

O. M. ULBING

FUEL INJECTION SYSTEM

Filed March 10, 1964

5 Sheets-Sheet 1

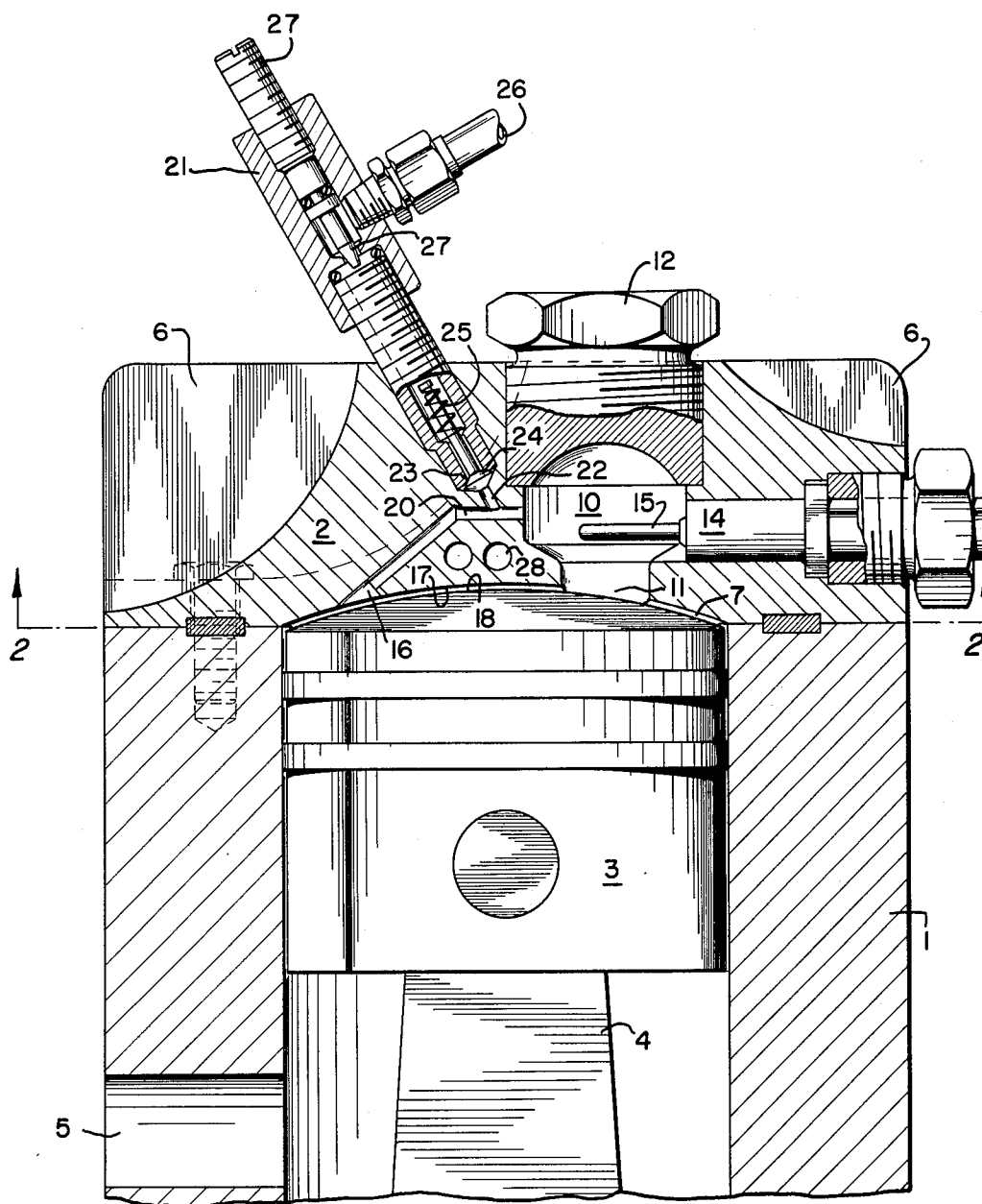


FIG. 1

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