

[54] **FUEL INJECTION SYSTEM FOR DIESEL ENGINE**[72] Inventor: **Shigeo Nagasawa**, Kyoto, Japan[73] Assignee: **Mitsubishi Jidosha Kogyo Kabushiki Kaisha**, Tokyo, Japan[22] Filed: **Dec. 22, 1969**[21] Appl. No.: **886,960**[52] U.S. Cl. **123/32 G, 123/179 L, 123/32 R**[51] Int. Cl. **F02b 3/00, F02n 17/00**[58] Field of Search **123/32.6, 32.61**[56] **References Cited****UNITED STATES PATENTS**

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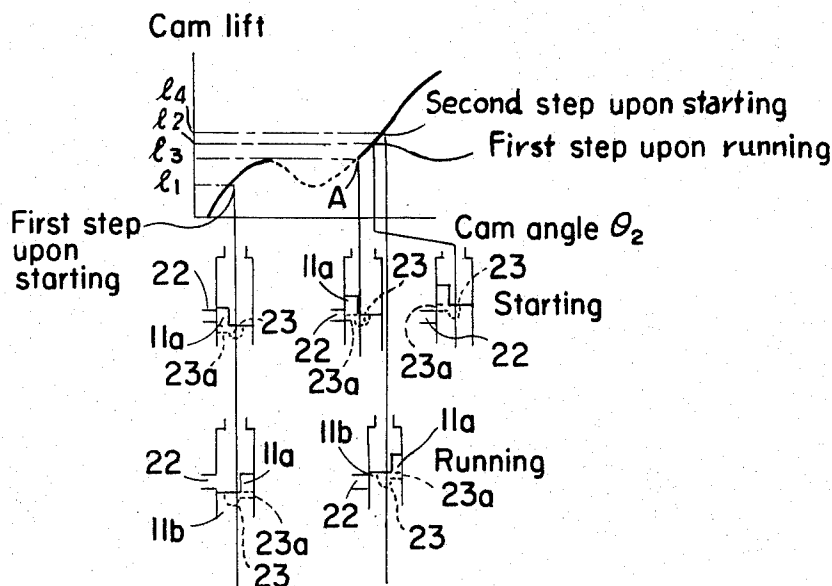
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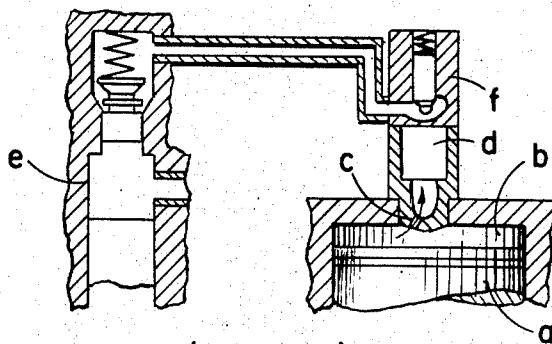
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Primary Examiner—**Laurence M. Goodridge**Assistant Examiner—**Ronald B. Cox**Attorney—**McGlew and Toren**[57] **ABSTRACT**

A fuel injection system for a diesel engine has a plunger barrel with a fuel intake port and a plunger slidable axially in the barrel. A plunger operating cam has a pair of lobes for operating the plunger. During either the intake or the compression stroke, the cam advances the plunger to a first position blocking the port to inject fuel, after which the plunger retracts. At the end of the compression stroke, the cam advances the plunger further to a second position to block the port to inject fuel.

