March 1, 1949. H. L. GATES 2,462,854

FUEL INJECTION SYSTEM

Filed July 3, 1945 2 Sheets-Sheet 1

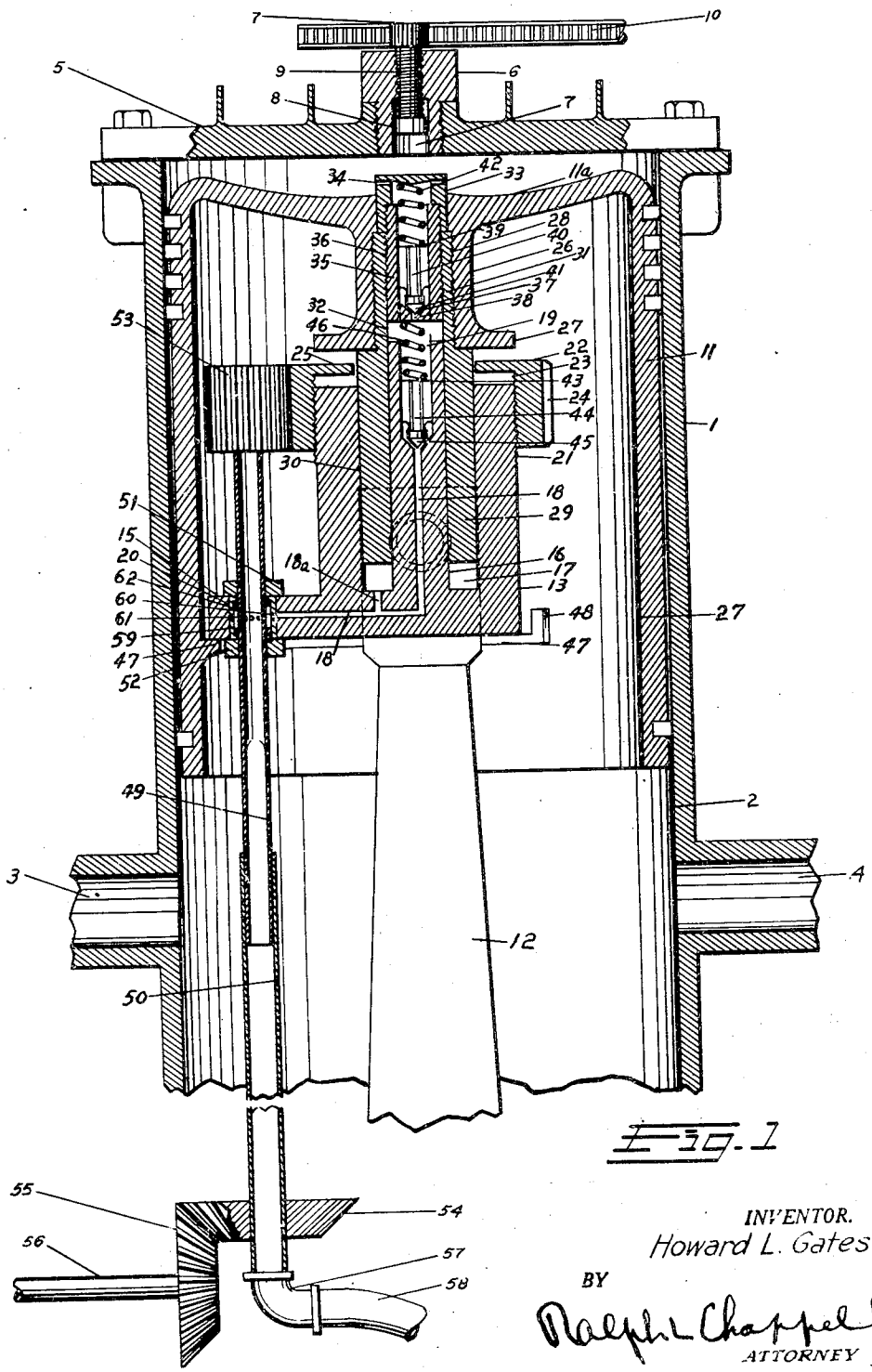


Fig. 1

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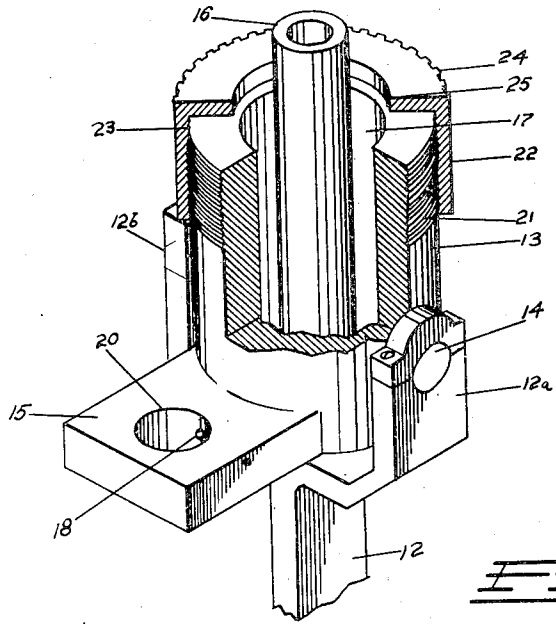


Fig. 2

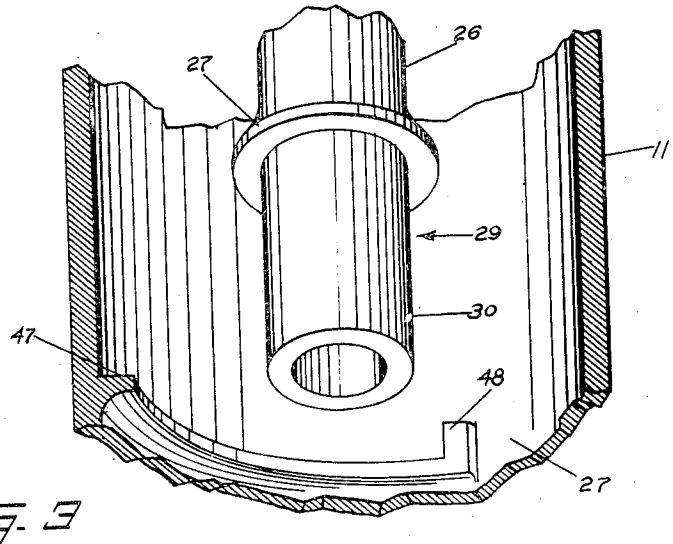


Fig. 3

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FUEL INJECTION SYSTEM

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15 Claims. (Cl. 123—32)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

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This invention relates to a fuel injection system for internal-combustion engines.

An object of this invention is to provide a fuel injection system in which the injector, fuel supply and pumping mechanism all are mounted internally of the engine cylinder.

Another object is to provide a fuel injection system in which the power-transmitting piston and connecting rod of the engine form part of the fuel injector thereby eliminating auxiliary fuel injecting pumps and connections.

Still another object is to provide a self-timing fuel injection system in which the pressure on the piston created in the engine combustion chamber during the compression stroke provides the necessary pumping force for injection.

A further object is to provide a self-timing fuel injection system in which injection is controlled by the compression pressure in the cylinder combustion chamber, which, in turn, is controlled by adjustable means for varying the combustion-chamber volume and hence the compression ratio.

Further objects and advantages of this invention, as well as its construction, arrangement and operation will be apparent from the following description and claims in connection with the accompanying drawings, in which,

Figure 1 is a longitudinal sectional view of a portion of a cylinder of an internal-combustion engine showing the fuel injection system comprising this invention,

Figure 2 is a perspective view of a portion of the engine connecting rod including the pumping housing of the fuel injector secured thereto, and

Figure 3 is a perspective view of a portion of the piston including the fuel-pumping plunger.