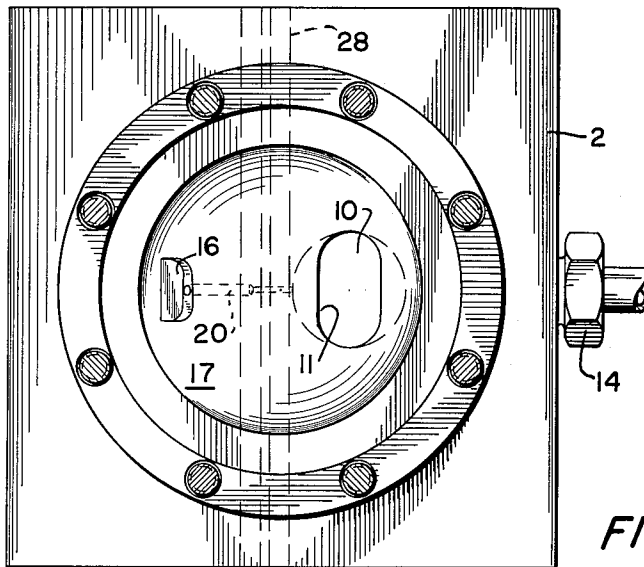


FIG. 2

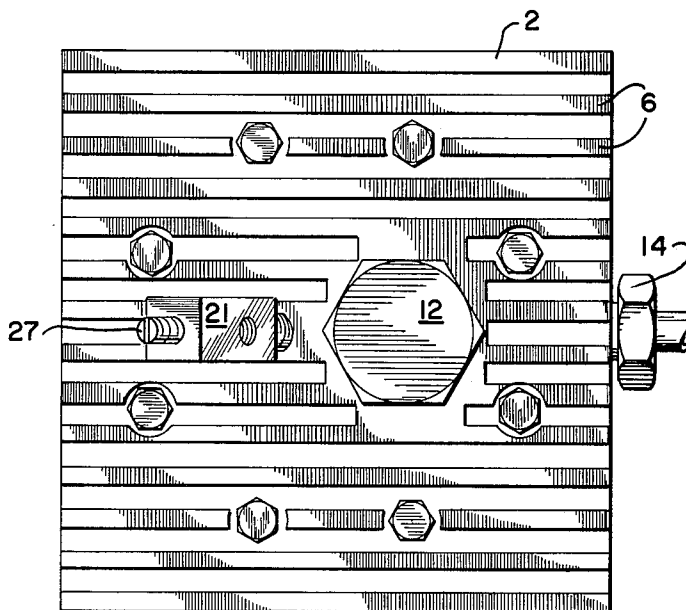


FIG. 3

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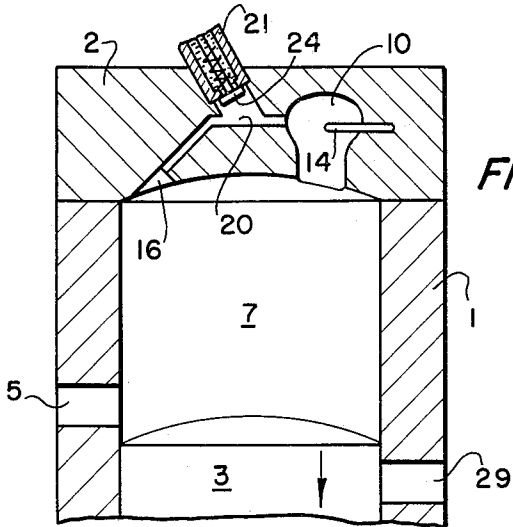


