March 10, 1953 W. H. MASHINTER 2,630,762

FUEL INJECTOR

Original Filed May 29, 1944 2 SHEETS—SHEET 1

Fig. 1.

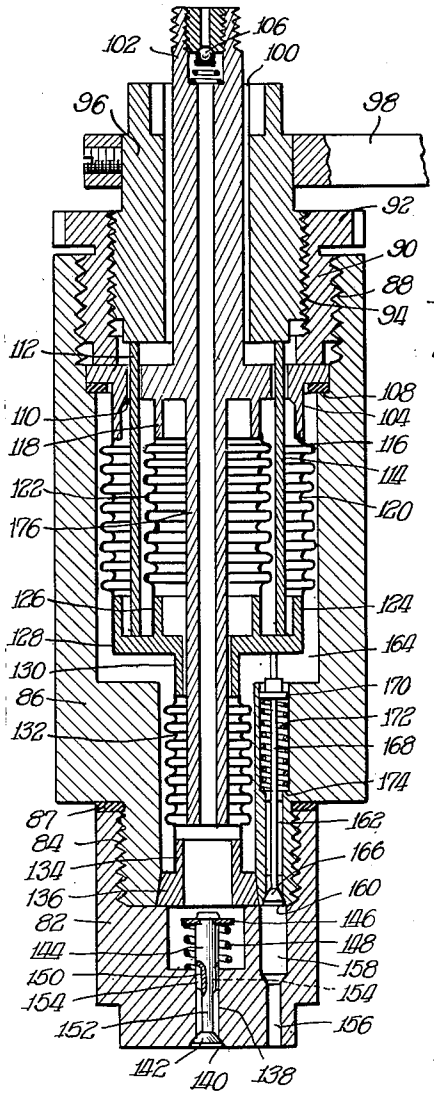
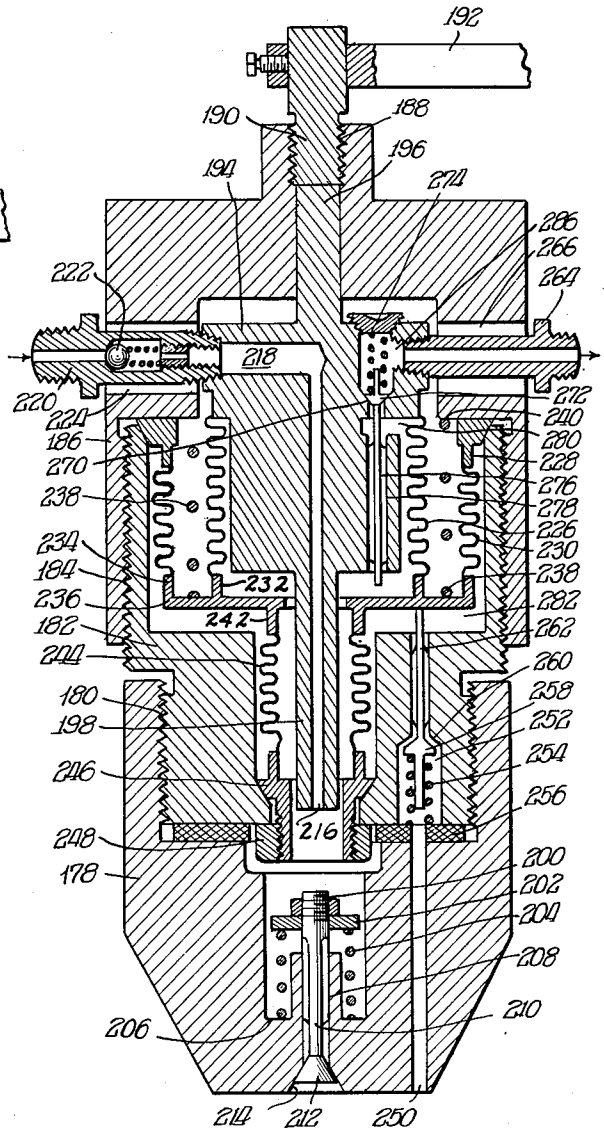


Fig. 2.



