Jan. 8, 1963 S. A. COLGATE 3,072,114

DIESEL FUEL INJECTOR

Filed March 21, 1960 2 Sheets-Sheet 1

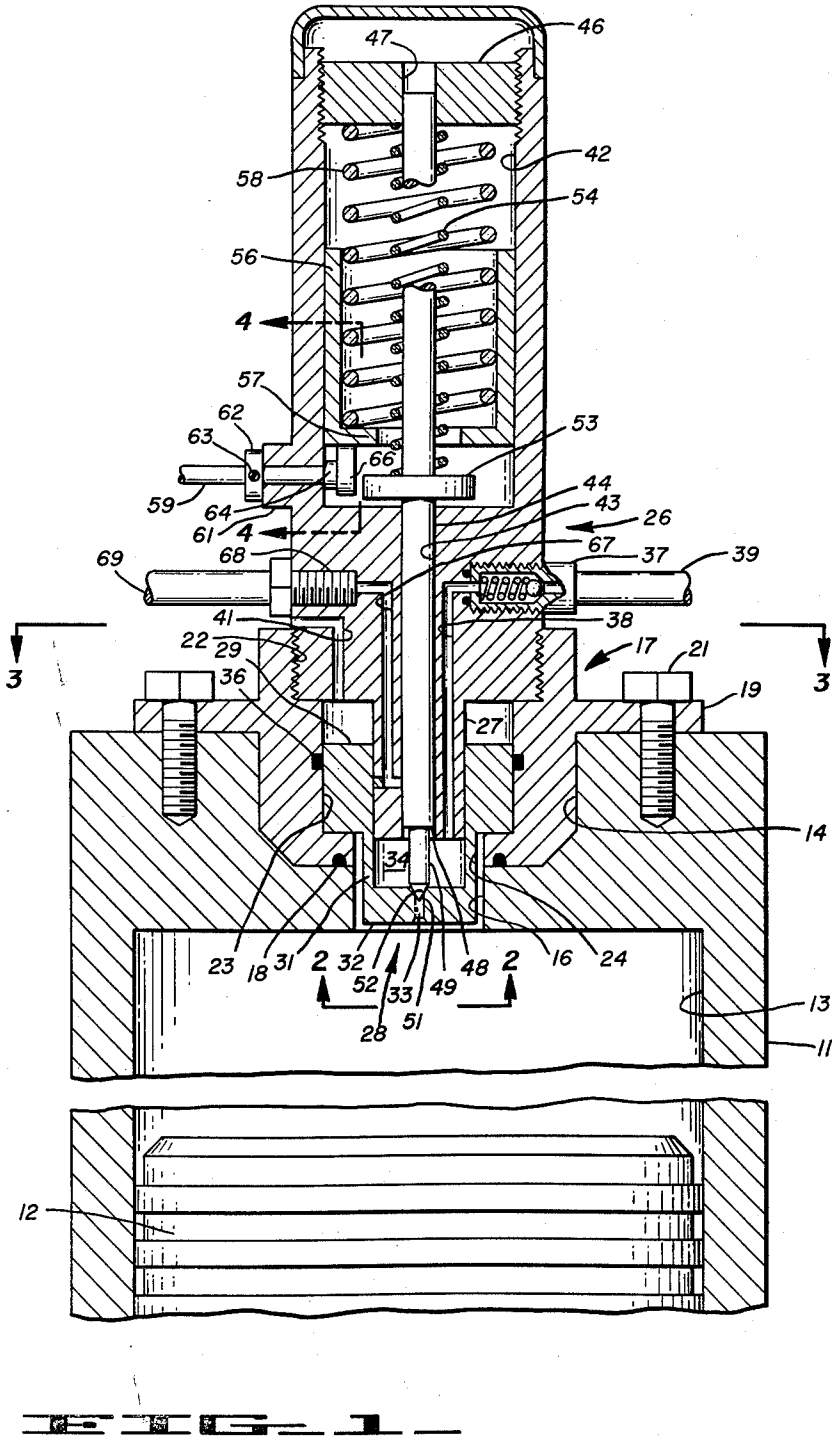


FIG. 1

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DIESEL FUEL INJECTOR

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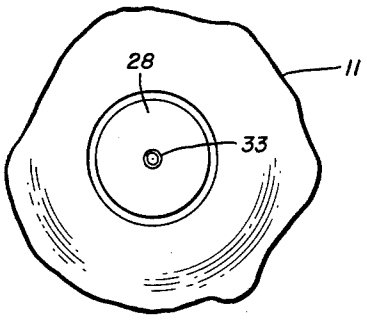


FIG. 2

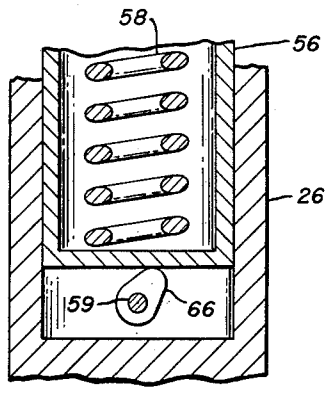


FIG. 4

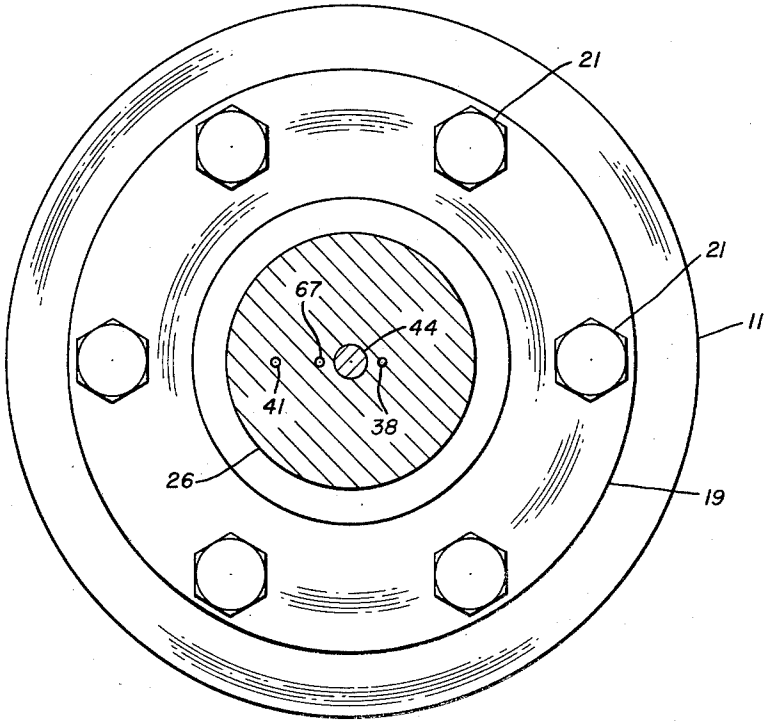


FIG. 3

United States Patent Office

3,072,114
Patented Jan. 8, 1963

3,072,114

DIESEL FUEL INJECTOR

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Filed Mar. 21, 1960, Ser. No. 16,381
5 Claims. (Cl. 123—139)

The present invention relates to internal combustion engines and more particularly to a self-actuating fuel injector for engines of the diesel class. This application is a continuation in part of co-pending application Serial No. 623,034 filed November 19, 1956, by the present inventor and entitled Internal Combustion Apparatus, now Patent 2,936,743, issued May 17, 1960.

In piston and cylinder engines operating on a diesel cycle, an injector is required to supply fuel to the cylinder at the end of each compression stroke of the piston. Such injection must be made against the high head pressure within the cylinder and should be accurately timed with respect to the position of the piston.

To accomplish fuel injection under the foregoing conditions, it has heretofore been the usual practice to employ injectors which are operated by remotely situated high pressure compressors or by mechanical coupling with the crankshaft of the engine. The usual compressors or other linkage between the crankshaft and fuel injectors considerably complicate the engine and increase the weight, bulk and proneness to breakdown thereof.