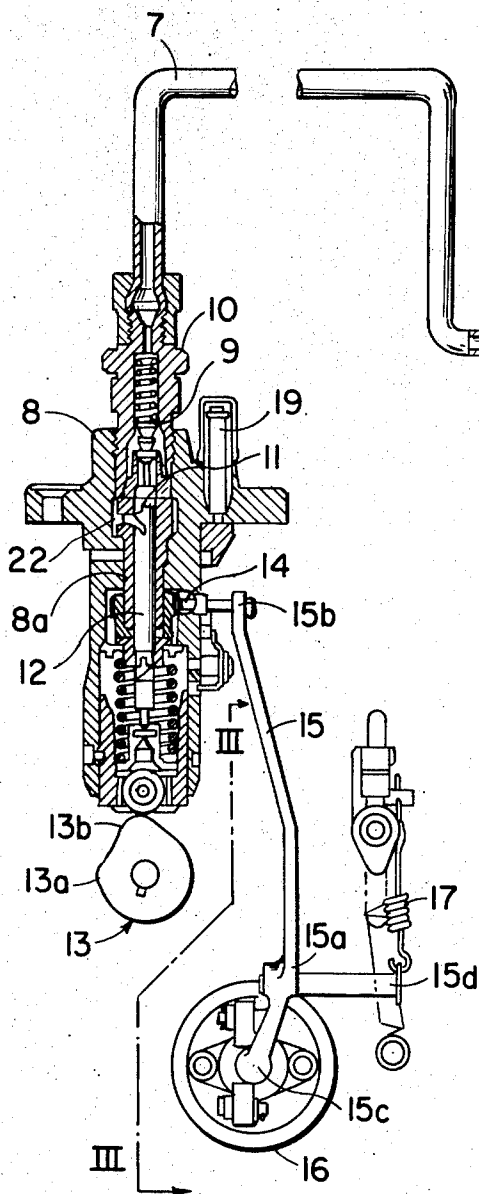
A switching device is effective to rotate the plunger between a starting position and a running position. In the starting position, the peripheral surface of the plunger blocks the port during the two fuel injections strokes of the plunger and, in the running position, the plunger is rotated to a position where its peripheral surface blocks the port only upon the further advance of the plunger to the second position. The invention improvement comprises