The fuel injection system comprising this invention includes a fuel injecting pump and nozzle mounted in the piston of an internal-combustion engine and a pumping chamber secured to the connecting rod. The piston has limited axial motion with respect to the connecting rod so that sufficient pressure applied to the face of the piston, as occurs during the compression stroke of the engine, results in fuel-pumping action and consequent injection of the fuel into the cylinder. The compression pressure in the combustion chamber of the cylinder governs the cycle time at which injection occurs and means are provided to vary such time of injection by adjusting the volume of the combustion chamber and hence the compression ratio.

In the drawings, there is shown in Figure 1 an

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internal-combustion engine of the two cycle type comprising a cylinder 1 having a bore 2, exhaust ports 3 and air inlet and scavenging ports 4. A finned cylinder head 5 closes the top of the cylinder and a closure plug 6 is mounted in the head 5 by screw threads for example. The plug 6 has a central cavity 7 which forms a continuation of the combustion chamber forming the upper portion of cylinder 1. An adjustable shield or plunger 8 is slidably mounted in the cavity 7 for regulating the volume thereof. The plunger 8 has a threaded shank 9 that engages the plug 6 as shown. The shank 9 extends through the plug 6 and its end projects exteriorly of the cylinder head 5. A pinion 7 is secured to the end of the shank 9 and meshes with an operating rack 10. Rotation of the pinion 7 by the rack 10 produces longitudinal adjustment of the plunger 8 within the cavity 7 and thereby varies the volume of the latter as well as the volume of the combustion chamber in the cylinder 1.

A piston 11 and connecting rod 12 are mounted in the bore 2 of the cylinder 1. The connecting rod 12 is connected to the engine crankshaft (not shown) and the piston and connecting rod assembly reciprocates in the cylinder bore 2. The fuel injector comprises a pumping housing 13 having a pair of diametrically opposed trunnions 14 as shown in Figure 2 which are suitably mounted in corresponding yoke arms 12a and 12b comprising the forked end of connecting rod 12. A lateral extension member 15 forms part of pumping housing 13 and is spaced away from the trunnions 14 approximately 90° circumferentially. The pumping housing 13 is cylindrical in shape and has a central column 16 forming an annular pumping chamber 17. The column portion 16 of the housing 13 is traversed by a fuel-oil duct 18 (see Figure 1) terminating in an enlarged valve chamber 19. A branch 18a of duct 18 leads to the pumping chamber 17, and the duct 18 at its opposite end connects with an opening 20 in extension 15 (see Figure 2). A fuel-oil gland 59 (Figure 1) in the form of a hollow cylindrical body having partly closed ends is seated in the opening 20 of extension 15 and is provided with an orifice 60 aligned with the entrance to duct 18 as shown in Figure 1. A portion of the periphery of the pumping housing 13 is threaded as shown at 21 Figures 1 and 2, and a regulating collar 22, which is internally threaded as at 23, is mounted thereupon. The periphery of the regulating collar 22 is provided with gear teeth 24 and an annular flange 25 on the regulating

collar 22 overlaps the end of the pumping housing 13 as shown in Figures 1 and 2.

The piston 11 has a piston face 11*a* and a skirt portion 27. A nozzle housing 26 in the form of a hollow boss projects downwardly from the face 11*a* of the piston 11 into the interior thereof, the nozzle housing 26 being coaxial with the piston as shown in Figures 1 and 3. The nozzle housing 26 terminates in a flared annular stop shoulder 27 and has an internally threaded bore 28 in which there is secured a fuel injector pump member 29. Pump member 29 consists of plunger 30 in the form of a hollow cylinder and a hollow threaded shank 31 that engages the threaded bore 28 in nozzle housing 26. The plunger portion 30 of fuel pump 29 is slidably mounted in the annular pumping chamber 17 in pumping housing 13, and it fits the column 16 exteriorly and the bore of the chamber 17 internally, as shown in Figure 1. The piston 11 is therefore floatingly mounted with respect to connecting rod 12 and pumping housing 13 and has rotatative and axial motion with respect to each of the latter. The annular flange 25 on regulating collar 22 is interposed between the shoulder 27 on fuel plunger 26 and the top of pumping housing 13 to limit the axial motion of the former with respect to the latter. This comprises a translatory motion between the piston 11 and the connecting rod 12.