INVENTOR.

William H. Mashinter,

BY

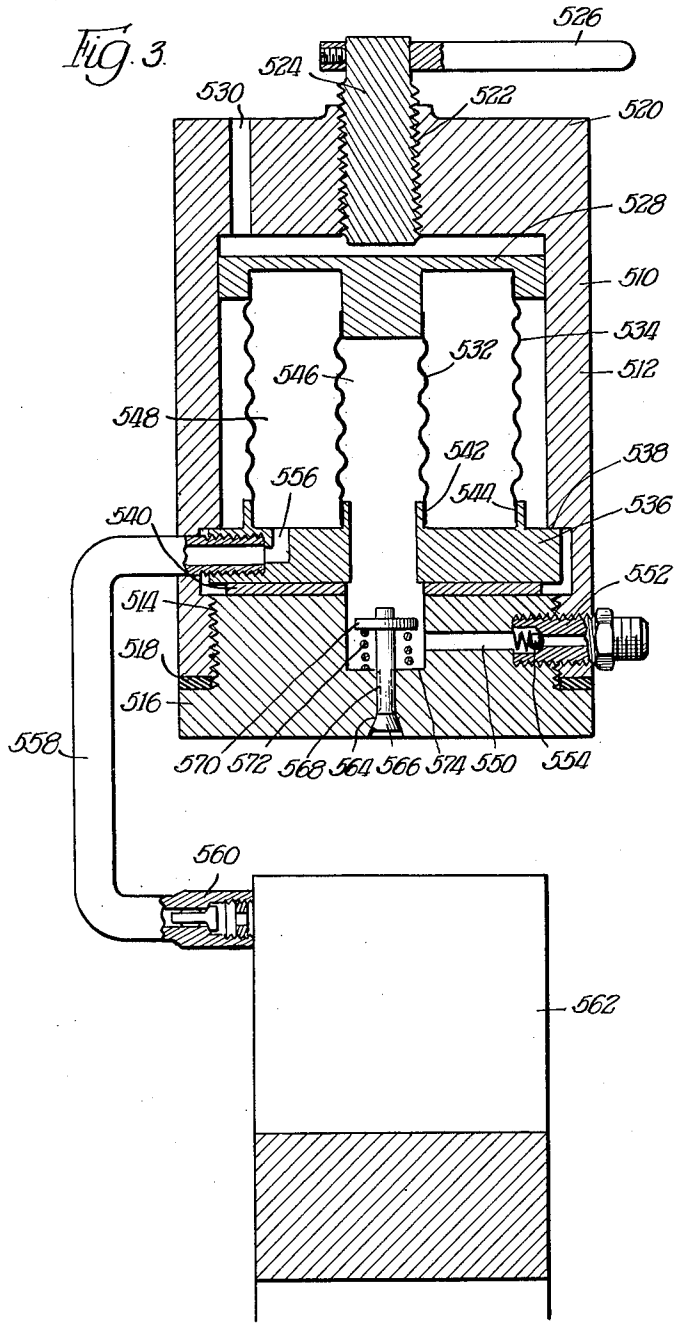
Mashinter, Hartley, Byron & Knight

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FUEL INJECTOR

Original Filed May 29, 1944 2 SHEETS--SHEET 2

Fig. 3.



INVENTOR.
William H. Mashinter,
BY
Dillmore, Humphrey, Pegram & Knight attys.

Patented Mar. 10, 1953

2,630,762

UNITED STATES PATENT OFFICE

2,630,762

FUEL INJECTOR

William H. Mashinter, Chicago, Ill., assignor of nineteen per cent to Margery D. McCormick and Alan G. McCormick, both of Chicago, Ill.

Original application May 29, 1944, Serial No. 537,793. Divided and this application November 2, 1945, Serial No. 626,221

6 Claims. (Cl. 103—152)

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This invention pertains to pump mechanism, injector mechanism or atomizing mechanism adapted to either supply solid liquid or spray comminuted fluid, or mixtures of fluid and solid.