at least one fuel passage in the plunger connecting the peripheral surface to the inner end face of the plunger and communicating with the port, during starting of the engine, and in the second plunger position.

1 Claim, 14 Drawing Figures



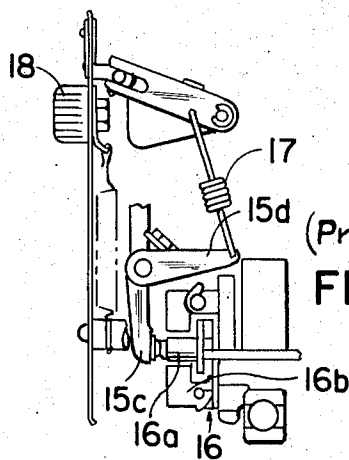
(Prior Art)

FIG. 1



(Prior Art)

FIG. 2

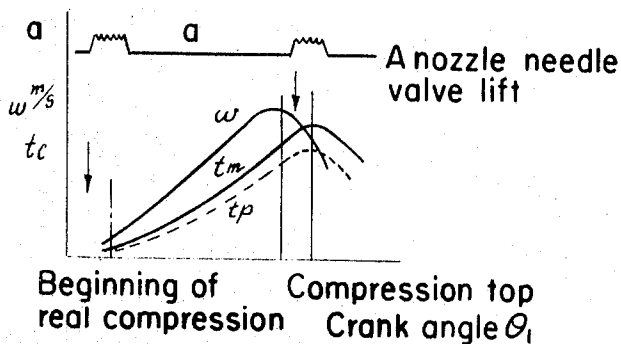
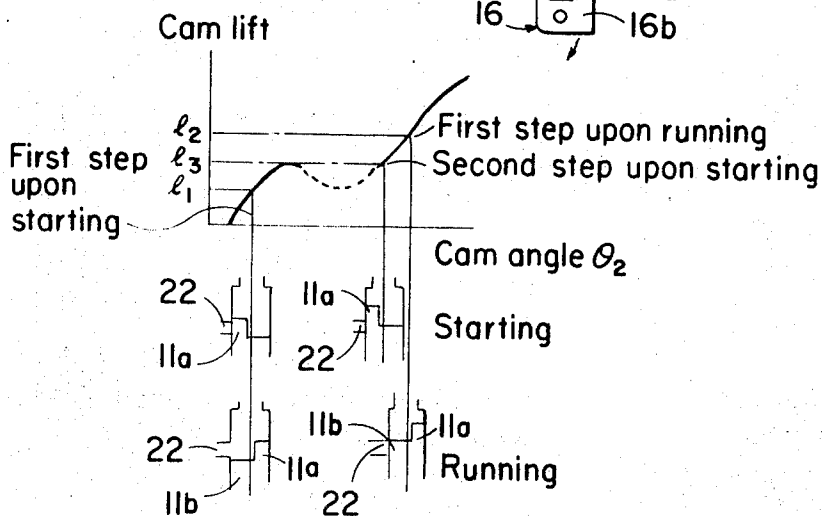
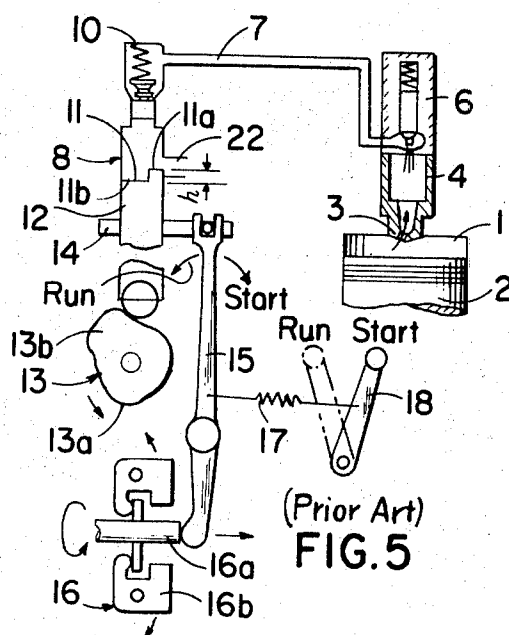
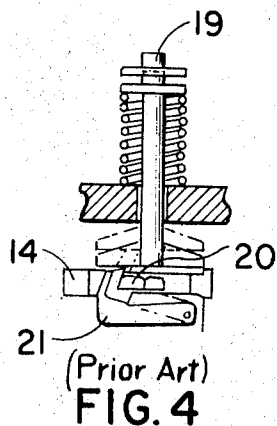