An injector nozzle 33 (Figure 1) is mounted in injector housing 26 and projects slightly outwardly from the face 11*a* of piston 11 into the combustion chamber formed between the cylinder head 5 and piston face 11*a* in cylinder 1. A plurality of radially disposed fuel orifices 34 are provided in the projecting portion of nozzle 33. The injector nozzle 33 is secured in injector housing 26 by a hollow threaded nipple 35 which is secured at one end by the internal threading 36 of the shank 31 of fuel pump 29, the nozzle 33 being threaded to the nipple 35 at its other end. One end of nipple 35 is partly closed by a conical valve seat 37 which is connected by opening 38 to the hollow interior of the plunger 29.

A spring-loaded fuel injection valve 39 is slidably mounted in the interior of nipple 31. The injection valve 39 consists of a cylindrical body traversed by a series of longitudinally extending, peripheral fuel-oil passages 40 and a conical closure member 41 which seats in the valve seat 37. Valve spring 42, located within the nozzle 33, normally holds valve 39 closed. A check valve 43 having grooves 44 and a conical closure member 45 similar to valve 39 in structure is slidably mounted within the recess 19 of the core 16 of the pump body 13. The check valve 43 is normally held closed by check valve spring 46 as shown in Figure 1.

An annular shoulder 47 extends circumferentially around the inner surface of the skirt portion 27 of piston 11 as shown in Figures 1 and 3. The shoulder 47 is not continuous but extends for approximately three quarters of the peripheral distance around the piston and terminates in a pair of upstanding stop lugs 48. The shoulder 47 limits upward movement of piston 11 as it slides relative to the plunger body 13 because of its engagement with extension 15 on pump body 13.

A combined fuel-supply line and injection-control operating rod is provided in the form of telescoping tubes 49 and 50. These tubes are noncircular in cross section for a portion of their length adjacent where they are joined so that they are rotatably locked together but capable of longitudinal sliding motion relative to each other to permit tube 49 to reciprocate with the piston 11 and crankshaft 12. Tube 49 is rotatably secured to the extension 15 on pump body 13 for translatory motion therewith, by means of a pair of thrust collars 51 and 52 attached to tube 49. The portion of tube 49 which fits in gland 59 is circular and rotatably mounted therein. A pinion 53 is fixedly mounted on the end of tube 49 and engages the peripheral gear 24 on regulating collar 22. The lower end of tube 50 is provided with a bevel gear 54 which is engaged by a control gear 55 driven by a manual or governer controlled shaft 56. Tube 50 is connected by a fitting 57 and suitable flexible tube means 58 to a fuel supply pump (not shown).

A special gland is provided in chamber 20 of the crank 15 to permit fuel flowing in tube 49 to enter duct 18 in the plunger block 13 for all angular positions of adjustment of the tube 49. Such gland (Figure 1) comprises a bushing 59 having an annular chamber 62 and an outlet orifice 60 aligned with the entrance of duct 18 (Figure 2). A number of radially disposed openings 61 are provided in the periphery of tube 49 inside chamber 62 (Figure 1) so that there is continuous communication between the interior of tube 49 and duct 18 as the former is rotated relative to the bushing 59.