FIG. 4

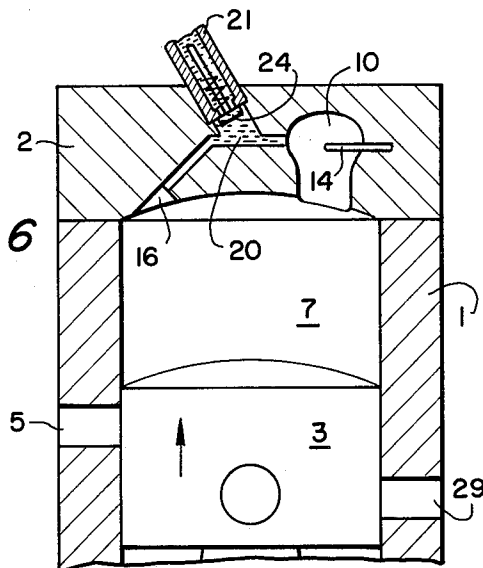


FIG. 6

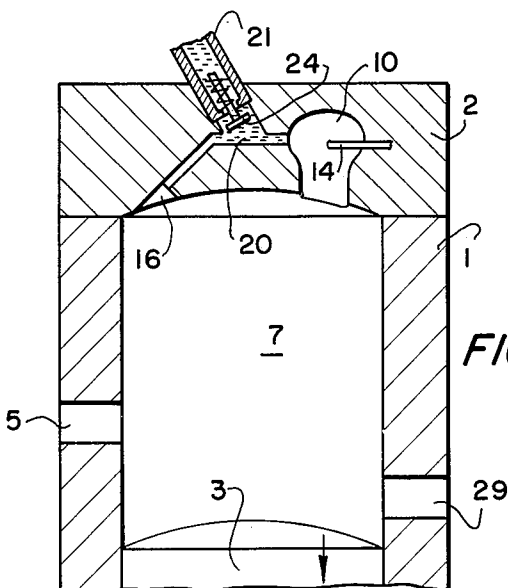


FIG. 5

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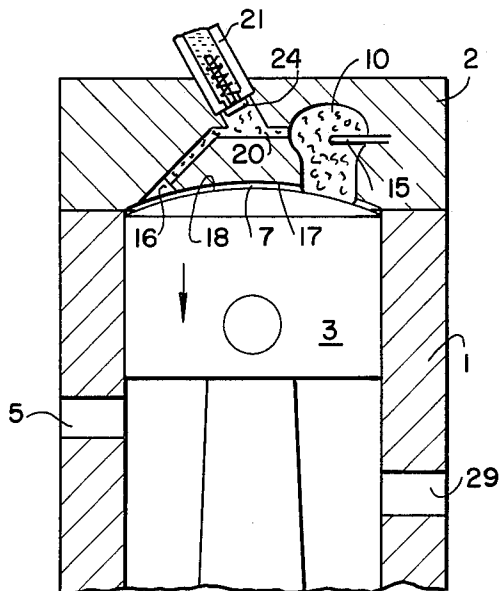


