tip port and above said control edge and said transfer and relief ports respectively being out of registry with said upper and lower recesses when said reciprocating means reaches the end of its said initial movement, whereby during the first portion of its said further movement the reciprocating means is opposed both by said spring means and compression of fuel in said pressure chamber by said plunger, said lower and upper recesses having respective upper and lower extremities in spaced relation whereby during subsequent further upward movement of the reciprocating means injection fuel delivery from the pressure chamber to the delivery port is discontinued in advance of relieving the fuel pressure in the tip port.

14. The invention defined in claim 13, wherein said transfer port is arranged to temporarily bridge both said recesses and thereby relieve the fuel pressure in said pressure chamber intermediate the discontinuance of injection fuel delivery to and the relief of pressure in said tip port.

15. The invention defined in claim 14, including plunger thrust supporting means adjustably movable longitudinally of the plunger axis relative to said stationary means for varying the extent of said initial movement of the reciprocating means.

16. The invention defined in claim 15, wherein said plunger is angularly adjustable about its longitudinal axis relative to said thrust supporting means and said bore and said upper extremity of said lower recess is inclined to the plunger axis, whereby the duration of fuel delivery to said tip port may be varied.

17. In an engine compression pressure operated fuel injector pump, stationary means forming a fuel receiving chamber, reciprocating means slidably guided by said stationary means, spring means normally holding said reciprocating means at the lower end of its stroke, a plunger thrustably supported by said stationary means, said reciprocating means having a bore slidably receiving said plunger and forming a fuel pressure chamber thereunder, a fuel nozzle, said bore having a tip port connected to said nozzle, relief and fill ports connected to said receiving chamber, and a blind transfer port, said plunger having connecting transverse and longitudinal passages, said longitudinal passage being continuously open to said pressure chamber and said transverse passage being in communication with said fill port only while the reciprocating means is in the lower range of its stroke, said plunger also having upper and lower external recesses providing and controlling communication between said pressure chamber and said tip and relief ports respectively during further upward movement of the reciprocating means above said range, said plunger also having upper and lower external recesses formed in the periphery thereof below said transverse passage, said recesses and said tip, transfer and relief ports being arranged relative to each other that during upward movement of said reciprocating means above said range fuel is trapped in said compression chamber and then is released therefrom via said lower recess and transfer port to said tip port for injection through said nozzle, and following said injection said tip port remains out of communication with said relief port to delay relief of fuel injection pressure in said nozzle pending a further upward movement of said reciprocating means.

18. In an engine compression pressure operated fuel injector pump, stationary means forming a fuel receiving chamber, reciprocating means slidably guided by said stationary means, spring means normally holding said reciprocating means at the lower end of its stroke, a plunger thrustably supported by said stationary means, said reciprocating means having a bore slidably receiving said plunger and forming a fuel pressure chamber thereunder, a fuel nozzle, said bore having a tip port connected to said nozzle, relief and fill ports connected to said receiving chamber, and a blind transfer port, said plunger having connecting transverse and longitudinal passages, said longitudinal passage being continuously open to said pressure chamber and said transverse passage being in communication with said fill port only while the reciprocating means is in the lower range of its stroke, said plunger also having upper and lower external recesses providing and controlling communication between said pressure chamber and said tip and relief ports respectively during further upward movement of the reciprocating means above said range, said lower recess having a direct connecting passage to said longitudinal passage and being in and out of registry respectively with said tip and relief ports when said fill port moves out of registry with said transverse passage whereby a primary injection of fuel is effected during the initial portion of

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said upward movement of said reciprocating means above said lower range, said lower recess having its upper extremity and said upper recess having its lower extremity arranged to cause the tip port to move out of registry with said lower recess and into registry with said upper recess in advance of said transfer and relief ports registering with the upper recess during said upward movement of the reciprocating means, whereby following the period of said primary injection further upward movement of the reciprocating means is opposed both by said spring means and compression of fuel in said pressure chamber by said plunger, and said transfer port to thereafter move sequentially into registry with said upper recess and out of registry with said lower recess while said tip port continues in registry with the upper recess and in advance of said relief port registering with said upper recess, whereby the period of said fuel compression is followed first by a period of secondary fuel injection and then a period of re-compression of fuel in said pressure chamber.

19. In an engine compression pressure operated fuel injector pump, a compression pressure driven piston, means forming a cylinder bore for said piston, a stationary body insertable into said bore opposite said piston, said piston having a reduced diameter portion reciprocally guided in said body, spring means surrounding said portion and tending to urge said piston away from said body, said reduced diameter portion and said bore defining an annular chamber into which engine air and combustion gases escaping past said piston tend to

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create a back pressure opposing said piston, said piston having an external groove and an outspringing ring mounted in said groove for sealingly engaging said bore, said groove having its side wall outwardly of said bore provided with circumferentially spaced notches through which gases may escape from behind said ring to relieve said back pressure in said chamber.

20. In an engine compression pressure operated fuel injector pump, a compression pressure actuated piston, means forming a cylinder bore for said piston, a stationary body insertable into said bore opposite said piston, said piston having a reduced portion reciprocally guided in said body, a spring surrounding said portion and compressed between said body and said piston, said body having a counterbore facing said piston, a seat for said spring on said body closing the open end of said counterbore, and an annular ring of soft synthetic rubber compressed in said counterbore by said spring seat, said ring having a plurality of axially spaced internal grooves, and inspringing metal rings mounted in said grooves and sealingly embracing said reduced piston portion.

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