The operation of the internal-combustion engine and the fuel injection system is as follows:

Fuel oil is continuously supplied from a suitable low-pressure pumping source through the flexible connection 58 and 57 and thence through tubes 50 and 49 into the chamber 62 of the gland 59. The fuel oil then enters duct 18 where it fills the annular chamber 17 formed between the end of plunger 29 and pump housing 13. Inasmuch as fuel pump 29 is slidably mounted in the plunger body 13, the pressure of the fuel oil is sufficient to raise fuel pump 29 and piston 11 with respect to the pump housing 13 by an amount limited by the engagement of shoulder 47 on piston 11 with extension 15 of the pumping housing 13, when the pressure in the combustion chamber is low, as, for example at the end of the expansion stroke. At the same time, the fuel oil also flows past check valve 45 and fills chamber 19, but does not enter the inside of nozzle 33 because injection valve 41 is held closed by the relatively strong injection pressure regulating spring 42.

During the compression stroke the pressure in the combustion chamber between the piston face 11*a* and cylinder head 5 rises, until, at a predetermined point, the compression pressure acting over the piston face 11*a*, forces the piston 11 together with plunger 30 of fuel pump 29 downwardly axially with respect to the pumping chamber 17 thereby pumping the fuel oil in chamber 19 through the injection valve 41 and out through the spray orifices 34 into the combustion chamber causing combustion to take place. As the gases expand during the combustion or power stroke piston 11 is forced downwardly, with shoulder 27 abutting shoulder 25 on regulating collar 22 until the piston 11 uncovers exhaust port 3 and scavenging air port 4. When the piston has uncovered scavenging air port 4, the nozzle 33 is aligned therewith and the inrushing scavenging air cleanses whatever deposits may have accumulated on the nozzle. At the completion of the combustion stroke the pressure of the incoming fuel in fuel line 49 is sufficient to again raise the piston 11 together with plunger 30 into cocked position with shoulder 27 on injector housing 26 spaced

from regulating collar 22 as previously described and the cycle continues.

The amount of fuel injected per stroke is regulated for various load and speed conditions by adjusting the gap between shoulder 27 and regulating collar 22. This is accomplished by adjusting operating shaft 56 which is controlled either by the engine governor or by a hand throttle, thereby rotating bevel gears 54 and 55, tubes 49, 50, pinion 53, and regulating collar 22. Collar 22 is thereby raised or lowered with respect to the pump body 13 on which it is threadingly mounted to rotate in the threaded engagement, thereby regulating the gap between the annular shoulder 25 on collar 22 and the flared shoulder 27 forming part of piston 11. The amount of gap is directly proportional to the pumping stroke of the injector mechanism and the amount of fuel injected is thereby proportionally controlled.

The pressure in the combustion chamber of the cylinder multiplied by the ratio of the area of the piston face 11*a* to that of the pumping end of plunger 29 determines the injection pressure of the fuel oil. Due to the fact that injection normally begins when the pressure of the air in the combustion chamber is sufficient to overcome the resistance offered by injection valve 39, the cycle time at which fuel injection begins can be regulated by increasing or decreasing the volume at the top of the cylinder, which regulates the cycle time at which the pressure due to compression is of a magnitude sufficient to initiate injection. The adjustable plunger 8 is used to regulate in this way the point of injection. The operating rack 10, which may be coupled to the same governor actuated means as control shaft 56, or which may be manually adjusted, regulates the position of plunger 8 and hence the compression ratio in the engine cylinder, thereby to advance or retard the point of injection in response to various load conditions.

The injection pressure is also controlled by the strength of the discharge-valve spring 42. Since the pressure acting on the fuel oil increases as the piston 11 moves upwardly on the compression stroke, a spring of suitable strength must be employed to prevent injection valve 41 opening too early during the compression stroke.