In the case of free piston engines such as are employed in power hammers, no crankshaft or equivalent rotary component is available to drive a fuel compressor or other linkage and operation of such engines on the diesel principle is still further complicated by the high piston reciprocation rates characteristic of the devices. While diesel operation has been used in free piston engines in some instances, the injection systems have been complex, heavy and less than satisfactory.

In addition to the problems associated with driving the injectors, prior designs have suffered from a further disadvantage in that accidental trapping of air in the injector fuel passages interrupts operation of the engine and requires that manual purging be performed. In prior designs, difficulty has been encountered from such factors as injection at less than the desired pressure, carbonization of the injection nozzle and inability to function at high piston reciprocation rates.

The present invention provides a novel fuel injector which overcomes the foregoing problems, the injector being driven and timed solely by the head pressure within the engine cylinder. No external compressor or driving linkage is required and the injector is thus compact, light, and capable of operation at extremely high piston reciprocation rates. The injector is automatically purged, injects only at a pre-determined minimum pressure, and is relatively free from carbonization. The invention thus makes practical the wide-spread use of diesel operation in free-piston devices and offers considerable advantages in other forms of diesel engine.

Salient elements of the invention comprise a housing secured to the cylinder head over an opening therein, the housing having a bore communicating with the cylinder in which bore a sliding injector piston is disposed. The end of the injector piston which is opposite the engine cylinder bears on a fuel chamber of less diameter than the piston. Thus as the head pressure rises within the engine cylinder, in response to upward movement of the engine piston therein, the injector piston must raise the pressure in the fuel chamber to a still higher value. Accordingly the fuel charge is pressurized for injection solely by the cylinder pressure itself, no external drive means for the injector being required.

To provide for injection, a fuel passage communicates

the fuel chamber with the cylinder head. Such passage is normally closed, however, by a needle valve on which a resilient element bears so that the passage will be opened for fuel injection only upon attainment of a predetermined minimum fuel pressure within the chamber.

To regulate the quantity of fuel injected, the needle valve is caused to abut against a second resilient element after a selected travel of the injector piston whereupon the valve again closes the injection passage.

Automatic purging of air trapped in the fuel chamber is provided for in that such air is compressible and therefore the normal movement of the injector piston does not raise the pressure within the chamber to the usual high value. Provided the force constants of the resilient elements are of appropriate values, the relatively low fuel chamber presure will not be sufficient to open the needle valve and no injection will occur. Owing to the relatively low back pressure within the fuel chamber, the injector piston will move past its normal stopping point, i.e. the point at which contact is made with the second resilient element. Such abnormal movement is arranged to uncover a vent passage through which the trapped air within the chamber is ejected.

Thus the invention overcomes the problems herebefore discussed, the injector being self-actuated and self-purging and directly responsive to movement of the engine piston within its cylinder.

It is therefore an object of this invention to provide a superior fuel injector for internal combustion engines which injector is driven by head pressure variation within the cylinder of said engine.

It is an object of this invention to provide a diesel fuel injector which is compact, self-actuated and which requires no external driving means or high pressure lines.

It is a further object of the invention to provide a fuel injector for an engine which injector is tuned to the head pressure of said engine and which injects fuel only at a predetermined minimum pressure.

It is an object of the invention to provide a diesel fuel injector particularly suited for use with engines of the free-piston class.

It is still a further object of this invention to provide a fuel injector having automatic provision for purging air entrapped in the fuel passages.

It is an object of the invention to provide a diesel fuel injector capable of operation at extremely high piston reciprocation rates.

It is another object of this invention to provide a self-actuated, self-purging, fuel injector which is compact, light and relatively free from carbonization.