Fuel injection pumps as heretofore designed commonly include a plunger working in a cylinder and intermittently actuated to deliver measured quantities of fuel to the engine. Because of the high fuel pressures ordinarily involved, a very close fit between plunger and cylinder is required for successful operation and a leak-proof fit is extremely difficult to obtain and impossible to maintain, particularly when using light fuels, such as gasoline, having little or no lubricating properties.

One object of the present invention is to provide a substantially leak-proof fuel injection pump.

Another object is to provide a fuel injection pump that is substantially immune to leakage producing wear.

Another object is to provide an improved bellows type of pump capable of withstanding high pressures over long periods of use.

Another object is to combine a bellows type of pump and a fuel injection nozzle into a unitary structure.

Another object is to provide a fuel injection nozzle having a self-contained bellows type of pump and a loaded discharge valve responsive to the pressure in the pump.

Another object is to provide a pump fed fuel injection nozzle having a self-cleaning discharge valve.

Another object is to provide a combined fuel pump and injection nozzle of improved, simple and inexpensive design.

Another object of the invention is to provide pump mechanism so constructed and arranged that it may be used to pump solid liquid.

Another object of the invention is to provide a pump for supplying fluid under pressure and in measured quantities to means for utilizing the supplied fluid, as where fuel is sprayed into the cylinder of an engine or where other liquid, such as water, is sprayed into such cylinder for power or antidetonating reasons.

Another object is to provide injecting means for supplying fuel to an internal combustion engine which may be used with manifold or separate cylinder injection and wherein the fuel is introduced in properly atomized condition over the entire range of operation of the engine, i. e., regardless of the operating speed of the engine.

Another object of the invention is to provide

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injecting means wherein the amount of fluid supplied therefrom is controlled by the pressure of the fluid delivered to the injecting means.

With these and various other objects in view, the invention may consist of certain novel features of construction and operation as will be more fully described and particularly pointed out in the specification, drawings and claims appended hereto.

In the drawings, which illustrate embodiments of the device and wherein like reference characters are used to designate like parts—

Figure 1 is a sectional view of a modified form of pump and nozzle adapted to be actuated by engine cylinder pressure of the cylinder to be supplied by the nozzle;

Figure 2 is a modified form of injector adapted to be actuated by pressure of the cylinder to be supplied by said injector; and,

Figure 3 is a sectional elevation of a modified form of injection system wherein the injector may be operated by the suction from the cylinder supplied by the fuel therefrom, or operated by an adjacent cylinder, or wherein the injector may supply fuel to an intake manifold;

This application is a division of application Serial No. 537,793, filed May 29, 1944, now Patent No. 2,530,128, November 14, 1950.

Referring first of all to the modification illustrated in Figure 1, a form of injector is illustrated which is adapted for cylinder injection wherein the compression pressure of the cylinder itself is utilized to operate the injector for supplying fuel to the cylinder, to which the injector is connected. The injector comprises the nozzle 82 having threaded engagement as at 84 to one end of the casing or housing 86, a seal 87 being interposed between the nozzle and casing to prevent leakage therebetween.

The opposite end of said housing has a threaded connection as at 88 to the end seal cap 90, said cap being conveniently formed with a suitably shaped head 92 for facilitating assembly. The cap 90 is internally threaded as at 94 for receiving complementary threads of the throttle screw 96, said screw being provided with means such as a lever 98 for rotating the screw to thereby move the screw linearly whereby the stroke of the injector is controlled.

The throttle screw is provided with the bore 100 through which the tubular upper extension 102 of the bellows top seal 104 extends. The tubular extension 102 is provided with the spring pressed check valve 106 opening toward the top seal 104 and the extension 102 is adapted

to be connected to a suitable source of fuel supply from which fuel may be supplied under pressure to the extension 102, or the device may operate as its own pump from the source of supply. The top seal 104 is secured between the cap 90 and the shoulder 108 provided on the casing 86 and suitable sealing means may be provided between the top seal and said shoulder.