Piston 11 is free to rotate relative to the plunger body 13 and connecting rod 12, since it is pivotally mounted with respect to the latter by the engagement of plunger 29 with plunger body 13. Such freely floating piston arrangement is advantageous inasmuch as it distributes wear between the piston 11 and cylinder wall 2. The piston 11 is normally held from coming off the connecting rod 12 by the annular shoulder 47 secured to the skirt of piston 11 as shown in Figures 1 and 3 abutting extension 15. The limit lugs 48 at each end of shoulder 47 prevent the piston 11 rotating to a point where the gap between the ends of shoulder 47 would align with arm 15. When it is desired to remove piston 11 for servicing after cylinder head 5 has been removed, regulating collar 22 is screwed all the way down until flange 25 abuts plunger housing 13. This leaves a wide gap between flange 25 and the flange 27 on the injector housing 26. Piston 11 can now be rotated until arm 15 clears the limit lugs 48 and is aligned with the gap between the ends of shoulder 47 previously mentioned, after which piston 11 can be removed. The external periphery of nozzle 33 has suitable flats or wrench slots to permit easy removal thereof. Each cylinder moreover can be easily isolated by removal of plug 6 in the cylinder head 5, thereby venting the cylinder to the atmosphere.

Various modifications and changes may be made in the above described device without departing from the spirit and scope of this invention as set forth in the appended claims.

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

What is claimed is:

1. In an internal-combustion engine having a reciprocating piston and connecting rod, the combination of a fuel injector comprising a spray nozzle mounted in said piston, a floatable mounting between said piston and connecting rod, said floatable mounting including a pumping chamber secured to the connecting rod and a fuel injection pump secured to said piston and movably mounted in said pumping chamber, said piston being movable relative to said connecting rod in response to pressure exerted on said piston during the compression stroke of said engine.

2. In an internal-combustion engine having a combustion cylinder and a power transmitting reciprocating connecting rod, the combination of a pumping chamber secured to said connecting rod, a piston slidably mounted in said cylinder, a fuel injecting plunger secured to said piston and slidably mounted in said pumping chamber to form a floatable connection between said connecting rod and piston, and a fuel spray nozzle mounted in said piston and having access to the combustion chamber of said engine, said piston and said fuel injecting plunger being movable relative to said pumping chamber in response to pressure exerted on said piston during the compression stroke of said engine.

3. A fuel injection system for internal-combustion engines having a cylinder and power transmitting connecting rod reciprocating therein comprising, a fuel pumping chamber secured to said connecting rod, a piston slidably mounted in said cylinder, a fuel injecting plunger secured to said piston and slidably mounted in said pumping chamber to form a floatable connection between said connecting rod and piston, a fuel spray nozzle mounted in said piston exposed to the combustion chamber of said cylinder, a fuel passage connecting said fuel pumping chamber with said fuel spray nozzle, said piston and said fuel injecting plunger being movable with respect to said pumping chamber in response to pressure exerted on said piston during the compression stroke of said engine.

4. A fuel injection system for internal-combustion engines having a cylinder and power transmitting connecting rod reciprocating therein comprising, a fuel pumping chamber secured to said connective rod, a piston slidably mounted in said cylinder, a fuel injecting plunger secured to said piston and slidably mounted in said pumping chamber for axial and rotative movement relative thereto, a fuel spray nozzle mounted in said piston and exposed to the combustion chamber of said cylinder; fuel passage means connecting said pumping chamber with said spray nozzle, valve means in said fuel passage regulating the flow of fuel to said nozzle, and elastic means engaging said valve means to normally hold the latter closed; said piston and said fuel injecting plunger being movable relative to said pumping chamber in response to pressure exerted on said piston during the compression stroke of said en-

gine, whereby fuel in said pumping chamber is forced through said fuel passage and valve into the combustion chamber of said engine.