The invention, both as to its organization and method of operation, together with further objects and advantages thereof, will best be understood by reference to the following specification taken in conjunction with the accompanying drawing, in which:

FIGURE 1 is a longitudinal section view showing an exemplary embodiment of the invention mounted on the head of a free piston engine,

FIGURE 2 is a view taken along line 2—2 of FIGURE 1 and showing the nozzle region of the injector,

FIGURE 3 is a cross section view taken along line 3—3 of FIGURE 1 and further clarifying the structure of the injector, and

FIGURE 4 is a section view taken along line 4—4 of FIGURE 1 and showing means by which the quantity of fuel injected into the cylinder is controlled.

Referring now to the drawing and more particularly to FIGURES 1 and 2 thereof, there is shown a portion of the cylinder 11 of a free-piston engine which engine may be, for example, of the type disclosed in the aforementioned co-pending application Serial No. 623,034. An engine piston 12 is slidably mounted in the cylinder and

reciprocates therein in the conventional manner, a rise of the piston acting to compress and heat air in the head region 13 of the piston so that the subsequent injection of combustible fuel will produce a downward power stroke.

To provide for the mounting of the fuel injector, an axial passage is formed in the top of cylinder 11, such passage having a broad upper section 14 and a narrower lower section 16 which opens into the cylinder head 13. To form a portion of an injector housing, a generally cylindrical injector base member 17 is fitted coaxially within upper passage section 14, an annular seal 18 being coaxially disposed around the underside of the base member.

To secure base member 17 to the cylinder 11, an annular flange 19 is formed at an intermediate position on the base member which flange abuts the top surface of the cylinder. As shown in FIGURES 1 and 3 in conjunction, a plurality of bolts 21 are transpierced through flange 19 and threadably engaged in the cylinder head, the bolts being equi-angularly distributed around the flange.

Base member 17 is provided with an axial bore having an upper section 22, a long intermediate section 23 and a short lower section 24 which sections are of progressively less diameter and the lowermost of which sections 24 has a diameter slightly less than that of the lower section 16 of the passage in the cylinder head.

The upper section 22 of the passage in base member 17 is threaded to receive the threaded lower end of a cylindrical injector body 26, the injector body being thus mounted in the base member in coaxial relationship therewith and forming another portion of the housing. A cylindrical extension 27 projects axially from the lower end of the injector body within passage section 23, the extension being of slightly less diameter than the lower bore section 24 of the base member.

To define a fuel chamber at the lower end of extension 27 and to amplify and transmit the cylinder head pressure to such chamber, an injector piston 28 is coaxially disposed within the base member 17. Piston 28 is provided with an upper annular portion 29 disposed coaxially around extension 27 within the intermediate passage section 23 of the base member, the annular portion 29 being of less length in the axial direction than passage section 23 so that the piston may slide upwardly in response to a rise of pressure within cylinder 11. Piston 28 is further provided with a cylindrical lower portion 31 which is coaxial with portion 29 and of lesser diameter and which extends downwardly through bore section 24 of the base member 17 and into passage 16 on the cylinder head.

The lower end of portion 31 of the injector piston is closed by an end member 32 which member has a narrow axial passage 33 flared at the lower end to provide a fuel injection nozzle. The region within the piston between end member 32 and the lower end of injector body extension 27 thus forms a fuel chamber 34 in which upward movement of the piston will act to raise the fuel pressure. An annular seal 36 is mounted in the interior wall of base member bore section 23 to form a gas tight seal around the piston which seal thus defines the area against which the head pressure in the cylinder acts. As will hereinafter be discussed in more detail, the cross section area of the fuel chamber 34 is considerably less than that enclosed by seal 36 so that a given head pressure within the cylinder 11 acts to create a greater pressure within the fuel chamber.

To supply fuel to chamber 34, a check valve fitting 37 is threadably engaged in the wall of injector body 26 and a passage 38 extends from the check valve to the fuel chamber through extension 27. Check valve 37 is arranged to limit fuel flow to a direction towards the chamber 34 and is connected, through a suitable conduit 39, with a supply of fuel.

To eliminate unwanted resistance to movement of piston 28, a vent passage 41 is provided in the lower portion of the injector body 26 which passage communicates with the upper end of base passage 23 and which opens at the side of the injector body.