(Prior Art)

FIG. 3

INVENTOR
Shigeo Nagasawa

by *McHew & Foren*
ATTORNEYS



INVENTOR
Shigeo Nagasawa

by *McGraw & Toren*
ATTORNEYS

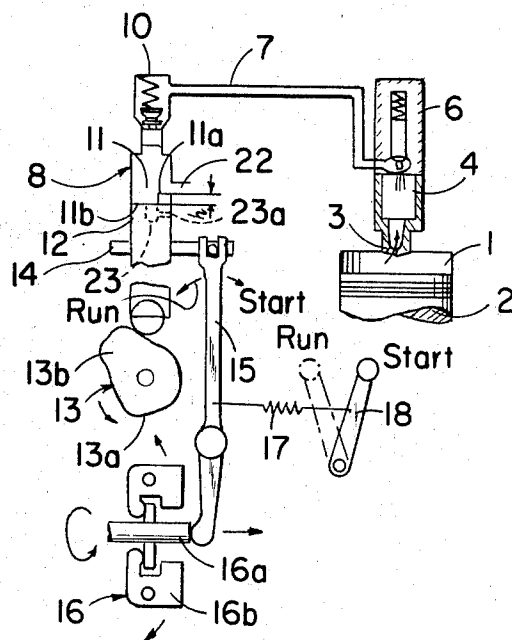


FIG. 8

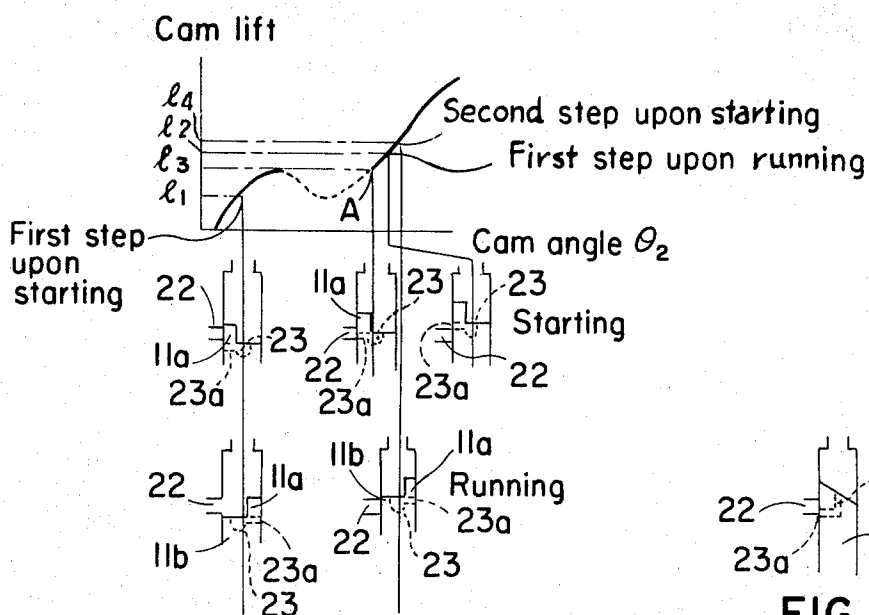


FIG. 9

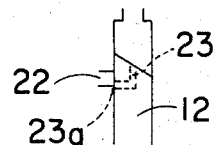


FIG. 10

INVENTOR
Shigeo Nagasawa

by *McGraw & Toren*
ATTORNEYS

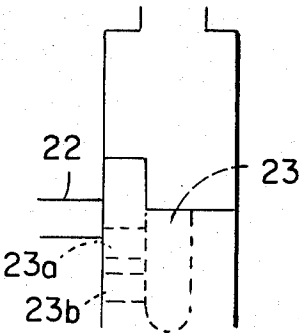


FIG. II

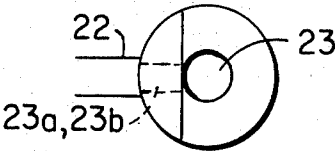


FIG. IIA

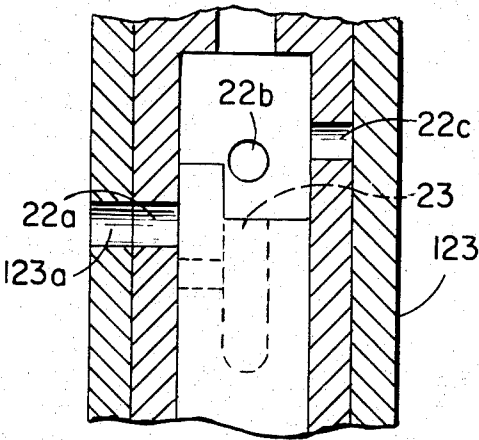


FIG. I2

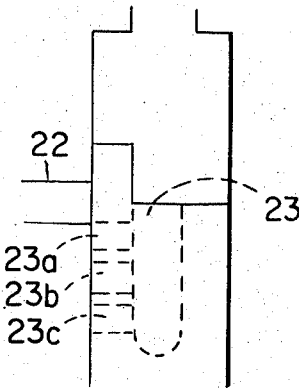


FIG. I3

FUEL INJECTION SYSTEM FOR DIESEL ENGINE

BACKGROUND OF THE INVENTION

In a known conventional diesel engine, it has been common practice to start fuel injection several degrees before the upper dead point (-10° — -3°) in the compression stroke and either upon starting or during running.

If the atmospheric temperature is low during starting, then, due to the fact that the entire engine is at a low temperature plus the fact that the temperature of the intake air is low, the air in a cylinder chamber cannot obtain a sufficiently high temperature even though the air is compressed. Consequently, the ignition lag is extended and, during the injection period of several degrees before the upper dead point in the compression stroke, the time in which the fuel droplet makes contact with the high temperature air, within the compression chamber, is shortened. Thus, ignition of the fuel droplet becomes very difficult.

In another known type of diesel engine, prior to the fuel injection and several degrees before the upper dead point in the compression stroke, an auxiliary fuel injection is performed at the beginning of the compression stroke. In this type of diesel engine, the overall weight of injection of the fuel is substantially constant either upon starting or upon running. The object of this type of diesel engine is to enhance the efficiency of the engine by improving the combustion conditions of the fuel, and also to facilitate control of the operation.

While this type of diesel engine has excellent starting characteristics due to the two-stroke auxiliary fuel injection, it has a disadvantage. Since the second step of auxiliary fuel injection follows the first step and, since the amount of fuel injected in the first step is determined by a cam lift of a plunger, it is impossible conveniently to adjust the time of commencement of fuel injection in the second step without varying the quantity of fuel injected in the first step, and without replacing a plunger operating cam by a cam having a different contour.