5. A fuel injection system for internal-combustion engines having a cylinder and power transmitting connecting rod reciprocating therein comprising, a fuel pumping chamber secured to said connecting rod, a piston slidably mounted in said cylinder, a fuel injecting plunger secured to said piston and slidably mounted in said pumping chamber for axial and rotative movement relative thereto, a fuel spray nozzle mounted in said piston and exposed to said combustion chamber of said cylinder, a fuel passage connecting said fuel pumping chamber with said spray nozzle, said piston and said fuel injecting plunger being movable with respect to said pumping chamber in response to pressure exerted on said piston during the compression stroke of said engine, and regulating means adjustably mounted on said pumping chamber, said regulating means having stop means interposed between said plunger and said pumping chamber for regulating the amount of axial motion between said plunger and said pumping chamber.

6. A fuel injection system for internal-combustion engines having a cylinder and power transmitting connecting rod reciprocating therein comprising, a fuel pumping chamber secured to said connecting rod, a piston slidably mounted in said cylinder, a fuel injecting plunger secured to said piston and slidably mounted in said pumping chamber, a fuel spray nozzle mounted in said piston and exposed to said combustion chamber of said cylinder, a fuel passage connecting said fuel pumping chamber with said spray nozzle, said piston and said fuel injecting plunger being movable with respect to said pumping chamber in response to pressure exerted on said piston during the compression stroke of said engine, regulating means adjustably mounted on said pumping chamber, stop means on said regulating means interposed between said plunger and said pumping chamber for regulating the pumping stroke of said plunger in said pumping chamber and operating means for adjusting the position of said regulating means on said pumping chamber, said operating means having fuel conducting means integral therewith accessible to said fuel passage in said fuel pumping chamber.

7. The structure defined in claim 6 in which said operating means comprises hollow telescoping fuel conducting tubes slidably and non-rotatably mounted with respect to each other and connectable at one end to a fuel supply source.

8. A fuel injection system for internal-combustion engines comprising a fuel pumping housing secured to a connecting rod of said engine, an annular fuel pumping chamber in said pumping housing, a hollow piston having a face portion and skirt portion, an annular fuel plunger projecting from the face portion of said piston, said fuel plunger being slidably receivable in said annular fuel pumping chamber for axial and rotative motion therein, a fuel spray nozzle mounted in the face portion of said piston coaxially with said fuel plunger, a fuel passage connecting said annular fuel pumping chamber with said spray nozzle, a fuel check valve and a spring loaded fuel injection valve mounted in said passage, a fuel supply line rotatably mounted in said pumping housing, said fuel line being secured to said pumping housing for translatory motion therewith, and gland means connecting said fuel supply line with said fuel passage in said pumping

housing to permit free flow of fuel therebetween as the fuel line is rotated relative to said pumping housing.

9. A fuel injection system for internal-combustion engines comprising, a fuel pumping housing secured to a connecting rod of said engine, an annular fuel pumping chamber in said pumping housing, a hollow piston having a face portion and skirt portion, an annular fuel plunger projecting from the face portion of said piston, said fuel plunger being slidably receivable in said annular fuel pumping chamber for reciprocating and rotative motion therein, shoulder means on said fuel plunger, a fuel spray nozzle mounted in the face portion of said piston coaxially with said fuel plunger, a fuel passage connecting said annular fuel pumping chamber with said spray nozzle, a regulating collar adjustably mounted on said fuel pumping housing for axial movement relative thereto, a shoulder on said regulating collar interposed between said fuel pumping housing and said shoulder means on said fuel plunger, said piston being axially movable relative to said pumping housing upon application of pressure on the face portion of said piston, and means for adjusting the position of said regulating collar axially of said pumping chamber whereby the shoulder on said regulating collar interposed between said fuel plunger shoulder and said pumping housing limits the amount of axial movement between said piston and said pumping housing.