Considering now means by which the injection passage 33 at the bottom of the chamber 34 is held closed until a desired minimum fuel pressure has been achieved, and means by which automatic purging of air from the fuel chamber is effected, an axial bore is provided in the injector body 26 which bore has a broad upper section 42 and a narrow lower portion 43 which lower portion is of less diameter than the fuel chamber and which passes through extension 27 and opens into the chamber.

A long cylindrical needle valve shaft 44 is slidably disposed along the axis of the injector body, the shaft having a lower portion conforming in diameter to bore 43 and extending therethrough. An annular retainer 46 is threadably engaged in the upper end of bore section 42, in coaxial relationship therein, and is provided with an axial guide passage 47 into which the upper end of the valve shaft 44 extends.

A step 48 is formed near the lower end of the valve shaft 44 and the terminal portion 49 thereof is of reduced diameter. The extreme lower end of the shaft 44 is provided with a conical point 51 and a matching conical valve seat 52 is formed in piston end member 32 at the top of injection passage 33. The members thus form a needle valve controlling the release of fuel from chamber 34 into the engine cylinder.

To yieldably hold point 51 against the valve seat 52, a flange 53 is formed on valve shaft 44 near the base of bore 42 in the injector body. A compression spring 54 is disposed coaxially around the upper portion of shaft 44 and bears against the flange 53 and retainer 46. Spring 54 thus exerts a downward force on the valve shaft 44 and tends to hold injection passage 33 closed. When the pressure within the fuel chamber 34 rises to an appropriate value, however, the fluid pressure against step 48 of the valve shaft 44 will lift the shaft against the force of spring 54 and fuel injection through passage 33 will occur. Thus the injection pressure may be predetermined by the force constant of the spring 54.

Considering now the throttle mechanism by which the quantity of fuel injected into the cylinder 11 is controlled, a tubular sleeve 56 is slidably disposed in bore 42 of the injector body in coaxial relationship therein. Sleeve 56 is of less length in the axial direction than bore 42 and is provided with an annular rim 57 at the lower end, which rim extends radially inward to overlap the flange 53 on valve shaft 44. Thus upward movement of the valve shaft 44 will cause flange 53 to abut against rim 57.

A second compression spring 58 is disposed within bore 42 in coaxial relationship therein, the spring 58 extending between the sleeve rim 57 and retainer 46. As will hereinafter be discussed in more detail, spring 58 is selected to exert a force against valve shaft 44, after abutment of flange 53 against sleeve rim 57, sufficient to hold the needle point 51 against valve seat 52 and thus to terminate fuel injection. Thus the amount of fuel injected is determined by the longitudinal position of sleeve 56 in bore 42, i.e. by the initial clearance between flange 53 and rim 57.

To establish, and selectively vary, this clearance, a rotatable throttle shaft 59 is transpierced through the side wall of the injector body 26 near the lower end of bore 42 thereof, a boss 61 being formed on the outer surface of the injector body to provide a journal for the shaft. An annular retainer 62 is secured on shaft 59 at the outer end of boss 61 by a set screw 63 and an annular washer 64 is disposed around the shaft within bore 52. Referring now to FIGURE 4 in conjunction with FIGURE 1, an ovate cam 66 is secured to the end of shaft 59 within bore 42 and beneath the lower rim 57 of sleeve 56. The sleeve 56 will be forced downwardly to abut

against the uppermost surface of the cam 66 by spring 58. Accordingly the turning of cam 66, means of shaft 59, will act to selectively vary the position of sleeve 56 and will therefore regulate the size of the fuel charge injected into cylinder 11. The shaft 59 may be operated by any of various throttle linkages well known to those skilled in the art.