SUMMARY OF THE INVENTION

This invention relates to fuel injection systems for diesel engines, and, more particularly, to an improved fuel injection system for a diesel engine greatly enhancing the starting performance under low temperature conditions.

The invention is directed to an improvement upon the type of diesel engine fuel injection system mentioned above and involving auxiliary injection of fuel during starting. In this type of fuel injection system, a plunger barrel has a fuel intake port and a plunger is slidable axially in the barrel. A cam operates the plunger and has cam lobes peripherally spaced in such a manner that, after the plunger has been advanced, during the intake stroke or the compression stroke, to a first position, and retracted, the plunger, at the end of the compression stroke, is advanced further to a second position. A switching device is operable to rotate the plunger through substantially 180° between a "starting" position and a "running" position.

In the starting position, the fuel intake port is blocked by the plunger peripheral surface so as to carry out two fuel injection strokes during the movement of the plunger to the first position and to the second posi-

tion, respectively. In the running position, the plunger is rotated to a position in which the fuel intake port is blocked by the plunger peripheral surface, to effect fuel injection, only when the plunger is moved to the second position.

In accordance with the invention, a flow passage is provided in the plunger connecting the peripheral surface of the plunger with its inner end face within the barrel. In the starting position of the plunger, this flow passage communicates with the fuel intake port when the plunger is advanced to the mentioned second position. In the running condition of the engine, the plunger is rotated to a position in which the flow passage can no longer communicate with the fuel intake port.

The invention arrangement has the advantage that, even if the atmospheric temperature is too low for the intake air to obtain a sufficiently high temperature, by setting the switching device at the starting position, the fuel is mixed uniformly with the intake air for a long time and then heated up in the first step of auxiliary fuel injection, so that the ignition lag is reduced to an extent that ignition occurs with certainty. The torque necessary for rotating the engine can be produced in the second step of auxiliary fuel injection. Thereafter, during running of the engine while the temperature of the engine is increased, fuel injection is performed only upon movement of the plunger to the second position, by switching the control or switching device to the "running" position. Thus, the engine will run smoothly while the fuel is being injected exactly at the rate necessary for running. Furthermore, the rate of fuel injection, during running, may be substantially reduced with respect to the rate of fuel injection during starting, thus preventing a reduction in thermal efficiency.

More particularly, the inner space of the barrel is connected to the fuel intake port, in the starting position of the plunger, between the time the plunger attains its first position and the time the plunger attains its second position. Thus, the time of commencement of fuel injection may be arbitrarily adjusted, as well as the quantity of injection in the second step, by appropriately delaying the time at which the fuel intake port is blocked by the plunger peripheral surface, and without changing the contour of the cam.

An object of the invention is to provide an improved fuel injection system for diesel engines.

Another object of the invention is to provide such a fuel injection system for diesel engines in which the starting operation is greatly improved.

A further object of the invention is to provide such an improved fuel injection system for diesel engines in which the rate of fuel injection, during running of the engine, may be substantially reduced with respect to the rate of fuel injection during starting of the engine, preventing any reduction in thermal efficiency.

Another object of the invention is to provide such a fuel injection system for diesel engines in which the time of commencement of fuel injection, as well as the amount of fuel injected in the second auxiliary injection step, may be arbitrarily adjusted without varying the contour of a plunger operating cam or without changing the plunger operating cam.

For an understanding of the principles of the invention, reference is made to the following description of typical embodiments thereof as illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 is a somewhat schematic longitudinal cross section view of a prior art fuel injection system for a diesel engine;

FIG. 2 is a view similar to FIG. 1 but illustrating a different form of prior art fuel injection system;

FIG. 3 is a partial side elevational view taken along the line III—III of FIG. 2, looking in the direction of the arrow;

FIG. 4 is a longitudinal sectional view, to a larger scale, of a principal part of FIG. 2;

FIG. 5 is a schematic diagrammatic view of the fuel injection system shown in FIG. 2;

FIG. 6 is a graphical illustration of the relation between the cam lift and the plunger upon starting and running respectively, of the system shown in FIG. 2;

FIG. 7 is a graphical illustration of the operating principle of the fuel injection system shown in FIG. 2;

FIG. 8 is a schematic diagrammatic view of one embodiment of fuel injection system, for a diesel engine, in accordance with the invention;