10. In an internal-combustion engine having a cylinder, cylinder head and reciprocating connecting rod, the combination of a cavity in said cylinder head accessible to said cylinder, a shield adjustably mounted in said cavity for varying the volume thereof, operating means connected to said shield, a fuel pumping chamber mounted on said connecting rod, a piston having a face portion and skirt portion slidably mounted in said engine cylinder, a fuel pumping plunger secured to said piston and slidably mounted in said fuel pumping chamber, a fuel spray nozzle mounted in said face portion of said piston accessible to the combustion chamber of said engine cylinder, a fuel passage connecting said fuel pumping chamber to said nozzle, said piston and said fuel pumping plunger being movable relative to said pumping chamber in response to pressure applied on the face portion of said piston, adjustable stop means between said fuel pumping plunger and said fuel pumping chamber for limiting the amount of motion therebetween, and control means for operating said adjustable stop means, said control means and said first mentioned shield operating means being responsive to load variations on said engine.

11. In an internal-combustion engine having a cylinder, cylinder head and power transmitting connecting rod reciprocally mounted in said cylinder, the combination of a fuel injector comprising a power transmitting piston slidably mounted in said cylinder, fuel pumping means secured to said piston, a fuel pumping chamber secured to said connecting rod, said fuel pumping chamber slidably receiving said fuel pumping means on said piston and forming a floatable connection between said connecting rod and piston, a fuel spray nozzle in said piston and a fuel passage connecting said fuel pumping chamber to said nozzle, said piston being axially movable relative to said fuel pumping chamber in response to pressure applied to said piston.

12. In an internal-combustion engine having

a cylinder, cylinder head and power transmitting connecting rod reciprocally mounted in said cylinder, the combination of a fuel injector comprising a power transmitting piston slidably mounted in said cylinder, fuel pumping means secured to said cylinder, a fuel pumping chamber secured to said connecting rod, said fuel pumping chamber slidably receiving said fuel pumping means on said piston for combined axial and rotatable motion relative thereto, a fuel spray nozzle in said piston, a fuel passage connecting said fuel pumping chamber with said fuel spray nozzle, spring loaded injection valve means in said fuel passage, said fuel pumping means being axially movable relative to said pumping chamber in response to pressure applied to said piston, a cavity in said cylinder head and adjustable means for varying the volume of said cavity and hence the compression ratio in said cylinder, whereby the cyclic time at which the pressure on said piston required to open said injection valve can be varied in response to said volumetric variation.

13. In an internal-combustion engine the combination of a combustion cylinder, a power transmitting piston and connecting rod mounted for reciprocating motion therein, said piston being floatably mounted upon said connecting rod, said floatable mounting including a fuel pumping chamber secured to one of said connecting rod and piston elements and a fuel injecting plunger secured to the other of said elements and slidably mounted within said fuel pumping chamber.

14. In an internal-combustion engine the combination of a combustion cylinder, a power transmitting piston and connecting rod mounted for reciprocating motion therein, said piston being floatably mounted upon said connecting rod, said floatable mounting including a fuel pumping chamber secured to one of said connecting rod and piston elements and a fuel injecting plunger secured to the other of said elements and slidably mounted within said fuel pumping chamber, a fuel spray nozzle in said piston, and a fuel passage connecting said pumping chamber to said nozzle, whereby reciprocating motion of said connecting rod and piston injects fuel into the combustion chamber of said engine.

15. In an internal-combustion engine comprising a cylinder, a piston reciprocable therein and a connecting rod providing a mounting for the piston, a fuel injector pump comprising a pumping chamber and a pump plunger severally secured one to the connecting rod and the other to the piston, the mounting of the connecting rod for the piston comprising a translatory motion to provide relative movement between the plunger and the pumping chamber to operate the injector pump.

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Certificate of Correction

Patent No. 2,462,854. March 1, 1949.

HOWARD L. GATES

It is hereby certified that errors appear in the printed specification of the above numbered patent requiring correction as follows:

Column 2, line 38, before the word "housing" insert *pumping*; column 3, line 20, for "floatingly" read *floatably*; lines 27, 28 and 29, strike out "This comprises a translatory motion between the piston 11 and the connecting rod 12." and insert the same in line 19, same column, before "The pistons"; column 5, line 12, strike out "threadingly";

and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 26th day of July, A. D. 1949.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.