The top seal is provided with spaced slots 110 through which upstanding fingers 112 of the aligning sleeve 114 extends, said fingers being adapted to abut against the throttle screw 96 for movement thereby. The top seal 104 is provided with the spaced concentric outer and inner rims 116 and 118 to which the upper ends of the bellows 120 and 122 are respectively connected in a leakproof manner, the lower ends of said bellows being similarly secured to the concentric outer and inner spaced rims 124 and 126 respectively of the intermediate seal 128. The seal 128 is provided with the oppositely extending rim 130 to which the upper end of the bellows 132 is connected in a leakproof manner, the lower end of said bellows being similarly connected to the upwardly extending rim 134 of the lower seal 136. The seal 136 is fixedly secured between the nozzle 82 and the casing 86.

The nozzle 82 is provided with the bore 138 terminating in the valve seat 140 on which the injection valve 142 is adapted to seat, the valve and seat being so constructed and arranged that the fuel passing through the bore past the valve will be sprayed. The valve 142 is provided with the stem 144 having a spring seat 146 thereon, a spring 148 being disposed between said seat and the nozzle for normally urging the valve 142 to closed position, the stem being cut out as at 150 for permitting passage of fuel past the stem. In cutting out the stem 144, it is preferable that the portion 152 of the stem is circular in section while the portions 154 of the cut-out are so arranged that they form lands or guiding means for the valve 142 to insure that said valve always seats properly.

The nozzle 82 is provided with the communicating bores 156 and 158 communicating with the valve seat 160 provided on the casing 86, the valve seat 160 communicating with the bore 162 extending upwardly and communicating with the chamber 164 formed between the casing 86 and the bellows 120. Valve 166 is provided with the valve stem 168 extending upwardly into the chamber 164 to be engaged by the seal 128, said stem being provided with the spring seat 170 on which the upper end of the spring 172 is seated, the lower end of the spring 172 being seated on the shoulder 174 provided in the casing 86 within the bore 162.

The top seal 104 is provided with the depending lower tubular extension 176 extending downwardly to a point adjacent the valve stem 144 whereby when fuel or other fluid is supplied, a cooling action will take place as the relatively cool, newly supplied fuel is introduced at a low point in the nozzle, that is, at the point subjected to the highest temperature.

In operation of this form of the device, assuming that the nozzle is applied to the cylinder of an internal combustion engine, and assuming that valve 142 is closed and the pressure within the bellows 132 and 122 is equal to supply pressure, the pressure within the chamber 164 is the same pressure as that in the engine cylinder, inasmuch as the valve 166 is open. The piston of the cylinder on its compression stroke will then cause a rise in pressure in the chamber 164 causing upward movement of the seal 128, compressing the bellows 120 and 122, which in turn elongates the bellows 132 supplying fuel to the valve 142 under pressure. When the pressure reaches a predetermined amount, valve 142 will be caused to open against the spring 148 permitting injection of the fuel into the cylinder.

Upward movement of the seal 128 will permit the spring 172 and compression pressure to urge the valve 166 towards closed position, and the spring 148 and compression pressure will urge valve 142 toward closed position, so that both valves 142 and 166 are closed during the firing of the fuel in the cylinder. Upward movement of the seal 128 is controlled by the position of the throttle screw 96, that is, the seal 128 will be caused to move upwardly by the engine compression until the fingers 112 of sleeve 114 engage the screw 96.

On the exhaust stroke the products of combustion will be removed from the cylinder with a consequent decrease in pressure. At a predetermined position of the piston, the pressure within the cylinder will be less than the pressure in the chamber 164 at which point the valve 166 will open with a consequent reduction in pressure in the chamber 164. This occurs at the time the seal 128 moves downwardly toward a position where the bellows are restored to their normal position and the valve 166 is open. In this position the injector is in position to repeat the cycle of operation.

In the construction illustrated in Figure 2, the injector comprises nozzle 178 connected as through threads 180 to the casing or housing 182. The casing is connected as through the threads 184 to the end head 186. The end head is provided with the threads 188 for reception of complementary threads of the throttle screw 190, said throttle screw 190 being provided with operating means such as the lever 192 whereby movement of the lever to rotate the screw 190 causes reciprocation of the screw. The screw is adapted to abut and control the movement of the inner bellows top seal 194 through the projection 196 provided on the seal 194.