FIG. 7

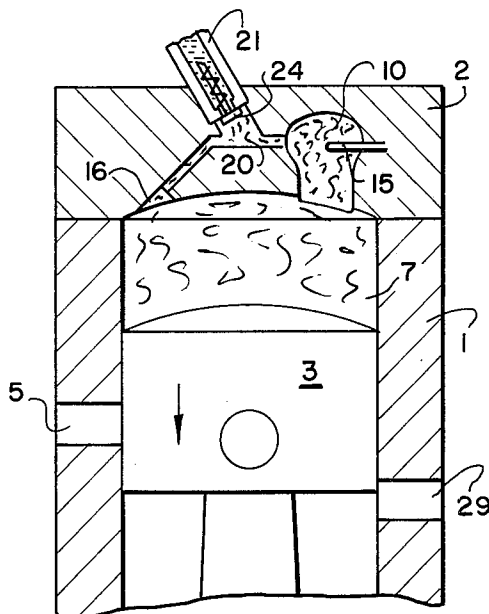


FIG. 8

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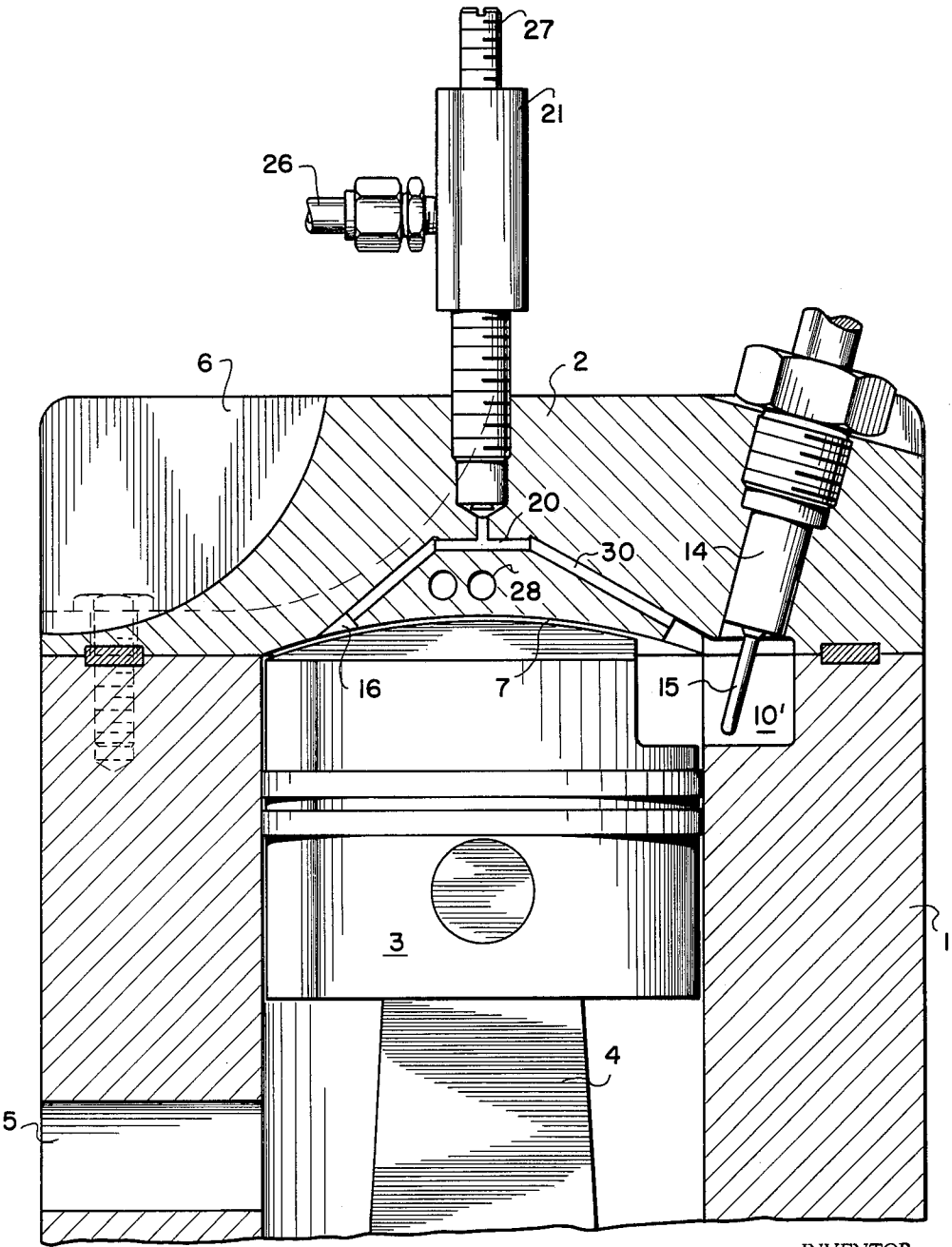


FIG. 9

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FUEL INJECTION SYSTEM

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7 Claims. (Cl. 123—32)

This invention relates to fuel injection systems for internal combustion engines.

Conventional fuel injection systems inject fuel into individual combustion chambers of engines under very high pressures through relatively expensive nozzles. As a result of the high pressures and the expensive nozzles, such systems are relatively expensive. Prior attempts have been made to develop injection systems utilizing relatively low pressures. However, insofar as is known, prior low pressure fuel injection systems have been relatively unsuccessful for various reasons.

The principal object of this invention is to provide a low pressure fuel injection system of improved design which substantially eliminates or minimizes the objections provided by earlier fuel injection systems of this type.

Other important objects of this invention include the following: to provide a low pressure fuel injection system having an ignition chamber which is connected to the combustion chamber by a passage which is relatively open and unrestricted; to provide a low pressure fuel injection system which provides fuel storage passages which are relatively cool and protected from the heat of the combustion chamber; to provide a low pressure fuel injection system which can use relatively light, fast-burning fuels and one which provides smoother, more uniform combustion in an engine; to provide a low pressure fuel injection system which inherently provides a self-governing action whereby it feeds more fuel to an engine during periods of high loads and feeds less fuel during periods of lesser loads; and to provide a low pressure fuel injection system which utilizes dynamic pressure differentials instead of static pressure differentials for operating the system and injecting the fuel into an ignition chamber.