FIG. 9 is a somewhat graphical illustration of the relation between the cam lift and the plunger, upon starting and running, respectively, of the embodiment of the invention shown in FIG. 8;

FIG. 10 is a schematic sectional view of the principal part of another embodiment of the invention;

FIG. 11 is a view, similar to FIG. 10, illustrating a modified form of the invention;

FIG. 11A is a top plan view taken at right angles to FIG. 11;

FIG. 12 is an axial sectional view through a further embodiment of the invention; and

FIG. 13 is a view, similar to FIG. 11, illustrating still another embodiment of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In a known auxiliary chamber type of diesel engine, as illustrated in FIG. 1, when the air compressed in a main chamber *b* by an upward stroke of a piston *a* flows into an auxiliary chamber *d* through a communication port *c*, the air within chamber *d* is cooled due to the choke loss at low temperature of the port *c*. Thus, even at the end of the compression stroke, it is difficult for the air within auxiliary chamber *d* to reach the ignition temperature. Therefore, during starting, the fuel spray injected from a fuel injection pump *e* through a nozzle *f* into auxiliary chamber *d* must arrive in main chamber *b* by passing through auxiliary chamber *d* and port *c*. However, since the speed of the air current flowing from main chamber *b* through port *c* is rather high, it is nearly impossible for the fuel spray to arrive in main chamber *b* against this air current. Accordingly, the starting performance is very poor, in an auxiliary chamber type of diesel engine, at low atmospheric temperatures.

To enhance the starting performance, there is a known fuel injection system for a diesel engine as illustrated in FIGS. 2 through 7. In this fuel injection system, a main chamber 1 has a piston 2 reciprocable therein, and main chamber 1 communicates with auxiliary chamber 4 through a port or aperture 3. In addition, a nozzle 6 provided with a nozzle needle valve 5 is

mounted on auxiliary chamber 4, and a fuel injection pump body 8 is connected to nozzle 6 through tubing 7.

In fuel injection pump body 8, there is slidably fitted, for axial reciprocation, a plunger 12 provided with a notched step portion 11, plunger 12 being mounted beneath a delivery valve holder 10 having a delivery valve 9. Plunger 12 is arranged to be driven axially of body 8 by means of a cam 13 which is rotated in synchronism with the rotation of the diesel engine.

A rack 14 meshes with teeth (not shown) on the outer periphery of plunger 12, and rack 14 is coupled to one end 15*b* of a fork lever 15 which is pivotally supported approximately at its center portion 15*a*. The other end 15*c* of fork lever 15 is in abutment with a sliding shaft 16*a* of an adjusting mechanism 16. An arm 15*d* extends from center portion 15*a* of fork lever 15, and is coupled to an adjustment knob or lever 18 through a spring 17. In addition, fuel injection pump body 8 is provided with a start button 19. 22 is a fuel intake port provided on plunger barrel 8*a* within pump body 8.

In this fuel injection system, if adjustment knob or lever 18 is preset to a starting position as shown in FIG. 5, and if start button 19, shown by a broken line in FIG. 4, is moved to the solid line position of FIG. 4, a rack pin 20, projecting from rack 14, is released from a stop 21 for movement of the rack from the running position to the starting position. Thereby plunger 12 is rotated to a position where the upper portion 11*a* of the notched step portion or inner end face 11 of plunger 12 is opposite fuel intake port 22.

Under these conditions, if the engine is rotated by means of a known starter device, which has not been illustrated, cam 13 is rotated counter-clockwise as viewed in FIGS. 2 and 3. Plunger 12 is displaced by a first cam lobe 13*a* from a lift *L*₁, shown in the left half portion of the upper section of FIG. 6, to another lift *L*₃ shown in the right half portion of the upper section in FIG. 6. During this period of time, fuel intake port 22 is blocked by upper portion or projection 11*a* of the inner end face 11 of plunger 12. Thus, a first fuel injection step is carried out to inject substantially one-half of the total amount of fuel to be injected. The timing for raising plunger 12 by means of the first cam mold 13*a* is set at the end of the intake stroke or at the beginning of the compression stroke. Therefore, the fuel injected into auxiliary chamber 4 by the first fuel injection step flows into main chamber 1 through port or aperture 3. During the compression stroke, this fuel is sufficiently mixed with the intake air and is heated to a high temperature.