The seal 194 is provided with the downwardly extending tubular member 198 extending toward the nozzle 178 and terminating adjacent the valve stem 200. The valve stem 200 is provided with the spring seat 202 forming the upper seat for one end of the spring 204, the lower end of the spring engaging the seat 206 provided in the nozzle. The valve stem is provided with the cut-out portion 208 terminating in the rounded portion 210 disposed adjacent the valve 212, the valve seating on the nozzle seat 214.

The bore 216 in projection 198 communicates with bore 218 to which the inlet fitting 220 is connected. The fitting 220 is provided with the spring loaded valve 222 adapted to seat toward the source of supply. The fitting extends through a suitable enlarged opening 224 in the head 186 and is movable with respect thereto. Thus fuel supplied through the fitting 220 and bores 218 and 216 is introduced to the injector at the hottest point thereof.

The upper end of the inner bellows 226 is secured to the seal 195 in a leakproof manner and a fixed outer seal 228 is secured between the head 186 and the upper end of the casing 182, and the upper end of the outer bellows 230 is secured to the seal 228 in a leakproof manner. The lower ends of the bellows 226 and 230 are respectively

secured to the concentric upwardly extending flanges 232 and 234 of the intermediate movable seal 236 in a leakproof manner. The seal 236 is urged downwardly by means of the spring 238, one end of the spring being seated on the seat 240 of the head 186 and the lower end of the spring being seated on the seal 236 between the bellows 226 and 230.

The seal 236 is provided with the oppositely extending flange 242 to which the upper end of the bellows 244 is secured in a leakproof manner, the lower end of said bellows being similarly secured to the bottom seal 246, secured to the casing by means of the lock nut 248.

The nozzle 178 is provided with the bore 250 communicating with the valve bore 252 provided in the casing 182, a spring 254 being interposed between the seal 256, disposed between the casing and the nozzle, and the valve 258 normally urging the valve to seated position in the seat 260. The valve 258 is provided with the upwardly extending stem 262 suitably guided and of a proper configuration to permit passage of fluid past the stem, the stem being adapted to be engaged by the seal 236 whereby movement downwardly by the seal opens the valve 258 and movement upwardly of the seal permits the spring 254 to move the valve toward closed position.

The seal 194 is provided with the outlet fitting 264 connected back to the source of supply, said fitting passing through the enlarged opening 266 provided in the end head, permitting relative movement between the fitting and the head. The fitting communicates with the bore 268, having the valve seat 270 adapted to be closed by the valve 272, the valve being urged toward closed position by means of the spring 274. The valve is provided with the valve stem 276 suitably guided as at 278 and said stem may likewise be suitably cut away for permitting passage of fluid therearound, the stem being adapted to be engaged by the seal 236 to move the valve 272 to open position. Adjacent the highest point of the bellows 226 an opening 280 is provided whereby should any air be trapped adjacent the top of the bellows, it will be exhausted by the valve 270.

In the operation of this form of the device, assuming that fuel has been supplied from the source of supply through fitting 220 and supply pressure is in the bellows 226 and 244 and assuming that the nozzle is applied for cylinder injection on the compression stroke, the valve 212 will be closed. Compression pressure will be supplied through bore 250, past valve 258 into chamber 282 formed between the bellows 230 and the casing 186. The pressure acting upon the movable seal 236 will cause upward movement thereof, permitting the valve 258 to move toward closed position.

Upward movement of the seal 236 will elongate the bellows 244 and will cause compression of bellows 226, causing fuel to be supplied under pressure to the valve 212 in the nozzle until a predetermined pressure causes opening of said valve 212 with the consequent injection of the fuel. The seal 236 moves upwardly until it engages the stem 276 and continued upward movement of the seal causes the valve 270 to open, thereby relieving the fuel pressure in bellows 244 and causing any air or vapor trapped between the bellows 226 and the seal 194 to be exhausted through fitting 264.