The invention is described in connection with the accompanying drawings wherein:

FIG. 1 is an axial section taken through an engine cylinder embodying this invention;

FIG. 2 is an internal face view of the cylinder head of FIG. 1;

FIG. 3 is an external face or top plan view of the cylinder head;

FIGS. 4 to 8 are diagrammatic views sequentially illustrating the operation of the invention; and

FIG. 9 is an axial section similar to FIG. 1 of a modified embodiment.

A two-stroke cycle engine is illustrated in FIG. 1 including a cylinder 1, a cylinder head 2, and a piston 3 connected to a piston rod 4. The cylinder 1 is shown containing an exhaust port 5 and the cylinder head 2 carries cooling fins 6. The piston 3 cooperates with the cylinder 1 and cylinder head 2 to form an enclosed combustion chamber 7 between the piston 3 and head 2. All of the foregoing structure is conventional. It should be noted that although the invention is shown and described in connection with a two-stroke cycle engine, it is also equally useful for a four-stroke cycle engine.

The cylinder head 2 contains a large bulb-shaped cavity forming an ignition chamber 10 which opens into the combustion chamber 7 through a port or opening 11 which is large enough to offer free and relatively unrestricted communication of gas between the ignition and combustion chambers 10 and 7. The opening 11 is located at the end of the trunk or stem of the bulb-

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shaped chamber 10. The top of the ignition chamber 10 is closed by a plug 12 threaded into the head 2 which facilitates access to or cleaning the chamber 10.

An electrically operated glow plug 14 is threaded into the cylinder head 2 and has an electrode 15 projecting into the ignition chamber 10. The glow plug 14 operates in the conventional manner wherein the electrode 15 is heated to a fuel igniting temperature by electricity flowing through it. Hence, fuel entering the ignition chamber 10 is ignited by the heated electrode 15. Generally, the compression ratio of the engine will be about 12 to 1 or higher to place the fuel under a sufficient pressure for the glow plug to ignite it.

An open pocket 16 is formed in the internal face 17 of the cylinder head 2 bordering the combustion chamber 7. The pocket 16 opens outwardly into the combustion chamber 7 without restriction, is spaced relatively far from the ignition chamber 10, and is much smaller than the ignition chamber 10.

During the compression stroke of the piston 3, the approach of the piston 3 to the inner face 17 of the cylinder head 2, as seen in FIG. 1, causes air to be compressed in both the chamber 10 and pocket 16. When the top 18 of the piston 3 gets close to the inner face 17 of the head 2, say .050 to .030 inch, the pressure in the pocket 16 will rise much faster than in the ignition chamber 10 because of the much smaller volume of air between the piston and the pocket 16 and the distance between the pocket 16 and ignition chamber 10. In effect, the air adjacent the pocket 16 is being "squished" or "squashed" and the area of the inner face 17 of the head 2 immediately around the pocket 16 corresponds to the typical "squish" area provided in the modern internal combustion engine for creating turbulence. The "squished" air cannot flow freely into the ignition chamber 10 because of the close proximity of the piston top 18 to the inner face of the head. As a result, a momentary differential of pressure occurs between the pocket 16 and the ignition chamber 10 with the higher pressure being in the pocket 16.

The pocket 16 and ignition chamber 10 are interconnected by a small fuel storage passage 20 running through the cylinder head 2. The passage 20 is small enough in diameter to retain fuel by capillary action whenever there is not a differential in pressure existing between its ends.