Considering now the means by which automatic purging of air in the fuel chamber 34 is effected, a vent passage 67 is provided in the lower end of the injector body one end of which passage opens at the side of the injector body, preferably into a fitting 68 and vent pipe 69. Vent passage 67 extends downwardly within extension 27 and opens into bore 43 thereof at a level immediately above the maximum height to which step 48 of valve shaft 44 is elevated during a normal fuel injection cycle. This level is that occupied by the step 48 when valve shaft flange 53 abuts sleeve rim 57 with cam 66 turned to provide maximum fuel injection.

Thus the portion of valve shaft 44 immediately above step 48 will normally block the vent passage 67 from the fuel chamber 34 during all stages of operation. In the event air is present in the chamber 34, however, the chamber pressure is much less than normal for a given upward force on the injector piston 28. The force exerted on step 48 of the valve shaft 44 is thus less than normal and is insufficient to overcome spring 54 and lift the needle valve 51 from seat 52. Accordingly the piston 28 rises without injection occurring and carries the needle valve shaft 44 upward. Since the back pressure against the injector piston 28 is relatively small, the piston continues to travel upwardly even after abutment of flange 53 against sleeve rim 57 inasmuch as the springs are selected to exert a combined force on the valve shaft 44 which is less than the upward force exerted on piston 28 by the head pressure within cylinder 11.

Thus the valve shaft 44 rises above the usual maximum elevation thereof uncovering vent passage 67 and allowing the trapped air to escape through vent pipe 69. Subsequent downward movement of the injector piston 28, as engine piston 12 descends in cylinder 11, draws a new charge of fuel into chamber 34 and operation proceeds in the usual manner.

Considering now the general operation of the injector as well as typical parameters thereof, it may be seen that the rise of engine piston 12 within cylinder 11 causes a high pressure to be exerted against the underside of injector piston 28. The effect of such pressure will be to raise the fuel pressure within chamber 34 to a much higher value owing to the area ratio of seal 36 relative to the chamber cross-section. A fuel chamber pressure of 5000 lbs. per square inch will be found typical for an area ratio of 10:1.

The high fuel pressure pushes upwardly on the still smaller cross-sectional area of needle valve shaft 44. The shaft 44 is held down by the force of spring 54 which is selected to have a force constant just sufficient to counterbalance the desired fuel injection pressure, for example an injection pressure of 5000 lbs. per square. inch. When the fuel pressure reaches this value, the needle valve 51 rises from seat 52 allowing the fuel to travel downwardly through passage 33 and enter the cylinder 11.

As fuel is being injected, the injector piston 28 rises and the needle valve 51 must continue ahead of the piston to permit injection. After a selected upward travel of the valve shaft 44, determined by the setting of throttle shaft 59 and cam 66, flange 53 abuts sleeve rim 57 and thus the second spring 58 resists further upward movement of the valve shaft. Spring 58 may have a force constant of the order of two times greater than that of spring 54 so that to continue injection the fuel pressure would have to exert a force on shaft 44 greater than the combined force of the two springs. A fuel pressure of 15,000 pounds per square inch would be required for example, which value is higher than that which will be reached. Accordingly fuel injection stops when flange 53 contacts the sleeve rim 57.

When the pressure in cylinder 11 is reduced by downward movement of the engine piston 12, spring 54 drives the valve shaft 44 and injector piston 28 downward and the injector returns to the initial condition.

It should be understood that an additional manually openable valved vent passage can be provided in the injector body 26 which passage may communicate with the fuel chamber 34 and serve for manual purging of air from the chamber prior to starting. Such provision may be found useful where the injector is used with an engine that must start after a single upward movement of the engine piston, such as some forms of free piston engine, but will not be needed where the usual multiple cycle starting is available.

It will be apparent to those skilled in the art that many variations in the configuration and arrangement of elements of the invention are possible within the spirit and scope of the invention. Thus while the invention has been disclosed with respect to a single exemplary embodiment, it is not intended to limit the invention except as defined in the following claims.