The amount of travel of the seal 236 necessary to open the valve 272 is controlled by the position of the throttle screw. After the predetermined amount of fuel has passed the valve 212, it will close. Valve 258 will remain closed, that is, the seal 236 will not have opened the valve during the power stroke and a portion of the exhaust stroke, at which time there will be a pressure drop in the cylinder and downward movement of the seal 236 will take place by action of the spring 238 and bellows, causing the seal to engage the valve stem 262 to move the valve 258 to open position. When open the pressure in the cylinder and in the chamber will equalize and the device will be in a position to repeat the cycle.

In the construction illustrated in Figure 3, the injector 510 consists essentially of the casing 512 secured as at 514 to the nozzle head 516, suitable sealing means 518 being provided therebetween. The upper head 520 of the casing is suitably threaded as at 522 for the reception of the throttle screw 524 provided with the throttle means 526. Rotation of the throttle means 526 causes linear movement of the screw 524, the end of which projects within the casing 512 limiting upward movement of the upper bellows end seal 528 which is preferably of hex shape whereby it is guided in its reciprocatory movement within the cylinder, the cylinder above the seal 528 being vented as at 530.

The seal 528 is fixedly secured in a leakproof manner to the upper end of the inner and outer bellows 532, 534. A lower seal 536 is secured between the nozzle 516 and the shoulder 538 provided in the casing, suitable sealing means 540 being interposed between the seal 536 and nozzle. The lower ends of bellows 532 and 534 are fixedly connected in a leakproof manner to the concentric flanges 542 and 544 provided on the lower seal 536, whereby a fuel chamber 546 and a vacuum chamber 548 is formed.

Chamber 546 communicates through bore 550 with the fitting 552 provided with the check valve 554 opening toward chamber 546, the fitting 552 being connected to a suitable source of fuel supply. Chamber 548 communicates through bore 556 with the pipe 558 which in turn is connected through the valve 560 to the engine cylinder 562, said cylinder being the cylinder supplied by fuel from the injector 510 and the cylinder operating said injector, it being understood, of course, that the injector may be supplied with fuel directly from the injector or through a manifold. The valve 560 opens toward the cylinder 562, and the nozzle 516 of the injector is provided with the valve seat 564 adapted to seat the valve 566, which is of similar configuration to the valve in Figure 1, the valve being provided with the cut away stem 568 and having the spring seat 570 thereon on which the upper end of the spring 572 is seated, the lower end of said spring being seated on the seat 574.

In operation of this form of the device, suction in cylinder 562 will be transmitted to the chamber 548 between the bellows causing the seal 528 to move downwardly compressing said bellows, causing fuel within the chamber 546 to open the valve 566 for supplying the measured fuel to the cylinder 562. After completion of the injection, valve 560 will close, due to the upward movement of the piston cylinder 562 permitting the bellows to return the seal 528 upwardly permitting spring 572 to close valve 566 and drawing fuel through fitting 552 into chamber 546.

Comparison of load-speed control of injectors of known type and those illustrated herein

In order to obtain the degree of control over the ratio of air and fuel (needed for optimum

economy and satisfactory performance) that is introduced into an engine cylinder, it is essential that the quantity of fuel per injection be maintained at a fixed ratio with respect to the quantity of air inducted per suction stroke of the engine cylinder.

In a naturally aspirated (not supercharged) internal combustion engine the quantity of air inducted per suction stroke of the engine decreases with increases in engine speed for each and every air throttle position according to the volumetric-efficiency curve (breathing rate) of the engine.

Thus it is evident that if a constant ratio of air and fuel is to be maintained at all times and under all conditions of speeds and loads (load-speed control), the "speed-delivery" characteristic of the injection system should conform to the same general form as the volumetric-efficiency curve of the engine.

In an engine operating on the Otto cycle (such as a gasoline spark-ignition engine) it is necessary to control the air-charge inducted by a throttle control over the air as well as the fuel introduced to the engine. Thus there is a family of volumetric-efficiency curves (one curve for each throttle position). In the diesel engine, as no air throttle is provided, there is only one volumetric-efficiency curve for the air charge inducted (full throttle).