A low pressure nozzle 21 is threaded into the cylinder head 2 and opens into a small bore 22 which opens into the fuel storage passage 20 intermediate its ends. The nozzle 21 includes an orifice 23 opening into the bore 22 and the fuel storage passage 20 and a spring-loaded poppet check valve 24 closing the orifice 23. The check valve 24 is biased to a closed position by a light spring 25 contained within the nozzle 21. The spring 25 is sufficiently light so that the valve 24 will open under a very low pressure differential, for example, 3 p.s.i. In each case the opening pressure differential for the valve 24 will be arranged to inject the fuel into the fuel passage 20 at the correct time and will depend on the fuel pressure in the nozzle 21 and the pressure in the combustion chamber 6 at the moment of injection. Normally, the fuel pressure is low, say 5 p.s.i., which is sufficient to cause the fuel to flow to the nozzle 21. Fuel is fed to the nozzle 21 from a suitable source through the pipe 26. The nozzle 21 contains an adjustable needle valve 27 for metering the fuel flowing through the orifice 23. This needle valve 27 can operate as the throttle for the engine to control the power and speed of the engine.

Generally, the check valve 24 opens as the piston 3 approaches the bottom of its stroke, because the pressure in the combustion chamber 7 will be the lowest at this point in the engine cycle. If this were a four-stroke engine, injection would occur during the suction stroke of the piston. The exact moment in which injection occurs

is not critical so long as a charge of fuel has been deposited in the fuel storage passage 20 by the time that the piston 3 starts its compression stroke.

A plurality of cooling ducts 28 are formed in the cylinder head 2 between the fuel storage passage 20 and the combustion chamber 7 to isolate the fuel storage passage 20 from the heat generated in the combustion chamber 7 and to cool the passage 20. Keeping the fuel storage passage 20 relatively cool aids in preventing pre-ignition of the fuel in the passage 20 during the compression stroke of the piston 3.

OPERATION

The operation of the low pressure fuel injection system is sequentially illustrated in FIGS. 4 to 8 in connection with a two-stroke cycle internal combustion system.

In FIG. 4, the piston 3 is moving along its down stroke or power stroke and has just passed the exhaust ports 5. At this time, the fuel nozzle valve 24 is closed and a substantial pressure still exists in the combustion chamber 7. Hence, the fuel supply passage 20 remains empty. The glow plug 14 is heated and ready to ignite fuel when it enters the ignition chamber 10.

FIG. 5 shows the piston 3 later in its down stroke after it has uncovered the intake ports 29 and the pressure in the combustion chamber 10 has dropped to a relatively low value. At this time, the pressure in the combustion chamber 10 is sufficiently low for the nozzle valve 24 to open and allow a charge of fuel to flow into the fuel storage passage 20. The fuel remains in the fuel storage passage 20 at this point in the cycle since there is no differential in pressure between its ends.

FIG. 6 shows the piston 3 during its up stroke or compression stroke after it has passed and closed the intake ports 29 and exhaust ports 5. The pressure in the combustion chamber 7 is rising considerably, the nozzle valve 24 has closed and the fuel remains in the fuel storage passage 20, since there is no differential in pressure between the ends of the passage 20.

FIG. 7 shows the piston 3 at the end of its compression stroke. At this time the air in the combustion chamber 7 is compressed to a high pressure and the pressure in the pocket 16 is slightly greater than in the ignition chamber 10, due to the air around the pocket being "squished" and to the kinetic velocity of the air being rammed into the pocket 16 by the approach of the piston top 18. The nearness of the piston top 18 to the cylinder head face 17 prevents free leakage of fluid across the top 18 of the piston between the pocket 16 and the ignition chamber 10.

The slightly higher pressure in the pocket 16 forces the fuel from the fuel storage passage 20 into the ignition chamber 10 where it is ignited by the glow plug 14.

FIG. 8 shows the piston 3 shortly after the start of its power stroke or down stroke. As soon as some of the fuel begins burning in the ignition chamber 10, the pressure in the ignition chamber 10 rises rapidly to force the burning fuel through the port 11 into the combustion chamber 7. Once in the combustion chamber 7, the burning fuel continues to burn during the remainder of its power stroke until the exhaust port 5 is uncovered as shown in FIG. 4.

It should be obvious that the foregoing system is equally useful with four-stroke cycle engines as with the two-stroke cycle engine described.