When first cam lobe 13*a* passes by the lower end of plunger 12, plunger 12 is lowered for a time to interrupt the fuel injection. Thereafter, a second cam lobe 13*b* comes into contact with the lower end of plunger 12 to raise plunger 12 and, upon arrival of the plunger at lift *L*₃, a second step of the fuel injection is begun. Meanwhile, the temperature *t*_m, shown in FIG. 7, of the mixture gas consisting of the mixed air and fuel within main chamber 1 becomes higher than the temperature *t*_p within auxiliary chamber 4. Thus, gas within main chamber 1 is more easily ignited than within auxiliary chamber 4. Furthermore, the fuel injected in the second step also flows, at least partially, into main chamber 1 in the period when the speed of

the current ω through aperture 3 is reduced, the fuel flowing through aperture 3 burning with the mixture gas so that the explosion force necessary for starting may be obtained and thus the engine may be started very easily.

When the engine has obtained a predetermined rpm, sliding shaft 16a slides in the direction of the arrow in FIG. 5, under the influence of centrifugal force of a weight 16b of adjusting mechanism 16. Correspondingly, rack 14 is moved, through fork lever 15 so that plunger 12 is turned through 180° and the lower portion 11b of the notched inner end face of plunger 12 is opposite fuel intake port 22.

Under these conditions, even if plunger 12 arrives at lift l_1 , due to first cam lobe 13a, fuel injection cannot be attained because fuel intake port 22 has not been blocked. It is only when plunger 12 arrives at lift l_2 due to second cam lobe 13b, that fuel intake port 22 is blocked by the lower portion 11b of the notched inner end face 11 of plunger 12, to cause the fuel to be injected. Thus, fuel injection in a smaller quantity than during starting, and exactly similar to a conventional engine, is effected for enabling sustaining of a normal running operation.

In addition, even though the engine has not obtained a predetermined rpm, if adjustment knob or lever 18 is set at the running position, plunger 12 is turned and an adjustment is made so that lower portion 11b of the inner end face 11 is opposed to fuel intake port 22.

In the known fuel injection system shown in FIGS. 2 through 7, by adjusting the height of the step portion of the inner end face 11 of plunger 12, or the lift l_1 and l_3 of the cam lobes, or both, in various manners, the amount of fuel injected in the first step during starting can be set at 25-75 percent of the total fuel injection amount, and the total fuel injection amount, during starting, can be set at 150-300 percent of the total fuel injection amount for the maximum output upon running.

As mentioned the known fuel injection system shown in FIGS. 2 through 7, has a better performance, during starting, than a direct injection type of engine, due to the fact that, upon starting, a first fuel injection step is effected at the beginning of the compression stroke when the speed of the air current in aperture 3 is low, so that the fuel can enter in sufficient amount into main chamber 1 whereby ignition may occur in chamber 1 at a higher temperature than the temperature of the compressed air in auxiliary chamber 4.

However, since the second step of fuel injection is begun at the moment when plunger 12 rises again and has arrived at cam lift l_3 , after it had initially been lifted to the level l_3 and then been retracted, and since the fuel injection amount in the first step is defined by the cam lifts l_1 and l_3 , it is impossible conveniently to adjust the time of initiation of fuel injection in the second step without varying the fuel injection amount in the first step and without replacing cam 13 by another cam having a different contour.

Referring to FIGS. 8 and 9, in accordance with the present invention, a fuel injection system, such as shown in FIGS. 2 through 7, is modified by providing a communicating flow path or passage extending from the lower portion 11b of the inner end face of plunger 12 downwardly and then laterally to the peripheral sur-

face of plunger 12, and opposing fuel intake port 22 in the starting state of the parts. In this connection, the opening 23a of passage 23, on the plunger peripheral surface, is provided at a level such that it may be opposite fuel intake port 22 at the position of cam lift l_3 .