All commercial forms of fuel injection pumps now in use utilize a plunger-barrel combination, as a pumping means. The type of injection pump in most extensive use at the present time, employs a port controlled by-pass, with an undercut section of the plunger as the slide valve means for controlling the porting of this by-pass port in order to control the quantity of fuel delivered by the pump.

The following formula expresses the leakage rate of the above type of plunger-barrel pumps.

$$\text{Leakage rate } \alpha \frac{cl^3dsP}{\mu L}$$

1. c is a constant.
2. l is the mean clearance between the barrel or casing and the plunger.
3. d is the pump plunger diameter.
4. s is the plunger velocity.
5. P is the pressure differential between the lapped portion between the plunger and the barrel.
6. μ is the viscosity of the liquid being pumped.
7. L is the length of the lapped fit.

Due to the leakage condition it is necessary in this piston type of pump to provide a cam profile with a rate of lift sufficient to overcome this leakage at slow speeds, especially cranking speeds as are encountered when cold-starting the engine. As a result, the speed-delivery characteristics of this type of pump tend to fall off at slow speeds (when the time for leakage is the greatest) and also at high speeds (when the pressure causing leakage is the greatest).

As a result of the above conditions the tendency at the higher throttle rack settings is to result in speed-delivery characteristics, which fall off much more rapidly with increasing engine speed than the volumetric efficiency of the engine does, and results in the failure to maintain the air to fuel ratio.

As the throttle rack position is decreased, (smaller amounts per injection), the "speed-delivery" characteristics continue to be altered until at the lower range of the throttle settings the curve has an exactly opposite slope. This condition is equally as undesirable as the former.

Thus it may be seen that as the quantity per injection at the higher throttle conditions falls off too rapidly due to leakage, there will be a speed at which delivery will fall below the quantities necessary, and result in a definite limit to engine speeds that can be obtained. This condition is especially bad when the high pressure pump and nozzle are separated by a delivery tube (due to adverse pressure wave characteristics).

In the modifications shown herein the effect of leakage is eliminated by the use of a hermetically sealed pumping element, and a unitary construction is employed in order to overcome the disadvantage of a pump-delivery-tube-nozzle combination. The absence of leakage makes possible the use without adverse effects of whatever cam shape is necessary in order that the "speed-delivery" characteristics of the injector will conform exactly to the volumetric-efficiency curve of the engine. Thus in the modifications herein, it is possible to obtain complete and automatic load-speed control.

The injectors shown herein may readily be operated as pusher or sump pumps located at the source of supply and supplying fuel to injectors or a carburetor, also they may be used to inject liquid, as water, into the cylinders (or manifold) for anti-detonating purposes.

It is to be understood that I do not wish to be limited by the exact embodiments of the device shown, which are merely by way of illustration and not limitation as various and other forms of the device will, of course, be apparent to those skilled in the art without departing from the spirit of the invention or the scope of the claims.

I claim:

1. In an injector, the combination of a housing having a pair of axially aligned chambers therein, one chamber being of larger diameter than the other, the smaller diameter chamber having a valve opening outwardly, resilient means urging said valve to closed position, a bellows secured at one end in said second chamber adjacent said valve, an intermediate seal movably disposed in said first chamber, the other end of said bellows being connected to said seal, a fixed seal spaced from said intermediate seal and fixed in said larger diameter chamber, an inner bellows fixed to said fixed and intermediate seals and communicating with said first bellows, an outer bellows fixed to said seals, an aligning sleeve between said bellows in said larger diameter chamber, means regulating the position of said sleeve to thereby regulate the relative movement of said bellows, fixed means for introducing fuel in said first and second bellows adjacent said valve, and a valve in said housing operated by said intermediate seal to permit exterior pressure to pulsate said outer bellows to thereby pulsate said other bellows causing fuel to be ejected from said first valve.