What is claimed is:

1. In a fuel injector for an internal combustion engine which engine is of the class having a cylinder and reciprocating engine piston therein, the combination comprising means defining a fuel chamber at the head of said cylinder which chamber is communicated with said cylinder through a narrow injection passage, a movable injector piston disposed at the head of said cylinder which injector piston has a first end exposed to the head pressure of said cylinder and which has a smaller surface opposite said first end which surface bears on said fuel chamber to raise the pressure therein to a value higher than said head pressure, a valve element movable to close said injection passage from said fuel chamber, said valve element being exposed to the pressure within said chamber acting in a direction to move said element to open said passage, a first resilient means bearing against said valve element in a direction to close said passage whereby injection of fuel into said cylinder does not occur until the pressure therein reaches a value capable of overcoming the force of said resilient means on said valve element, a second resilient means bearing against said valve element only after a degree of travel thereof, and means forming a vent passage communicating with said fuel chamber only after travel of said valve element past the point of engagement with said second resilient means.

2. In a mechanism for injecting fuel into an internal combustion engine which engine is of the class having a cylinder and reciprocating engine piston therein, the combination comprising means forming a fuel chamber at the head of said cylinder which chamber is communicated with said cylinder through a narrow injection passage, a movable injector piston disposed at the head of said cylinder which injector piston has a first end exposed to the head pressure of said cylinder and which has a smaller end portion opposite said first end which smaller end portion bears on said fuel chamber to elevate the pressure therein above that of said cylinder head, a sliding needle valve having a stepped end portion projecting into said fuel chamber towards said injection passage therein, a first resilient element urging said needle valve towards said injection passage, a second resilient element positioned to engage said needle valve after a predetermined retraction of said valve from the initial position hereof and, exerting a force on said needle valve in the direction of said injection passage, and means forming a vent channel openable into said fuel chamber upon retraction of said needle valve past the point of engagement with said resilient element whereby air trapped within said chamber is released.

3. A mechanism for injecting fuel into an internal combustion engine substantially as described in claim 2 and comprising the further combination of means for controllably adjusting said second resilient element to engage said needle valve after varying degrees of retraction thereof whereby the quantity of fuel injected into said cylinder may be controlled.

4. A fuel injector for an internal combustion engine which engine is of the class having a cylinder and reciprocable engine piston therein and which cylinder has an opening at the head thereof, said injector comprising a housing mountable over said opening in said cylinder and having a stepped bore aligned coaxially with said opening, said bore having a broad section in proximity to said cylinder and a narrow section more remote from said cylinder, said housing having a vent passage communicating with an intermediate point in said narrow section of said bore, a cylindrical injector piston slidingly disposed in said broad section of said bore in coaxial relationship therein, said injector piston having a first end facing said cylinder and having an opposite end surface of reduced area facing said narrow section of said bore, said injector piston being pierced by a narrow axial fuel injection passage, means defining a contractable fuel chamber within said broad section of said bore between said opposite end surface of said injector piston and said narrow section of said bore which chamber has said opposite end surface of said injector piston as one boundary thereof whereby the head pressure within said cylinder is amplified and transmitted to said chamber, a cylindrical needle valve coaxially disposed in said narrow section of said bore and having a pointed extremity of reduced diameter projecting into said fuel chamber towards said axial passage in said injector piston, a first spring exerting a longitudinal force on said needle valve

in the direction of said cylinder to close said passage, and a second spring positioned to engage said needle valve upon retraction of said reduced extremity thereof to the vicinity of said intermediate point in said narrow section of said bore, said second spring exerting an additional force on said needle valve in the direction of said cylinder.

5. A fuel injector for an internal combustion engine substantially as described in claim 4 wherein said needle valve projects from said narrow section of said bore at the end thereof remote from said fuel chamber and is provided with a flange and wherein said housing is formed with a coaxial tubulation around said flanged projection of said needle valve and comprising the further combination of a slidable sleeve disposed coaxially within said tubulation and extending radially inwardly to be abutted by said flange on said needle valve after retracting movement thereof, said second spring being disposed coaxially within said tubulation and urging said sleeve in the direction of said cylinder, and a controllably rotatable cam bearing against said sleeve to adjust the longitudinal position thereof within said tubulation.

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