Since the embodiment of the invention shown in FIGS. 8 and 9 is constructed in this manner, in case plunger 12 is set, during starting, so that the upper piece 11a of its notched stepped inner end face 11 is opposite fuel intake port 22, then, as illustrated in the upper half portion of FIG. 9, at the position where the cam lift l_3 is obtained by first cam lobe 13a, the upper space within barrel 8a and fuel intake port 22 are connected with each other through passage 23. Thus, even if plunger 12 is raised somewhat upwardly from the level of cam lift l_3 , by the second cam lobe 13b, the second step of the fuel injection is not commenced until opening 23a on the peripheral surface of plunger 12 has been displaced upwardly from fuel intake port 22 to the position of cam lift l_4 . At the position of cam lift l_4 , communication between the upper space within barrel 8a and fuel intake port 22 is interrupted, whereby the second fuel injection step is commenced.

However, and as illustrated in the lower half portion of FIG. 9, in the position of the parts in which plunger 12 is turned through 180° to be switched to the running state, as opening 23a of passage 23 is directed away from fuel intake port 22, the time of initiation of fuel injection, as well as the amount of injection during running, do not differ from those inherent with the omission of flow passage 23, and are thus maintained constant.

In the embodiment of the invention shown in FIGS. 8 and 9, it is possible to adjust the time of initiation of fuel injection, as well as the quantity of fuel injected, in the second step in the starting state, and in a very simple and easy manner by varying the diameter, the height or both, of the opening 23a on the peripheral surface of plunger 12, and without modifying the shape of cam lobes 13a and 13b. Thereby, there is obtained fuel injection upon starting which is most suitable for the various characteristics of the engine such as, for example, starting characteristics, output power, noise, etc., thus to enhance the performance of the engine.

In the embodiment of the invention shown in FIGS. 8 and 9, a notched step portion 11 is provided. However, the same function and advantage can be obtained when the upper or inner end face of plunger 12 is cut obliquely as shown in FIG. 10, and flow passage 23 is formed so as to dispose opening 23a at the side toward the higher end of the oblique end face of plunger 12.

Alternatively, instead of providing different top levels of plunger 12 on the respective sides, by forming the top face of plunger 12 in a plane perpendicular to the axis of the plunger, while providing a plurality of fuel intake ports 22 on barrel 8a at different levels, fitting a sleeve around the outer periphery of barrel 8a so as to be freely displaced in the axial and circumferential directions, and selectively displacing an opening formed in the sleeve to a position opposed to one of the plurality of fuel intake ports 22, there can be achieved two step injection upon starting and one step injection during running. Furthermore, although a single flow passage 23 has been shown in the illustrated embodiments, if desired two or more flow passages may be provided.

FIG. 11 and 11A illustrate an embodiment of the invention in which two axially spaced radial ports 23a and 23b communicate with passage 23. Referring to FIG. 12, an embodiment of the invention is illustrated including a sleeve 123 provided with a port 123a which is selectively registerable with any one of three angularly and axially spaced ports 22a, 22b and 22c in barrel 22. Sleeve 123 is both rotatable and axially displaceable relative to barrel 22.

The arrangement of FIG. 13 is substantially similar to that of FIGS. 11 and 11A, except that three ports 23a, 23b and 23c are provided and are spaced axially from each other.

While specific embodiments of the invention have been shown and described in detail to illustrate the application of the principles of the invention, it will be understood that the invention may be embodied otherwise without departing from such principles.

What is claimed is:

1. In a fuel injection system for a diesel engine, of the type including a plunger barrel having a radial fuel intake port, a plunger slidable axially in the barrel, a plunger operating cam having peripherally spaced lobes engageable with the plunger and operable, during one of the intake and compression strokes, to advance

the plunger to a first position to block the port to inject a first quantity of fuel and then to provide for plunger retraction to free the port, the cam, at the end of the compression stroke, advancing the plunger further to a second position to block the port to inject a second quantity of the same fuel, and a switching device effective on the plunger, only during starting of the engine, to position the plunger so that its peripheral surface blocks the port during advance of the plunger to the first and second positions, to effect two injections of the same fuel, and only during running of the engine, to position the plunger so that its peripheral surface blocks the port, for a single injection of the same fuel, only upon advance of the plunger to the second position, the improvement comprising at least one flow passage in said plunger connecting said peripheral surface of said plunger to the inner end face of said plunger and communicating with said port, only during starting of the engine, in said second plunger position; a plurality of fuel intake ports in said barrel at different levels; and a sleeve enclosing said barrel and displaceable axially and circumferentially thereof; said sleeve having an opening therein cooperable with a selected one of said fuel intake ports.

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