2. In an injector, the combination of a housing having a pair of axially aligned chambers therein, one chamber being of larger diameter than the other, the smaller diameter chamber having a valve opening outwardly, resilient means urging said valve to closed position, a bellows secured at one end in said second chamber adjacent said valve, an intermediate seal movably disposed in said first chamber, the other end of said bellows being connected to said seal, a fixed seal spaced from said intermediate seal and fixed

in said larger diameter chamber, a member movable in said larger diameter chamber having means extending into said bellows for introducing fuel therein adjacent said valve, an inner bellows connected to said last named member and said intermediate seal and communicating with said first bellows, an outer bellows connected to said intermediate and fixed seals, valve controlled outlet means in said last named member permitting fuel to return and exhausting fluid from said inner bellows from a high point therein, means for regulating the movement of said last named member, and a valve in said housing operated by said intermediate seal to permit exterior pressure to pulsate said outer bellows to thereby pulsate said other bellows causing fuel to be ejected from said first valve.

3. In an injector, the combination of a housing having a pair of axially aligned chambers therein, one chamber being of larger diameter than the other, the smaller diameter chamber having a valve opening outwardly, resilient means urging said valve to closed position, a bellows secured at one end in said second chamber adjacent said valve, an intermediate seal movably disposed in said first chamber, the other end of said bellows being connected to said seal, a fixed seal spaced from said intermediate seal and fixed in said larger diameter chamber, an inner bellows fixed to said fixed and intermediate seals and communicating with said first bellows, an outer bellows fixed to said seals, means regulating the relative movement of the bellows, fixed means for introducing fuel in said first and second bellows adjacent said valve, and a valve in said housing operated by said intermediate seal to permit exterior pressure to pulsate said outer bellows to thereby pulsate said other bellows causing fuel to be ejected from said first valve, and means for supplying fluid pressure for pulsating said bellows.

4. In an injector, the combination of a housing, a valve opening outwardly of said housing, a bellows having one end secured in said housing adjacent said valve, an intermediate seal secured to the other end of said bellows and movable in said housing to pulsate said bellows, inner and outer bellows each secured at one end to said seal and at the other end within said housing, a throttle member movable axially of said housing, means between said throttle member and seal whereby movement of said throttle member regulates movement of said seal to thereby regulate the pulsation of said bellows, means for introducing pulsating fluid to said intermediate seal and outwardly of said first named bellows and the outer of said second named bellows, said last named means including a valve biased toward closed position but adapted to be opened by said intermediate seal, and means for introducing fluid to be ejected past said valve in said first named bellows adjacent said valve.

5. In an injector, the combination of a housing having a pair of axially aligned chambers, one chamber being of larger diameter than the other, the smaller diameter chamber having an opening therein, a bellows secured at one end in said second chamber adjacent said opening, an intermediate seal movably disposed in said first chamber, the other end of said bellows being connected to said seal, a fixed seal spaced from said intermediate seal and fixed in said larger diameter chamber, an inner bellows fixed to said fixed and intermediate seals and communicating with said first bellows, an outer bellows fixed to said seals, an aligning sleeve between said bellows in said larger diameter chamber, means regulating the position of said sleeve to thereby regulate the relative movement of said bellows, fixed means for introducing fluid in said first and second bellows adjacent said opening, and a valve in said housing operated by said intermediate seal to permit pulsating pressure to pulsate said outer bellows to thereby pulsate said other bellows causing fluid to be ejected from said opening, and means for supplying fluid pressure for pulsating said bellows.

6. In an injector, the combination of a housing having an opening in one end, a bellows having one end secured in said housing adjacent said opening, an intermediate seal secured to the other end of said bellows and movable in said housing to pulsate said bellows, inner and outer bellows each secured at one end to said seal and at the other end within said housing, a throttle member movable axially of said housing, means between said throttle member and seal whereby movement of said throttle member regulates movement of said seal to thereby regulate the pulsation of said bellows, means for introducing pulsating fluid to said intermediate seal and outwardly of said first named bellows and the outer of said second named bellows, said last named means including a valve biased toward closed position but adapted to be opened by said intermediate seal, and means for introducing fluid to be ejected past said opening adjacent said valve.

WILLIAM H. MASHINTER.

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