This system inherently provides a partial governing action to the engine so that more fuel is fed to the combustion chamber 7 during high loads and less during low loads. As the load on the engine rises, the piston 3 slows down so that the nozzle valve 24 can remain open for a longer period, thus injecting a greater charge of fuel to the engine. On the other hand, as the load on the engine drops, it speeds up so that the valve 24 is open for less time during each cycle. As a result, a smaller charge of fuel is deposited in the fuel storage passage 20 during each cycle.

This system also automatically advances the moment of injection into the ignition chamber 10 as the speed of the engine rises. As the speed of the piston increases, the differential pressure across the pocket 16 and ignition chamber 10 will occur progressively sooner in the compression stroke of the piston 3. At idling speed, the piston 3 might have to be .05 inch from the head 2 before a differential pressure occurs across the pocket 16 and ignition chamber 10 sufficiently to force the fuel from the passage 20 into the ignition chamber. On the other hand at high speeds of the piston 3, a differential of pressure sufficient to force the fuel into the ignition chamber might occur when the piston 3 is .15 inch from the cylinder head 2.

It should be noted that the glow plug 14 may only be necessary during the starting of an engine if the compression ratio is sufficient to provide compression ignition once the engine is warm. Furthermore, a spark plug might be substituted for the glow plug.

While the described embodiments anticipate the use of a diesel cycle, this invention may also be useful with a stratified engine wherein a lean mixture is conveyed into the combustion chamber using a carburetor and additional fuel is injected near the ignition device to begin the ignition process at the proper moment. Once the fuel is ignited the lean mixture will burn although it is too lean to initially ignite. The stratified charge principle is well known to the engine art.

FIG. 9 embodiment

This embodiment includes a fuel ignition chamber 10' positioned at the side of the piston 3 and formed by cutting away a portion of the piston and a portion of the adjacent cylinder 1. The glow plug 14 is positioned with its electrode 15 projecting into the ignition chamber 10' and the fuel storage passage 20 is connected to the ignition chamber 10' by an extension passage 30. Otherwise than for the above changes, the FIG. 9 embodiment is like the FIG. 1 embodiment. The operations of both embodiments are identical.

Although a plurality of embodiments of the invention are illustrated and described, it should be understood that the invention is not limited simply to these embodiments, but contemplates other embodiments and variations which utilize the concepts and teachings of this invention.

Having described my invention, I claim:

1. In an internal combustion chamber having a cylinder closed at one end by a cylinder head and containing a reciprocable piston cooperating with the cylinder and cylinder head to form an enclosed combustion chamber, the combination of a low pressure fuel injection system comprising:

- (a) an ignition chamber formed at least in part in said cylinder and opening into the top of said combustion chamber;
- (b) means in said ignition chamber for igniting fuel in said ignition chamber;
- (c) a pocket formed in said cylinder head at the top of said combustion chamber spaced from said ignition chamber and arranged so that a pressure differential is created between said pocket and said ignition chamber by the approach of the piston to the top of its stroke and as a result of air being compressed caused by the "squish" effect between the piston and the cylinder head with the pressure in said pocket being higher, said "squish" effect being limited to the short period of time that the piston is very close to the cylinder head;
- (d) a small fuel storage passage in said head and interconnecting said pocket and said ignition chamber; and
- (e) means for injecting fuel into said fuel storage passage during a portion of the cycle of the piston when the pressure in the combustion chamber is relatively low.

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2. The fuel injection system of claim 1 wherein:
 (a) said means for injecting fuel into said fuel storage passage includes a nozzle having a check valve which is opened by a relatively low pressure differential.
3. The fuel injection system of claim 1 wherein:
 (a) the volume of said pocket is substantially less than the volume of said ignition chamber.
4. The fuel injection system of claim 3 wherein:
 (a) said ignition chamber opens into the combustion chamber through a port which is relatively unrestricted and does not hinder the movement of gas between said ignition and combustion chambers.
5. The fuel injection system of claim 4 wherein:
 (a) said pocket opens into the combustion chamber by an unrestricted opening.
6. The fuel injection system of claim 1 including:
 (a) a cooling passage in said cylinder head located between said fuel storage passage and said combustion chamber for aiding in cooling said fuel storage passage.

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7. The fuel injection system of claim 1 wherein:
 (a) a part of said ignition chamber is formed by providing a cavity in said piston remote from said pocket.

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